Volume 12, Number 3 September 2016

IJCB
INTERNATIONAL JOURNAL OF CENTRAL BANKING
Volume 12, Number 3 September 2016

IJCB

INTERNATIONAL JOURNAL OF CENTRAL BANKING

Special Issue: Challenges to Achieving Price Stability

IJCB International Journal of Central Banking

Volume 12, Number 3 September 2016

Special Issue: Challenges to Achieving Price Stability

*The contents of this journal, together with additional materials provided by article authors, are available without charge at **www.ijcb.org**.*

The *International Journal of Central Banking* is published quarterly (ISSN: 1815-4654). Online access to the publication is available free of charge at **www.ijcb.org**. Individual print subscriptions are available. Orders may be placed by phone (001 415 974 2035), via fax (001 415 974 2168), or by e-mail (editor@ijcb.org).

Renewals, claims, address changes, and requests for permission to reprint material from this journal should be addressed to:

International Journal of Central Banking
Economic Research Department
Federal Reserve Bank of San Francisco
101 Market Street
San Francisco, CA 94105
USA

Phone: 001 415 974 2035
Fax: 001 415 974 2168
E-mail: editor@ijcb.org

ISSN: 1815-4654

Challenges to Achieving Price Stability

Introduction to a Special Issue of the International Journal of Central Banking

This volume of the *International Journal of Central Banking* includes the proceedings from the conference titled "Challenges to Achieving Price Stability," hosted by the Banco de Mexico on November 23–24, 2015. In addition to the papers and discussions, this issue contains the prepared remarks given at the conference by Manuel Ramos-Francia (Vice-Governor and Member of the Board, Banco de Mexico). The conference was organized by Pierpaolo Benigno, Michael P. Devereux, Stephanie Schmitt-Grohe, and John Williams.

Challenges to Achieving Price Stability*
Opening Remarks

Manuel Ramos-Francia
Vice-Governor and Member of the Board
Banco de México

Good morning, I am Manuel Ramos-Francia, a Vice-Governor and Member of the Board at Banco de México. I am also currently the Chairman of the Deputies of the International Monetary and Financial Committee (IMFC) of the International Monetary Fund (IMF). I mention this because at the end of my remarks, I will briefly touch upon some of the topics that are being discussed at the IMFC concerning the role of the IMF in the global economy.

On behalf of Banco de México, I would like to extend everyone a warm welcome to the annual *International Journal of Central Banking* (*IJCB*) research conference, "Challenges to Achieving Price Stability." I would also like to express my gratitude to the conference organizers, the *IJCB*, and the Research Division of Banco de México.

As all of you know, in response to the global financial crisis, central banks in major advanced economies (AEs) adopted a series of unconventional monetary policies (UMPs) with two main objectives.[1] The first was to restore the functioning of financial markets and intermediation. This included all the way from liquidity provision to being a "market maker of last resort," and comprised purchases of private and public assets. The second objective was to provide further monetary accommodation at the zero lower bound (ZLB). This objective included purchases of government bonds, as well as forward guidance. The need for UMPs brought to light fundamental problems in the theoretical underpinnings of what was, at the time, considered mainstream central bank macroeconomic modeling.

*Opening remarks given at the *IJCB* annual research conference, "Challenges to Achieving Price Stability," hosted by Banco de México, November 23–24, 2015. The following are my views and do not necessarily reflect the views of Banco de México or the IMFC. I would like to thank Santiago García-Verdú for his comments and suggestions.

[1]IMF (2013b).

Willem Buiter (2009) has emphasized that central bank macro modeling mainly rested on a “complete-markets paradigm.” Indeed, default, bankruptcy, and insolvency are not possibilities in a world where there exists a set of securities that spans all periods and states of nature, and in which intertemporal budget constraints are satisfied. Consequently, with the exception of using some unusual assumptions, funding and market illiquidity are not possible in such a setup. More generally, in such a paradigm, banks are redundant institutions.[2]

On a related note, Buiter (2009) also stresses that the practice of linearizing models and of assuming additive shocks gave place to business-cycle dynamics that were, by construction, stable. Thus, it was a futile effort toward understanding financial stability issues.

These policies, many believe, have given rise to more questions than answers in that terrain where theory and policy are closely intertwined. Allow me to name some of the most prominent ones.

- Should long-term price stability continue to be the primary objective of monetary policy? Alternatively, should there be new objectives such as financial and external stabilities (these in conjunction with other policies)?[3]
- Should we rethink the monetary transmission channels and economic relationships such as the Phillips curve?[4]
- Will there be new challenges to central banks’ independence, because of both economic and political reasons?[5]
- How should monetary policy interact with macroprudential and capital flows management policies? Moreover, is there a justification for the implementation in some cases of the latter?[6]

[2] Freixas and Rochet (2008).

[3] See, e.g., Smets (2014).

[4] This question has given place to a lively debate. On the one hand, e.g., Faust and Leeper (2015) argue that the relationship between “measures of economic slack, such as the unemployment rate, and inflation has never been very tight, and that standard measures of slack have never shown any real predictive power for where inflation is heading.” On the other hand, e.g., Mericle and Struyven (2015) argue that the Phillips curve seems “alive and well” in the United States, although inflation has fallen short of its target.

[5] See, e.g., Kohn (2014).

[6] See, e.g., Ostry, Ghosh, Habermeier et al. (2011).

- How should we think about monetary policy at the ZLB?[7]
- Is there scope for aggressive monetary policy since, as some believe, the Wicksellian natural real rate may be close to zero or even negative at this time?[8]
- Should we forget about the dangers of fiscal dominance in countries where UMPs have been implemented?[9]
- Should there be greater international cooperation in the sphere of monetary policy?[10]

Of course, during the last few years, academics and policymakers alike have been working hard and diligently on many of these issues, potentially laying the foundations of new ways of thinking about monetary policy and its interactions with other policies. In fact, forums like the IJCB have actively contributed toward improving this debate and will surely keep doing so in the future.

Today, I want to concentrate on a couple of particular issues listed: whether under some circumstances capital controls are justified, and whether more international cooperation in monetary policy is warranted. Indeed, I believe that one of the most important issues that we have learned since the onset of the crisis is that, in a highly integrated world, monetary policy does not work in isolation in the country of origin. To be sure, many have argued that it is now necessary to think about the possible spillovers and, in tandem, spillbacks that monetary policy can in effect create.[11]

It is useful to recall that prior to the global financial crisis, the overall perception was that if each country maintained an adequate and orderly set of economic policies, then the world economy would take care of itself. The perception was that if one country made a policy mistake, any repercussions would be mostly limited to that same country. What was needed in order to maintain economic and financial stability was only the exchange of information. This concept was

---

[7] See, e.g., Coenen and Warne (2014) and Caruana (2015).

[8] See, e.g., Hamilton et al. (2015), Lubik and Matthes (2015), Rachel and Smith (2015), and Williams (2015), among others.

[9] See, e.g., Bank for International Settlements (2012).

[10] See, e.g., Ramos-Francia and García-Verdú (2013).

[11] See, e.g., IMF (2013a, 2015a, 2015c), Bowman, Londono, and Sapriza (2014), Bluwstein and Canova (2015), and Nuguer (2015), among others.

dubbed the house-in-order doctrine.[12] Needless to say, the recent global financial crisis was a harsh reminder of how inadequate such a perception was.

Indeed, it was thought that cooperation was not of first-order importance. As a result, there was no genuine joint effort to even debate and, thus, possibly agree on measures to take cooperation to a higher footing. Nowadays, we should know better. In effect, the world economy is quite different from how it was generally perceived then.

Let me mention a couple of points in this regard.[13] First, the level of interconnectedness between economies has dramatically increased in today's world. Beyond the global nature of many firms and financial institutions, this interconnectedness has changed in many dimensions during the past several years. Accordingly, among others, it has potentially increased feedback effects across different economies due to macroeconomic shocks. Thus, policies should be designed acknowledging this, ineludibly calling for cooperation.

Second, big economies need to take into consideration the consequences their policies might have beyond their borders—in particular, in small open economies. In this respect, one could take for granted that the implementation of certain policies is suitable for the markets for which they are envisioned. Yet, they might have unintended consequences in other economies.[14,15]

[12]Although documented by Padoa-Schioppa (2006), he did not advocate such a doctrine.

[13]We have seen what an inefficiently regulated, inadequately supervised, incessantly changing, and highly interconnected financial system can lead to. Thus, there is clearly a need to advance the cooperation agenda.

[14]In this context, it is convenient to recall, as way of an example, the Dodd-Frank law and, in particular, the Volcker rule. President Obama signed the Dodd-Frank Act into law on July 21, 2010. The final version of the Volcker rule was published in December 2013, and banks have had to comply with such norms starting in July 2015. In general, the Volcker rule prohibits an insured depository institution from engaging in proprietary trading (see, e.g., Board of Governors of the Federal Reserve System 2014). This measure intends to reduce systemic risk.

[15]The Volcker rule could affect financial markets (such as of government and corporate bonds, and of over-the-counter derivatives) within the referred economies. For instance, since financial institutions in emerging-market economies (EMEs) that are affiliated with banks in the United States are also subject to the restrictions required by that rule, their demand for local private-sector

Considering a broader perspective, I believe that few would dispute that today the world finds itself in a growth malaise. Different reasons have been given to explain this.[16]

- Some emphasize a persistent aggregate demand insufficiency, and that the ZLB and the latent financial instability avert a more active monetary policy, a situation which has been called "secular stagnation."[17,18,19]
- Others have underscored a slowdown in total factor productivity growth.[20]

As Rajan (2015), currently the Governor of the Reserve Bank of India, has argued, it is difficult "to disentangle the effects of weak aggregate demand from slow growth in potential supply." In this context, nevertheless, the ever-present need for growth for societies and, of course, for politicians, elected or otherwise, has become even more urgent. Adding to this, the possibility of deflation has increased for some central banks. In particular, given the high levels of debt maintained by some agents, among other factors, countercyclical policies have mainly proven to be ineffective in restoring growth. On the

securities may be negatively affected. Furthermore, although the Volcker rule exempts from its proprietary trading prohibition the operations of subsidiaries of U.S. institutions with their host-country governments' securities, when the U.S. financial institutions' cross-border operations in EMEs have a material importance in the domestic markets of these economies, the restriction imposed by the rule could affect the demand for government assets by U.S. banks. This, accordingly, might affect the local governments' financial capacity.

[16]Rajan (2015).

[17]Hansen (1939) originally coined the term in his presidential address for the American Economic Association in an era of sluggish growth for the U.S. economy. He questioned whether there would be sufficient investment demand to sustain economic growth (Teulings and Baldwin 2014).

[18]Summers brought back the "secular stagnation" term in a speech at the IMF (Summers 2013). See also Summers (2014, 2015, 2016).

[19]This interpretation emphasizes that levels rather than growth rates damage the economy's potential output associated with a crisis (Teulings and Baldwin 2014).

[20]Gordon (2012) argues that technological progress has returned to its low historical norm. Beyond technology, he focuses on four headwinds: demography, education, inequality, and public debt; Gordon (2014) claims that about half of the U.S. decline in participation comes from aging (Teulings and Baldwin 2014).

other hand, structural reform policies usually take time to implement and to deliver benefits to society, not least because politically they are complicated, as there is usually the need to end vested and deep-rooted interests.

Given then the need for growth, what other instruments are there to achieve it? Well, as all of you know, there are exports.[21] This is not only for the reasons that I just mentioned, but both because the potential global market for goods and services is, by definition, bigger than any individual country's market, and also because service-led growth needs a high value-added services sector which, for example, seems highly unlikely in most EMEs. Under sluggish growth conditions, however, all countries trying to increase exports at the same time is unfeasible.

Under reasonable circumstances, what would one expect about the workings of the global economy? Given the need for consumption smoothing at levels higher than present ones on the part of EMEs, one would expect to observe capital to flow from AEs to EMEs. One would thus expect the latter to invest and, at the end of the day, to enhance their economic growth and consumption, thereby increasing their demand for goods and services from advanced economies.

As we can remember from the 1990s and the early 2000s, in no small measure due to macroeconomic mismanagement, this ended in severe crises in many cases. As a result, many EMEs decided to change track, running current account surpluses or substantially lowering current account deficits, and accumulating international reserves, both to maintain exchange rate competitiveness and to self-insure against sudden-stop type of events (see Rajan 2015).

On the other hand, since the outset of the crisis, for AEs the central macroeconomic tool has been UMPs, both for financial and macroeconomic stabilization purposes and for attempting to restore growth.[22] These have been designed to compress term premiums and, in combination with forward guidance signaling low expected short-term rates, have contributed to lower long-dated bond yields to

[21] Rajan (2015).

[22] In fact, monetary policy has been referred to as "the only game in town." See, e.g., White (2012), Wolf (2012), Bini-Smaghi (2013), Jones (2014), Bernanke (2015), El-Erian (2016), and Roubini (2016).

historical minimums in many AEs. In tandem, they have precipitated a very active search-for-yield process.

Of course, this has meant record amounts of capital flowing to EMEs and, to varying degrees depending on the policies implemented by them, contributing to appreciate (unsustainably) their real exchange rates with the concomitant relative price distortions and, in many cases, leading to credit and/or consumption booms. An important reason for this was the perception on the part of many of these economies that, due to favorable terms-of-trade shocks over a long period of time in the form of high and increasing commodity prices, in combination with the readily available foreign capital, they would be able to sustainably consume more than was really the case. Clearly, this led to a deterioration of current accounts in many EMEs, and to their improvement in AEs.

Nevertheless, if domestic-demand-enhancing policies are not implemented along with UMPs, this amounts (as happened largely in the case of EMEs following their 1990s and early 2000s crises) to demand diversion and not to demand creation. In particular, UMPs seem to start losing traction at some point, which—together with the never-ending politically motivated quest for growth—can result in strong incentives to continue, and even enhance, these policies. Also, it can make recurring to "populist" economic policies very tempting.

On the other hand, if at some point the decision is reached for the need to start reversing these policies, then EMEs in particular face another daunting challenge: that of the possibility of strong capital outflows. Evidently, trying to prevent the worst effects of this leads EMEs to accumulate reserves.

In sum, both AEs and EMEs have incentives to be engaged in a quest to divert demand to their own economies through policies that alter central bank balance sheets and, in the case of EMEs, additionally to self-insure against sudden-stop type of events.[23] Indeed, if the global economy does find itself in a growth funk to begin with (e.g., in secular stagnation), incentives to seek growth and to excessively

[23]This has also led to discussions related to the structure of incentives derived from the current international monetary system (IMS) (non-system?). See Mateos y Lago, Duttagupta, and Goyal (2009), Farhi, Gourinchas, and Rey (2011), and IMF (2011, 2016b).

use UMPs to try to achieve it, in combination with EMEs' need to self-insure through accumulating reserves, will only end up reinforcing both the low growth equilibrium and the latent financial instability.

In my following remarks, I will dwell on the particular dilemma that many EMEs are currently facing, which results from the stage of the game we are presently at: the possibility of abrupt, large, disruptive capital outflows.

There has been an enduring and heated debate on the topic of capital flows and/or controls. As I mentioned, it has taken place amidst the unprecedented monetary policy stances that have been set in place in many AEs. Of course, EMEs have felt some of their spillovers. On the matter, the IMF has published two relatively influential working papers (Ostry et al. 2010 and IMF 2012).[24]

Broadly speaking, they recommend that if an economy faces a situation where authorities become cognizant of macroeconomic risks accumulating due to, among others, excessive capital inflows, it should respond with the following policies, albeit their exact implementation depends on the particular circumstances faced by each economy.

(i) Allow the exchange rate to appreciate.
(ii) Accumulate international reserves.
(iii) Intervene in the exchange rate market.
(iv) Relax monetary policies and tighten fiscal policies.

If all these responses have been judged to be exhausted, only then should authorities consider using capital controls. In particular, they should not be used to postpone other, perhaps very much needed, policies. In a nutshell, they see capital controls only as a complementary policy tool.[25]

In this context, two externalities initially called much of the attention of policymakers and academics alike. First, many have

[24]See also Ostry, Ghosh, Chamon et al. (2011), Ostry, Ghosh, Habermeier et al. (2011), and Ostry, Ghosh, and Korinek (2012).

[25]Needless to say, this was a significant shift in the IMF's stance on the subject. In effect, as stated in *The Economist* (2013), it was as "if the Vatican had given its blessing to birth control."

seen UMPs as experiments, with possible highly unknown repercussions.[26] In particular, one of the channels through which UMPs work is through exchange rates. Accordingly, there are terms that are closely associated with it: currency wars and competitive devaluation and/or easing.[27] Second, some EMEs, which are recipients of capital flows, have implemented capital controls. These have, quite possibly, brought about significant policy uncertainty. Moreover, such policy responses can lead to several further difficulties: for example, they can deflect capital flows toward other economies. Accordingly, even under the case in which capital controls could make sense from an individual perspective, from a multilateral one, they might turn out to be problematic.[28]

What is more, though capital controls have been advocated as a policy option under some conditions, they can in fact be easily circumvented most of the time. Since their significant enforceability issues are well known, I will not dwell on them.[29]

It is important to note that, evidently, the current rationale for implementing capital controls (or intervening in the foreign exchange market, for that matter) is precisely the opposite one that gave rise to the previous discussion: this time, it is the possibility of large, abrupt, capital outflows that has given rise to their renewed interest.

In this sense, it is useful to consider some of the economic rationales that have been put forward by the academic literature motivating the use of capital controls, this time around in order to mitigate the effects of sudden stops. In what follows, I will briefly review three of the main recent papers.[30] First, Farhi and Werning (2014) consider the possible occurrence of a sudden stop. In their model, capital controls are set as subsidies on capital inflows and taxes on outflows. The authorities have as an objective to mitigate the archetypal consequences of a sudden stop: exchange rate depreciations, interest rate increases, current account reversals, and drops

---

[26]Rajan (2013).

[27]Rajan (2014).

[28]See, e.g., Ostry, Ghosh, and Korinek (2012).

[29]Habermeier, Kokenyne, and Baba (2011) review the literature on capital controls. The authors argue that capital controls have little effect on overall flows.

[30]See also Ramos-Francia (2014b).

in consumption. Thus, the rationale they put forward for capital controls is to smooth the stabilization process when a sudden stop takes place.

Second, in Bengui and Bianchi (2014) households are occasionally subject to a credit constraint. Hence, their access to credit depends on the value of their current income, which in turn is a function of tradable and non-tradable goods prices. Then, if sufficient debt stock accumulates and a sudden stop takes place, the contraction of capital flows and the depreciation of the real exchange rate feed on each other through the credit constraint. In their model, a pecuniary externality exists because agents ignore the fact that as their debt increases they are more exposed to a sudden stop. The authors maintain that their externality can be addressed with capital controls. The gist of their model is that controls cannot be enforced on a fraction of agents. Thus, as authorities tighten the financial regulation (by establishing capital controls), the fraction of unregulated agents knows there is less probability of a sudden stop, and they take on additional debt. While the planner cannot control unregulated agents, she does account for these leakages when solving for her planning problem. The authors find that, notwithstanding the imperfect enforcement, capital controls are welfare improving. But when implemented, their cost essentially falls on the regulated fraction of agents, while their benefits are shared by both fractions.

Third, Korinek and Sandri (2014) study how pecuniary externalities lead to financial amplification in a small open economy. In their model, borrowers are financially constrained and do not internalize the effect their decisions have on the relative price of the non-tradable good (i.e., the real exchange rate). In contrast, savers are not financially constrained. Also, foreigners borrow/save and buy/sell the tradable good with domestic agents. When the financial constraint binds, the real exchange rate is more sensitive to changes in the borrowers' endowment, in particular in light of a sudden-stop-like episode. This is so given that agents' endowments are valued in terms of the price of non-tradable goods, a relative price, which deteriorates in the case of a sudden stop. The borrowers' constraint and the pecuniary externality lead to an amplification mechanism. Their model has the same flavor as the celebrated Kiyotaki and Moore (1997) model of credit cycles, as they both have an amplification mechanism through financial constraints and collateralized borrowing.[31,32]

In sum, recently, there has been a development in the literature that uses general equilibrium models in which, for the most part, pecuniary externalities are used to justify the implementation of capital controls. While the aforementioned papers have much merit, I believe they do not focus on the most salient difficulties policymakers, particularly in some EMEs, are facing today.[33]

In light of this, let me explain what I think are today some of the most important policy issues for EMEs. The main dilemma is the need to balance the possibility of large capital outflows and/or volatility with the need to try to restore higher growth coupled with reduced policy space.

In order to dwell further, let me first briefly describe the current setup. The first element to consider is how the process of normalization of monetary policy in the United States will take place. It goes without saying that this should not be understood as a statement regarding its adequacy. In fact, this is not the case here or elsewhere in my remarks today.

Second, broadly speaking, some of the key problems for policymakers in the context of capital flows can be divided into two stages. Initially, the low levels of interest rates in AEs, partially resulting from the implementation of QE policies, gave investors the incentives to perform carry-trade operations and, thus, increased the already quite large capital inflows to EMEs. Afterwards, in the prelude of the increase in the U.S. reference rate, there were episodes suggestive

[31]As known, Kiyotaki and Moore's (1997) model has two types of agents: borrowers and lenders. Borrowers need collateral (i.e., capital), since no one can force them to repay their debts. The existence of collateral amplifies output fluctuations. To see this, consider that, for instance, in a downturn, income from capital decreases, leading to a fall in its price and making it less valuable as a collateral. Accordingly, a less valuable collateral bounds the firms' investment, amplifying the downturn.

[32]See also Ramos-Francia (2014a).

[33]In the context of possibly large and volatile capital outflows, see Rey (2013) for an interesting view. In particular, she argues that given the presence of a global financial cycle, which under capital mobility affects the national monetary policies, a free-floating exchange rate regime might not be sufficient to conduct an independent monetary policy. Thus, she advocates restricting excessive leverage and credit, and managing the capital account.

of the extent to which capital flows could leave EMEs in a disorderly fashion.[34]

Associated with both stages, some elements can exacerbate such problems. For instance, there is the size of the global asset management companies (GAMCs), which have become very relevant players in EMEs' financial markets, partially because they operate mainly in an unleveraged way, whereas other financial institutions such as banks are now subject to much more stringent regulation. In particular, capital flows from GAMCs are large when compared to the size of some EMEs' financial markets.[35] These companies tend to follow similar investment strategies in EMEs' financial markets, leaning toward investing in just a few instruments like exchange-traded funds (ETFs) and wide indices like the World Government Bond Index (WGBI), and also tend to use similar risk-management tools.[36] All of this may contribute significantly to increase crowded trades.[37] Most of these elements can be considered cross-sectional channels of systemic risk.[38,39]

One of the current main causes of concern for policymakers in EMEs is not only the possibility of large capital outflows but also the volatility and overall dynamics of those flows. In this context, one useful approach to understanding this is to think of it as an agency problem among the owners of capital and its managers, involving a global monetary game, as in Morris and Shin (2014). In their model, asset managers (think of GAMCs)—which are risk neutral—interact with households—which are risk averse—in a risky bond market. All

[34]See, e.g., Ramos-Francia and García-Verdú (2016).

[35]Roxburgh, Lund, and Piotrowski (2011) provide an overview on how the global financial markets, including capital flows, had recovered since the global financial crisis.

[36]Moreover, a strand of the literature criticizes some of the risk-management tools that are still in use; e.g., see Rowe (2013).

[37]For instance, Pojarliev and Levich (2010) develop methods to measure the "crowdedness" of a trade. They underscore the importance of detecting crowded trades due to the risk they might pose to the global economy.

[38]Wagner (2014) argues that cross-sectional risk, being a dimension of systemic risk, can surge through various channels such as the use of common funding sources, risk-management practices, and trading strategies, among others. See also Schoenmaker (2014).

[39]The amount of risk they are taking is possibly above the socially optimal one. See, e.g., IMF (2015b).

agents have access to a money-market account that provides a floating rate. This rate directly depends on the monetary policy reference rate in the (core) country. Both types of agents have to decide where to allocate their capital, in the risky (EME?) bond or in the money-market account. A key characteristic of their model is that as the number of managers with a position in the risky bond increases, the level of the bond price increases, and vice versa.

In the global monetary game, managers decide whether to keep investing a unit of their capital in the risky bond or to allocate it to the money-market account. To that end, they receive a signal regarding the reference rate, which affects the return yield on the money-market account. Moreover, each manager receives an independent signal of the reference rate. Thus, they follow threshold strategies, i.e., they make their portfolio decision depending on the level in which the reference rate's signal falls relative to a threshold.

The agency problem is derived from the previous setup, since the ultimate investors are too far removed from portfolio managers. Under these circumstances, ranking the asset managers' performance can mitigate the agency problem. The point is that asset managers, evidently, are averse to ranking last. This is so since then they can face fund redemptions and, more generally, their asset-gathering capabilities can be affected. Thus, in their model, managers that rank last are penalized beyond their unfavorable portfolio return.[40] This aversion introduces a coordination mechanism in the managers' portfolio decisions. In particular, such decisions can lead to jumps in prices in anticipation of expected small changes in (core) central banks' reference rates. Arguably, these elements can lead to run-like dynamics in (the higher-risk economy's) financial markets.

There are two key empirical implications of their model. First, as mentioned, as the number of portfolio managers with a position in the risky bond increases, the bond price increases, and vice versa. For the same reason, as a group of portfolio managers sell their positions in the risky bond, its price decreases proportionally to the size

[40] In Morris and Shin (2014), the penalty depends on the proportion of investors whose portfolio has a higher value than the portfolio of the investor ranking last. Similarly, in Feroli et al. (2014), the penalty depends on the number of investors (referred to as *active investors*) with a position in the risky asset. As argued in Morris and Shin (2014), this mechanism is akin to the game of musical chairs. The effort one player exerts has an impact on the effort of others.

of the group. In contrast, in a large market, a decrease in its price will attract other managers and stave off the price reduction.[41]

In their model, there is no change in the economic fundamentals of the risky asset for its price to significantly change. In this regard, a typical characteristic of a systemic risk episode is that asset prices change without any apparent variation in their fundamentals.[42]

Second, as the number of portfolio managers with a position in the risky bond increases, the level of the interest rate threshold, which guides their portfolio decisions between the money-market account and the risky bond, decreases. Thus, as underscored by Morris and Shin (2014), the size of the managers sector is key to determining the possible market disruptions when monetary policy shocks take place.[43]

Their main empirical implications have been explored in at least two different contexts.[44] For instance, first, Feroli et al. (2014) explore the possibility of run-like dynamics in different types of open-end mutual funds. To assess these implications, they posit a model, which is a simplification of Morris and Shin's (2014) model. They find that for some types of funds, there is evidence of the possible presence of run-like dynamics.

---

[41]Thus, under the absence of this type of mechanism, one would expect to observe that changes in the managers' positions have little to no implications for the risky bond price and vice versa.

[42]Freixas, Laeven, and Peydró (2015).

[43]This has as a significant implication that as the U.S. monetary policy rate has been maintained at unprecedented low levels, it has given leeway to a significant number of managers' positions in the risky asset.

[44]Along this line, Miyajima and Shim (2014) have found evidence showing that, during the past couple of years, investor flows to asset managers and EMEs' asset prices have reinforced each other's movements. On a related note, the IMF (2015b) dedicates a whole chapter of its April Global Financial Stability Report to analyzing the asset-management industry and financial stability. It argues that "the delegation of day-to-day portfolio management introduces incentive problems between end investors and portfolio managers, which can encourage destabilizing behavior and amplify shocks." Similarly, Gelos and Oura (2015) argue that given the size of the asset-management industry and the fund managers' incentives problems, their behavior could amplify risk. Moreover, Jones (2015) claims that asset managers have incentives for institutional herding, and highlights the need for policy response beyond the traditional measures. For an overview, see the Office of Financial Research's (2013) report on the asset-management industry and financial stability.

Second, García-Verdú and myself (2015), under the same framework, explore the possible presence of run-like dynamics in bond flows associated with a group of EMEs. In effect, we find preliminary evidence favorable to the presence of run-like dynamics in bond flows.[45] Moreover, we find indications that changes in the U.S. monetary policy rate seem to affect the bond flows' dynamics. Interestingly enough, we also find that the U.S. monetary policy effects' strength on the bond flows dynamics has apparently increased in recent years. We run a battery of control and robustness exercises. In them, for instance, we find little evidence of run-like dynamics in equities flows associated with EMEs, and in bond flows associated with AEs, where financial markets are deeper.

Let me briefly discuss a possible policy response. At the heart of the model, there is an externality. Moreover, it is two-sided, affecting both EMEs and AEs. Stein (2014) argues that the policy response should depend on the level at which the run-like dynamics take place. If they take place at the investors' level, one could impose, for example, a redemption fee.[46] The economic rationale for such a measure is straightforward: a fee would make exiting investors internalize the effect on the risky bond price, which affects all of their peers that did not sell their positions, by making them incur considerable liquidity risk. Nonetheless, he argues that if the run-like dynamics take place at the fund managers' level, a policy response is less obvious.[47,48]

[45] Although the agency problem is probably a very important channel contributing to volatile capital flows dynamics, there are other channels consistent with it. On a related note, Shin (2016) has recently assessed the risk-taking channel for the U.S. dollar (USD). He explains that as its key feature one observes that when the USD depreciates, banks lend more in USD to agents outside the United States, and vice versa. This ties the value of the dollar to global credit conditions. In particular, such a channel has relevant macroeconomic implications, e.g., through borrowers' balance sheets and governments' fiscal positions, making the value of the USD central for financial conditions in EMEs.

[46] In the context of the global game, it is not important to differentiate between investors and fund managers.

[47] The Financial Stability Board (FSB) is presently analyzing policies that could internalize the large liquidity risk derived from possible massive redemptions in the referred markets. See, e.g., FSB (2016).

[48] In the context of very high and volatile capital flows, the IMF has been conducting research regarding countries' experiences on the management of capital flows and the implementation of macroprudential policies. See IMF (2016a) and G-20 (2016).

Adding to the risks emanating from herd behavior and run-like dynamics, the probability of disorderly capital outflows from EMEs has increased due to recent changes in banking regulation (e.g., see footnotes 14 and 15), which seem to have contributed to a reduction in banks' holdings and trading of EMEs' securities. Also, technological change in financial markets such as algorithmic trading has also led to an increase in liquidity risks, adding to capital flows volatility.

In this context, there might be the perception that large disruptions in EMEs' financial systems are, from an AE's perspective, inconsequential. This is unfortunate. Any such perception might run the risk of repeating the mistakes made prior to the global financial crisis, by assuming away the possibility of contagion through financial markets.

Notably, these issues are mostly unrelated to the problems that were used to motivate the use of capital controls. In fact, in policy circles, it was widely believed that the capital controls discussion had been settled a long time ago. Yet, in the last few years, there has been an unprecedented degree of monetary policy accommodation in AEs. Given the low levels of interest rates in AEs, the search for yield has led to enormous problems in policymaking in some EMEs.[49] This has taken place in both of its facets: at first, the large capital inflow stage and, afterwards, the possibility of large, abrupt capital outflows starting when the perception is generated that the core country could start the process of normalizing monetary policy and, evidently, during such a process.

All in all, at present the global economy is characterized by slow growth, risk of deflation in several AEs, low interest rates, search for yield, and episodes of elevated volatility in financial markets reflected in so-called risk-on, risk-off periods. In this context, to conclude, let me mention two points. The first pertains to some of the key policies EMEs can pursue. The second relates to the need to take international cooperation to a higher level.

First, going forward, EMEs as I have said, face potentially daunting challenges. In this context, it is very difficult to over-emphasize that nothing can substitute for solid macroeconomic fundamentals. Fiscal policy should be tightened for different reasons, to a large

[49] Ramos-Francia (2014b).

extent with the objectives of reducing pressures on the different components of risk in term premiums, and also of accommodating efficiently the shock to the real exchange rate. Monetary policy should be adjusted depending on different aspects, mainly on where long-term inflation expectations are anchored, but there may be complicated trade-offs present. In particular, the overall level of long-term inflation expectations is crucial to anchor the yield curve at the lowest possible levels, although financial stability considerations should also play a role in monetary policy. Financial authorities have to foster conditions under which financial markets can grow as deep, and as complete, as possible. Policymakers have to design, plan, and implement the necessary structural reforms and, finally, EMEs should have adequate international reserve levels to insure against possible sudden-stop type of events.

Crucially, these policies have to be seen and implemented as a package. In effect, there are neither silver bullets nor fail-safe reforms. Equally important is that EMEs that have consistently implemented more prudent macroeconomic policies should try to differentiate themselves from their peers as much as possible, especially now that the asset class seems to be under considerable strain.[50]

Second, regarding international cooperation, my contention is that for it to gain traction, we need to reassess its benefits and, in tandem, the eventual costs of continuing with the current international monetary system (IMS) (or non-system). This is not to say that cooperation can be easily achieved. In effect, in the words of the late Anna Schwartz, cooperation "is a fair-weather instrument because countries have independent interests that they will not sacrifice for the sake of the collectivity."[51] Rather, it is motivating cooperation that is necessary given the otherwise potential dire consequences.

The theory on non-cooperative repeated games can tell us about why and where there has been cooperation, and where we can expect to see it in the future. More specifically, in such games the players' willingness to cooperate closely depends on (i) their subjective

[50]Clearly, with large enough external macroeconomic shocks, proper macroeconomic management may not be enough to avoid considerable costs of adjustment.

[51]Schwartz (2000).

discount factors, (ii) the level of economic activity, and (iii) the prevailing economic uncertainty. Thus, it is a fragile equilibrium, and cooperation can be brought to a halt in various instances.[52,53]

Cooperation then has to be called for by the realization that it is in the economies' interests to cooperate and that not doing so could bring about significant and long-lasting costs. The world should advance much more quickly on cooperative/coordinated solutions to some of these problems. Financial institutions such as the world's central banks have advanced along these lines, e.g., successfully implementing swap lines during the global financial crisis.

In addition, the IMF, as a key multilateral institution, has made available several types of credit lines to countries with a strong record of economic policies but that, nonetheless, could face challenges in the current environment. In particular, at the IMFC and also at forums like the G-20, policy tools such as the (design and architecture of) global financial safety net are considered to be very important for the world economy to achieve a better equilibrium. Indeed, these policy tools are fundamental for creating a more resilient IMS and, thus, securing better global economic growth. Some solid steps have been taken in the right direction, but more work remains to be done.

Thank you for your attention. Without further ado, let me wish you all a very successful conference and cede the floor to John Williams.

References

Bank for International Settlements. 2012. "Threat of Fiscal Dominance?" *BIS Papers* 65 (May). (Papers from the BIS/OECD workshop "Policy Interaction: Fiscal Policy, Monetary Policy and Government Debt Management," held in Basel, Switzerland, December 2, 2011.)

Bengui, J., and J. Bianchi. 2014. "Capital Flow Management when Capital Controls Leak." Draft Version.

[52]See, e.g., Green and Porter (1984) and Mailath and Samuelson (2006).

[53]For an application of this result in the context of cooperation among central banks during crises see, e.g., Ramos-Francia and García-Verdú (2013).

Bernanke, B. S. 2015. “How the Fed Saved the Economy.” Opinion/Commentary. *Wall Street Journal*, October 4.

Bini-Smaghi, L. 2013. “Monetary Policy: Many Targets, Many Instruments, Where Do We Stand?” Paper presented at the “Rethinking Macro Policy II: First Steps and Early Lessons” Conference, hosted by the IMF, Washington, DC, April 16–17.

Bluwstein, K., and F. Canova. 2015. “Beggar-thy-Neighbor? The International Effects of ECB Unconventional Monetary Policy Measures.” Working Paper.

Board of Governors of the Federal Reserve System. 2014. “Banking and Consumer Regulatory Policy.” Press Release, December 18.

Bowman, D., J. M. Londono, and H. Sapriza. 2014. “US Unconventional Monetary Policy and Transmission to Emerging Market Economies.” International Finance Discussion Paper No. 1109, Board of Governors of the Federal Reserve System (June).

Buiter, W. 2009. “The Unfortunate Uselessness of Most ‘State of the Art’ Academic Monetary Economics.” *Financial Times* Blog Entry, March 3.

Caruana, J. 2015. “Beyond Zero Rates and Unconventional Monetary Policy.” Panel remarks at the Sixth Annual Conference on Monetary and Financial Shifts: Challenges and Possible Outcomes. Lima, Peru, October 6.

Coenen, G., and A. Warne. 2014. “Risks to Price Stability, the Zero Lower Bound, and Forward Guidance: A Real Time Assessment.” *International Journal of Central Banking* 10 (2, June): 7–54.

The Economist. 2013. “Just in Case. Capital Controls Are Back as Part of Many Countries’ Financial Armoury.” Special Report: World Economy, October 12.

El-Erian, M. A. 2016. *The Only Game in Town: Central Banks, Instability, and Avoiding the Next Collapse.* Random House.

Farhi, E., P.-O. Gourinchas, and H. Rey. 2011. *Reforming the International Monetary System.* CEPR Ebook.

Farhi, E., and I. Werning. 2014. “Dilemma not Trilemma? Capital Controls and Exchange Rates with Volatile Capital Flows.” *IMF Economic Review* 62 (4): 569–605.

Faust, J., and E. M. Leeper. 2015. “The Myth of Normal: The Bumpy Story of Inflation and Monetary Policy.” Paper presented at an economic symposium hosted by the Federal Reserve Bank of Kansas City, in Jackson Hole, Wyoming, August.

Feroli, M., A. K. Kashyap, K. Schoenholtz, and H. S. Shin. 2014. "Market Tantrums and Monetary Policy." Paper presented at the U.S. Monetary Policy Forum sponsored by the Initiative on Global Markets at the University of Chicago Booth School of Business, New York City, February 28.

Financial Stability Board. 2016. "Proposed Policy Recommendations to Address Structural Vulnerabilities from Asset Management Activities." Consultative Document (June 22).

Freixas, X., L. Laeven, and J. L. Peydró. 2015. *Systemic Risk, Crises, and Macroprudential Regulation.* MIT Press.

Freixas, X., and J.-C. Rochet. 2008. *Microeconomics of Banking.* MIT Press.

G-20. 2016. "Communiqué: G20 Finance Ministers and Central Bank Governors Meeting." Washington, DC, April 14–15.

Gelos, G., and H. Oura. 2015. "Asset Management and Financial Stability." Vox CEPR's Policy Portal Article, July 25.

Gordon, R. J. 2012. "Is US Economic Growth Over? Faltering Innovation Confronts the Six Headwinds." NBER Working Paper No. 18315.

———. 2014. "The Turtle's Progress: Secular Stagnation Meets the Headwinds." In *Secular Stagnation, Facts, Causes, and Cures*, ed. C. Teulings and R. Baldwin. CEPR Press (VoxEU.org book).

Green, E. J., and R. H. Porter. 1984. "Noncooperative Collusion under Imperfect Price Information." *Econometrica* 52 (1): 87–100.

Habermeier, K., A. Kokenyne, and C. Baba. 2011. "The Effectiveness of Capital Controls and Prudential Policies in Managing Large Inflows." IMF Staff Discussion Note No. 11/14 (August 5).

Hamilton, J. D., E. S. Harris, J. Hatzius, and K. D. West. 2015. "The Equilibrium Real Funds Rate: Past, Present and Future." (February. Revised in August.) Paper presented at the U.S. Monetary Policy Forum sponsored by the Initiative on Global Markets at the University of Chicago Booth School of Business, New York City, February 27.

Hansen, A. H. 1939. "Economic Progress and Declining Population Growth." *American Economic Review* 29 (1) 1–15.

International Monetary Fund. 2011. "Strengthening the International Monetary System: Taking Stock and Looking Ahead." Prepared by the Strategy, Policy, and Review Departments, in consultation with the Finance, Legal, Monetary and Capital Markets, and Research Departments, March 23.

———. 2012. "The Liberalization and Management of Capital Flows: An Institutional View." (November 14).

———. 2013a. "Global Impact and Challenges of Unconventional Monetary Policies." IMF Policy Paper (October 7).

———. 2013b. "Old Risks, New Challenges." Global Financial Stability Report (April).

———. 2015a. "2015 Spillover Report." IMF Report (July 23).

———. 2015b. "Navigating Monetary Policy Challenges and Managing Risks." Global Financial Stability Report (April).

———. 2015c. "Vulnerabilities, Legacies, and Policy Challenges: Risks Rotating to Emerging Markets." Global Financial Stability Report (October).

———. 2016a. "Communiqué of the Thirty-Third Meeting of the IMFC, Chaired by Mr. Agustín Carstens, Governor of the Bank of Mexico." Washington, DC, April 16.

———. 2016b. "Strengthening the International Monetary System — A Stocktaking." IMF Policy Paper (March 7).

Jones, B. 2015. "Asset Bubbles: Re-thinking Policy for the Age of Asset Management." IMF Working Paper No. 15/27.

Jones, C. 2014. "The Loneliness of a Central Banker." *Financial Times*, November 8.

Kiyotaki, N., and J. Moore. 1997. "Credit Cycles." *Journal of Political Economy* 105 (2): 211–48.

Kohn, D. 2014. "Federal Reserve Independence in the Aftermath of the Financial Crisis: Should We Be Worried?" Hutchins Center on Fiscal and Monetary Policy at Brookings.

Korinek, A., and D. Sandri. 2014. "Capital Controls or Macroprudential Regulation?" NBER Working Paper No. 20805.

Lubik, T. A., and C. Matthes. 2015. "Calculating the Natural Rate of Interest: A Comparison of Two Alternative Approaches." Economic Brief No. 15–10 (October), Federal Reserve Bank of Richmond.

Mailath, G. J., and L. Samuelson. 2006. *Repeated Games and Reputations: Long-Run Relationships.* New York: Oxford University Press.

Mateos y Lago, I., R. Duttagupta, and R. Goyal. 2009. "The Debate on the International Monetary System." IMF Staff Position Note 09/26 (November 11).

Mericle, D., and D. Struyven. 2015. "US Daily: Phillips Curve Alive and Well at Local Level." Goldman Sachs Research (September).

Miyajima, K., and I. Shim. 2014. "Asset Managers in Emerging Market Economies." *BIS Quarterly Review* (September): 19–34.

Morris, S., and H. S. Shin. 2014. "Risk-Taking Channel of Monetary Policy: A Global Game Approach." Working Paper, Princeton University.

Nuguer, V. 2015. "Financial Intermediation in a Global Environment." Working Paper No. 2015-05, Banco de México.

Office of Financial Research. 2013. "Asset Management and Financial Stability." Report (September 30).

Ostry, J. D., A. R. Ghosh, M. Chamon, and M. S. Qureshi. 2011. "Capital Controls: When and Why?" *IMF Economic Review* 59 (3): 562–80.

Ostry, J. D., A. R. Ghosh, K. Habermeier, M. Chamon, M. S. Qureshi, and D. B. S. Reinhardt. 2010. "Capital Inflows: The Role of Controls." IMF Staff Position Note 10/04 (February 19).

Ostry, J. D., A. R. Ghosh, K. Habermeier, L. Laeven, M. Chamon, M. S. Qureshi, and A. Kokenyne. 2011. "Managing Capital Flows: What Tools to Use?" IMF Staff Discussion Note No. 11/06 (April 5).

Ostry, J. D., A. R. Ghosh, and A. Korinek. 2012. "Multilateral Aspects of Managing the Capital Account." IMF Staff Discussion Note No. 12/10 (September 7).

Padoa-Schioppa, T. 2006. "Interdependence and Cooperation: An Endangered Pair?" *BIS Papers* 27 (February): 4–7. (Papers from the BIS conference on "Past and Future of Central Bank Cooperation," Basel, Switzerland, June 27–29, 2005.)

Pojarliev, M., and R. M. Levich. 2010. "Detecting Crowded Trades in Currency Funds." NBER Working Paper No. 15698 (January).

Rachel, L., and T. D. Smith. 2015. "Secular Drivers of the Global Real Interest Rate." Staff Working Paper No. 571, Bank of England (December).

Rajan, R. G. 2013. "A Step in the Dark: Unconventional Monetary Policy after the Crisis." Andrew Crockett Memorial Lecture. Bank for International Settlements, Basel, Switzerland, June 23.

———. 2014. "Competitive Monetary Easing: Is It Yesterday Once More?" Remarks at the Brookings Institution, Washington, DC, April 10.

———. 2015. "Going Bust for Growth." Paper presented at "Perspectives: Unprecedented Monetary Policy Intervention. The Current and Future Impact on Global Markets," organized by the AQR Asset Management Institute and London Business School, June 25.

Ramos-Francia, M. (discussant) 2014a. "Capital Controls or Macroprudential Regulation? A. Korinek and D. Sandri, authors." Discussion paper presented at conference on "Monetary Policy and Financial Stability in Emerging Markets," organized by NBER and the Central Bank of the Republic of Turkey, Istanbul, June 13–15. Available at http://www.banxico.org.mx.

———. 2014b. "A Global Framework for Volatile Flows?" Presented at "70 Years After Bretton Woods: Managing the Interconnectedness of the World Economy," Cusco, Peru, July 21–22. Available at http://www.banxico.org.mx.

Ramos-Francia, M., and S. García-Verdú. 2013. "Cooperation among Central Banks during Crises: Lessons from the Recent Experience." In *Central Bank Cooperation at the Beginning of the 21st Century*, 191–206. (Proceedings of the CEMLA 60th Anniversary Conference, Mexico City, Mexico, July 19–20.)

———. 2015. "Is Trouble Brewing for EMEs?" *BIS Papers* 83 (November): 243–72.

———. 2016. "On the Dynamics of the Term Premiums of EMEs." Working Paper (forthcoming), Banco de México.

Rey, H. 2013. "Dilemma not Trilemma: The Global Financial Cycle and Monetary Policy Independence." Paper presented at "Global Dimensions of Unconventional Monetary Policy," a symposium sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming, August 21–23.

Roubini, N. 2016. “Central Banks Are Still the Only Game in Town.” *The Guardian*, April 1.

Rowe, D. M. 2013. “Risk Management Beyond VaR.” Paper presented at the 2013 Financial Markets Conference, “Maintaining Financial Stability: Holding a Tiger by the Tail,” hosted by the Federal Reserve Bank of Atlanta in Atlanta, Georgia, April 10.

Roxburgh, C., S. Lund, and J. Piotrowski. 2011. “Mapping Global Capital Markets 2011.” Report, McKinsey Global Institute (August).

Schoenmaker, D., ed. 2014. “Macroprudentialism.” CEPR Press (VoxEU.org book).

Schwartz, A. J. 2000. “The Rise and Fall of Foreign Exchange Market Intervention.” NBER Working Paper No. 7751 (June).

Shin, H. S. 2016. “Global Liquidity and Procyclicality.” Speech given at the World Bank conference “The State of Economies, the State of the World,” Washington, DC, June 8.

Smets, F. 2014. “Financial Stability and Monetary Policy: How Closely Interlinked?” *International Journal of Central Banking* 10 (2, June): 263–300.

Stein, J. S. 2014. “Comments on ‘Market Tantrums and Monetary Policy’.”Presented at the U.S. Monetary Policy Forum sponsored by the Initiative on Global Markets at the University of Chicago, Booth School of Business.

Summers, L. H. 2013. Speech at the IMF 14th Annual Research Conference in Honor of Stanley Fischer, hosted by the International Monetary Fund, Washington, DC, November 8.

———. 2014. “US Economic Prospects: Secular Stagnation, Hysteresis and the Zero Lower Bound.” *Business Economics* 49 (2): 65–73.

———. 2015. “Low Real Rates, Secular Stagnation, and the Future of Stabilization Policy.” Keynote speech at the Nineteenth Annual Conference of the Central Bank of Chile, “Monetary Policy through Asset Markets: Lessons from Unconventional Measures and Implications for an Integrated World,” Santiago, Chile, November 20.

———. 2016. “The Age of Secular Stagnation: What It Is and What to Do About It.” *Foreign Affairs* March/April.

Teulings, C., and R. Baldwin, eds. 2014. *Secular Stagnation, Facts, Causes and Cures*. CEPR Press (VoxEU.org book).

Wagner, W. 2014. "Unintended Consequences of Macroprudential Policies." In *Macroprudentialism*, ed. D. Schoenmaker. CEPR Press (VoxEU.org book).

White, W. R. 2012. "Ultra Easy Monetary Policy and the Law of Unintended Consequences." Working Paper No. 126, Federal Reserve Bank of Dallas Globalization and Monetary Policy Institute.

Williams, J. C. 2015. "The Decline in the Natural Rate of Interest." Article based on the presentation for the National Association for Business Economics panel "The Outlook for the U.S. and Global Economy: Headwinds, Tailwinds and Whirlwinds," January 3.

Wolf, M. 2012. "Why Quantitative Easing Is the Only Game in Town." *Financial Times,* March 15.

The Financial and Macroeconomic Effects of the OMT Announcements*

Carlo Altavilla,[a] Domenico Giannone,[b] and Michele Lenza[a,c]
[a]European Central Bank
[b]Federal Reserve Bank of New York and CEPR
[c]ECARES-ULB

This paper evaluates the macroeconomic effects of the announcements of the European Central Bank's Outright Monetary Transactions (OMT) program. Using high-frequency data, we find that the OMT announcements decreased the Italian and Spanish two-year government bond yields by about 2 percentage points, while leaving unchanged the bond yields of the same maturity in Germany and France. These results are used to calibrate a scenario in a multi-country model describing the macrofinancial linkages in France, Germany, Italy, and Spain. The scenario analysis suggests that the reduction in bond yields due to the OMT announcements is associated with a significant increase in real activity, credit, and prices in Italy and Spain, with some relatively muted spillovers in France and Germany.

JEL Codes: E47, E58, C54.

1. Introduction

Since the onset of the financial crisis in August 2007, the Eurosystem has engaged in several unconventional monetary policy measures

*We would like to thank Günter Coenen, Stefania D'Amico, Carlo Favero, Philipp Hartman, Geoff Kenny, Tobias Linzert, Roberto Motto, Massimo Rostagno, Frank Smets, Giovanni Vitale, and participants at several seminars for their comments. The views expressed in this paper are those of the authors and do not necessarily reflect those of the European Central Bank, the Eurosystem, the Federal Reserve Bank of New York, or the Federal Reserve System.
Please address any comments to Carlo Altavilla (carlo.altavilla@ecb.europa.eu), Domenico Giannone (domenico.giannone@ny.frb.org), or Michele Lenza (michele.lenza@ecb.europa.eu).

in order to ensure the correct pass-through of the monetary policy stance to the economy.

In the first phase of the crisis, the non-standard measures were mostly intended to address impairments in the interbank markets. The major concern was to avoid a credit crunch stemming from liquidity and funding problems for banks. In this respect, the introduction of the fixed-rate full-allotment liquidity provision significantly contributed to limit bank funding stress. By accommodating all bids in the liquidity operations, this policy avoided banks' wholesale funding problems related to the freezing of the interbank market. However, with the financial fragmentation associated with the sovereign debt crisis that emerged in 2010, and the resulting concerns of international investors about excessive national debt in several euro-zone countries, the intervention activities have expanded to the secondary sovereign bond markets. Moreover, the initial increase in bond yields in Greece, Ireland, and Portugal subsequently spread to Italy and Spain, which faced a high cost of servicing their debt, arguably higher than would be justified by looking at economic fundamentals (see Hördal and Tristani 2013 for an empirical illustration of this point).

Among other forms of intervention aiming at avoiding impairments in the monetary policy transmission,[1] in the period July to September 2012 the Governing Council of the European Central Bank (ECB) announced the possibility to engage in outright monetary transactions (OMT) in the secondary markets for government bonds. In particular, on July 26, 2012, during a conference in London, President Draghi said that the ECB was ready to do "whatever it takes" to preserve the euro within the limits of its mandate. On August 2, 2012, during the press conference after the Governing Council meeting, President Draghi announced that the "ECB may undertake outright open market operations." Finally, on September 6, 2012, the ECB's Governing Council announced a number of technical features regarding the OMT program. More precisely, the ECB announced that no ex ante quantitative limits would be considered

[1]See, for example, Rivolta (2012), Szczerbowicz (2012), Eser and Schwaab (2013), Falagiarda and Reitz (2013), and Ghysels et al. (2014) for a discussion and an evaluation of unconventional monetary policy and, in particular, of the effects of the Securities Market Programme (SMP).

for the outright transactions in secondary sovereign bond markets, purchases would concentrate on bonds with a remaining maturity of up to three years, and without seniority (pari passu), and bond purchases would be conditional.

After almost two years since its announcement, none of the euro-area countries has activated the OMT. However, asset prices such as bond prices should have, at least in part, incorporated the information publicly available to market participants. Indeed, casual observation suggests that the OMT announcements may have had a significant impact on the financial sector (see, for example, Draghi 2013). In turn, changes in financial prices altered the behavior of private agents, potentially affecting real economic activity. This paper aims to quantify the financial and macroeconomic impact of the OMT *announcements* on four euro-area countries: Germany, France, Italy, and Spain. We conduct our evaluation in two stages.

First, in order to isolate the effects of the announcements on financial prices, we look at daily data on bond yields and conduct an event study along the lines of Altavilla and Giannone's (2014) study on the effects of the Federal Reserve's large-scale asset purchases (LSAPs). The main idea is to assess the effects of the policy announcements through the regression of sovereign bond yields on event dummies (taking value one in the date of the event, the OMT announcements, and zero elsewhere) while, at the same time, controlling for all the other relevant "news" made publicly available in the period under analysis. The "news" is the surprise component of macroeconomic and other relevant releases, i.e., the difference between the data release and the corresponding expectation of market participants (evaluated by looking at 151 categories of releases for the euro area, France, Germany, Italy, and Spain, made available by Bloomberg). We evaluate the impact of the OMT announcements on a measure of the "target" bond yields—assumed here to be the two-year government bond rates—and on ten-year government bond rates. The main outcome of the event study is that the OMT announcements had significant impacts on the bond yields of Italy and Spain—in particular, within the range of maturities indicated by the ECB as the target of the measure: Italian and Spanish two-year bond yields have declined by about 2 percentage points. At the same time, yields at similar maturities for Germany and France were not significantly affected.

Second, we employ a multi-country macroeconomic model in order to assess the macroeconomic impact of the previously estimated changes in bond yields due to the OMT announcements. For each of the four countries in our study, the model includes six variables (real GDP, consumer prices, M3, retail credit, and government bond rates for the two- and ten-year maturity) and also a measure of the ECB policy rate and expected euro-area aggregate bond market volatility. We allow for country heterogeneity, cross-country spillovers in the policy effects, and rich dynamics among countries/variables by adopting a flexible vector autoregressive (VAR) specification. For the estimation of the VAR, we address the high-dimensional data problem (twenty-six variables, five lags, and a quarterly sample starting in 1999:Q1) and use Bayesian shrinkage as suggested in Banbura, Giannone, and Reichlin (2010). In practice, the assessment of the likely macroeconomic effects of the OMT announcements is conducted over a horizon of three years after the announcements by comparing two scenarios, defined as "OMT" and "no-OMT" scenarios. The two scenarios mostly differ in the dynamics of the yield curve which, as we conclude from the event study previously described, were strongly affected by the OMT announcements. In particular, in the OMT scenario, for the whole horizon of three years, we assume that the two-year bond yields in Italy and Spain are about 2 percentage points lower than in the no-OMT scenario, while they are the same in France and Germany. In order to isolate as much as possible the effects of non-standard policy, we also assume that standard monetary policy is the same in the two scenarios. Our evaluation suggests that the OMT announcements are likely to be associated, in the three years following the announcements, with relevant increases in the real economy, consumer prices, and credit in Italy and Spain. France and Germany are only very moderately affected by the OMT announcements. The euro-area bond market volatility is likely to be lower in the OMT scenario than in the no-OMT scenario.

A growing amount of research has focused on the financial effects of the non-standard measures implemented in different countries. For the United States, using event-study methodology, Gagnon et al. (2011) found that QE1 decreased the bond rates by 91 basis points (bps). Krishnamurthy and Vissing-Jorgensen (2011) focus on both QE1 and QE2. They estimate that the impact of the first program on the safety premium reduced yields by more than 100 bps, with the second program having a more muted effect (about 20 bps). D'Amico and King (2013), instead, estimate that the effects of Federal Reserve purchases of Treasury securities during QE1 ($300 billion) has produced a decrease in the ten-year Treasury yield of almost 50 basis points. Joyce et al. (2011) suggest that QE measures adopted in the United Kingdom lowered long-term gilt yields by about 100 basis points and that most of the decline was generated by portfolio balance effects. Altavilla and Giannone (2014) find that the overall effect of the non-standard measures implemented in the United States—i.e., QE1, QE2, QE3, and forward guidance—have significantly decreased the long-term interest rate of about 200 bps. Finally, for the euro area, Rivolta (2012), Szczerbowicz (2012), Eser and Schwaab (2013), Falagiarda and Reitz (2013), and Ghysels et al. (2014) show that the Securities Market Programme (SMP) of the Eurosystem was successful at lowering yields relative to a situation of no intervention and at reducing market volatility and improving market functioning.

For the euro area, Lenza, Pill, and Reichlin (2010) estimated the effects of the post-Lehman unconventional liquidity policy by evaluating the elasticity of euro-area unemployment and industrial production to changes in money-market rates in a setup which bears some resemblance to the one in this paper.

In this paper, we carry out an event study to assess the financial effects of the ECB's unconventional policy in order to quantify asset prices changes between the policy and no-policy scenarios using a novel multi-country model. The model presented in the paper also allows for cross-country heterogeneity. The elasticity to changes in the bond yields implied by the estimated macroeconomic effects of the OMT announcements for Italy and Spain lie broadly in the middle of the range of estimates of the effects of LSAP policies in the United States and QE in the United Kingdom. For the United States, Chen, Cúrdia, and Ferrero (2012) provide the lower boundary, while Chung et al. (2012) and Baumeister and Benati (2013) provide the upper boundary. For the United Kingdom, Kapetanios et al. (2012) find that a permanent decrease in the term spread by 100 basis points would imply an increase in the level of GDP that ranges between 0.7 and 2.7 percent. The structure of the paper is the following. Section 2 elaborates on the event-study-based estimation of the impact of

OMT announcements on the yield curve of France, Germany, Italy, and Spain. Section 3 describes the multi-country VAR model and illustrates the macroeconomic impact of the OMT announcements. Section 4 concludes.

2. The Financial Effects of the OMT Announcements

In order to assess the effects of the OMT announcements on the Treasury bond markets in France, Germany, Italy, and Spain, we estimate for each country (in the sample from January 2007 to February 2013) the following equation:

$$\Delta y_t = c + \alpha D_t + \beta News_t + \varepsilon_t. \tag{1}$$

Equation (1) relates the daily changes in the financial variables of interest Δy_t (the changes in the two-year or ten-year bond yields) to a vector of event dummies D_t (i.e., variables with value one in the "event days" and zero elsewhere). Precisely, the dummies take value one in the day of the announcement and the day after, i.e., we assume a two-day event window. Such choice is driven by the consideration that during a period of low liquidity, the prices of bonds may react slowly in response to an announcement. The event dummies reflect the three major events related to the announcement of the OMT and that occurred between July and September 2012. The estimation is carried out by means of standard regression techniques.

We augment the regression estimated in classical event-study analysis by controlling for the main news stemming from economic releases, $News_t$, which could have influenced bond rates (see Altavilla and Giannone 2014 for a more detailed explanation of this method). More in detail, the "controlled" event-study analysis aims at taking into account all macroeconomic news that materialized within each event window and that could have, possibly, influenced the two- and ten-year government bond rates in that particular time window. For this purpose, the analysis uses a real-time data set that captures the information available to market participants at each point in time. In order to address the challenging task of reconstructing the information set of market participants, we use a data set available in Bloomberg. This data set provides, for each economic release at any point in time, the corresponding expectations of a panel of market participants. The expected values are median (consensus) forecasts collected before (up to one day) the official data release. For each of the 151 variables included in table 5, a time series of (standardized) daily news can be computed as the difference between the first-released (real-time) data and its expected value. This time series represents a measure of the news content of all the most relevant releases on economic data in the period under analysis. In fact, if a certain release is perfectly forecasted, then the release cannot be considered as "news" to market participants, and it would hardly affect asset prices. On the contrary, if a certain release is imperfectly forecasted, it contains some "news" for market participants and, hence, is likely to affect asset prices.[2] The estimated α coefficients return the effects of the policy measure. Standard tests can be used to evaluate whether the sum of the coefficients on the event dummies is statistically different from zero. Results are reported in table 1 for two different specifications of equation (1): in the "classical" specification, the alternative news is not included in the regression, while in the "controlled" specification it is included.

OMT announcements have been much more effective in reducing the government bond rates in Italy and Spain than in Germany and France, where bond markets have not significantly reacted to the policy events. The reduction in the two-year bond yields in both Italy and Spain is about 200 bps, while the effects on the ten-year bond rates in both countries are smaller, approximately 100 bps, consistently with the target of the policy measure, which explicitly focuses on the yields of bonds with remaining maturity up to three years. Table 1 also reveals that once the effects of all macroeconomic news are taken into account, the estimated effects of the OMT announcements do not significantly change. This suggests that the announcements are the most relevant news within the event window.

The reliability of event studies rests on the assumption that policy changes are immediately incorporated in prices and that their effects are persistent. These assumptions might not hold, especially in periods of financial turbulence. Another possible shortcoming of high-frequency analysis is the inability of capturing, because of the focus on a narrow time window, possible lagged effects and reversals.

[2]Appendix 1 provides some more details on the macroeconomic news we control for in our exercises.

Table 1. The Effects of OMT Announcements on Sovereign Bond Markets (in basis points)

Country	Maturity	First Announcement		Second Announcement		Third Announcement		Total
		July 26, 2012	July 27, 2012	Aug. 2, 2012	Aug. 3, 2012	Sept. 6, 2012	Sept. 7, 2012	
Classical								
DE	Two Years	0	1	−2	5	4	1	8
FR	Two Years	−7	−4	2	1	5	1	−4
IT	Two Years	−83	−24	−8	−61	−12	−12	−199***
ES	Two Years	−77	−43	−17	−70	0	−27	−234***
DE	Ten Years	4	7	−8	10	8	3	23*
FR	Ten Years	−7	0	−3	3	1	−3	−9
IT	Ten Years	−40	−12	33	−20	−21	−23	−82***
ES	Ten Years	−42	−24	28	0	−40	−37	−115***
Controlled								
DE	Two Years	0	1	−2	5	1	2	7
FR	Two Years	−6	−5	2	1	2	1	−5
IT	Two Years	−72	−16	−7	−62	−8	−9	−175***
ES	Two Years	−69	−30	−17	−71	2	−23	−209***
DE	Ten Years	6	6	−8	9	7	3	23*
FR	Ten Years	−4	−1	−3	2	4	−2	−4
IT	Ten Years	−33	−10	34	−21	−17	−22	−69***
ES	Ten Years	−37	−14	28	−1	−37	−36	−97***

Notes: The table reports for the days of the OMT announcements and the following days the results of the event study. The last column reports the results of the "classical" and "controlled" event-study analysis as a sum of the change in the days of announcements using a two-day event window. Controlled eventy study refers to the eventy-study regression in equation (1) where the daily changes in each selected asset price are regressed on event dummies and 151 macroeconomic news. *, **, and *** denotes significance of the F-test for abnormal return at 10 percent, 5 percent, and 1 percent, respectively.

To check whether the announcements of asset purchases may have had only a temporary impact on asset prices, we increase the size of the event window up to five consecutive days. Table 2 reports the cumulative changes in the two- and ten-year government bond yields as well as for the five-year sovereign credit default swap (CDS) as estimated with both classical and controlled event-study analysis. The results suggest that the impact of the announcements has been very persistent, with no signals of possible rebound in the following days.[3]

3. The Macroeconomic Effects of the OMT Announcements

The OMT announcements contributed to a *statistically* significant reduction in the spreads of long-term bond yields of Italy and Spain with their German counterparts, allowing a more even pass-through of the ECB accommodative monetary policy stance across euro-area countries. In this section, we provide an assessment of the *economic* significance of these effects on the yield-curve spreads, by turning to the evaluation of the likely macroeconomic effects of the OMT.

3.1 Data and Empirical Model

The analysis of the macroeconomic effects associated with the OMT announcements is based on a multi-country model of the macrofinancial linkages in France, Germany, Italy, and Spain. More in detail, for each country, six variables are included (real GDP, Harmonised Index of Consumer Prices (HICP), M3, retail credit, and government bond rates with the remaining maturity of two and ten years). The model also includes, as a measure of the common standard monetary policy actions, the euro-area overnight money-market rate (EONIA) and a measure of expected euro-area bond market volatility.[4] In order to allow for country heterogeneity, cross-country spillovers in the policy effects, and rich dynamics among countries/variables, all

[3]Appendix 2 reports the same results for other asset prices.

[4]Overall, the model includes twenty-six variables, available at the quarterly frequency in the sample 1999:Q1–2014:Q1. For more information on the data, see appendix 3.

Table 2. Asset Price Reactions (in Basis Points) and the Length of the Event Window

	Size of Event Window									
	One Day		Two Days		Three Days		Four Days		Five Days	
Variable	**Classical**	**Controlled**	**Classical**	**Controlled**	**Classical**	**Controlled**	**Classical**	**Controlled**	**Classical**	**Controlled**
Two-Year Government Bond										
Germany	1	−3	8	7	2	1	4	0	9	3
France	−1	−2	−4	−5	−8	−9	−8	−12	−7	−11
Italy	−103	−85	−199	175	−190	−159	−154	−130	−190	−172
Spain	−94	−77	−234	209	−325	−296	−286	−267	−291	−278
Ten-Year Government Bond										
Germany	4	7	23	23	23	24	22	23	33	32
France	−8	2	−9	−4	−10	0	−20	−10	−19	−11
Italy	−27	−10	−82	−69	−74	−53	−80	−57	−107	−86
Spain	−53	−39	−115	−97	−158	−139	−144	−129	−145	−133

Note: The table reports the results of the event-study analysis for different sizes of event windows.

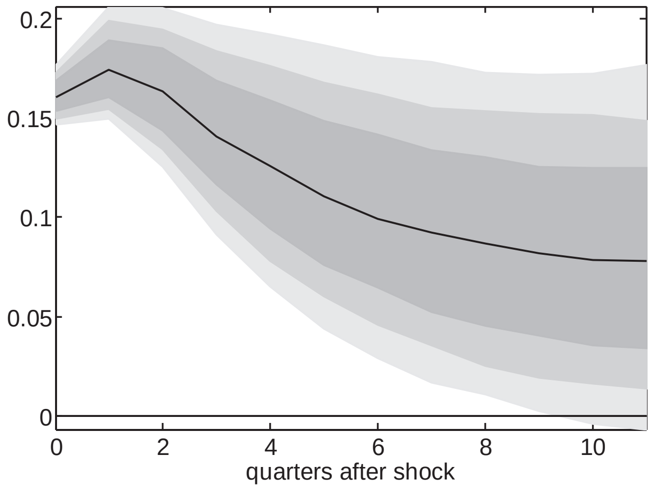
possible interactions among variables/countries are left unrestricted by adopting a flexible vector autoregressive (VAR) specification in (log-)levels and with five lags. For the estimation of the VAR, we address the high-dimensional data problem (twenty-six variables, five lags) and use Bayesian shrinkage as suggested in De Mol, Giannone, and Reichlin (2008) and Banbura, Giannone, and Reichlin (2010). The latter show that if the data are collinear, as is the case for macroeconomic variables, the relevant sample information is not lost when overfitting is controlled for by shrinkage via the imposition of priors on the parameters of the model to be estimated. The hyperparameters controlling for the informativeness of the prior distributions are treated, as suggested in Giannone, Lenza, and Primiceri (2015), as random variables so that we also account for the uncertainty surrounding the prior setup in our evaluation. Appendix 3 at the end sketches the main features of the setup.

3.2 An Illustration of the VAR Dynamics: The Effects of a Standard Monetary Policy Tightening

As a preliminary step, in order to document the ability of our approach to capture the main dynamic interrelationships between the variables, we study the economic developments in the different countries triggered by a tightening of standard monetary policy. More specifically, we estimate the reaction of GDP, consumer prices, credit, M3, the yield curve, and of euro-area aggregate bond market volatility to an exogenous monetary policy shock.

In order to identify the monetary policy shock, we use a recursive identification scheme (see Christiano, Eichenbaum, and Evans 1999 for an extensive discussion and economic interpretation of this type of identification scheme). The overnight money-market rate (EONIA) is assumed to proxy for the monetary policy rate. Our central assumption is that it takes at least one month for a change in the common euro-area monetary policy rate to transmit to real GDP and consumer prices in the four countries under analysis. Credit, M3, and the yield curve in all countries and euro-area bond market volatility, instead, can be affected contemporaneously by the change in the policy rate. Figure 1 shows the dynamics of the policy rate in response to an exogenous tightening of monetary policy.

Figure 1. Response of the Euro-Area Policy Rate to a Monetary Policy Shock

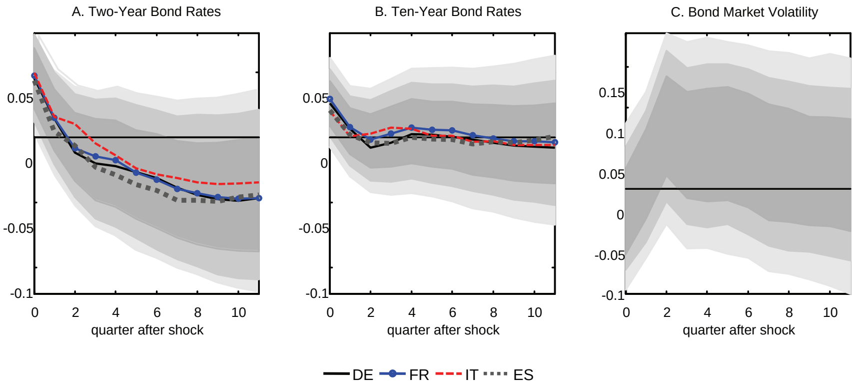


Notes: The figure reports the distribution of impulse responses of the EONIA levels, trimming the quantiles below the sixteenth and above the eighty-fourth. Vertical axis: percentage points. Horizontal axis: quarters after the shock. The black solid line represents the median of the posterior distribution.

On impact, the policy rate increases by about 16 basis points; it peaks one quarter after the shock and then gradually decreases. Figure 2 reports the reaction of the long-term interest rates (panels A and B) and a measure of euro-area bond market volatility (panel C) to the monetary policy tightening. We report the distribution of impulse responses for the euro area (computed, in panels A and B, as the GDP weighted average of the country responses) and the median of the individual country responses.

The bond rates increase on impact and then tend to quickly revert to pre-tightening levels. These results imply that a 1 percent increase in the EONIA rate leads, on impact, to an increase of about 40 and 30 basis points in the two- and ten-year bond yields, respectively. The results are broadly in line with previous studies on the effects of a federal funds rate shock on long-term bond yields. Kuttner (2001), for example, found similar values for the response of the two- and ten-year bond yields: an increase of 61 and 32 basis

Figure 2. Response of the Yield Curve and Bond Market Volatility to a Monetary Policy Shock



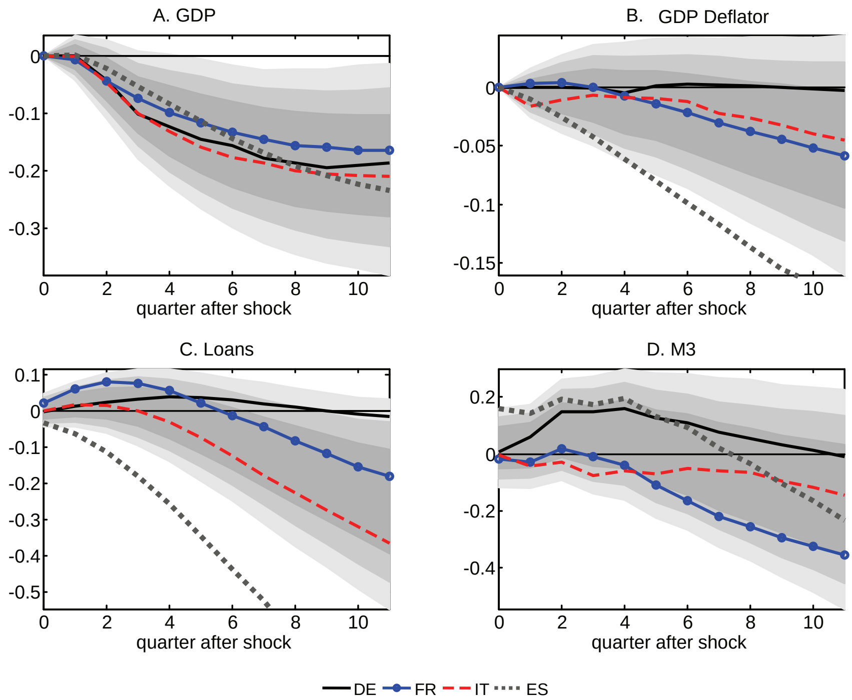
Notes: The figure reports the distribution of impulse responses of the levels of the variables in the euro area (GDP weighted average of the four countries in panels A and B), trimming the quantiles below the sixteenth and above the eighty-fourth. The four lines in panels A and B refer to the median responses in each of the four countries. Vertical axis: percentage points. Horizontal axis: quarters after the shock.

points, respectively, for a 1-percentage-point rise in the federal funds rate. Cochrane and Piazzesi (2002) found a larger reaction to the federal funds target: a 1 percent unexpected target change affects ten-year Treasury yields by 52 bps. Remarkably, the response of the yield curve to a tightening in the stance of standard euro-area-wide monetary policy is quite homogenous across countries. Hence, standard monetary policy tools may not be able to address the issue of heterogeneous yield-curve developments that arose during the euro-area sovereign crisis. Standard monetary policy also does not seem to be able to significantly affect euro-area bond market volatility.

Figure 3 reports the responses of the other variables in the model, expressed in log-levels: GDP (panel A), the GDP deflator (panel B), loans (to firms and households, panel C), and M3 (panel D).

Again, the shaded area represents the distribution of impulse responses in the euro area (computed as the GDP weighted average of the country responses), while the four lines represent, respectively, the median responses in the four countries.

Figure 3. Response of Macroeconomic Variables to a Monetary Policy Shock



Notes: The figure reports the distribution of impulse responses of the log-levels of the variables in the euro area (GDP weighted average of the four countries, in all panels), trimming the quantiles below the sixteenth and above the eighty-fourth. The four lines in all panels refer to the median responses in each of the four countries. Vertical axis: percentage points. Horizontal axis: quarters after the shock.

As expected, real GDP decreases in all countries in response to a tightening of the ECB monetary policy. Real GDP reaches its trough after about two years in all countries, with similar path and size of the reaction across countries. Consumer prices exhibit more cross-country heterogeneity, dropping in Italy, Spain, and France, while German prices are unaffected by the monetary policy tightening. Credit markets exhibit a more relevant extent of cross-country heterogeneity compared with real activity and prices. For example, Spain exhibits the most substantial drop in credit, while in Germany, Italy, and France loans initially increase (implying that aggregate loans also increase) before starting to drop after about one year (see den Haan, Sumner, and Yamashiro 2007 and Giannone, Lenza, and Reichlin 2012 for a similar result in the United States and the euro area, and possible interpretations).

Finally, M3, on impact, increases on average across countries. This apparent "lack of liquidity effect" is not surprising, and it is explained by the fact that M3 dynamics are dominated by those of short-term monetary assets (time deposits, marketable instruments) whose return is very sensitive to the policy rate. Hence, a tightening makes these assets more attractive than alternative investment options (see Giannone, Lenza, and Reichlin 2012 for an extensive discussion of this fact).

3.3 The Evaluation of the OMT Effects

The evaluation of OMT effects is made by comparing two scenarios, defined as the no-OMT and the OMT scenarios.[5] The counterfactual analysis is performed starting from 2012:Q3 (i.e., when the OMT has been announced) with a projection horizon of three years, and is constructed as follows. The model is estimated over the sample 1999:Q1–2012:Q3. The no-OMT scenario is simply given by the unconditional forecast of the VAR model for the following three years. The OMT scenario, instead, has the features summarized in table 3.

In particular, *relative to the no-OMT scenario paths*, the OMT announcements are assumed to decrease the two-year bond rates in Italy and Spain over the entire three-year projection horizon (by 1.75 and 2.09 percent in Italy and Spain, respectively, as estimated in the "controlled" event study). The two-year bond rates in France and Germany are left unchanged (i.e., equal to no-OMT values).

In order to further isolate the change in bond rates as mostly related to the OMT announcements, two further assumptions are also made. First, macroeconomic variables in all countries (real activity and prices) are not allowed to change at the time of the "OMT shock" compared with the no-OMT scenario (though they

[5]Lenza, Pill, and Reichlin (2010), Giannone et al. (2012), and Kapetanios et al. (2012) apply a similar methodology for the study of the effects of the ECB liquidity policy and the quantitative easing policy in the United Kingdom.

Table 3. Assumption for the OMT and the No-OMT Scenarios

Assumption A: Shift in the Path of Bond Yields
Italy and Spain: Two-year bond rates decrease over the entire three-year projection horizon (by 1.75 and 2.09 percent in Italy and Spain, respectively).
Germany and France: Impose the same path between OMT and non-OMT scenario.
Assumption B: OMT Only Driver of Changes in Yields
Real activity and prices in all countries are not allowed to change at the time of the OMT announcement (GDP and price changes are set to zero on impact).
Assumption C: Path of Monetary Policy
Impose the same path between OMT and non-OMT scenario.

Notes: The table reports the assumptions used in the conditional forecasting exercise to retrieve the OMT and no-OMT scenarios. The length of the projection horizon used in the analysis is three years.

are allowed to change subsequently). Second, in order to exclude that the differences between the OMT and no-OMT scenarios are related to different paths of standard monetary policy (characterized by the path of the short-term interest rate), we assume that the latter is the same in both scenarios.

Our measure of the effects associated with the OMT announcements is given by the difference of the path for the variables in the OMT and the no-OMT scenarios. Notice that, given that results are computed in terms of deviations in the OMT from the no-OMT scenarios in a linear VAR model, this assessment is independent of the path assumed for the no-OMT scenario.[6] Table 4 reports, for the country/variables pairs (columns 1 and 2) both (i) the median

[6]In order to assess the reaction of the variables in the scenarios, the Kalman-filter-based algorithm described in Banbura, Giannone, and Lenza (2015) is adopted. The algorithm extracts the most likely combination of shocks that, given past regularities, could have generated the scenario paths. All the scenarios assume that the structure of the economy (reflected in the estimated coefficients) and the nature and the relative importance of different shocks (reflected in the estimated covariance matrix of the shocks) remain the same as in the estimation sample.

Table 4. The Macroeconomic Effects Associated with the OMT Announcements

	Variables	Effect	Probability of Positive Effect
Germany	GDP	0.34	0.60
	Price	0.28	0.67
	Loans	1.08	0.90
France	GDP	0.46	0.64
	Price	0.28	0.68
	Loans	1.38	0.22
Italy	GDP	1.50	0.81
	Price	1.21	0.86
	Loans	3.58	0.82
Spain	GDP	2.01	0.80
	Price	0.74	0.65
	Loans	2.31	0.75

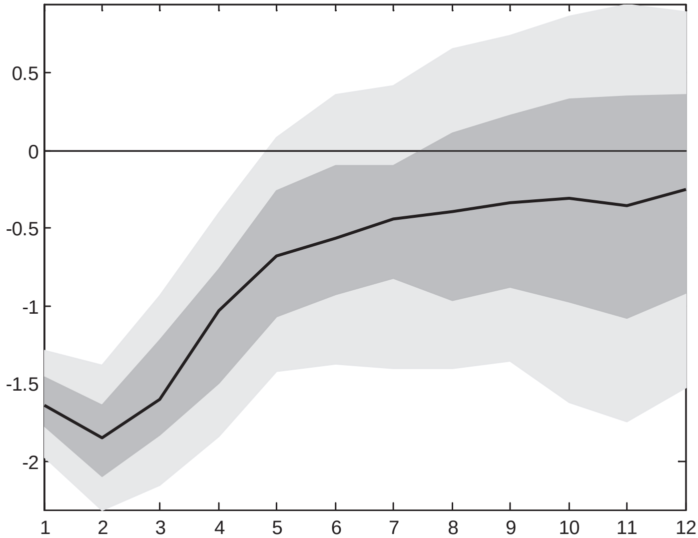
Notes: The table reports the effects associated with the OMT announcements in terms of percentage deviations in the OMT scenario relative to the no-OMT scenario at the end of the three-year projection horizon. The last column reports the probability that the effects are positive.

results (column 3) and (ii) the probability (column 4) that the effects are positive, both evaluated three years after the announcement.

The general outcome of the analysis is that the OMT announcements are very likely to be associated with positive and quite sizable effects on real activity, loans, and consumer prices in Italy and Spain. The size of the effects of GDP and prices is broadly in line with those estimated for the quantitative easing policies in the United States and the United Kingdom.[7] The evidence reported in table 3 points

[7]The elasticity implied in the estimates of the macroeconomic effects of the OMT announcements for Italy and Spain lie broadly in the middle of the range of estimates of the effects of LSAP policies in the United States and QE in the United Kingdom. For the United States, Chen, Cúrdia, and Ferrero (2012) provide the lower boundary, while Chung et al. (2012) and Baumeister and Benati (2013) provide the upper boundary. For the United Kingdom, Kapetanios et al. (2012) find that a permanent decrease in the term spread by 100 basis points would imply an increase in the level of GDP which ranges between 0.7 and 2.7 percent.

Figure 4. The Effects on Bond Market Volatility Associated with the OMT Announcements



Notes: The figure reports the distribution of the responses of bond market volatility (trimming the quantiles lower than the fifth and higher than the ninety-fifth). The black solid line represents the median of the posterior distribution. Vertical axis: percentage points. Horizontal axis: quarters after the shock.

to moderate (positive) spillovers on the real activity in France, and even smaller in Germany.

Figure 4 provides some additional evidence on the effects of the OMT announcements on bond market volatility. The OMT announcements are shown to reduce expected bond market volatility, a measure of uncertainty in the euro-area bond market, by about 1.5 percentage points. Given the definition of the volatility index, the latter result implies a reduction of 35 basis points in the standard deviation of following-month expected euro-area bond rates. This result is in contrast with the insignificant response of bond market volatility found for the effects of standard monetary policy.

4. Conclusions

The announcements that the Eurosystem might engage (under specific conditions) in outright monetary transactions had a sizable impact on financial markets in a period where monetary policy transmission was particularly impaired because of high redenomination risks perceived by market participants. We have found that such announcements have led to a decrease by about 200 basis points in the two-year government bond rates in Italy and Spain, while leaving German and French yields of bonds of comparable maturities largely unaffected.

Evaluating the impact on the real economy of the financial market effects through the lens of a multi-country BVAR model for the largest euro-area countries, we found that the announcements have statistically significant and economically relevant effects on credit and, in general, on economic growth in Italy and Spain with some relatively limited spillovers in France and Germany.

Over the last months, declining levels of interest rate on sovereign bonds, improving financial market conditions, and a decreasing dependency of the euro-area banking system on Eurosystem refinancing have signaled the gradual return to a phase of a normalization in the euro-area financial markets. Our findings attribute part of these improvements to the announcements of the OMT program.

Appendix 1. Event-Study Analysis, List of Macroeconomic Releases

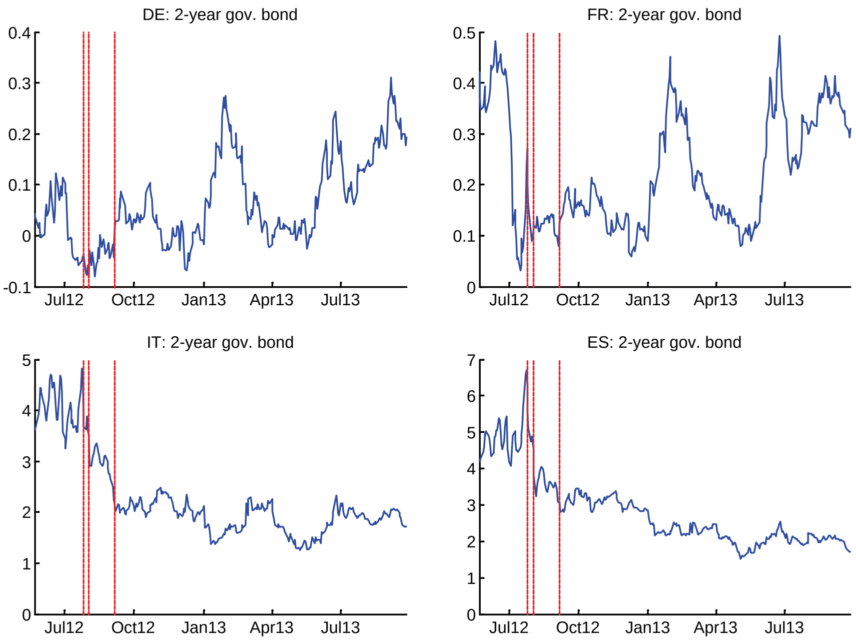
Table 5 reports the entire set of macroeconomic variables used in the high-frequency analysis to identify the effect of the OMT announcements on the government bond yield in Germany, France, Italy, and Spain.

Table 5. Macroeconomic Variables included in the Analysis

Euro Area	**France**	**Germany**	**Italy**	**Spain**
Business Climate Ind.	Bank of France Bus. Sentiment	Budget (% of GDP)	Budget Balance (Year-to-Date)	Adj. Real Ret. Sales (YoY)
ECB Interest Rates	Business Confidence Indicator	Capital Investment	Business Confidence	CPI (MoM)
Current Account SA	Central Govt. Balance (Euros)	Construction Investment	Consumer Conf. Ind. sa	CPI (YoY)
Consumer Conf.	Consumer Confidence Indicator	CPI (MoM)	CPI (NIC incl. tobacco, MoM)	CPI (Core Index) (MoM)
CPI – Core (YoY)	CPI (MoM)	CPI (YoY)	CPI (NIC incl. tobacco, YoY)	CPI (Core Index (YoY)
CPI Estimate (YoY)	CPI (YoY)	Current Account (Euro)	Deficit to GDP	CPI (EU Harm.) (MoM)
Current Account nsa	Consumer Spending (MoM)	Domestic Demand	Government Spending	CPI (EU Harm.) (YoY)
Economic Conf.	Consumer Spending (YoY)	Exports	Hourly Wages (MoM)	GDP (Constant SA) (QoQ)
GDP s.a (QoQ)	CPI	Exports SA (MoM)	Hourly Wages (YoY)	GDP (Constant SA) (YoY)
GDP s.a. (YoY)	CPI	Factory Orders MoM (sa)	Imports	House Price Index (QoQ)
Govt. Debt/GDP Ratio	CPI Ex. Tobacco Index	Factory Orders YoY (nsa)	Industrial Orders n.s.a. (YoY)	House Price Index (YoY)
Govt. Expend. (QoQ)	France Retail PMI	GDP nsa (YoY)	Industrial Orders s.a. (MoM)	Ind. Output WDA (YoY)
Gross Fix Cap. (QoQ)	GDP (QoQ)	GDP s.a. (QoQ)	Ind. Prod. nsa (YoY)	PPI (MoM)
Household Cons. (QoQ)	GDP (YoY)	GDP wda (YoY)	Ind. Prod. sa (MoM)	PPI (YoY)
Ind. Prod. sa (MoM)	Housing Perm. 3M YoY% Chg.	GfK Cons. Conf. Survey	Ind. Prod. wda (YoY)	Real Ret. Sales (YoY)
Ind. Prod. wda (YoY)	Housing Starts 3M YoY% Chg.	Government Spending	Ind. Sales n.s.a. (YoY)	Cons. Confidence
Indust. Conf.	ILO Mainland Unempl. Rate	IFO – Business Climate	Ind. Sales s.a. (MoM)	Trade Balance (Mln. Euros)
Labor Costs (YoY)	ILO Unemployment Rate	Import Price Index (MoM)	PMI Manufacturing	Unempl. MoM Net (000s)
M3 s.a. (YoY)	Imports (QoQ)	Import Price Index (YoY)	PMI Services	Unemp. Rate (Survey)
M3 s.a. 3 mth ave.	Ind. Prod. (MoM)	Imports	PPI (MoM)	
PPI (MoM)	Ind. Prod. (YoY)	Imports SA (MoM)	PPI (YoY)	
PPI (YoY)	Mainland Unemp. Chg. (000s)	Ind. Prod. YoY (nsa wda)	Private Consumption	
Ret. Sales (MoM)	Manuf. Prod. (MoM)	Ind. Prod. (YoY)	Retail Sales (YoY)	
Ret. Sales (YoY)	Manuf. Prod. (YoY)	Ind. Prod. MoM (sa)	Retail Sales s.a. (MoM)	
Services Conf.	Non-Farm Payrolls (QoQ)	PMI Manufacturing	Retailers' Confid. General	
Trade Balance	Own-Company Prod. Outlook	PMI Services	Total Investments	
Trade Balance sa	PMI Manufacturing	Private Consumption	Trade Balance (Total) (Euros)	
Unempl. Rate	PMI Services	Producer Prices (MoM)	Trade Balance Eu (Euros)	
Ind. New Ord. NSA (YoY)	PPI (MoM)	Producer Prices (YoY)	Trade Balance Non-Eu (Euros)	
Ind. New Ord. SA (MoM)	PPI (YoY)	Retail Sales (MoM)	Unempl. Rate	
PMI Composite	Production Outlook Indicator	Retail Sales (YoY)	Unempl. Rate (s.a.)	
PMI Manuf.	Total Jobseekers	Trade Balance	Unempl. Rate (SA)	
PMI Services	Trade Balance (Euros)	Unempl. Chg. (000s)		
ZEW Survey (Econ. Sent.)	Wages (QoQ)	Unempl. Rate (s.a.)		

Note: The table reports the macroeconomic variables used in the high-frequency analysis.

Figure 5. Two-Year Bond Rate: Daily Frequency



Notes: The figure reports the interest rates on the two-year government bond in Germany (DE), France (FR), Italy (IT), and Spain (ES) during the sample period of the event-study analysis, i.e., from May 2012 to September 2013. Vertical gridlines indicate the OMT announcement days, i.e., July 26, August 2, and September 6, 2012.

Appendix 2. Daily and Intradaily Effects of the Announcements

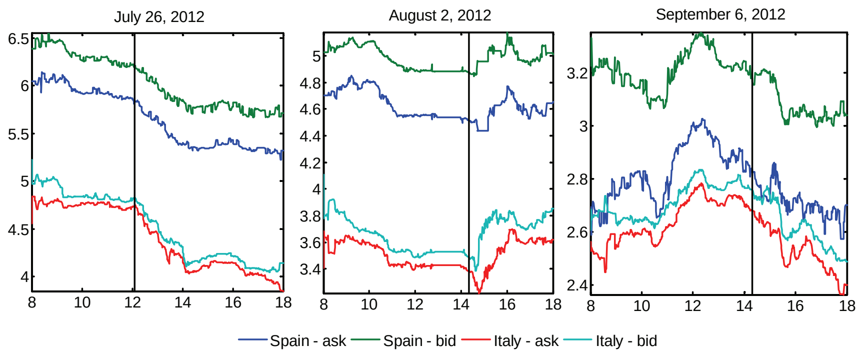
Figure 5 reports the interest rates on the two-year government bond in Germany (DE), France (FR), Italy (IT), and Spain (ES) during the sample period of the event-study analysis, i.e., from May 2012 to September 2013. Vertical gridlines indicate the announcement days.

Changing the size of the event window might be interpreted as a test for possible reversal and lagged effects. In line with the results presented in table 2, the estimated reaction of five-year sovereign CDS in the four selected economies, and the euro-area bond market volatility and stock market volatility to the OMT announcements, are not influenced by the length of the event window (see table 6).

Table 6. Asset Price Reactions (in Basis Points) and the Length of the Event Window

	Size of Event Window									
	One Day		**Two Days**		**Three Days**		**Four Days**		**Five Days**	
Variable	**Classical**	**Controlled**	**Classical**	**Controlled**	**Classical**	**Controlled**	**Classical**	**Controlled**	**Classical**	**Controlled**
	Five-Year CDS									
Germany	−5	−1	−16	−13	−21	−19	−20	−21	−23	−24
France	−9	−5	−35	−32	−41	−36	−43	−41	−51	−50
Italy	−41	−33	−154	−144	−154	−142	−163	−153	−175	−169
Spain	−40	−33	−156	−148	−178	−169	−177	−172	−202	−201
Euro Area: Bond Volatility	−1.2	−1.3	−1.0	−1.2	0.0	−0.1	0.5	0.1	0.1	−0.1
Euro Area: Stock Volatility	−5.3	−5.0	−9.8	−9.7	−5.9	−4.8	−5.9	−5.9	−6.6	−6.1

Figure 6. Intraday Bid and Ask of Two-Year Bond during the Days of OMT Announcements



Notes: The figure reports the value of the bid and ask two-year bond rates in Italy and Spain during the day of the three OMT-related announcements. Horizontal axis: trading hours. The vertical lines indicate the time when Mr. Draghi started to talk in London on July 26 (12:09) and on August 2 and September 6 (14:30).

Figure 6 reports the time patterns of the two-year bond bid and ask rates for Italy and Spain during the trading hours of the first OMT announcement. As depicted in the figure, these rates significantly drop after the announcement (the vertical line in the graph). This further corroborates that the announcement was the dominant event during that day.

Appendix 3. The Multi-Country VAR Model

Let y_t be an n-dimensional vector of variables; the general equation of a VAR is

$$y_t = c + A_1 y_{t-1} + \cdots + A_p y_{t-p} + \varepsilon_t$$
$$\varepsilon_t - N(0, \Sigma),$$

where $A_1 \ldots A_2$ are $n \times n$ matrices of coefficients, p $(= 5)$ the number of lags, and ε_t is an n-dimensional vectorial white noise.

Table 7 reports the definition and data transformations of the n $(= 26)$ variables we include in the VAR model. We estimate our

Table 7. VAR Variables Definition

Country	Variable	Transformation
France (FR)	Real GDP	4*Log-levels
	HICP	4*Log-levels
	M3	4*Log-levels
	Retail Loans	4*Log-levels
	Two-Year Bond Rates	Raw
	Ten-Year Bond Rates	Raw
Germany (DE)	Real GDP	4*Log-levels
	HICP	4*Log-levels
	M3	4*Log-levels
	Retail Loans	4*Log-levels
	Two-Year Bond Rates	Raw
	Ten-Year Bond Rates	Raw
Italy (IT)	Real GDP	4*Log-levels
	HICP	4*Log-levels
	M3	4*Log-levels
	Retail Loans	4*Log-levels
	Two-Year Bond Rates	Raw
	Ten-Year Bond Rates	Raw
Spain (ES)	Real GDP	4*Log-levels
	HICP	4*Log-levels
	M3	4*Log-levels
	Retail Loans	4*Log-levels
	Two-Year Bond Rates	Raw
	Ten-Year Bond Rates	Raw
Euro Area (EA)	EONIA (overnight money-market rate)	Raw
	Bond Volatility	Raw

model in (log-)levels. The data are quarterly and are available in the sample 1999:Q1–2012:Q4.

Retail credit is the sum of total credit to households and non-financial corporations. The implied bond volatility for the euro area is constructed by averaging the (end-of-period) implied volatility on call and put options of the Eurex Generic 1st "RX" Future.

This future contract is based on long-term notional debt securities issued by the German federal government with a term of 8.5–10.5 years.

Estimation and Conditional Forecasts

The large cross-section of variables (twenty-six) and number of lags (five), coupled with the relatively small sample, implies that classical maximum-likelihood techniques would provide unreliable estimates.

Hence, for the estimation of the VAR, we address the high-dimensional data problem by adopting Bayesian shrinkage as suggested in De Mol, Giannone, and Reichlin (2008) and Banbura, Giannone, and Reichlin (2010). The latter show that if the data are collinear, as is the case for macroeconomic variables, the relevant sample information is not lost when overfitting is controlled for by shrinkage via the imposition of priors on the parameters of the model to be estimated.

More precisely, in this paper we consider conjugate priors belonging to the normal/inverse-Wishart family where the prior for the covariance matrix of the residuals Σ is inverse-Wishart and the prior for the autoregressive coefficients is normal.

For the prior on the covariance matrix of the errors, Σ, we set the degrees of freedom equal to $n + 2$, which is the minimum value that guarantees the existence of the prior mean, which we set as $E[\Sigma] = \Psi$, where Ψ is diagonal.

The baseline prior on the model coefficients is a version of the so-called Minnesota prior (see Litterman 1979). This prior is centered on the assumption that each variable follows an independent random-walk process, possibly with drift, which is a parsimonious yet "reasonable approximation of the behaviour of an economic variable."

The prior moments for the VAR coefficients are as follows:

$$E[(A)_{ij}|\Sigma, \lambda, \Psi] = \begin{cases} 1 & \text{if } i = j \text{ and } s = 1 \\ 0 & \text{otherwise} \end{cases}$$

$$\mathrm{cov}((A_s)_{ij}, (A_r)_{hm}|\Sigma, \lambda, \Psi) = \begin{cases} \lambda^2 \frac{1}{s^2} \frac{\Sigma_{ih}}{\psi_j} & \text{if } m = j \text{ and } r = s \\ 0 & \text{otherwise} \end{cases}$$

Notice that the variance of this prior is lower for the coefficients associated with more distant lags, and that coefficients associated with the same variable and lag in different equations are allowed to be correlated. Finally, the key hyperparameter is λ—it controls the scale of all the variances and covariances, and effectively determines the overall tightness of this prior. The terms $\frac{\Sigma_{ih}}{\psi_j}$ account for the relative scale of the variables. The prior for the intercept, c, is non-informative (a very high prior variance).

We complement the prior with an additional prior to implement a so-called inexact differencing of the data. More precisely, rewrite the VAR equation in an error-correction form:

$$y_t = c + (A_1 + \cdots + A_p - I_n)y_{t-1} + B_1 \Delta y_{t-1} + \cdots + B_p \Delta y_{t-p} + \varepsilon_t,$$

where $B_s = -A_{s+1} - \cdots - A_p$.

A VAR in first differences implies the restriction $\Pi = 0$. We follow Doan, Litterman, and Sims (1984) and set a prior centered at 1 for the sum of coefficients on own lags for each variable, and at 0 for the sum of coefficients on other variables' lags. This prior also introduces correlation among the coefficients on each variable in each equation. The tightness of this additional prior is controlled by the hyperparameter μ. As μ goes to infinity, the prior becomes diffuse, while as it goes to 0, we approach the case of exact differencing, which implies the presence of a unit root in each equation.

Summing up, the setting of these priors depends on the hyperparameters λ, μ, and Ψ, which reflect the informativeness of the prior distributions for the model coefficients. These parameters have been usually set on the basis of subjective considerations or rules of thumb. We instead closely follow the theoretically grounded approach proposed by Giannone, Lenza, and Primiceri (2015). This involves treating the hyperparameters as additional parameters, in the spirit of hierarchical modeling. As hyperpriors (i.e., prior distributions for the hyperparameters), we use proper but almost flat distributions. In this setup, the marginal likelihood evaluated at the posterior mode of the hyperparameters is close to its maximum.

In order to compute conditional forecasts in our relatively large VAR, we use the Kalman-filter-based algorithm described in Banbura, Giannone, and Lenza (2015).

References

Altavilla, C., and D. Giannone. 2014. "The Effectiveness of Non-standard Monetary Policy Measures: Evidence from Survey Data." CEPR Discussion Paper No. 10001.

Banbura, M., D. Giannone, and M. Lenza. 2015. "Conditional Forecasts and Scenario Analysis with Vector Autoregressions for Large Cross-Sections." *International Journal of Forecasting* 31 (3): 739–56.

Banbura, M., D. Giannone, and L. Reichlin. 2010. "Large Bayesian Vector Auto Regressions." *Journal of Applied Econometrics* 25 (1): 71–92.

Baumeister, C., and L. Benati. 2013. "Unconventional Monetary Policy and the Great Recession: Estimating the Macroeconomic Effects of a Spread Compression at the Zero Lower Bound." *International Journal of Central Banking* 9 (2, June): 165–212.

Carter, C., and P. Kohn. 1994. "On Gibbs Sampling for State Space Models." *Biometrika* 81 (3): 541–53.

Chen, H., V. Cúrdia, and A. Ferrero. 2012. "The Macroeconomic Effects of Large-Scale Asset Purchase Programmes." *Economic Journal* 122 (564): F289–F315.

Christiano, L. J., M. Eichenbaum, and C. L. Evans. 1999. "Monetary Policy Shocks: What Have We Learned and to What End?" In *Handbook of Macroeconomics*, Vol. 1A, ed. J. B. Taylor and M. Woodford, 65–148 (chapter 2). Elsevier.

Chung, H., J.-P. Laforte, D. Reifschneider, and J. C. Williams. 2012. "Have We Underestimated the Likelihood and Severity of Zero Lower Bound Events?" *Journal of Money, Credit and Banking* 44 (s1): 47–82.

Cochrane, J. H., and M. Piazzesi. 2002. "The Fed and Interest Rates: A High-Frequency Identification." *American Economic Review* 92 (2): 90–95.

D'Amico, S., and T. King. 2013. "Flow and Stock Effects of Large-Scale Treasury Purchases: Evidence on the Importance of Local Supply." *Journal of Financial Economics* 108 (2): 425–48.

De Mol, C., D. Giannone, and L. Reichlin. 2008. "Forecasting Using a Large Number of Predictors: Is Bayesian Shrinkage a Valid Alternative to Principal Components?" *Journal of Econometrics* 146 (2): 318–28.

den Haan, W. J., S. W. Sumner, and G. M. Yamashiro. 2007. "Bank Loan Portfolios and the Monetary Transmission Mechanism." *Journal of Monetary Economics* 54 (3): 904–24.

Doan, T., R. Litterman, and C. A. Sims. 1984. "Forecasting and Conditional Projection Using Realistic Prior Distributions." *Econometric Reviews* 3 (1): 1–100.

Draghi, M. 2013. "Strengthening Financial Resilience." Speech by Mario Draghi at the 2013 International Monetary Conference, Shanghai, June 3.

Eser, F., and B. Schwaab. 2013. "Assessing Asset Purchases within the ECB's Securities Markets Programme." ECB Working Paper No. 1587.

Falagiarda, M., and S. Reitz. 2013. "Announcements of ECB Unconventional Programs: Implications for the Sovereign Risk of Italy." Working Paper No. 1866, Kiel Institute for the World Economy.

Gagnon, J., R. Raskin, J. Remache, and B. Sack. 2011. "The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases." *International Journal of Central Banking* 7 (1, March): 3–43.

Ghysels, E., J. Idier, S. Manganelli, and O. Vergote. 2014. "A High Frequency Assessment of the ECB Securities Markets Programme." ECB Working Paper No. 1642.

Giannone, D., M. Lenza, H. Pill, and L. Reichlin. 2012. "The ECB and the Interbank Market." *Economic Journal* 122 (564): F467–F486.

Giannone, D., M. Lenza, and G. Primiceri. 2015. "Prior Selection for Vector Autoregressions." *Review of Economics and Statistics* 97 (2): 436–51.

Giannone, D., M. Lenza, and L. Reichlin. 2012. "Money, Credit, Monetary Policy and the Business Cycle in the Euro Area." CEPR Discussion Paper No. 8944.

Hördal, P., and O. Tristani. 2013. "Macro Factors and Sovereign Bond Spreads: A Quadratic No-Arbitrage Model." Mimeo, European Central Bank.

Joyce, M., A. Lasaosa, I. Stevens, and M. Tong. 2011. "The Financial Market Impact of Quantitative Easing." *International Journal of Central Banking* 7 (3, September): 113–61.

Kapetanios, G., H. Mumtaz, I. Stevens, and K. Theodoridis. 2012. "Assessing the Economy-wide Effects of Quantitative Easing." *Economic Journal* 122 (564): F316–F347.

Krishnamurthy, A., and A. Vissing-Jorgensen. 2011. "The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy." *Brookings Papers on Economic Activity* 2: 215–87.

Kuttner, K. N. 2001. "Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market." *Journal of Monetary Economics* 47 (3): 523–44.

Lenza, M., H. Pill, and L. Reichlin. 2010. "Monetary Policy in Exceptional Times." *Economic Policy* 25 (62): 295–339.

Litterman, R. B. 1979. "Techniques of Forecasting Using Vector Autoregressions." Working Paper No. 115, Federal Reserve Bank of Minneapolis.

Rivolta, G. 2012. "An Event Study Analysis of ECB Unconventional Monetary Policy." Mimeo, University of Milan.

Szczerbowicz, U. 2012. "The ECB Unconventional Monetary Policies: Have They Lowered Market Borrowing Costs for Banks and Governments?" Working Paper No. 2012-36, CEPII Research Center.

Discussion of “The Financial and Macroeconomic Effects of the OMT Announcements”*

Stefania D’Amico
Federal Reserve Bank of Chicago

1. Introduction

In their paper titled “The Financial and Macroeconomic Effects of the OMT Announcements,” Carlo Altavilla, Domenico Giannone, and Michele Lenza (henceforth, AGL) aim at quantifying the financial and macroeconomic effects of the European Central Bank’s (ECB’s) announcements about the possibility of engaging in outright monetary transactions (OMTs). Specifically, the financial impact is estimated using an ameliorated version of the commonly used event-study methodology; subsequently, the estimated size of the high-frequency financial impact is imposed as an “OMT shock” in a lower-frequency vector autoregression (VAR); and finally, the macroeconomic effect is given by the difference between the macro variables’ forecasts implied by the VAR with and without the “OMT shock,” which decreases the government bond yields only of Italy and Spain. The key result is that the financial and macroeconomic effects are found to be statistically and economically significant for relatively more distressed euro-zone countries.

While most of the literature that attempts to measure the impact of central bank unconventional policies focuses on financial markets, AGL is one of the few studies that goes beyond the financial impacts and tries to determine the wider economy effects. Therefore, it is a nice advance over previous efforts to quantify the efficacy of the ECB’s unconventional monetary policies in the euro area, which is much more difficult than evaluating the efficacy of the

*This paper reflects only the views of the author, and does not necessarily reflect the views of the Federal Reserve Bank of Chicago, the Federal Reserve System, or their staff.

Federal Reserve's unconventional policies in the United States. This is because, in the case of the euro zone, researchers have to account for a multi-country framework with very heterogeneous countries; a model specification that is flexible enough to capture spillovers among variables and countries; the ECB's policy decision announcements taking place in stages, arguably more complex and less transparent; and the possibilities that past regularities in relations across variables and countries may not hold in the post-announcement period—not to mention having to deal with a shorter sample period due to the introduction of the euro in 1999.

Recognizing all these difficulties has been an extremely humbling process that has raised some additional concerns relative to those that usually apply to the type of analysis and methodologies employed in this study (e.g., we all know that event-study analysis cannot tell us anything about the impact's persistency; this would be one of the usual concerns that I am not going to address in this discussion), which to some extent are common to many empirical works focused on evaluating central bank unconventional policies.

The first set of concerns is about applying the event-study methodology to the OMT announcements, as these announcements are about the *possibility* of engaging in a policy rather than *actually* engaging in a policy or engaging in a policy with well-defined parameters. To fix ideas, before analyzing the problematic aspects of OMT announcements in more detail, it might help to order a few unconventional monetary policy announcements by an increasing degree of difficulty in the identification and estimation of their effects: the first U.S. large-scale asset purchase (LSAP) program, the third U.S. LSAP program, and the ECB's OMTs. The first LSAP is, in my mind, the only case where an event-study methodology can be applied with little concern, as it was mostly unexpected, all the relevant information is released during the announcement, and the content of the announcement reveals clearly the program's main characteristics, that is, a fixed size, a specific duration, and even the intended maturity distribution of purchases. The third LSAP is much harder to evaluate based on the related announcements because it was mostly expected, that is, the information about a potential third round of quantitative easing (QE) was incrementally released to the public through different Federal Reserve communication tools, and it was open ended, which implies that on the announcement day market participants could not determine the total size and duration of the program. The three OMT announcements not only were mostly expected by investors but also were about programs that never were activated, so the resolution of uncertainty is incomplete. Thus, the associated expectation formation process after and in between each of the OMT announcements will also be incomplete. This in turn implies that the effect on asset prices will not be exhausted within a small time window around the announcements. This is the reason why I think that the event-study methodology, in this particular case, can only *partially* capture the impact of these policies.

The second set of concerns deals with applying a linear model with time-invariant parameters to estimate the macroeconomic effect of OMT announcements. Although this is always a concern when we estimate VAR models, and therefore it may seem an unfair comment, in the particular cases where we deal with exceptional economic circumstances and unconventional policies that are meant to shape expectations about future events, these concerns become more important, especially if the analysis does not control properly for direct measures of expectations. I will elaborate on this in more detail in section 3.

The third set of concerns has to do with the choice of a pertinent counterfactual to evaluate the macroeconomic impact of the OMT announcements. More specifically, I will suggest an alternative "counterfactual" that, for various reasons that I will mention soon, I consider at least as valid as the one used in this study.

Finally, I will conclude by providing some additional suggestions that could both improve the robustness of the empirical analysis and widen its scope a bit.

2. The Financial Impact of OMT Announcements

As already mentioned, the financial impact is estimated using a controlled event-study approach that focuses on three *consecutive* announcements about the *same* unconventional monetary policy, that is, the OMTs. During the last announcement, the technical features of the OMTs are released; however, this program has never been activated. It is extremely challenging to identify and estimate the effects of unconventional monetary policy announcements for which it is hard to determine the type of announcement, the size of the program, the duration of the program, the euro-zone countries that qualify for the program, and so on. Most of these features, which after the first two announcements were still left to the ECB's discretion, were never revealed to the public, and in the end, the OMT policy turned out to be only about communication (and no action), albeit incomplete communication. Thus, it is reasonable to assume that after the first two announcements, market participants could have been waiting for more clarification, and it can be seen from the plots of the government bond yields shown in AGL that those yields declined significantly well before the third OMT announcement, suggesting that news about the content of the last ECB press release had emerged between announcements.

For example, *Der Spiegel* on September 6, 2012, reported the following: "The ECB has resembled a sieve this week. Ahead of Thursday's much anticipated press conference, financial websites and business papers were full of reports detailing ECB President Mario Draghi's plan for holding down the borrowing costs of debt-plagued euro-zone member states. Discretion was in short supply." This strongly suggests that after the first OMT announcement, as the ECB signals its intentions gradually and ahead of the official policy announcements, it becomes increasingly harder to even identify the relevant events to include in the event study, not to mention to choose the length of the event window.

The ECB's OMT announcements are one of the many instances where this type of concern applies. As is often the case, for most unconventional policy announcements following the first one of a significant series, central banks moved to provide *incremental* news about their intentions through different communication tools, such as each policy meeting's statement (including those meetings characterized by inaction), policymakers' speeches and interviews, and even policy conferences (e.g., the Jackson Hole Economic Policy Symposium). More importantly, frequently, the beginning and adjustment of these policies became conditional to data, implying that any data release could affect expectations about these programs, and these changes in expectations would get priced in across various financial assets. In other words, when central banks' communication about a certain program becomes gradual, incremental, and conditional to data, it becomes extremely tricky to correctly identify all the relevant events. Unless it is possible to control for the evolution of market expectations about the unconventional policy ahead of the few chosen announcements, it is difficult to obtain correct estimates of the financial impact relying only on event studies. Nevertheless, this is often the best an econometrician can do given the available information.

Further, dealing with consecutive announcements about a program that does not get implemented makes it even harder to apply the event-study methodology, as following each of the announcements there is no validation of the change in expectations triggered by the announcement itself, so expectations and therefore asset prices must keep changing in subsequent days. I do not have a good suggestion on how to deal with this particular problem. Previous studies have suggested different approaches to address some of the complications introduced by different types of unconventional policy announcements. For example, Trebesch and Zettelmeyer (2014) show how to modify the methodology of D'Amico and King (2013), which has been used to estimate the impact of the first LSAP (the relatively easier case), to measure the effects of open-ended programs such as the ECB's Securities Markets Programme (SMP) or similarly the Federal Reserve's third LSAP; D'Amico et al. (2014) illustrate the importance of isolating the unexpected component of the Federal Reserve's LSAPs' and maturity extension programs' (MEPs') announcements to evaluate the efficacy of these policies. But, as was already stressed in the introduction, dealing with these Federal Reserve policies' announcements is much easier than dealing with the OMT announcements. The only tentative suggestion I have is to try to develop a two-step estimation procedure for the daily regressions, where in the first step, maybe using interest rate derivatives, AGL should try to keep track of the probability of an OMT announcement occurring given the macroeconomic surprises in the period before the announcement, that is, using their same notation, try to estimate the $\Pr(D_t = 1 \mid News_{t-1})$, where D is the dummy that equals one if the announcement occurs and *News* is the macroeconomic surprises. Then, in the second step, estimate the impact of the OMT announcements controlling for this probability. And eventually, following the first OMT announcement, AGL should try to keep track of the probability of the OMT program being activated conditional to the previous announcement and macroeconomic surprises, that is, using again their same notation $\Pr(OMT_t > 0 \,|\, D_{t-1} = 1, News_{t-1})$.

3. The Macroeconomic Effect of OMT Announcements

Let me first start with what I perceive to be the broader objective of the OMTs and then discuss how this might affect the estimation of the macroeconomic effect. In one of the statements about OMTs, ECB President Mario Draghi said the following: "OMTs will enable us to address severe distortions in government bond markets which originate from, in particular, unfounded fears on the part of investors of the reversibility of the euro. Hence, under appropriate conditions, we will have a fully effective backstop to avoid destructive scenarios." Differently from the Federal Reserve's LSAPs and MEPs, it seems to me that the most immediate objective of the OMTs is not to stimulate economic activity but to provide insurance against worst-case scenarios. Therefore, effectively, these announcements may have changed the shocks' distribution by cutting the extreme right tail, if we think in terms of very large and positive shocks to government bond yields. Alternatively, if we think in terms of lower probability of destructive growth scenarios, then we might say that these announcements eliminated the extreme left tail. Either way, risk is strongly reduced and the volatility of the variables included in the VAR might be much smaller. In other words, the post-OMT sample period may be characterized by non-Gaussian distributions of the shocks, and non-linearities become more relevant than previously experienced.

Further, in principle, "whatever-it-takes" type of announcements (that is, the first announcement included in the AGL's study), similarly to forward guidance, are about *commitments* to *future* policy actions. In other words, their main objective is to manipulate expectations about the future state of the economy by convincing investors today that the central bank will act tomorrow, if necessary. If the VAR model includes direct measures of expectations and these commitments to future policies are perceived as something new, then they will manifest either as shocks to expectations of future variables or as future changes in the VAR's coefficients (e.g., the coefficients of the perceived monetary policy rule). But, if the VAR model doesn't control properly for expectations, almost certainly they will show up as future changes in the coefficients, making time-invariant parameters a more acute problem.

Overall, considering the potential issues raised so far about non-linearities and time-varying parameters, it seems to me that, to improve the econometric analysis, it becomes important to try to do the following: (i) control for direct measures of expectations in VAR models (see for example, Chun 2011; Orphanides and Wei 2012; D'Amico and King 2015; Piazzesi, Salomao, and Schneider 2015); (ii) show robustness of the VAR estimation to the inclusion/exclusion of the OMT period to verify the stability of the parameters; and (iii) eventually, estimate a time-varying VAR that can capture shifts between the pre- and post-OMT periods (e.g., Baumeister and Benati 2013).

Let me now turn to the discussion of the choice of a pertinent counterfactual to correctly quantify the macroeconomic effect of the "OMT shock." When I started reading the section about the forecasting exercise, my first reaction was to think immediately about a more obvious way (at least to me) to quantify the impact of a shock when I am estimating a VAR: to compute impulse response functions (IRFs). That is, instead of stopping the estimation in 2012:Q3 and evaluating the macroeconomic effect through the lens of a forecasting exercise that prevents the use of the full sample (especially considering the length of the quarterly sample period), what about using all the available data, including the post-OMT period, and simulating the IRFs to a 200-basis-point shock in the path of the two-year yield that leaves the policy rate path unchanged over the same period? It might capture better what actually happened following the "OMT shock." Further, using this alternative approach, it is easier to verify if the IRFs to the "OMT shock" change once the post-OMT period is excluded. And, if in 2012:Q3 there was a structural break in the regularities across variables and countries relations, then the forecasting exercise based on the pre-2012:Q3 estimates might not be the best approach.

3.1 Additional Suggestions for the VAR Estimation

If we are trying to evaluate the impact of a policy that might change the amount of government-issued bonds that mature in one to three years, it might be reasonable to include quantity variables in the

VAR, as, at the very least, those variables might help us understand the heterogeneous response across countries. For example, I would control for the amount of government debt with three years or less left to maturity in each country and/or banks' holdings of GIIPS (Greece, Italy, Ireland, Portugal, and Spain) countries' debt in each country (e.g., Acharya et al. 2015).

In addition, to better capture the risk channel of OMTs and avoid issues related to the impact of unconventional monetary policy on the term structure of interest rates, in the VAR specification I would replace the ten-year yields with the credit default swap spreads.

Finally, if the spillovers between OMT effects on the two-year yield and the policy rate path are significantly different from zero in the VAR estimation, killing these spillovers in the OMT scenario—depending on whether policy tools that affect the policy rate and the OMTs are perceived as complements or substitutes—can bias estimates of the macroeconomic effect in either directions. For example, if OMT announcements are interpreted as signaling that the policy rate path might stay lower for longer (that is, the policy tools are perceived as complements), then killing those spillovers (that is, assuming that the policy rate path is unchanged) might bias downward the estimated magnitude of the macroeconomic effect.

4. Additional Considerations for Future Research

To widen a bit the scope of AGL's analysis and in light of the recent literature investigating the different channels of the transmission mechanism of unconventional monetary policies (e.g., Krishnamurthy and Vissing-Jorgensen 2011; D'Amico et al. 2012; Li and Wei 2013), I would encourage the authors to try to shed some light on the channels of the OMTs' transmission mechanism by answering some of the following questions: Why is the ten-year yield changing significantly following the OMT announcements if government bond purchases would be concentrated in the one- to three-year maturity sector? Then, why not consider more granular maturities and see if there is a pivotal point at around the three-year maturity threshold? Why do Italy and Spain react differently from Germany and France? Why do stock prices increase significantly in both distressed and core countries following OMT announcements (Krishnamurthy, Nagel, and Vissing-Jorgensen 2015), but the macro effect is much larger in distressed countries? And finally, is it possible to learn something about the effect of sterilization relative to QE operations?

References

Acharya, V. V., T. Eisert, C. Eufinger, and C. Hirsch. 2015. "Whatever It Takes: The Real Effects of Unconventional Monetary Policy." Working Paper (November).

Baumeister, C., and L. Benati. 2013. "Unconventional Monetary Policy and the Great Recession: Estimating the Macroeconomic Effects of a Spread Compression at the Zero Lower Bound." *International Journal of Central Banking* 9 (2, June): 165–212.

Chun, A. L. 2011. "Expectations, Bond Yields and Monetary Policy." *Review of Financial Studies* 24 (1): 208–47.

D'Amico, S., W. English, D. López-Salido, and E. Nelson. 2012. "The Federal Reserve's Large-Scale Asset Purchase Programmes: Rationale and Effects." *Economic Journal* 122 (564, November): F415–F446.

D'Amico, S., and T. B. King. 2013. "Flow and Stock Effects of Large-Scale Treasury Purchases: Evidence on the Importance of Local Supply." *Journal of Financial Economics* 108 (2): 425–48.

———. 2015. "What Does Anticipated Monetary Policy Do?" Federal Reserve Bank of Chicago Working Paper No. 2015-10 (November).

D'Amico, S., C. Li, J. Sears, and M. Cahill. 2014. "The Term-Premium Effect of the Federal Reserve's Asset Purchase Announcements." Working Paper (October).

Krishnamurthy, A., S. Nagel, and A. Vissing-Jorgensen. 2015. "ECB Policies involving Government Bond Purchases: Impact and Channels." Working Paper (December).

Krishnamurthy, A., and A. Vissing-Jorgensen. 2011. "The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy." *Brookings Papers on Economic Activity* (Fall): 215–87.

Li, C., and M. Wei. 2013. "Term Structure Modeling with Supply Factors and the Federal Reserve's Large-Scale Asset Purchase Programs." *International Journal of Central Banking* 9 (1, March): 3–40.

Orphanides, A., and M. Wei. 2012. "Evolving Macroeconomic Perceptions and the Term Structure of Interest Rates." *Journal of Economic Dynamics and Control* 36 (2): 239–54.

Piazzesi, M., J. Salomao, and M. Schneider. 2015. "Trend and Cycle in Bond Premia." Working Paper (March).

Trebesch, C., and J. Zettelmeyer. 2014. "ECB Interventions in Distressed Sovereign Debt Markets: The Case of Greek Bonds." CESifo Working Paper No. 4731 (March).

Beggar-Thy-Neighbor? The International Effects of ECB Unconventional Monetary Policy Measures*

Kristina Bluwstein[a] and Fabio Canova[b]
[a]European University Institute
[b]BI Norwegian Business School, CAMP, and CEPR

This paper examines the effects of unconventional monetary policy measures by the European Central Bank on nine European countries not adopting the euro with a novel Bayesian mixed-frequency structural vector autoregressive technique. Unconventional monetary policy disturbances generate important domestic fluctuations. The wealth, the risk, and the portfolio rebalancing channels matter for international propagation; the credit channel does not. The responses of foreign output and inflation are independent of the exchange rate regime. International spillovers are larger in countries with more advanced financial systems and a larger share of domestic banks. A comparison with conventional monetary policy disturbances and with announcement surprises is provided.

JEL Codes: E52, F42, C11, C32, G15.

*We are grateful to Klaus Adam, Jordi Gali, Ajeandro Justiniano, Giorgio Primiceri, Anders Vredin, Knut Are Aaastvert, Aleksei Netsunajev, Sweder van Wijnbergen, Marco Lo Duca, Andrea Nobili, and participants of seminars at the European Central Bank, Norges Bank, Riksbank, the European University Institute, the University of Amsterdam, Bank of Italy, BIS, Federal Reserve Bank of Chicago, Federal Reserve Bank of Richmond, the International Journal of Central Banking Conference "Challenges to Achieving Price Stability," the ECB conference "Non-standard Policy Measures," and the Empirical Monetary Economics Workshop at Sciences Po, for comments and suggestions. Canova acknowledges the financial support from the Spanish Ministerio do Economia y Competitividad through the grant ECO2012-33247. Corresponding author (Bluwstein): Department of Economics, European University Institute, Via della Piazzuola 43, 50133 Firenze, Italy; e-mail: kristina.bluwstein@eui.eu.

1. Introduction

In recent years there has been an unprecedented use of unconventional monetary policy (UMP) measures by central banks of advanced economies. These measures have attracted increasing criticism from leaders of developing and peripheral countries. For example, India's Central Bank Governor Raghuram Rajan, in a 2014 Brookings speech, stated:

> When monetary policy in large countries is extremely and unconventionally accommodative, capital flows into recipient countries tend to increase local leverage; this is not just due to the direct effect of cross-border banking flows but also the indirect effect, as the appreciating exchange rate and rising asset prices, especially of real estate, make it seem that borrowers have more equity than they really have. . . . But when source countries move to exit unconventional policies, some recipient countries are leveraged, imbalanced, and vulnerable to capital outflows. Given that investment managers anticipate the consequences of the future policy path, even a measured pace of exit may cause severe market turbulence and collateral damage.

In addition, concerns have been voiced that UMP measures could lead to "beggar-thy-neighbor" effects. Brazilian President Rousseff remarked in 2012: "Quantitative easing policies . . . have triggered . . . a monetary tsunami, have led to a currency war and have introduced new and perverse forms of protectionism in the world."

For Europe, where non-euro members are linked to the euro area either through membership in the European Union or significant trade and financial ties, concerns that recent quantitative easing (QE) measures could lead to large appreciation pressures, to increased financial volatility, and to perverse real effects are widespread. For example, Riksbank Deputy Governor Per Jansson states that "ECB measures . . . create challenges. . . . The plan is to make extensive purchases of financial assets, equivalent to three times Swedish GDP over a period of just one year . . . In the event of a more tangible and rapid appreciation of the krona, it will be even more difficult for the Riksbank to attain an inflation rate in line with the target."[1]

The economic implications of international spillovers are expected to be severe, as demonstrated by the recent example of Switzerland, who abandoned its floor to the euro in January 2015 in anticipation of QE measures and lost about 50 billion Swiss francs in foreign exchange holdings over the first half of the year. Thus, for both academic and policy purposes, it is crucial to understand if these international spillovers exist, to measure the repercussions in foreign economies, and to design policies that can contain their negative consequences.

This paper sheds light on these issues using an empirical model, which combines slow-moving monthly macroeconomic variables, weekly monetary policy variables, and fast-moving daily financial variables. To handle the frequency mismatch, we employ a Bayesian mixed-frequency vector autoregressive model. The setup accounts for macroeconomic–financial linkages without the time-aggregation biases that are present when lower-frequency data are used, and enables us to give a structural interpretation to the international spillovers. Such an interpretation is not possible when only high-frequency data is used.

We focus on three questions. First, do European Central Bank (ECB) UMP measures generate important financial and real spillovers in European countries not adopting the euro? If so, does the exchange rate regime play a role? Second, does the degree of financial and banking integration matter? Third, which channel of international transmission is operative? What is the relative importance of exchange rate and financial links?

Many papers have analyzed the domestic effects of UMP measures (see Cecioni, Ferrero, and Secchi 2011 for a review). For the euro area, there is evidence that they had positive regional output effects (Lenza, Pill, and Reichlin 2010; Gambacorta, Hofmann, and Peersman 2012; Darracq Paries and De Santis 2013, Lewis and Roth 2015) but that real responses were slower and less significant than those induced by conventional monetary policy measures (Peersman 2012). The inflation effects instead seem to be muted (Lewis and Roth

[1]Minutes of the Monetary Policy Committee meeting of February 11, 2015.

2015). In addition, high-frequency event studies find a reduction in market spreads (Abbassi and Linzert 2011; Angelini, Neri, and Panetta 2011; Beirne et al. 2011) and a fall in the term premia and government bond yields following a UMP announcement, especially when intraday data are used (see Ghysels et al. 2013).

A number of studies have also begun investigating the international consequences of the Federal Reserve's UMP measures for emerging markets and found that QE caused the U.S. dollar to depreciate, foreign stock prices to rise, and credit default swap (CDS) spreads to decrease (see, e.g., Neely 2010; Chen et al. 2012; Chinn 2013; Fratzscher, Lo Duca, and Straub 2013). Moessner (2014) observes that international effects for advanced and emerging countries are similar, Chen et al. (2012) claim that the impact in emerging countries is stronger (see also Aizenman, Binici, and Hutchison 2014), and Bhattarai, Chattarjee, and Park (2015) find that the "fragile five" emerging economies are affected most. Lim (2014) claims that at least 5 percent of financial inflows to developing countries between 2000 and 2013 were due to the Federal Reserve's UMP. Passari and Rey (2015) find that financial flows to developed countries may also have been large.

For euro-area UMP measures, Boeckx, Dossche, and Peersman (2014) show that, after a liquidity increase, the countries with less capitalized banks have smaller bank lending and output effects, while Lo Duca, Fratzscher, and Straub (2014) find that confidence and asset prices improve. Since the effects on yields are small, they conclude that UMP policies have limited international impact. Chen et al. (2012) note that the international effects of euro UMP measures are weaker than those of the United States. In this paper, we measure the effects of ECB UMP measures in a structural framework that considers both financial and macroeconomic variables. We examine the pairwise transmission between the euro area and nine European countries not adopting the euro and attempt to disentangle channels of transmission of UMP disturbances.

We find that UMP shocks generate important financial market responses in the euro area, sizable macroeconomic fluctuations, and some differences in terms of timing or persistence relative to conventional monetary policy shocks. Interestingly, while UMP disturbances induce significant inflation, conventional monetary policy disturbances primarily affect output. Thus, a combination of conventional and unconventional measures may help to better control output and inflation dynamics. Announcement surprises produce financial market responses that are similar to those of conventional policy shocks, but the domestic macroeconomic effects are weak.

International spillovers exist but there is considerable cross-country heterogeneity. The exchange rate regime is not the reason for this heterogeneity. Advanced economies, which tend to be more financially integrated with the euro area and have a larger share of domestic banks, have stronger output and inflation dynamics than those in the euro area. The macroeconomic effects for financially less developed countries, which have a larger share of foreign banks, are varied, but the magnitude of output and inflation responses are the opposite of those of advanced economies. International transmission occurs via both the exchange rate channel and financial links (wealth, risk, and portfolio rebalancing channels). However, the exchange rate does not seem to shape the responses of foreign macroeconomic variables to euro-area UMP shocks. This is in contrast to the international transmission of conventional policy shocks, where the exchange rate is crucial to understand foreign dynamics.

Our investigation has important policy implications. Letting exchange rate float will not prevent non-euro-area countries from importing ECB unconventional monetary policy decisions (see also Rey 2013). Since the dynamics of financial flows are crucial and the presence of global banks in the area is important in determining domestic outcomes (see also Cetorelli and Goldberg 2012; Bruno and Shin 2015a), measures indirectly restricting financial flows and bank leverage could be more effective in insulating small open economies from undesired output and inflation fluctuations. Bruno and Shin (2015b) and Devereux, Young, and Yu (2015) provide the theoretical justification for using such measures.

The paper is structured as follows: Section 2 gives an overview of the channels through which UMP measures may induce domestic and international adjustments. Section 3 describes the estimation methodology, the identification strategy, and the data. Section 4 presents domestic responses. Section 5 discusses international spillovers. Section 6 investigates why international macrofinancial linkages are heterogeneous. Section 7 examines the robustness of the results. Conclusions are in section 8. The appendices present an overview of the UMP actions by the ECB, the details of the mixed-frequency algorithm, and additional results.

2. Channels of International Transmission

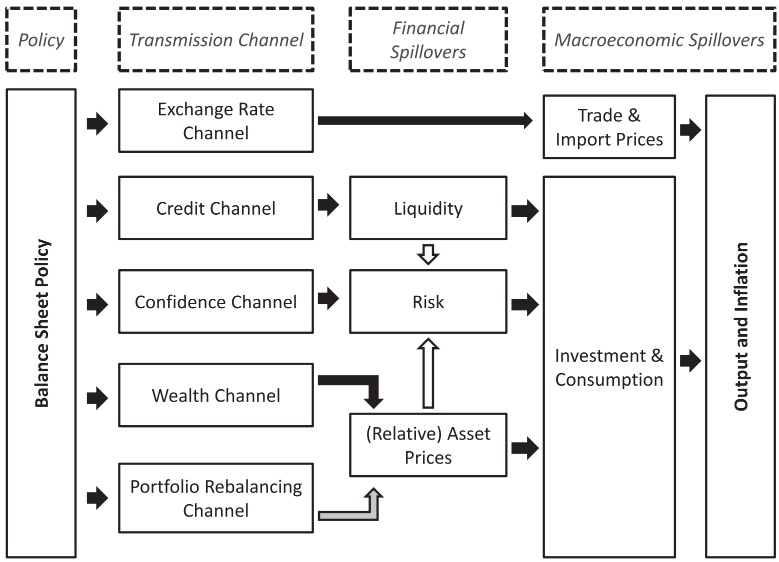
There is quite a lot of literature analyzing the mechanics of domestic monetary policy transmission (see, e.g., Krishnamurthy and Vissing-Jorgensen 2011). As far as conventional monetary policy is concerned, the expectation, the exchange rate, and the interest rate channels have been emphasized (e.g., Russell 1992). Basic to the idea that monetary policy affects the economy is the notion that central bank decisions influence (i) price-level expectations and thus the domestic aggregate supply via price and wage settings; and (ii) expectations of future short-term interest rates, which feed into long-term interest rates. As long-term interest rates matter for investment and consumption, the domestic aggregate demand is also altered.

Both aggregate demand and aggregate supply effects could be reinforced when monetary policy alters the value of the domestic currency. Exchange rate variations influence the quantity and the price of imports and exports and thus both the aggregate supply and aggregate demand. Monetary policy may also tilt the term structure of interest rates and thus consumption and investment decisions. The interest rate channel is considered the main transmission mechanism for conventional monetary policy in Europe before the introduction of the euro (Angeloni 2012).

When discussing UMP, two other channels become potentially relevant. UMP measures may alter asset prices if they change the user cost of capital (*wealth channel*), and they may reduce uncertainty and financial risk perceptions (*confidence channel*). The latter stabilization purpose has been heavily emphasized during the recent financial crisis.

Figure 1 shows the channels of international transmission relevant for unconventional policies. UMP measures may alter the bilateral nominal (real) exchange rate, which affects net trade and import prices for the partner country (*exchange rate channel*). In turn, these variations affect foreign prices, production, and consumption. The relative magnitude of the changes in foreign inflation and output depends on substitution and income effects (Mishkin 2001).

Figure 1. Channels of International Unconventional Monetary Policy Transmission



Notes: The gray arrow indicates an indirect effect. The white arrows indicate contemporaneous effects.

There has been an increased interest in the financial channels of international transmission since the onset of the financial crisis. The *credit channel* comprises the bank lending and the balance sheet sub-channels. The *bank lending channel* refers to the effect that UMP measures have on bank reserves when the amount of market liquidity changes (recall that banks are the main financial institutions in the euro area). The *balance sheet channel* refers to variations in the net worth of banks (and firms) due to changes in the value of cash flows and collateral. These two sub-channels alter credit conditions by affecting both the quantity and quality of loans. In economies that are financially integrated, global credit conditions may also be affected.

UMP measures may change the relative cost of capital. This may have an effect on the relative price of stocks, bonds, houses, and land, which in turn may lead to international capital flows (*wealth channel*). Both the wealth and the credit channels feed into financial risk, investment, and consumption decisions. While these channels are also present when conventional monetary policy actions are undertaken, unconventional policy—hence an expansion or change in the composition of the balance sheet of the central banks—activates the *portfolio rebalancing channel* (Krishnamurthy and Vissing-Jorgensen 2011). It has been argued that balance sheet policies may reduce private portfolios' duration risk (e.g., Bernanke 2010; Gagnon et al. 2011). Thus, yields on long-term securities should decline with long-term borrowing increasing. As a consequence, aggregate demand and financial risk should be altered. Besides a duration (temporal) effect, the *portfolio rebalancing channel* could lead to an international (spatial) rebalancing between UMP and non-UMP countries, as investors seek higher yields or lower risk (see Passari and Rey 2015). This rebalancing effect may also affect nominal exchange rates (see Bruno and Shin 2015b). Finally, the *confidence channel* influences perceptions of uncertainty and risk. Changes in liquidity and asset prices may also have an indirect effect on risk, as they influence the confidence of investors, and thus investment and consumption decisions.[2]

Table 1 lists the programs and the timing of ECB unconventional measures during the sample we consider. A detailed explanation of what each measure involves is in appendix 1. "Unorthodox" policies fell into two broad categories: liquidity policies and sovereign debt policies. The former were introduced as a reaction to the financial crisis to ease tensions and make the interbank market function properly. The presumption was that the additional liquidity would be channeled to private borrowers and that real activity would then pick up. If the additional liquidity would become available in global markets and if foreign banks were willing to use it to finance domestic projects, foreign real activity could have also received a boost. The second type of policies were introduced during the sovereign debt crisis to restore confidence in the euro, to lower long-term yields for troubled economies, and to restart normal lending practices.

Thus, while ECB unconventional policies could have had a direct effect on credit and confidence, they may have only indirectly affected the exchange rate and the portfolio of agents, if they induced

[2]While figure 1 does not mention the *signaling channel*, we account for signaling effects in the empirical analysis.

Table 1. Timeline of ECB Unconventional Monetary Measures

Date	Tool	Total Size in € Billions (Outstanding)
Dec. 2007–Ongoing	Reciprocal Currency Agreement	271.6
Mar. 2008–May 2010	6-month long-term refinancing operations	66
May–Dec. 2009	12-month long-term refinancing operations	614
Jun. 2009–Jun. 2010	Covered Bond Purchase Program	45
May 2010–Aug. 2012	Securities Markets Programme	195
Aug. 2011	12-month long-term refinancing operations	49.8
Oct. 2011	13-month long-term refinancing operations	57
Nov. 2011–Oct. 2012	Covered Bond Purchase Program 2	15
Dec. 2011	36-month long-term refinancing operations	489
Feb. 2012	36-month long-term refinancing operations	530
Jul. 2012	Draghi's "whatever it takes" speech	
Aug. 2012–Ongoing	Outright Monetary Transactions	
Jul. 2013	Forward guidance	

Sources: ECB weekly financial statements; ECB Statistical Warehouse; Cecioni, Ferrero, and Secchi (2011).

capital flows. In addition, they could have produced global wealth effects if, in response to the additional liquidity, the banking system changed the composition of its portfolio of assets toward more risky activities.

3. The Mixed-Frequency Methodology

Due to the high-frequency nature of financial variables and the slow reporting of macroeconomic data, applied economists typically face a frequency mismatch when trying to jointly examine macrofinancial linkages in response to shocks. The most common solution is to aggregate high-frequency data into lower-frequency data, but valuable information is lost in the process and conclusions may be affected (see Ghysels et al. 2013 and Rogers, Scotti, and Wright 2014). Alternatively, one may discard low-frequency data and focus on event studies that look at financial variables' movements around policy announcement dates (see Krishnamurthy and Vissing-Jorgensen 2011). This approach is also sub-optimal since it ignores macroeconomic effects. In addition, because high-frequency data is volatile, noise may drive the conclusions.

In this paper, we provide a mixed-frequency compromise (see Foroni and Marcellino 2013 for a survey of mixed-frequency methods): key macro variables are converted from monthly to weekly frequency using an augmented Gibbs sampler technique; financial variables are aggregated from daily to weekly frequency by taking averages. Because ECB unconventional policy data is reported weekly, a weekly frequency balances the desire to smooth some of the noise without discarding too much information. The empirical model we consider is

$$y_t = \mathbf{A}y_{t-1} + \mathbf{B}\omega_t + \epsilon_t,\ \epsilon_t \sim N(0, \Sigma), \tag{1}$$

where $\omega_t = [\mathbf{1}, \omega_{\mathbf{t}}^*]$ is a vector of control variables, and $y_t = (z_t,\, x_t)$ is a vector of endogenous variables containing the low-frequency data, z_t, and the high-frequency data, x_t. z_t has missing observations, since we only observe a mid-month average or end-of-the-month value, z_t^i.

3.1 Mixed Frequency with Irregular Spacings

Researchers trying to combine weekly with monthly data face a problem, fairly neglected in the literature. Because of the irregular nature of weeks (some months contain four weeks, others five weeks), the standard Gibbs sampler cannot be used mechanically to predict missing values and needs to be modified to take into account the possibility of irregularly spaced observations.

The approach we employ is similar to Chiu et al. (2011) and Qian (2013), uses a Bayesian setting, and differs from the usual Kalman-filter approach (Carter and Kohn 1994) employed in the literature because missing data is sampled directly from a constrained multivariate normal distribution. Furthermore, unlike Kalman-filter techniques, the approach works sequentially, and this increases the computational speed. There are two main drawbacks of the approach: the dependence of the Gibbs draws increases. We avoid this problem by appropriately thinning the chains. The number of nodes at which the distribution needs to be evaluated increases and this affects the tightness of the standard errors.

Apart from having to deal with irregularly spaced weeks, we also need to solve a time-aggregation problem. Because monthly data is generally reported as a midpoint average, we need to take this into account when drawing missing data. Unlike with end-of-the-period sampling, where one draws the latent variables from an unconstrained multivariate normal distribution, we need to draw all missing variables simultaneously from a constrained multivariate normal distribution, so that the draws satisfy the monthly average. The algorithm employed to estimate the parameters is described in detail in appendix 2.

To avoid imposing too much a priori information which is unjustified, given our ignorance about the properties of UMP shocks, we will use flat priors on all the coefficients of the model.

3.2 Identification of UMP Shocks

Since the countries we consider are relatively small open economies, they are likely to have little influence on the euro area, while the latter has presumably a larger impact on them. Hence, there is a natural block exogeneity in the system with the euro-area block coming first. The block exogeneity assumption has been used quite a lot in the empirical international literature (e.g., Cushman and Zha 1997; Mackowiak 2007; Dungey and Pagan 2009). It is stronger than the one employed by Kim and Roubini (2000), where block exogeneity is only imposed on the contemporaneous matrix. The estimates we compute are equivalent to those obtained with the two-step approach of Canova (2005).

For each country pair, the structural system is

$$\mathbf{A_{0,11}} y_{1t} = \mathbf{A_{1,11}}(\mathbf{L}) y_{1t-1} + \mathbf{B}_1 \omega_t + \epsilon_{1t},\ \epsilon_{1t} \sim N(0, \Sigma_1) \tag{2}$$

$$\mathbf{A_{0,21}} y_{1t} + \mathbf{A_{0,22}} y_{2t} = \mathbf{A_{1,21}}(\mathbf{L}) y_{1t-1} + \mathbf{A_{1,22}}(\mathbf{L}) y_{2t-1} + \mathbf{B}_2 \omega_t + \epsilon_{2t},\ \epsilon_{2t} \sim N(0, \Sigma_2). \tag{3}$$

The endogenous variables of the small open economy are $y_{2t} = [IP_t, \pi_t, e_t, sp_t, l_t, risk_t]'$; those of the euro area are $y_{1t} = [IP_t^*, \pi_t^*, UMP_t^*, sp_t^*, l_t^*, risk_t^*]'$. The control variables are $\omega_t = [News_t, i_{t-1}, i_{t-1}^*, PC_t]$. $IP_t(IP_t^*)$ is a real activity measure, $\pi_t(\pi_t^*)$ is inflation, UMP_t^* is the unconventional monetary policy variable, e_t is the nominal exchange rate, $sp_t(sp_t^*)$ is stock prices, $l_t(l_t^*)$ is a measure of liquidity, and $risk_t(risk_t^*)$ is a measure of risk. $News_t$ is a dummy variable capturing UMP announcements; the conventional monetary policy tool (the interest rate) is denoted by $i_{t-1}(i_{t-1}^*)$. Finally, PC_t is the first principal component of a number of control variables and is described in more detail in the next subsection. It is important to have both the conventional monetary policy tool and the UMP announcements as controls to avoid confounding their effects with those of the shocks of interest.

The variables included are chosen so as to be able to examine the transmission channels discussed in section 2. The exchange rate channel is operative if UMP shocks generate significant exchange rate movements; significant responses of the liquidity variable, on the other hand, would indicate that credit channel is important; a strong and significant response of stock prices would suggest the presence of a wealth channel; and finally, a strong and significant response of the risk variable would indicate that the confidence channel matters.

Because theory is silent regarding the features of UMP shocks, we identify them in an agnostic way. We assume that output and inflation matter for UMP decisions within a week, but that the UMP variable reacts to financial variables only with a week delay. Note that these restrictions have to hold only for a week and are therefore weaker than similar restrictions imposed on a monthly or a quarterly VAR.

The assumption that unconventional monetary policy reacts to financial factors with a delay of at least a week is satisfied for the long-term refinancing operation (LTRO) programs that make up the largest proportion of UMP measures in our sample. However, for the Securities Markets Programme (SMP), it may be less appropriate, since Lo Duca, Fratzscher, and Straub (2014) pointed out that some of the decisions were made at a daily frequency. The ordering of the variables within the financial block is arbitrary. We have stock prices before the liquidity spread, since we assume they react more slowly to monetary policy than liquidity in the interbank market due to transaction costs. The risk variables appear last, since risk perceptions react fast and take all available information into account. In section 7 we examine the robustness of the conclusions when different identification and ordering assumptions are employed.

3.3 Data

All data comes from Datastream and the ECB. The sample spans from December 18, 2008 until May 10, 2014. The starting and ending dates have been chosen in order to (i) avoid major structural breaks, (ii) avoid the high-volatility period following the Lehman crisis, (iii) have a time period where UMPs were frequently used, and (iv) skip the era of negative interest rates, applied on bank deposits by the ECB in June 2014. Excluding the first six months of the sample does not change the essence of the results we present.

We focus on nine European countries; some are EU members and some are not. Since they have the largest trade and financial linkages with the euro area, they are the most likely candidates to be influenced by the ECB's policies. The majority of countries have floating currency regimes (Czech Republic, Hungary, Norway, Poland, Romania, and Sweden). Denmark and Bulgaria are instead pegged to the euro, while Switzerland is a hybrid case, since it switched from a floating regime to an exchange rate floor in September 2011. Rey (2013) has argued that when cross-border flows and leverage of global institutions matter, monetary policy is transmitted globally even under floating exchange rate. Our sample allows us to examine how important the exchange rate regime is for international transmission of unconventional monetary policies and to analyze whether policies targeted to affect liquidity and sovereign risk have a different impact than conventional measures.

In the baseline exercises, the monthly Industrial Production (IP) Index is used as a real activity measure and the monthly consumer price index is used to compute inflation. The policy variable is calculated summing up LTRO, SMP, and covered bond purchase (CBP) programs I and II. The daily financial variables are the bilateral nominal exchange rate; the liquidity spread, measured by the difference between the three-month and overnight interbank rates (e.g., EURIBOR-EONIA for the euro area); stock market indices; and CDS spreads. The CDS for the euro area are computed weighting individual euro members' CDS using Eurostat weights. The announcement dummy, $News_t$, sums up the event dummies for LTROs, collateral changes, SMP, and CBP I and II. Implicit in this setup is the assumption that only surprises orthogonal to the monetary information present at $t-1$ and to the announcement news at t are considered. Changing the timing of the conditioning variables (announcement surprises at $t+1$ and interest rates at t) does not change the conclusions we obtain. Thus, the possibility that UMP measures were taken as a substitute or as a complement to conventional surprises is statistically weak.[3]

Apart from the nominal interest rate and the announcement dummy of euro-area UMP measures, we use a principal component (PC) indicator as control variable. This PC is computed using U.S. and UK (conventional and unconventional) policy variables, global real economy indicators, oil prices, Eastern European and EU (excluding euro-area) financial indicators, global trade price, and global equity indicators. Its inclusion enables us to filter out dynamics that could be spuriously attributed to UMP measures but are in fact due to, e.g., oil price shocks, global business-cycle variations, or monetary policy decisions made outside the euro area.

Since VAR data is used as a conditioning set to draw the latent variables, it is essential that all variables (and in particular the higher-frequency ones) exhibit an approximate normal distribution. IP, prices, UMP variables, asset prices, and CDS enter the VAR in log-growth rates. We use first differences for the liquidity spread,

[3]When we examine the role of conventional monetary policy shocks, we switch the role of interest rates and of the balance sheet variable. When we examine announcement surprises, we keep the nominal interest rates as predetermined and use the balance sheet variable at $t-1$ as a control variable. While it would make more sense to treat all monetary variables jointly as endogenous, the mixed-frequency approach would become intractable with the larger-sized VAR.

and interest rates remain in level. The financial data transformed this way shows less skewness and almost no kurtosis. Note that, while long-run relationships will be lost, our transformation helps to have the data on a similar scale, making the Gibbs sampler more efficient and economic interpretation easier.

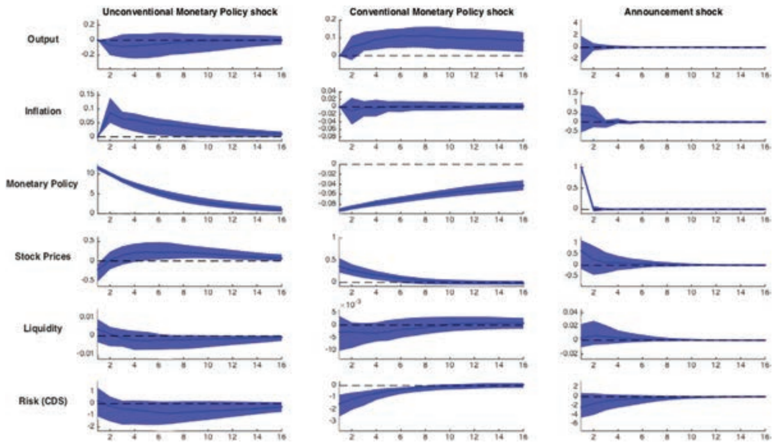
We have some latitude in choosing the unconventional monetary variable and the risk measure. Thus, we have conducted a number of robustness experiments. In particular, we examined euro-area responses when an excess liquidity variable is used instead of a balance sheet UMP variable. This series is computed using the difference between the current account and reserve requirements, net of the deposit and marginal lending facilities, and purifies the balance sheet variable from the demand effects due to the fixed-rate full-allotment provision (see also Lewis and Roth 2015). We furthermore split the balance sheet variable into liquidity measures and sovereign measures. We also checked what happens when we substituted the VIX index for CDS risk, when possible. The next section comments on the results, and appendix 3 plots the responses we obtain in alternative systems.

4. Domestic Transmission

We first present the dynamics produced by UMP shocks in the euro area; see the first column of figure 2. We plot euro-area responses to compare our results with those present in the literature, and to provide a benchmark to understand international dynamics. Figure 2 also reports the responses obtained following an expansionary conventional monetary policy shock (second column) and a UMP announcement surprise (third column).

A few features of the dynamics are noteworthy. First, following a UMP shock, inflation significantly and persistently increases, while real activity responses are negative on impact and then insignificant. This latter pattern is in contrast to what researchers have found for the United States and the United Kingdom. However, while central banks in these countries engaged in large-scale asset purchase programs to drive up yields and aggregate demand, euro-area UMP measures were aimed mainly at providing liquidity for the interbank market. In order for output effects to materialize, additional liquidity is needed to reach the real economy via bank lending, and there

Figure 2. Responses of Euro-Area Variables to Shocks



Notes: The shaded regions report point-wise 68 percent credible intervals. The horizontal axis reports weeks; the vertical axis reports monthly growth rates for all variables but the liquidity spread, the interest rate (for conventional monetary policy), and the announcement dummy.

is little evidence that this has happened (Borstel, Eickmeier, and Krippner 2015). In addition, since euro-area members differ substantially in their bank lending responses, failure to observe positive aggregate real activity responses may be due to regional heterogeneities (Santis and Surico 2013; Altavilla, Canova, and Ciccarelli 2015).

To understand whether the lack of positive real activity responses depends on particular features of the empirical model, we have rerun the analysis (i) with aggregated monthly variables, (ii) with excess liquidity as an indicator of unconventional monetary policy; and (iii) splitting liquidity from sovereign bond unconventional policies (see appendix 3). Real activity responses are still insignificant at all horizons in the monthly VAR, while disturbances to excess liquidity variable produce the same pattern of real activity and inflation responses as in the baseline case. This lets us conclude that the use of mixed-frequency data and of the balance sheet variable as a measure of UMP is not responsible for our conclusions. Aggregating liquidity and sovereign debt programs may not be ideal if the task is to measure the real effectiveness of UMP measures, since they are likely to work through different channels. In fact, while liquidity disturbances lead to the same pattern of output and inflation responses as in the baseline case, sovereign debt disturbances produce small medium-term positive real activity responses and negative but insignificant inflation responses.

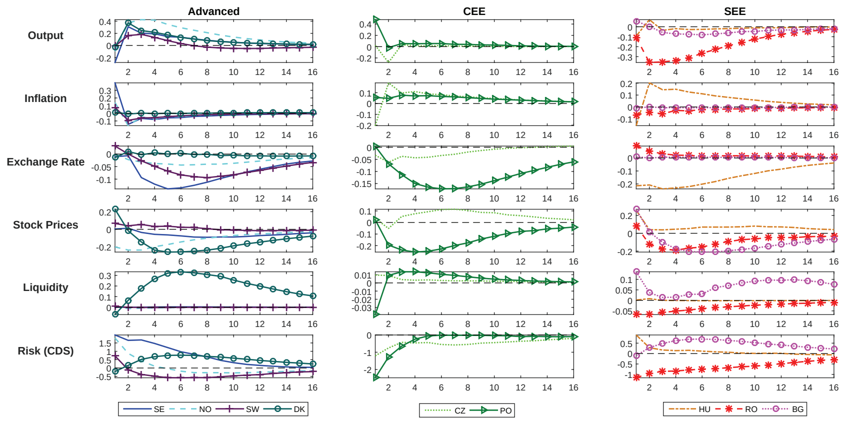
Second, financial variable responses are in line with expectations. Stock prices initially fall and then persistently increase and the responses are generally significant; liquidity spread responses are positive but insignificant on impact and turn significantly negative in the medium run; risk responses are generally negative but insignificant. Thus, while the liquidity and the wealth channels seem operative, at least in the medium run, the confidence channel is weak.

Third, as in Peersman (2012), we find that real activity responses are stickier and less significant than those obtained after conventional monetary policy disturbances. Conventional monetary policy shocks have a persistently positive effect on output—the peak response occurs after eight to ten weeks—but an insignificant effect on inflation. Hence, jointly using conventional and unconventional monetary tools may help to better control output and inflation dynamics in the area.

Fourth, risk perceptions persistently decrease following a conventional monetary policy disturbance, and stock prices increase for up to eight weeks, while the liquidity spread is not significantly affected. The dynamics of these three financial variables are both quantitatively and qualitatively in line with what is known in the euro area (see, e.g., Christoffel, Coenen, and Warne 2008). The weak response of inflation and the strong decrease in risk are a feature of our sample period, which only starts in 2008 and includes both the financial and the European sovereign debt crises.

Finally, a UMP announcement surprise does not have measurable effects on output or inflation. The responses of financial variables, although less significant, resemble those produced by a conventional policy disturbance (see also Szczerbowicz 2015). Altavilla, Giannone, and Lenza (2014) have shown that OMT announcements have significant effects on output of Mediterranean countries. Our results are not necessarily in contrast with theirs. First, while they find that output positively reacts in Spain and Italy, no effect is found in France and Germany. Hence, the aggregate effects they find may

Figure 3. Responses to a Euro-Area UMP Shock, Foreign Countries



Notes: The lines report the point-wise posterior median responses in deviations from euro-area responses. The horizontal axis reports weeks; the vertical axis reports monthly growth rates for all variables but the liquidity spread. The size of the shock is 10 percent of UMP.

be insignificant. Second, they consider only the announcement of one program, while we examine the effects of announcements of all UMP programs. Third, their methodology is different: while they use the persistent financial responses that announcements induce as a measure for announcement effects in the VAR, we use a dummy approach. Finally, as Ghysels et al. (2013) and Rogers, Scotti, and Wright (2014) argued, to measure the effects of announcements, higher-frequency data, ideally intradaily, should be used. Hence, our announcements effects could be underestimated.

5. International Transmission

Figure 3 shows the median posterior responses of the variables of the nine foreign economies to a euro-area UMP shock, in deviations from the responses obtained in the euro area (except for the exchange rate, which is plotted in level). For instance, positive and significant responses of real activity would indicate that a UMP shock generates foreign output responses that are significantly larger than those obtained in the euro area. For presentation purposes, responses are grouped into different country groups: (i) advanced countries—Sweden, Norway, Denmark, and Switzerland, (ii) Central Eastern European countries (CEE)—Poland and the Czech Republic, and (iii) Southeastern European countries (SEE)—Hungary, Romania, and Bulgaria. Figure 6 in appendix 3 reports group average responses with the posterior credible sets.

Output responses to euro-area UMP shocks are quite heterogeneous. While in advanced countries responses are persistently positive and significantly larger than in the euro area after two weeks, those in the CEE countries are insignificant, and those in SEE countries are persistently negative and significantly smaller than in the euro area after about two weeks. Inflation responses are also heterogeneous: they are positive for CEE and SEE countries, generally after about two or three weeks, and negative for advanced economies.

Why are macroeconomic responses so different across countries? One possibility is that certain countries are insulated from foreign shocks while others are not because of different exchange rate regimes. Such an explanation does not seem to hold up since, e.g., both peggers and floaters are part of the advanced-countries group. As is pointed out by Rey (2013), having floating exchange rates does not necessarily insulate a country from importing foreign monetary policy decisions. A related explanation could be that different real exchange rate dynamics lead to different trade gains across country groups. Again, this explanation seems incapable of accounting for the heterogeneities we find: real exchange rate responses are all negative (the local currency appreciate versus the euro). Fratzscher, Lo Duca, and Straub (2013) and Lo Duca, Fratzscher, and Straub (2014) also find a (nominal) appreciation using an event-study approach and much higher-frequency data. Therefore, while the exchange rate channel is activated following UMP shocks, differential exchange rate dynamics do not explain the pattern of macroeconomic responses we obtain.

Gopinath (2015) suggests that similar currency appreciations do not necessarily lead to similar dynamics of exports and imports, if firms engage in non-competitive pricing and alter markups following a nominal appreciation. Therefore, if countries have different levels of non-competitiveness, similar appreciations of the currency may lead to different inflation responses across countries. While the inflation dynamics we present could be consistent with this explanation, it is hard to see how differential non-competitive behavior may lead to the variety of output responses that we obtain.

Another reason why output and inflation responses could be different is that euro-area UMP shocks occur at the same time as, e.g., oil shocks, and hence our responses are potentially spurious. Again, this explanation does not seem to be relevant for two reasons: we have conditioned on oil prices (via PCs) in the VAR, and (ii) the only oil-producing country of our sample (Norway) displays large output responses but also negative stock price responses, which are hard to rationalize if UMP shocks proxied for oil shocks.

Cross-country heterogeneities of output and inflation responses could be generated if euro-area UMP disturbances hit countries at different stages of the business and the financial cycles. As figures 12 and 13 in appendix 3 show, both types of cycles in the nine countries are closely synchronized.

Another possibility one can consider to account for the international macroeconomic heterogeneities is that some countries conducted their own UMP measures when the ECB engaged in nonconventional policies, while others did not. While lack of detailed information prevents us from directly linking monetary decisions to existing heterogeneities, we have one country—Sweden—where liquidity policies were conducted from October 2008 until December 2010, but not thereafter. Thus, comparing the responses in the two subsamples, we can check whether the presence of domestic UMP measures makes a difference. Figures 10 and 11 in appendix 3 report the responses following a UMP shock in the euro area. When liquidity measures were in place, relative output responses were positive and relative inflation responses were insignificant; when they were not, relative output responses were insignificant and relative inflation responses were positive. However, since the second subsample roughly corresponds to the period when the ECB implemented sovereign debt policies, it is difficult to reliably attribute these differences to the presence of domestic UMP measures. We discuss our favorite explanation in section 6.

Stock price responses are significantly different from those obtained in the euro area. They initially increase for all countries but Norway and then fall for up to eight weeks, with Denmark as the exception. Note that the responses in CEE and SEE countries are slightly more persistent than in advanced countries. Positive international stock price responses have also been found in event studies such as Fratzscher, Lo Duca, and Straub (2013) and Lo Duca, Fratzscher, and Straub (2014) and are consistent with the presence of both wealth and portfolio rebalancing channels: at least on impact stock prices increase significantly more than in the euro area. In the medium run, stock prices of all countries either increase by less than in the euro area or fall.

There is considerable heterogeneity in the response of the risk spread: consistent with the finding of Fratzscher, Lo Duca, and Straub (2013), it declines relative to the euro area for CEE and SEE countries (with the exception of Hungary), while it increases for advanced countries. Risk responses are large in absolute value, even though we are using CDS spreads to infer risk. Given that country risk usually serves as a floor for domestic financial risk, the true effects may be even larger.

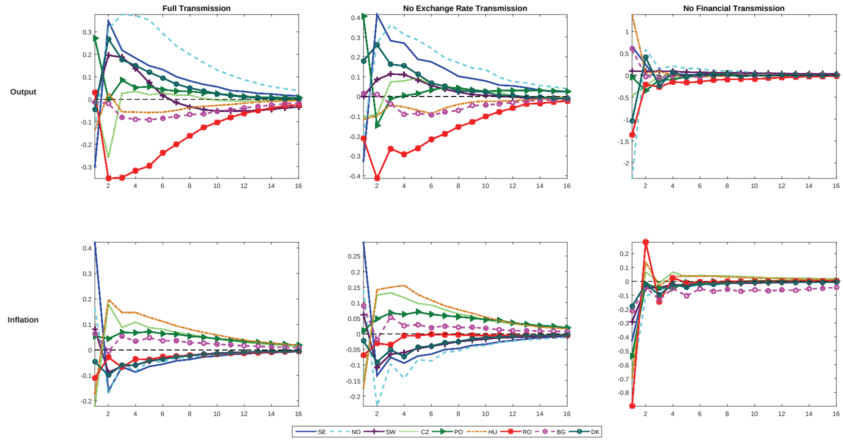
The credit channel, on the other hand, is weak. Except for Romania and perhaps Poland, the liquidity spread is not responding significantly to euro-area UMP disturbances. This is in line with Taylor and Williams (2008), who find that the LIBOR-OIS spread did not react to the Federal Reserve's QE1.

In sum, the financial market responses we obtain are in line with those found in high-frequency event studies. Hence, aggregating daily financial data does not entail a significant loss of information regarding the international transmission of UMP measures. Interestingly, our analysis shows that macroeconomic responses to UMP disturbances are very much country specific, even when financial market responses are similar.

5.1 A Counterfactual

To quantify the relative importance of the financial versus the exchange rate channels in transmitting UMP disturbances, we perform a counterfactual exercise: we trace out the dynamics of the foreign variables to a euro-area UMP shock holding either stock prices, liquidity and risk spreads, or the exchange rate constant. Thus, in the former case, international links are generated via the

Figure 4. Counterfactual Responses to a Euro Area UMP Shock, Foreign Countries



Notes: The lines report the point-wise posterior median impulse responses in deviations from the euro-area responses. The horizontal axis reports weeks; the vertical axis reports monthly growth rates.

exchange rate; in the latter case, only financial transmission takes place. Figure 4 presents the results. In the first column, we report the benchmark output and inflation responses we had in figure 3; in the second, the responses obtained switching off the exchange rate channel; and in the third, the responses obtained switching off the financial channels.

Eliminating the exchange rate channel slightly alters the magnitude but does not change the shape of the responses. Overall, exchange rate movements seem to slightly reduce output responses and slightly amplify inflation responses. In contrast, shutting off financial channels has major effects on foreign output and inflation responses: output responses are now insignificant except on impact and display no persistence, and inflation now drops on impact, because the currency generally appreciates and imported inflation falls. Note also that output and inflation responses are now more homogenous. Hence, cross-country differences in financial–macro linkages are likely to be the reason for the cross-country heterogeneity of the output and inflation responses.

5.2 International Effects of Conventional Monetary Policy and Announcement Surprises

In appendix 3 we present the international responses obtained when conventional monetary policy shocks and announcement surprises are considered.

Conventional monetary policy shocks also induce heterogeneous international dynamics. For advanced countries, the exchange rate temporarily appreciates relative to the euro, but there is little difference with the euro area as far as output and inflation responses are concerned, and this occurs despite the fact that both the liquidity and the risk spreads are quite heterogeneous across countries. For CEE countries, the exchange rate depreciates relative to the euro, but output falls and stock prices increase, while the risk spread eventually decreases. Finally, for SEE countries, the local currency generally depreciates and output temporarily increases, while stock prices fall and the risk spreads increase.

Announcement surprises produce macroeconomic responses, which are similar to those obtained in the euro area for many advanced and SEE countries. The exchange rate and the financial responses resemble those obtained with a conventional monetary policy shock, with Denmark being the exception. However, exchange rate responses are far less persistent. Also, the SEE countries seem to be the countries whose financial markets benefit most from ECB measures: stock prices increase while the liquidity and the risk spread decrease.

In sum, the evidence suggests that the exchange rate, wealth, risk, and portfolio rebalancing channels spill euro-area UMP shocks to foreign countries. Advanced economies tend to have output and inflation dynamics that resemble those of the euro area, even though output effects are larger and inflation effects smaller. For the remaining countries, the macroeconomic consequences differ. The exchange rate channel does not seem to shape the responses of foreign macroeconomic variables, but the financial channels are important for the international transmission. This is in sharp contrast to the international transmission of conventional monetary policy shocks, where exchange rate movements drive foreign output and inflation dynamics.

6. Why Are Foreign Macroeconomic Responses Heterogeneous?

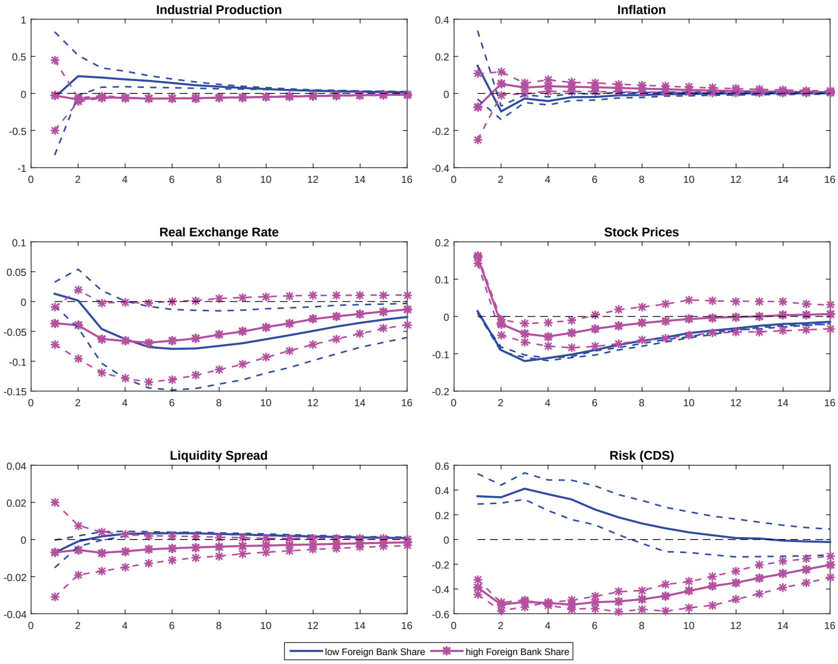
As we have seen, positive financial spillovers from UMP disturbances do not necessarily translate into positive real transmission. In addition, even in countries where financial market responses are somewhat similar, real responses are heterogeneous. In this section, we examine the reasons behind this heterogeneity.

The International Monetary Fund (2013) states that between 70 and 90 percent of assets in CEE and SEE countries is held by foreign banks and claims that these assets amount to at least 50 percent of domestic GDP. Since foreign banks in the countries under consideration are mostly from the euro area, they have access to the cheap ECB liquidity, and they may invest into foreign financial markets what they borrow from the ECB rather than lend it to domestic agents. This would positively affect foreign asset prices and reduce foreign risk but would not lead to positive real spillovers, as foreign loans would not be affected. Hence, if countries are heterogeneous in the composition of their banking sector, similar financial market responses may lead to different real effects. In particular, in countries featuring a large share of foreign banks, global liquidity increases should have the large effects on stock prices and small pass-through to the real economy.

Figure 5 reports the average responses for countries with a low foreign bank share (at least two-thirds of banks are domestic) and high foreign ownership. Confirming our intuition, we find no significant difference in the dynamics of the liquidity spread in the two groups, but we observe a stark difference in the response of stock prices and risk. Countries with a high share of foreign bank ownership experience an increase in stock prices and a reduction in risk relative to the euro area; countries with a lower share of foreign banks feature declining stock prices and increasing risk. In addition, while the former display falling relative real output growth, the latter show a significant relative output increase a few weeks after the euro-area UMP shock.

To provide further evidence that the structure of domestic financial markets is crucial to understand the international transmission of UMP disturbances, we group countries according to the level of financial development (as provided by the World Economic Forum

Figure 5. Comparative Impulse Responses to a UMP Shock



Notes: The lines report the point-wise average posterior median responses in deviations from the euro-area responses. The dotted line represents the 68 percent point-wise credible sets. Countries with a low foreign bank share are Sweden (52 percent), Norway (58 percent), Poland (63 percent), and Denmark (61 percent); countries with a high foreign bank share are Switzerland (72 percent), Czech Republic (92 percent), Hungary (100 percent), Romania (72 percent), and Bulgaria (81 percent). Data on foreign bank shares come from the Bank for International Settlements and are for 2012.

2012) and the credit-to-GDP ratio. With these two alternative classifications, the groups remains unchanged except for Poland and Switzerland, which switch groups. The financially advanced, high credit-to-GDP ratio countries (Sweden, Norway, Denmark) behave like the countries that have a low foreign bank share, while the less financially advanced, low credit-to-GDP economies (CEE and SEE) show the same responses as the countries that have a high foreign bank share. These results agree with Aizenman, Chinn, and

Ito (2015), who claim that higher levels of financial development can mitigate the negative effects of a foreign UMP shock and that financially more open but potentially less developed small economies are more sensitive to foreign UMP shocks. They also agree with Dedola, Rivolta, and Stracca (2015), who show that spillovers of U.S. monetary shocks are largest for emerging economies whose level of financial development is generally low, and with Ongena, Schindele, and Vonnak (2015), who point out that local lending in foreign currencies, which is common among countries that have a high foreign bank share, leads to a stronger international bank lending channel.

7. Robustness

The results presented so far are derived under the identification assumption that a UMP shock has no weekly effect on output and inflation and that the UMP variable does not respond within a week to financial variables. While the first assumption is hard to dispute, the second could be debatable. Furthermore, the ordering of variables within the financial block is arbitrary. In this section we discuss what happens when we alter identification assumptions. The responses for these cases are in appendix 3.

7.1 Changing the Ordering of Euro-Area Financial Variables

We considered three alternative orderings of the variables of the euro-area block: two where financial variables are permuted (R1: output, inflation, UMP, liquidity, stock prices, and risk; R2: output, inflation, UMP, risk, stock prices, and liquidity), and one where the policy variable reacts within a week to macro and financial variables, meaning that the ECB monitored financial markets on a weekly basis when deciding UMP which, as mentioned, seem to have occurred with the Securities Markets Programme—roughly 10 percent of the UMP in our sample (R3: output, inflation, stock prices, liquidity, risk, and UMP).

No major differences are noticeable between the baseline and the R1 and R2 schemes except for the kink in the liquidity spread responses for Romania. Thus, the order of the variables within the financial block is inconsequential for the transmission of UMP shocks.

Some changes appear when the R3 scheme is used. The responses for euro-area variables are qualitatively similar, even though stock prices and risk responses are less significant. Internationally, the most notable change is in the dynamics of pegger countries: the responses of inflation and of the liquidity spread are now stronger; those of stock prices and of risk are weaker. Thus, the relative importance of the wealth and portfolio channels may depend on whether we allow the UMP variable to react to financial variables.

7.2 Identification of UMP via Sign and Zero Restrictions

While the identification scheme that we have used for euro-area UMP shocks imposes relatively weak restrictions, we also examined the dynamics with an identification scheme that mixes sign and zero restrictions. In particular, we still assume that output and inflation do not react to UMP shocks within a week, but impose that a positive UMP shock increases the UMP variable and makes the liquidity spread non-positive for one period. Restrictions of this type have been used by Gambacorta, Hofmann, and Peersman (2012) and Carrera, Forero, and Ramirez-Rondan (2015) and seem reasonable since several UMP measures aim at increasing the liquidity of financial markets.

Since this scheme identifies a set rather than a point in the space of contemporaneous matrices, responses are generally more uncertain. Qualitatively speaking, the responses for the exchange rate, the liquidity spread, and risk are as in the baseline, while the response of stock prices is, on average, more negative. Interestingly, the dynamic responses of output and inflation are similar to those of the R3 scheme for most countries.

7.3 Identification via Heteroskedasticity

The use of higher-frequency data makes us less sensitive to the issue of policy endogeneity but still imposes some restrictions on financial variables. As a further check on the robustness of our conclusions, we use volatility changes to identify UMP shocks as in Rigobon (2003). The method requires that there are at least two regimes with different volatilities (e.g., low and high), assumes that shocks are uncorrelated, and assumes that the contemporaneous impact matrix and the parameters of the VAR are stable. While the restrictions such an identification scheme imposes are weak, one should also remember that regimes are often arbitrarily chosen and that shocks identified this way have very little economic interpretation (Kilian 2011).

We check for the presence of different regimes/structural breaks in the reduced-form VAR residuals informally. There is a decrease in volatility in a number of the equations roughly corresponding to Mario Draghi's famous "whatever it takes" speech on July 26, 2012. This decrease is marked in the liquidity and UMP equations for the euro area, and in the exchange rate, liquidity, and risk equations for some countries.

To estimate the system, we condition the Gibbs sampler on the variances for the two regimes as in Kulikov and Netsunajev (2013). We divide the sample into pre-Draghi speech state, s_1, and post-Draghi speech state, s_2, and assume that the variance of the structural errors is state dependent:

$$\varepsilon_t(s_j)|s_t \sim Normal(0, \mathbf{D}(s_t)).$$

The diagonal matrix, $\mathbf{D}(s_2)$, determines the short-run matrix, $\mathbf{A_0}$, once posterior variances are computed using $\mathbf{\Sigma^{-1}}(1) = \mathbf{A_0'A_0}$, $\mathbf{\Sigma^{-1}}(2) = \mathbf{A_0'D(s_2)^{-1}A_0}$, where $D(s_1) = I$.

Since not all countries display volatility changes around the chosen breakpoint, general conclusions are difficult to draw. While responses are not very significant, the basic conclusions we have obtained are unchanged: output responses vary across countries, with advanced countries displaying strong positive responses while responses in CEE and SEE countries are negative; the real exchange rate appreciates for most countries; and the credit channel is weak.

8. Conclusion

This paper examined the international transmission of euro-area UMP disturbances. We contributed to the literature in three ways. From a methodological point of view, we provide a way to combine low-frequency macroeconomic data with high-frequency financial data, minimizing time-aggregation and policy endogeneity biases. From an economic point of view, we shed light on the effect of unconventional ECB measures using a framework where macrofinancial linkages are properly accounted for and an international perspective is adopted. From a policy perspective, we provide new evidence on the role of exchange rate regime in internationally transmitting monetary policy decisions in a world where cross-border flows and leverage matter.

We focused the analysis on three questions. First, do ECB UMP measures generate important macroeconomic effects domestically and in European countries not adopting the euro? We document that UMP shocks generate important euro-area financial market responses, sizable macroeconomic fluctuations. Interestingly, while UMP disturbances induce significant inflation, conventional monetary policy disturbances primarily affect output. This means that a combination of conventional and unconventional measures may help to better control output and inflation dynamics. Announcement surprises produce financial market responses, which are similar to those of conventional policy shocks, but output and inflation effects are weak. International spillovers exist, but there is considerable cross-country heterogeneity. The exchange rate regime is not the reason for this heterogeneity.

Second, does the degree of financial integration matter for international transmission? Is it true that larger financial market integration led to more significant international real co-movements in response to UMP disturbances? Advanced economies, which are more financially integrated with the euro area and have a larger share of domestic banks, tend to have output and inflation dynamics that are qualitatively similar but generally stronger than those in the euro area. The macroeconomic effects for financially less developed countries, which have a larger share of foreign banks, are varied, but output and inflation responses are the opposite of those of advanced economies.

Third, which channel of international transmission is operative? What is the relative importance of exchange rate and financial spillovers in propagating UMP shocks? International transmission occurs both through the exchange rate channel and the financial (wealth, risk, and portfolio rebalancing) channels. However, the exchange rate does not seem to shape the responses of foreign macroeconomic variables to euro-area UMP shocks. This is in contrast to the international transmission of conventional policy shocks, where the exchange rate is crucial to understanding foreign dynamics.

Our results have important policy implications. In our sample of countries, the exchange rate regime is unimportant to explain cross-country differences in the dynamics of real activity and inflation. Exchange rate movements are closely watched by policymakers and, as the quotes from the introduction suggest, are considered crucial for the international propagation of UMP decisions. However, when financial channels are dominant and capital flows important, controlling exchange rate movements will not prevent non-euro-area countries from importing the unconventional monetary policy decisions of the ECB (see also Rey 2013). Since the dynamics of financial flows are crucial and the presence of global banks in the area is important in determining domestic outcomes (Cetorelli and Goldberg 2012), policies that indirectly restrict financial flows and bank leverage could be more effective in insulating the small open economies from undesired output and inflation fluctuations. Bruno and Shin (2015b) and Devereux, Young, and Yu (2015) provide the theoretical justification for using such measures.

The current work can be extended in various ways. One could study announcement effects in more detail. While we controlled for them in the estimation, we did not consider any potential anticipatory effect that announcements can generate. Taking expectations into account might increase the significance of the credit channel. We could include the recent QE measures in the analysis. Finally, we have assumed that structural parameters are stable. Ciccarelli, Maddaloni, and Peydro (2013) suggested that time variations could play a role in international policy transmission. Investigations of this type can improve our understanding of how UMP measures are transmitted and give policymakers a more solid foundation when deciding which policy to implement.

Appendix 1. ECB Unconventional Measures

The ECB's unconventional toolbox included five liquidity policy measures to aid the interbank market. The first of these tools was introduced in October 2008—the new fixed-rate full-allotment tender procedure—and was designed to ensure that the high demand for liquidity, which reached a peak of 95 billion euros during the crisis, could be met. The policy allows credit institutions to acquire an unlimited amount of euros in an auction at a fixed rate. The second tool, also introduced in October 2008, expanded the list of assets that were accepted as collateral. These two tools together ensured an almost unlimited refinancing to the 2,200 credit institutions that had access. The third tool allowed lengthening of the maturities of the longer-term refinancing operations (LTROs) from three months to up to three years. In March and July 2008, the first six-month full allotments were announced, and twelve-month LTROs were introduced in June 2009. In December 2011 and then again in February 2012, LTROs with a maturity of three years were introduced to provide more long-term liquidity and to ease interbank market tensions. The fourth tool ensured enough liquidity of foreign currency, particularly of the U.S. dollar. This was conducted through a direct swap line with the Federal Reserve. The final measure, covered bond purchases (CBPs), introduced in 2009, allowed the ECB to purchase debt securities issued by banks. This allowed banks to have even longer-term funding than through refinancing operations following the complete shutdown of the covered bond market during the financial crisis.[4] In November 2011, a second round of CBPs was introduced. These five tools make up what we term (in-) direct liquidity policy.

As far as sovereign debt policy is concerned, a measure was introduced in May 2010 that allowed the ECB to purchase public and private debt securities—the Securities Markets Programme (SMP). The official objective of the SMP is to provide more liquidity to "dysfunctional" market segments to ensure that transmission channels for monetary policy are properly operating. The ECB conducted sterilizing operations to reabsorb the excess liquidity. The composition of the SMP consisted of 47 percent Italian debt, 22 percent Spanish, 16 percent Greek, and the remaining percent in Irish and Portuguese debt. The final measure—Outright Monetary

[4] CBPs are different from asset-backed securities. The risk associated with covered bonds stays with the originator, so that the ECB was not necessarily subjected to more risk and the issuing institution still had an incentive to constantly evaluate credit risk. This is in contrast to the United States and the United Kingdom, where the Federal Reserve started buying asset-backed securities, commercial paper, and direct obligation of mortgage-backed securities and the Bank of England introduced an asset purchase facility, to ease the non-bank credit market. Since banks are the biggest holders of covered bonds in Europe, such a measure was designed to improve interbank market conditions.

Transactions (OMT)—was announced in August 2012, when the SMP was aborted. Similarly to the SMP, the OMT is the sterilized purchase, conditional on certain domestic economic conditions, of one- to three-year maturing government debt.

Appendix 2. Mixed-Frequency VAR Algorithm

This appendix describes the algorithm used to draw sequences for the posterior distribution of the missing variables and of the parameters—see also Qian (2013).

Let $z_{\diagdown t}$ be the vector of all missing observations and let (z, x) represent all recorded observations. The algorithm works as follows:

1. Define a matrix of data Y (missing observations are indicated by NaN).

2. Analyze the aggregation structure (if data comes as sum, average, end-of-period) and define a matrix, M, indicating which observations are missing. For example, if we have two variables—one monthly average which we observe once in the final week, and one weekly which we observe four times—we construct $\overrightarrow{M}$, vectorizing $\underset{kxT}{M}$ column by column, so that $\overrightarrow{M} = [0, 0, 0, 1, 1, 1, 1, 1]'$.

3. Transform the averaged data into summed data, where the average is $\overline{z}_{a,b} \equiv \frac{1}{b-a+1} \sum_{t=0}^{b-a} \hat{z}_{\diagdown t+a}$ and the sum $z_b = (b - a + 1)\overline{z}_{a,b}$.

4. Specify a normal prior for the coefficients, A, B, and an inverted-Wishart prior for the variance Σ.

5. Draw initial values for the coefficients, A, B, and for the variance Σ.

6. Specify initial values for the latent data by substituting missing values with sums computed from step 3.

7. Construct the matrix $\underset{Tk\times Tk}{T}$ that will account for time aggregation. In our case $T = 262$ and $k = 12$. Initially, $\underset{3144\times 3144}{T}$ is

an identity matrix. Using the matrix M, we scan each row, i, and column, j, for missing values, m. In the previous example, we have $m = 1, 2, 3$ in $i = 1$ right before $j = 4$. We add one for every missing variable to the transformation matrix in row $(j-1)k+i$ and column $(j-1)k+i-mk$. The transformation matrix is then

$$\underset{8\times 8}{T} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}.$$

8. Transform the data using $\overrightarrow{M}Y$, so that we have both a latent disaggregated block and an observed block.

9. Start the Gibbs sampler:
   (a) Estimate the VAR coefficients and draw parameter estimates from $f(A^i, B^i|\hat{Y}^i, \Sigma^{i-1})$.

   (b) Estimate the variances of the VAR and draw the variance estimates from $f(\Sigma^{i-1}|\hat{Y}^i, A^i, B^i)$.

   (c) Compute the covariance matrix of the VAR using draws for the coefficients, $\hat{A}, \hat{B}$, and the variance $\hat{\Sigma}$.

   (d) Constrain the multivariate normal (MVN) distribution using the transformation matrix A, so that $y_t \sim MVN(A\eta, A\Omega A') = MVN(\mu, \Sigma)$. The distribution for the latent variables is

$$z_{\setminus t}|z, x \sim MVN(\mu_0 + \Sigma_{01}\Sigma_{11}^{-1}((z, x)' - \mu_1),$$
$$\Sigma_{00} - \Sigma_{01}\Sigma_{11}^{-1}\Sigma_{10}),$$

   where Σ_{01} is a submatrix of Σ representing the covariances between the missing and the observed observations. Σ_{00} is the variance of the missing observations and Σ_{11} is the variance of the observed data.

(e) Sample missing data from the conditional constrained MVN described in step 9(d) (in blocks). That is, for all $t = 1, \ldots, T$, we draw missing data from $f(\hat{z}_t^i | x, \hat{z}_{\setminus t}^{i-1}, A^i, B^i, \Sigma^i)$.

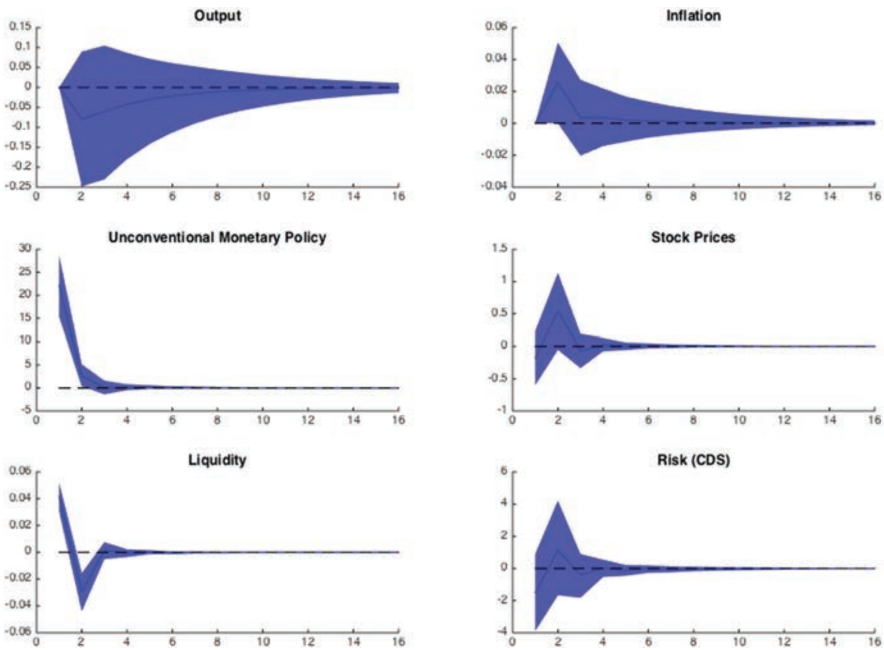
(f) Repeat steps (a) through (e).

10. Examine convergence using, e.g., CUSUM statistics.

The results we present are based on 12,500 draws: we discard the first 2,500 as burn-in and retain every 20th draw to reduce serial correlation. Inference is based on 500 saved draws.

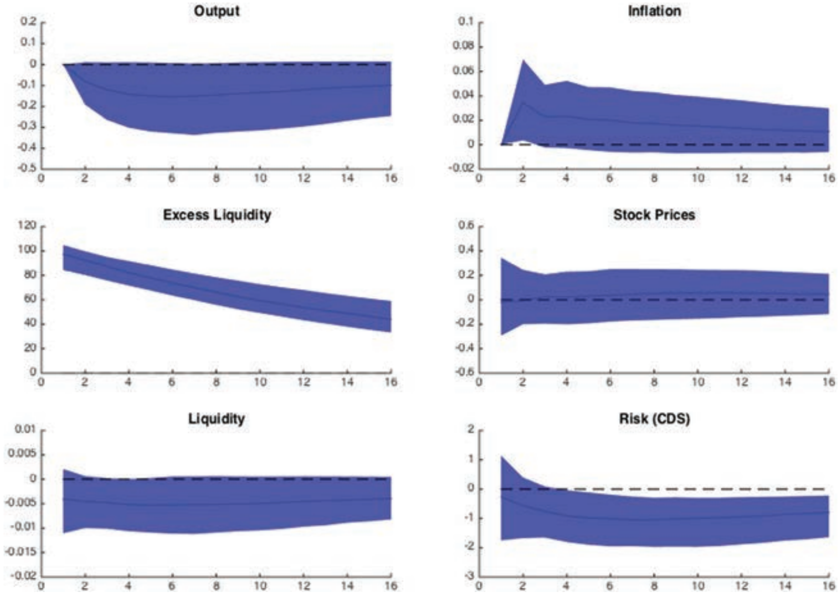
Appendix 3. Additional Results

Figure 6. Euro-Area Responses to UMP Shocks: Monthly VAR



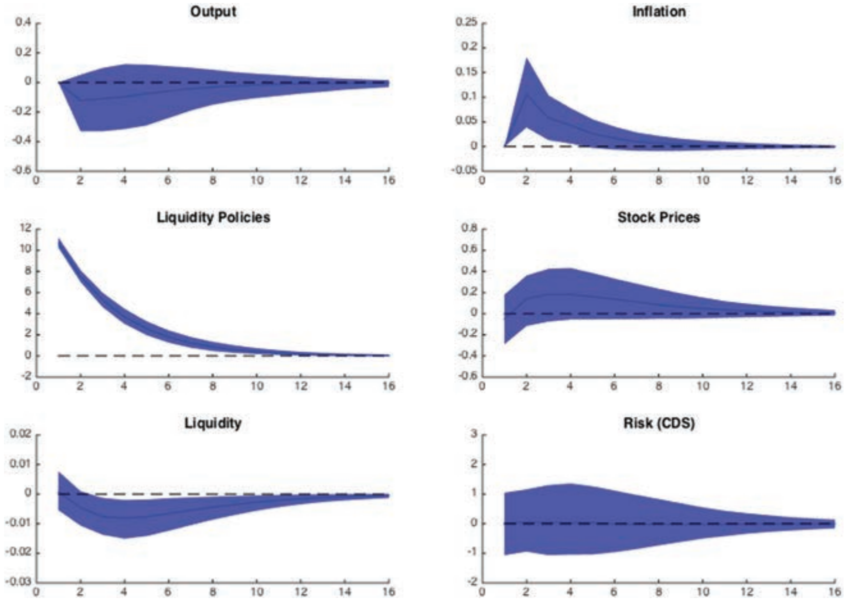
Notes: The shaded regions report point-wise 68 percent credible intervals. The horizontal axis reports weeks; the vertical axis reports monthly growth rates for all variables but the liquidity spread.

Figure 7. Euro-Area Responses to UMP Shocks: Excess Liquidity as a Measure of UMP



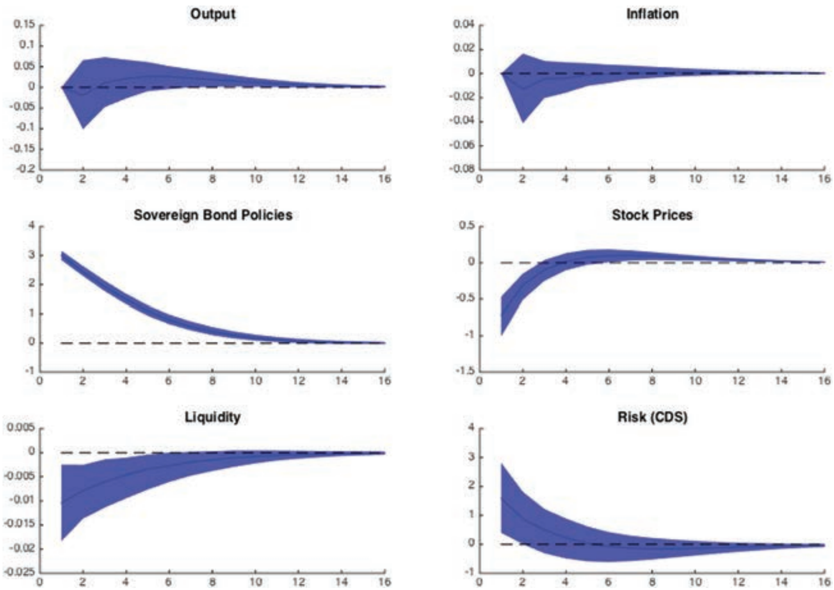
Notes: The shaded regions report point-wise 68 percent credible intervals. The horizontal axis reports weeks; the vertical axis reports monthly growth rates for all variables but the liquidity spread and excess liquidity.

Figure 8. Euro-Area Responses to UMP Shocks: Shocks to UMP Liquidity Variable



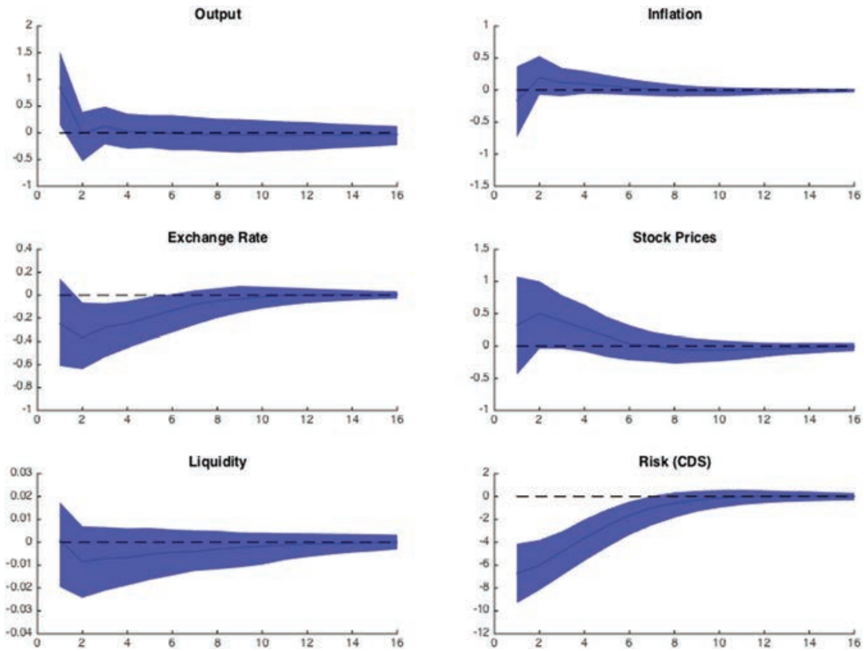
Notes: The shaded regions report point-wise 68 percent credible intervals. The horizontal axis reports weeks; the vertical axis reports monthly growth rates for all variables but the liquidity spread.

Figure 9. Euro-Area Responses UMP Shocks: Shocks to UMP Sovereign Bond Variable



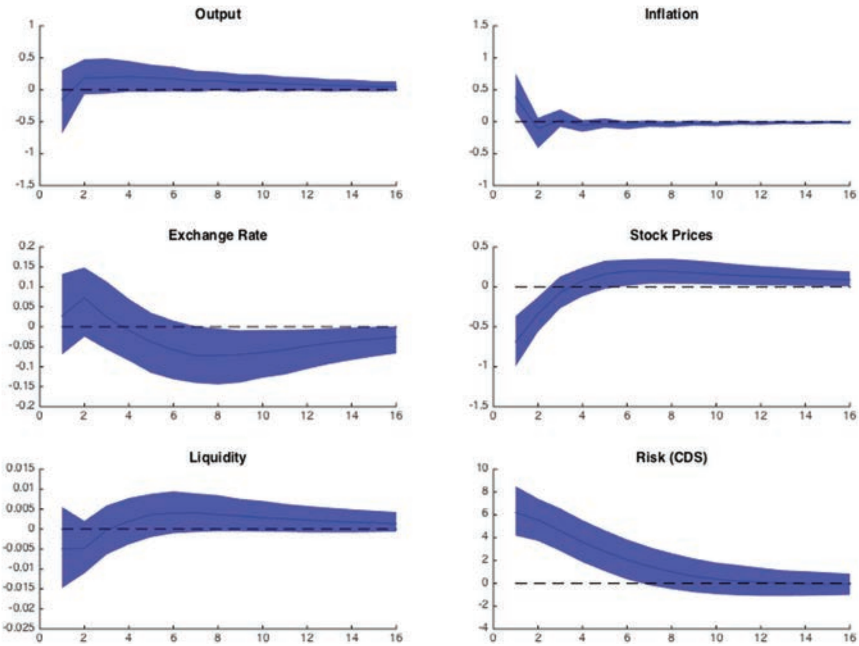
Notes: The shaded regions report point-wise 68 percent credible intervals. The horizontal axis reports weeks; the vertical axis reports monthly growth rates for all variables but the liquidity spread.

Figure 10. Swedish Responses to UMP Shocks: Sample with Sweden UMP Measures



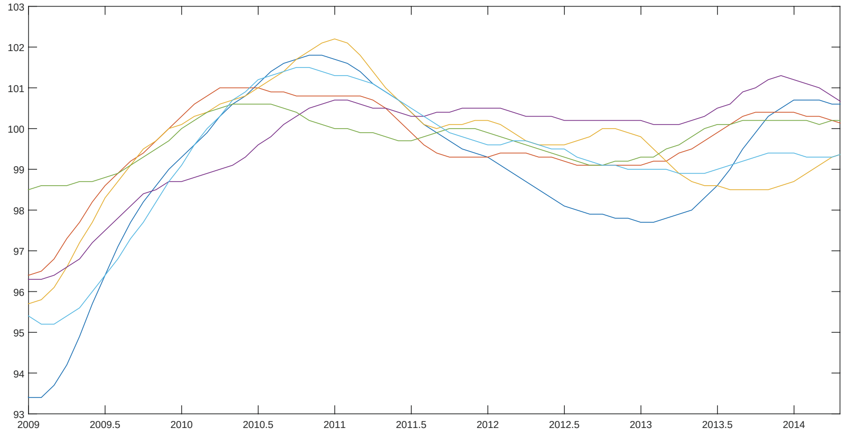
Notes: The shaded regions report point-wise 68 percent credible intervals. The horizontal axis reports weeks; the vertical axis reports monthly growth rates for all variables but the liquidity spread in absolute terms.

Figure 11. Swedish Responses to UMP Shocks: Sample without Sweden UMP Measures



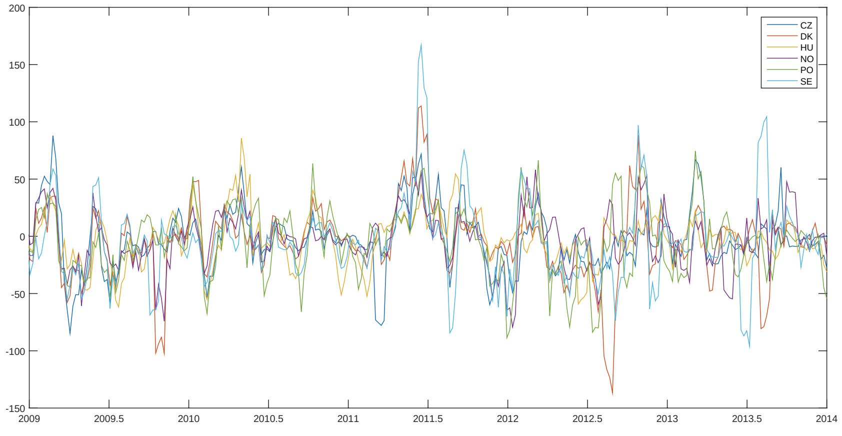
Notes: The shaded regions report point-wise 68 percent credible intervals. The horizontal axis reports weeks; the vertical axis reports monthly growth rates for all variables but the liquidity spread in absolute terms.

Figure 12. Real Activity Dynamics in the Nine Countries



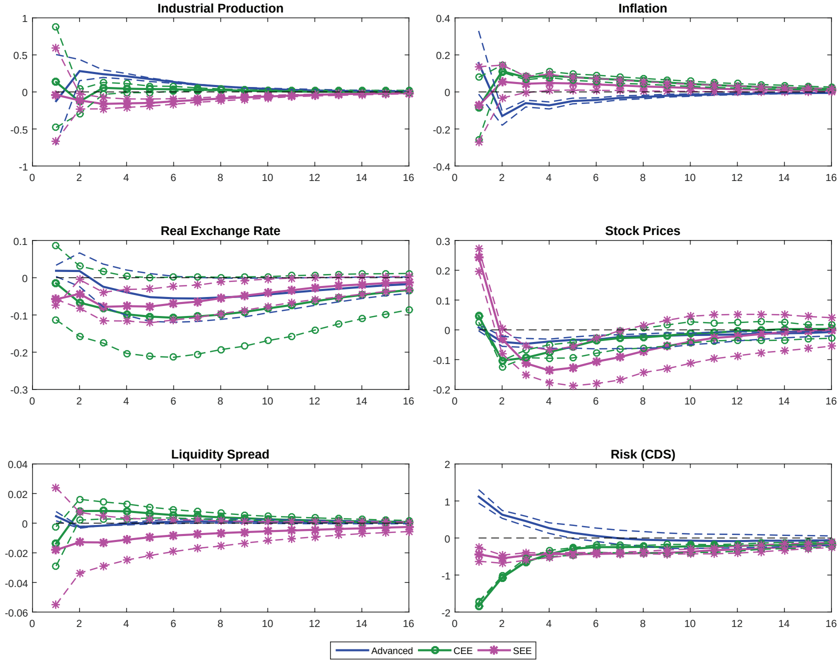
Notes: The horizontal axis reports time; the vertical axis reports the level of the IP index.

Figure 13. Financial Dynamics in the Nine Countries



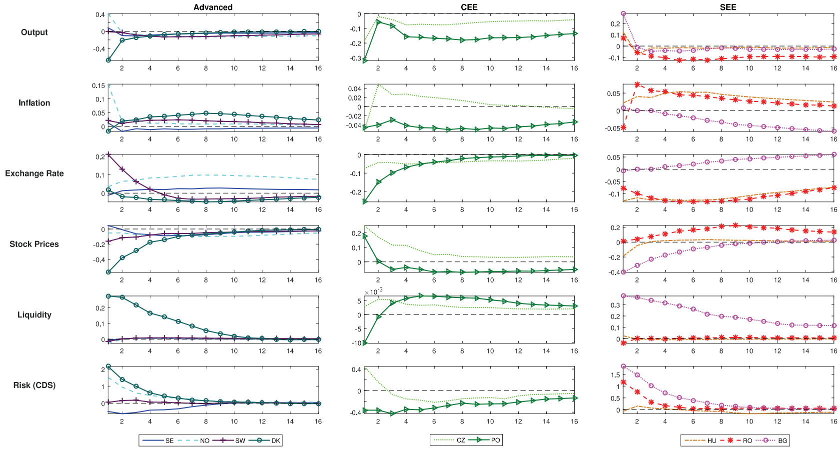
Notes: The figure reports the dynamics of the first principal component of stock prices, liquidity, and risk spreads. The horizontal axis reports time; the vertical axis reports monthly growth rates.

Figure 14. Group Responses to Euro-Area UMP Shocks



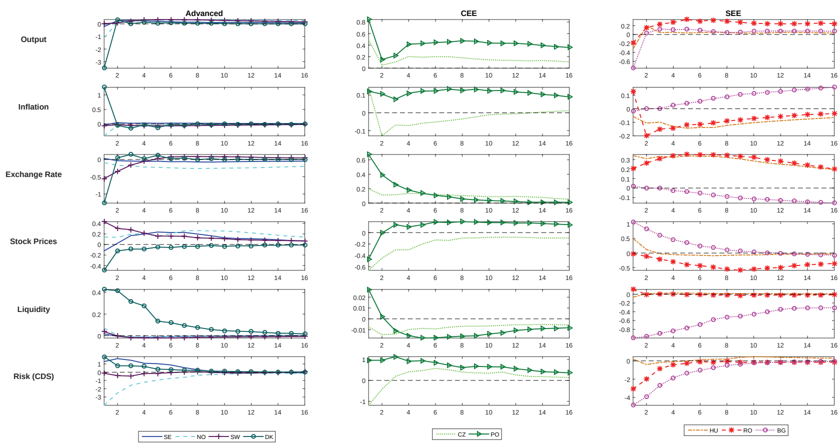
Notes: The solid lines report point-wise average posterior median responses in deviations from euro-area responses. The dotted lines report point-wise 68 percent credible intervals. The x-axis reports weeks; the y-axis reports monthly growth rates for all variables but the liquidity spread.

Figure 15. Foreign Responses to Conventional Euro-Area Interest Rate Shocks



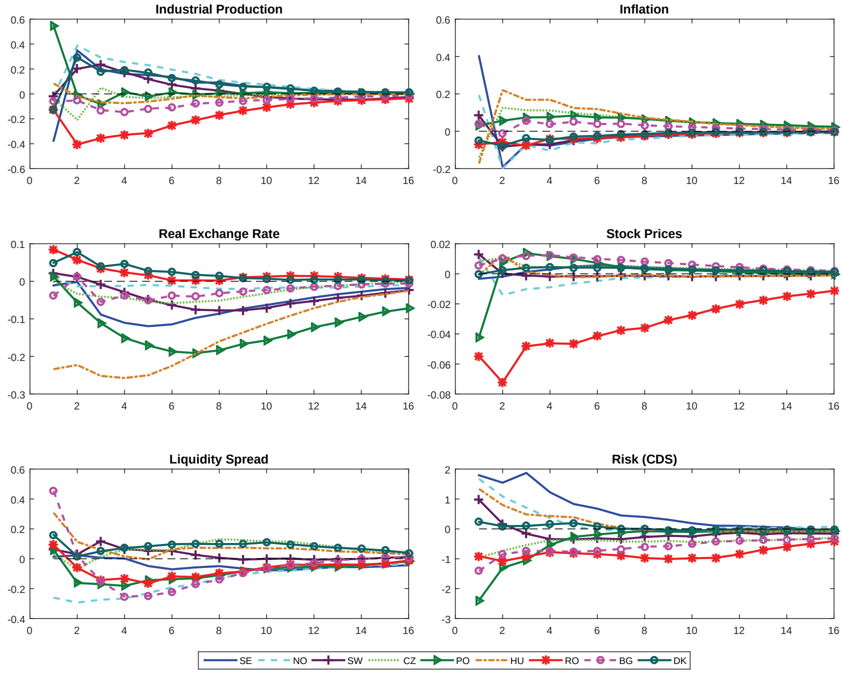
Notes: The lines report point-wise posterior median responses in deviations from euro-area responses. The x-axis reports weeks; the y-axis reports monthly growth rates for all variables but the liquidity spread. The size of the shock corresponds to 10 monthly basis points.

Figure 16. Foreign Responses to Euro-Area Announcement Shocks



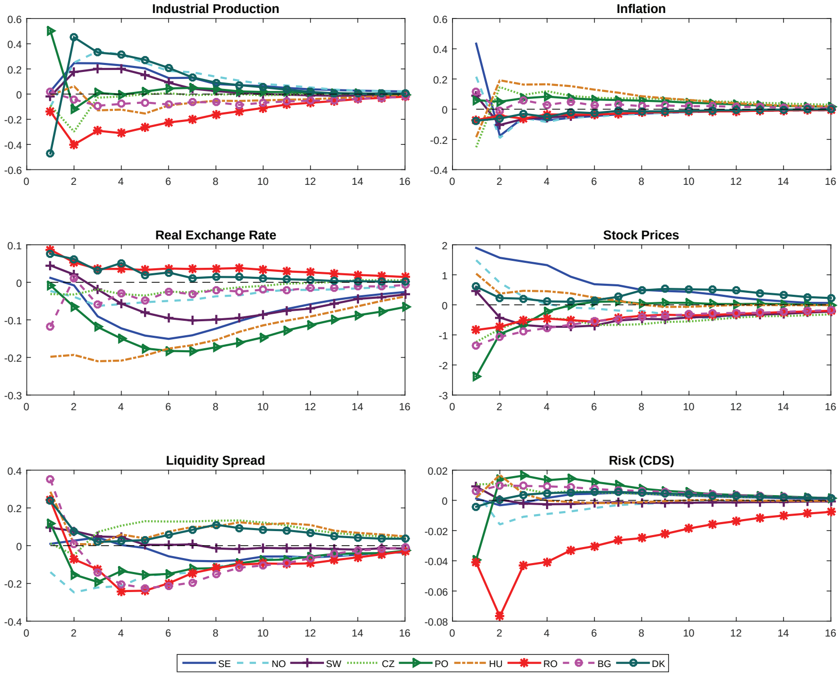
Notes: The lines report point-wise posterior median responses in deviations from euro-area responses. The x-axis reports weeks; the y-axis reports monthly growth rates for all variables but the liquidity spread. The size of the shock is one policy announcement.

Figure 17. Foreign Responses to Euro-Area UMP Shocks: Identification R1



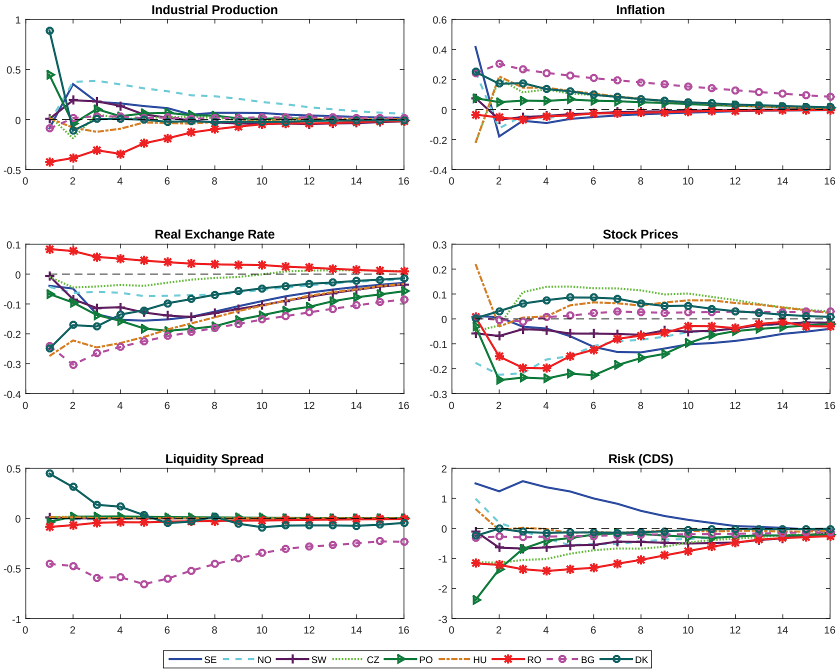
Notes: The lines report point-wise posterior median responses in deviations from euro-area responses. The x-axis reports weeks; the y-axis reports monthly growth rates for all variables but the liquidity spread. The size of the shock is one standard deviation of UMP growth (a 10 percent monthly increase in the quantity of UMP).

Figure 18. Foreign Responses to Euro-Area UMP Shocks: Identification R2



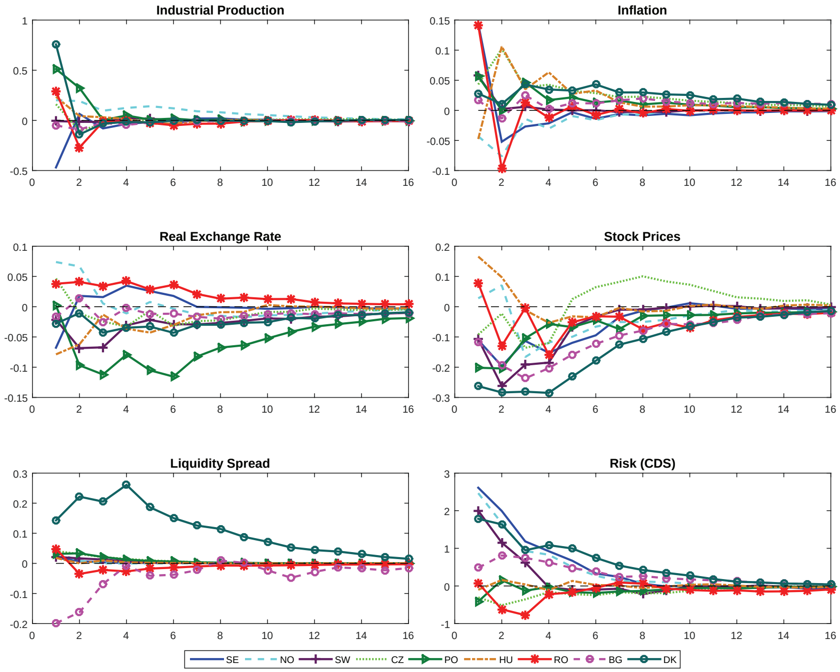
Notes: The lines report point-wise posterior median responses in deviations from euro-area responses. The x-axis reports weeks; the y-axis reports monthly growth rates for all variables but the liquidity spread. The size of the shock is one standard deviation of UMP growth (a 10 percent monthly increase in the quantity of UMP).

Figure 19. Foreign Responses to Euro-Area UMP Shocks: Identification R3



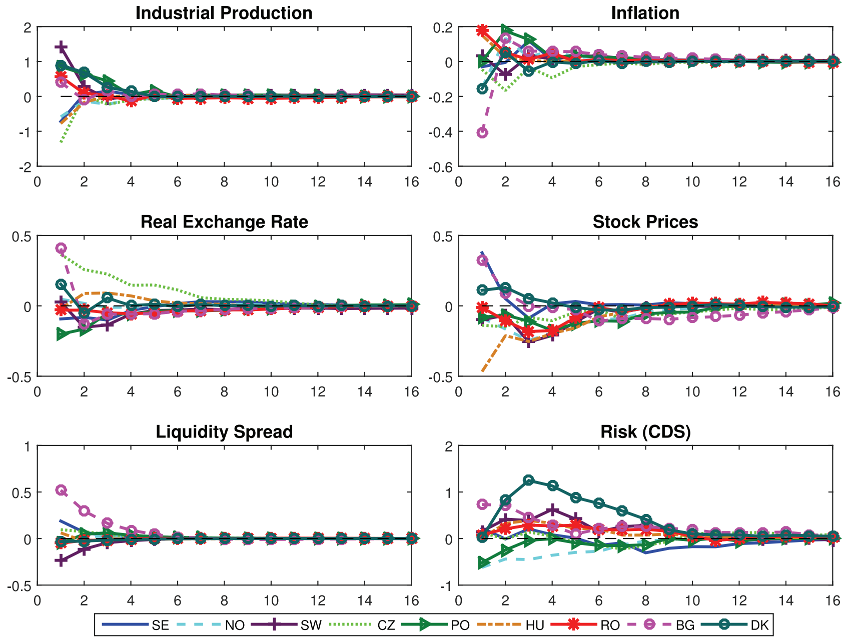
Notes: The lines report point-wise posterior median responses in deviations from euro-area responses. The x-axis reports weeks; the y-axis reports monthly growth rates for all variables but the liquidity spread. The size of the shock is one standard deviation of UMP growth (a 10 percent monthly increase in the quantity of UMP).

Figure 20. Foreign Responses to Euro-Area UMP Shocks: Identification via Zero and Sign Restrictions



Notes: The lines report point-wise posterior median responses in deviations from euro-area responses. The x-axis reports weeks; the y-axis reports monthly growth rates for all variables but the liquidity spread. The size of the shock is one standard deviation of UMP growth (a 10 percent monthly increase in the quantity of UMP).

Figure 21. Foreign Responses to Euro-Area UMP Shocks: Identification via Heteroskedasticity



Notes: The lines report point-wise posterior median responses in deviations from euro-area responses. The x-axis reports weeks; the y-axis reports monthly growth rates for all variables but the liquidity spread. The size of the shock is one standard deviation of UMP growth (a 10 percent monthly increase in the quantity of UMP).

References

Abbassi, P., and T. Linzert. 2011. "The Effectiveness of Monetary Policy in Steering Money Market Rates during the Recent Financial Crisis." ECB Working Paper No. 1328.

Aizenman, J., M. Binici, and M. M. Hutchison. 2014. "The Transmission of Federal Reserve Tapering News to Emerging Financial Markets." NBER Working Paper No. 19980.

Aizenman, J., M. D. Chinn, and H. Ito. 2015. "Monetary Policy Spillovers and the Trilemma in the New Normal: Periphery

Country Sensitivity to Core Country Conditions." NBER Working Paper No. 21128.

Altavilla, C., F. Canova, and M. Ciccarelli. 2015. "Monetary Policy Pass-Through and Heterogeneous Bank Lending." Technical Report.

Altavilla, C., D. Giannone, and M. Lenza. 2014. "The Financial and Macroeconomic Effects of the OMT Announcements." Working Paper No. 352, Centre for Studies in Economics and Finance.

Angelini, P., S. Neri, and F. Panetta. 2011. "Monetary and Macroprudential Policies." Temi di discussione (Working Paper) No. 801, Bank of Italy, Economic Research and International Relations Area.

Angeloni, I. 2012. *Monetary Policy Transmission in the Euro Area: A Study by the Eurosystem Monetary Transmission Network.* Cambridge: Cambridge University Press.

Beirne, J., L. Dalitz, J. Ejsing, M. Grothe, S. Manganelli, F. Monar, B. Sahel, M. Susec, J. Tapking, and T. Vong. 2011. "The Impact of the Eurosystem's Covered Bond Purchase Programme on the Primary and Secondary Markets." ECB Occasional Paper No. 122.

Bernanke, B. S. 2010. "Opening Remarks: The Economic Outlook and Monetary Policy." In *Macroeconomic Challenges: The Decade Ahead*, 1–16. Proceedings of the Annual Economic Policy Symposium sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming, August 26–28.

Bhattarai, S., A. Chattarjee, and W. Y. Park. 2015. "The Effects of U.S. Quantitative Easing on Emerging Markets." Technical Report, University of Illinois.

Boeckx, J., M. Dossche, and G. Peersman. 2014. "Effectiveness and Transmission of the ECB's Balance Sheet Policies." CESifo Working Paper No. 4907.

Borstel, J., S. Eickmeier, and L. Krippner. 2015. "The Interest Rate Pass-Through in the Euro Area during the Sovereign Debt Crisis." Discussion Paper No. 10/2015, Deutsche Bundesbank.

Bruno, V., and H. S. Shin. 2015a. "Capital Flows and the Risk-Taking Channel of Monetary Policy." *Journal of Monetary Economics* 71: 119–32.

———. 2015b. "Cross-Border Banking and Global Liquidity." *Review of Economic Studies* 82 (2): 534–64.

Canova, F. 2005. "The Transmission of US Shocks to Latin America." *Journal of Applied Econometrics* 20 (2): 229–51.

Carrera, C., F. P. Forero, and N. Ramirez-Rondan. 2015. "Effects of U.S. Quantitative Easing on Latin American Economies." Working Paper No. 2015-35, Peruvian Economic Association.

Carter, C. K., and R. Kohn. 1994. "On Gibbs Sampling for State Space Models." *Biometrika* 81 (3): 541–53.

Cecioni, M., G. Ferrero, and A. Secchi. 2011. "Unconventional Monetary Policy in Theory and in Practice." Questioni di Economia e Finanza (Occasional Paper) No. 102, Bank of Italy, Economic Research and International Relations Area.

Cetorelli, N., and L. S. Goldberg. 2012. "Banking Globalization and Monetary Transmission." *Journal of Finance* 67 (5): 1811–43.

Chen, Q., A. J. Filardo, D. He, and F. Zhu. 2012. "International Spillovers of Central Bank Balance Sheet Policies." SSRN Scholarly Paper No. 2185394.

Chinn, M. D. 2013. "Global Spillovers and Domestic Monetary Policy." BIS Working Paper No. 436.

Chiu, C. W. J., B. Eraker, A. T. Foerster, T. B. Kim, and H. D. Seoane. 2011. "Estimating VARs Sampled at Mixed or Irregular Spaced Frequencies: A Bayesian Approach." Technical Report.

Christoffel, K., G. Coenen, and A. Warne. 2008. "The New Area-Wide Model of the Euro Area: A Micro-founded Open-Economy Model for Forecasting and Policy Analysis." ECB Working Paper No. 944.

Ciccarelli, M., A. Maddaloni, and J.-L. Peydro. 2013. "Heterogeneous Transmission Mechanism: Monetary Policy and Financial Fragility in the Euro Area." *Economic Policy* 28 (75): 459–512.

Cushman, D. O., and T. Zha. 1997. "Identifying Monetary Policy in a Small Open Economy under Flexible Exchange Rates." *Journal of Monetary Economics* 39 (3): 433–48.

Darracq Paries, M., and R. A. De Santis. 2013. "A Non-standard Monetary Policy Shock: The ECB's 3-Year LTROs and the Shift in Credit Supply." ECB Working Paper No. 1508.

Dedola, L., G. Rivolta, and L. Stracca. 2015. "If the Fed Sneezes, Who Gets a Cold?" Mimeo.

Devereux, M., E. Young, and C. Yu. 2015. "A New Dilemma: Capital Controls and Monetary Policy in Sudden Stop Economies." NBER Working Paper No. 21791.

Dungey, M., and A. Pagan. 2009. "Extending a SVAR Model of the Australian Economy." *The Economic Record* 85 (268): 1–20.

Foroni, C., and M. Marcellino. 2013. "Mixed Frequency Structural Models Identification, Estimation, and Policy Analysis." Working Paper No. 2013/06, Norges Bank.

Fratzscher, M., M. Lo Duca, and R. Straub. 2013. "On the International Spillovers of US Quantitative Easing." Discussion Paper No. 1304, DIW Berlin.

Gagnon, J., M. Raskin, J. Remache, and B. Sack. 2011. "Large-scale Asset Purchases by the Federal Reserve: Did They Work?" *Economic Policy Review* (Federal Reserve Bank of New York) 17 (1, May): 41–59.

Gambacorta, L., B. Hofmann, and G. Peersman. 2012. "The Effectiveness of Unconventional Monetary Policy at the Zero Lower Bound: A Cross-Country Analysis." BIS Working Paper No. 384.

Ghysels, E., J. Idier, S. Manganelli, and O. Vergote. 2013. "A High Frequency Assessment of the ECB Securities Markets Programme." SSRN Scholarly Paper No. 2365833.

Gopinath, G. 2015. "The International Price System." Technical Report, Harvard University.

International Monetary Fund. 2013. "Central, Eastern and Southeastern Europe—Financing Future Growth: The Evolving Role of Banking Systems in CESEE." Central Eastern and Southeastern Europe: Regional Economic Issues Series.

Kilian, L. 2011. "Structural Vector Autoregressions." CEPR Discussion Paper No. 8515.

Kim, S., and N. Roubini. 2000. "Exchange Rate Anomalies in the Industrial Countries: A Solution with a Structural VAR Approach." *Journal of Monetary Economics* 45 (3): 561–86.

Krishnamurthy, A., and A. Vissing-Jorgensen. 2011. "The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy." *Brookings Papers on Economic Activity* 43 (2, Fall): 215–87.

Kulikov, D., and A. Netsunajev. 2013. "Identifying Monetary Policy Shocks via Heteroskedasticity: A Bayesian Approach." Working Paper No. 2013-9, Bank of Estonia.

Lenza, M., H. Pill, and L. Reichlin. 2010. "Monetary Policy in Exceptional Times." *Economic Policy* 25 (62): 295–339.

Lewis, V., and M. Roth. 2015. "The Financial Market Effects of the ECB's Balance Sheet Policies." Technical Report, Deutsche Bundesbank.

Lim, J. J. 2014. "Tinker, Taper, QE, Bye? The Effect of Quantitative Easing on Financial Flows to Developing Countries."

Lo Duca, M., M. Fratzscher, and R. Straub. 2014. "ECB Unconventional Monetary Policy Actions: Market Impact, International Spillovers and Transmission Channels." Policy Research Working Paper No. 6820, World Bank.

Mackowiak, B. 2007. "External Shocks, U.S. Monetary Policy and Macroeconomic Fluctuations in Emerging Markets." *Journal of Monetary Economics* 54 (8): 2512–20.

Mishkin, F. S. 2001. "The Transmission Mechanism and the Role of Asset Prices in Monetary Policy." NBER Working Paper No. 8617.

Moessner, R. 2014. "International Spillovers from US Forward Guidance to Equity Markets." DNB Working Paper No. 427.

Neely, C. J. 2010. "The Large Scale Asset Purchases Had Large International Effects." Working Paper No. 2010-018, Federal Reserve Bank of St. Louis.

Ongena, S., I. Schindele, and D. Vonnak. 2015. "In Lands of Foreign Currency Credit, Bank Lending Channels Run Through?" SSRN Scholarly Paper ID 2507688.

Passari, E., and H. Rey. 2015. "Financial Flows and the International Monetary System." NBER Working Paper No. 21172.

Peersman, G. 2012. "Effectiveness of Unconventional Monetary Policy at the Zero Lower Bound." 2012 Meeting Paper No. 400, Society for Economic Dynamics.

Qian, H. 2013. "Vector Autoregression with Mixed Frequency Data." MPRA Paper No. 47856.

Rajan, R. 2014. "Competitive Monetary Easing: Is It Yesterday Once More?" Remarks at the Brookings Institution, Washington, DC, April 10.

Rey, H. 2013. "Dilemma not Trilemma: The Global Financial Cycles and Monetary Policy Independence." Technical Report, London Business School.

Rigobon, R. 2003. "Identification Through Heteroskedasticity." *Review of Economics and Statistics* 85 (4): 777–92.

Rogers, J. H., C. Scotti, and J. H. Wright. 2014. "Evaluating Asset-Market Effects of Unconventional Monetary Policy: A Cross-Country Comparison."

Russell, S. 1992. "Understanding the Term Structure of Interest Rates: The Expectations Theory." *Review* (Federal Reserve Bank of St. Louis) 74 (4): 36–50.

Santis, R. A., and P. Surico. 2013. "Bank Lending and Monetary Transmission in the Euro Area." *Economic Policy* 28 (75): 423–57.

Szczerbowicz, U. 2015. "The ECB Unconventional Monetary Policies: Have They Lowered Market Borrowing Costs for Banks and Governments?" *International Journal of Central Banking* 11 (4, December): 91–127.

Taylor, J. B., and J. C. Williams. 2008. "A Black Swan in the Money Market." NBER Working Paper No. 13943.

World Economic Forum. 2012. "The Financial Development Report 2012." Insight Report.

Discussion of "Beggar-Thy-Neighbor? The International Effects of ECB Unconventional Monetary Policy Measures"

Klaus Adam
University of Mannheim and CEPR

1. Introduction

The paper by Bluwstein and Canova advances our understanding about the existence and nature of potential spillovers of non-standard monetary policy measures executed in the euro area into other European economies. It appears to be the first paper analyzing the output, inflation, and financial market spillovers of European Central Bank (ECB) non-standard measures for neighboring European Union countries and thus is a most welcome addition to the increasing number of empirical studies analyzing and quantifying the effects on non-standard monetary policy measures. Understanding the spillover effects of non-standard measures is especially important for assessing whether or not the potential gains of non-standard measures within the euro area come at the expense of other neighboring economies, which would limit their overall usefulness from an aggregate standpoint.

The analysis covers the data period starting in December 2008 and ending in May 2014, thus excluding the recent period with large-scale public bond purchases of the ECB that was initiated in the beginning of 2015 under the Public Sector Purchase Programme (PSPP). Nevertheless, over the considered sample period the ECB implemented a large number of non-standard policy measures, including foreign currency lending operation (backed by currency swap agreements with other central banks), longer-term refinancing operations (LTROs) of increasing duration, and covered bond purchases (CBPs). In addition, it has announced the Outright Monetary Transactions (OMT) program, which was never activated, and it has issued forward guidance on the future path of interest rates. There is thus no shortage of non-standard measures within the considered sample period, even if the implemented measures display a considerable degree of heterogeneity over time.

The list of countries considered for potential spillover effects includes a set of advanced European countries (Denmark, Sweden, Norway, and Switzerland), two Central and Eastern European countries (Czech Republic and Poland), and three Southeastern European countries (Bulgaria, Hungary, and Romania). The omission of the United Kingdom is noteworthy but may be motivated by the fact that it conducted non-standard monetary policy on its own on a fairly large scale. Clearly, the set of considered countries displays a substantial degree of heterogeneity in terms of their exchange rate arrangements, their economic structure, and their stage of economic and financial development. This heterogeneity will also be reflected in the transmission outcomes.

To analyze the spillovers, the analysis uses an innovative mixed-frequency vector autoregression (VAR) approach at a weekly frequency, which allows the combining of higher-frequency financial data with lower-frequency macroeconomic data within a common dynamic framework. The authors use this approach to first estimate euro-area dynamics and then add, in a second stage, a VAR for the non-euro-area country, so as to estimate the spillover effects.

In terms of findings, the main takeaways for the euro area are as follows: (i) non-standard monetary policy measures are found to have no significant effect on euro-area output and only a slightly positive effect on inflation, which is marginally significant at the 32 percent level for about six to eight weeks; and (ii) announcements of non-standard measures are found to have no significant effects on euro-area output, inflation, stock prices, credit default swap (CDS) spreads, or the three-month EURIBOR-EONIA spread.

Overall, with regard to the effect on non-standard measures on standard monetary policy target variables, i.e., output and inflation, the documented responses are somewhat disappointing and suggest that the non-standard measures implemented during the sample period had largely insignificant effects in the euro area. The fact that even the stock market reaction to announcement effects proves insignificant, however, suggests that the analysis is missing an important part of the reaction. As is well known (see Krishnamurthy, Nagel, and Vissing-Jorgensen 2015), the stock market did react significantly around OMT announcement days. It may thus be the case that the heterogeneity across the considered non-standard measures damages the statistical significance of the average effects identified by the VAR.

Regarding the transmission of non-standard measures into non-euro-area countries, the main findings are as follows: (i) advanced countries tend to display a mildly positive output response and no inflation response; (ii) Central and Eastern European countries display no significant output response and a positive inflation response; and (iii) Southeastern European countries tend to display a negative output response (particularly Romania) and a positive inflation response (particularly Bulgaria).

In terms of output gains or losses, non-standard monetary policy measures in the euro area thus appear *not* to have any quantitatively significant beggar-thy-neighbor effects for European countries outside the euro area. Given that non-standard policy measures also fail to have significant output effects in the euro area itself, this may not come as too big of a surprise.

My discussion of these findings will focus on the following points: I will start by discussing some aspects of the VAR specification used for estimating the effects of non-standard monetary policy, then discuss how the stance of non-standard monetary policy is measured in the main analysis and how robust the main findings are toward using other measures. Finally, I will review some of the intriguing findings about what drives the heterogeneity of the transmission into other European economies.

2. VAR Specification and Weak Exogeneity Assumptions

The estimation approach pursued consists of first estimating a VAR for the euro-area variables y_{1t}, given by

$$A_{0,11}y_{1t} = A_{1,11}(L)y_{1t-1} + B_1\omega_t + \epsilon_{1t},$$

where $A_{0,11}$, $A_{1,11}$, and B_1 denote coefficient matrices and y_{1t} contains monthly euro-area variables (industrial production, monthly CPI inflation, a measure of the non-standard monetary policy stance, stock prices, the three-month EURIBOR-EONIA spread, and a (weighted) euro-area CDS spread). A distinguishing feature of the VAR specification is that the variable vector ω_t is treated as weakly exogenous to the dynamics of y_{1t} and contains—amongst other things—a number of (standard and non-standard) monetary policy variables. In particular, ω_t contains in the baseline specification the short-term nominal interest rate and the announcement dummy for non-standard policy measures. The fact that monetary policy variables are treated as weakly exogenous in a VAR that seeks to estimate the effects of monetary policy distinguishes the paper from other studies, which typically include the policy variables in the vector of endogenous variables y_{1t}, e.g., Boeckx, Dossche, and Peersman (2014). Presumably, this approach is motivated by the fact that interest rate dynamics were constrained over part of the sample periods by their lower bound and that linear VAR dynamics have difficulties in appropriately capturing the non-linearities. This said, the assumption of weak exogeneity may not be innocuous.

Following Engle, Hendry, and Richard (1983), some variable ω_t is weakly exogenous to some the parameters of interest (the coefficient matrices $A_{0,11}$, $A_{1,11}$, and B_1 that the authors seek to estimate), if the dynamics of ω_t are free to vary *independently* of the parameters $A_{0,11}$, $A_{1,11}$, and B_1. Since ω_t includes monetary policy variables, this requires—amongst other things—that monetary policy can vary freely without affecting the dynamics of y_{1t} conditional on ω_t. This assumption would be violated by any structural economic model in which different monetary policy rules give rise to different dynamics for output and/or inflation.

The previous considerations suggest that the weak exogeneity assumption is likely going to be violated in practice and that the estimates of $A_{0,11}$, $A_{1,11}$, and B_1 and thus the estimated impulse response functions are asymptotically biased. The extent to which this bias is quantitatively relevant is, however, a priori unclear. It is equally unclear whether or not including the policy variables in y_{1t} and estimating a linear VAR specification leads—due to the omission of non-linearities—to smaller biases or to different conclusions. While I am sympathetic to the approach pursued by the authors, it would have been great to understand better to what extent results prove sensitive toward including the policy variables in the vector of endogenous variables y_{1t}.

Another feature of the VAR specification is that its specification varies depending on the considered policy shock. To estimate the effects of unconventional monetary policy shocks, the specification is as described in the previous paragraphs. When estimating the effects of a conventional monetary policy shock, however, the authors move the short-term nominal interest rate into the vector y_{1t} and put the non-standard policy variable into the set of weakly exogenous variables ω_t. A third specification is used when estimating the effects of "announcements" about unconventional monetary policy. The announcement variable is then moved into the vector y_{1t} and the unconventional monetary policy variable is included (in lagged form) in the set of weakly exogenous variables ω_t. Unfortunately, it remains somewhat unclear exactly what motivates these different specifications. Clearly, tracking over time the data-implied dynamic response of the policy variable following an initial policy disturbance requires including the policy variable in the set of endogenous variables. The authors apparently believe it to be important to track this dynamic response, possibly to guard against potential violations of the weak exogeneity assumption. This said, if endogeneity of some variable is a concern, then it would be more appealing to consistently treat the variable as endogenous across all specifications.

3. Measuring the Stance of Non-Standard Monetary Policy in the Euro Area

The baseline approach measures the stance of unconventional monetary policy by summing up the liquidity issued through the long-term refinancing operations (LTROs), through purchases of government bonds within the Securities Market Programme (SMP), and through purchases within the covered bond purchase programs (CBPs). It is important to note that besides purchasing rather different assets,[1] these programs have fairly different maturity structures and thus may have rather different effects on the economy.[2] Furthermore, some of these programs, especially the LTROs, may simply be a substitute for (repeated) standard short-term liquidity operations, so that by summing up the total liquidity issued via LTROs, one

[1] LTROs do not purchase assets but issue liquidity against appropriate collateral.

[2] The maturity of LTROs gradually increased from six months to thirty-six months. The SMP injected liquidity for a period equal to the maturity profile of the acquired bonds, i.e., on average for several years, while covered bonds tend to have an even longer maturity profile.

may exaggerate the overall amount of additional liquidity issued. This in turn may induce a downward bias in the size of effects of unconventional measures in the euro area and their spillovers into other economies. To check the robustness to such considerations, the authors repeat their analysis using a measure of excess liquidity instead as their unconventional monetary policy variable. Excess liquidity is thereby defined as the amount of central bank balances that are issued in excess of the mandatory reserve requirements and net of reserves that are redeposited at the Eurosystem. Unfortunately, however, the euro-area inflation response to a euro-area unconventional monetary policy shock becomes largely insignificant once the stance of monetary policy is measured using excess reserves. See figure 7 in appendix 3.

4. Transmission into Non-Euro-Area Countries

An interesting finding of the paper is that the country spillovers appear to be heterogeneous depending on whether the share of banks owned by foreign owners is high or low. Countries with a low foreign bank share experience a stock price decline, and (CDS) risk increases following an expansionary euro-area non-standard monetary policy shock; countries with a high foreign bank share experience the opposite reaction. What is interesting is the fact that it is precisely the countries facing a worsening in financial conditions (stock price decline and CDS increase) that experience an expansion of industrial production, while countries with improving financial conditions experience a slight real contraction. This difference is obtained even though the exchange rate responses for both country sets are fairly similar.

Since countries with a low foreign bank share tend to be financially more advanced countries, the reported results tend to be in line with previous findings in literature, but it remains somewhat mysterious how precisely countries whose financial conditions deteriorate more can experience a better real performance. Understanding this seemingly paradoxical finding would be of importance. Unfortunately, the evidence presented in section 5.1 which—at least in principle—could shed light on the transmission channels has fairly weak theoretical foundations. Contrary to the authors' suggestion, one cannot reliably compute the impact of a particular transmission channel simply by exogenously altering the path of endogenous variables in the VAR (exchange rates, stock prices, etc.). In any case, the findings that financial development matters for the impact of non-standard monetary policy measures points toward the existence of a potentially important trade-off in terms of having to accept either adverse financial market consequences or experience worse real responses.

References

Boeckx, J., M. Dossche, and G. Peersman. 2014. "Effectiveness and Transmission of the ECB's Balance Sheet Policies." CESifo Working Paper No. 4907.

Engle, R. F., D. F. Hendry, and J.-F. Richard. 1983. "Exogeneity." *Econometrica* 51 (2): 277–304.

Krishnamurthy, A., S. Nagel, and A. Vissing-Jorgensen. 2015. "ECB Policies Involving Government Bond Purchases: Impacts and Channels." Mimeo, Stanford University.

Options-Implied Probability Density Functions for Real Interest Rates*

Jonathan H. Wright
Johns Hopkins University

This paper constructs options-implied probability density functions for real interest rates. These use options on TIPS, which were launched in 2009. Data availability limits us to studying short-maturity probability density functions for intermediate- to long-term TIPS yields. The PDFs imply high uncertainty about real rates. I also estimate empirical pricing kernels using these option prices along with time-series models fitted to real interest rates. The empirical pricing kernel implies that investors have high marginal utility in states of the world with high real rates.

JEL Codes: C58, E43, G12.

1. Introduction

Options markets provide risk-neutral distributions of the future values of many asset prices and even macroeconomic variables. These include probability density functions (PDFs) for future nominal interest rates (see a long literature, including Li and Zhao 2009) and inflation (Kitsul and Wright 2013). But to date, as far as I know, no work has been done on options-implied PDFs for real interest rates. This is the task undertaken in the present paper. A PDF for real interest rates cannot be backed out from PDFs from nominal interest rates and inflation without making an assumption about the correlation between these two. However, over the past seven years, the Chicago Board Options Exchange (CBOE) has traded options on a Treasury Inflation-Protected Securities (TIPS) exchange-traded

---

*I am grateful to Eric Swanson and John Williams for very helpful comments on an earlier draft. All errors and omissions are my sole responsibility. Author contact: Department of Economics, Johns Hopkins University, Baltimore, MD 21218; wrightj@jhu.edu.

fund (ETF). I show that these can be used to construct risk-neutral PDFs of intermediate- to long-term TIPS yields at short horizons. The standard deviation of options-implied PDFs for nominal interest rates is often treated as a measure of monetary policy uncertainty. Yet, aggregate demand should be determined by real rather than nominal rates, and so PDFs for real rates arguably give a better measure of investors' beliefs about the future effective stance of monetary policy. Even the limited snapshot of uncertainty about real interest rates that can be obtained from the available data may thus be important to monetary policymakers.

The plan for the remainder of this paper is as follows. In section 2, I describe the data and the methodology for extracting risk-neutral PDFs (also known as state-price densities) for real interest rates. Section 3 contains the results for implied volatilities and risk-neutral PDFs. Section 4 evaluates these as physical density forecasts and finds some evidence for the existence of risk premia, notwithstanding the short available data span. Section 5 provides econometric-based physical density forecasts for real interest rates and then adapts the methodology of Rosenberg and Engle (2002) to obtain a time-varying empirical pricing kernel. Based on these results, investors generally appear to view high real interest rate states as having high marginal utility. Section 6 concludes.

2. Data and Methodology

Since January 2009, the CBOE has traded call and put options on the Barclays TIPS ETF. These options have expiration dates of up to nine months ahead and various strike prices. The underlying asset is a portfolio of TIPS with a duration that is stable at seven years. I obtained prices (both trades and quotes) from the CBOE from inception to the end of January 2016. Table 1 lists some summary statistics of these options. On average, forty-nine options change hands a day,[1] where each option is for the purchase/sale of 100 shares in the ETF, each of which has a value of roughly $100. Thus the daily transaction volume has a notional underlying amount of about $500,000. This amount is minuscule relative to trading in

[1]This is the total number of options that change hands each day—the number of distinct trades is smaller.

Table 1. Options Summary Statistics

	Mean	**SD**	**Min.**	**Max.**
Trades				
Daily Call Volume	28	106	0	2,528
Daily Put Volume	21	71	0	1,175
Quotes				
Moneyness (Call)	0.94	0.07	0.57	1.14
Moneyness (Put)	1.03	0.06	0.79	1.34
Maturity	102	73	1	243
Bid-Ask Spread (%)	18.4	11.2	0.9	50.0

Notes: Volume represents the total volume per day in number of contracts. Each contract is for 100 units in the ETF. Moneyness is the ratio of the strike price to the underlying price for all trades. Maturity is measured in days. Bid-ask spread is measured as the ask price less the bid price, divided by the midpoint, and multiplied by 100 to be in percentage points.

conventional interest rate derivatives—for comparison, trading volume in Eurodollar options averaged around 440,000 contracts per day in 2015. But that does not mean that the prices are uninformative. In experimental game theory, it is common to study individuals' behavior when tiny sums are at stake. Prediction markets are a good example of cases in which the stakes are small, but there is strong evidence that prices are nonetheless quite informative (Wolfers and Zitzewitz 2004). The dollar trading volumes in TIPS options are far bigger than those in experimental games and in prediction markets, and it seems reasonable to presume that they are reflective of traders' beliefs. Nonetheless, it is clear that this is a small and illiquid market and results should be treated with caution, especially in 2009 and 2010, when liquidity was particularly limited.

I do all empirical work with midpoints of bid and ask quotes. This makes for a large data set of $n = 164{,}320$ options quotes. I prefer this to using actual trades because that would give a much smaller data set and one in which bid-ask bounce would be a major concern. Bid-ask spreads are wide and average around 18 percent. The quotes on call/put options have average moneyness slightly below/above one, respectively, indicating that the options quotes tend to be in the money. Note, however, that the price of an in-the-money put/call option can be converted to that of an out-of-the-money call/put option via put-call parity, which is an arbitrage relationship (Stoll 1969).

2.1 Semiparametric State-Price Densities

In estimating state-price densities, one possible approach is to use the observed quotes on options at a particular maturity on a particular day in isolation to directly estimate the state-price density at that maturity on that day, as in Bliss and Panigirtzoglou (2002) and Kitsul and Wright (2013). In the current context, I do not use that approach for a number of reasons. Firstly, there are on average twenty-one strike prices for each maturity/trading day combination, which constitutes a very small sample size, especially given that the data are noisy. Secondly, there are gaps in the available strike prices in many cases. Thirdly, the available options are for fixed maturity dates (the third Friday of the month), whereas it is easier to compare state-price densities over time when they are for fixed horizons, like three months ahead.

Instead, I use a smoothing approach to estimate prices that are not actually observed. Intuitively, the idea is to infer prices from the observed prices of options that are similar in maturity, strike price, and other characteristics. This smooths out measurement error in individual quotes. More precisely, I adopt the semiparametric approach proposed by Aït-Sahalia and Lo (1998). I convert the observed options prices into Black-Scholes implied volatilities. Let these options-implied volatilities be $\{\sigma_i\}_{i=1}^n$, where n is the total number of options, pooling all call and put options on all trading days, strike prices, and expiration dates. I assume that the implied volatility is a function of a state vector, $\sigma(Z_i)$, where the $p \times 1$ state vector, Z_i, includes the strike price or moneyness of the option. I assume that the price of a call option is $C_{BS}(S, X, r_f, d, \tau, \sigma(Z))$, where $C_{BS}(.)$ is the Black-Scholes expression for the price of a call option, S is the price of the underlying security, X is the strike price of the option, r is the risk-free rate, d is the dividend yield of the security, and τ is the time to maturity of the option. I estimate the implied volatility function nonparametrically as

$$\hat{\sigma}(Z) = \frac{\Sigma_{i=1}^n \Pi_{j=1}^p k\left(\frac{Z_j - Z_{ij}}{h_j}\right)\sigma_i}{\Sigma_{i=1}^n \Pi_{j=1}^p k\left(\frac{Z_j - Z_{ij}}{h_j}\right)}, \tag{1}$$

where $k(\cdot)$ is the Gaussian kernel and the bandwidth h_j is set to $\frac{c_0 \sigma_j n^{-1/11}}{\log(n)}$, where σ_j is the standard deviation of Z_{ij}. The value of c_0 is determined by tenfold cross-validation.[2] The nonparametric estimate of the implied volatility gives an implied call option price for any choice of Z, S, r_f, d, and τ. The second derivative of this call price is then the state-price density, or risk-neutral options-implied PDF (Breeden and Litzenberger 1978). In the empirical work, the risk-free rate is measured from three-month LIBOR—over the period in question, short-term risk-free rates are very close to zero. Meanwhile, the dividend yield is measured as the trailing twelve-month yield on the TIPS ETF.

Equation (1) can be estimated over the full sample, effectively pooling information across the whole sample period. Alternatively, equation (1) can be estimated for each calendar month separately. This pools information across multiple days but allows for the possibility of lower frequency changes that are not captured by the state vector. I have computed the PDFs in both ways. However, in order to conserve space, I report the result only using the approach where the implied volatility is estimated for each calendar month separately.

This of course gives us a PDF for the price of a share in the TIPS ETF. But this ETF has a duration of about seven years, giving the approximation

$$\Delta y_t \simeq -\frac{1}{7} \Delta \log(P_t), \tag{2}$$

where P_t is the price of the ETF and y_t is the zero-coupon TIPS yield. This in turn allows the PDF for the TIPS price to be converted into a PDF for the TIPS yield. I use the data set of Gürkaynak, Sack, and Wright (2010) for zero-coupon TIPS yields. It should be noted that equation (2) is empirically a very good approximation—regressing three-month changes in seven-year zero-coupon yields on

[2]Standard, or leave-one-out, cross-validation would pick c_0 so as to minimize the mean square fitting error, where the fit for each observation is computed omitting that one observation. This would be very computationally costly given the large sample size that I have. Instead, I split the data into ten roughly equal-sized bins, and compute the errors within each bin, where the fit is computed omitting that bin. The parameter c_0 is chosen to minimize the mean square fitting error over all these bins. This reduces the number of nonparametric function estimates from the sample size to ten.

the corresponding change in the log price of the TIPS ETF gives a coefficient estimate of almost exactly $-\frac{1}{7}$ (–0.159) with an R-squared of 93 percent.

Moreover, as the vast majority of changes in TIPS yields are level shifts, equation (2) can also provide a good approximation to the PDF for the change in any TIPS yield with maturity in at least the five- to ten-year range. The information that can be gathered from these TIPS options is limited by the fact that they are short-maturity options on longer-term TIPS yields, but this nonetheless represents an important first look at state-price densities for real interest rates.

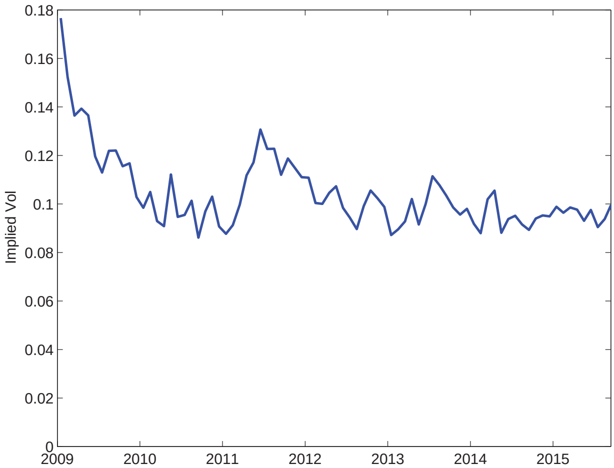
3. Results

3.1 Implied Volatilities

I first plot the average annualized implied volatility of TIPS prices, by month, averaged across all options with moneyness between 0.9 and 1.1, in figure 1. The implied volatility was high in early 2009. This was in the immediate aftermath of the financial crisis—TIPS prices were volatile and liquidity was unusually poor. Implied volatilities climbed in 2011, which was during the European debt crisis. Since 2012, TIPS implied volatilities have been fairly stable. Over the sample period, TIPS implied volatilities have averaged around 10 percentage points at an annualized rate. Given the relationship between real yields and prices (equation (2)), this means that the options-implied volatility of real rates is around 1.4 percentage points per annum. Using daily real yield data (Gürkaynak, Sack, and Wright 2010), the realized volatility of seven-year TIPS zero-coupon yields over the sample period is 80 basis points per annum. In other financial markets, it is standard to find that options-implied volatilities exceed realized volatilities, and this is interpreted as a variance risk premium (Bollerslev, Tauchen, and Zhou 2009; Choi, Mueller, and Vedolin 2013). I observe the same phenomenon for TIPS yields.

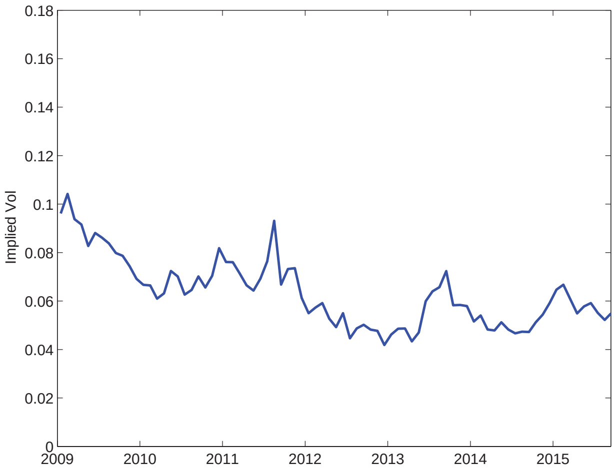
To compare these implied volatilities with their nominal counterparts, I used the same methodology to obtain the annualized implied volatility of options on ten-year nominal Treasury futures—a long-standing and very liquid options market. These are shown in figure 2. The options-implied volatility of a ten-year nominal futures

Figure 1. Implied Volatility of TIPS Options



Notes: This figure plots the annualized volatility of TIPS implied by the Black-Scholes formula averaged over all options within a month, using only options with moneyness between 0.9 and 1.1.

Figure 2. Implied Volatility of Nominal Treasury Options



Notes: This figure plots the annualized volatility of ten-year nominal Treasury futures contracts implied by the Black-Scholes formula averaged over all options within a month, using only options with moneyness between 0.9 and 1.1.

contract was also elevated in early 2009, but not as much as the TIPS implied volatility. This is perhaps because the financial crisis led to fewer strains in the market for nominal Treasury securities. The options-implied volatility of a ten-year nominal futures contract fell in the first part of 2011, while TIPS implied volatilities were rising, though the nominal implied volatility climbed a bit later that year. The effect of the "taper tantrum" of mid-2013 is more apparent in nominal implied volatilities than in TIPS implied volatilities. That's perhaps not surprising, since Federal Reserve large-scale asset purchases were overwhelmingly concentrated in nominal securities. Nominal implied volatilities also climbed in late 2014, as oil prices slid, and this did not affect TIPS implied volatilities very much.

Over the sample period, nominal implied volatilities have averaged around 7 percentage points at an annualized rate. As discussed in Burghardt and Belton (2005), the precise terms of a ten-year nominal Treasury futures contract are such that the effective underlying security is a nominal coupon security with 6.5 to 7 years to maturity (the "10-year" label is somewhat misleading). The duration of this security is around six years. So the options-implied volatility of six-year zero-coupon nominal yields is around 1.2 percentage points per annum. Meanwhile, using daily nominal yield data, the realized volatility of six-year nominal zero-coupon yields over the sample period is 92 basis points per annum.

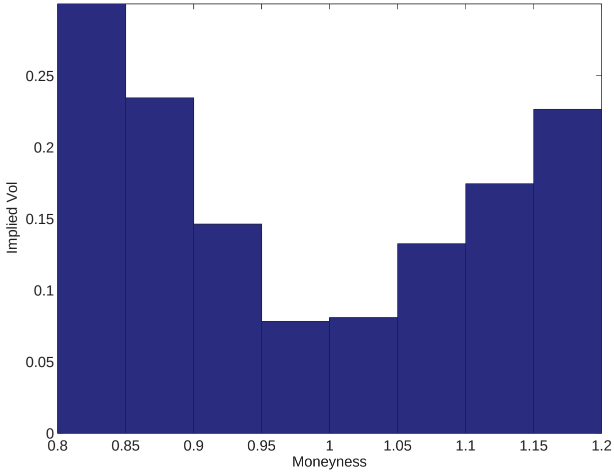
As Campbell, Shiller, and Viceira (2009) point out, whereas one might in theory think that TIPS yields ought to be determined by the long-run marginal product of capital and ought to be very stable, in practice TIPS yields are quite unstable. This shows up in the options market as well. The spread between options-implied and realized volatility (the variance risk premium) seems to be bigger for TIPS than for nominal bonds.

Figure 3 plots the average TIPS implied volatility by moneyness of the option. Under the Black-Scholes assumptions, this should be flat. But it in fact exhibits a pronounced volatility smile.

3.2 Computing PDFs

I next turn to the construction of the full PDFs. I consider two choices of the state vector that governs the implied volatility of different options, as follows:

Figure 3. Implied Volatility of TIPS Options



Notes: This figure plots the annualized volatility of TIPS implied by the Black-Scholes formula averaged across the whole sample by moneyness bin. The moneyness is the ratio of the strike price to the underlying price.

- S1: The state vector is $(X, S, \tau)'$—the strike price, price of the underlying security and maturity.
- S2: The state vector is $(X/S, \tau, \sigma_{EGARCH})'$—the moneyness and maturity of the option, and the volatility of daily changes in seven-year TIPS yields implied by an EGARCH(1,1) model with conditionally t-distributed errors. The parameters of the EGARCH model are estimated by maximum likelihood over the whole period for which TIPS yields are available (since January 1999).

The idea of using EGARCH-filtered volatility as an element of the state vector was used in the context of nominal interest rate derivatives by Li and Zhao (2009).

Table 2 shows the options pricing errors using either of these two state vectors—the percentage difference between actual options prices and the fitted options price using the nonparametric estimate of the volatility function in equation (1) (estimated for each month separately, as discussed above). The median absolute pricing error is a bit above 2 percent with either state vector. R^2 values—the

Table 2. Options Fitting Errors

State Variables	S1	S2
Median Absolute Error	2.38	2.06
R-squared	75.6	82.0

Notes: The median absolute error is the median absolute difference between actual and fitted options prices, in percentage points. The fitted options prices are Black-Scholes prices, with volatility given by equation (1). The R-squared is the ratio of the variance of fitted implied volatilities to observed implied volatilities, in percentage points.

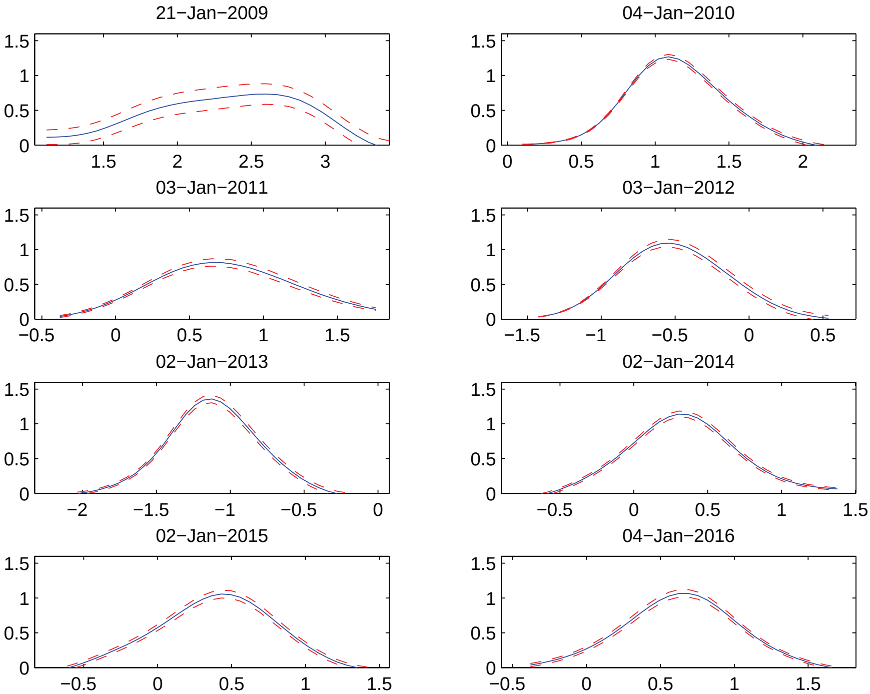
ratio of the variance of fitted implied volatilities to observed implied volatilities—are around 80 percent. The methodology is using fitted options prices, so it is an important check on the adequacy of the methodology and state vector that the options pricing errors not be too big. It can be seen from table 2 that this is indeed the case.

State variables S1 and S2 both contain three elements and are thus equally parsimonious. State vector S1 can be thought of as pooling options with similar maturity and moneyness over days when the level of real rates is similar. State vector S2 can instead be thought of as pooling options with similar maturity and moneyness over days when the level of real rate volatility is similar. Both of these are reasonable modeling choices. From table 2 we see that in the sample at hand, both state vectors provide a good fit to observed options prices, although S2 does a bit better.

Figures 4 and 5 show the implied PDFs for real yields at the three-month maturity as of the first day of each year from 2009 to 2016, inclusive, for the two different state vectors. The densities have a standard deviation of real rates that is around 60 basis points. The densities are more dispersed in the early years of the sample (2009–11) than more recently, especially when using state vector S2. Asymptotic 95 percent confidence intervals are included in these figures.[3] The uncertainty in the PDFs is driven by measurement error in options prices. While measurement error for individual

[3]These are formed from the variance-covariance matrix of implied volatilities, computed assuming i.i.d. measurement error in options prices and then applying the delta method.

Figure 4. Three-Month-Ahead PDF for Real Rates: State Variable S1



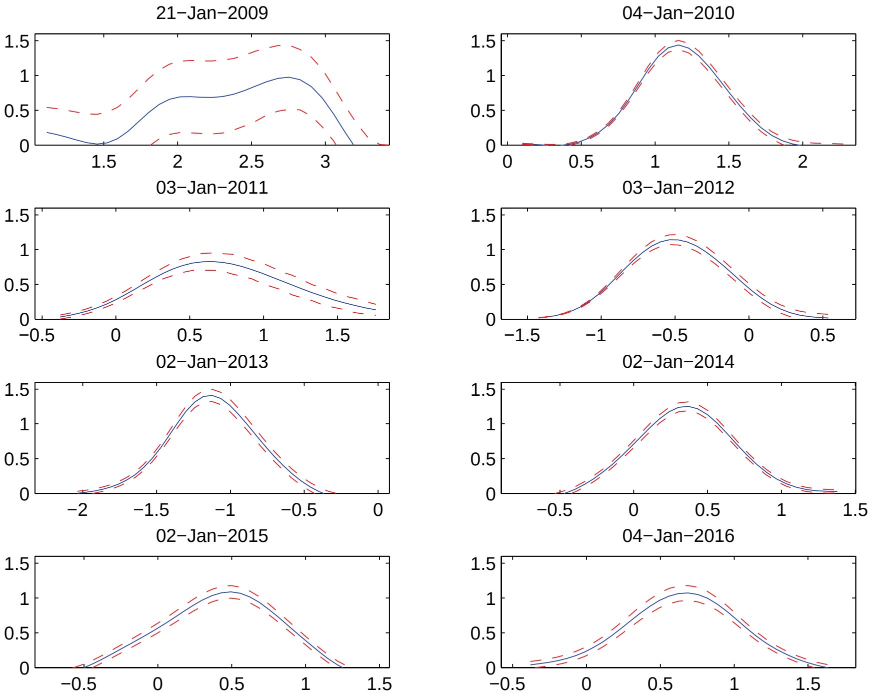
Notes: This figure plots the three-month-ahead PDF for seven-year TIPS yields constructed by the method described in the paper using the state variable S1. The PDFs are shown as of the first day in each year. Dashed lines are asymptotic 95 percent confidence intervals. The estimation of the implied volatility function in equation (1) is done for each calendar month separately.

options prices is considerable, with the smoothing procedure it is overwhelmed by the large sample size, leaving tight confidence intervals. The prices used to construct the state-price density are these smoothed prices that average out measurement error in individual quotes.[4]

Figures 6 and 7 repeat the exercise at the six-month maturity. Again, the densities are more dispersed early in the sample,

[4]If equation (1) were estimated over the entire sample, the standard errors would be even tighter.

Figure 5. Three-Month-Ahead PDF for Real Rates: State Variable S2



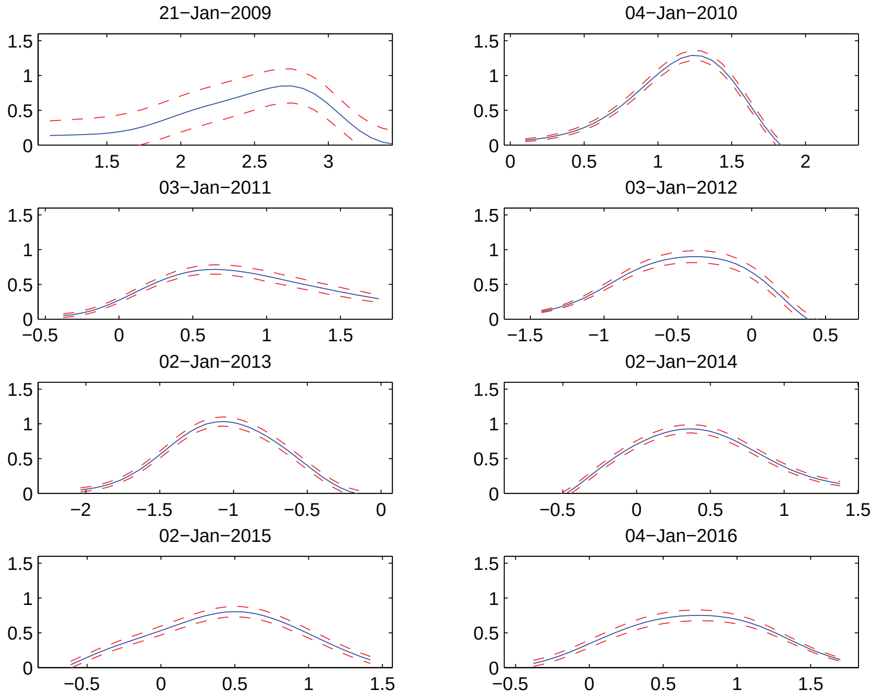
Notes: This figure plots the three-month-ahead PDF for seven-year TIPS yields constructed by the method described in the paper using the state variable S2. The PDFs are shown as of the first day in each year. Dashed lines are asymptotic 95 percent confidence intervals. The estimation of the implied volatility function in equation (1) is done for each calendar month separately.

especially when using state vector S2, and are precisely estimated. The densities are modestly skewed in the direction of higher real rates.

4. Evaluation of Density Forecasts

If agents were risk neutral, then the PDFs reverse-engineered from options ought to be good density forecasts for future TIPS yields. As the market in TIPS options is still young, evaluation of these options-implied density forecasts is difficult. Still, I have

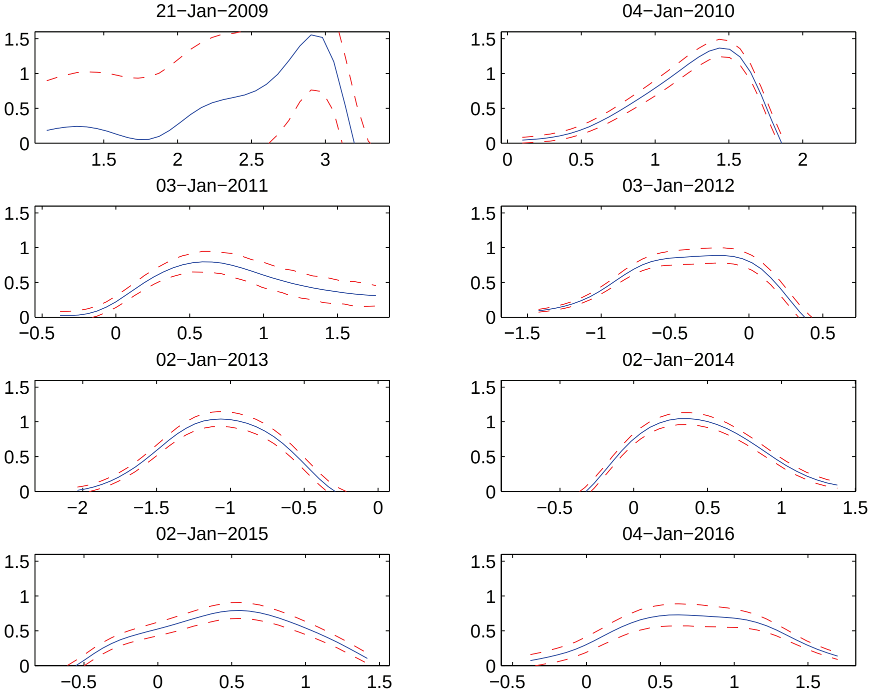
Figure 6. Six-Month-Ahead PDF for Real Rates: State Variable S1



Notes: This figure plots the six-month-ahead PDF for seven-year TIPS yields constructed by the method described in the paper using the state variable S1. The PDFs are shown as of the first day in each year. Dashed lines are asymptotic 95 percent confidence intervals. The estimation of the implied volatility function in equation (1) is done for each calendar month separately.

twenty-eight non-overlapping one-quarter-ahead density forecasts, which is enough to make an attempt at density forecast evaluation. I follow Diebold, Gunther, and Tay (1998) in evaluating these density forecasts by checking that the probability integral transform (PIT) of the realized data is both uniform on the unit interval and independent over time. Figure 8 shows the histogram of the PIT of the realized data for non-overlapping forecasts of one-quarter-ahead TIPS yields made at the end of each quarter from 2009:Q1 to 2015:Q4, respectively, using state variable S1. The realized real rate tends to

Figure 7. Six-Month-Ahead PDF for Real Rates: State Variable S2

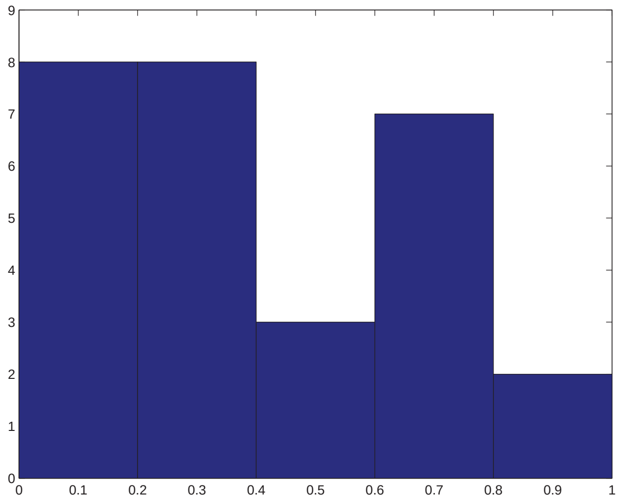


Notes: This figure plots the six-month-ahead PDF for seven-year TIPS yields constructed by the method described in the paper using the state variable S2. The PDFs are shown as of the first day in each year. Dashed lines are asymptotic 95 percent confidence intervals. The estimation of the implied volatility function in equation (1) is done for each calendar month separately.

lie toward the left of the forecast density, consistent with a positive real term premium. The likelihood-ratio test of Berkowitz (2001)—which jointly tests that the PIT is both uniform and independent over time—rejects with a p-value of below 0.01. Thus, despite a small sample, I can reject the hypothesis that the options-implied PDFs embeds no risk premium at conventional significance levels.

The finding that the options-implied PDFs embed a risk premium, even though statistically significant, could nevertheless be idiosyncratic to this unusual period. Swanson and Williams (2014)

Figure 8. Histogram of the Probability Integral Transform



Notes: This figure shows the histogram of the probability integral transform of three-month-ahead density forecasts of TIPS yields. As described in Diebold, Gunther, and Tay (1998), with an optimal density forecast, these should be uniform on the unit interval in population. The density forecasts are made at the end of each quarter from 2009:Q1 to 2015:Q4, for a total of twenty-eight forecasts, using state variable S1.

document that interest rate futures and surveys both consistently predicted near-term liftoff from the zero lower bound throughout much of the period from 2009 to 2015, even though that didn't actually happen until the end of 2015. Interest rate futures embed a term premium, but surveys should not. Time alone will tell whether realized real rates continue to lie toward the left of the forecast density or whether this was idiosyncratic to the years following the Great Recession.

5. Physical PDFs and the Empirical Pricing Kernel

Probability densities under the physical (P) measure weight different outcomes by their actual probabilities. The implied PDFs extracted from options reweight outcomes by marginal utility, and so give probabilities under the risk-neutral (Q) measure. Outcomes in which the marginal utility of an investor is high get more weight under the risk-neutral measure than under the physical measure. The evidence from the last section indicates that physical and risk-neutral PDFs are significantly different, even with the short sample period that is available.

In this section, I estimate physical PDFs for real interest rates and adapt the methodology of Rosenberg and Engle (2002) to obtain a time-varying empirical pricing kernel projected onto real interest rate states.

First, I fit a univariate EGARCH(1,1) model with t-distributed conditional errors to daily changes in seven-year TIPS yields. I estimate the model over the whole period for which TIPS yields are available by maximum likelihood, exactly as in the construction of state variable S2 above. Then, at each date, I simulate density forecasts for these TIPS yields. If the model is correctly specified, then these are density forecasts under the physical measure. Figure 9 shows these EGARCH-based density forecasts at the start of each year at the three-month horizon; results at the six-month horizon are not shown, but are qualitatively similar. This specification does not allow for mean reversion in real interest rates, but it does allow for potentially asymmetric conditional volatility and conditional excess kurtosis. These latter features are most important for near-term density forecasts.

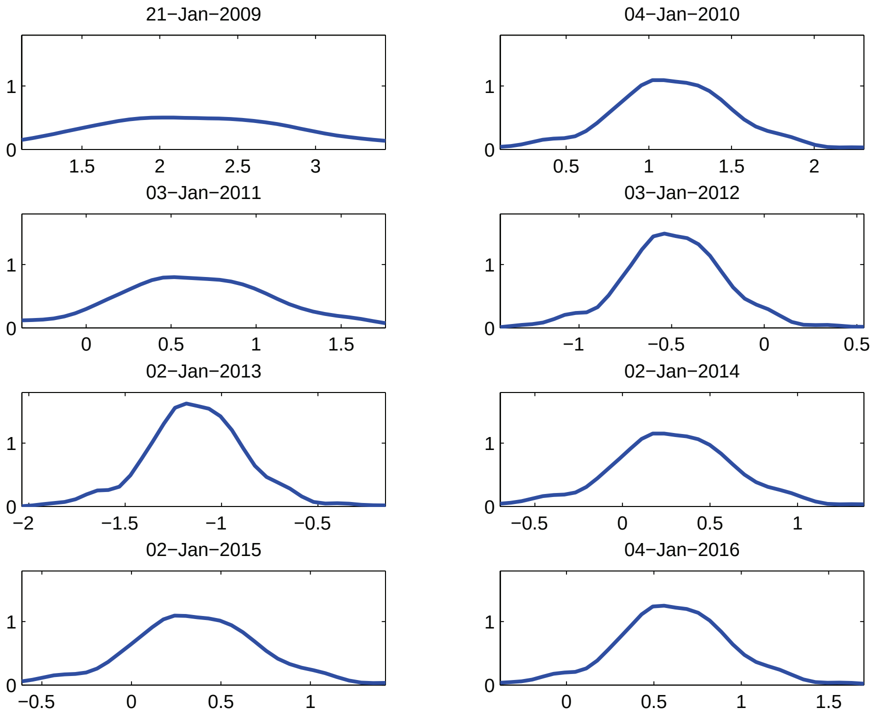
Let r_t denote the seven-year real interest rate. I specify a pricing kernel from time t to time $t+\tau$ that is a nonlinear function of $r_{t+\tau}$:

$$M_t(\theta_t, r_{t+\tau}) = \theta_{0t} \exp(\theta_{1t} T_1(r_{t+\tau}) + \theta_{2t} T_2(r_{t+\tau})), \tag{3}$$

where $\theta_t = (\theta_{1t}, \theta_{2t})'$ is a vector of parameters, $\theta_{0t} = \frac{e^{-r_{ft}(\tau)\tau}}{E(\exp(\theta_{1t}T_1(r_{t+\tau})+\theta_{2t}T_2(r_{t+\tau})))}$, $r_{ft}(\tau)$ is the nominal τ-period risk-free rate, and $T_j(.)$ is a Chebyshev polynomial, such that $T_j(x) = \cos(j \cos^{-1}(\frac{2x-a-b}{b-a}))$, where a and b are the endpoints of the interval over which the Chebyshev polynomial is expected to provide an approximation.[5] These are set to 1.2 percentage points below and above the current real interest rate, r_t. At each time t, this gives an empirical pricing kernel.

[5]The specification of θ_{0t} ensures that the expectation of the pricing kernel is the inverse of the price of a τ-period risk-free bond.

Figure 9. Physical PDF for Real Rates: Three-Month Horizon



Notes: This figure plots the three-month-ahead PDF for seven-year TIPS yields constructed from fitting a t-EGARCH model to daily changes in seven-year TIPS yields, as described in the text. The PDFs are shown as of the first day in each year.

Let $f_t^Q(r_{t+\tau})$ denote the risk-neutral PDF for $r_{t+\tau}$ as of time t, obtained in section 3. The horizon τ is either three or six months, and the state vector can be either S1 or S2. Let $f_t^P(r_{t+\tau})$ denote the physical PDF obtained from the fitted EGARCH model. As is well known,

$$f^Q(r_{t+\tau}) = e^{r_{f,t}(\tau)} f^P(r_{t+\tau}) M_t, \tag{4}$$

where M_t is the pricing kernel from time t to time $t + \tau$. I estimate the parameters of the pricing kernel to solve the optimization problem:

$$\hat{\theta}_t = \arg\min_{\theta_t} \Sigma_{i=1}^{L}(f^Q(r_{i,t+\tau}) - e^{r_{f,t}(\tau)} f^P(r_{i,t+\tau}) M_t(\theta_t, r_{i,t+\tau}))^2, \tag{5}$$

where $\{r_{i,t+\tau}\}_{i=1}^{L}$ is a grid of possible values of $r_{t+\tau}$. The grid consists of 32 points in the interval $r_t \pm 1.2$ percentage points.

Intuitively, this procedure is simply measuring the empirical pricing kernel as the ratio of the Q-measure PDF to the P-measure PDF. However, following the approach of Rosenberg and Engle (2002), I restrict the pricing kernel to have the functional form in equation (3).

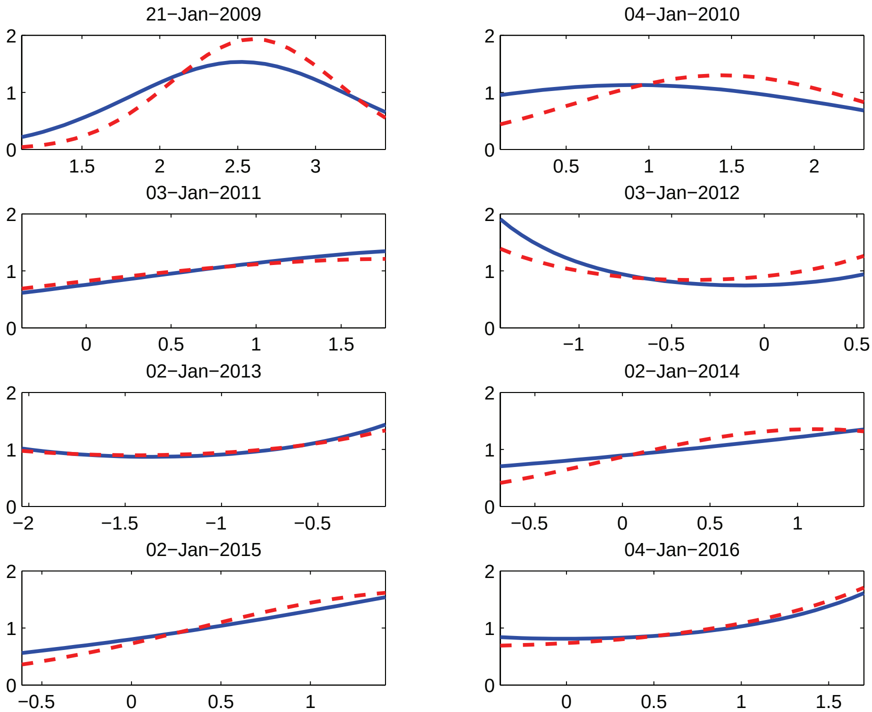
Figure 10 shows the estimated empirical pricing kernels at the start of each year, at the horizon, τ, of three months. Although the pricing kernels vary over time, the empirical pricing kernels generally slope up, meaning that marginal utility is highest in high real interest rate states of the world. As in the previous section, this is consistent with a positive real term premium. It contrasts somewhat with estimated pricing kernels for stock returns or inflation, which are found to be U-shaped in returns and inflation (see, for example Aït-Sahalia and Lo 2000, Jackwerth 2000, and Kitsul and Wright 2013).

6. Conclusion

Options on TIPS have recently been launched, and in this paper I have used these to construct risk-neutral probability densities for real interest rates going back to 2009. The nature of the options that trade means that it is only possible to obtain PDFs at horizons of a few months and for real interest rates at the seven-year maturity. This contrasts with the situation for nominal interest rates, where there is a wide range of expiration times and underlying maturities.

The PDFs that I obtained imply high uncertainty about real rates, especially in 2009–11. As is well known, options-implied PDFs embed risk premia, and I have shown direct evidence that they should not be interpreted as physical density forecasts. Risk-neutral PDFs overweight high marginal utility states of the world, relative to their actual physical probabilities. The high marginal utility states of the world appear to be associated with high real interest rates. However, Feldman et al. (2015) make a strong case that policymakers

Figure 10. Empirical Pricing Kernels: Three-Month Horizon



Notes: This figure plots the three-month empirical pricing kernels as a function of seven-year TIPS yields, constructed as described in section 5. Results are shown using state variable S1 (solid line) and state variable S2 (dashed line). The empirical pricing kernels are shown as of the first day in each year.

should actually *want* risk-neutral probabilities, weighted by marginal utility, rather than physical probabilities.

I hope that the PDFs for index-linked bond yields provided here can be useful to central banking practice, and can be used and analyzed more extensively as the market in TIPS options matures. Since 2009, TIPS and nominal interest rate implied volatilities have diverged at times, and they might do so more in the future. Uncertainty about future real interest rates can now—subject to many limitations—be directly reverse-engineered from asset prices.

References

Aït-Sahalia, Y., and A. W. Lo. 1998. "Nonparameteric Estimation of State-Price Densities Implicit in Financial Asset Prices." *Journal of Finance* 53 (2): 499–547.

———. 2000. "Nonparametric Risk Management and Implied Risk Aversion." *Journal of Econometrics* 94 (1–2): 9–51.

Berkowitz, J. 2001. "Testing Density Forecasts, with Applications to Risk Management." *Journal of Business and Economic Statistics* 19 (4): 465–74.

Bliss, R., and N. Panigirtzoglou. 2002. "Testing the Stability of Implied Probability Density Functions." *Journal of Banking and Finance* 26 (2–3): 381–422.

Bollerslev, T., G. Tauchen, and H. Zhou. 2009. "Expected Stock Returns and Variance Risk Premia." *Review of Financial Studies* 22 (11): 4463–92.

Breeden, D. T., and R. H. Litzenberger. 1978. "Prices of State Contingent Claims Implicit in Option Prices." *Journal of Business* 51 (4): 621–51.

Burghardt, G., and T. Belton. 2005. *The Treasury Bond Basis: An In-Depth Analysis for Hedgers, Speculators and Arbitrageurs.* McGraw-Hill.

Campbell, J. Y., R. J. Shiller, and L. Viceira. 2009. "Understanding Inflation-Indexed Bond Markets." *Brookings Papers on Economic Activity* (Spring): 79–120.

Choi, H., P. Mueller, and A. Vedolin. 2013. "Bond Variance Risk Premiums." Working Paper.

Diebold, F. X., T. A. Gunther, and A. S. Tay. 1998. "Evaluating Density Forecasts with Applications to Financial Risk Management." *International Economic Review* 39 (4): 863–83.

Feldman, R., K. Heinecke, N. Kocherlakota, S. Schulhofer-Wohl, and T. Tallarini. 2015. "Market-Based Probabilities: A Tool for Policymakers." Working Paper, Federal Reserve Bank of Minneapolis.

Gürkaynak, R. S., B. Sack, and J. H. Wright. 2010. "The TIPS Yield Curve and Inflation Compensation." *American Economic Journal: Macroeconomics* 2 (1): 70–92.

Jackwerth, J. C. 2000. "Recovering Risk Aversion from Option Prices and Realized Returns." *Review of Financial Studies* 13 (2): 433–51.

Kitsul, Y., and J. H. Wright. 2013. "The Economics of Options-Implied Inflation Probability Density Functions." *Journal of Financial Economics* 110 (3): 696–711.

Li, H., and F. Zhao. 2009. "Nonparametric Estimation of State-Price Densities Implicit in Interest Rate Cap Prices." *Review of Financial Studies* 22 (11): 4335–76.

Rosenberg, J. V., and R. F. Engle. 2002. "Empirical Pricing Kernels." *Journal of Financial Economics* 64 (3): 341–72.

Stoll, H. R. 1969. "The Relationship Between Put and Call Option Prices." *Journal of Finance* 24 (5): 801–24.

Swanson, E. T., and J. Williams. 2014. "Measuring the Effect of the Zero Lower Bound on Medium- and Longer-Term Interest Rates." *American Economic Review* 104 (10): 3154–85.

Wolfers, J., and E. Zitzewitz. 2004. "Prediction Markets." *Journal of Economic Perspectives* 18 (2): 107–26.

Discussion of "Options-Implied Probability Density Functions for Real Interest Rates"

Eric T. Swanson
University of California, Irvine

Options data provide us with substantial information about the future price of an asset. For example, researchers can use interest rate options to infer the market-implied risk-neutral probability density function (PDF) of the underlying interest rate at expiration (see, e.g., Bank for International Settlements 1999; Bliss and Panigirtzoglou 2002). These option-implied PDFs provide useful information about market participants' views of the likely outcomes for the underlying interest rate, and the relative likelihood of those different outcomes.[1]

Options on nominal interest rates have been widely traded for over thirty years. More recently, the introduction of options on inflation swaps has allowed researchers to estimate market-implied risk-neutral PDFs for inflation as well (Kitsul and Wright 2013). However, unlike with futures data, there is no simple way to combine the PDF for inflation with the PDF for the nominal interest rate to obtain the PDF for the real interest rate. If inflation and the nominal interest rate are correlated (as they would be under a Taylor rule, for example), then this correlation will be important for the PDF of the real interest rate, but it cannot be inferred from the individual PDFs for inflation and the nominal interest rate.

In "Options-Implied Probability Density Functions for Real Interest Rates," Jonathan Wright introduces us to newly available data on options on U.S. Treasury Inflation-Protected Securities (TIPS)—in particular, on a basket of TIPS held by an exchange-traded mutual fund—and uses these to compute market-implied

[1] It's important to note that these PDFs are computed under the risk-neutral measure—hence the term "market-implied risk-neutral PDF"—so they do not quite represent actual probabilities. Instead, they are the probabilities that are implied by the observed options prices, assuming that market participants are risk neutral.

risk-neutral PDFs for the real interest rate directly.[2] This marks the first time anyone has computed a market-implied PDF for the U.S. real interest rate. The results are summarized in figure 4 of Jonathan's paper. The implied risk-neutral PDFs have a fairly standard hump shape with fat tails, and a variance that appears to have changed substantially over time.

1. Data Limitations

The primary contribution of Jonathan's paper—the introduction and analysis of a new data set—carries with it some important limitations related to the novelty of that data. First, these TIPS options are still very lightly traded. On an average day in Jonathan's sample, only forty-nine options contracts in total changed hands. (Note that this is the total trading volume; the number of trades is necessarily less than or equal to this.) In comparison, total trading volume in Eurodollar options averaged about 400,000 contracts per day in 2015, and total trading volume in Treasury note options was of a similar magnitude.[3] This implies that the Chicago Board Options Exchange TIPS options data are about 10,000 times more sparse than the interest rate options data that many researchers are more familiar with and may have used in the past. Jonathan correctly points out that the relatively low trading volumes in the new data set do not imply that the prices are uninformative, particularly if we focus on bid and ask quotes rather than actual executed trades. (By focusing on the midpoint of bid and ask quotes, the number of observations in Jonathan's sample increases to about ninety-five per day, on average.) Nevertheless, low trading volumes imply that prices will tend to be noisier and less informative than they would be in a thicker market.

Low trading volumes also tend to produce large bid-ask spreads, and that is the case for these TIPS options as well. As Jonathan notes, bid-ask spreads average about 18 percent in these data.

[2] To be precise, the PDFs are for the implied yield to maturity on the basket of TIPS underlying the mutual fund.

[3] See the CME Group's Monthly Average Daily Volume Report, available at http://www.cmegroup.com/market-data/volume-open-interest.html.

Jonathan's analysis focuses on the midpoints of the bid and ask quotes, but nevertheless the "true" shadow price could lie anywhere in between, in theory. This suggests that there could be measurement error of the true shadow price of each contract on the order of ± 9 percent.

Finally, note that bid and ask quotes are not available for every strike price on every day of the sample. Quotes seem to be particularly sparse earlier in the sample (in 2009 and 2010), and many of the quotes that do exist then are for deep in- or out-of-the-money strikes, which convey very little information. Thus, one should treat the earlier years of Jonathan's sample with particular caution.

2. Standard Errors

Given the significant limitations of the data, discussed above, it's natural to wonder why Jonathan's reported standard errors in his figures 4–7 are so small. After all, each data point in the sample is plausibly contaminated with a measurement error of ± 9 percent, and that error alone would seem to suggest wider standard-error bands than are reported in the figures.

The difference is due to the type of standard errors that Jonathan is reporting. In particular, they are not the standard errors that would result from analyzing a single day of data in isolation. Instead, the standard errors are what one gets from pooling data on the given day with data from all other days that are *similar to* the given day within the month. (I discuss this pooling and Jonathan's non-parametric estimation procedure in more detail below.) Because there are effectively many days that are similar to any given day in Jonathan's data, the sample size is effectively larger—as if we had roughly 2,000 observations instead of 95. Thus, the standard errors are correspondingly smaller, because the effective sample size is larger.

In other words, the standard errors are computed under the assumption that the given day has many other days that are just like it. The reported standard errors are for this large set of days, all of which can be thought of as being essentially identical to the given day.

3. Estimation Methodology for Probability Density Functions

A related question is whether Jonathan's non-parametric estimation strategy of the implied volatility function is the best approach (see equation (1) of his paper). When working with heavily traded options data, such as Eurodollar options, it is standard practice to estimate the market-implied risk-neutral PDF for each day in isolation. In other words, treat each day as independent from the others in the sample, and estimate the market-implied PDF using the cross-section of options prices available on that day.

TIPS options do not have nearly as many price observations as do Eurodollar options; nevertheless, there may be more than enough observations per day to make the cross-sectional estimation strategy feasible. For example, there are roughly ninety-five observations per trading day in Jonathan's sample, and although these are typically split across three or four different expirations, that still leaves about twenty-four to thirty-two different observations per expiration per day. In comparison, Bliss and Panigirtzoglou (2002) had 10.8 observations per day for their short sterling options data set, and found that their cross-sectional estimation strategy worked very well.

In the Bliss-Panigirtzoglou (2002) approach, the options prices on a given day are first converted into implied volatilities.[4] (Note that Jonathan does this same transformation in the run-up to equation (1); the idea here is exactly analogous to converting bond prices into bond yields to maturity—for most questions, it is more natural to work in "bond yield space" than in "bond price space," and in the options market it is likewise more natural to work in "implied volatility space" than in "options price space.") The prices of these different strikes, when converted into implied volatilities, typically form a "volatility smile," which is a smooth functional form that

[4]This is done by using the Black-Scholes formula assuming log-normality. As noted in the main text above, this is simply a way of transforming the options price data into "implied volatility space" rather than "options price space," because the former lends itself more naturally to fitting a smooth parametric function. Once this curve fitting is done, then the fitted yields can be transformed back to options price space. Thus, the log-normality assumption here plays no role in the analysis; it's simply a convenient way of transforming the data temporarily.

is easy to summarize with a small number of parameters. It only takes about five to ten such observations to get a reasonably good estimate of the smile (Bliss and Panigirtzoglou 2002), so the twenty-four to thirty-two observations in Jonathan's sample should be more than sufficient. Once the parametric functional form for the volatility smile is estimated, we can then transform it back to options price space and from there compute the implied PDFs using the second derivative of the options price with respect to the strike, as in Breeden and Litzenberger (1978).

Jonathan's non-parametric approach (following Ait-Sahalia and Lo 1998) relaxes the parametric functional form assumptions for the volatility smile required by Bliss and Panigirtzoglou (2002), but only by imposing alternative restrictions across time. This is because there aren't enough observations on any one day to get a good non-parametric estimate, so one must pool together observations on "similar days" and perform the non-parametric estimation on the pooled data. In this case, "similar days" are defined as those that have similar values for the assumed state vector Z, and Jonathan considers two different choices for Z.

Intuitively, for the non-parametric approach to be more accurate than the parametric approach, it must be the case that the intertemporal restrictions of the former are more consistent with the data than are the functional form restrictions on the volatility smile imposed by the latter. In my view, this is unlikely to be the case over long samples, such as the full 2009–16 pooled sample that Jonathan used in the first draft of this paper. Volatility smiles are, almost by definition, well approximated by a low-dimensional polynomial. Thus, I am very comfortable making parametric functional form assumptions here, and these restrictions are likely to fit the data quite well.

In contrast, I would be much less comfortable pooling together data from dates that may be years apart, as would be the case in the non-parametric approach applied to Jonathan's whole sample. In Jonathan's state vector S1, the "state of the world" is essentially completely described by the spot real interest rate r. (The other two state variables in S1 are the strike price and the maturity of the option, which one can think of as parameters of the option rather than the state of the world.) Thus, if the five-year TIPS yield was about 0.5 percent in November 2009, and is also about 0.5 percent currently, the pooled non-parametric approach would say that the data from November 2009 and today should be pooled together, because the state of the world is the same. This restriction strikes me as implausible, for many reasons; for example, the U.S. economy was close to the trough of a deep recession in November 2009, with the unemployment rate at 10 percent and the Federal Reserve pursuing unconventional monetary policy, while today the United States is in the midst of an ongoing expansion, with an unemployment rate of 5 percent and monetary policy that is acting much more conventionally. The true state of the world seems very different today than it was in November 2009.

Jonathan's second state vector, S2, provides a better alternative to S1 but still suffers from the same type of problem. In S2, the state of the world is completely described by σ_{EGARCH}, the estimated volatility of real yields rather than the level of those yields. (Again, there are two additional state variables in S2, the strike/spot price ratio and the maturity of the option, which describe parameters of the option rather than the state of the world.) The advantage of this approach is that it controls for uncertainty in the economy and only pools together days on which economic uncertainty was similar. Nevertheless, this restriction still seems much harder to justify than a smooth parametric functional form for the volatility smile.

In the revised version of the paper, Jonathan has greatly reduced these problems by performing the non-parametric analysis on each month in the sample separately. Thus, Jonathan's non-parametric approach no longer pools observations that are more than thirty days apart, so the state of the world across the pooled observations is almost certainly more similar than in the original, full-sample analysis. To the extent that the state of the world does change over the course of any given month, it may be well captured by the change in the real interest rate or the change in interest rate volatility. If so, then Jonathan's non-parametric approach should work just fine.

Nevertheless, one might worry that the state of the world changed rapidly in some months of the sample—particularly during the financial crisis and deep recession in 2007–9—and that the differences across days in some of those months are not well captured by a single state variable such as the real interest rate or interest rate volatility. For example, are we comfortable pooling observations at the beginning and end of September 2008, which are separated by the collapse of Lehman Brothers and AIG? And are we comfortable pooling observations at the beginning and end of March 2009, which are separated by the Federal Reserve's dramatic "QE1" announcement? Thus the same concerns I raise above could still apply, albeit to a lesser extent.

These concerns do not invalidate the non-parametric approach in Jonathan's paper, but they do raise legitimate caveats regarding that approach. A more parametric approach, along the lines of Bliss and Panigirtzoglou (2002) discussed above, could be used to produce snapshots of the options market on each and every day, which could provide a more accurate picture.

4. PDF Forecast Errors

Finally, Jonathan evaluates his estimated market-implied PDFs using the methods of Diebold, Gunther, and Tay (1998) and Berkowitz (2001). These methods apply the inverse of the cumulative distribution function (CDF) estimated at each point in time to map the outcomes of the predicted variable back onto the unit interval. If the model is doing a good job of producing PDFs, then the outcomes should be mapped back to a uniform distribution over the unit interval.

Figure 8 of Jonathan's paper shows that these mapped outcomes are quite far from uniformly distributed. But not only is this distribution not uniform, it is also heavily biased downward. This implies that the outcomes of the real interest rate between 2009 and 2015 were typically *lower* than the mean and median of the options-implied PDFs, and often fell in the first and second quintiles of that PDF distribution.

Thus, it is obvious from figure 8 that the options-implied PDFs were biased upward over this period. Jonathan takes this bias at face value and analyzes what it implies about the risk-neutral versus actual (or physical) probability measures underlying the options data. However, it's also possible that these under-realizations of the real interest rate are a feature of the sample period considered and would not be reproduced in a different sample. In support of this possibility, consider the evidence in Swanson and Williams (2014), who showed that bond yields, interest rate futures, and surveys all consistently predicted an increase in the federal funds rate throughout much of this period from 2009 to 2015, even though those federal funds rate increases never materialized. Thus, Treasury bonds, interest rate futures, and surveys from this period *all* tended to over-predict the nominal interest rate, and would also produce a transformed forecast error distribution that would look a lot like Jonathan's figure 8. Thus, it's not clear that those biased forecast errors in the TIPS options market should be taken as anything other than an idiosyncratic feature of the very special 2009–15 period.

5. Conclusions

In summary, Jonathan's paper introduces us to a new options data set and provides us with the first market-implied risk-neutral PDFs for the U.S. real interest rate (as opposed to the nominal interest rate or inflation). This kind of information is difficult or impossible to get any other way. Jonathan's non-parametric estimation strategy has been favored by some prominent authors (Ait-Sahalia and Lo 1998), but the parametric approach discussed by Bliss and Panigirtzoglou (2002) provides an attractive alternative that could perhaps produce more accurate estimates, with standard errors that are representative of a single day's data rather than a larger pooled sample. Although the options-implied PDFs that Jonathan estimates were biased over the 2009–15 sample, other interest rate forecasts were biased over that period as well, so one should hesitate before attributing that bias to TIPS option investors' risk aversion.

References

Ait-Sahalia, Y., and A. Lo. 1998. "Nonparametric Estimation of State-Price Densities Implicit in Financial Asset Prices." *Journal of Finance* 53 (2): 499–547.

Bank for International Settlements. 1999. *Estimating and Interpreting Probability Density Functions.* Proceedings of a workshop held at the Bank for International Settlements, Basel, Switzerland, June 14.

Berkowitz, J. 2001. "Testing Density Forecasts with Applications to Risk Management." *Journal of Business and Economic Statistics* 19 (4): 465–74.

Bliss, R., and N. Panigirtzoglou. 2002. "Testing the Stability of Implied Probability Density Functions." *Journal of Banking and Finance* 26 (2–3): 381–422.

Breeden, D., and R. Litzenberger. 1978. "Prices of State-Contingent Claims Implicit in Options Prices." *Journal of Business* 51 (4): 621–51.

Diebold, F., T. Gunther, and A. Tay. 1998. "Evaluating Density Forecasts with Applications to Financial Risk Management." *International Economic Review* 39 (4): 863–83.

Kitsul, Y., and J. Wright. 2013. "The Economics of Options-Implied Probability Density Functions." *Journal of Financial Economics* 110 (3): 696–711.

Swanson, E., and J. Williams. 2014. "Measuring the Effect of the Zero Lower Bound on Medium- and Longer-Term Interest Rates." *American Economic Review* 104 (10): 3154–85.

The Effect of Unconventional Monetary Policy on Inflation Expectations: Evidence from Firms in the United Kingdom*

Lena Boneva,[a,b] James Cloyne,[a,c] Martin Weale,[a] and Tomasz Wieladek[c,d]
[a]Bank of England
[b]London School of Economics
[c]CEPR
[d]Barclays

This paper investigates the effect of quantitative easing (QE) and other unconventional monetary policies on price and wage growth expectations of UK manufacturing firms. To identify the effect of QE on firms' expectations, we use a novel approach of combining microeconometric data with macroeconomic shocks: QE is exogenous to inflation expectations of individual firms, and so are other macroeconomic developments like aggregate inflation or GDP growth. We find that firms' price and wage inflation expectations increase by 0.22 percentage points in response to £50 billion of QE, implying that inflation expectations are part of the transmission mechanism of QE. In contrast, we find a positive but small and insignificant effect of forward guidance on price and wage inflation expectations.

JEL Codes: D22, E52, E31.

*First version: November 1, 2013. We thank Pierpaolo Benigno, Julio Carrillo, James Talbot, Garry Young, Alice Pugh, John Barrdear, and seminar participants at the Bank of England and the Annual IJCB Research Conference 2015 for comments, advice, and support with the data. Lena Boneva gratefully acknowledges financial support from Cusanuswerk and the ESRC. Tomasz Wieladek's contribution to this paper was completed while employed by the Bank of England and does not represent the views of Barclays. The views expressed in this paper are our own and not those of the Bank of England. The data used in our paper are proprietary and are obtained under license from the Confederation of British Industry (CBI). The licensing contract permits Bank of England staff to use the data for research purposes. Author e-mails: Lena.Boneva@bankofengland.co.uk, James.Cloyne@bankofengland.co.uk, Martin.Weale@bankofengland.co.uk, and tomaszwieladek@gmail.com.

1. Introduction

Following the onset of the "Great Recession" and after short-term interest rates hit the zero lower bound, several central banks adopted unconventional monetary policies to support their economies. Unconventional instruments ranged from purchases of different assets (quantitative easing, QE) to forward guidance on the future conduct of monetary policy. Some instruments, such as the Bank of England's Funding for Lending Scheme (FLS), were designed to directly stimulate domestic non-financial lending. Among these new instruments, purchases of government bonds were probably most widely used across countries: including Operation Twist the Federal Reserve System bought government bonds worth \$1567 billion, and the government bond purchases by the Bank of England amounted to £375 billion.

Modern macroeconomic theory places strong emphasis on the importance of inflation expectations. Monetary stabilization policy involves anchoring long-term expectations at the inflation target and credibly ensuring a stable path for private-sector expectations back to the inflation target following any disturbance. Moreover, at the zero lower bound, preventing inflation expectations from falling is crucial to avoid a liquidity trap (Krugman 1998), and the recent unconventional monetary policy actions were aimed at avoiding such an adverse outcome.

This paper therefore investigates whether the recent unconventional policy interventions in the United Kingdom succeeded in increasing inflation expectations. Specifically, we investigate the effect of unconventional monetary policy measures on the manufacturing price and wage inflation expectations of UK manufacturing firms using a novel panel data set collected by the Confederation of the British Industry (CBI). The data cover the period 2008–14. We find that firms' expectations for annual own price inflation increase by 0.22 percentage points in response to £50 billion of QE. Similarly, their expectations for industry-wide annual price inflation increase by 0.19 percentage points. The increase in expected wage growth is somewhat higher at 0.28 percentage points.

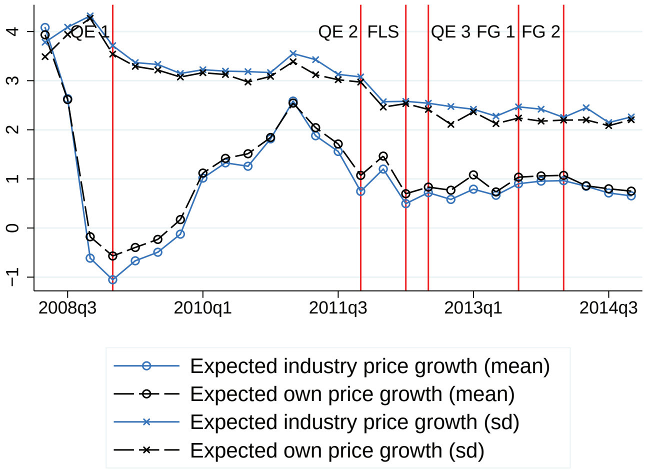
Whilst evidence of whether unconventional monetary policies affected firms' expectations is scarce, there is a growing literature on the effects of QE on asset prices and macroeconomic outcomes.

Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), and D'Amico and King (2012) document that the first U.S. large-scale asset purchases program led to a statistically significant decline of about 30–90 basis points in Treasury yields. Following asset purchases by the Bank of England, Meier (2009) and Joyce et al. (2011) find a decline of UK gilt yields of about 40–100 basis points. But to gauge the effect these policies have on financial markets, existing studies have used time-series regressions or event-study techniques focused on dates around the announcement. Despite being an important contribution to understanding whether QE worked, these papers have typically not assessed how financial market movements translated into effects on the wider economy.

Studies that do examine the wider impact of unconventional monetary policy typically adopt vector autoregression methods or structural macroeconomic models. In terms of structural models, Chung et al. (2011) use the Federal Reserve Board's U.S. macroeconomic model to examine the possible impact of U.S. large-scale asset purchases and find that real GDP and inflation were, respectively, 3 percent and 1 percent higher as a result of the Federal Reserve's asset purchase policy. Del Negro et al. (2011) study the Federal Reserve's liquidity facilities through the lens of a DSGE model with financial frictions and find that these policies were highly effective at preventing an even deeper recession. But these economic models are typically based on strong assumptions about the precise transmission mechanism of asset purchases.

Kapetanios et al. (2012) estimate a range of time-varying structural vector autoregression (SVAR) models on UK data and conclude that £200 billion in asset purchases increased inflation by $1\frac{1}{4}$ percent and real GDP by $1\frac{1}{2}$ percent. In a related study, Weale and Wieladek (2016) find, using a wide range of alternative identification schemes that do not impose restrictions on the response of output and inflation, a similar impact on real GDP, but an effect on inflation that is three times as large. Baumeister and Benati (2013) produce related estimates for the United States. Studies that investigate the effect of QE using time-series data are, however, subject to two major econometric challenges. First, QE is observed only for a short period of time, which makes the application of many time-series estimators difficult. Secondly, identifying the effect of QE on the macroeconomy

Figure 1. Monetary Policy Announcements and Inflation Expectations (means and standard deviations)



faces a serious endogeneity problem because QE both affects and responds to macroeconomic developments.

To illustrate the endogeneity problem in macroeconomic data, figure 1 reports the cross-sectional averages of manufacturing price and wage inflation expectations in our data set together with announcements of unconventional monetary policies in the United Kingdom. The series clearly move together and policy actions, naturally, appear highly correlated with the state of the economy. At the aggregate level, it is therefore difficult to identify whether the policy decision is caused by or drives macroeconomic developments such as expected or realized price growth. We exploit the fact that QE and other unconventional policy actions are exogenous with respect to expectations of individual firms. Of course, while this tackles the reverse causality issue, there could be common factors shifting both monetary policy and firm-level expectations jointly. We address this omitted-variable problem by including a wide range of macroeconomic variables that are likely to have influenced the policymakers' decisions as proxies for the components of the monetary policy rule. Since these variables are also aggregate variables, there is no reverse causality problem from including them.

Recently, the formation of expectations has attracted much attention.[1] The closest papers to ours are by Bryan, Meyer, and Parker (2014), Coibion and Gorodnichenko (2015), Coibion, Gorodnichenko, and Kumar (2015), and Cloyne et al. (2016). Coibion and Gorodnichenko (2015) and Coibion, Gorodnichenko, and Kumar (2015) uncover new stylized facts about how various economic agents form their expectations. For example, Coibion and Gorodnichenko (2015) document that survey expectations of professional forecasters, firms, households, and Federal Open Market Committee (FOMC) members are heterogeneous and react sluggishly to news, like predictions made by noisy information models. Coibion, Gorodnichenko, and Kumar (2015) collect new survey data on firms' expectations in New Zealand. Besides providing further evidence against full information and rationality, they show that firms pay particular attention to news in variables that matter, while discounting other news. Bryan, Meyer, and Parker (2014), who use the Federal Reserve Bank of Atlanta's Business Inflation Expectations (BIE) survey, compare firms' expectations with those of professional forecasters and households. They also explore how well firms' expectations forecast their perceived inflation and relate the accuracy of expectations to uncertainty about future inflation. In Cloyne et al. (2016), we explore the issue of whether firms' expectations matter for their pricing decisions today.[2] Compared with these papers, the contribution of our work is to estimate the effects of monetary policy on firms' expectations of growth in (i) the prices of their output, (ii) the prices of the output of their industry, and (iii) the wage rates that they pay. We summarize these as firms' expectations of price and wage inflation.

[1]There is a large theoretical literature on the formation of inflation expectations—as, e.g., Carroll (2003)—that we do not survey here.

[2]Other related work includes Hori and Shimizutani's (2005) study of the determinants of households' inflation expectations in Japan using a quarterly panel data set. They find that inflation expectations are affected by current inflation and past inflation expectations. The majority of Japanese households do not revise their inflation expectations following policy announcements by the Bank of Japan. Finally, Pesaran and Weale (2006) survey alternative models of expectation formation and discuss their testable implications.

It is possible that unconventional policy interventions also reduced uncertainty.[3] Unfortunately, our data set does not include direct information on firms' uncertainty about expected price and wage inflation, although we can still compute the dispersion across firms over time. Figure 1 reports the standard deviation of firms' inflation expectations. In general, dispersion declines over this period, consistent with reduced uncertainty since the early part of the crisis. But examining the role of monetary policy in driving this faces a similar identification problem to the one discussed earlier. Moreover, in studying dispersion, we would lose the cross-sectional dimension that we exploit for identification. The effect of unconventional monetary policies on uncertainty is an important topic, although outside the scope of this paper.

The rest of the paper proceeds as follows: Section 2 describes the CBI's Industrial Trends Survey (ITS) we use in this paper. Section 3 discusses our empirical approach. Our main results and a series of robustness exercises are reported in sections 4 and 5. Section 6 concludes.

2. Data

To investigate the effect of QE on price and wage inflation expectations of individual firms, we ideally need panel data on firms' expectations and with a range of firm-specific characteristics. In the United Kingdom the Confederation of British Industry (CBI) has collected quarterly data on firms' expected price and wage growth since 2008. While the broader CBI survey has a much longer history, we focus only on the sample for which information on price and wage inflation expectations is available. The CBI survey is conducted for several different sectors of the economy, but we use only the Industrial Trends Survey (ITS), which surveys firms in the manufacturing sector. We do this for two reasons. First, the ITS has the advantage that there is a large sample of firms (about 400 in each quarter) and these firms are relatively homogeneous (being all in manufacturing).

[3]For example, Weale (2013) presented evidence that the variance of option prices of future LIBOR rates decreased significantly after both the Funding for Lending Scheme and forward guidance announcements in the United Kingdom.

Second, the number of firms in the other sectors is not large enough to conduct separate analyses. Pooling the surveys would also group together very different types of firms, making it hard to interpret the results. The remainder of this section provides more information on the ITS survey and discusses how we measure the unconventional policy interventions of the Bank of England.

2.1 Overview of the Industrial Trends Survey

The ITS asks UK firms about their estimates of expected future trends in prices and wages, among other questions. Lui, Mitchell, and Weale (2011) document that the ITS data contain valuable information about developments in the manufacturing sector, and Mitchell, Smith, and Weale (2013) find that an aggregate indicator of output growth constructed from individual CBI survey responses can provide a useful early indicator of realized output growth. The survey is carried out on a quarterly basis, and our data set starts in 2008:Q2 and ends in 2014:Q4. The questions that provide us with our main dependent variables of interest are as follows:

- "What has been the percentage change over the past twelve months in the general level of output prices in the UK markets that your firm competes in, and what is expected to occur over the next twelve months?"
- "What has been the percentage change over the past twelve months in your firm's own average output price for goods sold into UK markets and what is expected to occur over the next twelve months?"
- "What has been the percentage change over the past twelve months in your firm's wage/salary cost per person employed (including overtime and bonuses) and what is expected to occur over the next twelve months?"

Firms can answer these questions by choosing one of eleven buckets or by entering their own answer manually. The midpoints of the buckets range from −9 percent to +9 percent in the case of inflation and from −1.5 percent to +7.5 percent for wages.[4] We put the manual answers into the corresponding buckets. If the manual answers lie outside the bucket ranges, they are allocated to the largest bucket on either side.[5]

2.2 Descriptive Statistics

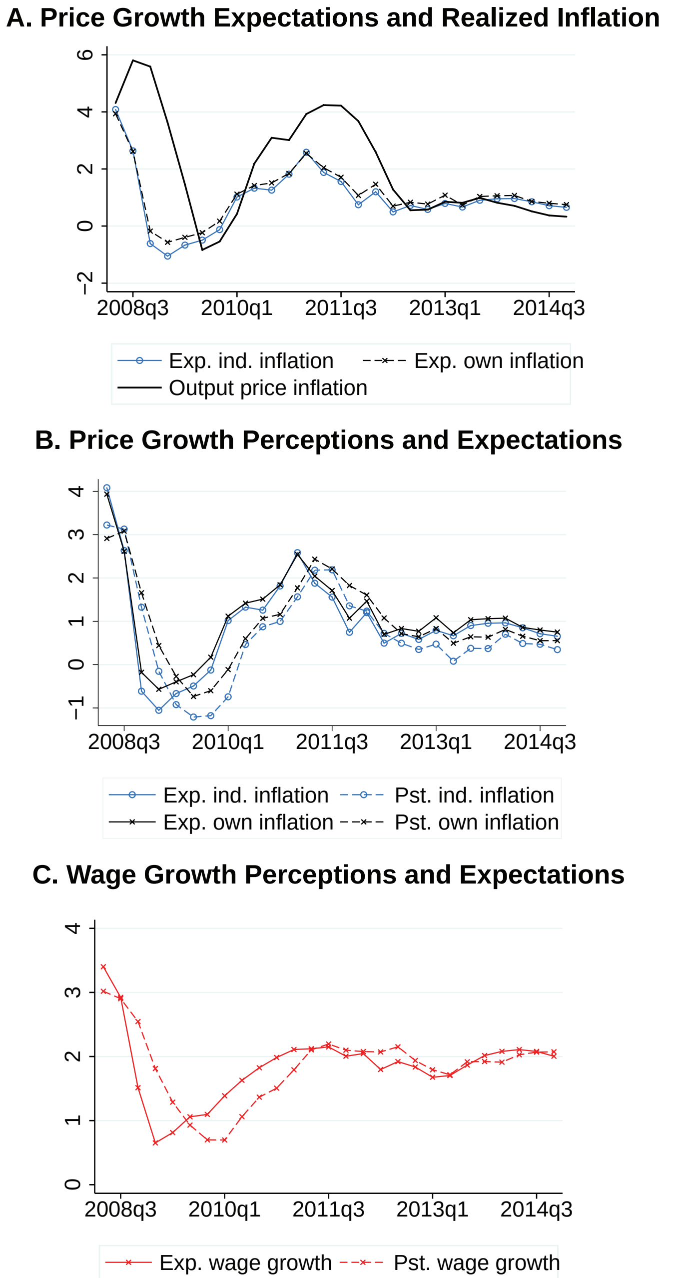
We start by documenting the key aggregate characteristics of our data. It is worth noting that our sample period coincides with a deep UK recession. So it is not surprising that in the survey we observe a sharp decline in inflation expectations in 2008/9 (figure 2A). The observed decline in firms' expected price growth was of much the same magnitude as the fall in output price inflation in the manufacturing sector. Overall, firms' price and wage inflation expectations lead output price growth in the manufacturing sector over the sample period. This is reassuring because it can be interpreted as an indication that the ITS is representative of the manufacturing sector. Expected own and industry-wide price growth was, however, only around 1 percent on average, and this is significantly below realized aggregate CPI inflation rates.[6] Bryan, Meyer, and Parker (2014), for the United States, also find that firms' expectations are, on average, informative about aggregate price measures. For example, they find that unit-cost inflation expectations correlate with firms' expectations of core CPI inflation. Expected price and wage growth leads perceived outcomes, too (figures 2B–2C).

[4]Specifically, the buckets are −8.1 to −10 percent; −6.1 to −8 percent; −4.1 to −6 percent; −2.1 to −4 percent; −0.1 to −2 percent; no change; 0.1 to 2 percent; 2.1 to 4 percent; 4.1 to 6 percent; 6.1 to 8 percent; and 8.1 to 10 percent for inflation. For wages, they are −1.1 to −2 percent; −0.1 to −1 percent; no change; 0.1 to 1 percent; 1.1 to 2 percent; 2.1 to 3 percent; 3.1 to 4 percent; 4.1 to 5 percent; 5.1 to 6 percent; 6.1 to 7 percent; and 7.1 to 8 percent.

[5]This treatment does not affect our results, as fewer than 1 percent of all answers are entered manually.

[6]One possible reason for this difference in levels is that firms exclude the effects of taxes such as value-added tax (VAT) from their responses. A further possible explanation for the level difference between the survey data and the official data is that some respondents may misinterpret the questions by answering "no change" when they mean that the rate of growth rather than the price level has not changed. But a recent answering practices survey conducted by the CBI suggests that this is not the case.

Figure 2. Cross-Sectional Averages of Price and Wage Growth Expectations and Perceptions



Turning to the cross-sectional dispersion, figure 3 shows histograms for expected price and wage inflation. For own and industry-wide expectations, the distributions are centered around zero, but there is a second mode around 3 percent (figures 3A and 3B). The histogram for wage growth expectations is bimodal, too, with one mode at 2.5 percent and another at zero (figure 3C). Compared with price growth expectations, the histogram for expected wage growth is less dispersed, although this probably reflects the smaller range of the bins on the survey for reporting wage expectations. The survey also has information on firms' current perceptions of price and wage growth. Using this, there is also a distribution of forecast errors across firms, and we discuss this further in appendix 1. Importantly, however, the strong co-movement between the survey averages and the aggregate official data suggests that the cross-sectional heterogeneity averages out at the aggregate level.

2.3 Choice of Sample

In principle the survey is a panel with firms approached repeatedly. Unfortunately, however, as shown in figure 4, there is a sizable number of firms for which we observe only a few consecutive quarters. In other words, the panel is unbalanced and the number of exits and re-entrants is large relative to the sample size (there are periods of substantial, although sometimes temporary, non-response by firms). In large part, the reason for this is that the ITS is intended to provide a rapid snapshot of the state of the economy. Therefore, late respondents are only followed up within a set time frame after the official closing date of the survey. That time period usually amounts to one or two days.

Over the twenty-six quarters between 2008 and 2014, the average number of quarterly returns from each respondent is 6.3 but the median is only 3. Out of the 1,717 firms which reply to the survey over this period, only 5 firms provide complete records for the full sample period.

This characteristic of our data poses some challenges on how to select a reliable and representative sample. On the one hand, firms that remain in the survey for a longer period may be more reliable, but, on the other hand, using more observations increases statistical

Figure 3. The Distribution of Expected Price and Wage Growth

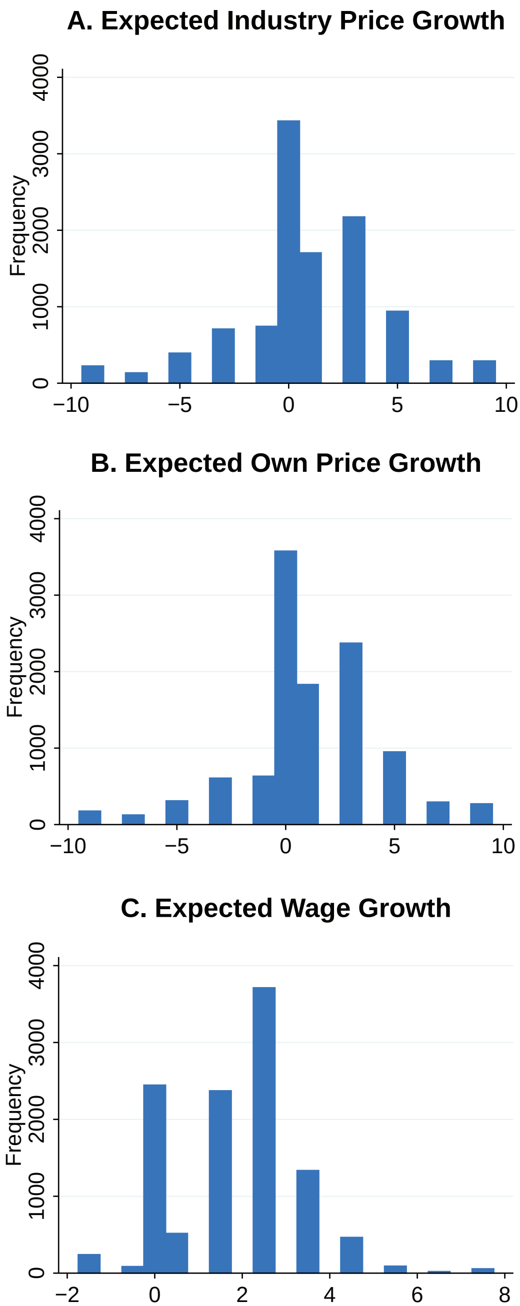
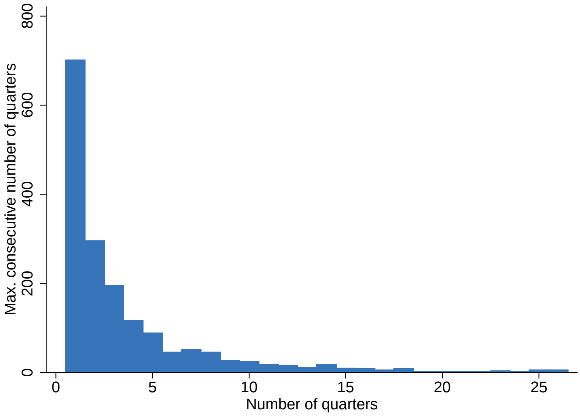


Figure 4. Maximum Number of Consecutive Quarters



Note: The maximal number of subsequent observations for each firm is reported.

significance and reduces the risk of selection effects. As a compromise, we decided to include only firms that remained in the survey for at least four consecutive quarters. In appendix 3 we discuss sample selection in more detail. Specifically, we formally test whether the distribution of the dependent variables changes as we use alternative criteria to select our sample. Reassuringly, we fail to reject the equality of distributions as we limit the sample to firms observed for at least four quarters compared with other sample choices.

2.4 Unconventional Monetary Policy Measures

Between 2009 and 2014, the Bank of England deployed three main unconventional policy measures to stabilize output and prices following the onset of the Great Recession: (i) QE, which largely involved the purchase of government securities from the private sector using newly created central bank reserves[7]; (ii) the Funding for Lending Scheme, which offered banks discounted access to funding conditional on increasing lending; and (iii) the Bank provided forward guidance on when it would consider raising the Bank Rate from 1/2

[7]The Bank of England also purchased a small amount of corporate bonds and commercial paper. However, these purchases only amount to £3 billion compared with £375 billion of gilt purchases.

percent, regarded at the time as the effective lower bound. The key announcement dates can be seen in figure 1.[8]

As can be seen, the most-used tool over this period was quantitative easing (QE), and we will therefore focus more heavily on this instrument. Unlike monetary policy through the short-term interest rate, where the announcement of the policy coincides with implementation, asset purchases were first announced and then implemented. If the announcement of asset purchases is a signal that monetary conditions are going to be looser in the future or that the central bank will do "whatever it takes" to save the economy, then announcements are the more relevant variable of interest. On the other hand, e.g., in the presence of preferred-habitat investors, the implementation of QE (actual purchases) will affect the long end of the yield curve and hence financial conditions in the wider economy.

In the United Kingdom, QE was also typically implemented shortly after it was announced, with purchases of £25 billion per month. This is different from the United States, where purchases were implemented over a longer period following QE announcements. At a quarterly frequency, as in this paper, announcements and implementation will therefore be very highly correlated. For all these reasons, we therefore measure QE as the *announcement of additional asset purchases* in a given quarter scaled by nominal GDP in 2009:Q1.[9] This measure of QE is reported in figure 5. The episodes corresponding to QE1, QE2, and QE3 can be clearly identified. In section 5, we assess the robustness of our results to alternative measures of QE that are based on either a binary indicator for the QE announcement dates or the difference in the outstanding QE amounts.

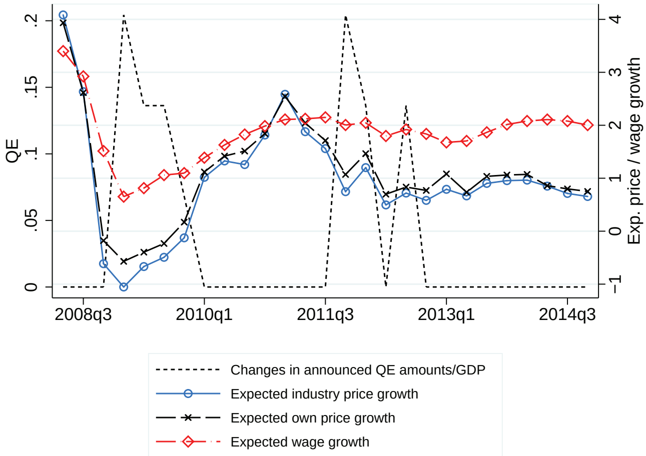
In the baseline regressions, we will also include a binary variable for announcements of forward guidance in 2013:Q3 and 2014:Q1.[10]

[8] Appendix 2 discusses how the timing of the survey fieldwork relates to the timing of the unconventional policy actions in the United Kingdom.

[9] This is equivalent to the change in the intended stock of assets purchased.

[10] In addition, we add a binary variable for the quarter when the Bank of England's Funding for Lending Scheme was implemented. Because this coincided with the European Central Bank President's "whatever it takes" speech (which was widely reported as having helped stabilize economic conditions in the euro zone), we do not place much emphasis on the results for this.

Figure 5. Inflation Expectations and Additional Announcements of Asset Purchases



As noted by Dale and Talbot (2013), "the primary aim of the MPC's forward guidance is to clarify its reaction function and thus make its current policy setting more effective. It is not an attempt to inject additional stimulus by pre-committing to a 'lower for longer' policy with the aim of pushing inflation above target for a period, raising inflation expectations and reducing real interest rates, such as that described by Woodford (2012)." That said, it is nonetheless interesting to see whether, in addition to QE, this intervention affected expectations of firms, as we explore in section 4.

3. Econometric Methodology

To investigate the effects of QE on firms' price and wage inflation expectations, we estimate the following linear panel data model:

$$Y_{it} = \alpha_i + \beta P_t + \delta M_t + \phi X_{it} + e_{it}, \tag{1}$$

where Y_{it} is the expectation of own price, industry-wide price, or own wages inflation over the next twelve months of firm i and quarter t. α_i are individual fixed effects to control for unobserved heterogeneity, which is important when estimating panel data models (Hsiao

2003). P_t are the monetary policy announcements, M_t are macroeconomic and financial variables, and X_{it} are firm-specific variables.[11] Some of the robustness checks reported in section 5 also control for a set of industry-specific variables.

Consistency of the OLS estimates requires that there is no reverse causality and that there are no common factors that influence both the independent and the dependent variables. Formally, we require strict exogeneity of the form

$$E(e_{it}|P_1,\ldots,P_T,M_1,\ldots,M_T,X_{i1},\ldots,X_{iT},\alpha_i)=0. \tag{2}$$

Because monetary policy is exogenous from the point of view of the individual firm, using macroeconomic data helps us to overcome the reverse causality issue that is a major concern for time-series studies. That is, QE and other unconventional monetary policy measures are not directly caused by individual firms' expectations. This will also be true for other macroeconomic, financial, or industry-specific factors.

To tackle the omitted-variable issue and ensure that there are no common factors affecting both firms' expectations and the policy variables, we control for many macroeconomic and financial factors. Specifically, we use GDP growth, aggregate wage growth, CPI inflation, the growth in the effective exchange rate, oil price growth, the VIX, a measure of UK credit spreads, and a measure of news in UK data releases as control variables. Among these, CPI inflation and GDP growth are arguably the most important, as these are likely to be key variables in the reaction function of the central bank. In section 5 we show that our results are not sensitive to considering a more parsimonious list of macro controls or to including additional industry-specific variables.

In our baseline specification we also include some firm-level variables. Since firm-level variables could be endogenous, we only include those likely to be fixed characteristics or to only change slowly over

[11] In view of the categorical nature of our dependent variables, the regression model (1) can be interpreted as an approximation of an ordered probit model. The responses are categorical even though the number of categories is large. In the robustness section, we document that an ordered probit gives similar results when compared to OLS.

time. Specifically, we use whether the firm is an exporter and the discrete bin the firm reported for the number of employees. For this latter variable, the bin sizes are large and so changes between quarters in this variable are likely to be slow moving. That said, in the robustness section we also show that our results are unaffected by excluding these.

4. The Effects of Unconventional Policies on Firms' Price and Wage Inflation Expectations

Table 1 reports our main results. First we discuss the effects of quantitative easing. We find that QE has a positive and significant effect on price and wage inflation expectations. QE is measured as the announced increase in asset purchases scaled by nominal quarterly GDP in 2009:Q1. This implies that for £50 billion of QE, firms' own price inflation expectations (for inflation over the next year) increase by 0.22 percentage points.[12] For industry-wide inflation expectations, the increase is similar at 0.19 percentage points. The effect on wage expectations is 0.28 percentage points.

One interesting feature of these results is that all measures of expectations are affected: expectations of industry prices, own prices, and wages. The unconditional correlation between wage and price expectations is around 0.3, although it is noteworthy that QE has similar effects on both price and wage inflation expectations. One reason for this could be that these are firm-reported expectations for wage inflation over the next twelve months. To the extent a firm expects to increase prices as a result of QE, it is natural that they might also expect to have to increase wages. The causality could also work the other way: in light of stronger demand, firms expect wages to be higher than otherwise would have been the case, and expect to put up prices accordingly. In related work, Cloyne et al. (2016), we explore the link between costs, expectations, and pricing behavior of firms using the framework of the New Keynesian Phillips curve.

One caveat in interpreting these estimates is the co-incidence between the first QE episode and the final cut in Bank Rate to $\frac{1}{2}$

[12] That is the regression coefficient, 1.598 times the size of the shock $\frac{50}{367}$ where the denominator is nominal GDP in 2009:Q1.

Table 1. Fixed Effects Regressions of Price and Wage Inflation Expectations on QE

	Expected Industry Price Inflation	Expected Own Price Inflation	Expected Wage Growth
QE	1.598*	1.407*	2.078*
	(2.19)	(2.06)	(7.10)
FG	0.181	0.114	0.059
	(1.93)	(1.25)	(1.14)
FLS	0.588**	0.505**	0.496**
	(3.51)	(3.03)	(7.08)
GDP Growth	0.124**	0.117**	0.045**
	(3.60)	(3.55)	(3.02)
Wage Growth	0.118**	0.087**	0.072**
	(4.02)	(3.23)	(5.57)
CPI Inflation	0.395**	0.377**	0.338**
	(5.28)	(5.43)	(9.59)
Effective Exchange Rate Growth	−0.043**	−0.036**	0.001
	(−3.77)	(−3.35)	(0.30)
Oil Price Growth	0.006**	0.005*	−0.003**
	(2.88)	(2.55)	(−3.06)
VIX	−0.062**	−0.049**	−0.029**
	(−7.91)	(−6.69)	(−8.00)
Credit Spread	−0.003**	−0.003**	−0.005**
	(−3.45)	(−3.36)	(−13.31)
Macroeconomic News	−0.028**	−0.023**	−0.009**
	(−5.82)	(−5.55)	(−3.78)
Exporter	0.348	0.085	0.177*
	(1.75)	(0.43)	(1.97)
Employees/1,000	−0.156	0.053	0.053
	(−0.72)	(0.27)	(0.67)
Constant	1.542**	1.555**	2.782**
	(5.12)	(5.31)	(20.39)
Observations	7,189	7,277	7,499
Adjusted R^2	0.122	0.105	0.159

Notes: t-statistics are in parentheses. * denotes $p < 0.05$, ** denotes $p < 0.01$.

percent per annum. As such, our estimates should strictly be taken as evidence of the effects of the packages of policy measures announced on the QE dates. That said, after that first QE episode, the other announcements implemented only further amounts of QE.

As discussed earlier, we also include variables for two other unconventional policies: the Funding for Lending Scheme (FLS) and forward guidance (FG). Table 1 also shows that the effects of forward guidance on price and wage inflation expectations have the intuitive sign (positive) but are insignificant. We also include a dummy for the quarter where the Bank of England's Funding for Lending Scheme was implemented. Here we find a sizable and significant effect on wage and price expectations.

The lack of effect on average inflation expectations from FG and the positive effect from the FLS accords with evidence on the reaction of financial markets presented by Weale (2013). A number of arguments might also support the view that FG could reduce uncertainty but might not affect average expectations. For example, using the distinction of Campbell et al. (2012), *delphic* FG—which aims to communicate the central bank's view about the current state of the economy—may or may not affect the mean of inflation expectations. In contrast, *odyssean* FG—which is designed to impart extra stimulus in a "lower for longer" manner—should also affect the mean.[13]

Directly comparing our results for the effects of different policy instruments does require some caution. The FG intervention is measured by a dummy variable. Naturally this has much less variation than our QE measure, and the lack of significance may simply reflect a lack of identification. The FLS announcement also occurred in the same quarter as the ECB President's "whatever it takes" speech (which was widely reported as having helped stabilize economic conditions in the euro area). As noted above, this dummy does have a significant and positive effect on price and wage inflation expectations. But we do not believe it is possible to disentangle the effects of the two separate policies. We therefore prefer to interpret our

[13]We thank the referee for pointing out this interesting interpretation of our results. Consequently, our results do not necessarily imply that forward guidance does not affect firms' expectations in general.

results for the FLS dummy as a control for the combined effect of the unconventional policies announced in this quarter.

One advantage of using macroeconomic data as control variables is that we can also see whether these have the expected effect on the manufacturing price and wage inflation expectations of firms. We find that GDP growth has a significant and positive effect on price and wage inflation expectations. Turning to the role of prices, CPI inflation has a positive effect on firms' inflation and wage expectations. Both of these results seem intuitive.

In terms of wider macroeconomic variables, price and wage inflation expectations are positively related to wage growth and negatively to credit spreads and the VIX. The VIX is a measure of volatility that is computed from stock market options in the United Kingdom. The negative effect seems reasonable given that the VIX is a well-known measure of macroeconomic uncertainty and movements in the VIX and credit spreads were well correlated with the European sovereign debt crisis over this period. We also control for macroeconomic news, defined as the difference between the outturns of main macroeconomic indicators and their consensus forecasts. This variable acts to control for forward-looking factors in the determination of inflation expectations.

Our regressions also include firm characteristics. To avoid reverse causality, we include only firm-specific variables that describe the current state of the firm and are slow in adjusting to expectations such as the firm's exporter status and the number of employees. But these variables are not significant in determining price and wage inflation expectations.

5. Robustness and Extensions

5.1 Alternative Estimation Methods

Our OLS estimates are subject to two econometric concerns. First, we have treated all manual responses outside of the highest and lowest buckets as though they are answers at the midpoint of these buckets, with a corresponding treatment of those lower than the lowest bucket. This means that our data are censored, and failure to take this into account may distort our estimates. Secondly, there is some evidence (Pesaran and Weale 2006) that when people respond to surveys of the type from which these data are drawn, they tend to show a preference for some numbers over others, with the implication that responses which appear to be cardinal may in fact be better seen as ordinal. In particular the central bucket, "no change" is likely to include responses slightly different from zero, with the implication that the adjacent buckets may also slightly differ from their labeling.

Both of these issues can be addressed, although at the expense of making strong parametric assumptions about the nature of the underlying disturbance process. The tobit model is the classic means of estimating models using censored data; it assumes that the residuals of equation (1) are normally distributed. Given this, it is possible to estimate the underlying relationship. The second issue can be dealt with by estimating an ordered probit model, again making the assumption that the residuals of the equation which drives the latent variable (actual price and wage inflation expectations) are normally distributed. With both of these alternative specifications, we continue to find that QE has a significant effect on both wage and price expectations, while forward guidance does not. Thus our results are robust to the simplifying assumptions we have made in estimating by OLS.[14]

5.2 Sensitivity to Controls

In this section we consider the robustness of our results to different sets of control variables. First, we use a more parsimonious set of macro controls. These results are reported in table 2. In this specification we only include the binary variable for FLS and other policy announcements, GDP growth, wage growth, inflation, and the credit spread. The results for the policy coefficients are largely unchanged from the baseline regression.

Next, we consider adding an extra control for U.S. QE, an important potential omitted variable. Table 3 again shows that our findings are very similar in magnitude.[15] The effect of UK QE on firms'

---

[14]Tobit and ordered probit estimates are available from the authors on request.

[15]The significant effects of U.S. QE suggest international spillovers that could be the subject of interesting future work.

Table 2. Fixed Effects Regressions of Price and Wage Inflation Expectations on QE (fewer macro controls)

	Expected Industry Price Inflation	Expected Own Price Inflation	Expected Wage Growth
QE	1.352	1.177	2.046**
	(1.83)	(1.72)	(6.90)
FG	0.139	0.080	0.078
	(1.48)	(0.87)	(1.51)
Observations	7,189	7,277	7,499
Adjusted R^2	0.103	0.092	0.148

Notes: t-statistics are in parentheses. * denotes $p < 0.05$, ** denotes $p < 0.01$. The same set of control variables as in table 1 is included, with the exception of exchange rate growth, oil price growth, and VIX.

Table 3. Fixed Effects Regressions of Price and Wage Inflation Expectations on QE (controlling for U.S. QE)

	Expected Industry Price Inflation	Expected Own Price Inflation	Expected Wage Growth
QE	1.380	1.238	2.052**
	(1.90)	(1.82)	(6.90)
FG	0.353**	0.252*	0.080
	(3.31)	(2.45)	(1.51)
U.S. QE	0.001**	0.001**	0.000
	(4.25)	(3.87)	(1.18)
Observations	7,189	7,277	7,499
Adjusted R^2	0.124	0.107	0.159

Notes: t-statistics are in parentheses. * denotes $p < 0.05$, ** denotes $p < 0.01$. The same set of control variables as in table 1 is included.

expected price growth loses significance at the 5 percent level but clearly remains significant at the 10 percent level. The effect of UK QE, however, still remains highly significant for firms' expected wage growth. Interestingly, the forward guidance dummy now becomes

Table 4. Fixed Effects Regressions of Price and Wage Inflation Expectations on QE (including industry controls)

	Expected Industry Price Inflation	Expected Own Price Inflation	Expected Wage Growth
QE	1.699*	1.590*	2.162**
	(2.31)	(2.31)	(7.29)
FG	0.144	0.095	0.045
	(1.50)	(1.01)	(0.086)
Observations	7,062	7,151	7,373
Adjusted R^2	0.126	0.107	0.159

Notes: t-statistics are in parentheses. * denotes $p < 0.05$, ** denotes $p < 0.01$. The same set of control variables as in table 1 is included in addition to industry controls (employee growth, gross value-added growth, and output price inflation).

significant. While controlling for U.S. QE is of course important, this is also the only specification that supports an effect of forward guidance. Given that this coefficient is not significant in any other regression, we do not see this as evidence against our previous conclusion that the effects of forward guidance are too imprecisely estimated to give a clear indication of whether it affected firms' expectations.

If monetary policy were responding to the conditions in manufacturing, we would not be adequately capturing this by including UK macro aggregates. To guard against this concern, table 4 reestimates our baseline specification including industry-level employee growth, gross value-added growth, and output price inflation. Reassuringly, the policy coefficients are all very similar to our baseline results.

A further concern is that the firm-level variables are endogenous. This is particularly true for the employees variable. Table 5 therefore presents the results where these are excluded. Again, the main results are very similar.

Finally, we examine whether adding labor productivity measures affects our findings. Since productivity growth can be an important determinant of wages, it seems natural to include this as a further control. Table 6 adds two-digit industry-level labor productivity measures to the equation for wage expectations (keeping all

Table 5. Fixed Effects Regressions of Price and Wage Inflation Expectations on QE (excluding firm-specific controls)

	Expected Industry Price Inflation	Expected Own Price Inflation	Expected Wage Growth
QE	1.588*	1.410*	2.083**
	(2.18)	(2.07)	(7.10)
FG	0.186*	0.114	0.060
	(1.98)	(1.25)	(1.17)
Observations	7,189	7,277	7,499
Adjusted R^2	0.121	0.105	0.158

Notes: t-statistics are in parentheses. * denotes $p < 0.05$, ** denotes $p < 0.01$. The same set of control variables as in table 1 is included, with the exception of firm-specific variables.

Table 6. Fixed Effects Regressions of Wage Inflation Expectations on QE (including two-digit productivity)

	Expected Wage Growth
QE	2.101**
	(7.17)
FG	0.057
	(1.10)
FLS	0.500**
	(7.12)
Productivity	0.025**
	(3.49)
Observations	7,464
Adjusted R^2	0.100

Notes: t-statistics are in parentheses. * denotes $p < 0.05$, ** denotes $p < 0.01$.

the baseline control variables).[16] As can be seen, the effects of unconventional monetary policies are very similar. As expected, we also

[16]We do not have a measure of firm-level productivity and, in any case, this variable would be endogenous if included in the regression.

find a positive and significant effect of industry-level productivity on firm-level wage expectations.

5.3 Alternative Sample Restrictions

Our baseline specification restricts the sample to firms that are observed for at least four consecutive quarters. Tables 7 and 8 assess the sensitivity to this choice by restricting the sample to firms that answered the survey for at least two and six consecutive quarters, respectively. When estimating equation (1) using these alternative samples, we find that the effects of QE are similar to our baseline results.

We also formally test whether the size of the estimated coefficients on QE are significantly different across different choices of the sample size using a likelihood-ratio (LR) test. The null hypothesis of this test is that estimated regression coefficients in the sample with at least four consecutive quarters are equal to the coefficients in the sample with at least k consecutive quarters, where $k = 2, 3, 5, \ldots, 8$.[17] We fail to reject the hypothesis that the effects of QE vary across alternative samples.[18]

5.4 An Alternative Measure of QE

Our main results in table 1 measure QE as the increase in announced QE amounts scaled by quarterly nominal GDP in 2009:Q1. We explore the robustness of our findings to using an alternative measure of QE that is based on either a binary indicator for the QE announcement dates or the difference in the outstanding QE amounts scaled by nominal GDP in 2009:Q1. As documented in tables 9 and 10, our baseline results are robust to using these alternative QE measures.

[17] The LR test statistic is given by $LR = -2(LR_{full} - (LR_{group1} + LR_{group2}))$ and under H_0, it is asymptotically distributed as χ^2 with df = number of estimated coefficients.

[18] If we test for equality of all regression coefficients, H_0 is rejected in more than half of all cases. However, testing the equality of all coefficient estimates is likely to be too restrictive given that our focus is only on the policy coefficients.

Table 7. Fixed Effects Regressions of Price and Wage Inflation Expectations on QE (using firms with at least two consecutive quarters)

	Expected Industry Price Inflation	Expected Own Price Inflation	Expected Wage Growth
QE	1.804**	1.818**	2.278**
	(2.83)	(2.99)	(8.63)
FG	0.187*	0.189*	0.058
	(2.09)	(2.20)	(1.27)
Observations	9,924	10,025	10,213
Adjusted R^2	0.120	0.107	0.162

Notes: t-statistics are in parentheses. * denotes $p < 0.05$, ** denotes $p < 0.01$. The same set of control variables as in table 1 is included.

Table 8. Fixed Effects Regressions of Price and Wage Inflation Expectations on QE (using firms with at least six consecutive quarters)

	Expected Industry Price Inflation	Expected Own Price Inflation	Expected Wage Growth
QE	1.452	2.069**	2.109**
	(1.72)	(2.63)	(6.24)
FG	0.221	0.229*	0.060
	(1.95)	(2.14)	(0.99)
Observations	5,072	5,159	5,365
Adjusted R^2	0.121	0.106	0.151

Notes: t-statistics are in parentheses. * denotes $p < 0.05$, ** denotes $p < 0.01$. The same set of control variables as in table 1 is included.

5.5 Heterogeneity across Firms

In previous sections we studied the average effects of unconventional monetary policy on firms' expectations. These averages, however, may mask some interesting heterogeneity across firms. While a thorough investigation of the transmission mechanism of unconventional

Table 9. Fixed Effects Regressions of Price and Wage Inflation Expectations on Outstanding Amounts of QE

	Expected Industry Price Inflation	Expected Own Price Inflation	Expected Wage Growth
QE (outstanding)	2.009*	1.827	3.627**
	(2.04)	(1.95)	(7.44)
FG	0.213*	0.142	0.116*
	(2.27)	(1.56)	(2.21)
Observations	7,189	7,277	7,499
Adjusted R^2	0.122	0.105	0.161

Notes: t-statistics are in parentheses. * denotes $p < 0.05$, ** denotes $p < 0.01$. The same set of control variables as in table 1 is included.

Table 10. Fixed Effects Regressions of Price and Wage Inflation Expectations on a Binary QE Measure

	Expected Industry Price Inflation	Expected Own Price Inflation	Expected Wage Growth
QE (binary)	0.301**	0.254*	0.388**
	(2.64)	(2.34)	(7.84)
FG	0.187*	0.119	0.067
	(1.99)	(1.30)	(1.30)
Observations	7,189	7,277	7,499
Adjusted R^2	0.122	0.105	0.160

Notes: t-statistics are in parentheses. * denotes $p < 0.05$, ** denotes $p < 0.01$. The same set of control variables as in table 1 is included.

monetary policy is outside the scope of this paper, in this section we document some interesting differences across firm types that may shed some light on which firms are most affected by monetary policy. In particular, we explore whether firm size, exporter status, and the degree of investment constraints might lead to differential effects of monetary policy on expectations. Given the discussion above, and that our QE variable has more variation over the sample, we focus on the effects of QE in this section.

Table 11. Fixed Effects Regressions of Price and Wage Inflation Expectations on QE (splitting sample by size and exporter status)

	Expected Industry Price Inflation	Expected Own Price Inflation	Expected Wage Growth
Small Firms			
QE	1.645 (1.94)	1.281 (1.61)	1.901** (5.65)
Large Firms			
QE	0.978 (0.67)	1.666 (1.35)	2.264** (3.74)
Exporter			
QE	1.061 (1.24)	0.804 (0.99)	1.547** (4.46)
Non-exporter			
QE	2.414 (1.76)	2.786* (2.12)	3.144** (5.95)

Notes: t-statistics are in parentheses. * denotes $p < 0.05$, ** denotes $p < 0.01$.

Interestingly, a distinction based on firm size did not produce significant heterogeneity. Table 11 shows that the point estimates for the effects of QE are similar for large and small firms. The effects lose significance, but if firm size is not the relevant dimension of heterogeneity, this is not surprising since splitting the sample lowers the number of observations but does not produce a more homogeneous group. Table 11 also reveals a similar picture when we split the sample by exporter status.

The ITS also includes some interesting questions about investment and, in particular, about which factors hold back expected capital expenditure. Along this dimension, we do find some clear heterogeneity in the effects of QE on inflation expectations. Our conjecture is that firms facing fewer investment constraints are more

Table 12. Fixed Effects Regressions of Price and Wage Inflation Expectations on QE: Firms Whose Expected Capital Expenditure Authorizations Are Limited by Alternative Factors

	Expected Industry Price Inflation	Expected Own Price Inflation	Expected Wage Growth
Shortage of Internal Finance and/or Inability to Raise External Funds			
QE	−1.243 (−0.71)	−2.012 (−1.33)	1.994** (3.15)
Cost of Finance			
QE	0.691 (0.20)	4.016 (1.52)	2.689* (2.15)
Inadequate Return			
QE	2.027 (1.43)	2.449 (1.96)	1.695** (3.22)
Shortage of Labor			
QE	−0.894 (−0.26)	0.456 (0.14)	3.468* (2.16)
Uncertainty about Demand			
QE	2.809** (3.12)	2.812** (3.27)	2.625** (6.38)

Notes: t-statistics are in parentheses. * denotes $p < 0.05$, ** denotes $p < 0.01$.

likely to plan ahead, as they will be more directly affected by the effect of monetary policy on, for example, capital markets and bank lending. This echoes Coibion, Gorodnichenko, and Kumar (2015), who find that firms tend to pay more attention to information that is relevant to them.

Table 12 reports the results for firms whose expected capital expenditures are limited by a number of factors. Table 12 shows that we no longer find an effect of QE on the price inflation expectations of "constrained firms." This is true across a range of constraints such

Table 13. Fixed Effects Regressions of Price and Wage Inflation Expectations on QE: Firms Whose Expected Capital Expenditure Authorizations Are Not Limited by Alternative Factors

	Expected Industry Price Inflation	Expected Own Price Inflation	Expected Wage Growth
Shortage of Internal Finance and/or Inability to Raise External Funds			
QE	3.328** (4.07)	3.155** (4.02)	2.658** (7.92)
Cost of Finance			
QE	2.479** (3.20)	2.385** (3.22)	2.638** (8.78)
Inadequate Return			
QE	2.801** (3.00)	2.885** (3.19)	3.149** (8.18)
Shortage of Labor			
QE	2.713** (3.46)	2.552** (3.43)	2.521** (8.29)
Uncertainty about Demand			
QE	2.161 (1.59)	1.707 (1.26)	2.674** (5.87)
Notes: t-statistics are in parentheses. * denotes $p < 0.05$, ** denotes $p < 0.01$.			

as a shortage of funds, the cost of finance, and a shortage of labor. On the other hand, when we look at firms that report that their capital expenditure expectations have not been limited by these factors, we find the familiar positive and significant effects of QE (table 13).

6. Conclusions

An important lesson from the Great Depression is that persistent deflation can lead to undesirable economic outcomes, such as debt deflation spirals (Fisher 1933) and enduring economic stagnation (Hansen 1939). And the beginning of the Great Recession had important parallels with the Great Depression (Almunia et al. 2009). To prevent history from repeating itself, central banks around the world implemented a number of unconventional monetary policies, including large-scale asset purchases of government and private-sector assets, forward guidance on interest rates, and policies targeted to directly stimulate lending. But the extent to which these different policies had a material impact on output and inflation is still not well understood. An important channel through which these policies can affect the latter is through their impact on inflation expectations. To our knowledge, this is the first paper to examine the impact of these policies on firm inflation expectations with a new data set from the United Kingdom.

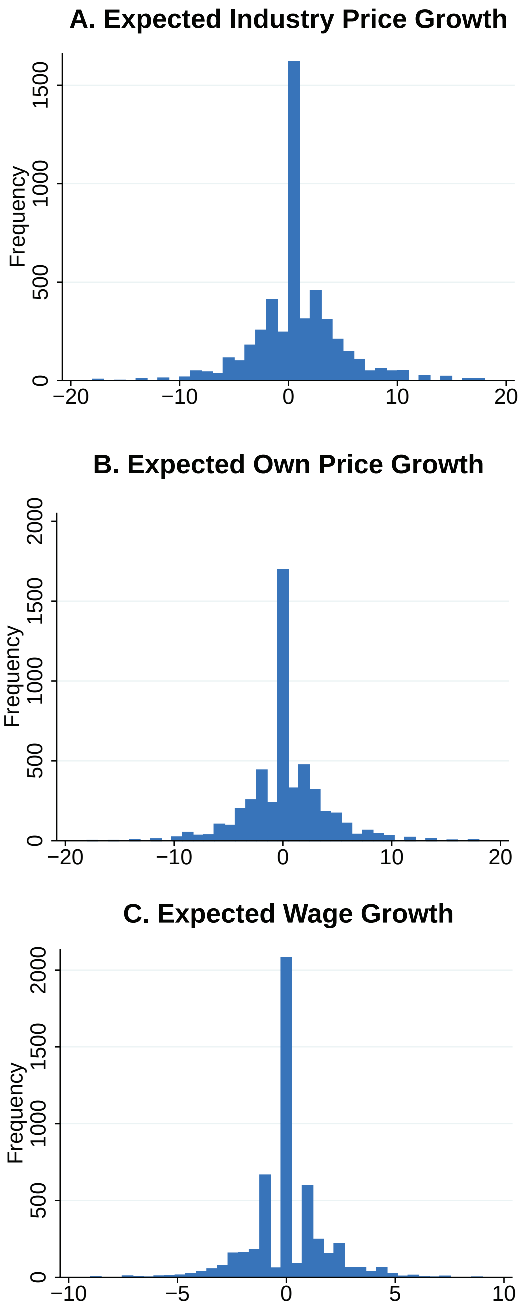
To identify the effect of QE on firms' expectations, we use a novel approach of combining microeconometric data with macroeconomic shocks: QE is exogenous to inflation expectations of individual firms. We can therefore estimate the effect of QE on firms' inflation expectations using a panel data model that also includes a wide range of aggregate and industry-wide developments. Our main result is that firms' own inflation expectations increased by 0.22 percentage points in response to £50 billion QE in the United Kingdom. Our findings suggest that inflation expectations play a role in transmission of QE to the real economy. In contrast, the effect of the Monetary Policy Committee's forward guidance is not statistically significant.

The ability of central banks to stabilize inflation expectations at the zero lower bound and ensure the economy does not slip into deflation remains a key aspect of the policy debate. Our findings suggest that QE interventions played a modest role in stabilizing inflation expectations in the United Kingdom in recent years. Our findings for Funding for Lending and forward guidance were not conclusive, but precisely estimating the effects of other unconventional policies on expectations remains an interesting avenue for future research.

Appendix 1. Forecast Errors

An interesting question is, how accurate are firms' expectations of price and wage growth? Figure 6 reports histograms of the forecast

Figure 6. Distribution of Forecast Errors



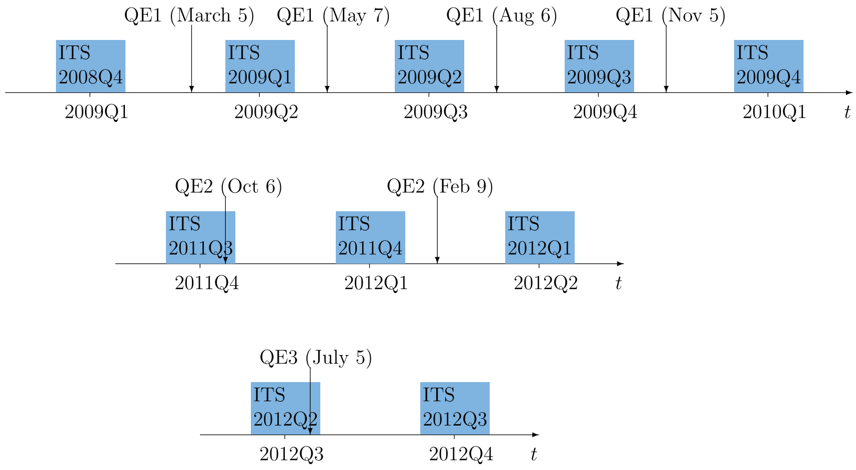
Note: Forecast errors are computed as the difference between firm's inflation or wage perception and expectations formed for the same quarter.

errors from the perspective of the individual firm, that is, the difference between perceptions of price and wage growth over the past year and expectations formed one year ago. A possible interpretation of this difference is unanticipated aggregate or idiosyncratic shocks that were realized in the interim period. The measures of forecast errors are centered around zero, but there is significant dispersion.

Appendix 2. The Timing of Policy Interventions

The timing of the survey fieldwork and the announcement of QE is shown in figure 7. In each quarter, the survey fieldwork starts approximately ten days before the end of the current quarter and ends approximately ten days after the start of the next quarter. In the case of the 2008:Q4 ITS, for example, the survey period started around December 20, 2008, and ended around January 10, 2009. The policy announcements took place outside the fieldwork periods, with the exception of QE2 and QE3, where the announcements took place

Figure 7. QE Announcements and Survey Periods



Notes: The shaded boxes denote the period where the fieldwork for the survey was completed. The fieldwork starts approximately ten days before the end of the current quarter and ends approximately ten days after the start of the next quarter.

a few days before the fieldwork for the previous quarter was completed. In these cases, we assume that the survey for the previous quarter was not much affected by the announcements.

Appendix 3. Sample Selection

In our baseline specification, we only use firms that answer the survey for at least four consecutive quarters. To investigate if this sample-selection rule induces selection effects, we formally test if the distribution of the dependent variables changes if we use an alternative criterion to select our estimation sample. We perform a Kolmogorov-Smirnov test of the null hypothesis that the distribution of the dependent variables does not change when we consider firms that remained in the survey for at least k consecutive quarters as compared with four quarters (where $k = 2, 3, 5, \ldots, 8$). We fail to reject equality of distribution in all cases considered (except for one), meaning that restricting the sample does not produce any selection effects.

References

Almunia, M., A. Benetrix, B. Eichengreen, K. O'Rourke, and G. Rua. 2009. "From Great Depression to Great Credit Crisis: Similarities, Differences and Lessons." NBER Working Paper No. 15524.

Baumeister, C., and L. Benati. 2013. "Unconventional Monetary Policy and the Great Recession: Estimating the Macroeconomic Effects of a Spread Compression at the Zero Lower Bound." *International Journal of Central Banking* 9 (2, June): 165–212.

Bryan, M., B. Meyer, and N. Parker. 2014. "The Inflation Expectations of Firms: What Do They Look Like, Are They Accurate, and Do They Matter?" Working Paper No. 2014-27a, Federal Reserve Bank of Atlanta (December 2014, revised January 2015).

Campbell, J., C. Evans, J. Fisher, and A. Justiniano. 2012. "Macroeconomic Effects of Federal Reserve Forward Guidance." *Brookings Papers on Economic Activity* (Spring): 1–80.

Carroll, C. D. 2003. "Macroeconomic Expectations of Households and Professional Forecasters." *Quarterly Journal of Economics* 118 (1): 269–98.

Chung, H., J.-P. Laforte, D. Reifschneider, and J. Williams. 2011. "Have We Underestimated the Likelihood and Severity of the Zero Lower Bound Events?" Working Paper No. 2011-11, Federal Reserve Bank of San Francisco.

Cloyne, J., L. Boneva, M. Weale, and T. Wieladek. 2016. "Firms' Expectations and Price Setting: Evidence from Micro Data." External MPC Unit Discussion Paper No. 47, Bank of England (July).

Coibion, O., and Y. Gorodnichenko. 2015. "Information Rigidity and the Expectations Formation Process: A Simple Framework and New Facts." *American Economic Review* 105 (8): 2644–78.

Coibion, O., Y. Gorodnichenko, and S. Kumar. 2015. "How Do Firms Form Their Expectations? New Survey Evidence." NBER Working Paper No. 21092.

Dale, S., and J. Talbot. 2013. "Forward Guidance in the UK." In *Forward Guidance*, ed. W. den Haan. London: Centre for Economic Policy Research.

D'Amico, S., and T. King. 2012. "Flow and Stock Effects of Large-Scale Asset Purchases: Evidence on the Importance of Local Supply." FEDS Working Paper No. 2012-44, Board of Governors of the Federal Reserve System.

Del Negro, M., G. Eggertsson, A. Ferrero, and N. Kiyotaki. 2011. "The Great Escape? A Quantitative Evaluation of the Fed's Liquidity Facilities." Staff Report No. 520, Federal Reserve Bank of New York.

Fisher, I. 1933. "The Debt-Deflation Theory of Great Depressions." *Econometrica* 1: 337–57.

Gagnon, J., M. Raskin, J. Remache, and B. Sack. 2011. "The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases." *International Journal of Central Banking* 7 (1, March): 3–43.

Hansen, A. 1939. "Economic Progress and Declining Population Growth." *American Economic Review* 29 (1): 1–15.

Hori, M., and S. Shimizutani. 2005. "Price Expectations and Consumption under Deflation: Evidence from Japanese Household Survey Data." *International Economics and Economic Policy* 2 (2): 127–51.

Hsiao, C. 2003. *Analysis of Panel Data.* Cambridge: Cambridge University Press.

Joyce, M. A. S., A. Lasaosa, I. Stevens, and M. Tong. 2011. "The Financial Market Impact of Quantitative Easing in the United Kingdom." *International Journal of Central Banking* 7 (3, September): 113–61.

Kapetanios, G., H. Mumtaz, I. Stevens, and K. Theodoridis. 2012. "Assessing the Economy-wide Effects of Quantitative Easing." *Economic Journal* 122 (564): F316–F347.

Krishnamurthy, A., and A. Vissing-Jorgensen. 2011. "The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy." *Brookings Papers on Economic Activity* 43 (Fall): 215–87.

Krugman, P. 1998. "It's Baaack: Japan's Slump and the Return of the Liquidity Trap." *Brookings Papers on Economic Activity* 1998 (2): 137–205.

Lui, S., J. Mitchell, and M. Weale. 2011. "Qualitative Business Surveys: Signal or Noise?" *Journal of the Royal Statistical Society: Series A* 174 (2): 327–48.

Meier, A. 2009. "Panacea, Curse, or Nonevent? Unconventional Monetary Policy in the United Kingdom." IMF Working Paper No. 09/163.

Mitchell, J., R. J. Smith, and M. R. Weale. 2013. "Efficient Aggregation of Panel Qualitative Survey Data." *Journal of Applied Econometrics* 28 (4): 580–603.

Pesaran, M. H., and M. Weale. 2006. "Survey Expectations." In *Handbook of Economic Forecasting,* ed. G. Elliott, C. W. J. Granger, and A. Timmerman, 715–76 (chapter 14). Elsevier.

Weale, M. 2013. "Forward Guidance and Its Effects." Speech at the National Institute of Economic and Social Research, London, December 11.

Weale, M., and T. Wieladek. 2016. "What Are the Macroeconomic Effects of Asset Purchases?" *Journal of Monetary Economics* 79 (May): 81–93.

Woodford, M. 2012. "Methods of Policy Accommodation at the Interest-Rate Lower Bound." Paper presented at the Annual Economic Policy Symposium sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming, August 30–September 1.

Discussion of "The Effect of Unconventional Monetary Policy on Inflation Expectations: Evidence from Firms in the United Kingdom"*

Julio A. Carrillo
Banco de México

The New Keynesian paradigm stands on the premise that firms face rigidities that make them adjust prices infrequently (Galí 2008).[1] As a consequence, firms need to be forward looking and form expectations about future production costs and future demand in order to change prices. To the extent that expected inflation reflects changes in expected production costs, firms' inflation expectations will partially determine today's prices and inflation. In this context, an important lesson of this literature is that a central bank may keep inflation under control not only by affecting aggregate demand through the traditional interest rate channel but also by anchoring agents' expectations about future inflation (see Bernanke et al. 1999, Woodford 2005, and Gürkaynak et al. 2007). A natural policy question is thus, how does monetary policy, either conventional or unconventional, affect price setters' inflation expectations? The paper under discussion sheds light on this topic, although it focuses only on unconventional policy measures.

Lena Boneva, James Cloyne, Martin Weale, and Tomasz Wieladek analyze the effect of various unconventional monetary policies by the Bank of England on inflation and wage growth expectations of UK manufacturing firms since the onset of the financial crisis. With its policy rate near 0.50 percent since March 2009, the

*I'd like to thank Luis G. Hernández for his excellent assistance. Author contact: Banco de México, Directorate General of Economic Research, Calle 5 de Mayo #18, C.P. 06069, Mexico City, Mexico. Tel. +52-55-5237-2701. E-mail: jcarrillo@banxico.org.mx.

[1]An alternative rationale for the existence of nominal rigidities, popularized by Mankiw and Reis (2002), argues instead that firms do not count with the most updated information to adjust prices optimally in response to macroeconomic events.

Bank of England adopted three types of unconventional policies: large-scale asset purchases (dubbed quantitative easing, or QE), forward guidance on its future monetary policy stance (or FG), and the Funding for Lending Scheme (or FLS, which is a program addressed to banks and other entities to encourage them to increase their loans).[2] Boneva et al. use firm-level data from the Industrial Trend Survey (ITS), collected quarterly by the Confederation of British Industry since 2008, about expected industry-specific inflation, expected own-firm inflation, and expected wage growth. Then, they run single-equation panel regressions of each of these variables on *announcement* measures of QE, FLS, and FG, and include controls for firm-specific and industry-level variables, and other macroeconomic and financial variables.[3] By adding these control variables, and thus discarding the effect of common trends, Boneva et al. identify the marginal effect of unconventional policies on firms' expectations. Interestingly, the authors find that only QE announcements have a significant and positive effect on firms' expectations, while FLS and FG announcements have no effect on these variables, at least in levels. These results hold in a number of robustness exercises, which include changing the regression model (e.g., to a probit or tobit), the sample selection, the measure of QE, etc.

This type of analysis is very important for the evaluation of unconventional policies, as it tells us which policy announcements seem to shape firms' expectations. My first comment on Boneva et al.'s results is that, although they are interesting in themselves, they tell us little about how the expectation channel works on those policy-sensitive firms. A further step in the analysis is to provide a story about why firms seem to pay attention to certain policy announcements and not to others. My second comment is that Boneva et al.'s analysis is limited to the *level* of firms' expectations (the first moment), but it does not explore the policy effects

[2]As is well known, the Federal Reserve, the European Central Bank, and the Bank of Japan have adopted similar unconventional policies in response to the 2008 financial crisis.

[3]Boneva et al.'s approach solves the reverse causality problem that appears when running similar regressions using only aggregate variables. This is the case because the expectations of an individual firm do not Granger-cause any unconventional policy measure, and thus the orthogonality conditions of the estimating equations are satisfied.

on the *dispersion* of firms' expectations (the second moment). This is important because if a certain policy dissipates future uncertainty in the economy, it could have an impact on the second moment of firms' expectations. I develop these two comments in the following paragraphs.

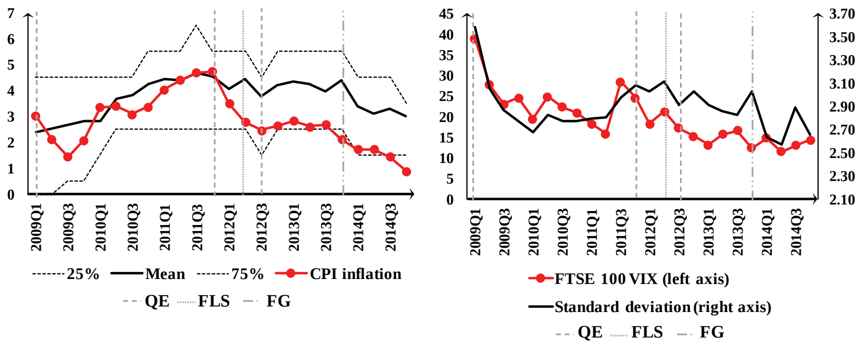
1. How Do Firms Form Their Expectations?

Interpreting firms' inflation expectations is a difficult task. There are three reasons for this: First, business surveys with quantitative questions about expected changes in inflation are scant.[4] Second, the measures used to proxy inflation expectations differ from study to study. And third, firm heterogeneity is so large (in terms of size, industry, number of competitors, price updating frequency, etc.) that taking central measures, such as the mean or median, might provide poor indicators about firms' beliefs.

Recent quantitative studies about firms' perceptions on current and future states of macro variables include Bryan, Meyer, and Parker (2014) for firms in the southeastern United States; Coibion, Gorodnichenko, and Kumar (2015) for firms in New Zealand; and the paper under discussion for UK manufacturing firms. These studies are not exactly comparable, because they measure inflation expectations differently. Bryan, Meyer, and Parker use expectations about unit costs as their core measure, and argue that the latter approximates closer the notion of price setters' expectations as embedded in the New Keynesian Phillips curve; Coibion, Gorodnichenko, and Kumar ask firms about expected changes in prices *overall*; and, as mentioned earlier, Boneva et al. investigate expectations on industry-specific prices, own-firm prices, and wages. Despite these differences, the studies share some common features. For instance, in all three, the dispersion of firms' inflation expectations is larger than that of professional forecasters. When compared with households, results are mixed. For Bryan, Meyer, and Parker, unit-cost expectations have a lower variance than households' inflation expectations; however, for Coibion, Gorodnichenko, and Kumar and Boneva

[4]Most of the available surveys on firms' expectations are qualitative. See Mitchell, Smith, and Weale (2013) and Bryan, Meyer, and Parker (2014) for details.

Figure 1. Households' Inflation Expectations in the United Kingdom



Notes: The left panel compares the current general CPI inflation in the United Kingdom with the mean and twenty-fifth and seventy-fifth quartiles of the households' inflation expectations a year ahead, as computed from the Bank of England's Inflation Attitude Survey conducted by GfK. The survey can be found on the Bank of England's website. The right panel compares the FTSE 100 VIX index, a measure of aggregate uncertainty, with the standard deviation of households' inflation expectations a year ahead.

et al., firms' inflation perceptions are as wide as those of households. Although Boneva et al. do not compare the dispersion of firms' expectations with that of households, we can verify that the standard deviation of households' inflation expectations in the United Kingdom stayed close to 3.0 from 2010 up to the end of 2013 (see figure 1 in this discussion).[5] This number is similar to that reported by Boneva et al. in their table 2 for firms' industry-specific and own-firm inflation expectations.

Regarding how informative firms' perceptions are about actual inflation, Bryan, Meyer, and Parker find that unit-cost inflation expectations correlate with firms' expectations on core CPI inflation and, on average, they both agree with the levels reported by professional forecasters. For Boneva et al., the firms' industry-specific and own inflation expectations, in mean levels, are always lower

[5]The data on households' inflation expectations were extracted from the Bank of England's Inflation Attitude Survey. As is discussed later, the dispersion of inflation expectations of firms and households displayed a similar trend from 2009 to 2014.

than annual CPI inflation. However, these three measures clearly co-move, with the mean of firms' expectations leading CPI inflation a few quarters (see figure 1 in their paper). In contrast, figure 1 in this discussion shows that UK households' one-year-ahead inflation expectations were, on average, closer in levels to current CPI inflation up to 2010; however, households' expectations do not seem to lead CPI inflation. In this context, firms' inflation expectations seem more informative about future CPI inflation in the United Kingdom.

On the other hand, when firms are asked about more general notions of inflation, like *prices in general*, the picture changes dramatically. Coibion, Gorodnichenko, and Kumar find that firms' general inflation perceptions poorly forecast future CPI inflation, and in fact they do not relate with actual inflation either. A similar feature is shown by Bryan, Meyer, and Parker, who present evidence that firms perform as badly as households when asked about their beliefs on changes in prices in general, and that these beliefs are unrelated to those on unit cost or the core CPI index.

In sum, firms perform reasonably well for measures of inflation that closely relate to them (e.g., unit costs, own prices) or for specific measures (e.g., the core CPI index, industry specific), and they do poorly for more general measures of inflation. To reconcile these facts, Coibion, Gorodnichenko, and Kumar call for a rational inattention hypothesis, such as the one posited by Mackowiak and Wiederholt (2009). In such a context, agents endogenously choose which pieces of information to process, since breaking down information is costly and resources are limited. The theory predicts that firms will choose to pay attention only to factors with large effects on their profits. Along these lines, Boneva et al. and Bryan, Meyer, and Parker report evidence that indicators such as GDP or—unsurprisingly—production costs are more important than general inflation for a firm's price-setting decision. If so, it is likely that firms spend more resources to predict output growth, and in turn they will disagree less on these predictions as opposed to their inflation forecasts. Interestingly, this prediction seems to hold. Coibion, Gorodnichenko, and Kumar show that the variance of firms' expectations on GDP growth is several times lower than that of inflation expectations; Boneva et al. report similar numbers for the variance of output growth expectations against the variance of inflation expectations.[6] This evidence provides support to the rational inattention hypothesis.

So, the missing link in Boneva et al.'s findings is why firms, on average, decided to pay more attention to QE announcements than to others. A possibility is that firm managers interpreted the Bank of England's QE policy as an important steering factor of aggregate output, while they judged other policies neutral on output. To test this hypothesis goes beyond the scope of Boneva et al.'s paper. But, given their rich database, they could still provide some answers to questions such as the following: Which firms seem to react more to a QE policy? What are their characteristics? Do they share a common pattern? This information might improve our understanding of how firms form their expectations, and ultimately answer the question of how QE announcements seem to affect firms' profits functions while other policies do not.

2. Effects on the Dispersion of Expectations

The level of agents' expectations is not the only dimension that monetary policy can affect; there is also the uncertainty surrounding these expectations. Take for instance the options traded for the three-month future LIBOR rate at different horizons. As Martin Weale (2013) discussed in a speech before the National Institute of Economic and Social Research in London, the prices of these options give us information about both the average expected level of LIBOR rates and the degree of disagreement among financial agents about these levels. Such a disagreement is given by the dispersion of option prices. Weale (2013) presented evidence that the FLS and FG announcements affected financial markets differently. For instance, the mean of future LIBOR rates at various horizons decreased in response to the FLS announcement but stayed put in response to the FG announcement. However, the variance of option prices of future LIBOR rates decreased significantly after both FLS and FG announcements. Interestingly, FG had a significant impact

[6] See table 2 in their paper. Furthermore, Mitchell, Smith, and Weale (2013) show that an aggregate indicator for output growth built from the same ITS survey for UK firms provides accurate early estimates of realized output growth.

only for short-term horizons (three and six months), while FLS had a significant impact for horizons of a year or longer.

The fact that FLS modified the mean and dispersion of agents' expectations on LIBOR rates is not surprising. FLS was precisely intended to ease liquidity for banks and reduce their dependency on the interbank market.[7] *Why did FG seem to affect only the dispersion of agents' expectations and not their mean?* A rationale might be found in Campbell et al. (2012), who distinguish between two types of FG policies: *delphic* and *odyssean*. Although both policies reveal predicted paths in the monetary policy stance, the difference between them is whether the announced future policy rates relate with normal-times actions (the delphic type) or whether they explicitly deviate from them (the odyssean type). Delphic FG intends to communicate the central bank's view about the current state of the economy, and it might thus reduce uncertainty.[8] In contrast, odyssean FG could be explicitly used to stimulate the economy beyond normal-times policy, e.g., a central bank announces that it will keep its policy rate lower than what it would normally do, given its expected paths of inflation and output. Odyssean FG relates to the type of policy put forward by Eggertsson and Woodford (2003) as a remedy for an economy stuck with a policy rate at its lower bound.[9]

As it turns out, one would expect that odyssean FG announcements will shape the mean of agents' expectations, and even perhaps their variance (similar to the effect of a future monetary policy shock that is unveiled today, i.e., a monetary news shock). In turn, delphic FG announcements might or might not affect the mean of agents' expectations; instead, if such announcements contain information that reduce aggregate uncertainty, then the dispersion of agents' expectations might decrease as well. Figure 14 in Boneva et al. shows that the variance of firms' inflation expectations reached a peak at the beginning of 2009, stayed relatively stable from 2010 to 2012, and decreased thereafter until the end of the sample. A remarkably

[7]See Weale (2013) for further details.

[8]For instance, the Norges Bank implements delphic FG when it announces predicted paths for its policy rate.

[9]This is a remedy that has been critically revisited by Del Negro, Giannoni, and Patterson (2012), given the moderate effects of these policies seen in the data.

similar behavior is also shown in households' inflation expectations in the United Kingdom, displayed in figure 1 in this discussion. Coincidentally, the latest downward trend in the dispersion of households' inflation expectations begins after the FLS announcement in 2012, and it seems further reinforced by the FG announcement in 2013. In the context of Boneva et al.'s analysis, it would be extremely interesting to test whether the dispersion of firms' inflation expectations significantly responded, in statistical terms, to the FLS and FG announcements.

3. Concluding Remarks

Analyses such as that of Boneva et al. are necessary efforts to help us understand how firms form their expectations, and how the latter might be shaped and anchored by monetary policy. A few conclusions drawn from the discussed paper, and from related efforts like those of Bryan, Meyer, and Parker (2014) and Coibion, Gorodnichenko, and Kumar (2015), can be summarized as follows: (i) firms form better-informed expectations for measures of inflation that closely relate to them (e.g., unit costs, own prices) and do poorly for more general measures of inflation; (ii) firms seem to pay more attention to those factors that largely affect their profit function, which supports the rational inattention hypothesis of Mackowiak and Wiederholt (2009); (iii) in the UK manufacturing sector, the mean of firms' inflation expectations seems to react only to the Bank of England's QE announcements, which prompts the question of why these announcements seemed more important for firms' profits than other type of announcements; and (iv) unconventional policies might have affected as well the dispersion of firms' inflation expectations, although this hypothesis has not been formally tested.

References

Bernanke, B. S., T. Laubach, F. S. Mishkin, and A. S. Posen. 1999. *Inflation Targeting: Lessons from the International Experience.* Princeton, NJ: Princeton University Press.

Bryan, M. F., B. Meyer, and N. B. Parker. 2014. "The Inflation Expectations of Firms: What Do They Look Like, Are They

Accurate, and Do They Matter?" Working Paper No. 2014-27, Federal Reserve Bank of Atlanta.

Campbell, J. R., C. L. Evans, J. D. Fisher, and A. Justiniano. 2012. "Macroeconomic Effects of FOMC Forward Guidance." *Brookings Papers on Economic Activity* (Spring): 1–80.

Coibion, O., Y. Gorodnichenko, and S. Kumar. 2015. "How Do Firms Form Their Expectations? New Survey Evidence." NBER Working Paper No. 21092.

Del Negro, M., M. Giannoni, and C. Patterson. 2012. "The Forward Guidance Puzzle." Staff Report No. 574, Federal Reserve Bank of New York.

Eggertsson, G. B., and M. Woodford. 2003. "The Zero Bound on Interest Rates and Optimal Monetary Policy." *Brookings Papers on Economic Activity* (Spring): 139–235.

Galí, J. 2008. *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework.* Princeton, NJ: Princeton University Press.

Gürkaynak, R., A. T. Levin, A. N. Marder, and E. T. Swanson. 2007. "Inflation Targeting and the Anchoring of Inflation Expectations in the Western Hemisphere." *Economic Review* (Federal Reserve Bank of San Francisco) 2007: 25–47.

Mackowiak, B., and M. Wiederholt. 2009. "Optimal Sticky Prices under Rational Inattention." *American Economic Review* 99 (3): 769–803.

Mankiw, N. G., and R. Reis. 2002. "Sticky Information versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve." *Quarterly Journal of Economics* 117 (4): 1295–1328.

Mitchell, J., R. J. Smith, and M. R. Weale. 2013. "Efficient Aggregation of Panel Qualitative Survey Data." *Journal of Applied Econometrics* 28 (4): 580–603.

Weale, M. 2013. "Forward Guidance and Its Effects." Speech at the National Institute of Economic and Social Research, London, December 11.

Woodford, M. 2005. "Central Bank Transparency and Communications Policy." In *The Greenspan Era: Lessons for the Future*, 399–474. Federal Reserve Bank of Kansas City. (Proceedings of an economic policy symposium sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming, August 25–27.)

Long-Run Inflation Uncertainty*

Stefan Nagel
University of Michigan, NBER, and CEPR

In this commentary I argue that option price data offer useful insights into the long-run macroeconomic uncertainty perceived by investors. Data on inflation options in the United States show substantial dispersion in the risk-neutral distribution of long-run inflation rates. This may indicate that substantial uncertainty about the inflation target still exists. However, I argue that a high dispersion in the risk-neutral distribution could also reflect disagreement among investors who are confident in their own forecasts and do not necessarily perceive a high degree of subjective uncertainty. Disagreement could potentially reconcile the relative stability of inflation in recent years with the substantial dispersion in the risk-neutral distribution of long-run inflation and in survey forecasts of long inflation.

JEL Codes: E31, E44, G13.

1. Introduction

The topic of the session that I have been asked to comment on is *expectations*. In any evaluation of the *challenges to achieving price stability*—the overall theme of this conference—macroeconomic expectations should play an important role. Decisions of price setters and investors today depend on their forward-looking assessment of the macroeconomic situation. Many instruments in central bankers' toolkits, and forward guidance in particular, work through their effects on the public's expectations. However, macroeconomists' understanding of the formation of expectations is still quite limited, and there is still substantial room for improvement in the

*Author contact: Stephen M. Ross School of Business and Department of Economics, University of Michigan, 701 Tappan Street, Ann Arbor, MI 48109; e-mail: stenagel@umich.edu.

measurement of expectations. The two papers in this session advance research on these two important fronts.

The paper by Jonathan Wright titled "Options-Implied Probability Density Functions for Real Interest Rates" (this issue) looks at market-based measures of the (risk-neutral) distribution of real interest rates extracted from prices of traded options. Market-based measures offer the promise of a high-frequency assessment of the entire term structure of distributions of future outcomes, although their interpretation is not entirely straightforward due to conflation with risk premia, illiquidity effects, and other confounding factors.

In my commentary, I will focus on long-term inflation expectations—arguably the most important place to look for threats to price stability. And I want to focus on one aspect of the long-run outlook for which market-based measures like those in Wright's paper are particularly useful: subjective uncertainty. Surveys often focus on point forecasts without eliciting the subjective uncertainty of the respondent (the U.S. Survey of Professional Forecasters (SPF) is a notable exception). Option price data are therefore a useful source of information about the uncertainty perceived by investors.

Subjective uncertainty measures can help shed light on a number of important policy questions. One example that I will discuss is anchoring of inflation expectations. The anchoring hypothesis not only makes predictions about the (lack of) reaction of point forecasts to news but also about the (lack of) subjective uncertainty about long-run inflation rates. Data on long-run inflation uncertainty—market-based or otherwise—should therefore be informative about the degree to which monetary authorities succeeded in anchoring expectations.

The issue of subjective uncertainty is also closely related to the issue of expectations heterogeneity. If there is substantial uncertainty about outlook for inflation, people may also disagree about this outlook. For this reason, the article by Boneva et al. titled "The Effect of Unconventional Monetary Policy on Inflation Expectations: Evidence from Firms in the United Kingdom" in this issue performs an important task by providing insight into the expectations formation of firms. The expectations of decision makers in firms are not necessarily identical to those of commonly surveyed households or professional forecasters. The literature on firms' expectations is still quite small, even though firms, as price setters, play a crucial role in determining the rate of inflation.

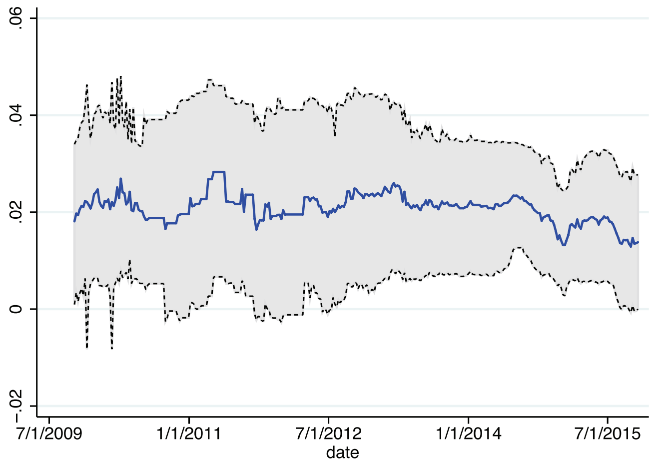
I will argue below that expectations heterogeneity is likely to affect the risk-neutral distribution of outcomes and hence market-based measures of uncertainty. As far as I am aware, this is not an issue that has received a lot of attention in the literature. On the one hand, the fact that market-based measures of uncertainty could be informative about disagreement is another reason to be interested in studying these measures. On the other hand, the potential presence of disagreement effects complicates the interpretation of these measures. The effect of belief dispersion on market-based measures of uncertainty could be particularly relevant in recent years, as unconventional monetary policies have, at least anecdotally, led to a substantial disagreement about the inflation outlook among financial market participants.

2. Market-Based Measures of Long-Run Inflation Uncertainty

For some years now, inflation caps and floors have been traded in the United States. The owner of an inflation cap (floor) receives a payment if the average CPI inflation rate exceeds (is lower than) the strike of the cap (floor). Prices of these derivative instruments can be used to extract market-based measures of investors' beliefs about inflation. Unlike inflation-indexed bond prices or inflation swaps, these option-like derivatives allow the extraction of a whole probability distribution at various horizons. The extracted probability distribution reflects beliefs under the risk-neutral measure, i.e., the probabilities are adjusted for risk premia. For now, I will interpret the probability distribution extracted from long-maturity inflation caps and floors as reflecting investors' perception of long-run inflation uncertainty. I will discuss the effect of risk premia further below.

Figure 1 shows the percentiles of the risk-neutral density of five-year average (annualized) CPI inflation based on data from the Federal Reserve Bank of Minneapolis. The figure presents the median, the 10th percentile, and the 90th percentile of the risk-neutral density. As the figure shows, investors seem to perceive a substantial degree of uncertainty about long-run inflation. In October 2015, the

Figure 1. Percentiles of the Risk-Neutral Density of Five-Year Inflation



Note: The figure shows the 10th percentile, median, and 90th percentile of the risk-neutral distribution of inflation over a five-year horizon extracted from inflation options by the Federal Reserve Bank of Minneapolis.

spread between the 90th and the 10th percentile is about 3 percentage points. This spread has come down a little bit since 2011 when it maxed out at around 4 percentage points, but it is still substantial.

The high degree of dispersion in the risk-neutral distribution of long-run inflation is striking and difficult to reconcile with the view that inflation expectations are well anchored. In the United States, the persistence of inflation has decreased substantially in the past few decades (Williams 2006). Inflation expectations seem to be less sensitive to macroeconomic news in recent years than in earlier decades (Davis 2012). Evidence of this kind has given increasing support to the idea that the Federal Reserve has gained credibility in its intention and ability to keep inflation close to a stable long-run target. Bernanke (2007) expresses this view, for example, albeit with the caveat that the anchoring of expectations is not perfect. Indeed, Gürkaynak et al. (2007) find that prices of nominal and real bonds in the United States still imply some sensitivity of long-run inflation expectations to macroeconomic news.

There are two somewhat separate notions of anchored expectations: (i) insensitivity of inflation expectations to macroeconomic news, including recent surprise inflation; and (ii) a high degree of confidence in the intention and ability of the monetary authority to keep inflation close to a target. It is possible that inflation expectations are anchored in the sense of (i) but that there is nevertheless substantial uncertainty about the long-run target. For illustration, consider the following model of perceived inflation dynamics:

$$\pi_{t+1} = \pi_t^* + \sigma\epsilon_{t+1}, \tag{1}$$

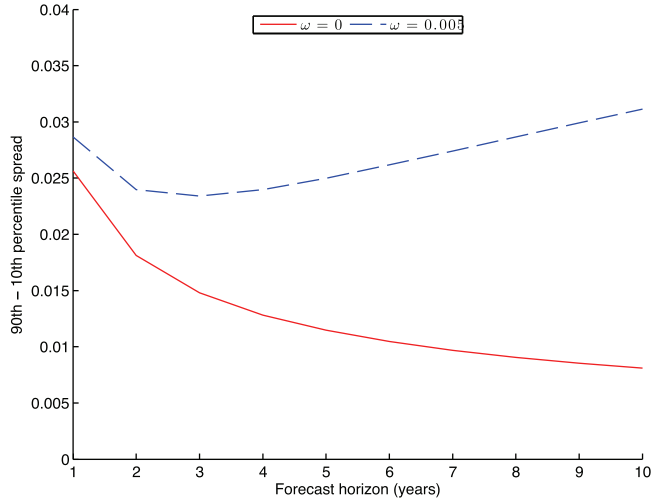
$$\pi_t^* = \pi_{t-1}^* + \omega u_t, \tag{2}$$

where ϵ_t and u_t are uncorrelated standard normal shocks. In this model, ϵ shocks have no effect on inflation expectations. In this sense, expectations are well anchored. However, if $\omega > 0$, there can be considerable uncertainty about the future path of the target π^* and hence long-run inflation rates. The signals u that move the perceived target need not be news associated with regular macroeconomic announcements. In this sense, substantial target uncertainty could very well be consistent with a low sensitivity of inflation expectations to macroeconomic news.

The term structure of uncertainty about inflation should be informative about the relative importance of ϵ and u shocks. Figure 2 shows the forecast uncertainty in terms of the spread between the 90th and 10th percentile of the distribution over various horizons from one to ten years ahead (with $\sigma = 0.01$). The solid line shows that in the absence of target rate uncertainty ($\omega = 0$), there is strong decay of the uncertainty over longer horizons as the ϵ shocks average out. If there is target rate uncertainty ($\omega = 0.005$), the random-walk nature of the perceived target process induces higher uncertainty for inflation rates averaged over longer horizons, which can offset the decrease in the transitory shock uncertainty. Similar implications about long-run inflation uncertainty follow from a more sophisticated unobserved-components stochastic volatility model (Stock and Watson 2010) as estimated in Kitsul and Wright (2013).

Figure 3 plots the 90th–10th percentile spreads from the extracted risk-neutral distribution of inflation for one-year, two-year, and five-year horizons. As the figure shows, there is about as much uncertainty about the five-year inflation rate as there is

Figure 2. Long-Run Inflation Uncertainty with and without Uncertainty about Target



Note: The figure shows the spread between the 90th and 10th percentile of the distribution of inflation rates.

about inflation rates over one-year and two-year horizons. This pattern would be difficult to explain in a model in which the public has little uncertainty about the inflation target. It looks very similar to the target rate uncertainty case in figure 2.

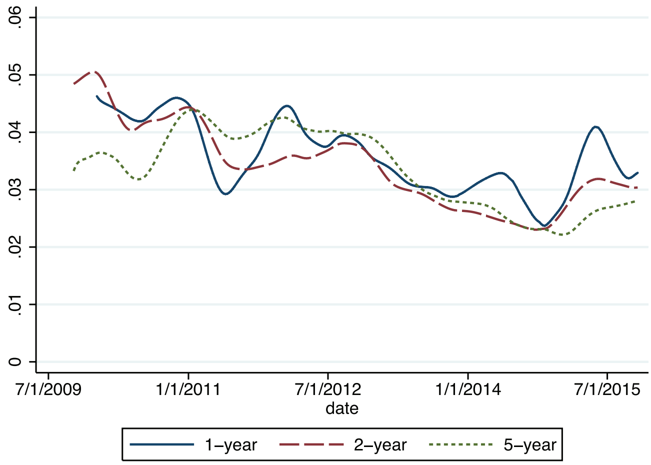
3. Interpreting Dispersion in the Risk-Neutral Distribution

3.1 Lack of Anchoring?

The relatively high degree of dispersion in the risk-neutral distribution of long-run inflation evident in figures 1 and 3 raises questions about the success of the monetary authority in anchoring long-run inflation expectations. Apparently, a substantial degree of uncertainty about long-run inflation still exists.

This evidence is also reason to be somewhat skeptical of explanations that attribute the relative stability of inflation expectations

Figure 3. Interpercentile Range (90th–10th Percentile) of the Risk-Neutral Density of Inflation over Various Horizons



Note: Smoothed with local linear regression and tricube kernel with bandwidth 0.10 (of sample size).

("missing disinflation") in the recent Great Recession to firm anchoring of inflation expectations. If inflation expectations really were so firmly anchored, why would there be so much uncertainty priced into long-maturity inflation options? Clearly, more research is needed on this point, but the evidence suggests that it may be worth looking for alternative explanations. For example, Coibion and Gorodnichenko (2015) show that much of the missing disinflation can be explained by the fact that households' inflation expectations were very sensitive to the rise in oil prices in the years leading up to 2013. This explanation, based on lack of anchoring, would be consistent with the high degree of uncertainty about long-run inflation rates reflected in market-based probabilities. It may also help explain why the median of the risk-neutral distribution of long-run inflation in figure 1 has declined substantially in 2015 coincident with a fall in oil prices.

3.2 Risk Premia?

So far I have treated the percentile spreads of the risk-neutral distribution of inflation as a representation of subjective uncertainty of financial market participants. Of course, since the risk-neutral probabilities reflect the product of actual probabilities and the stochastic discount factor, the risk-neutral probabilities are affected by risk premia. For example, if financial market participants dislike states of very low and very high inflation and are willing to pay a premium to insure against these states, the risk-neutral probabilities of these tail states will be higher than the actual probabilities. However, while such risk premia can make the risk-neutral distribution more dispersed compared with the actual distribution, it is not obvious that there is a simple risk premium explanation for the fact that the dispersion does not decay with longer horizons. It seems difficult to explain this feature of the data without substantial actual uncertainty about long-run inflation rates.

It is also worth keeping in mind that one could argue, along the lines of Feldman et al. (2015), that policymakers should base their decisions on the risk-neutral distribution. A social-welfare-maximizing policy should take into account not only the subjective probabilities that the public attaches to future states of the world but also the price that the public is willing to pay to insure against these states of the world. Risk-neutral probabilities capture both of these aspects. With regard to long-run inflation, a dispersed risk-neutral distribution indicates some combination of high uncertainty about long-run inflation and a high willingness to pay for high-inflation and deflation insurance. This indicates that the public would value policies—e.g., credible commitment to an inflation target—that reduce the likelihood of reaching these states of the world.

However, in imperfect markets subject to segmentation frictions, illiquidity, and limited participation, the interpretation of risk-neutral probabilities is not straightforward. I illustrate this next by pointing out how investor disagreement could potentially influence the dispersion of the risk-neutral distribution.

3.3 Expectations Heterogeneity?

Discussions of the interpretation of risk-neutral probabilities typically focus on how risk premia, and, occasionally, illiquidity distortions in option prices drive a wedge between actual and risk-neutral probabilities. Interpretation of risk premia is typically based on a representative-agent framework, where the stochastic discount factor is interpreted as revealing the marginal valuation that households place on resources in different states of the world. However, the risk premia embedded in the risk-neutral distribution, especially in its tails, can also reflect the disagreement between agents about the likelihood of future events rather than their subjective uncertainty. The literature on market-based probabilities has not paid much attention to this possibility.

To see how expectations heterogeneity can affect the risk-neutral distribution, it is easiest to consider a model in which the public can buy options, but only specialized, risk averse, imperfectly hedged intermediaries can sell options. This setup is broadly consistent with the evidence in Gârleanu, Pedersen, and Poteshman (2009) that market makers are net sellers of options in the stock index option market. Applied to the inflation options market, this would mean that prices of inflation caps reflect the beliefs of investors expecting high inflation (while those expecting deflation cannot sell these options) and the price of floors reflects the beliefs of investors expecting deflation. Intermediaries can smooth out some of these effects, but if they are risk averse and cannot perfectly hedge, they will only partly do so. As a consequence, the tail probabilities of the risk-neutral distribution are elevated relative to actual probabilities. In this interpretation, risk premia embedded in risk-neutral probabilities are the manifestation of differences in beliefs. Buraschi and Jiltsov (2006) provide a more sophisticated asset pricing model with disagreement that implies similar effects on the risk-neutral distribution.

For these reasons, it is possible that the relatively high dispersion of the risk-neutral distribution of long-run inflation in figures 1 and 3 reflects disagreement between market participants rather than a high level of subjective uncertainty of market participants in their own assessment of future inflation. Anecdotally, judging by the diversity of opinions that various investors, pundits, and others expressed in reaction to the Federal Reserve's unconventional monetary policy measures, there was plenty of disagreement in recent years. Moreover, research has identified various dimensions of systematic disagreement between individuals. For example, Coibion and Gorodnichenko (2015) highlight differences between professional forecasters and households. Malmendier and Nagel (2016) document disagreement between individuals of different age with different accumulated inflation experiences. The paper by Boneva et al. in this issue shows that there is disagreement between different types of firms in the United Kingdom.

The view that considerable disagreement about inflation persisted in the wake of the Great Recession in the United States would also be consistent with the evidence in Cecchetti and Hakkio (2009) that adoption of an explicit inflation-targeting regime does not reduce the dispersion of private-sector inflation expectations by much. Since the Federal Reserve has not adopted an explicit inflation target, there is even more reason to expect disagreement about the long-run inflation outlook to persist. Disagreement could potentially offer a common explanation of the facts that inflation rates and the mean or median of professional forecasts were not sensitive to realized inflation rates and macroeconomic news in recent years, but at the same time substantial dispersion in survey forecasts and in the risk-neutral distribution extracted from option prices persisted.

4. Concluding Remarks

To sum up, option price data offer useful insights into the macroeconomic uncertainty perceived by investors. In particular, data on inflation options in the United States indicate that there is substantial dispersion in the risk-neutral distribution of long-run inflation. Even though realized inflation was quite stable in recent years and measures of the central tendency of the perceived inflation distribution did not move much, market participants still seem to perceive uncertainty about the ability and willingness of the Federal Reserve to keep long-run inflation close to a stable target.

However, challenges remain in the interpretation of market-based measures of uncertainty. One issue that seems to deserve more attention of researchers is the role of disagreement in generating the risk premia that are embedded in the risk-neutral distribution of macroeconomic outcomes. Conventional interpretations take a representative-agent approach. But there is reason to believe that the tails of the risk-neutral distribution extracted from option prices could be influenced by disagreement among investors. If so, a high degree of dispersion in the risk-neutral distribution could indicate differences in opinion among investors (who may be quite confident in their own forecasts) rather than high levels of subjective uncertainty.

References

Bernanke, B. S. 2007. “Inflation Expectations and Inflation Forecasting.” Speech at NBER Summer Institute Monetary Economics Workshop, Cambridge, MA, July 10. Available at http://www.federalreserve.gov/newsevents/speech/Bernanke20070710a.htm.

Buraschi, A., and A. Jiltsov. 2006. “Model Uncertainty and Option Markets with Heterogeneous Beliefs.” *Journal of Finance* 61 (6): 2841–97.

Cecchetti, S. G., and C. Hakkio. 2009. “Inflation Targeting and Private Sector Forecasts.” NBER Working Paper No. 15424.

Coibion, O., and Y. Gorodnichenko. 2015. “Is the Phillips Curve Alive and Well after All? Inflation Expectations and the Missing Disinflation.” *American Economic Journal: Macroeconomics* 7 (1): 197–232.

Davis, J. S. 2012. “Inflation Expectations Have Become More Anchored Over Time.” *Economic Letter* (Federal Reserve Bank of Dallas) 7 (13).

Feldman, R., K. Heinecke, N. Kocherlakota, S. Schulhofer-Wohl, and T. Tallarini. 2015. “Market-Based Probabilities: A Tool for Policymakers.” Working Paper, Federal Reserve Bank of Minneapolis.

Gârleanu, N., L. H. Pedersen, and A. M. Poteshman. 2009. “Demand-Based Option Pricing.” *Review of Financial Studies* 22 (10): 4259–99.

Gürkaynak, R. S., A. T. Levin, A. N. Marder, and E. T. Swanson. 2007. “Inflation Targeting and the Anchoring of Inflation Expectations in the Western Hemisphere.” *Economic Review* (Federal Reserve Bank of San Francisco) 2007: 25–47.

Kitsul, Y., and J. H. Wright. 2013. “The Economics of Options-Implied Inflation Probability Density Functions.” *Journal of Financial Economics* 110 (3): 696–711.

Malmendier, U., and S. Nagel. 2016. “Learning from Inflation Experiences.” *Quarterly Journal of Economics* 131 (1): 53–87.

Stock, J. H., and M. W. Watson. 2010. “Modeling Inflation After the Crisis.” NBER Working Paper No. 16488.

Williams, J. C. 2006. “Inflation Persistence in an Era of Well-Anchored Inflation Expectations.” Economic Letter No. 2006-27, Federal Reserve Bank of San Francisco.

Policy Spillovers and Synergies in a Monetary Union*

Óscar Arce, Samuel Hurtado, and Carlos Thomas
Banco de España

We provide a general equilibrium framework for analyzing the effects of supply- and demand-side policies, and the potential synergies between them, in an asymmetric monetary union that faces a liquidity trap and a slow deleveraging process in its "periphery." We find that the joint implementation of pro-competition structural reforms in the periphery, a fiscal expansion in the "core," and forward guidance about the future path of nominal interest rates produces positive synergies between the three policies: forward guidance reinforces the expansionary effects of country-specific policies, and the latter in turn improve the effectiveness of forward guidance. Our results provide a case for complementing current unconventional monetary stimuli in the euro area with national efforts on the structural reform and fiscal fronts.

JEL Codes: E44, E63, D42.

1. Introduction

The global financial crisis initiated in 2008 triggered a deep and prolonged setback for aggregate demand in all major industrialized economies, paving the way for persistently low inflation rates. In the euro area (EA), the crisis has also revealed forcefully the imbalances

*The views expressed herein are those of the authors and not necessarily those of the European Central Bank, Banco de España, or the Eurosystem. Part of this research was conducted while Samuel Hurtado was working at the European Central Bank (ECB). We thank Andrea Ferrero, Stefano Neri, conference participants at the ADEMU Prague Workshop on "Macroeconomic and Financial Imbalances and Spillovers," the Annual IJCB Research Conference and the ECB conference "Challenges for Macroeconomic Policy in a Low Inflation Environment," as well as seminar participants at the ECB and Banco de España, for their comments and suggestions. All remaining errors are ours. Author e-mails: Arce: o.arce@bde.es; Hurtado: samuel.hurtado@bde.es; Thomas: carlos.thomas@bde.es.

and efficiency gaps across its member states. In most of the so-called periphery, the combination of high indebtedness, deleveraging, and widespread dysfunctionalities in labor and product markets is feeding fears of a long-lasting scenario of weak and fragile growth, with adverse consequences for the entire union.

Against this context, many voices are calling for a simultaneous implementation of supply- and demand-side policies within the EA. On the supply side, the removal of inefficiencies and the enhancement of market competition are invoked as the only lever available to the periphery so as to regain its competitiveness vis-à-vis the rest of the EA. On the demand side, given that the periphery lacks sufficient fiscal space to stimulate domestic demand and that the European Central Bank (ECB) is already constrained by the zero lower bound (ZLB), the attention has shifted toward the role of non-standard monetary policies and the possibility of expansionary fiscal measures in the "core." Moreover, the policy debate has progressively moved toward two closely interlinked areas: first, the potential for policy-induced spillovers across countries within the EA and, second, the likely complementarities or *synergies* between non-standard monetary policy, structural reforms, and fiscal policy.[1]

The issue of fiscal spillovers in a monetary union has recently been the subject of formal quantitative analysis, e.g., by Erceg and Lindé (2013) and Blanchard, Erceg, and Lindé (2014). However, relatively less is known about cross-country spillovers induced by the adoption of structural reforms in one part of the union. Critically, even less is known about the potential synergies between such structural reforms, fiscal expansion in the rest of the union, and union-wide unconventional monetary policies at the ZLB.

In this paper, we address these issues in the context of a model of an asymmetric two-country ("core" and "periphery") monetary union. In both countries, households and firms borrow long term subject to collateral constraints. We construct a baseline scenario aimed at capturing key features of the current macroeconomic landscape in the EA. First, the periphery is assumed to be hit by an adverse financial shock that tightens the collateral requirements on

[1] See, for example, Draghi (2014, 2015, 2016), European Commission (2014), International Monetary Fund (IMF) (2014), and Obstfeld (2016).

the loans to households and firms. This shock, combined with collateral constraints and long-run debt, gives rise to a protracted and costly process of deleveraging in the periphery with implications for the monetary union as a whole. Second, a union-wide demand shock causes a reduction in union-wide inflation that is large enough to drive the monetary authority's nominal interest rate toward its ZLB. Both shocks combine to produce a long-lasting recession and persistently low inflation in the currency union as a whole.

Against this background, we analyze the effects of two types of country-specific macroeconomic policies: structural reforms in the periphery (consisting of reductions in price and wage setters' monopolistic rents) and a temporary increase in government spending in the core. We show that the cross-country spillovers of such policies depend critically on the incidence of the ZLB. Outside of the ZLB, structural reforms have a positive output effect on the periphery already on impact but produce a slight positive impact on the core too, thanks to the monetary accommodation of the ensuing disinflationary pressures. A government expenditure expansion in the core, on the contrary, aggravates the recession in the periphery, as the central bank tightens its policy rate in response to the inflationary pressures coming from the core. By contrast, in a liquidity trap the sign of the previous cross-country spillovers are reversed. First, reforms in the periphery, which remain expansionary for the latter, although less so, produce a negative (though relatively small) effect on the core. Similarly, absent the previously discussed monetary tightening, a fiscal expansion in the core produces sizable positive spillovers for the periphery.[2]

We next consider the possibility that the monetary authority follows a "forward guidance" policy with the aim of raising area-wide GDP and inflation while in the liquidity trap. In particular, we analyze the case in which the central bank can credibly commit to keeping the interest rate at zero for two quarters more than what its standard rule would dictate. Such a policy is found to have positive effects, of a similar magnitude, in the output of both regions. This last result is remarkable because, during the deleveraging phase (which lasts longer than the liquidity trap in our simulations), the

[2]This last result coincides with the one in Erceg and Lindé (2013) or Blanchard, Erceg, and Lindé (2014).

credit flow in the periphery is frozen, such that credit-constrained agents are not exposed to the usual intertemporal consumption substitution channel of forward guidance. Thus, in our setup the effectiveness of forward guidance on the periphery seems to be more related to other transmission channels, such as the core-periphery trade channel and net worth effects on the balance sheets of deleveraging agents.

We then quantify the synergies between the three policies, an exercise for which our non-linear model (and our fully non-linear solution method) is well suited. We find that the short-run expansionary effects of national stimulus measures (reforms in the periphery and fiscal expansion in the core) increase by a sizable amount when in parallel the monetary authority implements a policy of forward guidance. Conversely, the expansionary impact of forward guidance is largely enhanced when at the same time each country implements its respective policy package. Importantly, these positive synergies take place both for the monetary union as a whole and for each individual country.

We stress two prominent channels for these synergies. On the one hand, country-specific policies produce expansionary effects that run beyond the short term, especially in the case of structural reforms that may deploy permanent effects on output. Thus, the forward-guidance-driven reduction in long-run real interest rates raises the present-discounted value of such gains, via income and net worth effects, with the resulting positive effect on current consumption and investment (*discounting effect*). On the other hand, country-specific policies affect the endogenous path of the nominal interest rate when the latter follows a standard ZLB-constrained Taylor rule, including the date at which the nominal rate exits the ZLB (the *lift-off date*). For instance, an inflationary fiscal expansion tends to shorten the duration of the ZLB, which moderates its positive impact;[3] thus, a simultaneous commitment to keeping interest rates at zero for longer eliminates such moderating effect and augments the expansionary impact of the fiscal stimulus. This positive *lift-off effect* changes sign in the case of deflationary structural reforms. Our analysis thus stresses the importance of jointly implementing forward guidance

[3]This effect was first illustrated by Erceg and Lindé (2014).

and *both* supply- and demand-side country-specific policies, as it is this package that brings together the discounting and (positive) lift-off effects and thus maximizes the positive synergies.[4]

Related Literature. By analyzing the joint implementation of demand- and supply-side policies, we contribute to a long-standing tradition in macroeconomics, with early contributions by Blanchard et al. (1985), Buiter (1987), and Bean (1994), among others. Our paper revisits this topic in the context of a quantitative modern dynamic general equilibrium (DGE) framework.

More specifically, our paper contributes to the literature on the evaluation of macroeconomic policies in a currency union in the context of quantitative DGE models. Our analysis shares several themes with previous contributions, such as the effects of national policies (fiscal expansion/consolidation, structural reforms, etc.) and their cross-country spillovers, the role of the ZLB in shaping the impact of such policies, and the effects of forward guidance by the monetary authorities in the face of a binding ZLB. Relative to this literature, which we summarize next, one important contribution is that we analyze quantitatively the synergies between national policies and (non-standard) union-wide monetary measures, in sync with recent policy debates in the EA.

A recent literature studies the effects of country-specific fiscal policies, and the associated cross-country spillovers, in two-country monetary union models. Erceg and Lindé (2013) analyze different strategies of fiscal consolidation by one country, with particular attention to the constraints imposed by currency union membership, including the possibility of a binding ZLB. In a similar framework, Blanchard, Erceg, and Lindé (2014) study the spillovers of fiscal expansion in one country to the other under different assumptions about the incidence of the ZLB or the degree of home bias in government purchases, as well as the welfare implications of such an expansion. In addition to the analysis of synergies discussed above, we also build on this literature by studying the cross-country spillovers of

[4]We also find a relevant role for the periphery's endogenous deleveraging dynamics in creating these synergies. In particular, while all the different policy measures tend to *shorten* the duration of deleveraging in the periphery (thus reinforcing their expansionary effects), they do so by *more* when jointly implemented than when taken in isolation. This channel is common to both supply- and demand-side stimuli.

structural reforms in one part of the currency union and how such spillovers depend on whether the ZLB binds or not.

The role of forward guidance about future interest rates as a means of alleviating the restrictions imposed by the ZLB is the subject of a recent and growing literature, after the seminal theoretical analysis of Eggertsson and Woodford (2003). Levin et al. (2010), Campbell, Fisher, and Justiniano (2012), Del Negro, Giannoni, and Patterson (2012), Benigno, Eggertsson, and Romei (2014), and McKay, Nakamura, and Steinsson (2015) are some notable recent examples of DSGE (dynamic stochastic general equilibrium) model-based analyses of forward guidance. We complement this literature by studying, in the context of a multi-country monetary union model, the interaction between forward guidance and different supply- and demand-side country-specific macroeconomic policies. Our analysis reveals an important role of forward guidance in strengthening the expansionary effects of national supply- and demand-side policies.

Our paper is also related to a recent literature that studies the effects of structural reforms, via reductions in price and/or wage markups, in a currency union where the monetary authority is either constrained by the ZLB (Fernández-Villaverde, Guerrón-Quintana, and Rubio-Ramírez 2012; Eggertsson, Ferrero, and Raffo 2014; Gerali, Notarpietro, and Pisani 2015) or by its concern for nominal exchange rate stabilization (Galí and Monacelli 2014). One contribution of our analysis to this line of research is to add fiscal expansion by the core countries in the union and forward guidance by the monetary authority, and to study the resulting complementarities across these policies.

Finally, Andrés, Arce, and Thomas (2015) study the effects of structural reforms in a small open economy that belongs to a monetary union (with the resulting lack of monetary accommodation) and undergoes a prolonged process of private-sector deleveraging due to the coexistence of long-term debt, collateral constraints, and a negative financial shock.[5] We build on their analysis by considering a two-country monetary union structure, which allows us to

[5]As argued by those authors, the assumption of long-term debt brings model debt dynamics closer to those observed in actual deleveraging episodes, both historical ones and those currently ongoing in the EA periphery.

analyze the cross-country spillovers of country-specific policies and the synergies between the latter policies and the common monetary policy.[6]

The rest of the paper is organized as follows. Section 2 lays out the model and presents the calibration and solution method. Section 3 constructs our main baseline scenario, which includes a binding ZLB and deleveraging in the periphery. Section 4 analyzes the effects of country-specific macroeconomic policies (structural reforms in the periphery, fiscal expansion in the core) and forward guidance by the common monetary authority, both with and without ZLB. It then quantifies the synergies between these policies. Section 5 concludes.

2. Model

We now present a general equilibrium model of a monetary union with two countries or regions: the "periphery" (denoted by H) and the "core" (denoted by F). The union-wide population is normalized to 1, where a fraction s live in the periphery and the remaining $1-s$ in the core.

The real side of the economy is fairly standard. In each country, households obtain utility from consumption goods and from housing units. Consumption goods are produced using a combination of household labor, commercial real estate, and equipment capital goods. Construction firms build real estate (both for residential and commercial purposes) using labor and consumption goods; the latter are also used as inputs by equipment capital goods producers. Consumption goods and labor markets are both characterized by monopolistic competition and nominal rigidities.

On the financial side, the structure is as follows. In each country, there are three types of consumers: patient households, impatient households, and (impatient) entrepreneurs. In equilibrium, the latter two borrow from the former and from lenders in the other country. Debt contracts are long term. In periods in which borrowers

[6] Andrés, Arce, and Thomas (2015) find a relevant role for the endogenous deleveraging dynamics that follow a negative financial shock in transmitting the effects of structural reforms. Similarly, here we find that debt dynamics in the periphery can contribute to creating positive synergies between the different policies.

are able to receive new credit flows, they do so subject to collateral constraints. If the value of their collateral is too low for them to receive new credit flows, they just repay their outstanding debts at a fixed contractual rate. Real estate is the only collateralizable asset. We will henceforth refer to impatient and patient households as "constrained" and "unconstrained" households, respectively.

Finally, a common monetary authority sets the nominal policy interest rate using a standard Taylor rule and subject to the ZLB constraint.

All variables are in real terms and in per capita unless otherwise specified, with the consumption goods basket of each country acting as the numeraire in that country. From now onward, we focus on the model structure in the periphery country.[7] The core country is modeled analogously. All equilibrium conditions, including first-order conditions of agents' optimization problems, are listed in appendix 1.

2.1 Households

There is a representative constrained household and a representative unconstrained household, denoted respectively by superscripts c and u.

2.1.1 Cost Minimization

Before analyzing dynamic household optimization, we first derive the static cost-minimization problem, which is common to both household types (and to entrepreneurs). Households consume a basket of home and foreign goods, denoted respectively by subscripts H and F,

$$c_t^x = \left(\omega_H^{1/\varepsilon_H} \left(c_{H,t}^x \right)^{(\varepsilon_H - 1)/\varepsilon_H} + (1 - \omega_H)^{1/\varepsilon_H} \left(c_{F,t}^x \right)^{(\varepsilon_H - 1)/\varepsilon_H} \right)^{\varepsilon_H/(\varepsilon_H - 1)}, \tag{1}$$

[7] Given our focus on the decision problems from the point of view of the agents in the periphery, we will also refer to them as home agents, and to agents in the core as foreign agents. Likewise, goods produced in the periphery and the core will also be referred to as home and foreign goods, respectively.

for $x = c, u$; $c^x_{H,t}$ and $c^x_{F,t}$ are baskets of home and foreign good varieties, respectively,

$$c^x_{H,t} = \left(\int_0^1 c^x_{H,t}(z)^{(\varepsilon_p - 1)/\varepsilon_p} \, dz \right)^{\varepsilon_p/(\varepsilon_p - 1)}, \tag{2}$$

$$c^x_{F,t} = \left(\int_0^1 c^x_{F,t}(z')^{\left(\varepsilon^*_p - 1\right)/\varepsilon^*_p} \, dz' \right)^{\varepsilon^*_p/\left(\varepsilon^*_p - 1\right)}, \tag{3}$$

where $\varepsilon_p, \varepsilon^*_p > 1$ are the elasticities of substitution across home and foreign good varieties, respectively. Let $P_{H,t}(z)$ and $P_{F,t}(z')$ denote the prices of home good variety z and foreign good variety z', respectively. Household $x = c, u$ minimizes nominal consumption expenditure, $\int_0^1 P_{H,t}(z)\, c^x_{H,t}(z)\, dz + \int_0^1 P_{F,t}(z')\, c^x_{F,t}(z')\, dz'$, subject to (1), (2), and (3). The first-order conditions can be expressed as

$$c^x_{H,t} = \omega_H \left(\frac{P_{H,t}}{P_t} \right)^{-\varepsilon_H} c^x_t, \quad c^x_{F,t} = (1 - \omega_H) \left(\frac{P_{F,t}}{P_t} \right)^{-\varepsilon_H} c^x_t, \tag{4}$$

$$c^x_{H,t}(z) = \left(\frac{P_{H,t}(z)}{P_{H,t}} \right)^{-\varepsilon_p} c^x_{H,t}, \quad c^x_{F,t}(z') = \left(\frac{P_{F,t}(z')}{P_{F,t}} \right)^{-\varepsilon^*_p} c^x_{F,t},$$

for $z, z' \in [0, 1]$, where

$$P_t = \left(\omega_H P^{1-\varepsilon_H}_{H,t} + (1 - \omega_H) P^{1-\varepsilon_H}_{F,t} \right)^{1/(1-\varepsilon_H)},$$

$$P_{H,t} = \left(\int_0^1 P_{H,t}(z)^{1-\varepsilon_p} \, dz \right)^{1/(1-\varepsilon_p)}$$

are the periphery's *consumer price index* (CPI) and *producer price index* (PPI), respectively, and where

$$P_{F,t} = \left(\int_0^1 P_{F,t}(z')^{1-\varepsilon^*_p} \, dz' \right)^{1/\left(1-\varepsilon^*_p\right)}$$

is a price index of foreign goods. Nominal spending in home and foreign goods equals $\int_0^1 P_{H,t}(z)\, c^x_{H,t}(z)\, dz = P_{H,t} c^x_{H,t}$ and $\int_0^1 P_{F,t}(z')\, c^x_{F,t}(z')\, dz' = P_{F,t} c^x_{F,t}$, respectively, whereas total nominal consumption spending equals $P_{H,t} c^x_{H,t} + P_{F,t} c^x_{F,t} = P_t c^x_t$.

As noted before, consumption goods are also used as inputs by construction firms and equipment capital producers. The latter are assumed to combine home and foreign goods analogously to households. This gives rise to investment demand functions analogous to (4).

2.1.2 Unconstrained Households

The unconstrained household maximizes

$$E_0 \sum_{t=0}^{\infty} (\beta^u)^t \zeta_t \left\{ \log (c_t^u) + \vartheta \log (h_t^u) - \chi \int_0^1 \frac{n_t^u (i)^{1+\varphi}}{1+\varphi} di \right\},$$

where ζ_t is a union-wide shock to the discount factor of all consumers, $n_t^u (i)$ are labor services of type $i \in [0,1]$, and h_t^u are housing units, subject to the following budget constraint (expressed in units of the consumption goods basket):

$$\begin{aligned} & c_t^u + d_t + p_t^h \left[h_t^u - (1-\delta_h) h_{t-1}^u \right] \\ & \quad = \frac{R_{t-1}}{\pi_t} d_{t-1} + (1-\tau_w) \int_0^1 \frac{W_t (i)}{P_t} n_t^u (i) \, di - T_t, \end{aligned}$$

where d_t is the real value of net holdings of riskless nominal debt, R_t is the gross nominal interest rate at which home agents lend and borrow, δ_h is the depreciation rate of real estate, p_t^h is the real price of real estate, $\pi_t \equiv P_t / P_{t-1}$ is gross CPI inflation, $W_t (i)$ is the nominal wage for labor services of type i, τ_w is a tax rate on labor income, and T_t are lump-sum taxes.

2.1.3 Constrained Households

The constrained household's preferences are given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \zeta_t \left\{ \log (c_t^c) + \vartheta \log (h_t) - \chi \int_0^1 \frac{n_t^c (i)^{1+\varphi}}{1+\varphi} di \right\},$$

where $\beta < \beta^u$, i.e., the constrained household is relatively impatient. The household faces the following budget constraint:

$$\begin{aligned} & c_t^c + p_t^h \left[h_t - (1-\delta_h) h_{t-1} \right] \\ & \quad = b_t - \frac{R_{t-1}}{\pi_t} b_{t-1} + (1-\tau_w) \int_0^1 \frac{W_t (i)}{P_t} n_t^c (i) \, di - T_t, \end{aligned}$$

where b_t is the real value of household debt outstanding at the end of period t.

Unlike in most of the literature, which typically assumes short-term (one-period) debt, we assume that debt contracts are *long term*. In the interest of tractability, we assume that at the beginning of time t the household repays a fraction $1-\gamma$ of all nominal debt outstanding at the end of period $t-1$, regardless of when that debt was issued.[8] This type of perpetual debt is similar to the one proposed by Woodford (2001) as a tractable way of modeling long-term debt. In *real* terms, the outstanding principal of household debt then evolves as follows:

$$b_t = \frac{b_{t-1}}{\pi_t} + b_t^{new} - (1-\gamma)\,\frac{b_{t-1}}{\pi_t} = b_t^{new} + \gamma\frac{b_{t-1}}{\pi_t}, \tag{5}$$

where b_t^{new} is gross new credit net of *voluntary* amortizations, i.e., amortizations beyond the contractual debt repayment $(1-\gamma)\,b_{t-1}/\pi_t$.

We assume that, in "normal times" (in a sense to be specified below), household borrowing is subject to collateral constraints, as in Kiyotaki and Moore (1997). Following Iacoviello (2005), outstanding debt b_t cannot exceed a fraction m_t (the "loan-to-value ratio," which we assume to be exogenously time varying) of the expected discounted value of the household's residential stock: $b_t \leq m_t R_t^{-1} E_t \pi_{t+1} p_{t+1}^h h_t$. For brevity, we will refer to such pledgeable value of collateral as *collateral value*. This debt limit, however, is only effective as long as it exceeds $\gamma b_{t-1}/\pi_t$, which we will henceforth refer to as the *contractual amortization path*. Indeed, if the collateral value falls below such path, lowering b_t to the value of collateral would require lenders not only to reduce gross new credit to zero (its lower bound) but also to *impose* additional amortizations beyond those agreed in the contract (i.e., $b_t^{new} < 0$). Since lenders cannot force borrowers to pay back faster than the contractual amortization rate, the contractual amortization path becomes the effective debt limit.

[8] Total (gross) debt payments in each period are then $(1-\gamma)+(R_{t-1}-1)$ times nominal debt outstanding, i.e., the sum of amortization and interest payments.

Therefore, long-run debt implies the following *asymmetric borrowing constraint:*

$$b_t \leq R_t^{-1} m_t E_t \pi_{t+1} p_{t+1}^h h_t, \text{ if } \frac{m_t}{R_t} E_t \pi_{t+1} p_{t+1}^h h_t \geq \gamma \frac{b_{t-1}}{\pi_t}, \quad (6)$$

$$b_t \leq \gamma \frac{b_{t-1}}{\pi_t}, \qquad \text{if } \frac{m_t}{R_t} E_t \pi_{t+1} p_{t+1}^h h_t < \gamma \frac{b_{t-1}}{\pi_t}. \quad (7)$$

This asymmetry gives rise to a *double debt regime*. In "normal times" in which collateral values exceed the contractual amortization path, debt is restricted by the former. In this baseline regime, households can receive new credit against their housing collateral, with the constraint that such new credit does not exceed the gap between collateral values and the amortization path.[9] However, in the face of shocks that reduce collateral values sufficiently, the economy switches to an alternative regime, in which new credit disappears and debt is restricted instead by the contractual amortization path. Notice that changes from one regime to the other take place endogenously, and may thus be affected by policy or by other shocks.

For future reference, we obtain here the optimal choice of housing,

$$\lambda_t^c p_t^h = \frac{\zeta_t \vartheta}{h_t} + \beta E_t \lambda_{t+1}^c \left(1 - \delta_h\right) p_{t+1}^h + \xi_t \frac{m_t}{R_t} E_t \pi_{t+1} p_{t+1}^h, \quad (8)$$

where $\lambda_t^x = \zeta_t / c_t^x$ and ξ_t are the Lagrange multipliers associated with the budget constraint of consumer type $x = c, u, e$ and with the collateral constraint (equation (6)), respectively. Equation (8) illustrates that, when the collateral constraint is binding ($\xi_t > 0$), the marginal value of housing is higher due to the possibility of borrowing against it. This possibility disappears once the economy enters into the alternative debt regime, in which the collateral constraint ceases to be effective.

2.2 Production

Entrepreneurs produce an intermediate good and sell it to retailers, who transform it into consumption good varieties. Entrepreneurs

[9] Indeed, from (5) and (6) we obtain $b_t^{new} \leq m_t R_t^{-1} E_t \pi_{t+1} p_{t+1}^h h_t - \gamma b_{t-1} / \pi_t$.

and retailers conform the consumption goods sector. In addition, construction firms produce real estate, both for residential and commercial use, whereas equipment capital is produced by capital goods producers. All sectors operate under perfect competition, except retailers, who enjoy monopolistic power.

2.2.1 Entrepreneurs

A representative entrepreneur produces an intermediate product and sells it to retailers at a perfectly competitive real (CPI-deflated) price mc_t. The entrepreneur maximizes

$$E_0 \sum_{t=0}^{\infty} \beta^t \zeta_t \log c_t^e,$$

with the consumption basket c_t^e defined analogously to (1), subject to

$$\begin{aligned} c_t^e + p_t^h \left[h_t^e - (1-\delta_h) h_{t-1}^e\right] + q_t \left[k_t - (1-\delta_k) k_{t-1}\right] \\ = mc_t y_t^e - \frac{W_t}{P_t} n_t^e + b_t^e - \frac{R_{t-1}}{\pi_t} b_{t-1}^e + \sum_{s=r,h,k} \Pi_t^s, \\ y_t^e = k_{t-1}^{\alpha_k} \left(h_{t-1}^e\right)^{\alpha_h} \left(n_t^e\right)^{1-\alpha_k-\alpha_h}, \end{aligned}$$

where y_t^e is output of the intermediate good, k_{t-1} is equipment capital with unit price q_t, δ_k is the depreciation rate of equipment capital, h_{t-1}^e is commercial real estate, n_t^e is a basket of labor services, W_t is a nominal wage index, b_t^e is the real value of entrepreneurial debt outstanding at the end of period t, and $\{\Pi_t^s\}_{s=r,h,k}$ are real profits from the retail, construction, and equipment goods-producing sectors.[10]

Entrepreneurs' maximization is also subject to an asymmetric borrowing constraint analogous to the one on constrained households,

$$b_t^e \leq R_t^{-1} m_t^e E_t \pi_{t+1} p_{t+1}^h h_t^e, \text{ if } \frac{m_t^e}{R_t} E_t \pi_{t+1} p_{t+1}^h h_t^e \geq \gamma^e \frac{b_{t-1}^e}{\pi_t}, \tag{9}$$

[10]Notice that entrepreneurs are assumed to own the firms in the latter sectors. We adopt this specification because we are interested in analyzing how profit accumulation affects productive investment decisions, which in our model are made by the entrepreneurs.

$$b_t^e \leq \gamma^e \frac{b_{t-1}^e}{\pi_t}, \qquad \text{if } \frac{m_t^e}{R_t} E_t \pi_{t+1} p_{t+1}^h h_t^e < \gamma^e \frac{b_{t-1}^e}{\pi_t}, \tag{10}$$

where we allow for a different loan-to-value ratio (m_t^e) and contractual amortization rate $(1-\gamma^e)$ for entrepreneurs. Again, it is instructive to analyze here the optimal demand for commercial real estate,

$$\lambda_t^e p_t^h = \beta E_t \lambda_{t+1}^e \left\{ mc_{t+1} \alpha_h \frac{y_{t+1}^e}{h_t^e} + (1-\delta_h) p_{t+1}^h \right\} + \xi_t^e \frac{m_t^e}{R_t} E_t \pi_{t+1} p_{t+1}^h, \tag{11}$$

where ξ_t^e is the Lagrange multipliers associated with constraint (9). Analogously to the case of constrained households, in periods in which the collateral constraint binds ($\xi_t^e > 0$), the marginal value of commercial real estate is higher thanks to the possibility of borrowing against it.

2.2.2 Retailers

A continuum of monopolistically competitive retailers indexed by $z \in [0,1]$ purchase the intermediate input from entrepreneurs at the real price mc_t and transform it one for one into final good varieties. Retailers' real marginal cost is thus mc_t. Each retailer z faces a demand curve

$$y_t(z) = \left(\frac{P_{H,t}(z)}{P_{H,t}} \right)^{-\varepsilon_p} y_t \equiv y_t^d \left(P_{H,t}(z) \right), \tag{12}$$

where y_t is aggregate demand of the basket of home goods (to be derived below). Assuming Calvo (1983) price setting, a retailer that has the chance of setting its nominal price at time t solves

$$\max_{P_{H,t}(z)} E_t \sum_{s=0}^{\infty} (\beta\theta_p)^s \frac{\lambda_{t+s}^e}{\lambda_t^e} \left[(1-\tau_p) \frac{P_{H,t}(z)}{P_{t+s}} - mc_{t+s} \right] y_{t+s}^d \left(P_{H,t}(z) \right),$$

where θ_p is the probability of not adjusting the price and τ_p is a tax rate on retailers' revenue. The first-order condition is standard (see appendix 1), with all time-t price setters choosing a common optimal price $\tilde{P}_{H,t}$. If retailers were able to reset prices in every period ($\theta_p = 0$), they would set

$$\tilde{P}_{H,t} = \frac{1}{1-\tau_p}\frac{\varepsilon_p}{\varepsilon_p - 1} P_t mc_t.$$

Therefore, the term $\frac{1}{1-\tau_p}\frac{\varepsilon_p}{\varepsilon_p-1}$ represents the *desired price markup* over nominal marginal cost, and thus measures the degree of monopolistic distortions in product markets.

2.2.3 Construction Firms

A representative construction firm maximizes its expected discounted stream of profits, $E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t^e}{\lambda_0^e} \Pi_t^h$, where $\Pi_t^h = p_t^h I_t^h - \frac{W_t}{P_t} n_t^h - i_t^h$, subject to the production technology

$$I_t^h = \left(n_t^h\right)^{\omega} \left\{ i_t^h \left[1 - \frac{\Phi_h}{2} \left(\frac{i_t^h}{i_{t-1}^h} - 1 \right)^2 \right] \right\}^{1-\omega},$$

where n_t^h are labor services, i_t^h are consumption goods, and I_t^h are new real estate units.[11]

2.2.4 Equipment Capital Producers

A representative equipment capital producer maximizes its expected discounted stream of profits, $E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t^e}{\lambda_0^e} \Pi_t^k$, where $\Pi_t^k = q_t I_t - i_t$, subject to the technology

$$I_t = i_t \left[1 - \frac{\Phi_k}{2} \left(\frac{i_t}{i_{t-1}} - 1 \right)^2 \right],$$

where i_t are consumption goods, and I_t are new equipment capital goods.

[11] We include labor services in the production function of construction firms so as to allow for long-run changes in real estate prices. Without labor in construction ($\omega = 0$), real estate prices are always unity in the long run. More generally, it can be shown that $p_{ss}^h = \left(w_{ss}\right)^{\omega} \omega^{-\omega} \left(1-\omega\right)^{-(1-\omega)}$.

2.3 Wage Setting

Both entrepreneurs and construction firms use a basket of labor services by constrained and unconstrained households,

$$n_t^s = \left(n_t^{s,c}\right)^{\mu_s} \left(n_t^{s,u}\right)^{1-\mu_s},$$

where $n_t^{s,x}$ are labor services provided by type-x households, $x = c, u$, to each sector $s = e, h$. We assume that both worker types (constrained and unconstrained) earn the same wage. Cost minimization then implies $(1-\mu_s)\, n_t^{s,c} = \mu_s n_t^{s,u}$ for $s = e, h$. From each household type, each sector demands in turn a basket of labor service varieties,

$$n_t^{s,x} = \left(\int_0^1 n_t^{s,x}(i)^{(\varepsilon_w - 1)/\varepsilon_w}\, di\right)^{\varepsilon_w/(\varepsilon_w - 1)},$$

for $x = c, u$ and $s = e, h$, where $\varepsilon_w > 1$ is the elasticity of substitution across labor varieties $i \in [0, 1]$. Cost minimization implies $n_t^{s,x}(i) = \left(W_t(i)/W_t\right)^{-\varepsilon_w} n_t^{s,x}$, for $x = c, u$ and $s = e, h$, where $W_t \equiv \left(\int_0^1 W_t(i)^{1-\varepsilon_w}\, di\right)^{1/(1-\varepsilon_w)}$ is the nominal wage index. Total demand for each variety of labor services is thus

$$\begin{aligned} n_t^x(i) \equiv n_t^{e,x}(i) + n_t^{h,x}(i) &= \left(\frac{W_t(i)}{W_t}\right)^{-\varepsilon_w} \left(n_t^{e,x} + n_t^{h,x}\right) \\ &\equiv n_t^{d,x}\left(W_t(i)\right), \end{aligned}$$

for $x = c, u$. Total nominal wage income earned by each type-x household equals $\int_0^1 W_t(i)\, n_t^x(i)\, di = W_t n_t^x$, where $n_t^x \equiv n_t^{e,x} + n_t^{h,x}$.

As in Erceg, Henderson, and Levin (2000; EHL), nominal wages are set à la Calvo (1983). In particular, a union representing all type-i workers maximizes the utility of the households to which such workers belong. Then a union that has the chance to reset the nominal wage at time t chooses $W_t(i)$ to maximize

$$\begin{aligned} &\sum_{x=c,u} E_t \sum_{s=0}^{\infty} \left(\beta^x \theta_w\right)^s \\ &\times \left[\lambda_{t+s}^x \left(1-\tau_w\right) \frac{W_t(i)}{P_{t+s}} n_{t+s}^{d,x}\left(W_t(i)\right) - \zeta_{t+s} \chi \frac{\left(n_{t+s}^{d,x}\left(W_t(i)\right)\right)^{1+\varphi}}{1+\varphi}\right], \end{aligned}$$

where θ_w is the probability of not adjusting the wage and $\beta^c = \beta$. All time-t wage setters choose a common optimal wage $\tilde{W}_t$; see the first-order condition in appendix 1. If workers were able to reset wages in every period ($\theta_w = 0$), then they would charge a markup,

$$\frac{1}{1-\tau_w}\frac{\varepsilon_w}{\varepsilon_w - 1},$$

over a weighted average of constrained and unconstrained households' marginal rates of substitution between consumption and labor. Therefore, the term $\frac{1}{1-\tau_w}\frac{\varepsilon_w}{\varepsilon_w-1}$ represents the *desired wage markup*, and thus measures the degree of monopolistic distortions in the labor market.

2.4 Fiscal Authority

The fiscal authority demands a basket of home good varieties analogous to (2), which we denote by g_t and which is exogenously determined. Thus, government demand for each home variety z is $g_t(z) = (P_{H,t}(z)/P_{H,t})^{-\varepsilon_p} g_t$. Assuming full home bias in government purchases, the total nominal value of government purchases is $\int_0^1 P_{H,t}(z)\, g_t(z)\, dz = P_{H,t} g_t$. For simplicity, we assume that the fiscal authority balances its budget period by period by adjusting lump-sum taxes T_t,

$$\tau_w \frac{W_t}{P_t}(n_t^c + n_t^u) + \tau_p \frac{P_{H,t}}{P_t} y_t + 2T_t = \frac{P_{H,t}}{P_t} g_t.$$

2.5 Common Monetary Authority

The common monetary authority sets the gross nominal policy interest rate R_t^{MU} according to a simple inflation-based Taylor rule and subject to the zero bound on net interest rates,

$$R_t^{MU} = \max\left\{1, \bar{R}^{MU}\left(\pi_t^{MU}\right)^{\rho_\pi}\right\}, \tag{13}$$

where $\rho_\pi > 1$, $\bar{R}^{MU}$ is the long-run target for the policy rate, and

$$\pi_t^{MU} = s\pi_t + (1-s)\,\pi_t^*$$

is a measure of the union-wide gross CPI inflation rate, where $\pi_t^* \equiv P_t^*/P_{t-1}^*$ is foreign CPI inflation.

2.6 International Linkages

In section 2.1.1 we derived home agents' optimal demand for imported (foreign) goods. As regards the exports side of international trade, we assume that foreign agents demand baskets of home good varieties analogous to (2), denoted by $c^{c*}_{H,t}$, $c^{u*}_{H,t}$, etc. The law of one price is assumed to hold for each home good variety, such that $P^{*}_{H,t}(z) = P_{H,t}(z)$ for all $z \in [0,1]$, implying $P^{*}_{H,t} = P_{H,t}$.[12] Thus, export demand for each home good variety z is $x_t(z) = (P_{H,t}(z)/P_{H,t})^{-\varepsilon_p} x_t$, where real per capita exports equal

$$\begin{aligned} x_t &= \frac{1-s}{s}\left(c^{c*}_{H,t} + c^{u*}_{H,t} + c^{e*}_{H,t} + i^{*}_{H,t} + i^{h*}_{H,t}\right) \\ &= \frac{1-s}{s}\left(1-\omega^{*}_{F}\right)\left(\frac{P_{H,t}}{P^{*}_{t}}\right)^{-\varepsilon_F}\left(c^{c*}_{t} + c^{u*}_{t} + c^{e*}_{t} + i^{*}_{t} + i^{h*}_{t}\right). \quad (14) \end{aligned}$$

In equation (14), ω^{*}_{F} and ε_F are the relative weight on foreign goods and the elasticity of substitution between home and foreign goods, respectively, in foreign agents' consumption and investment baskets; P^{*}_{t} is the core's CPI; and z^{*}_{t}, $z = c^c, c^u, c^e, i, i^h$, are per capita demand for home goods by the different foreign agents.

As mentioned before, home agents can lend to and borrow from foreigners and other domestic agents at a riskless nominal rate R_t. We denote by

$$nfa_t \equiv d_t - b_t - b^{e}_{t} \quad (15)$$

the periphery's real (CPI-deflated) per capita net foreign asset position. Following standard practice in the literature, in order to guarantee stationarity of the net foreign asset position, we assume that R_t is given by

$$R_t = R^{MU}_{t} \exp\left(-\psi \frac{P_t nfa_t}{P_{H,t} gdp_t}\right),$$

where $\psi > 0$ and gdp_t is the real (PPI-deflated) per capita GDP, to be derived later.

[12] The same holds for foreign good varieties: $P_{F,t}(z') = P^{*}_{F,t}(z')$ for all $z' \in [0,1]$, such that $P_{F,t} = P^{*}_{F,t}$.

2.7 Aggregation and Market Clearing

Each retailer z demands $y_t^d\left(P_{H,t}\left(z\right)\right)$ units of the intermediate input, as given by (12). Total demand for the latter equals $\int_0^1 y_t^d\left(P_{H,t}\left(z\right)\right)dz = y_t\Delta_t$, where $\Delta_t \equiv \int_0^1 \left(P_{H,t}\left(z\right)/P_{H,t}\right)^{-\varepsilon_p} dz$ denotes relative price dispersion. Market clearing in the intermediate good market thus requires

$$k_{t-1}^{\alpha_k}\left(h_{t-1}^e\right)^{\alpha_h}\left(n_t^e\right)^{1-\alpha_h-\alpha_k} = y_t\Delta_t.$$

Aggregate demand for the basket of home good varieties is given by

$$y_t = c_{H,t}^c + c_{H,t}^u + c_{H,t}^e + i_{H,t} + i_{H,t}^h + g_t + x_t. \tag{16}$$

Total demand for real estate must equal total supply,

$$h_t + h_t^u + h_t^e = I_t^h + \left(1-\delta_h\right)\left(h_{t-1} + h_{t-1}^u + h_{t-1}^e\right).$$

Total demand for equipment capital must equal total supply: $k_t = I_t + \left(1-\delta_k\right)k_{t-1}$. Labor market clearing requires $n_t^c + n_t^u = n_t^e + n_t^h$. We define real (PPI-deflated) per capita GDP as

$$\begin{aligned} gdp_t &\equiv y_t + \frac{P_t}{P_{H,t}}\left(q_tI_t - i_t\right) + \frac{P_t}{P_{H,t}}\left(p_t^hI_t^h - i_t^h\right) \\ &= \frac{P_t}{P_{H,t}}c_t^{tot} + \frac{P_t}{P_{H,t}}\left(q_tI_t + p_t^hI_t^h\right) \\ &\quad + \left[x_t - \frac{P_{F,t}}{P_{H,t}}\left(c_{F,t}^{tot} + i_{F,t} + i_{F,t}^h\right)\right], \end{aligned}$$

where in the second equality we have used (16) and $z_{H,t} = \frac{P_t}{P_{H,t}}z_t - \frac{P_{F,t}}{P_{H,t}}z_{F,t}$ for $z = c^c, c^u, c^e, i, i^h$, and where $c_t^{tot} \equiv c_t^c + c_t^u + c_t^e$ is total consumption (total consumption imports $c_{F,t}^{tot}$ are defined analogously).

Zero net supply of nominal international bonds requires

$$sP_tnfa_t + \left(1-s\right)P_t^*nfa_t^* = 0,$$

where the core's real per capita net foreign asset position, nfa_t^*, is defined analogously to (15). We may combine all domestic market clearing conditions and budget constraints to obtain the periphery's current account identity,

$$nfa_t = \frac{R_{t-1}}{\pi_t} nfa_{t-1} + \frac{P_{H,t}}{P_t} x_t - \frac{P_{F,t}}{P_t} \left(c^{tot}_{F,t} + i_{F,t} + i^h_{F,t} \right).$$

2.8 Calibration and Solution Method

We calibrate our two-country monetary union model to the European Monetary Union, where the country labeled "periphery" broadly represents the member states in the so-called EA periphery. As explained in the introduction, we are motivated by the recent experience of the peripheral EA economies, where the private sector is still embarked in a gradual deleveraging process, and for which structural reforms in product and labor markets have been advocated as a means of fostering economic recovery.

The share of the total population that lives in the periphery is set to $s = 1/3$, following Blanchard, Erceg, and Lindé (2014). The rest of the calibration closely follows Andrés, Arce, and Thomas (2015), who calibrate a similar model to the Spanish economy.[13] The time period is a quarter. Some parameters will be calibrated by matching the model's steady state to a number of empirical targets in 2007, the year prior to the start of the international financial crisis.[14]

The discount factor of the impatient agents is set to $\beta = 0.98$, following Iacoviello (2005). For patient households, we choose $\beta^u = 1.025^{-1/4}$, which is consistent with a steady-state nominal interest rate of $R_{ss} = 1.025^{1/4}\pi_{ss} = \bar{R}^{MU} e^{-\psi(nfa^y_{ss})}$. We set the long-run inflation target $\bar{\pi}^{MU}$ to 1, which implies $\pi_{ss} = \pi^*_{ss} = 1$ in a stationary equilibrium. Choosing $\bar{R}^{MU} = 1.02^{1/4}$ for the nominal policy interest rate, we then set ψ to replicate net foreign assets over GDP in 2007, $nfa^y_{ss} = -79.3$ percent. The inverse labor supply elasticity is set to $\varphi = 4$, consistent with a large body of micro evidence. The weight parameter in the consumption basket, ω_H, is set to match

[13]We thus opt for calibrating the home country to Spain, rather than building consolidated aggregates for the peripheral EMU economies.

[14]We do not claim, however, that the Spanish economy was in (or close to) a steady state in 2007. Instead, our model's steady state should be interpreted as the economy's initial condition for the purpose of our simulation exercises.

gross exports over GDP in 2007 (26.9 percent). Based on evidence for Spain in García et al. (2009), the price elasticity of exports and imports is set to $\varepsilon_F = \varepsilon_H = 1$.

The elasticities of substitution across varieties of consumption goods and labor services, ε_p and ε_w, and the tax rates on retailers' revenue and labor income, τ_p and τ_w, determine the desired markups in product and labor markets, respectively. We set $\varepsilon_p = 7$ and $\tau_p = 0$, implying an initial price markup of $(1-\tau_p)^{-1}\varepsilon_p/(\varepsilon_p - 1) = 1.17$, which is broadly consistent with estimates by Montero and Urtasun (2014) based on Spanish firm-level data. Wage markups are hard to estimate empirically, so we adopt an alternative calibration strategy. We follow Galí (2011) in reinterpreting the EHL model of wage setting in a way that delivers equilibrium unemployment (see appendix 2 for details). Targeting an unemployment rate of 8.6 percent in 2007, we obtain an initial wage markup of $(1-\tau_w)^{-1}\varepsilon_w/(\varepsilon_w - 1) = 1.43$, which we achieve by setting $\tau_w = 0$ and $\varepsilon_w = 3.31$.[15]

The elasticity of entrepreneurial output with respect to equipment capital and commercial real estate are set to $\alpha_k = 0.11$ and $\alpha_h = 0.21$, which are chosen to replicate the labor share of GDP in 2007 (61.6 percent) and the share of equipment capital in the total stock of productive capital.[16] As in Iacoviello and Neri (2010) we set $\delta_h = 0.01$, whereas δ_k is set to a standard value of 0.025. The elasticity of construction output with respect to labor ω is set to match the construction share of total employment in 2007 (13.4 percent). The weight of utility from housing services, ϑ, is chosen to replicate gross household debt over annual GDP (80.2 percent). The share of constrained and unconstrained workers in the labor baskets is set to $\mu_h = \mu_e \equiv \mu = 1/2$. The scale parameters of

[15]Our choice of τ_p and τ_w is motivated as follows. In this paper, we implement structural reforms by changing the elasticity parameters ε_p and ε_w. Setting $\tau_p = \tau_w = 0$ allows us to isolate the effects of structural reforms from additional fiscal effects operating through the budget constraint of constrained households (in particular, through changes in lump-sum taxes T_t). See Andrés, Arce, and Thomas (2015) for a discussion of the effects of reforms implemented via reductions in τ_p and τ_w.

[16]Using data from BBVA Research, we obtain that the value of equipment capital was 21.4 percent of the total value of productive capital in 2007.

convex investment adjustment costs, Φ_h and Φ_k, are chosen such that the fall in construction and equipment capital investment in our baseline deleveraging scenario resembles their behavior during the crisis.[17]

The Calvo parameters are set to $\theta_p = 2/3$ and $\theta_w = 3/4$, such that prices and wages are adjusted every three and four quarters on average, respectively. This is consistent with survey evidence for the Spanish economy (see, e.g., Druant et al. 2009).

The parameters that regulate the debt constraints are calibrated as follows. According to data from the Spanish Land Registry office, loan-to-value (LTV) ratios for new mortgages prior to the crisis were slightly below 70 percent. We thus set $\bar{m} = 0.70$ for the household's initial loan-to-value ratio. The entrepreneurial initial loan-to-value ratio is chosen to match the ratio of gross non-financial corporate debt to annual GDP (125.4 percent in 2007), which yields $\bar{m}^e = 0.64$. Finally, we calibrate the contractual amortization rates, $1 - \gamma$ and $1 - \gamma^e$, in order to replicate the average age of the stock of outstanding mortgage debt prior to the crisis. This yields $1 - \gamma = 0.02$ and $1 - \gamma^e = 0.03$ per quarter.[18]

For the core, for simplicity we assume a fully symmetric calibration, with two exceptions. First, the weight on periphery goods in the consumption basket of core consumers, ω_F^*, is set in order to normalize the terms of trade in the initial steady state to 1.[19] Second, we allow for an additional parameter in the interest rate premium

[17] In particular, we set Φ_h and Φ_k such that the accumulated fall in construction and equipment capital investment eight quarters after the financial shock replicates their accumulated fall eight quarters after their peak in 2007:Q4 (24.5 percent and 28 percent, respectively).

[18] Under our debt contracts (with a constant fraction of outstanding debt amortized each period), the average age of the debt stock converges in the steady state to $\gamma/(1-\gamma)$ and $\gamma^e/(1-\gamma^e)$ for households and entrepreneurs, respectively. According to calculations by Banco de España, based on data from the Land Registry office and large financial institutions, the average age of outstanding mortgage debt prior to the crisis was close to 12.5 years for households and 8 years for non-financial corporations and entrepreneurs. This yields $\gamma = 12.5 \times 4/(12.5 \times 4 + 1) = 0.98$ and $\gamma^e = 8 \times 4/(8 \times 4 + 1) = 0.97$.

[19] Unlike in the case of ω_H, which was calibrated to match an exports target for the home country (equivalently, an imports target, given the target for the ratio of net foreign assets to GDP), ω_F^* cannot be targeted to the foreign country's exports because these must equal the home country's imports in the model.

of the core and set it such that interest rates are the same in both countries in the initial steady state.[20]

Finally, we assume a standard value of 1.5 for the Taylor-rule coefficient ϕ, which together with the long-run target for the policy rate chosen above ($\bar{R}^{MU} = 1.02^{1/4}$) completes the specification of the monetary policy rule. Table 1 summarizes the calibration.

2.8.1 Solution Method

We assume perfect foresight in all our simulations. We solve for the fully non-linear equilibrium path, using a variant of the Newton-Raphson algorithm developed by Laffargue (1990), Boucekkine (1995), and Juillard (1996) (LBJ). As discussed in the previous section, our assumption of long-run debt contracts gives rise to two debt regimes for households and entrepreneurs. If collateral values are above the contractual debt amortization paths, then debt levels are restricted by the former, according to equations (6) and (9). If the opposite holds, then new credit flows collapse to zero and debt is restricted by the contractual amortization path (equations (7) and (10)). Moreover, the presence of the ZLB on nominal interest rates (see equation (13)) implies that the economy may also switch endogenously between two monetary policy regimes, depending on whether the ZLB binds or not. We have therefore extended the LBJ algorithm to allow for endogenous changes of *both* debt and monetary policy regimes. In particular, the dates at which these regime changes take place are solved as equilibrium objects.

3. Baseline Scenario: Deleveraging and the ZLB

In this section we construct a baseline scenario that is meant to capture some important features of the current economic situation in the EA and, particularly, in its peripheral economies. On the one hand, the latter economies are experiencing a protracted process of private-sector deleveraging. With this aim, we will first simulate the effects of a deleveraging shock in the periphery, assuming the common monetary authority is able to reduce nominal interest

[20]In particular, we assume $R_t^* = R_t^{MU} \exp\left[-\psi^* \left(P_t^* nfa_t^* / P_{F,t} gdp_t^*\right) + \psi_0^*\right]$, with $\psi^* = \psi$, and set ψ_0^* such that $R_{ss} = R_{ss}^*$.

Table 1. Calibration

Parameter	Value	Description
s	1/3	Relative size of home country
		Preferences
β^u, β^{u*}	0.994	Unconstrained household discount factor
β, β^*	0.98	Constrained household discount factor
φ, φ^*	4	(Inverse) labor supply elasticity
ϑ, ϑ^*	0.38	Weight on housing utility
$\varepsilon_p, \varepsilon_p^*$	7	Elasticity of substitution across consumption varieties
$\varepsilon_w, \varepsilon_w^*$	3.31	Elasticity of substitution across labor varieties
ω_H, ω_F^*	0.72, 0.86	Weight on domestic goods in consumption basket
$\varepsilon_H, \varepsilon_F$	1	Elasticity of substitution between domestic and imported goods
		Technology
α_h, α_h^*	0.21	Elasticity output with regard to real estate
α_k, α_k^*	0.11	Elasticity output with regard to equipment
ω, ω^*	0.43	Elasticity construction with regard to labor
δ_h, δ_h^*	0.01	Depreciation real estate
δ_k, δ_k^*	0.025	Depreciation equipment
μ, μ^*	0.5	Share of constr. households in labor baskets
Φ_h, Φ_h^*	6.1	Investment adjustment costs construction
Φ_k, Φ_k^*	2.4	Investment adjustment costs equipment
		Price/Wage Setting
θ_p, θ_p^*	0.67	Fraction of non-adjusting prices
θ_w, θ_w^*	0.75	Fraction of non-adjusting wages
		Debt Constraints
$\bar{m}, \bar{m}^*$	0.70	Household LTV ratio
$\bar{m}^e, \bar{m}^{e*}$	0.64	Entrepreneur LTV ratio
γ, γ^*	0.98	Amortization rate household debt
γ^e, γ^{e*}	0.97	Amortization rate entrepreneurial debt
		Monetary Policy
$\phi, \bar{R}^{MU}$	1.5, $1.02^{1/4}$	Taylor-rule coefficient, long-run policy rate

rates so as to partially counteract the resulting fall in union-wide inflation.

On the other hand, the ECB is currently restricted in its ability to further reduce nominal interest rates, as the latter are already very close to the zero bound. Thus, we will consider a second scenario in which, simultaneously to the deleveraging shock, a negative union-wide demand shock occurs that pushes the monetary authority's nominal interest rate against its ZLB. The latter scenario, with both private-sector deleveraging in the periphery and a binding ZLB, will constitute the main baseline scenario with respect to which we will evaluate the effects of, and synergies between, alternative macroeconomic policies.

3.1 Adjustment to Deleveraging out of the ZLB

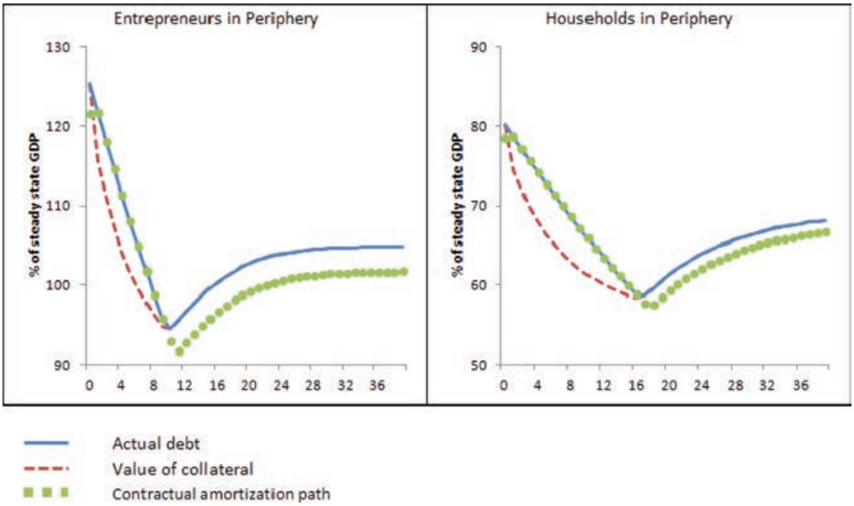
In order to better understand the effects of a deleveraging shock in our model of collateral constraints and long-run debt, we first subject the model economy to a negative financial shock in the periphery that reduces the availability of credit for borrowers. Our "credit crunch" consists of an unexpected, gradual, permanent drop in the LTV ratios of both households and entrepreneurs—m_t and m_t^e, respectively. In particular, we assume an autoregressive process for both LTV ratios: $x_t = (1 - \rho^x)\,\bar{x} + \rho^x x_{t-1}$, $x = m, m^e$, where we set $\rho^m = \rho^{m^e} = 0.75$. We then simulate an unanticipated fall in the long-run LTV ratios $(\bar{m}, \bar{m}^e)$ of 7.5 percentage points from their baseline values in table 1, which accords well with recent experience in Spain.[21]

Figure 1 displays the response to the credit crunch of collateral values and contractual amortization paths, together with the actual equilibrium path of outstanding debt, both for entrepreneurs and households in the periphery. Before the shock ($t = 0$), the economy rests in the steady state of the baseline regime, where debt levels equal pledgeable collateral values.[22] The credit crunch shock

[21]Data from the Spanish Land Registry office shows that average LTV ratios for new mortgages declined by 7.7 percentage points in the six years between 2007:Q3 and 2013:Q3.

[22]Indeed, the fact that constrained households and entrepreneurs are both more impatient than unconstrained households, $\beta < \beta^u$, guarantees that the collateral constraint binds for both agents in the steady state.

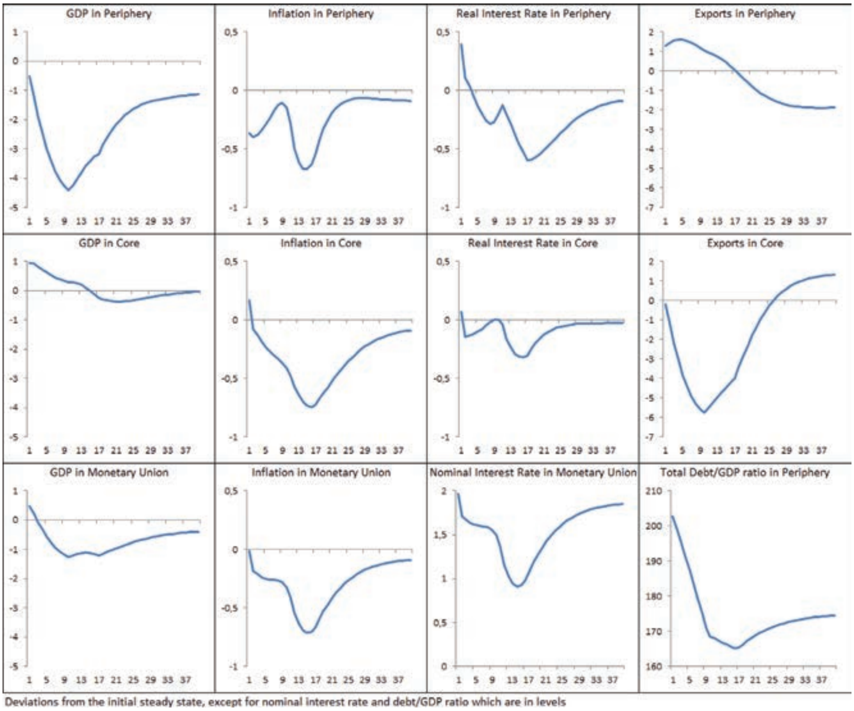
Figure 1. Debt Dynamics after a Deleveraging Shock in the Periphery



drives collateral values *below* the contractual amortization paths already on impact ($t = 1$). Therefore, the economy switches on impact to the alternative regime in which entrepreneurial and household debt stocks decay at the contractual amortization rates. In this phase, the economy undergoes a gradual and prolonged deleveraging process.

Eventually, collateral values rise again above the contractual amortization path, at which point borrowers are able to regain access to fresh funds. We denote by T^* and T^{**} the time at which the endogenous regime change takes place for entrepreneurs and households, respectively. Notice that collateral values and debt both experience a surge at the time of the regime change. This is because real estate becomes again valuable as collateral (see equations (8) and (11)), which pushes up borrowers' demand for real estate and hence its price. Thus, T^* and T^{**} also represent the *duration* of the deleveraging phase for entrepreneurs and households. In the scenario analyzed here, the equilibrium duration of the deleveraging phase is $T^* = 10$ quarters for entrepreneurs and $T^{**} = 17$ quarters for households, the latter being longer due

Figure 2. The Effects of a Deleveraging Shock in the Periphery



mainly to the lower amortization rate of household debt ($1 - \gamma < 1 - \gamma^e$).[23]

Figure 2 shows the response of both countries to the deleveraging shock in the periphery.[24] In the latter, the shock produces a deep and protracted recession, which ends around the period in which

[23]Figure 1 shows that the debt constraints (7) and (10) are binding during $t = 1, \ldots, T^{**} - 1$ and $t = 1, \ldots, T^{*} - 1$, respectively, whereas the collateral constraints (6 and 9) are binding for $t \geq T^{**}$ and $t \geq T^{*}$, respectively. We have verified that the corresponding Lagrange multipliers are indeed strictly positive in the relevant periods, both in the baseline scenario and in all subsequent simulations. Results are available upon request.

[24]In all figures, all variables are in percent, except interest rates (real and nominal), which are in annualized percentage points.

entrepreneurs regain access to new loans ($t = 10$). Such recession is due to the fall in domestic demand (consumption and investment); the latter is only partially counteracted by an improvement in net exports, thanks to the periphery's improvement in competitiveness vis-à-vis the core in the first few years and the contraction in domestic demand.[25] The resulting union-wide deflation leads the monetary authority to reduce nominal interest rates according to the Taylor rule, which produces a mild economic expansion in the core.

3.2 Adjustment to Deleveraging at the ZLB

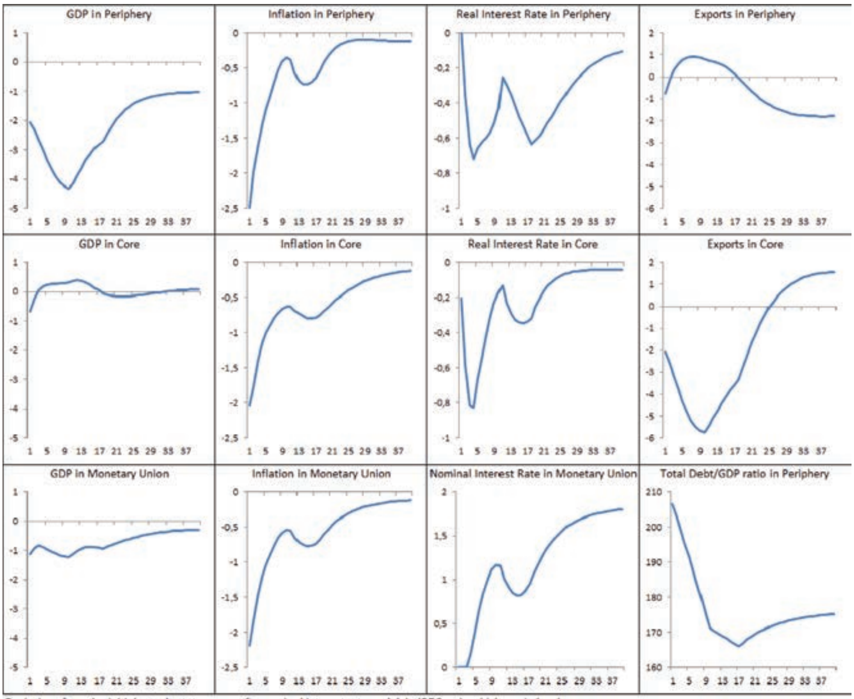
We move next to our main baseline scenario, where, contemporaneously to the deleveraging shock in the periphery, a common negative demand shock affects both countries. In particular, we assume an unanticipated temporary increase in consumers' discount factors. Assuming $\zeta_t = \zeta_{t-1}^{\rho_\zeta} e^{u_t^\zeta}$, we set $u_1^\zeta = 0.005$, i.e., discount factors increase on impact by 2 annualized percentage points, and $\rho_\zeta = 0.90$; we choose this calibration such that the short-run fall in union-wide GDP replicates approximately that of EA GDP during the last recession.[26]

As shown in figure 3, the fall in union-wide inflation in this scenario is large enough to make the monetary authority's nominal interest rate hit the ZLB constraint on impact. After four quarters, the latter constraint ceases to bind, and nominal interest rates increase gradually in sync with union-wide inflation. Not surprisingly, this scenario is more severe for both countries than that displayed in figure 2: peripheral GDP falls more on impact, whereas the core now enters in recession for a few quarters. Overall, our baseline scenario draws a picture of prolonged economic downturn and persistently low inflation at the union level.

[25]The response of variables such as consumption, investment, terms of trade, and net exports are not shown in the figures for brevity, but are available upon request.

[26]In particular, union-wide GDP falls by about 0.85 percent in the first two quarters of the simulation. This is close to the accumulated fall in EMU GDP in the first two quarters of the last recession, which amounted to 0.96 percent.

Figure 3. Baseline Scenario: Deleveraging in the Periphery and a Binding ZLB



Deviations from the initial steady state, except for nominal interest rate and debt/GDP ratio which are in levels

4. Macroeconomic Policies at the ZLB

The baseline scenario constructed in the previous section is meant to broadly capture some of the main macroeconomic difficulties that the EA currently faces: sluggish aggregate demand (aggravated in the periphery by an ongoing deleveraging process), persistently low inflation, and nominal interest rates at their zero bound. Such a scenario poses significant challenges for economic authorities in the EA. Among the measures considered in order to foster recovery in the euro area, three have attracted particular attention from the economic authorities: (i) structural reforms in product and factor markets in countries with weaker public finances (mainly countries in the "periphery"); (ii) countercyclical fiscal policies in those economies with fiscal room to implement them (all of them in the "core"), and

(iii) non-standard monetary policy measures by the ECB aimed at pushing down the interest rate curve beyond the zero-constrained short end, such as forward guidance about the future path of policy interest rates.[27]

We now use our model to analyze the effects of these economic policy measures. We start by looking at the effects of country-specific policies: structural reforms and countercyclical fiscal policies.

4.1 Country-Specific Policies: Structural Reforms and Fiscal Expansion

Structural Reforms. We implement structural reforms by means of an unanticipated, permanent reduction in desired price and wage markups in the periphery, $\varepsilon_p/(\varepsilon_p - 1)$ and $\varepsilon_w/(\varepsilon_w - 1)$, respectively. Both are assumed to fall by 1 percent, following Eggertsson, Ferrero, and Raffo (2014).[28] Figure 4 displays the *marginal* effects of these reforms (i.e., with respect to the baseline scenario without such reforms), depending on whether the baseline scenario features the union-wide negative demand shock, i.e., a binding ZLB.[29] As a natural outcome of the greater degree of competition and efficiency in product and labor markets, structural reforms give rise to transitory lower inflation rates. This deflationary pressure tends to depress ceteris paribus the aggregate demand in the periphery, via the increase in the real value of debt ("debt deflation" channel). The latter effect is amplified when nominal interest rates cannot be reduced further (dashed lines in figure 4), thereby prompting an increase in real short-term interest rates that has an adverse impact on consumption and investment.

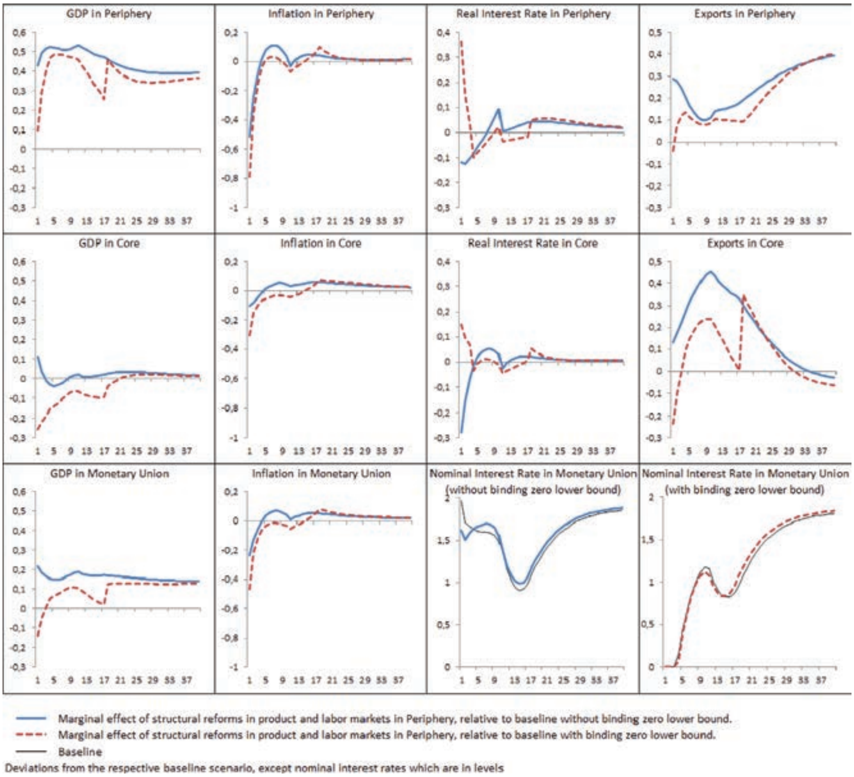
These contractionary effects are, however, dominated, even in the short term, by a combination of expansionary channels. First, reforms have permanent positive effects on income and consumption, the anticipation of which leads to higher consumption and

[27]See, for example, Coeuré (2014), Draghi (2014), European Commission (2014), and IMF (2014).

[28]In particular, ε_p increases from 7 to 7.45, and ε_w increases from 3.31 to 3.39.

[29]In figures 4–9, which display the marginal effects of alternative macroeconomic policies, spikes typically reflect policy-induced changes in the endogenous duration of households' and entrepreneurs' deleveraging processes (T^*, T^{**}).

Figure 4. Marginal Effects of Structural Reforms in the Periphery



investment in the short run. Second, the previous effect also benefits demand for real estate, pushing up its price and the value of borrowers' collateral. This "collateral channel" fosters spending by borrowers once they regain access to new loans, thus reinforcing the medium and long-run gains in activity. Third, the improvement in the periphery's competitiveness vis-à-vis the core gives rise to a significant and lasting increase in its exports and in domestic demand for its own goods. All these effects give rise to a strong positive effect on peripheral GDP.

In the core, the spillover effect from these reforms depends critically on the incidence of the ZLB. Outside of it, the reduction in the nominal policy interest rate produces a (small) increase in GDP.

At the ZLB, however, monetary policy cannot counteract the core's loss of competitiveness, giving rise to a temporary contraction.

Fiscal Expansion. We now consider the effects of a fiscal expansion in the core, implemented through an exogenous temporary increase in government expenditure. Assuming $g_t^* = \rho_g g_{t-1}^* + u_t^{g*}$, we set u_1^{g*} such that g_t^* increases on impact by 1 percent of (ex ante) core GDP, or 0.67 percent of (ex ante) union-wide GDP, which closely resembles the size of the initial public contribution to the so-called Juncker plan for the financing of public infrastructures;[30] we also set $\rho_g = 0.75$, such that the plan has a half-life of about a year. As reflected in figure 5, the fiscal stimulus deploys clearly positive effects on the core's economic activity, but has opposing effects on the periphery's GDP depending on whether the economy is in a liquidity trap.

When monetary policy is not restricted by the ZLB, the positive effects of stronger activity in the core on the periphery through the exports channel are neutralized by the monetary tightening in response to higher union-wide inflation. The net spillover effect on the periphery is actually negative in the short term, although it disappears quickly. By contrast, at the ZLB, the inflationary pressure stemming from the core causes a reduction in real interest rates in both countries. This favors the periphery both through higher exports (thanks to higher spending in the core) and higher domestic demand, the result being a relatively sizable and persistent positive spillover effect.

4.2 Forward Guidance about Monetary Policy

The previous subsection has considered the effects of country-specific policies and how such effects depend on the incidence of the ZLB. We now turn our attention to the effects of "forward guidance" by the common monetary authority when the latter is constrained by the ZLB.

[30] The "Juncker plan" (technically, European Fund for Strategic Investments) aims for an initial push to direct public investment of €63 billion, i.e., 0.66 percent of 2014 EMU GDP. In broader terms, the plan aims for an increase in total (public and private) investment of about €315 billion, or 3.3 percent of euro-area GDP, over a period of three years (2015–17).

Figure 5. Marginal Effects of a Fiscal Expansion in the Core

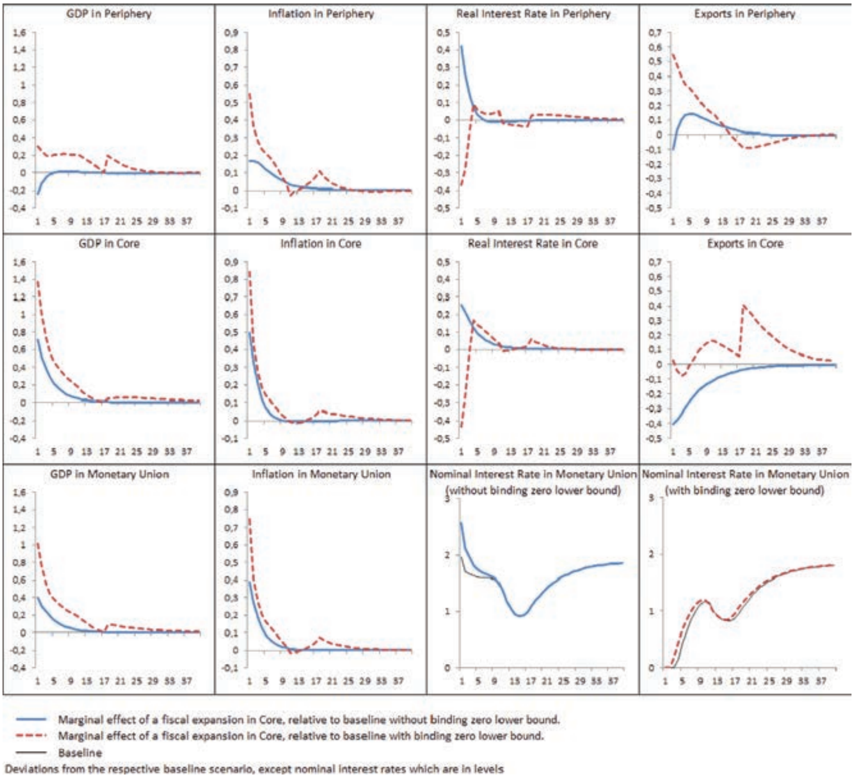
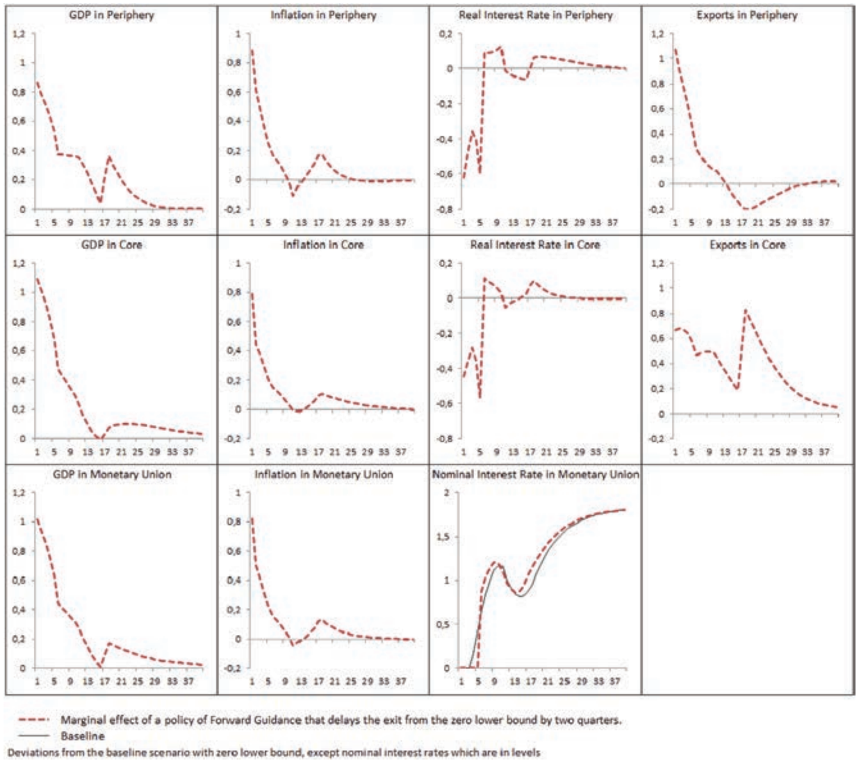


Figure 6 shows the effects (relative to our baseline scenario with a binding ZLB) that would follow from a commitment by the central bank to keep interest rates at zero for two quarters more than what its Taylor rule would dictate in the baseline scenario, i.e., until period $t = 5$ is included.[31] This non-standard monetary policy measure allows to boost GDP in both regions in the short run. The main channel, common to both regions, is the reduction in long-run real interest rates relative to the baseline scenario. The subsequent expansion in activity prompts an increase in inflation in both regions which, coupled with the fact that the nominal policy rate is stuck at

[31] As explained in section 3.2, in the baseline scenario the policy rate exits the liquidity trap at $t = 4$.

Figure 6. Marginal Effects of Forward Guidance



zero for a number of periods, amplifies the decline in long-run real rates and hence the positive impact on economic activity.

It is worth emphasizing that forward guidance produces significant expansionary effects on both countries, which are of similar magnitude on impact, in spite of the presence of binding collateral constraints. This non-Ricardian feature is particularly acute in the periphery since, while deleveraging, no new credit flows to existing debtors. Absent this last feature of the model, forward guidance would produce an unrealistically high expansionary effect on impact,[32] an issue that has received some attention in the recent

[32]Specifically, in the model version in which the periphery does not enter the slow deleveraging regime, the impact of forward guidance would be around two and a half times bigger than the one in our baseline.

literature on forward guidance in DSGE models (the *forward guidance puzzle*).[33]

5. Policy Synergies

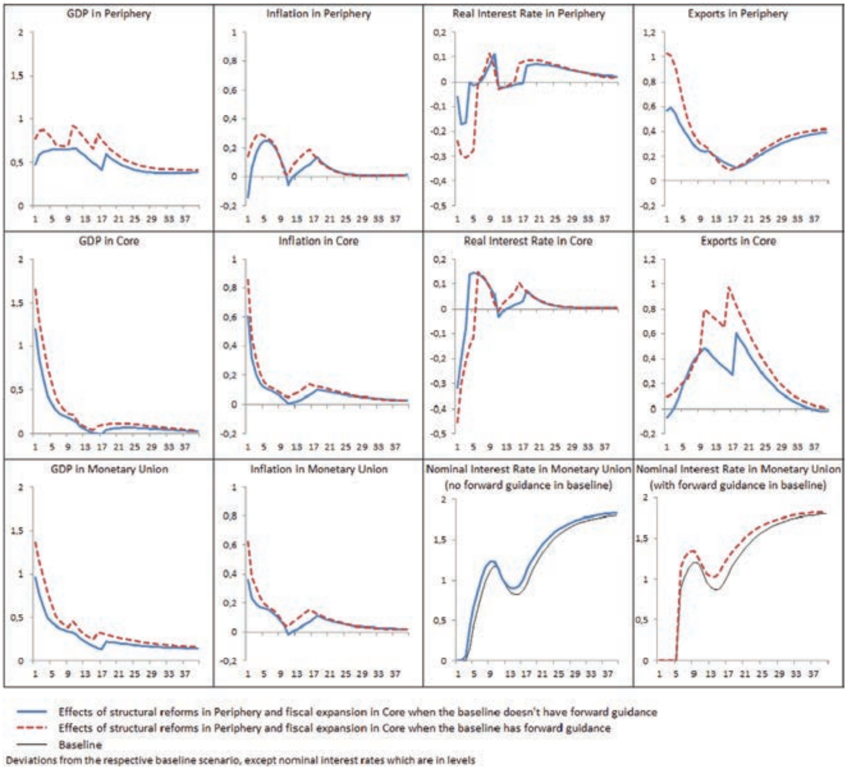
The previous exercises show that the three types of policies considered have the potential to alleviate the costs associated with negative real and financial shocks. The three policies, however, are implemented by different authorities: the two national governments and the common monetary authority. As discussed before, in policy circles, increasing attention is being devoted to the potential gains that could be achieved if the different authorities within the EA were to *jointly* implement their respective policy/reform packages. Thus, a key question to ask in the context of our model is whether some complementarities or *synergies* exist between the policies considered thus far. In particular, we now investigate to what extent each policy reinforces the effects of the other. The non-linear nature of our model (together with our reliance on a fully non-linear solution method) makes it well suited for analyzing this issue.

We start by quantifying how forward guidance modifies the effectiveness of country-specific policies. Figure 7 compares the marginal effects of jointly implementing structural reforms in the periphery and fiscal expansion in the core vis-à-vis two different reference scenarios that differ in the monetary policy stance: one in which the monetary authority passively follows its ZLB-constrained Taylor rule (which corresponds to our baseline scenario in section 3.2), and one in which the monetary authority implements a forward guidance policy as formulated in the previous subsection. Clearly, country-specific policies are more effective, both in the periphery and the core, when in parallel to such policies the central bank commits to a lower future path for its policy rate.

We now analyze to what extent the implementation of national policies favors or hinders the effectiveness of forward guidance by the common monetary authority. Figure 8 compares the marginal effects of forward guidance relative to two different scenarios: one in which national authorities implement their respective policy pack (reforms

[33] See, e.g., Del Negro, Giannoni, and Patterson (2012), De Graeve, Ilbas, and Wouters (2014), and McKay, Nakamura, and Steinsson (2015).

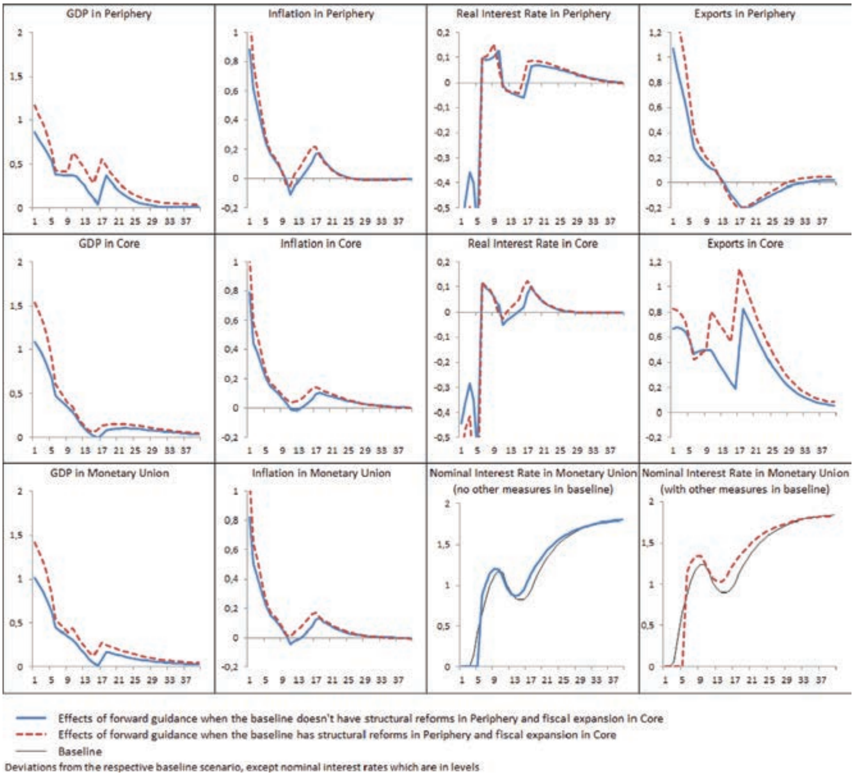
Figure 7. Marginal Effects of National Policies, with and without Forward Guidance in the Baseline



in the periphery, fiscal expansion in the core), and one in which they do not. Again, we find sizable synergies between both groups of policies: forward guidance is more effective in fostering economic activity, both in the core and in the periphery, when governments in the latter countries carry out their respective measures.

To summarize, our analysis suggests that, in a scenario characterized by a liquidity trap and a prolonged deleveraging process in a sizable part of the monetary union, the joint implementation of country-specific policy stimuli and forward guidance by the common monetary authority may give rise to first-order gains in short-run economic activity, not just in the union as a whole but also in each individual country.

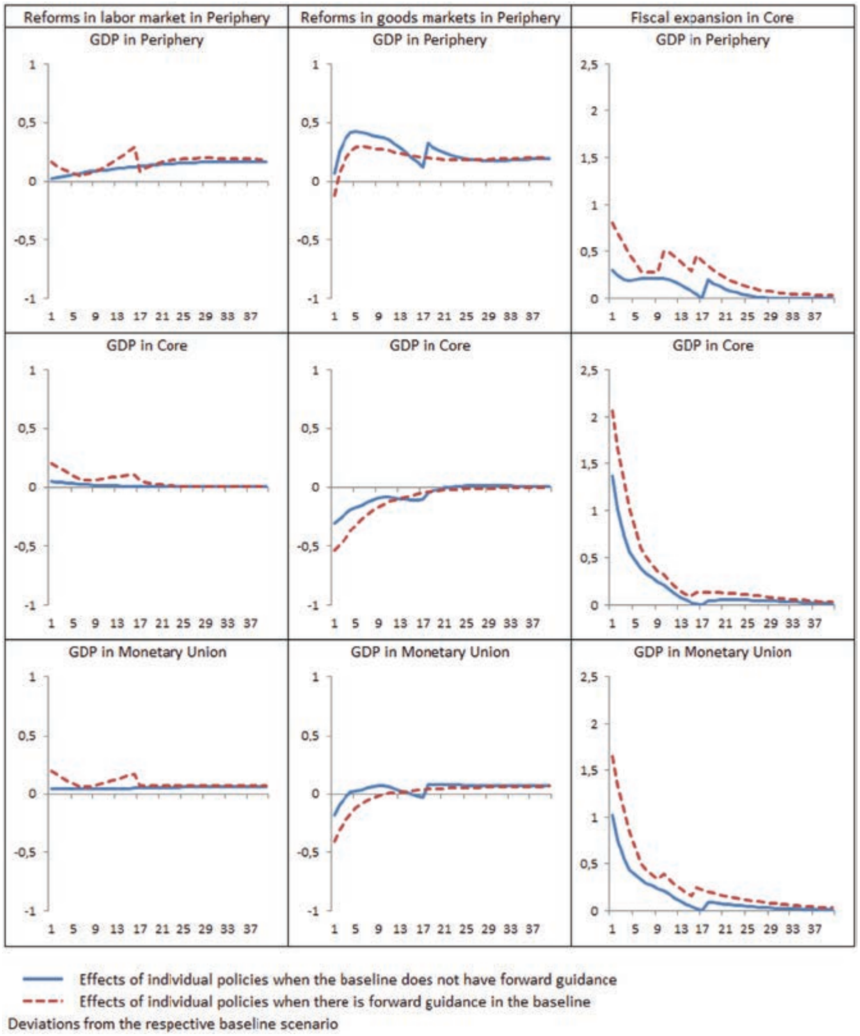
Figure 8. Marginal Effects of Forward Guidance, with and without National Policies in the Baseline



5.1 Inspecting the Synergy Channels

So far we have analyzed the synergies between forward guidance, on the one hand, and a combination of country-specific policies, on the other. In order to gain further insights into the sources of these synergies, here we analyze the interaction between forward guidance and individual country-specific policies, i.e., we consider separately structural reforms in the periphery and fiscal expansion in the core. Moreover, we also distinguish between reforms in product markets and labor markets, as both types of reforms may differ in their potential for synergies. Figure 9 displays the marginal effects of a labor market reform and a product market reform—both in the

Figure 9. GDP Synergies between Country-Specific Policies and Forward Guidance



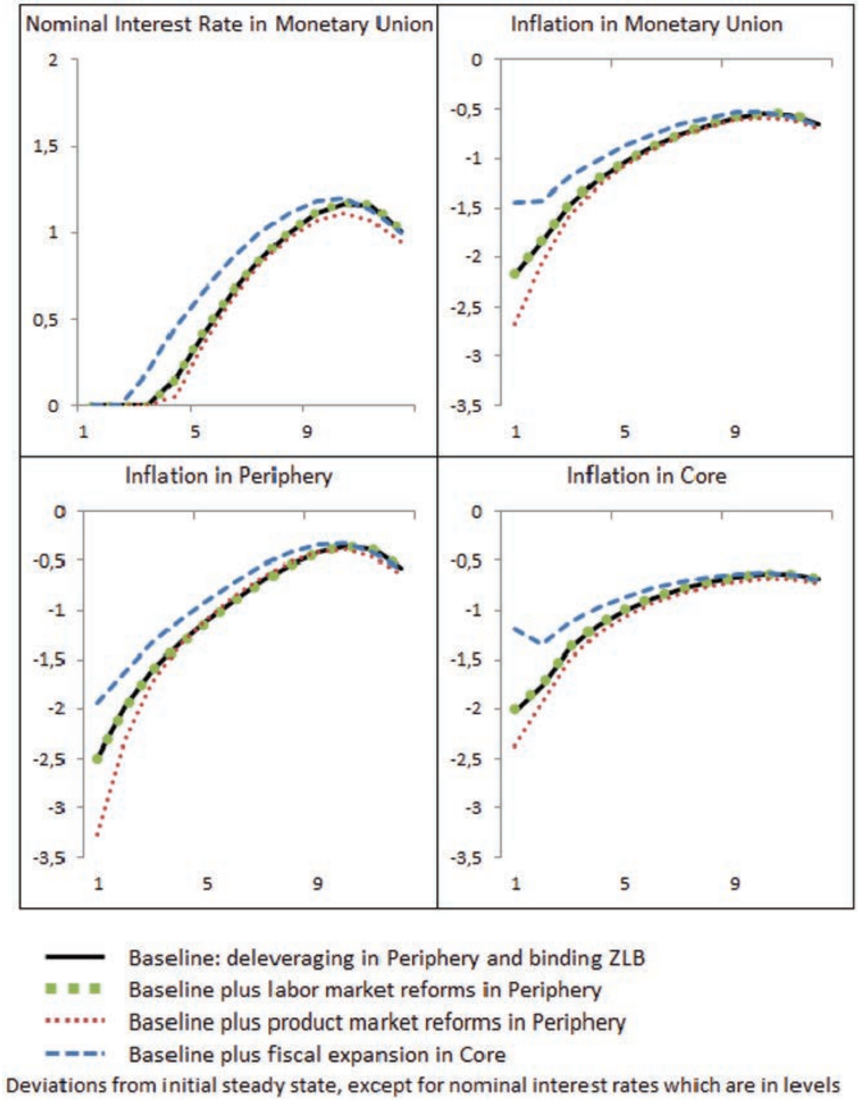
periphery—and fiscal expansion in the core, relative to two different reference scenarios: one where the monetary authority follows the ZLB-constrained Taylor rule (the baseline scenario described in section 3.2), and one where it announces and applies forward guidance. Again, the latter is defined as a commitment to keeping nominal interest rates at zero until two quarters after the lift-off date in the baseline, no-policy-change scenario. We find that, unlike the labor market reform, the product market reform displays *negative* synergies with forward guidance, whereas the fiscal expansion in the core has clearly positive synergies.

To understand these results, we focus on two different mechanisms through which synergies arise in our framework. On the one hand, country-specific policies unleash positive effects on domestic GDP that go beyond the short term. This is particularly the case for structural reforms (both in product and labor markets), as these have permanent expansionary effects on the periphery's GDP, as shown by the solid lines in figure 9. Thus, the fall in long-run real interest rates induced by forward guidance amplifies the present-discounted value of such future expansionary effects. This induces an additional stimulus in current consumption and investment decisions, giving rise to an increase in area-wide economic activity and inflation in the short term. We may refer to this channel as the *discounting effect*.

On the other hand, country-specific policies imply different endogenous effects on the nominal interest rate path when monetary policy follows the standard ZLB-constrained Taylor rule. As shown in figure 10, a demand-side stimulus such as a fiscal expansion in the core brings forward the lift-off date for the policy rate by one quarter, which tends to buffer the expansionary impact of this measure.[34] However, if the central bank commits to keeping interest rates at zero for longer than what the Taylor rule would imply in the baseline, then the same fiscal expansion does *not* produce an upward shift in the nominal interest rate path relative to the no-expansion reference scenario. As a result, forward guidance strengthens the effects of the fiscal expansion, i.e., a positive synergy arises. By contrast, a supply-side measure such as a structural reform has the opposite effect on monetary policy. As shown by figure 10, the product market reform (i.e., the 1 percent reduction in desired price markups) is not deflationary enough to delay the

[34]See Erceg and Lindé (2014) for an in-depth analysis of the effects of government spending shocks at the ZLB when the lift-off date is endogenous to the size of such shocks.

Figure 10. Effects of Country-Specific Policies on Nominal Interest Rates and Inflation



lift-off date, but it does moderate the magnitude of the nominal interest rate increase once the latter exits the ZLB, which strengthens the expansionary effect of the reform. Following the same logic as before, forward guidance partially undoes the positive effect from the reform. We may refer to this channel as the *lift-off effect*.[35]

In light of these two channels, we can better understand the difference in the sign and size of synergies between forward guidance and different country-specific policies. In the case of the fiscal expansion in the core, the lift-off date effect is particularly important in generating positive synergies with forward guidance, whereas the discounting effect is relatively less important, as the expansionary effects are rather short-lived. The product market reform features both the (positive) discounting effect and a negative lift-off effect. Quantitatively, the second effect dominates, giving rise to the negative synergies with forward guidance. Finally, the labor market reform features a similar discounting effect but essentially no lift-off effect, because it is much less deflationary than the comparable product market reform.[36] As a result, it generates positive synergies.

Finally, it is worthwhile to explore the role that the deleveraging process in the periphery may play in creating policy synergies. Table 2 shows the periods in which entrepreneurs and households exit their respective deleveraging phase (T^{*}, T^{**}) in each scenario. All the policy measures tend to *bring forward* the end of deleveraging and hence the economic recovery in the periphery. For instance, when all policies are implemented simultaneously, deleveraging is shortened relative to the baseline by [10 18] − [9 15] = [1 3] quarters for entrepreneurs and households, respectively. Notice also that forward guidance shortens deleveraging by [10 18] − [10 16] = [0 2] quarters relative to the baseline scenario, but by [10 17] − [9 15] = [1 2] quarters when the reference scenario includes the

[35]Strictly speaking, neither the product nor the labor market reform delay the lift-off *date* relative to the baseline. Therefore, the lift-off effect in this case refers to the intensity of the nominal rate increase once outside of the ZLB. For larger price markup reductions than the one assumed here (1 percent), the product market reform does delay the lift-off date. Results are available upon request.

[36]As emphasized by Andrés, Arce, and Thomas (2015), reductions in desired wage markups must overcome a *double* layer of nominal rigidities (first wages, then prices) before affecting actual production prices.

Table 2. Dates of Exit from ZLB and Deleveraging

Scenario	ZLB	Deleveraging	
		Entrepreneurs	Households
Baseline (no policies)	4	10	18
Product Market Reform	4	10	17
Labor Market Reform	4	10	18
Fiscal Expansion	3	10	17
Forward Guidance	6	10	16
Reforms (product + labor)	4	10	17
Reforms + Fiscal Expansion	3	10	17
All Policies	6	9	15

national policy package (reforms + fiscal expansion); i.e., relative to what it could achieve if implemented in isolation, forward guidance shortens entrepreneurial deleveraging by one more quarter when national policies are applied simultaneously. The same result holds for the differential effect of the national policy package on deleveraging. These results therefore suggest that the effects of the various policies on the endogenous deleveraging dynamics in the periphery may also contribute toward creating synergies among such policies.

6. Concluding Remarks

We have provided a general equilibrium framework for analyzing the effects of supply- and demand-side policies, the associated cross-country spillovers, and the potential synergies between such policies, in an asymmetric monetary union that faces a liquidity trap and a slow deleveraging process in its "periphery." The set of policies that we consider is inspired by the current situation in the EA. On the demand side, we analyze (i) the effects of forward guidance about the future path of nominal policy interest rates, as a means of alleviating the constraints imposed by a binding ZLB on short-term rates; and (ii) those of a fiscal expansion in the "core," i.e., in those countries in the union with sufficient fiscal capacity to implement such an expansion. On the supply side, we study the role of pro-competition structural reforms in the periphery.

In terms of spillovers, we find that the effects of national policies on other countries depend crucially on whether monetary policy is constrained by the ZLB. Thus, deflationary structural reforms in the periphery tend to create (small) contractionary effects in the "core" when the monetary authority cannot accommodate such a deflationary pressure. On the contrary, a fiscal expansion in the core may benefit the periphery, provided the monetary authority is stuck at the ZLB and hence does not react to the resulting inflationary pressure.

As regards the synergies across these policies, we find potentially sizable short-run economic gains from their joint implementation. Thus, forward guidance reinforces the expansionary effects of country-specific policies, and the latter in turn improve the effectiveness of forward guidance. Two prominent channels through which these synergies take places are the following. First, forward guidance lowers long-run real interest rates and hence increases the present-discounted value of the future output and consumption gains produced by national stimulus policies, thus fostering investment and consumption already in the short run. Second, under our implementation of forward guidance, the latter reinforces the expansionary effects of demand-side policy stimuli, such as a fiscal expansion, by avoiding the upward shift in the nominal interest rate path that such stimuli would otherwise produce.

It should be stressed that our results are conditional on our assumed form of forward guidance. Exploring the synergies between country-specific policies and forward guidance for alternative formulations of the latter is an important avenue for further research.

Appendix 1. Equilibrium Conditions

In order to express all equations in terms of stationary variables, we define $p_{H,t} \equiv P_{H,t}/P_t, \pi_{H,t} \equiv P_{H,t}/P_{H,t-1}$ (PPI inflation), $\hat{p}_t \equiv P_{H,t}/P_{F,t}$ (terms of trade), $\tilde{p}_t \equiv \tilde{P}_{H,t}/P_{H,t}$, $w_t \equiv W_t/P_t$, $\tilde{w}_t \equiv \tilde{W}_t/W_t$, and $\pi_{wt} \equiv W_t/W_{t-1}$; analogously for the foreign economy, $p^*_{F,t} \equiv P^*_{F,t}/P^*_t$, $\pi_{F,t} \equiv P^*_{F,t}/P^*_{F,t-1}$, $\hat{p}^*_t \equiv P_{F,t}/P_{H,t}$, etc.

Home Country

- Unconstrained household budget constraint and first-order conditions (c_t^u, d_t, h_t^u),

$$\lambda_t^u = \frac{\zeta_t}{c_t^u}, \tag{17}$$

$$\begin{aligned} c_t^u + d_t + p_t^h \left[h_t^u - (1-\delta_h)\, h_{t-1}^u\right] \\ = \frac{R_{t-1}}{\pi_t} d_{t-1} + (1-\tau_w)\, w_t n_t^u - T_t, \end{aligned} \tag{18}$$

$$\lambda_t^u = \beta^u E_t \frac{R_t}{\pi_{t+1}} \lambda_{t+1}^u, \tag{19}$$

$$\lambda_t^u p_t^h = \frac{\zeta_t \vartheta}{h_t^u} + \beta^u E_t \lambda_{t+1}^u (1-\delta_h)\, p_{t+1}^h. \tag{20}$$

- Constrained household budget constraint, debt constraints, and first-order conditions (c_t^c, b_t, h_t),

$$\lambda_t^c = \frac{\zeta_t}{c_t^c}, \tag{21}$$

$$\begin{aligned} c_t^c + \frac{R_{t-1}}{\pi_t} b_{t-1} + p_t^h \left[h_t - (1-\delta_h)\, h_{t-1}\right] \\ = b_t + (1-\tau_w)\, w_t n_t^c - T_t, \end{aligned} \tag{22}$$

$$b_t \leq \begin{cases} R_t^{-1} m_t E_t \pi_{t+1} p_{t+1}^h h_t, \\ \qquad \text{if } m_t R_t^{-1} E_t \pi_{t+1} p_{t+1}^h h_t \geq \gamma b_{t-1}/\pi_t, \\ \gamma b_{t-1}/\pi_t, \\ \qquad \text{if } m_t R_t^{-1} E_t \pi_{t+1} p_{t+1}^h h_t < \gamma b_{t-1}/\pi_t, \end{cases} \tag{23}$$

$$\begin{aligned} \lambda_t^c = \beta E_t \frac{R_t}{\pi_{t+1}} \lambda_{t+1}^c + \xi_t \mathbf{1}(\varkappa_t \geq 0) + \mu_t \mathbf{1}(\varkappa_t < 0) \\ - \beta\gamma E_t \frac{\mu_{t+1}}{\pi_{t+1}} \mathbf{1}(\vartheta_{t+1} < 0), \end{aligned} \tag{24}$$

$$\begin{aligned} \lambda_t^c p_t^h = \frac{\zeta_t \vartheta}{h_t} + \beta E_t \lambda_{t+1}^c (1-\delta_h)\, p_{t+1}^h \\ + \xi_t \mathbf{1}(\varkappa_t \geq 0) \frac{m_t}{R_t} E_t \pi_{t+1} p_{t+1}^h, \end{aligned} \tag{25}$$

where μ_t is the Lagrange multiplier on constraint (7) in the text, $\mathbf{1}(\cdot)$ is the indicator function, and $\varkappa_t \equiv R_t^{-1} m_t E_t \pi_{t+1} p_{t+1}^h h_t - \gamma b_{t-1}/\pi_t$.

- Entrepreneur budget constraint, debt constraints, and first-order conditions (c_t^e, b_t^e, h_t^e, n_t^e, k_t),

$$\lambda_t^e = \frac{\zeta_t}{c_t^e}, \tag{26}$$

$$\begin{aligned} c_t^e &= mc_t k_{t-1}^{\alpha_k} \left(h_{t-1}^e\right)^{\alpha_h} \left(n_t^e\right)^{1-\alpha_h-\alpha_k} - w_t n_t^e \\ &\quad - p_t^h \left[h_t^e - (1-\delta_h) h_{t-1}^e\right] + b_t^e - \frac{R_{t-1}}{\pi_t} b_{t-1}^e \\ &\quad - q_t \left[k_t - (1-\delta_k) k_{t-1}\right] + \Pi_t^r + \Pi_t^h + \Pi_t^k, \end{aligned} \tag{27}$$

$$b_t^e \leq \begin{cases} R_t^{-1} m_t^e E_t \pi_{t+1} p_{t+1}^h h_t^e, \\ \qquad \text{if } m_t^e R_t^{-1} E_t \pi_{t+1} p_{t+1}^h h_t^e \geq \gamma^e b_{t-1}^e/\pi_t, \\ \gamma^e b_{t-1}^e/\pi_t, \\ \qquad \text{if } m_t^e R_t^{-1} E_t \pi_{t+1} p_{t+1}^h h_t^e < \gamma^e b_{t-1}^e/\pi_t, \end{cases} \tag{28}$$

$$\begin{aligned} \lambda_t^e &= \beta E_t \frac{R_t}{\pi_{t+1}} \lambda_{t+1}^e + \xi_t^e \mathbf{1}\left(\varkappa_t^e \geq 0\right) + \mu_t^e \mathbf{1}\left(\varkappa_t^e < 0\right) \\ &\quad - \beta \gamma^e E_t \frac{\mu_{t+1}^e}{\pi_{t+1}} \mathbf{1}\left(\vartheta_{t+1}^e < 0\right), \end{aligned} \tag{29}$$

$$\begin{aligned} \lambda_t^e p_t^h &= \beta E_t \lambda_{t+1}^e \Big[mc_{t+1} \alpha_h k_t^{\alpha_k} \left(h_t^e\right)^{\alpha_h - 1} \left(n_{t+1}^e\right)^{1-\alpha_h-\alpha_k} \\ &\quad + (1-\delta_h) p_{t+1}^h \Big] + \xi_t^e \frac{m_t^e}{R_t} E_t \pi_{t+1} p_{t+1}^h \mathbf{1}\left(\varkappa_t^e \geq 0\right), \end{aligned} \tag{30}$$

$$w_t = mc_t (1-\alpha_h-\alpha_k) k_{t-1}^{\alpha_k} \left(h_{t-1}^e\right)^{\alpha_h} \left(n_t^e\right)^{-\alpha_h-\alpha_k}, \tag{31}$$

$$\begin{aligned} \lambda_t^e q_t &= \beta E_t \lambda_{t+1}^e \Big[mc_{t+1} \alpha_k k_t^{\alpha_k - 1} \left(h_t^e\right)^{\alpha_h} \left(n_{t+1}^e\right)^{1-\alpha_h-\alpha_k} \\ &\quad + (1-\delta_k) q_{t+1} \Big], \end{aligned} \tag{32}$$

where μ_t^e is the Lagrange multiplier on constraint (7) in the text, and $\varkappa_t^e \equiv R_t^{-1} m_t^e E_t \pi_{t+1} p_{t+1}^h h_t^e - \gamma^e b_{t-1}^e/\pi_t$.

- Retailers' optimal price decision, and aggregate profits,

$$E_t \sum_{s=0}^{\infty} (\beta\theta_p)^s \frac{\lambda_{t+s}^e}{\lambda_t^e} \left[\frac{(1-\tau_p)\,\tilde{p}_t}{\prod_{j=1}^{s} \pi_{H,t+j}} p_{H,t+s} - \frac{\varepsilon_p}{\varepsilon_p - 1} mc_{t+s} \right] \times \left(\frac{\prod_{j=1}^{s} \pi_{H,t+j}}{\tilde{p}_t} \right)^{\varepsilon_p} y_{t+s} = 0, \tag{33}$$

$$\Pi_t^r = y_t \left((1-\tau_p)\, p_{H,t} - mc_t \Delta_t \right). \tag{34}$$

- Dynamics of PPI inflation and price dispersion,

$$1 = (1-\theta_p)\,\tilde{p}_t^{1-\varepsilon_p} + \theta_p \pi_{H,t}^{\varepsilon_p - 1}, \tag{35}$$

$$\Delta_t \equiv (1-\theta_p)\,\tilde{p}_t^{-\varepsilon_p} + \theta_p \pi_{H,t}^{\varepsilon_p} \Delta_{t-1}. \tag{36}$$

- Construction firm output, first-order conditions (n_t^h, i_t^h), and profits,

$$I_t^h = \left(n_t^h\right)^{\omega} \left\{ i_t^h \left[1 - \frac{\Phi_h}{2} \left(\frac{i_t^h}{i_{t-1}^h} - 1 \right)^2 \right] \right\}^{1-\omega}, \tag{37}$$

$$w_t = p_t^h \omega \left(n_t^h\right)^{\omega-1} \left\{ i_t^h \left[1 - \frac{\Phi_h}{2} \left(\frac{i_t^h}{i_{t-1}^h} - 1 \right)^2 \right] \right\}^{1-\omega}, \tag{38}$$

$$\begin{aligned} 1 = {} & p_t^h \left(n_t^h\right)^{\omega} (1-\omega) \left\{ i_t^h \left[1 - \frac{\Phi_h}{2} \left(di_t^h\right)^2 \right] \right\}^{-\omega} \\ & \times \left[1 - \frac{\Phi_h}{2} \left(di_t^h\right)^2 - \Phi_h \left(di_t^h\right) \frac{i_t^h}{i_{t-1}^h} \right] \\ & + \beta \frac{\lambda_{t+1}^e}{\lambda_t^e} p_{t+1}^h \left(n_{t+1}^h\right)^{\omega} (1-\omega) \\ & \times \left\{ i_{t+1}^h \left[1 - \frac{\Phi_h}{2} \left(di_{t+1}^h\right)^2 \right] \right\}^{-\omega} \Phi_h di_{t+1}^h \left(\frac{i_{t+1}^h}{i_t^h} \right)^2, \end{aligned} \tag{39}$$

$$\Pi_t^h = p_t^h I_t^h - w_t n_t^h - i_t^h, \tag{40}$$

for $di_t^h \equiv i_t^h / i_{t-1}^h - 1$.

- Equipment capital producers output, first-order condition (i_t), and profits,

$$I_t = i_t \left[1 - \frac{\Phi_k}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right], \tag{41}$$

$$\begin{aligned} 1 &= q_t \left[1 - \frac{\Phi_k}{2}(di_t)^2 - \Phi_k (di_t) \frac{i_t}{i_{t-1}}\right] \\ &\quad + E_t \frac{\lambda^e_{t+1}}{\lambda^e_t} q_{t+1} \Phi_k di_{t+1} \frac{i^2_{t+1}}{i^2_t}, \end{aligned} \tag{42}$$

$$\Pi^k_t = q_t I_t - i_t, \tag{43}$$

for $di_t \equiv i_t / i_{t-1} - 1$.

- Optimal wage decision,

$$\begin{aligned} &\sum_{x=c,u} E_t \sum_{s=0}^{\infty} (\beta^x \theta_w)^s \left[\frac{(1-\tau_w)\tilde{w}_t}{\prod_{j=1}^{s} \pi^w_{t+j}} \frac{w_{t+s}}{\frac{1}{\lambda^x_{t+s}}} - \frac{\zeta_{t+s}\chi \left(n^x_{t+s}\right)^{\varphi}}{(\varepsilon_w - 1)/\varepsilon_w} \right. \\ &\left. \times \left(\frac{\tilde{w}_t}{\prod_{j=1}^{s} \pi^w_{t+j}}\right)^{-\varepsilon_w \varphi}\right] \left(\frac{\prod_{j=1}^{s} \pi^w_{t+j}}{\tilde{w}_t}\right)^{\varepsilon_w} n^x_{t+s} = 0, \end{aligned} \tag{44}$$

with $\beta^c = \beta$.

- Dynamics of wage inflation and wage dispersion,

$$1 = (1-\theta_w)\tilde{w}_t^{1-\varepsilon_w} + \theta_w \pi_{wt}^{\varepsilon_w - 1}, \tag{45}$$

$$\Delta^{w,n}_t = (1-\theta_w)\tilde{w}_t^{-\varepsilon_w} + \theta_w \pi_{wt}^{\varepsilon_w} \Delta^{w,n}_{t-1}. \tag{46}$$

- Fiscal authority's budget constraint,

$$\tau_w w_t (n^c_t + n^u_t) + \tau_p p_{H,t} y_t + 2T_t = p_{H,t} g_t. \tag{47}$$

- Aggregate employment,

$$N^c_t = n^c_t \Delta^{w,n}_t, \tag{48}$$

$$N^u_t = n^u_t \Delta^{w,n}_t, \tag{49}$$

$$N_t = N^c_t + N^u_t. \tag{50}$$

- Export demand,

$$x_t = \frac{1-s}{s}\left(1-\omega_F^*\right)\left(\hat{p}_t p_{F,t}^*\right)^{-\varepsilon_F}\left(c_t^{c*}+c_t^{u*}+c_t^{e*}+i_t^*+i_t^{h*}\right). \tag{51}$$

- Intermediate good market clearing,

$$y_t\Delta_t = k_{t-1}^{\alpha_k}\left(h_{t-1}^e\right)^{\alpha_h}\left(n_t^e\right)^{1-\alpha_h-\alpha_k}. \tag{52}$$

- Labor market clearing,

$$n_t^c + n_t^u = n_t^e + n_t^h. \tag{53}$$

- Consumption-goods-basket market clearing,

$$y_t = c_{H,t}^c + c_{H,t}^u + c_{H,t}^e + i_{H,t} + i_{H,t}^h + g_t + x_t. \tag{54}$$

- Real estate market clearing,

$$h_t + h_t^u + h_t^e = I_t^h + \left(1-\delta_h\right)\left(h_{t-1} + h_{t-1}^u + h_{t-1}^e\right). \tag{55}$$

- Equipment capital market clearing,

$$k_t = \left(1-\delta_k\right)k_{t-1} + I_t. \tag{56}$$

- Real wages,

$$w_t = w_{t-1}\frac{\pi_{wt}}{\pi_t}. \tag{57}$$

- Terms of trade,

$$\hat{p}_t = \hat{p}_{t-1}\frac{\pi_{H,t}}{\pi_{F,t}}. \tag{58}$$

- Relative demand for domestic goods,

$$z_{H,t} = \omega_H p_{H,t}^{-\varepsilon_H} z_t, \quad z = c^c, c^u, c^e, i, i^h. \tag{59}$$

- Relative demand for constrained/unconstrained household labor,

$$\left(1-\mu\right)n_t^c = \mu n_t^u, \tag{60}$$

where $\mu \equiv \mu_e = \mu_h$.

- Relative domestic producer prices,

$$p_{H,t}^{\varepsilon_H - 1} = \omega_H + (1-\omega_H)\hat{p}_t^{\varepsilon_H - 1}. \tag{61}$$

- CPI inflation,

$$\pi_t^{1-\varepsilon_H} = \frac{\omega_H \left(p_{t-1}^*\right)^{1-\varepsilon_H}}{\omega_H \left(p_{t-1}^*\right)^{1-\varepsilon_H} + 1 - \omega_H} \pi_{H,t}^{1-\varepsilon_H} + \frac{1-\omega_H}{\omega_H \left(p_{t-1}^*\right)^{1-\varepsilon_H} + 1 - \omega_H} \pi_{F,t}^{1-\varepsilon_H}. \tag{62}$$

- Real (PPI-deflated) GDP,

$$gdp_t = y_t + \frac{1}{p_{H,t}}\left(q_t I_t - i_t\right) + \frac{1}{p_{H,t}}\left(p_t^h I_t^h - i_t^h\right). \tag{63}$$

- Gross nominal interest rate,

$$R_t = R_t^{MU} \exp\left(-\psi \frac{d_t - b_t - b_t^e}{p_{H,t} gdp_t}\right). \tag{64}$$

Foreign Country

- Zero net supply of international bonds,

$$s\left(d_t - b_t - b_t^e\right) + (1-s)\frac{p_{H,t}}{\hat{p}_t p_{F,t}^*}\left(d_t^* - b_t^* - b_t^{e*}\right) = 0.$$

- Unconstrained household first-order conditions (c_t^{u*}, d_t^*, h_t^{u*}),

$$\lambda_t^{u*} = \frac{\zeta_t}{c_t^{u*}}, \tag{65}$$

$$\lambda_t^{u*} = \beta^{u*} E_t \frac{R_t^*}{\pi_{t+1}^*} \lambda_{t+1}^{u*}, \tag{66}$$

$$\lambda_t^{u*} p_t^{h*} = \frac{\zeta_t \vartheta^*}{h_t^{u*}} + \beta^{u*} E_t \lambda_{t+1}^{u*}\left(1-\delta_h^*\right) p_{t+1}^{h*}. \tag{67}$$

- Constrained household budget constraint, debt constraints, and first-order conditions (c_t^{c*}, b_t^*, h_t^*),

$$\lambda_t^{c*} = \frac{\zeta_t}{c_t^{c*}}, \tag{68}$$

$$c_t^{c*} + \frac{R_{t-1}^*}{\pi_t^*} b_{t-1}^* + p_t^{h*}\left[h_t^* - (1-\delta_h^*)\, h_{t-1}^*\right]$$
$$= b_t^* + (1-\tau_w^*)\, w_t^* n_t^{c*} - T_t^*, \tag{69}$$

$$b_t^* \le \begin{cases} R_t^{*-1} m_t^* E_t \pi_{t+1}^* p_{t+1}^{h*} h_t^*, \\ \qquad \text{if } m_t^* R_t^{*-1} E_t \pi_{t+1}^* p_{t+1}^{h*} h_t^* \ge \gamma^* b_{t-1}^* / \pi_t^*, \\ \gamma^* b_{t-1}^*/\pi_t^*, \\ \qquad \text{if } m_t^* R_t^{*-1} E_t \pi_{t+1}^* p_{t+1}^{h*} h_t^* < \gamma^* b_{t-1}^* / \pi_t^*, \end{cases} \tag{70}$$

$$\lambda_t^{c*} = \beta^* E_t \frac{R_t^*}{\pi_{t+1}^*} \lambda_{t+1}^{c*} + \xi_t^* \mathbf{1}\left(\varkappa_t^* \ge 0\right) + \mu_t \mathbf{1}\left(\varkappa_t^* < 0\right)$$
$$- \beta^* \gamma^* E_t \frac{\mu_{t+1}}{\pi_{t+1}^*} \mathbf{1}\left(\varkappa_{t+1}^* < 0\right), \tag{71}$$

$$\lambda_t^{c*} p_t^{h*} = \frac{\zeta_t \vartheta^*}{h_t^*} + \beta^* E_t \lambda_{t+1}^{c*} (1-\delta_h^*)\, p_{t+1}^{h*}$$
$$+ \xi_t^* \mathbf{1}\left(\varkappa_t^* \ge 0\right) \frac{m_t^*}{R_t^*} E_t \pi_{t+1}^* p_{t+1}^{h*}, \tag{72}$$

where μ_t is the Lagrange multiplier on constraint (7) in the text, $\mathbf{1}(\cdot)$ is the indicator function, and $\varkappa_t^* \equiv R_t^{*-1} m_t^* E_t \pi_{t+1}^* p_{t+1}^{h*} h_t^* - \gamma^* b_{t-1}^*/\pi_t^*$.

- Entrepreneur budget constraint, debt constraints, and first-order conditions (c_t^{e*}, b_t^{e*}, h_t^{e*}, n_t^{e*}, k_t^*),

$$\lambda_t^{e*} = \frac{\zeta_t}{c_t^{e*}}, \tag{73}$$

$$c_t^{e*} = mc_t^* \left(k_{t-1}^*\right)^{\alpha_k^*} \left(h_{t-1}^{e*}\right)^{\alpha_h^*} \left(n_t^{e*}\right)^{1-\alpha_h^*-\alpha_k^*} - w_t^* n_t^{e*}$$
$$- p_t^{h*}\left[h_t^{e*} - (1-\delta_h^*)\, h_{t-1}^{e*}\right] + b_t^{e*} - \frac{R_{t-1}^*}{\pi_t^*} b_{t-1}^{e*}$$
$$- q_t^*\left[k_t^* - (1-\delta_k^*)\, k_{t-1}\right] + \Pi_t^{r*} + \Pi_t^{h*} + \Pi_t^{k*}, \tag{74}$$

$$b_t^{e*} \le \begin{cases} R_t^{*-1} m_t^{e*} E_t \pi_{t+1}^* p_{t+1}^{h*} h_t^{e*}, \\ \qquad \text{if } m_t^{e*} R_t^{-1} E_t \pi_{t+1}^* p_{t+1}^{h*} h_t^{e*} \ge \gamma^{e*} b_{t-1}^{e*} / \pi_t^*, \\ \gamma^{e*} b_{t-1}^{e*}/\pi_t^*, \\ \qquad \text{if } m_t^{e*} R_t^{-1} E_t \pi_{t+1}^* p_{t+1}^{h*} h_t^{e*} < \gamma^{e*} b_{t-1}^{e*} / \pi_t^*, \end{cases} \tag{75}$$

$$\lambda_t^{e*} = \beta^* E_t \frac{R_t^*}{\pi_{t+1}^*} \lambda_{t+1}^{e*} + \xi_t^{e*} \mathbf{1} \left(\varkappa_t^{e*} \geq 0 \right) + \mu_t^{e*} \mathbf{1} \left(\varkappa_t^{e*} < 0 \right)$$
$$- \beta^* \gamma^{e*} E_t \frac{\mu_{t+1}^{e*}}{\pi_{t+1}^*} \mathbf{1} \left(\varkappa_{t+1}^{e*} < 0 \right), \tag{76}$$

$$\lambda_t^{e*} p_t^{h*} = \beta^* E_t \lambda_{t+1}^{e*} \Big[mc_{t+1}^* \alpha_h^* \left(k_t^* \right)^{\alpha_k^*} \left(h_t^{e*} \right)^{\alpha_h^* - 1} \left(n_{t+1}^{e*} \right)^{1 - \alpha_h^* - \alpha_k^*}$$
$$+ \left(1 - \delta_h^* \right) p_{t+1}^{h*} \Big] + \xi_t^{e*} \left(m_t^{e*} / R_t^* \right) E_t \pi_{t+1}^* p_{t+1}^{h*}$$
$$\times \mathbf{1} \left(\varkappa_t^{e*} \geq 0 \right), \tag{77}$$

$$w_t^* = mc_t^* \left(1 - \alpha_h^* - \alpha_k^* \right) \left(k_{t-1}^* \right)^{\alpha_k^*} \left(h_{t-1}^{e*} \right)^{\alpha_h^*} \left(n_t^{e*} \right)^{-\alpha_h^* - \alpha_k^*}, \tag{78}$$

$$\lambda_t^{e*} q_t^* = \beta^* E_t \lambda_{t+1}^{e*} \Big[mc_{t+1}^* \alpha_k^* \left(k_t^* \right)^{\alpha_k^* - 1} \left(h_t^{e*} \right)^{\alpha_h^*} \left(n_{t+1}^{e*} \right)^{1 - \alpha_h^* - \alpha_k^*}$$
$$+ \left(1 - \delta_k^* \right) q_{t+1}^* \Big], \tag{79}$$

where μ_t^{e*} is the Lagrange multiplier on constraint (7) in the text, and $\varkappa_t^{e*} \equiv R_t^{-1} m_t^{e*} E_t \pi_{t+1}^* p_{t+1}^{h*} h_t^{e*} - \gamma^{e*} b_{t-1}^{e*} / \pi_t^*$.

- Retailers' optimal price decision, and aggregate profits,

$$E_t \sum_{s=0}^{\infty} \left(\beta^* \theta_p \right)^s \frac{\lambda_{t+s}^{e*}}{\lambda_t^{e*}} \left[\frac{\left(1 - \tau_p^* \right) \tilde{p}_t^*}{\prod_{j=1}^s \pi_{F,t+j}} p_{F,t+s}^* - \frac{\varepsilon_p^*}{\varepsilon_p^* - 1} mc_{t+s}^* \right]$$
$$\times \left(\frac{\prod_{j=1}^s \pi_{F,t+j}}{\tilde{p}_t^*} \right)^{\varepsilon_p^*} y_{t+s}^* = 0, \tag{80}$$

$$\Pi_t^{r*} = y_t^* \left[\left(1 - \tau_p^* \right) p_{F,t}^* - mc_t^* \Delta_t^* \right]. \tag{81}$$

- Dynamics of PPI inflation and price dispersion,

$$1 = \left(1 - \theta_p^* \right) \left(\tilde{p}_t^* \right)^{1 - \varepsilon_p^*} + \theta_p^* \left(\pi_{F,t} \right)^{\varepsilon_p^* - 1}, \tag{82}$$

$$\Delta_t^* \equiv \left(1 - \theta_p^* \right) \left(\tilde{p}_t^* \right)^{-\varepsilon_p^*} + \theta_p^* \left(\pi_{F,t} \right)^{\varepsilon_p^*} \Delta_{t-1}^*. \tag{83}$$

- Construction firm output, first-order conditions (n_t^{h*}, i_t^{h*}), and profits,

$$I_t^{h*} = \left(n_t^{h*}\right)^{\omega^*} \left\{ i_t^{h*} \left[1 - \frac{\Phi_h^*}{2} \left(\frac{i_t^{h*}}{i_{t-1}^{h*}} - 1 \right)^2 \right] \right\}^{1-\omega^*}, \tag{84}$$

$$w_t^* = p_t^{h*} \omega^* \left(n_t^{h*}\right)^{\omega^*-1} \left\{ i_t^{h*} \left[1 - \frac{\Phi_h^*}{2} \left(\frac{i_t^{h*}}{i_{t-1}^{h*}} - 1 \right)^2 \right] \right\}^{1-\omega^*}, \tag{85}$$

$$\begin{aligned} 1 = {} & p_t^{h*} \left(n_t^{h*}\right)^{\omega^*} (1-\omega^*) \left\{ i_t^{h*} \left[1 - \frac{\Phi_h^*}{2} \left(di_t^{h*}\right)^2 \right] \right\}^{-\omega^*} \\ & \times \left[1 - \frac{\Phi_h^*}{2} \left(di_t^{h*}\right)^2 - \Phi_h^* \left(di_t^{h*}\right) \frac{i_t^{h*}}{i_{t-1}^{h*}} \right] \\ & + \beta^* \frac{\lambda_{t+1}^{e*}}{\lambda_t^{e*}} p_{t+1}^{h*} \left(n_{t+1}^{h*}\right)^{\omega^*} (1-\omega^*) \\ & \times \left\{ i_{t+1}^{h*} \left[1 - \frac{\Phi_h^*}{2} \left(di_{t+1}^{h*}\right)^2 \right] \right\}^{-\omega^*} \Phi_h^* di_{t+1}^{h*} \left(\frac{i_{t+1}^{h*}}{i_t^{h*}} \right)^2, \end{aligned} \tag{86}$$

$$\Pi_t^h = p_t^{h*} I_t^{h*} - w_t^* n_t^{h*} - i_t^{h*}, \tag{87}$$

for $di_t^{h*} \equiv i_t^{h*}/i_{t-1}^{h*} - 1$.

- Equipment capital producers output, first-order condition (i_t^*), and profits,

$$I_t^* = i_t^* \left[1 - \frac{\Phi_k^*}{2} \left(\frac{i_t^*}{i_{t-1}^*} - 1 \right)^2 \right], \tag{88}$$

$$\begin{aligned} 1 = {} & q_t^* \left[1 - \frac{\Phi_k^*}{2} \left(di_t^*\right)^2 - \Phi_k^* \left(di_t^*\right) \frac{i_t^*}{i_{t-1}^*} \right] \\ & + E_t \frac{\lambda_{t+1}^{e*}}{\lambda_t^{e*}} q_{t+1}^* \Phi_k^* di_{t+1}^* \left(\frac{i_{t+1}^*}{i_t^*} \right)^2, \end{aligned} \tag{89}$$

$$\Pi_t^{k*} = q_t^* I_t^* - i_t^*, \tag{90}$$

for $di_t^* \equiv i_t^*/i_{t-1}^* - 1$.

- Optimal wage decision,

$$\sum_{x=c,u} E_t \sum_{s=0}^{\infty} (\beta^{x*}\theta_w^*)^s \left[\frac{(1-\tau_w^*)\,\tilde{w}_t^*}{\prod_{j=1}^{s}\pi_{t+j}^{w*}} \frac{w_{t+s}^*}{\frac{1}{\lambda_{t+s}^{x*}}} - \frac{\zeta_{t+s}\chi\left(n_{t+s}^{x*}\right)^{\varphi}}{(\varepsilon_w^*-1)/\varepsilon_w^*} \right.$$

$$\left. \times \left(\frac{\tilde{w}_t^*}{\prod_{j=1}^{s}\pi_{t+j}^{w*}}\right)^{-\varepsilon_w^*\varphi} \right] \left(\frac{\prod_{j=1}^{s}\pi_{t+j}^{w*}}{\tilde{w}_t^*}\right)^{\varepsilon_w^*} \times n_{t+s}^{x*} = 0, \quad (91)$$

with $\beta^{c*} = \beta^*$.

- Dynamics of wage inflation and wage dispersion,

$$1 = (1-\theta_w^*)\left(\tilde{w}_t^*\right)^{1-\varepsilon_w^*} + \theta_w^*\left(\pi_{wt}^*\right)^{\varepsilon_w^*-1}, \quad (92)$$

$$\Delta_t^{w*} = (1-\theta_w^*)\left(\tilde{w}_t^*\right)^{-\varepsilon_w^*} + \theta_w^*\left(\pi_{wt}^*\right)^{\varepsilon_w^*}\Delta_{t-1}^{w*}. \quad (93)$$

- Fiscal authority's budget constraint,

$$\tau_w^* w_t^*\left(n_t^{c*}+n_t^{u*}\right) + \tau_p^* p_{F,t}^* y_t^* + 2T_t^* = p_{F,t}^* g_t^*. \quad (94)$$

- Aggregate employment,

$$N_t^{c*} = n_t^{c*}\Delta_t^{w*}, \quad (95)$$

$$N_t^{u*} = n_t^{u*}\Delta_t^{w*}, \quad (96)$$

$$N_t^* = N_t^{c*} + N_t^{u*}. \quad (97)$$

- Export demand,

$$x_t^* = \frac{s}{1-s}(1-\omega_H)\left(\hat{p}_t^* p_{H,t}\right)^{-\varepsilon_F}\left(c_t^c + c_t^u + c_t^e + i_t + i_t^h\right). \quad (98)$$

- Intermediate goods market clearing,

$$y_t^*\Delta_t^* = \left(k_{t-1}^*\right)^{\alpha_k^*}\left(h_{t-1}^{e*}\right)^{\alpha_h^*}\left(n_t^{e*}\right)^{1-\alpha_h^*-\alpha_k^*}. \quad (99)$$

- Labor market clearing,

$$n_t^{c*} + n_t^{u*} = n_t^{e*} + n_t^{h*}. \quad (100)$$

- Consumption-goods-basket market clearing,

$$y_t^* = c_{F,t}^{c*} + c_{F,t}^{u*} + c_{F,t}^{e*} + i_{F,t}^* + i_{F,t}^{h*} + g_t^* + x_t^*. \quad (101)$$

- Real estate market clearing,

$$h_t^* + h_t^{u*} + h_t^{e*} = I_t^{h*} + (1-\delta_h^*)\left(h_{t-1}^* + h_{t-1}^{u*} + h_{t-1}^{e*}\right). \tag{102}$$

- Equipment capital market clearing,

$$k_t^* = (1-\delta_k^*)\, k_{t-1}^* + I_t^*. \tag{103}$$

- Real wages,

$$w_t^* = w_{t-1}^* \frac{\pi_{wt}^*}{\pi_t^*}. \tag{104}$$

- Terms of trade,

$$\hat{p}_t^* = 1/\hat{p}_t. \tag{105}$$

- Relative demand for domestic goods,

$$z_{F,t}^* = \omega_F^* \left(p_{F,t}^*\right)^{-\varepsilon_F} z_t^*, \quad z = c^c, c^u, c^e, i, i^h. \tag{106}$$

- Relative demand for constrained/unconstrained household labor,

$$(1-\mu^*)\, n_t^{c*} = \mu^* n_t^{u*}, \tag{107}$$

 where $\mu \equiv \mu_e = \mu_h$.
- Relative domestic producer prices,

$$\left(p_{F,t}^*\right)^{\varepsilon_F - 1} = \omega_F^* + (1-\omega_F^*)\left(\hat{p}_t^*\right)^{\varepsilon_F - 1}. \tag{108}$$

- CPI inflation,

$$\begin{aligned}(\pi_t^*)^{1-\varepsilon_F} = {} & \frac{\omega_F^*\left(\hat{p}_{t-1}^*\right)^{1-\varepsilon_F}}{\omega_F^*\left(\hat{p}_{t-1}^*\right)^{1-\varepsilon_F} + 1 - \omega_F^*}\pi_{F,t}^{1-\varepsilon_F} \\ & + \frac{1-\omega_F^*}{\omega_F^*\left(\hat{p}_{t-1}^*\right)^{1-\varepsilon_F} + 1 - \omega_F^*}\pi_{H,t}^{1-\varepsilon_F}. \end{aligned} \tag{109}$$

- Real (PPI-deflated) GDP,

$$gdp_t^* = y_t^* + \frac{1}{p_{H,t}^*}\left(q_t^* I_t^* - i_t^*\right) + \frac{1}{p_{H,t}^*}\left(p_t^{h*} I_t^{h*} - i_t^{h*}\right). \quad (110)$$

- Gross nominal interest rate,

$$R_t^* = R_t^{MU} \exp\left(-\psi^* \frac{d_t^* - b_t^* - b_t^{e*}}{p_{H,t}^* gdp_t^*} + \psi_0^*\right). \quad (111)$$

Union-Wide Variables

- Nominal policy interest rate,

$$R_t^{MU} = \left(\bar{R}^{MU}\right)^{1-\rho_R} \left(R_{t-1}^{MU}\right)^{\rho_R} \left(\pi_t^{MU}\right)^{\rho_\pi (1-\rho_R)}.$$

- Union-wide CPI inflation rate,

$$\pi_t^{MU} = s\pi_t + (1-s)\,\pi_t^*.$$

Appendix 2. Equilibrium Unemployment

Following Galí (2011), we assume that each representative household consists of a unit squared of individuals indexed by $(i, j) \in [0,1] \times [0,1]$, where i represents the variety of labor service provided by the individual and j indexes the individual's disutility from working, given by χj^φ. Let $n_t^x(i)$ denote the number of variety-i workers in household $x = c, u$ employed at time t. Total household disutility from working is given by

$$\chi \int_0^1 \int_0^{n_t^x(i)} j^\varphi dj di = \chi \int_0^1 \frac{n_t^x(i)^{1+\varphi}}{1+\varphi} di,$$

for $x = c, u$. Given the type-specific wage $W_t(i)$, the number of type-i workers that each household *would like to* send to work is given by

$$\arg\max_{n_t^x(i)} \left\{\lambda_t^x \frac{W_t(i)}{P_t} n_t^x(i) - \zeta_t \chi \frac{n_t^x(i)^{1+\varphi}}{1+\varphi}\right\} = \left(\frac{\lambda_t^x}{\zeta_t \chi} \frac{W_t(i)}{P_t}\right)^{1/\varphi}$$
$$\equiv l_t^x(i),$$

for $x = c, u$, where $\lambda_t^x \equiv 1/c_t^x$. Unemployment in the market for type-i labor is just the number of workers willing to work at the going wage minus effective labor demand: $u_t(i) \equiv \sum_{x=c,u} l_t^x(i) - \sum_{x=c,u} n_t^x(i)$. Let

$$l_t^x \equiv \int_0^1 l_t^x(i)\,di = \left(\frac{\lambda_t^x}{\zeta_t \chi}\frac{W_t}{P_t}\right)^{1/\varphi} \int_0^1 \left(\frac{W_t(i)}{W_t}\right)^{1/\varphi} di$$
$$= \left(\frac{\lambda_t^x}{\zeta_t \chi}\frac{W_t}{P_t}\right)^{1/\varphi} \Delta_t^{w,l},$$
$$N_t^x \equiv \int_0^1 n_t^x(i)\,di = n_t^x \int_0^1 \left(\frac{W_t(i)}{W_t}\right)^{-\varepsilon_w} di = n_t^x \Delta_t^{w,n}$$

denote total household-specific labor supply and labor demand, respectively, for $x = c, u$, where $\Delta_t^{w,l} \equiv \int_0^1 (W_t(i)/W_t)^{1/\varphi}\,di$ and $\Delta_t^{w,n} \equiv \int_0^1 (W_t(i)/W_t)^{-\varepsilon_w}\,di$ are indexes of wage dispersion. Then aggregate unemployment is

$$u_t \equiv \int_0^1 u_t(i)\,di = l_t - N_t,$$

where $l_t \equiv \sum_{x=c,u} l_t^x$ and $N_t \equiv \sum_{x=c,u} N_t^x$ are aggregate labor supply and labor demand, respectively. Finally, the unemployment rate is $u_t^{rate} \equiv u_t/l_t$.

References

Andrés, J., O. Arce, and C. Thomas. 2015. “Structural Reforms in a Debt Overhang.” Mimeo, Banco de España.

Bean, C. R. 1994. “The Role of Demand Management Policies in Reducing Unemployment.” In *Reducing Unemployment: Current Issues and Policy Options.* Proceedings of the Annual Economic Policy Symposium, 99–167. Federal Reserve Bank of Kansas City.

Benigno, P., G. B. Eggertsson, and F. Romei. 2014. “Dynamic Debt Deleveraging and Optimal Monetary Policy.” NBER Working Paper No. 20556.

Blanchard, O., R. Dornbusch, J. H. Dreze, H. Giersch, R. Layard, and M. Monti. 1985. *Employment and Growth in Europe: A Two-Handed Approach.* Brussels: Centre for European Policy Studies.

Blanchard, O., C. J. Erceg, and J. Lindé. 2014. "The Euro Area Recovery: Should the Core Expand Spending to Help the Periphery?" Working Paper.

Boucekkine, R. 1995. "An Alternative Methodology for Solving Nonlinear Forward-Looking Models." *Journal of Economic Dynamics and Control* 19 (4): 711–34.

Buiter, W. H. 1987. "The Right Combination of Demand and Supply Policies: The Case for a Two-Handed Approach." NBER Working Paper No. 2333.

Calvo, G. 1983. "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics* 12 (3): 383–98.

Campbell, J. R., J. D. M. Fisher, and A. Justiniano. 2012. "Monetary Policy Forward Guidance and the Business Cycle." Mimeo, Federal Reserve Bank of Chicago.

Coeuré, B. 2014. "Structural Reforms: Learning the Right Lessons from the Crisis." Speech delivered at the Latvian Central Bank, Riga, October 17.

de Graeve, F., P. Ilbas, and R. Wouters. 2014. "Forward Guidance and Long Term Interest Rates: Inspecting the Mechanism." Working Paper No. 292, Sveriges Riksbank.

Del Negro, M., M. Giannoni, and C. Patterson. 2012. "The Forward Guidance Puzzle." Staff Report No. 574, Federal Reserve Bank of New York.

Draghi, M. 2014. "Unemployment in the Euro Area." Speech at the Federal Reserve Bank of Kansas City's Annual Economic Symposium, Jackson Hole, Wyoming, August 22.

———. 2015. "Structural Reforms, Inflation and Monetary Policy." Introductory speech, ECB Forum on Central Banking, Sintra, May 22.

———. 2016. "Introductory Statement to the Press Conference." Statement given at press conference in Frankfurt, April 21. Available at https://www.ecb.europa.eu/press/pressconf/2016/html/is160421.en.html.

Druant, M., S. Fabiani, G. Kézdi, A. Lamo, F. Martins, and R. Sabbatini. 2009. "How Are Firms' Wages and Prices Linked: Survey Evidence in Europe." ECB Working Paper No. 1084.

Eggertsson G., A. Ferrero, and A. Raffo. 2014. "Can Structural Reforms Help Europe?" *Journal of Monetary Economics* 61 (January): 2–22.

Eggertsson, G., and M. Woodford. 2003. "The Zero Bound on Interest Rates and Optimal Monetary Policy." *Brookings Papers on Economic Activity* 1: 139–233.

Erceg, C. J., D. W. Henderson, and A. Levin. 2000. "Optimal Monetary Policy with Staggered Wage and Price Contracts." *Journal of Monetary Economics* 46 (2): 281–313.

Erceg, C., and J. Lindé. 2013. "Fiscal Consolidation in a Currency Union: Spending Cuts vs. Tax Hikes." *Journal of Economic Dynamics and Control* 37 (2): 422–45.

———. 2014. "Is There a Fiscal Free Lunch in a Liquidity Trap?" *Journal of the European Economic Association* 12 (1): 73–107.

European Commission. 2014. "Annual Growth Survey 2015."

Fernández-Villaverde, J., P. Guerrón-Quintana, and J. Rubio-Ramírez. 2012. "Supply-Side Policies and the Zero Lower Bound." *IMF Economic Review* 62 (2): 248–60.

Galí, J. 2011. "The Return of the Wage Phillips Curve." *Journal of the European Economic Association* 9 (3): 436–61.

Galí, J., and T. Monacelli. 2014. "Understanding the Gains from Wage Flexibility: The Exchange Rate Connection." CEPR Discussion Paper No. 9806.

García, C., E. Gordo, J. Martínez-Martín, and P. Tello. 2009. "Una actualización de las funciones de exportación e importación de la economía española." Documento Ocasional 0905, Banco de España.

Gerali, A., A. Notarpietro, and M. Pisani. 2015. "Structural Reforms and Zero Lower Bound in a Monetary Union." Working Paper No. 1002, Banca d'Italia.

Iacoviello, M. 2005. "House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle." *American Economic Review* 95 (3): 739–64.

Iacoviello, M., and S. Neri. 2010. "Housing Market Spillovers: Evidence from an Estimated DSGE Model." *American Economic Journal: Macroeconomics* 2 (2): 125–64.

International Monetary Fund. 2014. "Is It Time for an Infrastructure Push? The Macroeconomic Effects of Public Investment." In *World Economic Outlook* (October), chapter 3. Washington, DC: International Monetary Fund.

Juillard, M. 1996. "DYNARE: A Program for the Resolution and Simulation of Dynamic Models with Forward Variables through the Use of a Relaxation Algorithm." CEPREMAP Working Paper No. 9602.

Kiyotaki, N., and J. Moore. 1997. "Credit Cycles." *Journal of Political Economy* 105 (2): 211–48.

Laffargue, J. P. 1990. "Résolution d'un modèle macroéconomique avec anticipations rationnelles." *Annales d'Economie et Statistique* 17: 97–119.

Levin, A., D. López-Salido, E. Nelson, and T. Yun. 2010. "Limitations on the Effectiveness of Forward Guidance at the Zero Lower Bound." *International Journal of Central Banking* 6 (1, March): 143–89.

McKay, A., E. Nakamura, and J. Steinsson. 2015. "The Power of Forward Guidance Revisited." NBER Working Paper No. 20882.

Montero, J. M., and A. Urtasun. 2014. "Price-Cost Markups in the Spanish Economy: A Microeconomic Perspective." Banco de España.

Obstfeld, M. 2016. "Foreword." In *World Economic Outlook* (April). Washington, DC: International Monetary Fund.

Woodford, M. 2001. "Fiscal Requirements for Price Stability." *Journal of Money, Credit and Banking* 33 (3): 669–728.

Discussion of "Policy Spillovers and Synergies in a Monetary Union"*

Andrea Ferrero
University of Oxford

1. Introduction

The financial crisis that started in the United States in 2007 hit Europe hard. Two quarters after the bankruptcy of Lehman Brothers in September 2008, German real GDP had fallen by about 6.5 percent—more than in any periphery country (Greece, Ireland, Italy, Portugal, and Spain). However, while Germany and the rest of the core European countries started to recover, the euro-area periphery suffered a second wave of the crisis in 2010, associated with concerns about the sustainability of government debt. The paper by Arce, Hurtado, and Thomas studies the policy response in this type of environment.

2. Summary

The authors build a two-country open-economy model with nominal rigidities and financial frictions. In each country, households consume differentiated domestic and foreign goods, value housing services (assumed to be proportional to the stock of housing), and dislike hours worked. Households can be of two types: constrained and unconstrained. The difference between the two types is their degree of patience. As in Iacoviello (2005), households are subject to a collateral constraint that limits their debt to a fraction of the expected value of housing in the following period. Differently from most of the literature, however, debt contracts are assumed to be long term. In each period, households repay only a fraction $1 - \gamma$ of their total outstanding liabilities. A second departure from most

*The author thanks Andrea Raffo for useful conversations. Author e-mail: andrea.ferrero@economics.ox.ac.uk.

of the literature is that the collateral constraint is asymmetric. In response to a large negative shock that sufficiently reduces the value of collateral, households cannot obtain new credit and need to repay the fraction of long-term debt that matures in a given period.

Entrepreneurs combine capital (equipment), commercial real estate, and labor to produce an intermediate input, which is then sold to retailers in a competitive market. Entrepreneurs accumulate capital and are subject to a collateral constraint similar to that of the households. Retailers operate in monopolistic competition and set prices on a staggered basis (Calvo 1983). Construction firms and capital producers transform the final consumption good into real estate and equipment, respectively, subject to adjustment costs. Finally, labor unions set the nominal wage on behalf of the household on a staggered basis.

In each country, a fiscal authority collects lump-sum taxes and distortionary labor and profit taxes to finance an exogenous level of spending. The two countries are assumed to form a currency union. The common monetary authority sets the nominal interest rate for the whole area following a feedback interest rate rule that responds to the union-wide CPI inflation rate.

The authors construct a crisis scenario as a combination of two shocks. The first is a large negative demand shock (a discount factor shock) that hits both countries symmetrically. The second is a deleveraging shock that only hits the home country (the periphery), modeled as a tightening of the collateral constraint parameter m_t for both households and entrepreneurs. As a result of the two shocks, GDP in the periphery falls by 4 percent after two years, while GDP in the core is roughly unchanged. Inflation falls in both the core and periphery by about 2 percentage points. The shocks are large enough to drive the nominal interest rate at the zero lower bound (ZLB) for four quarters.

Against this backdrop, the authors consider three types of policies. The first are structural reforms that permanently reduce markups in the periphery. The second is a fiscal expansion in the core. Finally, the third is forward guidance on nominal interest rate by the common monetary authority. As in Andrés, Arce, and Thomas (2015), structural reforms have positive effects on the level of output, both in the short and in the long run. However, structural reforms are deflationary, especially at the ZLB. Conversely, a fiscal expansion in the core and forward guidance are expansionary. Moreover, the latter two policies reinforce the positive effects of structural reforms, mitigating their deflationary consequences and supporting the GDP recovery. Thus, the authors conclude that these three policies have strong synergies if implemented jointly in a crisis.

3. Comments

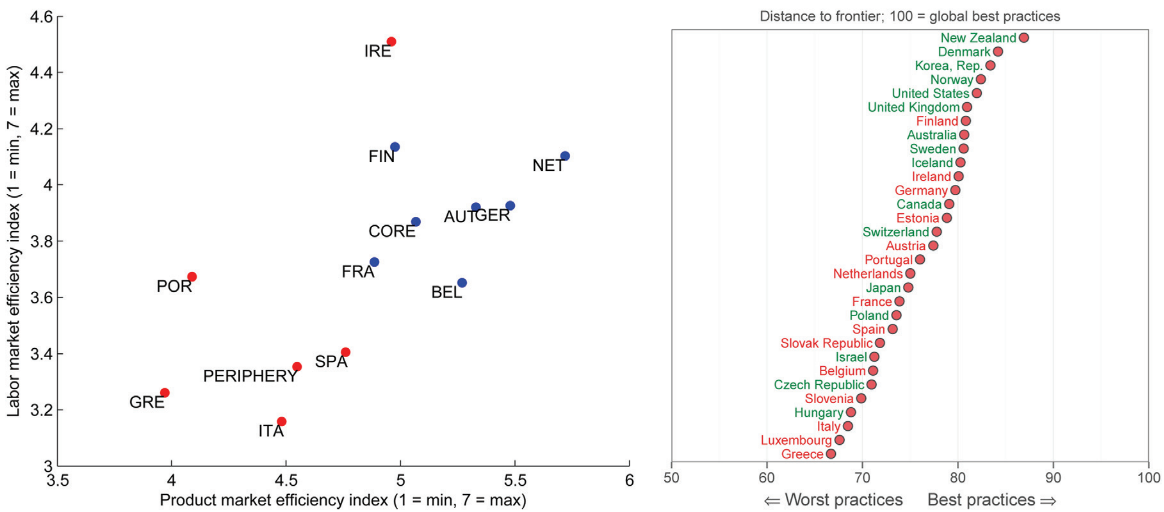
The authors have written a nice and timely paper. The issue is certainly at the forefront of the policy debate. As the second wave of the crisis in Europe had an asymmetric nature, the policy response became quite problematic. The presence of a common currency prevented exchange rate devaluations. In addition, the very nature of the crisis made any significant fiscal expansion virtually impossible. Finally, the ZLB constrained the degree of monetary accommodation.

In this context, structural reforms emerged as one of the few, if not the only, viable option. Prominent members of various institutions (e.g., Barroso 2012; Draghi 2015) have strongly urged peripheral countries to implement a broad set of labor and product market reforms. Periphery countries (perhaps with the exception of Ireland in some dimension) score very low in indexes of product and labor market efficiency (left panel of figure 1), as well as in the ease of doing business (right panel of figure 1).

3.1 The Case Against Structural Reforms

The literature shows that the long-run effects of structural reforms are unambiguously positive. When modeled (as in this paper) as a reduction in markups, structural reforms that close the competitiveness gap between the periphery and the core generate large permanent gains on the level of output, of the order of 5 percentage points (Bayoumi, Laxton, and Pesenti 2004). In the short run, however, markup reductions are associated with deflationary pressures. In normal times, the central bank can lower interest rates to stabilize inflation, but at the ZLB monetary policy accommodation is impaired. In a standard two-country model of a monetary union, Eggertsson, Ferrero, and Raffo (2014) show that, under reasonable

Figure 1. Indexes of Product and Labor Market Efficiency and Ease of Doing Business



Notes: The left panel shows indexes of product (horizontal axis) and labor (vertical axis) market efficiency (source: Schwab 2011). The right panel shows the index of ease of doing business (source: World Bank Group 2014).

parameterizations, structural reforms at the ZLB can be contractionary in the short run, in spite of significant long-run benefits.[1]

The paradox of structural reforms at the ZLB can be easily illustrated in the context of a simple New Keynesian model. For simplicity, consider a closed economy in which aggregate demand is described by a forward-looking Euler equation,

$$y_t = \mathbb{E}_t y_{t+1} - \sigma^{-1}(i_t - \mathbb{E}_t \pi_{t+1} - r_t^e), \tag{1}$$

where y_t is output, π_t is the inflation rate, i_t is the nominal interest rate, r_t^e is the (exogenous) efficient real interest rate (the real interest rate that would prevail absent nominal rigidities and markup shocks), and $\sigma > 0$ is the coefficient of relative risk aversion. Aggregate supply is described by the forward-looking Phillips curve

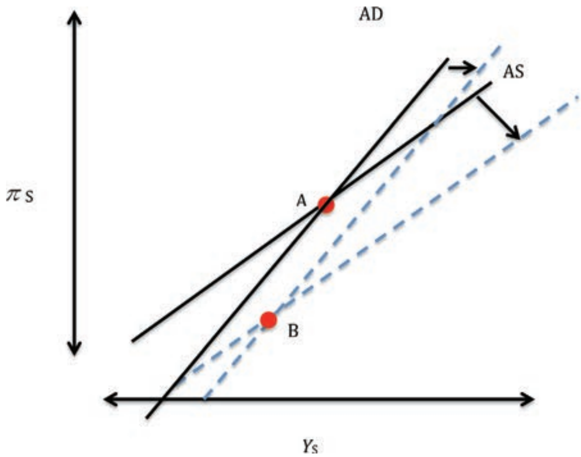
$$\pi_t = \kappa y_t + \beta \mathbb{E}_t \pi_{t+1} + \kappa \psi \omega_t, \tag{2}$$

where κ and ψ are combinations of structural parameters, and ω_t is a wedge between the first-best and the flexible price of output, due to firms' market power and time-varying markups in the labor market. Suppose further that monetary policy implements strict inflation targeting ($\pi_t = 0\ \forall t$). In this simple model, output becomes a negative function of ω_t ($y_t = -\psi\omega_t$). Structural reforms that reduce markups in product and labor markets would boost output both in the short and in the long run by lowering ω_t.

At the ZLB, however, the short-run adjustment can flip sign. Consider a negative shock to the efficient real interest rate, such that $r_S^e < 0$ (where a subscript S stands for short run). Assume that this shock is large enough to drive the nominal interest rate to the ZLB. The efficient real interest rate reverts back to the steady state with probability $1 - \mu$, while the crisis persists with probability μ. Under the assumption that once the shock reverts back to the steady state another crisis will never occur, the model can be written in terms of a short-run and a long-run equilibrium. The latter coincides with the "normal-times" equilibrium, in which lower markups

[1]In fact, in Eggertsson, Ferrero, and Raffo (2014), the larger the scope of the reforms, and hence their long-run output gains, the worse the short-run consequences are.

Figure 2. Contractionary Short-Run Effects of Structural Reforms in a Simple New Keynesian Model



boost output. Therefore, long-run output remains a negative function of ω_L (where a subscript L stands for long run). The short-run equilibrium is instead described by the following two relationships:

$$\text{AD:} \qquad y_S = y_L + \frac{\sigma^{-1}\mu}{1-\mu}\pi_S + \frac{\sigma^{-1}}{1-\mu}r_S^e \tag{3}$$

$$\text{AS:} \qquad \pi_S = \frac{\kappa}{1-\mu\beta}y_S + \frac{\kappa\psi}{1-\mu\beta}\omega_S. \tag{4}$$

Note that, at the ZLB, aggregate demand is upward sloping in a $\{y_S, \pi_S\}$ space. Structural reforms still have long-run gains, and they shift the aggregate demand curve to the right (because $y_L = -\psi\omega_L$). However, the very same structural reforms, if implemented in the short run (i.e., if $\omega_S = \omega_L$), are deflationary, shifting also the aggregate supply curve to the right. In equilibrium, the economy may end up with lower output and lower inflation than if structural reforms had not been implemented (point B in figure 2).[2]

The worst-case scenario could occur if a country is forced to implement structural reforms in a crisis and its government does not

[2]The equilibrium outcome is ultimately a quantitative question, as the relative adjustment of aggregate demand and supply depends on parameter values.

enjoy wide support. Under these circumstances, political instability may force the incumbent government to resign. The new government may be less committed to the reform plan, or may have even run on a platform opposing the reforms. Anticipating this outcome, the long-run gains of the reforms may become highly uncertain, while the short-run costs would still remain present. This scenario is reminiscent of the recent events in Greece, as well as of Latin American economies following the financial crises of the 1980s.[3] For this reason, Draghi (2015) has emphasized the importance of credibility in implementing structural reforms.

3.2 The Case For Structural Reforms

The previous considerations would suggest that the optimal strategy would be to commit to implement structural reforms once the economy is out of a crisis, and the central bank can provide support through monetary accommodation (Fernandez-Villaverde, Guerron-Quintana, and Rubio-Ramirez 2012).[4] Obviously, this commitment may not be credible. In a crisis, financial market participants expect countries to immediately undertake concrete steps that correct structural economic problems. In this sense, a short-run contraction, possibly deeper than the initial recession, may be necessary to navigate through the crisis.

A second argument in favor of structural reform is related to investment. One limitation of the negative results in Eggertsson, Ferrero, and Raffo (2014) is the absence of capital accumulation. In the discussion of that paper, Fernandez-Villaverde (2015) points out how the increase in the effective real interest rate, due to a combination of deflation and the ZLB, would actually stimulate investment.[5] A counterargument to this line of reasoning is that financial frictions that impair demand, and are modeled in reduced form as a

[3]In a recent paper, Funke, Schularick, and Trebesch (2015) document how political turnover (with extremist parties gaining consensus) and street protests increase significantly in times of crisis.

[4]See also Eggertsson, Ferrero, and Raffo (2014) for a state-contingent implementation of delayed reforms.

[5]This mechanism is at work in Gerali, Notarpietro, and Pisani (2015), who consider the effects of structural reforms in a small open economy that belongs to a currency union.

discount factor shock, are likely to also negatively affect investment (Eggertsson 2012).

One of the merits of Arce, Hurtado, and Thomas's paper is to explore this channel in details. Building upon Andrés, Arce, and Thomas (2015), the authors allow for capital accumulation, but also include financial frictions, in the form of collateral requirements for both households and firms. At a first sight, the tightening of collateral constraints seems to weaken the case for reforms. The deflationary pressures associated with the reforms should aggravate the deleveraging process along the lines of a typical debt-deflation spiral. Two effects work in the opposite direction. First, the income effect of structural reforms boosts asset prices. This channel is related to what, in practice, is often termed "the confidence effect." The reason why financial markets react positively to reforms is that the expectation of higher output in the future raises asset prices today. Second, the presence of long-term debt in the model tempers the typical debt-deflation mechanism. Taken together, structural reforms in this paper have positive effects on real activity, in spite of the short-run deflationary pressures.

While the positive effects that operate via asset prices may not be as strong with different financial frictions, the authors have made a first important step in the direction of gaining a better understanding of the investment channel of structural reforms.

3.3 The Holy Trinity

Arce, Hurtado, and Thomas propose a combination of policies that, at least in theory, works well to deal with a crisis like the one recently experienced by the euro-area periphery. Structural reforms boost long-term output prospects and carry positive short-run gains through the response of asset prices. Unconventional monetary policy mitigates the deflationary pressures.[6] And fiscal expansions in countries that are not under stress (like the euro-area core in this case) avoid negative cross-country spillovers. This package could constitute the "Holy Trinity" of the policy response in a crisis.

[6] The paper focuses on forward guidance. In a model that breaks the irrelevance of open-market operations (e.g., Chen, Cúrdia, and Ferrero 2012), quantitative easing would likely play a similar role.

International institutions should seriously consider this type of policy recommendation in future crisis episodes, with particular emphasis on the synergies among the different policy measures.

The case of monetary support through unconventional policies is rather obvious. The crisis by itself creates deflationary pressures that structural reforms amplify, especially because the implementation occurs at the ZLB. To the extent that inflation stabilization is one of the objectives (if not the only one) of monetary policy, central banks should be easily convinced to adopt unconventional measures when the interest rate has reached its lower bound.

The case for fiscal stimulus in the core is less obvious. In the crisis scenario that the authors construct, GDP in the core only falls by half a percentage point on impact, and recovers in less than a year. Structural reforms in the periphery create a negative spillover on the core through the trade channel, because the periphery is now more competitive. But this effect is small (a quarter of a percentage point on impact) and short-lived. In practice, core countries that predicate fiscal virtue may be hard to convince to undertake a substantial fiscal expansion to contain a relatively small slowdown in economic activity.

4. Empirical Observations

Besides political–economic considerations, two other limitations influence the analysis in this paper. The first is that, while already quite rich in many respects, the model does not distinguish between tradable and non-tradable sectors. Structural reforms affect markups for all firms and for the periphery labor market as a whole. Available empirical evidence (see table 1) reveals that the competitiveness gap between core and periphery is particularly severe in the service sector. On one dimension, this evidence suggests that the experiment in the paper may over-estimate the effects of structural reforms, as in the paper those are applied to the whole economy. Additionally, product and labor market liberalizations in the service sector do not significantly affect the terms of trade and are unlikely to bring about large variations in the trade balance. Therefore, one of the channels of transmission highlighted in this paper might be muted.

The second limitation is the lack of strong evidence in support of the positive effects of structural reforms. Structural reforms seem

Table 1. Estimates of Product Market Markups

	Italy and Spain	France and Germany
Aggregate	1.36	1.25
Manufacturing	1.17	1.14
Services	1.48	1.33

Source: Conway, Janod, and Nicoletti (2005).

a clear case of "theory ahead of the data." One exception is the recent paper by McAdam and Stracca (2015). The authors construct a database of labor market reforms for the period 1970–2015 and study their effects on various labor market variables and macroeconomic aggregates. Their findings point to a dichotomy. Reforms appear to have a positive impact on employment but no effect on income growth.[7] As a result, the labor share of income decreases, since reforms that reduce markups would boost employment but decrease wages for given income. While the consequences for employment are consistent with the theory in this paper, the absence of any effect on income questions the significance of the long-run gains on output, which are at the core of the model. Furthermore, the fall in the labor share of income raises concerns about the political economy of structural reforms and the possibility that this type of liberalization may actually foster inequality.

5. Conclusions

Arce, Hurtado, and Thomas have written a timely and important paper. Their analysis takes stock of what we have learned during the crisis, and proposes a new package of economic policies (the "Holy Trinity") to deal with similar future episodes. The package consists of a combination of structural reforms, unconventional monetary policy measures, and a fiscal expansion in trade partners with fiscal capacity. Structural reforms imply long-run output gains. Their negative short-run consequences for real activity can

[7]The study also finds that reforms supported by monetary and fiscal accommodation have a somewhat stronger positive effect.

be compensated by a positive reaction of asset prices. In addition, unconventional monetary policy can accommodate the deflationary pressures implicit in markup reductions. Finally, a fiscal expansion in trade partners less affected by the crisis can mitigate the negative cross-country spillovers.

The credibility element of structural reforms, and of the monetary and fiscal support, is crucial for the long-run benefits to have a short-run impact, via income effects and asset prices. In my discussion, I have highlighted the political–economic constraints that structural reforms may face, as well as some empirical limitations of the analysis.

More research, especially on the empirical side, is clearly needed to understand the short-run effects of structural reforms and hence become confident in their ability to successfully deal with crisis episodes.

References

Andrés, J., O. Arce, and C. Thomas. 2015. "Structural Reforms in a Debt Overhang." Unpublished, Bank of Spain.

Barroso, J. M. 2012. "The 2012 State of the Union." Closing Remarks at the Plenary Session of the European Parliament, Strasbourg, France, September 12.

Bayoumi, T., D. Laxton, and P. Pesenti. 2004. "Benefits and Spillovers of Greater Competition in Europe: A Macroeconomic Assessment." NBER Working Paper No. 10416.

Calvo, G. 1983. "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics* 12 (3): 383–98.

Chen, H., V. Cúrdia, and A. Ferrero. 2012. "The Macroeconomic Effects of Large-scale Asset Purchase Programmes." *Economic Journal* 122 (564): F289–F315.

Conway, P., V. Janod, and G. Nicoletti. 2005. "Product Market Regulation in OECD Countries: 1998 to 2003." Working Paper No. 419, OECD Economics Department.

Draghi, M. 2015. "Structural Reforms, Inflation, and Monetary Policy." Speech at the ECB Forum on Central Banking, Sintra, Portugal, May 22.

Eggertsson, G. 2012. "Was the New Deal Contractionary?" *American Economic Review* 102 (1): 524–55.

Eggertsson, G., A. Ferrero, and A. Raffo. 2014. “Can Structural Reforms Help Europe?” *Journal of Monetary Economics* 61: 2–22.

Fernandez-Villaverde, J. 2015. “Discussion of ‘Can Structural Reforms Help Europe?’” *Journal of Monetary Economics* 61: 23–29.

Fernandez-Villaverde, J., P. Guerron-Quintana, and J. Rubio-Ramirez. 2012. “Supply-Side Policies and the Zero Lower Bound.” Unpublished, University of Pennsylvania.

Funke, M., M. Schularick, and C. Trebesch. 2015. “Politics in the Slump: Polarization and Extremism after Financial Crises, 1870–2014.” Unpublished, Free University of Berlin.

Gerali, A., A. Notarpietro, and M. Pisani. 2015. “Structural Reforms, Investment and Zero Lower Bound in a Monetary Union.” *The Manchester School* 83 (2): 120–39.

Iacoviello, M. 2005. “House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle.” *American Economic Review* 95 (3): 739–64.

McAdam, P., and L. Stracca. 2015. “Structural Reforms for Inclusive Growth? Empirical Evidence from the OECD.” Unpublished, European Central Bank.

Schwab, K., ed. 2011. *The Global Competitiveness Report 2011–2012*. Geneva: World Economic Forum.

World Bank Group. 2014. *Doing Business 2015: Going Beyond Efficiency*. Washington, DC: World Bank.

Financial Intermediation in a Global Environment*

Victoria Nuguer
Banco de México

I develop a two-country DSGE model with global banks (financial intermediaries in one country lend to banks in the other country). Banks are financially constrained on how much they can borrow from households. The main goal is to obtain a framework that captures the international transmission of a financial crisis through the balance sheet of the global banks as well as to explain the insurance mechanism of the international asset market. A negative shock to the value of capital in one country generates a global financial crisis through the international interbank market. Unconventional credit policies help to mitigate the effects of a financial disruption. The policies help to improve domestic consumers' welfare. The non-cooperative equilibrium yields both central banks intervening.

JEL Codes: G01, E44, F40, G21.

*I am infinitely grateful to my supervisor, Luisa Lambertini, for her advice and invaluable guidance. I also thank Nobu Kiyotaki for supervising my work during my visit to Princeton University in Spring 2012. I am grateful to Peter Karadi, Florian Pelgrin, Pinar Uysal, Chiara Forlati, Gabriel Tenorio, Robert Kollmann, and Mick Devereux for their helpful comments. I thank seminar participants at the Macro/International Macro Student Workshop — Princeton University, the Third Sinergia Common Workshop "The Macroeconomics of Financial Crises," the INFINITI Conference 2013, the University of Lausanne Brownbag Macro workshop, the Gerzensee Alumni Conference 2013, and the IJCB 2015 Conference. I gratefully acknowledge financial support from the Swiss National Science Foundation, Grant CRSI11-133058. All remaining errors are my own. Any views expressed herein are those of the author and do not necessarily reflect those of Banco de México. Author contact: Banco de México, Dirección General de Investigación Económica, Calle 5 de Mayo #18, 06059 Ciudad de México, México; Tel.: +52 55 5237 2000, ext. 3584; e-mail: vnuguer@banxico.org.mx.

1. Introduction

Global banks propagated the financial crisis of 2007–9 internationally. The crisis originated in the U.S. housing sector and spread to a number of economies that had investments in the United States. As a result of the loss of the value of U.S. assets and the large asset position of Swiss banks with U.S. counterparties, the banks in Switzerland were forced to write down several hundred billion U.S. dollars on bad loans. UBS, the largest Swiss bank and one of the largest global banks in the world, wrote off more than $50 billion U.S. dollars related to bad investments. Because UBS was not the only European bank that had a sizable presence and got into difficulty in the United States, the Federal Reserve carried out unconventional policies to help reduce the stress of these banks, such as the Term Auction Facility or relaxing the access of banks at the discount window.

Several papers explain the international transmission of the crisis through banks. Dedola, Karadi, and Lombardo (2013), Kamber and Thoenissen (2013), Kollmann (2013), Kollmann, Enders, and Müller (2011), and Ueda (2012) develop international models with global banks; however, banks do not lend to each other. International lending is done through cross-country lending from households to banks and from banks to firms. Unconventional monetary policy in the United States has been introduced in Gertler and Karadi (2011), Gertler and Kiyotaki (2010), and Gertler, Kiyotaki, and Queralto (2012), among others.

In terms of empirical work, there is a growing literature explaining the role of global banks in the transmission of the financial crisis. Kalemli-Ozcan, Papaioannou, and Perri (2013) analyze cross-border banking flows of the Bank for International Settlements (BIS) and show that the financial crisis generated more business-cycle co-movement among more financially integrated countries. Cetorelli and Goldberg (2011) look at emerging economies and find that the main channel of transmission of the global financial crisis was the reduction in cross-border lending by foreign banks. Helbling et al. (2011) with a VAR highlight that credit market shocks in the United States explain the latest global recession for advanced economies. The research on this paper puts the emphasis on the cross-border interbank lending from global banks as a channel of transmission of the financial crisis.

In this sense, this paper aims to contribute to both the empirical and the theoretical debate on the relation between cross-border banking flows, global banks, and the transmission of the crisis. Moreover, I look at the welfare effects of unconventional monetary policy in the theoretical model.

In terms of empirical contribution, I run a VAR to analyze the international transmission of the crisis from the United States to Switzerland. I am interested in Switzerland, because two of the biggest foreign banks that have an impact on the United States are there: UBS and Credit Suisse. In 2008, the total assets of UBS, \$1.2879 trillion U.S. dollars, alone represented 246 percent of Swiss GDP and 8.7 percent of U.S. GDP. As early as 2007, UBS was considered one of the largest firms in the U.S. mortgage market (see Morgenson 2007). I find that the cross-border banking flows from Switzerland to the United States propagated the global financial crisis from the United States to Switzerland. A reduction in U.S. loans prompted a fall in asset prices in both countries; moreover, final domestic demand and how much Swiss banks lend to U.S. banks collapsed.

In terms of theoretical novelty, I build a two-country (home and foreign) model with global banks (banks that interact with other banks across international borders) and financial frictions. I examine the international transmission of a financial crisis through the global interbank market. Home is a relatively small country with a big banking sector, such as Switzerland, while foreign is a big economy with a relatively small banking sector, such as the United States. The model builds on the closed-economy models of Gertler and Karadi (2011) and Gertler and Kiyotaki (2010). There are home and foreign banks. They use their net worth and local deposits to finance domestic non-financial businesses. Banks can also lend to and borrow from each other through the global interbank market. Although banks can finance local businesses by buying their securities without friction, they face a financing constraint in raising deposits from local households because banks are subject to a moral hazard problem. Home banks (Swiss banks) have a longer average lifetime and a larger net worth (relative to the size of the economy) than foreign banks (U.S. banks); as a consequence, home banks lend to foreign banks in the interbank market and effectively participate in risky finance in the U.S. market.

As in the previous literature, Gertler and Karadi (2011), Gertler and Kiyotaki (2010), and Gertler, Kiyotaki, and Queralto (2012), I simulate the model giving a negative shock to the value of capital, the so-called quality-of-capital shock. When there is a reduction in the value of capital and securities in the United States, both U.S. and Swiss banks lose some of their net worth. Because banks are constrained on raising deposits, they have to reduce businesses' financing, which further depresses the value of securities and the banks' net worth. Swiss banks are affected because the asset price of their loans in the United States falls, and so does their net worth. Then, Swiss banks have to reduce the provision of loans to domestic firms because their asset side is shrinking and they are financially constrained. Therefore, the adverse shock in the larger economy leads to a decline in the asset price, investment, and domestic demand in both economies through the global interbank market.

First, I examine how a country-specific quality-of-capital shock is transmitted internationally. By looking at different models, I argue that the model with global banks is the only one that is able to replicate the facts shown in the vector autoregression (VAR). I compare a model without financial frictions with a model with financial frictions but without global banks, à la Gertler and Kiyotaki (2010). Countries in these two models are in financial autarky. In these models there is very little transmission of the financial crisis, which is due to the trade channel. Then, I allow for an international asset, which I will call the international interbank market. When foreign banks are allowed to borrow from home banks, the interbank market insures the foreign economy against the shock. Given that there are no financial frictions involved in borrowing from home banks, there is integration of the domestic asset markets. In comparison to the financial autarky case, integration amplifies the transmission of the shock and prompts a global financial crisis. To a quality-of-capital shock in foreign, the model shows similar characteristics to the VAR evidence: there is asset price co-movement across countries, home banks decrease how much they lend to foreign banks, and the home economy experiences a decrease in the final domestic demand.

Second, I turn to policy analysis during a crisis. It is important to distinguish between unilateral and international cooperative policies. Unilateral policies imply a country-specific authority that carries out a policy in their own jurisdiction, focusing on the benefits and costs for the domestic households, and taking as given what is done in the other country. Cooperative policies in this paper imply a unique-global welfare, the sum of home and foreign welfare, weighted by the size of their populations. I analyze the effects, benefits, and costs of these two scenarios. I investigate if international cooperative policies imply higher (lower) benefits (costs) for each country than performing unilateral ones. For the range of parameters studied here, the non-cooperative equilibrium implies an active central bank in each country, while the cooperative equilibrium implies that only the foreign central bank should carry out a given policy, while the home central bank should do nothing.

I focus on three interventions: the government can lend directly to non-financial firms, provide credit in the interbank market, or provide direct financing to banks by buying part of their total net worth. I assume that there is no information asymmetry between the government and the banks, as opposed to the households and the banks. Looking at the second-order approximation of the model, in all the policies, there is a higher price of the domestic asset, which relaxes the domestic banks' constraint. Foreign banks borrow more from domestic households and less from home banks. Consumption in foreign increases and labor decreases; foreign households are better off. Because the income from the international asset decreases, the exchange rate depreciates for home. Home banks direct more credit to domestic non-financial firms, but total credit decreases, which reduces domestic deposits. Home households start to work more and consume less, their production is consumed by foreign households, and, consequently, they are worse off.

When both central banks intervene, home consumers are better off in comparison to only the foreign central bank intervening. The asset price at home goes up and home banks lend more abroad. Deposits at home increase, as do income and consumption, while labor decreases. Foreign banks face higher foreign capital and lower demand for domestic deposits because of the increase in loans from home. Foreign consumers are worse off when the home central bank is active. If both central banks intervene with the same parameters, foreign consumers are still better off and home households are worse off in comparison to the no-policy case.

There are two caveats to the results. First, the results are a consequence of the terms-of-trade effect. When the real exchange rate appreciates (depreciates) for foreign (home), foreign consumers are better off, while home consumers are worse off. Second, the first-order approximation of the model looks at the reaction of an unexpected policy, while the second-order approximation entails an ex ante reaction. When facing a quality-of-capital shock, the agents take into account that the government will intervene.

What is new in this framework is the study of the international transmission mechanism of a financial crisis through the global interbank market with constrained financial intermediaries. The introduction of the global interbank market in the model prompts a high level of co-movement between the foreign and the home economy, with similarities to the VAR shown in section 2. There is international co-movement of asset prices, banks' net worth, and total final demands.

1.1 Related Literature

Three strands of literature are related to my analysis. The first concerns international real business cycles; the second strand is related to the introduction of financial intermediaries in open economies; and the third group refers to the international transmission of financial shocks. Regarding international business-cycle synchronization, Backus, Kehoe, and Kydland (1992) build a standard international real business cycle (IRBC) model. They find that to a technology shock correlated across countries, the model predicts a negative international correlation for investment and output, which does not match the data. It is efficient to allocate the resources in the more productive country, while reducing them in the less productive one. After a country-specific quality-of-capital shock, my model is able to replicate international co-movement of investment and final domestic demands, as seen in the data. Several papers try to improve the results in Backus, Kehoe, and Kydland (1992) by including frictions in the financial markets; Faia (2007) introduces the Bernanke, Gertler, and Gilchrist (1999) model in a two-country framework. This literature does not model banks explicitly.

Financial intermediaries have been added to international models in the last few years. Mendoza and Quadrini (2010) study financial globalization in a two-country model with banks and a country-specific capital shock. However, production is constant. Ueda (2012) analyzes the international business cycle in a two-country DSGE model with banks. Although he presents a comprehensive model, financial frictions arise because there is an asymmetric information problem between the firms and the financial intermediaries. There is no gap for an international interbank market: global banks have deposits from both countries and lend in either of them. Kollmann, Enders, and Müller (2011) also omit the cross-country intrarelation of banks. In their paper, they look at how far a bank capital requirement affects the international transmission of a shock in a two-country model with global banks. They find that a very large loan loss induces a decline of activity in both countries.

Krugman (2008) points out the relevance of the international transmission of financial shocks to understand how the latest crisis that originated in the U.S. housing sector was transmitted to different countries. Devereux and Yetman (2010) develop a two-country DSGE model to highlight how balance-sheet-constrained agents and portfolio interdependence prompt a large spillover to the other country, given a productivity shock. Devereux and Sutherland (2011) extend the last paper by analyzing how macroeconomic outcomes and welfare behave for different levels of financial integration in the bond and equity markets. They find that bond and equity integration is welfare improving with positive co-movement across countries. In a complementary paper, Dedola and Lombardo (2012) show how equalization of asset prices leads to a higher propagation of an asymmetric shock. In this literature, banks are not modeled explicitly and the authors solve the model using portfolio choice. In my model, I add banks and simplify the portfolio problem by pinning down from the data the fraction of interbank lending from home to foreign banks.

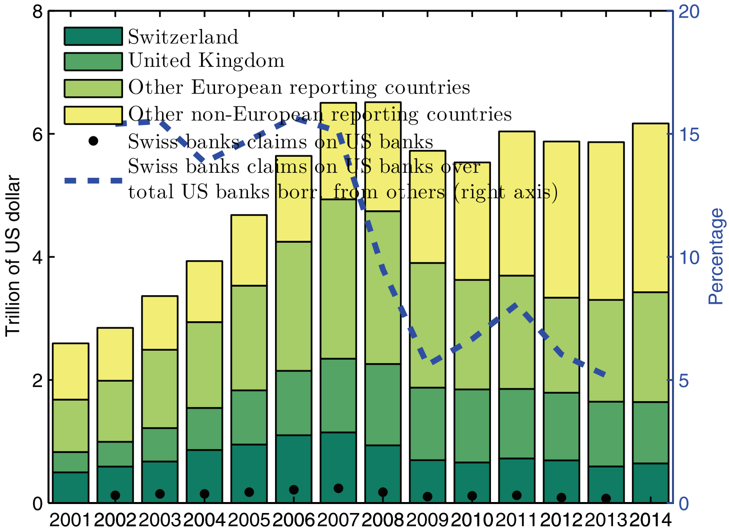
My paper is closely related to the works of Dedola, Karadi, and Lombardo (2013) and Kamber and Thoenissen (2013). Dedola, Karadi, and Lombardo (2013) develop a two-country model with banks à la Gertler and Karadi (2011). Households lend to home and foreign banks; banks make loans to home and foreign firms, i.e., there is full integration. The initial net foreign asset position is zero, the economies are symmetric, and there is only one homogeneous good (there is no role for international relative prices). As opposed to this, in my model there is international interbank lending rather than direct cross-country lending and there is deposit markets segmentation, the economies are asymmetric, and the real exchange rate plays a very important role. These characteristics break the equalization of cross-country interest rate spreads. Moreover, at the deterministic steady state, home banks lend to foreign banks, as seen in the data for Switzerland and the United States. To a country-specific quality-of-capital shock, the different characteristics of the model allow the framework presented in this paper to generate a larger propagation across countries of the financial crisis, while in Dedola, Karadi, and Lombardo (2013) there is very little global transmission after this type of shock. As I will explain later, the international relative prices are key to explaining the differences in the welfare results.[1]

Kamber and Thoenissen (2013) study the relation between the financial exposure of the banking sector and the transmission of foreign banking sector shocks. In their paper, the deposit market is perfectly integrated with the uncovered interest rate parity (UIP) holding every period, which does not hold in the data. They look at a default shock, i.e., a fraction of the stock of capital is destroyed and some loans (held by the small and the big economy) are not repaid. My approach differs from theirs in four ways. First, the deposit interest rate differs across countries and the UIP does not hold. Second, I study a reduction in the quality of the loans in the big economy; the financial friction causes foreign banks to lend less to home banks, prompting a more restricted borrowing constraint for the home banks, without a direct impact of the shock on their balance sheet. Third, the transmission mechanism in the model highlights the asymmetries across countries not only in their size but also in the size of their banking sector. Fourth, I analyze unconventional policy in this setup and possible policy coordination across countries.

The rest of the paper is organized as follows. In the next section, I describe the empirical evidence. In section 3, I present the full model in detail. In section 4, I explain the unconventional credit

[1]Dedola, Karadi, and Lombardo's (2013) model has positive output co-movement after a financial shock, rather than a quality-of-capital shock. They relate the two shocks to the beginning of the recent financial crisis. The quality-of-capital shock can be understood as an unexpected realization that the capital installed was of lower quality or productivity than thought, while the financial shock, a shock to the fraction of assets that banks can divert, can be interpreted as a sudden loss of confidence in the financial sector.

Figure 1. Foreign Claims of BIS Reporting Countries on U.S. Counterparties, 2005:Q2–2013:Q4



Source: BIS Consolidated Bank Statistics, FRED, SNB, and Shin (2012).

policy. Section 5 studies the effects of the foreign quality-of-capital shock. I examine the model with and without policy response and I focus on the welfare comparison across the different unconventional policies. I conclude in section 6.

2. Empirical Evidence

The United States is a relatively big economy with a small banking sector. In 2008, the assets of U.S. commercial banks were only 77 percent of the U.S. GDP. The size of the assets of banks outside the United States with U.S. counterparties was 6.5 percent of the total of U.S. commercial banks assets (and 5 percent of U.S. GDP).[2] These loans came mainly from Switzerland. Figure 1 documents this evidence; the left axis shows the cumulative of the BIS reporting countries.

[2]The data correspond to BIS reporting countries. U.S. counterparties include banks and non-bank institutions.

Swiss banks' claims on U.S. banks (the black dots in figure 1), the interbank market channel between Switzerland and the United States, represented 19 percent of total Swiss claims on U.S. counterparties and less than 1 percent of U.S. commercial banks' total assets, in 2008. The right axis documents the ratio of Swiss claims with respect to total claims from banks other than U.S. banks.[3] Borrowing from others was 16.3 percent of total assets in 2008, and Swiss banks' claims on U.S. banks represented 10 percent of borrowing from others. This percentage was around 15 percent during the first half of the 2000s and fell below 8 percent after Lehman Brothers collapsed. This highlights the fall in Swiss banks' financing to U.S. banks after the financial crisis started.

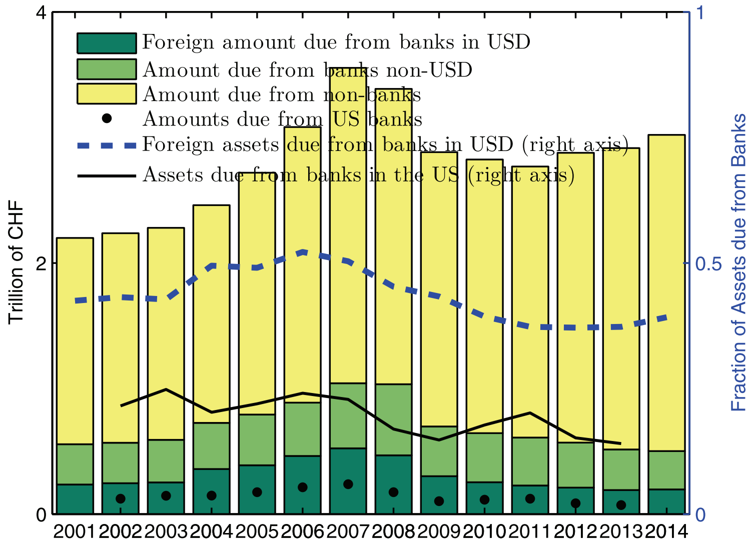
Switzerland is a relatively small economy with a big banking sector. In 2008, the assets of Swiss banks were 542 percent of the Swiss GDP. The Swiss banks' assets with U.S. counterparties were 16 percent of the Swiss banks' total assets.[4] In figure 2, I report the decomposition of Swiss banks' assets. On the left axis are the cumulative of the amounts of assets due from non-banks, due from banks and denominated in currency other than U.S. dollars, and due from banks and denominated in U.S. dollars. I also plot the amount due from U.S. banks (black dots). Assets from U.S. banks (the interbank market channel) represented around 20 percent of assets due from banks (solid black line on the right axis), while assets denominated in U.S. dollars represented around 40 percent. In 2008, UBS and Credit Suisse held 72 percent of the total amount due from foreign banks in foreign currency. Total assets of UBS, $1.2879 trillion U.S. dollars, alone represented 246 percent of Swiss GDP and 8.7 percent of U.S. GDP. As early as 2007, UBS was considered one of the big firms in the U.S. mortgage market (Morgenson 2007). Swiss banks in general and UBS in particular are net lenders to the United States.

To invest in U.S. financial intermediaries, UBS borrowed U.S. dollars. During normal times, UBS could roll over their debts. In 2007, the problems in the U.S. housing sector hit financial

[3]Total claims from others correspond to "Borrowing from others" (than U.S. banks) in the Assets and Liabilities of Commercial Banks in the United States H-8, Federal Reserve Board.

[4]Swiss banks' assets denominated in U.S. dollars were 30 percent of total Swiss banks' assets. This implies that Swiss banks have U.S.-dollar-denominated loans in countries other than the United States.

Figure 2. Foreign Claims of BIS Reporting Countries on U.S. Counterparties, 2005:Q2–2013:Q4



Source: Swiss National Bank Statistics.

institutions, and many banks found themselves in distress. This, in addition to the failure of Lehman Brothers in September 2008, triggered a severe liquidity crisis in the interbank market. The spread between the interest rates on interbank loans and the U.S. Treasury bills increased by 350 basis points. Assets in the United States started to lose value. Not only did the assets of U.S. commercial banks lose value, but assets in the United States held by global banks did too. To honor its debts and because assets were losing value, UBS started to sell its assets in the United States. From 2008 to 2009, UBS' assets shrank by 28 percent; it reported losses for at least $50 billion U.S. dollars (Craig, Protess, and Saltmarsh 2011). The decrease in the value of UBS' assets in the United States brought about a reduction in the net worth of UBS and other Swiss banks. Because of the large position that UBS held in the United States, and because of the large size of the Swiss banking system, the crisis in the United States spread to the Swiss economy.

As a result of the financial crisis, the Federal Reserve and other central banks introduced a set of so-called unconventional monetary policies. In particular, the Federal Reserve started to intervene directly in the credit market, lending to non-financial institutions and reducing the restrictions to access the discount window, among other policies.

All the unconventional policies that the Federal Reserve carried out as lender of last resort totaled $29,616.4 billion U.S. dollars, almost twice the U.S. GDP in 2008. Excluding the liquidity swap agreements with other central banks, 83.9 percent ($16.41 trillion U.S. dollars) of all assistance was provided to only fourteen institutions. Among them I find the two big Swiss banks: UBS and Credit Suisse, receiving 2.2 percent and 4 percent of the assistance, respectively (Felkerson 2011).

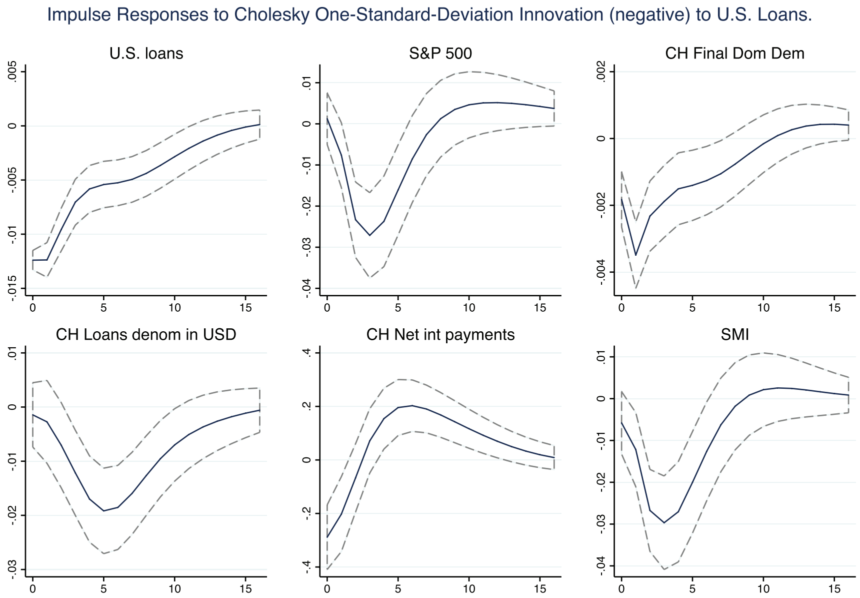
To understand better the transmission of the financial crisis from the United States to Switzerland, I estimate a VAR. Figure 3 shows the orthogonalized impulse response functions from a VAR with two lags with U.S. and Swiss data. The core VAR consists of six variables: real loans of U.S. banks, the S&P500 index, real Swiss domestic demand, real Swiss U.S.-dollar-denominated loans, real Swiss net interest payments, and the Swiss market index (SMI) from 1988:Q2 to 2012:Q2.[5] The starting point corresponds to the availability of the Swiss data. All data are in log (except the net interest payments that are demeaned) and detrended using the Hodrick-Prescott (HP) filter. The Cholesky ordering corresponds to the order of the listed variables.[6]

In choosing the structure of the VAR, I am making several assumptions. First, I do not include an exogeneity block, because

[5]See online appendix 1 (on the *IJCB* website, http://www.ijcb.org) for the definition and the sources of the data. I use the Swiss banks' U.S.-dollar-denominated loans and not the Swiss banks' loans with U.S. counterparties because data on the first are given quarterly and start in 1980, while data regarding the second are provided annually and start in 2002. The magnitudes between the two are different but they highly co-move.

[6]The Akaike information criterion (AIC) suggests the use of two lags. Given the comments of Kilian (2011), I performed different robustness checks. Changing the order for the Cholesky decomposition of the Swiss variables does not alter the behavior of the impulse response functions. Including the Swiss real interest rate and the consumer price index does not alter the results either. A smaller specification of the VAR also suggests that the lag order equals 2 and the general behavior is similar. I have estimated a VAR with the Wilshire 5000 index instead of the S&P500 index and the results do not change.

Figure 3. VAR Evidence



Notes: VAR estimated for 1988:Q2 to 2012:Q2. The dashed lines indicate the 67 percent confidence intervals. The Cholesky ordering is U.S. loans, S&P500, Swiss final domestic demand, Swiss loans denominated in U.S. dollars, Swiss net interest payments, and SMI. The vertical axis shows the percent deviation from the baseline. VAR estimated with two standard deviations confidence intervals are available on request. The results are robust to this specification.

I want the VAR to be as close as possible to my model, which is a two-country one. Second, the ordering of the country variables implies that Swiss series do not influence U.S. ones contemporaneously, and only with one lag; nevertheless, the estimated parameters of U.S. data to changes in Swiss data are smaller than the reaction of Swiss variables to domestic ones. In the same sense, a variable ordered before another has an impact on the latter on the same period. In particular, I first put the data that has the shock; then, I order the rest of the U.S. series. After that, the first Swiss variable is total domestic demand, because it is not affected in that period by other Swiss series. The loans of Swiss banks in U.S. dollars follow, then the net interest payments, and finally the stock exchange index.

The VAR exposes the response to a one-standard-deviation (negative) innovation to the loans and leases in bank credit for all U.S. commercial banks. The shock captures one of the initial characteristics of the financial crisis: the decrease in the value of the U.S. banks' loans. The shock suggests a decrease in the S&P 500 index. Then, the crisis is transmitted to Switzerland, where final domestic demand, the loans denominated in U.S. dollars that Swiss banks make, net interest payments, and the stock market index fall. Swiss domestic demand and net interest payments react on impact. The return that Swiss banks get from the loans in U.S. dollars shrinks and drives the initial reduction in the net interest payments. After four periods, there is less volume of loans denominated in U.S. dollars, and the total net interest payment bounces. The VAR highlights a significant and negative reaction of the Swiss (real and financial) economy to a decrease in the U.S. banks' loans and leases. Furthermore, the co-movement of the stock indexes suggests a strong cross-country relation of the asset prices. While U.S. loans go down because of the shock, the Swiss banks' loans denominated in U.S. dollars shrink, emphasizing the co-movement across countries. In this paper, I build a dynamic stochastic general equilibrium (DSGE) model that explains these interactions. I describe the model in the next section.

3. The Model

The model builds on the work of Gertler and Kiyotaki (2010). My focus, however, is on the international transmission of a simulated financial crisis. In particular, I introduce an international interbank market channel which contributes to the international spillover of the crisis.

I keep the framework as simple as possible to analyze the effects of global financial intermediation. In line with the previous literature, I focus on a real economy, abstracting from nominal frictions. First, I present the physical setup, a two-country real business-cycle model with trade in goods. Second, I add financial frictions. I introduce banks that intermediate funds between households and non-financial firms. Financial frictions constrain the flow of funds from households to banks. A new feature of this model is that home banks can invest in the foreign economy by lending to foreign banks. This is the international interbank market channel. Moreover, I assume that foreign banks are not constrained on how much they can borrow from home banks. Households and non-financial firms are standard and I describe them briefly, while I explain in more detail the financial firms. In what follows, I describe the home economy; otherwise specified, the foreign economy is symmetric. Foreign variables are expressed with an asterisk. The complete model is presented in online appendix 2 (on the *IJCB* website, http://www.ijcb.org). I describe a model in which foreign banks also lend to home banks in online appendix 5.

3.1 Physical Setup

There are two countries in the world: home and foreign. Each country has a continuum of infinitely lived households. In the global economy, there is also a continuum of firms of mass unity. A fraction m corresponds to home, while a fraction $1-m$ corresponds to foreign. Using an identical Cobb-Douglas production function, each of the firms produces output with domestic capital and labor. Aggregate home capital, K_t, and aggregate home labor hours, L_t, are combined to produce an intermediate good X_t in the following way:

$$X_t = A_t K_t^{\alpha} L_t^{1-\alpha}, \qquad \text{with} \quad 0<\alpha<1, \tag{1}$$

where A_t is the productivity shock. This is the domestic production of the home economy.

With K_t as the capital stock at the end of period t and S_t as the aggregate capital stock "in process" for period $t+1$, I define

$$S_t = I_t + (1-\delta)K_t \tag{2}$$

as the sum of investment, I_t, and the undepreciated capital, $(1-\delta)K_t$. Capital in process, S_t, is transformed into final capital, K_{t+1}, after taking into account the quality-of-capital shock, Ψ_{t+1},[7]

[7]Note that I do not include adjustment costs in investment in this equation because this comes from the problem of Gertler and Kiyotaki (2010); in their setup, $K_{t+1} = \Psi_t[I_t + \pi(1-\delta)K_t] + \Psi_t(1-\pi)(1-\delta)K_t$, where π is the probability of having an investment opportunity in that island, and Ψ_t is the quality-of-capital shock. I include the adjustment costs in the resource constraint and the problem becomes standard.

$$K_{t+1} = S_t \Psi_{t+1}. \tag{3}$$

Following the previous literature, the quality-of-capital shock introduces an exogenous variation in the value of capital. The shock affects asset price dynamics, because the latter are endogenous. The disruption refers to economic obsolescence, in contrast with physical depreciation. The shocks Ψ_t and Ψ_t^* are mutually independent and i.i.d. The foreign quality-of-capital shock serves as a trigger for the financial crisis.

As in Heathcote and Perri (2002), there are local perfectly competitive distributor firms that combine domestic and imported goods to produce final goods. These are used for consumption and investment, and are produced using a constant elasticity of substitution technology

$$Y_t = \left[\nu^{\frac{1}{\eta}} X_t^{H\,\frac{\eta-1}{\eta}} + (1-\nu)^{\frac{1}{\eta}} X_t^{F\,\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{4}$$

where η is the elasticity of substitution between domestic and imported goods. There is home bias in production. The parameter ν is a function of the size of the economy and the degree of openness, λ: $\nu = 1 - (1-m)\lambda$ (Sutherland 2005).

Non-financial firms acquire new capital from capital goods producers, who operate at a national level. As in Christiano, Eichenbaum, and Evans (2005), there are convex adjustment costs in the gross rate of investment for capital goods producers. Then, the final domestic output equals the domestic households' consumption, C_t, domestic investment, I_t, and government consumption, G_t,

$$Y_t = C_t + I_t \left[1 + f\left(\frac{I_t}{I_{t-1}} \right) \right] + G_t. \tag{5}$$

Turning to preferences, households maximize their expected discounted utility

$$U(C_t, L_t) = E_t \sum_{t=0}^{\infty} \beta^t \left[\ln C_t - \frac{\chi}{1+\gamma} L_t^{1+\gamma} \right], \tag{6}$$

where E_t is the expectation operator conditional on information available on date t, and γ is the inverse of Frisch elasticity. I abstract from many features in the conventional DSGE models, such as habits in consumption, nominal prices, wage rigidity, etc.

In online appendix 3, I define the competitive equilibrium of the frictionless economy which is the benchmark when comparing the different models with financial frictions. It is a standard international real business-cycle model in financial autarky with trade in goods. Next, I add financial frictions.

3.2 Households

There is a representative household for each country. The household is composed of a continuum of members. A fraction, f, are bankers, while the rest are workers. Workers supply labor to non-financial firms and return their wages to the households. Each of the bankers manages a financial intermediary and transfers non-negative profits back to its household subject to its flow-of-funds constraint. Within the family, there is perfect consumption insurance.

Households deposit funds in a bank; I assume that they cannot hold capital directly. Deposits are riskless one-period securities, and they pay a return R_t, determined in period $t-1$.

Households choose consumption, deposits, and labor (C_t, D_t^h, and L_t, respectively) by maximizing expected discounted utility, equation (6), subject to the flow-of-funds constraint,

$$C_t + D_{t+1}^h = W_t L_t + R_t D_t^h + \Pi_t - T_t, \tag{7}$$

where W_t is the wage rate, Π_t are the profits from ownership of banks and non-financial firms, and T_t are lump-sum taxes. The first-order conditions for the problem of the households are standard and are defined in online appendix 2.

3.3 Non-Financial Firms

3.3.1 Goods Producers

Intermediate competitive goods producers operate at a local level with constant-returns-to-scale technology with capital and labor as inputs, given by equation (1). The gross profits per unit of capital Z_t are

$$Z_t = \alpha P_t^H L_t^{1-\alpha} K_t{}^{\alpha-1} \quad \text{with} \quad P_t^H = \nu^{\frac{1}{\eta}} Y_t^{-1} \left(X_t^H\right)^{-\frac{1}{\eta}}. \tag{8}$$

The price of the final home good is equalized to 1.

To simplify, I assume that non-financial firms do not face any financial frictions when obtaining funds from intermediaries and they can commit to pay all future gross profits to the creditor bank. A goods producer will issue new securities at price Q_t to obtain funds for buying new capital. Each unit of security is a state-contingent claim to the future returns from one unit of investment, because there is no financial friction. By perfect competition, the price of new capital equals the price of the security, and goods producers earn zero profits state by state.

The production of these competitive goods is used locally and abroad,

$$X_t = X_t^H + \frac{1-m}{m} X_t^{H*}, \tag{9}$$

to produce the final good Y_t following the constant elasticity of substitution (CES) technology shown in equation (4). The law of one price holds for intermediate goods: $P_t^{H*} NER_t = P_t^H$, where NER_t is the nominal exchange rate; however, due to home bias, the law of one price does not hold in the aggregate level, and I define the real exchange rate as $\varepsilon_t = \frac{P_t^* NER_t}{P_t}$.

3.3.2 Capital Producers

Capital producers use final output, Y_t, to make new capital subject to adjustment costs. They sell new capital to goods producers at price Q_t. The objective of non-financial firms is to maximize their expected discounted profits, choosing I_t

$$\max_{I_t} E_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau} \left\{ Q_\tau I_\tau - \left[1 + f\left(\frac{I_\tau}{I_{\tau-1}}\right)\right] I_\tau \right\}.$$

The first-order condition yields the price of capital goods, which equals the marginal cost of investment:

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} f'\left(\frac{I_t}{I_{t-1}}\right) - E_t\Lambda_{t,t+1}\left[\frac{I_{t+1}}{I_t}\right]^2 f'\left(\frac{I_{t+1}}{I_t}\right). \tag{10}$$

Profits, which arise only out of the steady state, are redistributed lump sum to households.

3.4 Banks

To finance their lending, banks get funds from domestic households and use retained earnings from previous periods. Banks are constrained on how much they can borrow from households. In order to limit the banker's ability to save to overcome being financially constrained, inside the household I allow for turnovers between bankers and workers. I assume that with i.i.d. probability σ a banker continues being a banker in the next period, while with probability $1-\sigma$ it exits the banking business. If it exits, it transfers retained earnings back to its household and becomes a worker. To keep the number of workers and bankers fixed, in each period a fraction of workers becomes bankers. A bank needs positive funds to operate; therefore, every new banker receives a startup constant fraction ξ of total assets of the bank.

To motivate the global interbank market, I assume that the survival rate of home banks σ is higher than that of foreign banks σ^*. Remember that the home economy is the relatively small open economy with a big financial sector. Then, home banks can accumulate more net worth to operate. In equilibrium, home banks lend to foreign banks. This interaction between home and foreign banks is what I call the global interbank market. Home banks fund their activity through a retail market (deposits from households) and foreign banks fund their lending through a retail and a wholesale market (where home banks lend to foreign banks).

At the beginning of each period, a bank raises funds from households, deposits d_t, and with retained earnings from the previous periods, net worth n_t, it decides how much to lend to non-financial firms s_t. Home banks also choose how much to lend to foreign banks b_t.

Banks are constrained on how much they can borrow from households. In this sense, financial frictions affect the real economy. By assumption, there is no friction when transferring resources to nonfinancial firms. Firms offer banks a perfect state-contingent security, s_t. The price of the security (or loan) is Q_t, which is also the price of the assets of the bank. In other words, Q_t is the market price of the bank's claim on the future returns from one unit of present capital of non-financial firm at the end of period t, which is in process for period $t+1$.

Next, I describe the characteristics of home and foreign banks.

3.4.1 Home Banks

For an individual home bank, the balance sheet implies that the value of the loans funded in that period, $Q_t s_t$ plus $Q_{bt} b_t$, where Q_{bt} is the price of loans made to foreign banks, has to equal the sum of the bank's net worth, n_t, and home deposits, d_t,

$$Q_t s_t + Q_{bt} b_t = n_t + d_t.$$

Let R_{bt} be the global asset rate of return from period $t-1$ to period t. The net worth of an individual home bank at period t is the payoff from assets funded at $t-1$, net borrowing costs:

$$n_t = [Z_t + (1-\delta)Q_t]s_{t-1}\Psi_t + R_{b,t}Q_{bt-1}b_{t-1} - R_t d_{t-1},$$

where Z_t is the dividend payment at t on loans funded in $t-1$, and is defined in equation (8).

At the end of period t, the bank maximizes the present value of future dividends, taking into account the probability of continuing being a banker in the next periods; the value of the bank is defined by

$$V_t = E_t \sum_{i=1}^{\infty} (1-\sigma)\sigma^{i-1}\Lambda_{t,t+i} n_{t+i}.$$

Following the previous literature, I introduce a simple agency problem to motivate the ability of the bank to obtain funds. After the bank obtains funds, it may transfer a fraction θ of assets back to its own household. Households limit the funds lent to banks.

If a bank diverts assets, it defaults on its debt and shuts down. Its creditors can reclaim the remaining $1-\theta$ fraction of assets. Let $V_t(s_t, b_t, d_t)$ be the maximized value of V_t, given an asset and liability configuration at the end of period t. The following incentive constraint must hold for each bank individually to ensure that the bank does not divert funds:

$$V_t(s_t, b_t, d_t) \geq \theta(Q_t s_t + Q_{bt} b_t). \tag{11}$$

The borrowing constraint establishes that for households to be willing to supply funds to a bank, the value of the bank must be at least as large as the benefits from diverting funds.

At the end of period $t-1$, the value of the bank satisfies the following Bellman equation:

$$\begin{aligned} &V(s_{t-1}, b_{t-1}, d_{t-1}) \\ &\quad = E_{t-1}\Lambda_{t-1,t}\left\{(1-\sigma)n_t + \sigma\left[\max_{s_t,b_t,d_t} V(s_t, b_t, d_t)\right]\right\}. \end{aligned} \tag{12}$$

The problem of the bank is to maximize equation (12) subject to the borrowing constraint, equation (11).

I guess and verify that the form of the value function of the Bellman equation is linear in assets and liabilities,

$$V(s_t, b_t, d_t) = \nu_{st} s_t + \nu_{bt} b_t - \nu_t d_t, \tag{13}$$

where ν_{st} is the marginal value of assets at the end of period t, ν_{bt} is the marginal value of global lending, and ν_t is the marginal cost of deposits.

I maximize the objective function (12) subject to (11) and rewrite the first-order conditions that I show in online appendix 2 to define the excess value of a unit of assets relative to deposits:

$$\mu_t = \frac{\nu_{st}}{Q_t} - \nu_t.$$

Also, I define the leverage ratio net of international borrowing by rewriting the incentive compatibility constraint,

$$\phi_t = \frac{\nu_t}{\theta - \mu_t}. \tag{14}$$

Therefore, the balance sheet of the individual bank is

$$Q_t s_t + Q_{bt} b_t = \phi_t n_t. \tag{15}$$

The last equation establishes how tightly the constraint is binding. The leverage has negative co-movement with the fraction that banks can divert, θ, and positive with the excess value of bank assets, μ_t.

I verify the conjecture regarding the form of the value function using the Bellman equation (12) and the guess (13). For the conjecture to be correct, the cost of deposits and the excess value of bank assets have to satisfy

$$\nu_t = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{t+1} \tag{16}$$

$$\mu_t = E_t \Lambda_{t,t+1} \Omega_{t+1} \left[R_{kt+1} - R_{t+1} \right], \tag{17}$$

where the stochastic discount factor of the households is $\Lambda_{t,t+1}$ and the shadow value of net worth at $t+1$ is

$$\Omega_{t+1} = (1-\sigma) + \sigma(\nu_{t+1} + \phi_{t+1}\mu_{t+1}) \tag{18}$$

and holds state by state. The gross rate of return on bank assets is

$$R_{kt+1} = \Psi_{t+1} \frac{Z_{t+1} + Q_{t+1}(1-\delta)}{Q_t}. \tag{19}$$

Regarding the shadow value of net worth, equation (18), the first term corresponds to the probability of exiting the banking business; the second term represents the marginal value of an extra unit of net worth given the probability of survival. For a continuing banker, the marginal value of net worth corresponds to the sum of the benefits of an extra unit of deposits, ν_{t+1}, and the payoff of holding assets, the leverage ratio times the excess value of loans, $\phi_{t+1}\mu_{t+1}$. Because the leverage ratio and the excess return vary countercyclically, the shadow value of net worth varies countercyclically, too. In other words, because the banks' incentive constraint is more binding during recessions, an extra unit of net worth is more valuable in bad times than in good times.

Then, from equation (16), the marginal value of deposits is equal to the expected augmented stochastic discount factor (the household discount factor times the shadow value of net worth) times the risk-free interest rate, R_{t+1}. According to equation (17), the excess value of a unit of assets relative to deposits is the expected value of the product of the augmented stochastic discount factor and the difference between the risky and the risk-free rate of return, $R_{kt+1} - R_{t+1}$. The spread is also countercyclical.

Home banks lend to domestic non-financial firms and to foreign banks through the international interbank market; therefore, from the first-order conditions of the bank,

$$\frac{\nu_{st}}{Q_t} = \frac{\nu_{bt}}{Q_{bt}},$$

which implies that the discounted rate of return on home assets has to be equal to the discounted rate of return on global loans:

$$E_t \Lambda_{t,t+1} \Omega_{t+1} R_{kt+1} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{bt+1}. \tag{20}$$

Banks are indifferent between providing funds to non-financial home firms and to foreign banks because the expected return on both assets is equalized. R_{bt} is defined in the next section and is related to the return on non-financial foreign firms expressed in home final goods. Next, I turn to the foreign banks' problem.

3.4.2 Foreign Banks

The problem of the foreign banks is similar to the one of the home banks, except that now the interbank market assets, b_t^*, are loans from home banks and they are on the liability side:

$$Q_t^* s_t^* = n_t^* + d_t^* + Q_{bt}^* b_t^*.$$

The net worth of the bank can also be thought of in terms of payoffs; then, the total net worth is the payoff from assets funded at $t-1$, net of borrowing costs which include the international loans,

$$n_t^* = [Z_t^* + (1-\delta) Q_t^*] s_{t-1}^* \Psi_t^* - R_t^* d_{t-1}^* - R_{bt}^* Q_{bt-1}^* b_{t-1}^*.$$

The framework can be thought of as one with asset market integration because banks cannot divert funds financed by other banks. In particular, home banks can perfectly recover the interbank market loans. Foreign banks are only constrained on obtaining funds from foreign households. Then, from the optimization problem of the foreign banks, the shadow value of global borrowing and domestic assets are equalized,

$$\frac{\nu_{st}^*}{Q_t^*} = \frac{\nu_{bt}^*}{Q_{bt}^*}; \tag{21}$$

or in terms of returns,

$$E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{kt+1}^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{bt+1}^*. \tag{22}$$

The expected discounted rate of return on global interbank loans is equal to the expected discounted rate of return on loans to non-financial foreign firms. Given a shock, the return on the global interbank asset is as volatile as the return on the domestic asset, emphasizing the transmission mechanism from one country to the other. Furthermore, the expected discounted rate of return on the global asset equalizes to the one on loans to non-financial home firms; see equation (20). Then, the home loan market and the foreign loan market co-move. This is the integration of the asset markets.

With Ω_{t+1}^* as the shadow value of net worth at date $t+1$, and R_{kt+1}^* as the gross rate of return on bank assets, after verifying the conjecture of the value function, I define the marginal value of deposits and the excess return on assets as

$$\nu_t^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{t+1}^*$$
$$\mu_t^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* \left[R_{kt+1}^* - R_{t+1}^* \right]$$

with

$$\Omega_{t+1}^* = 1 - \sigma^* + \sigma^* \left(\nu_{t+1}^* + \phi_{t+1}^* \mu_{t+1}^* \right)$$
$$R_{kt+1}^* = \Psi_{t+1}^* \frac{Z_{t+1}^* + Q_{t+1}^*(1-\delta)}{Q_t^*}. \tag{23}$$

3.4.3 Aggregate Bank Net Worth

Finally, aggregating across home banks, from equation (15),

$$Q_t S_t + Q_{bt} B_t = \phi_t N_t. \tag{24}$$

Capital letters indicate aggregate variables. From the previous equation, I define the households' deposits:

$$D_t = N_t(1 - \phi_t). \tag{25}$$

Furthermore,

$$N_t = (R_{k,t}Q_{t-1}S_{t-1} + R_{b,t}Q_{b,t-1}B_{t-1})(\sigma + \xi) - R_t D_{t-1}\sigma. \tag{26}$$

The last equation specifies the law of motion of the home banking system's net worth. The first term in the parentheses represents the return on loans made in the last period. The second term in the parentheses is the return on funds that the household invested in the foreign economy. Both loans are scaled by the old bankers (that survived from the last period) plus the startup fraction of loans that young bankers receive. The last term in the equation is the total return on households' deposits that banks need to pay back.

For foreign banks, the aggregation yields

$$N_t^* = R_{k,t}^* Q_{t-1}^* S_{t-1}^*(\sigma^* + \xi^*) - R_t^* D_{t-1}^* \sigma^* - R_{bt}^* Q_{bt-1}^* B_{t-1}^* \sigma^*, \tag{27}$$

where R_{bt}^* equals R_{kt}^*, from equation (22). The balance sheet of the aggregate foreign banking system can be written as

$$Q_t^* S_t^* - Q_{bt}^* B_t^* = \phi_t^* N_t^*. \tag{28}$$

3.4.4 Global Interbank Market

At the steady state, home banks invest in the foreign economy because the survival rate of home banks is higher than the survival rate of foreign banks; therefore, home banks lend to foreign banks. An international interbank market arises. Foreign banks have an incentive to borrow from home banks because foreign banks are more constrained than home banks.[8] Another way of thinking about the global interbank market is to assume that the deposits foreign

[8]Note that because banks face a borrowing constraint, the difference in the survival rate of banks, which implies different augmented discount factors, does not prompt that the small economy owns all the wealth of the world, as in an unconstrained open capital markets model.

banks get from foreign households are not enough to cover the capital that foreign firms demand. In the foreign country (the bigger economy), capital is higher than national savings. Since at home deposits are higher than capital, there is a gap for an international transaction.

Regarding the interest rate, the return on loans to foreign banks made by home banks is $E_t(R_{bt+1}) = E_t(R^*_{bt+1}\frac{\varepsilon_{t+1}}{\varepsilon_t})$. The rate on global loans is equalized to the return on loans to home firms, R_{kt}, in expected terms in equation (20); home banks are indifferent between lending to home firms or to foreign banks. For foreign banks, equation (22) equalizes the rate of return on global loans to the rate of return on foreign loans. The double equalization drives the asset market integration. In addition, the rate of return on the global asset market is related to the gross return on capital in the foreign country in the following way:

$$R^*_{b,t+1} = \Psi^*_{t+1}\frac{Z^*_{t+1} + Q^*_{b,t+1}(1-\delta)}{Q^*_{bt}}, \tag{29}$$

which equalizes the returns on the international asset and the foreign lending.

3.5 Equilibrium

To close the model, the different markets need to be in equilibrium. The equilibria in the final goods market, the intermediate competitive goods market, and the labor market for home and for foreign are standard and are described in online appendix 2. The market for securities is in equilibrium when

$$S_t = I_t + (1-\delta)K_t = \frac{K_{t+1}}{\Psi_{t+1}}.$$

If the economies are in financial autarky, the net exports for home are zero in every period; the current account results in

$$CA_t = 0 = \frac{1-m}{m}X_t^{H*} - \tau_t X_t^F, \tag{30}$$

with τ_t as the terms of trade, defined by the price of imports relative to exports for the home economy.

On the other hand, if there are global banks in the economy, the current account is

$$CA_t = Q_{b,t}B_t - R_{bt}Q_{b,t-1}B_{t-1} = X_t^{*H}\frac{1-m}{m}\frac{P_t^H}{P_t} - X_t^F\tau_t\frac{P_t^H}{P_t}. \tag{31}$$

The global asset is in zero net supply, as a result:

$$B_t = B_t^*\frac{1-m}{m}. \tag{32}$$

To close the model, the last condition corresponds to the riskless debt. Total household savings equal total deposits plus government debt. Government debt is a perfect substitute of deposits to banks,

$$D_t^h = D_t + \mathcal{D}_{gt}. \tag{33}$$

I formally define the equilibrium of the banking model in online appendix 3.

4. Unconventional Policy

In 2008, the interest rate was almost zero percentage points, and to stabilize the financial system and mitigate the effects of an even deeper recession, the Federal Reserve started to intervene in different markets as lender of last resort to increase credit flows in the economy. From among the policies that the Federal Reserve carried out, I focus on two types: direct lending in credit markets and equity injections in the banking system. For the former, the Federal Reserve extended credit particularly to partnerships and corporations. The Commercial Paper Funding Facility (CPFF), Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF), Money Market Investor Funding Facility (MMIFF), and the Term Asset-Backed Securities Loan Facility (TALF) are programs that have these characteristics. Regarding equity injections, the Treasury provided capital facilities to Bear Stearns, JP Morgan Chase, Maiden Lane LLC, American International Group (AIG), Bank of America, and Citigroup. The facilities were under the Troubled Assets Relief Program (TARP) and started after the collapse of Lehman Brothers in September 2008.

There were also coordinated actions between the Federal Reserve and other central banks because of global banks. Specifically, the Federal Reserve provided U.S. dollars to other central banks, such as the Swiss National Bank (SNB), the European Central Bank, and the Bank of England. Afterwards, these central banks provided liquidity to the banks in their jurisdiction, so that banks located in these jurisdictions would continue lending to U.S. institutions. These arrangements, called liquidity swaps, were expected to improve liquidity in the U.S. financial markets.

All the unconventional policies that the Federal Reserve carried out as lender of last resort totaled $29,616.4 billion U.S. dollars—almost twice the U.S. GDP in 2008. Excluding the liquidity swap agreements with other central banks, 83.9 percent ($16.41 trillion U.S. dollars) of all assistance was provided to only fourteen institutions. Among them there were two big Swiss banks: UBS and Credit Suisse received 2.2 percent and 4 percent of the assistance, respectively (Felkerson 2011).

UBS and Credit Suisse were exposed to illiquid securitized loans in the United States. They received assistance from the Federal Reserve by the Term Securities Lending Facility (TSLF), CPFF, mortgage-backed securities, and the term repurchase transactions (ST OMO, or single-tranche open-market operations), and from the SNB. As a policy action, the SNB created the "StabFund" fund to purchase toxic assets from UBS. In October 16, 2008, the SNB announced the creation of a special vehicle to acquire up to $60 billion U.S. dollars of sub-prime and other compromised assets from UBS. The arrangement also included the purchase by the Swiss federal government of $6 billion U.S. dollars in mandatory convertible notes issued by UBS. This last measure helped to strengthen UBS' liability side. StabFund bought $38.7 billion U.S. dollars from UBS' compromised assets; the SNB provided $25.8 billion U.S. dollars in cash (about 5 percent of Swiss GDP). In November 2013, UBS signed a purchase agreement to acquire the StabFund from the SNB (Swiss National Bank 2013).

In this section, I introduce three interventions carried out by the central banks. The first two policies, direct intervention in the loan market and direct intervention in the interbank market, are inspired by the policies that the Federal Reserve carried out to extend credit in specific markets. The third policy provides capital directly to banks and corresponds to equity injections; this policy can be related to the TARP program that the Treasury put in action, but also to the "StabFund" that the SNB created. I build the modeling of these policies on Dedola, Karadi, and Lombardo (2013), Gertler and Karadi (2011), Gertler and Kiyotaki (2010), and Gertler, Kiyotaki, and Queralto (2012).

The extent to which the central bank intervenes is determined endogenously. The level of intervention follows the difference between the spread of the expected return on capital and the deposit rate, and their stochastic steady-state level under no policy:

$$\varphi_t^* = \nu_g^* \tau_{gt}^* \left[E_t(R_{k,t+1}^* - R_{t+1}^*) - \left(R_k^{*SSS} - R^{*SSS} \right) \right], \tag{34}$$

where ν_g^* is a policy instrument, and τ_{gt}^* follows an AR(1) process when there is a quality-of-capital shock in foreign; otherwise, it equals zero. This specification contrasts with the policy proposed in the previous literature in two dimensions. First, I target the stochastic steady-state premium instead of the deterministic one. The spread is where banks accumulate earnings; by targeting the deterministic steady state, the net worth takes longer to return to its steady-state value. In this sense, Kiyotaki (2013) suggests targeting the mean of the ergodic distribution of the variables taking into account the distribution of the shocks. Second, the policy is only active when there is a quality-of-capital shock in foreign, while in the other papers the policy is active when the premium is different from its deterministic steady state, even if it is coming from a productivity shock. I assume that $\tau_{gt}^* = \rho_{\tau_g^*} \tau_{gt-1}^* + \varepsilon_{\Psi^*,t}$, where $\varepsilon_{\Psi^*,t}$ is the same exogenous variable that drives the foreign quality-of-capital shock.

According to the specification, the policies are carried out only by the policymaker of the country directly hit by the shock (foreign) or by both policymakers. Next, I describe the three policies separately.

4.1 Loan Market Intervention

The central bank can lend directly to local non-financial firms in order to mitigate the effects of the crisis. The policymaker endogenously determines the fraction of private credit. The level of intermediation follows equation (34). The total assets of a firm are

$$Q_t^* S_t^* = Q_t^* (S_{pt}^* + \mathcal{S}_{gt}^*),$$

where S_{pt}^* are the loans made by financial intermediaries, and $\mathcal{S}_{gt}^*$ are the ones made by the government. Assuming that $\mathcal{S}_{gt}^*$ is a fraction of total credit, I can rewrite equation (28) as

$$Q_t^* (\underbrace{S_t^* - \varphi_t^* S_t^*}_{S_{pt}^*}) - Q_{bt}^* B_t^* = \phi_t^* N_t^*$$

$$Q_t^* S_t^* (1 - \varphi_t^*) - Q_{bt}^* B_t^* = \phi_t^* N_t^*. \tag{35}$$

Furthermore, the equations of the foreign banking system become

$$Q_t^* S_t^* (1 - \varphi_t^*) = N_t^* + D_t^* + Q_{bt}^* B_t^*$$

$$N_t^* = (\sigma^* + \xi^*)[Z_t^* + (1 - \delta) Q_t^*] S_{t-1}^* \Psi_t^* (1 - \varphi_{t-1}^*) - \sigma^* R_t^* D_{t-1}^*$$
$$- \sigma^* R_{bt}^* Q_{b,t-1}^* B_{t-1}^*.$$

4.2 Interbank Market Intervention

The second policy is the provision of funds to banks through the interbank market. To what extent the policymaker intervenes is determined endogenously by equation (34). By providing funds in the interbank market, the government increases the total quantity available in the market as such. There are public and private funds in the interbank market,

$$B_t^* = \mathcal{B}_{gt}^* + \tfrac{m}{1-m} B_t, \tag{36}$$

with $\mathcal{B}_{gt}^* = \varphi_t^* Q_t^* S_t^*$. Foreign banks receive higher funding under policy than under no policy. The net worth of foreign banks does not change in structure; the only difference is that B_t^* follows equation (36). The interest rate that the banks pay on government loans is the same as the one paid to home banks.

4.3 Equity Injection

The third policy is equity injections. Under this policy, the central bank gives funds to domestic banks and the banks then decide how to allocate these extra resources optimally. Again, the quantity of funds that the government provides is a fraction of the total assets of the foreign banks, $\mathcal{N}^*_{gt} = \varphi^*_t Q^*_t S^*_t$. The net worth of the foreign banking system is set to be

$$N^*_t = (\sigma^* + \xi^*)\left[Z^*_t + (1-\delta)Q^*_t\right]K^*_t - \sigma^* R^*_t D^*_{t-1} \\ - \sigma^* R^*_{bt} Q^*_{bt-1} B^*_{t-1} - \sigma^* R^*_{gt} \mathcal{N}^*_{g,t-1}.$$

Redefining equation (28) yields

$$Q^*_t S^*_t = \phi^*_t N^*_t + \mathcal{N}^*_{gt} + Q^*_{bt} B^*_t. \quad (37)$$

The interest rate paid to the government is equal to the interest rate on capital.

4.4 Government

Consolidating monetary and fiscal policy, total government expenditure is the sum of consumption, G^*_t, loans to firms (or total intervention), $\mathcal{S}^*_{gt}$, and debt issued in the last period, $R^*_t \mathcal{D}^*_{gt-1}$. Government resources are lump-sum taxes, T^*_t, new debt issued, $\mathcal{D}^*_{gt}$, and the return on the intervention that the government made in the last period. The consolidated budget constraint of the government is

$$G^*_t + Q^*_t \mathcal{S}^*_{gt} + R^*_t \mathcal{D}^*_{gt-1} = T^*_t + \mathcal{D}^*_{gt} + \left[Z^*_t + (1-\delta)Q^*_t\right]\Psi^*_t \mathcal{S}^*_{gt-1},$$

where I present the equation with total loans to firms, but it should be defined according to the policy.

The debt that government issues is a perfect substitute of the deposits to banks; therefore, the rate that they pay is the same and households are indifferent between lending to banks and to the government. Government expenditure includes a constant fraction of total output and a cost for each unit of intervention issued,

$$G^*_t = \tau^*_{1S} Q^*_t S^*_{gt} + \tau^*_{2S}\left(Q^*_t S^*_{gt}\right)^2 + \bar{g}^* Y^*.$$

The efficiency costs are quadratic on the intervention of the central bank, as in Gertler, Kiyotaki, and Queralto (2012).

5. Crisis Experiment

In this section, I present numerical experiments to show how the model captures key aspects of the international transmission of a financial crisis because of the global interbank market. First, I present the calibration. Second, I analyze a crisis experiment without response from the government and I highlight the role of the global asset market in the transmission of the crisis and how it works as an insurance for the economy that is hit by a shock. Third, I evaluate how well the model explains the financial crisis data. Fourth, I study how credit market interventions by the foreign and the home central bank can mitigate the effects of the crisis. Fifth, I evaluate the welfare of the consumers under the different policies, and, finally, I study non-cooperative versus cooperative policies. In online appendix 5, I relax the assumption that foreign banks cannot lend to home banks and I perform the same exercises as in the baseline model.

5.1 Calibration

The calibration is specified in table 1. The parameters that correspond to the non-financial part of the model, i.e., households and non-financial firms, follow the literature. The discount factor, β, is set to 0.99, resulting in a risk-free interest rate of 1.01 percent at the steady state. The inverse of the Frisch elasticity of labor supply, γ, and the relative weight of labor in the utility faction, χ, are equal to 0.1 and 5.584, respectively. The capital share in the production of the intermediate good, α, is 0.33 and the parameter in the adjustment cost in investment, κ, equals 1. The quarterly depreciation rate of capital is 2.5 percent.

The parameters that enter into the CES aggregator, η and ν, follow the calibrated values for Switzerland in Cuche-Curti, Dellas, and Natal (2009). The elasticity of substitution between home and foreign goods in the production of the final good, η, is set to be greater than 1. This implies substitutability between domestic and foreign goods. The home bias, ν, is defined by the size of the home economy and the degree of openness. I calibrate the size of the countries to match the ratio between Swiss and U.S. GDP as an average between 2002 and 2008.

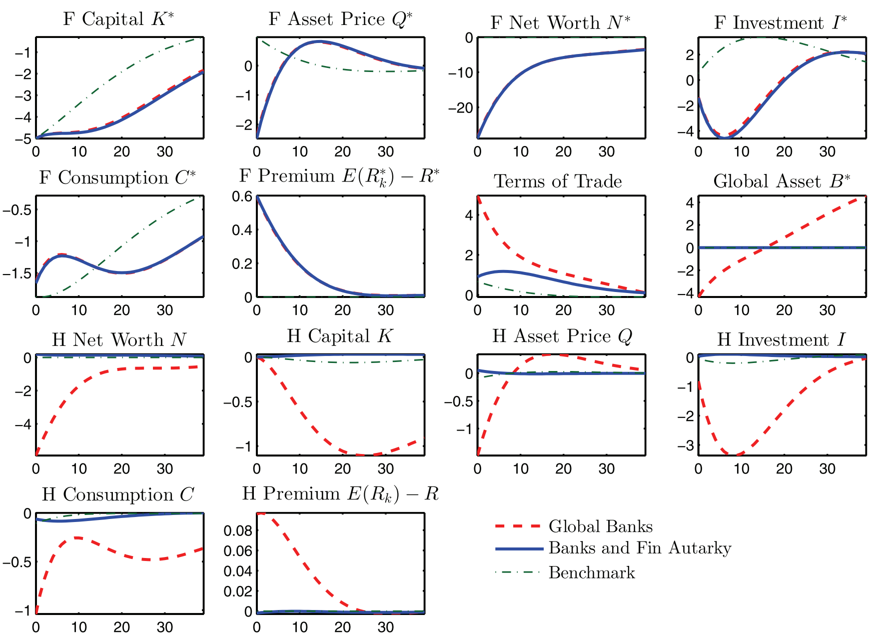
Table 1. Calibration

		Home	Foreign
β	Discount Factor	0.9900	0.9900
γ	Inverse Elasticity of Labor Supply	0.1000	0.1000
χ	Relative Utility Weight of Labor	5.5840	5.5840
α	Effective Capital Share	0.3330	0.3330
κ	Adj. Cost Parameter	1.0000	1.0000
δ	Depreciation	0.0250	0.0250
ν	Home Bias	0.8500	0.9625
η	Elasticity of Substitution	1.1111	1.1111
m	Size of the Countries	0.0400	0.9600
ξ	Startup	0.0018	0.0018
θ	Fraction of Div. Assets	0.4067	0.4074
σ	Survival Rate	0.9740	0.9720
$\bar{g}$	Steady-State Gov. Expenditure	0.1240	0.2000
τ^*_{1S}	Cost of Issuing Loans		0.00125
τ^*_{2S}	Cost of Issuing Loans		0.0120

The parameters of the banking sector are such that the average credit spread is 110 basis points per year; the credit spreads are equal for both economies at the steady state. This is a rough approximation of the different spreads for the pre-2007 period. In particular, how tightly the constraint is binding, explained by the parameter θ, matches that target. The startup fraction that the new banks receive, ξ, is 0.18 percent of the last period's assets, which corresponds to the value used by Gertler and Kiyotaki (2010). The global interbank market exists because the survival rate is different across countries, 0.974 for home and 0.972 for foreign banks. On average, home banks survive nine years, while foreign banks survive around eight years.[9] At the steady state, the holding of global assets represents 16 percent of the total assets of the home banks, which

[9]Data from the SNB, for Switzerland, and from the FDIC, for the United States, on the number of financial institutions show that, over the past thirteen years, the number of Swiss institutions has been more stable and less decreasing than the number of U.S. institutions.

Figure 4. Impulse Responses to a 5 Percent Decrease in Ψ_t^*, Model Comparison



matches the data for total lending by Swiss banks to U.S. counterparties from the year 2002 until 2008, and constitutes 17 percent of Swiss banks' total assets. In online appendix 4, I evaluate the deterministic steady state of the home economy that results from this calibration and I compare it with Swiss data from 2002 until 2008. I assume a negative i.i.d. shock that occurs in foreign.

5.2 *No Policy Response*

Figure 4 shows the impulse responses to a decline in the foreign quality of capital of 5 percent in period t comparing three models. The first model is one without financial frictions and in financial autarky, and is the thin dashed-dotted line. The second model has financial frictions à la Gertler and Kiyotaki (2010) but no trade in assets, and is the solid line. The third model is one with financial frictions and a global interbank market (financial openness); it is the thick dashed line. The comparison of these models shows how the transmission mechanism across countries changes given the different assumptions. In the first two models, there is only international spillover due to the trade of intermediate goods. In the third model, I add the international financial mechanism. The comparison helps one understand the insurance and the transmission role of the interbank market. The size of the shock triggers a 30 percent decrease in the net worth of foreign banks and 7 percent of the net worth of home banks, i.e., roughly the rates seen during the latest financial crisis. In online appendix 8, figure A6 shows a larger set of impulse response functions.

When there is a decrease in the foreign quality of capital, and there are no financial frictions (i.e., no banks) in the economy, all the resources are channeled to recover from the initial shock. Investment and asset price go up. On impact, households cut down on consumption because of lower labor income. Final domestic demand and production in foreign fall because of the negative shock. The foreign economy cuts back not only on the demand for local goods, X_t^{*F}, but also on imports, X_t^{*H}. There are fewer foreign goods in the economy because of the shock. As a result, every unit of foreign good is more expensive and the terms of trade slightly improve (deteriorate) for foreign (home). The trade balance is defined by equation (30) and equals zero in every period because there is no international borrowing/lending.

Foreign demand of home goods decreases, but the home economy starts demanding more domestic products because they are relatively cheaper. Home increases its production, X_t, while substituting foreign with domestic goods. Nevertheless, consumption and investment decrease because the interest rate is higher. In the model without financial frictions and in financial autarky, there is no international co-movement either in asset prices or in production. However, there is co-movement in total demand and consumption, while the terms of trade deteriorate for the home economy.

Adding financial frictions but no global banks to the model results in a model similar to Gertler and Kiyotaki (2010). There are banks and they are financially constrained; when their asset (capital) goes down, banks face a decrease in their net worth. Because banks are more constrained on how much they can borrow, there is a fire sale of assets that prompts the asset price, Q_t^*, to go down.

The spread between the foreign rate of return on capital and the risk-free rate, $E(R_k^*) - R^*$, widens. The behavior of the spread is a characteristic of the crisis period. The expected rate of return on capital increases because of the fall in capital.

Foreign production and consumption shrink. There are fewer foreign goods and they are relatively more expensive; similarly to the model without financial frictions, the terms of trade slightly improve for foreign. Home goods are cheaper, the production of home goods increases, and investment increases as well. Home businesses increase their demand for loans, banks are less constrained, and their net worth goes up. Consumption falls because of the reduction in total wages. Similarly to the previous model, asset prices and production do not co-move across countries. Although there is a larger spillover to the home economy with financial frictions than without them, home banks get an increase on their net worth after a negative quality-of-capital shock in foreign.

When I allow for a global asset, home banks lend to foreign banks. In the global interbank market, foreign banks borrow internationally; they diversify their liabilities and pool a country-specific shock. These asset market characteristics have been discussed by Cole and Obstfeld (1991) and Cole (1993).

The decrease in the value of assets and securities in foreign prompts foreign banks to be more financially constrained. The reaction is similar to the model without global banks and is shown by the solid and the thick dashed lines in figure 4. The mechanism that takes place for foreign variables is the same in both models with financial frictions. However, final domestic demand is less affected by the shock when there are global banks because foreign partially pools the country-specific shock.

There is asset market integration: the asset price in foreign falls, and so does the asset price of the global asset. Home banks face a reduction in their net worth because of a country-specific shock in foreign. Home financial intermediaries are more financially constrained and reduce lending to domestic businesses. Investment and the price of capital shrink. The global interbank market transmits the crisis from foreign to home.

Two types of spillovers disturb the home economy: the demand and the global asset effects. The demand effect prompts an increase in production because the home exchange rate is depreciating. The global asset effect generates a tightening of the home borrowing constraint because there is a decrease in the value of international lending. The global asset effect predominates and the net worth of home banks falls and households cut down on consumption. Global banks imply financial openness; the current account is now defined in equation (31).

In a model with global banks and financial frictions, home and foreign consumption, asset price, and total demand co-move, while production does not. The asset markets across countries are integrated because of the equalization of returns of the asset market at home and abroad.

The results are different from the work of Dedola, Karadi, and Lombardo (2013). In their model, in response to a country-specific quality-of-capital shock with integration in the capital market, but not in the deposit market, assets and net worth of home and foreign move in different directions. To a negative quality-of-capital shock in foreign, foreign loans to home decrease and home loans (assets) to domestic firms increase to compensate for the former reduction. Then, home banks' net worth increase. The leverage and the spread are equalized across countries. This would imply UBS increasing loans in the United States after a quality-of-capital shock in the United States, which is exactly the opposite of what happened during the latest financial crisis. Moreover, the reaction of the home real variables is almost negligible. The equalization of the spreads across countries is a key element to understand their results; however, this does not go in line with the data.[10]

The qualitative behavior of the model matches the VAR evidence shown in figure 3. In the data, a decrease in the U.S. loans prompts a decrease in the domestic asset price that is then transmitted to the Swiss economy. Total final demand, foreign U.S.-dollar-denominated loans, net interest payments, and asset prices fall.

Home has a larger co-movement with the foreign economy in a framework with financial openness than without it. The home economy experiences a crisis because of the quality-of-capital shock

[10]For comparison with Dedola, Karadi, and Lombardo (2013), in figure A12 in online appendix 8, I compare a financial shock with a quality-of-capital shock. In my model, the quality-of-capital shock resembles the VAR better than the financial shock.

abroad, as shown by the VAR evidence and the model. Moreover, through the global interbank market, the foreign economy manages to partially insure itself against the shock.

5.2.1 Case Study: The Great Recession

I evaluate how well the model simulates the effects of the Great Recession in Switzerland. I use data for the United States and Switzerland from 2008:Q1 until 2013:Q1. The data has been HP filtered after taking the log of the real per capita values. Credit in the United States is from the BIS data set, credit by domestic banks to the private non-financial sector; Swiss loans to U.S. banks data come from the SNB; the consumption in Switzerland is OECD data. The data are normalized for 2007:Q4.

I fit in the credit data in the United States as loans to non-financial firms in the model, and I back up the behavior of the quality-of-capital shock in foreign that matches the domestic capital. Then, I simulate the model with financial frictions but in financial autarky (solid line) and the model with global banks (dotted line). The data are the dashed-dotted line. The results are in figure 5.

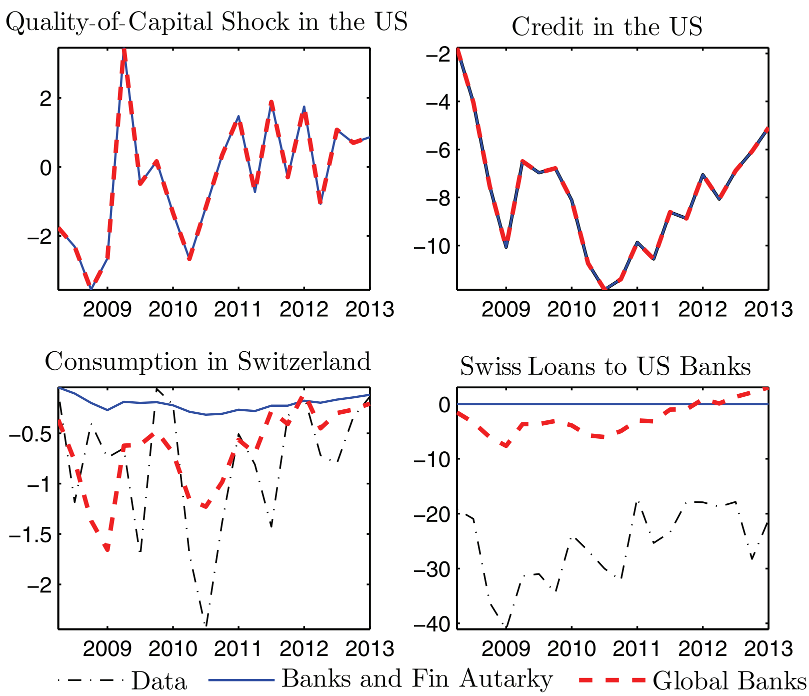
The simulation of the crisis shows that the model with global banks performs well at replicating the financial crisis in Switzerland. The model with global banks follows the movement of the Swiss consumption, while the model without global banks prompts very little reaction. This comes from the channel that I analyze in this paper: cross-border banking flows. In the model with global banks, I allow for lending from Swiss banks to U.S. banks, which falls during the financial crisis and prompts, through financial friction, the reaction of real variables in Switzerland.

This exercise implies that the global interbank market helps explain the behavior of Swiss variables during this period, in comparison to a model without this feature. This highlights the necessity of incorporating this channel for the Swiss economy, given that it is a relatively small economy with a big financial sector.

5.3 Policy Response

One of the reasons that motivated the Federal Reserve to act was the abnormal credit spread in several markets. In this sense, the central

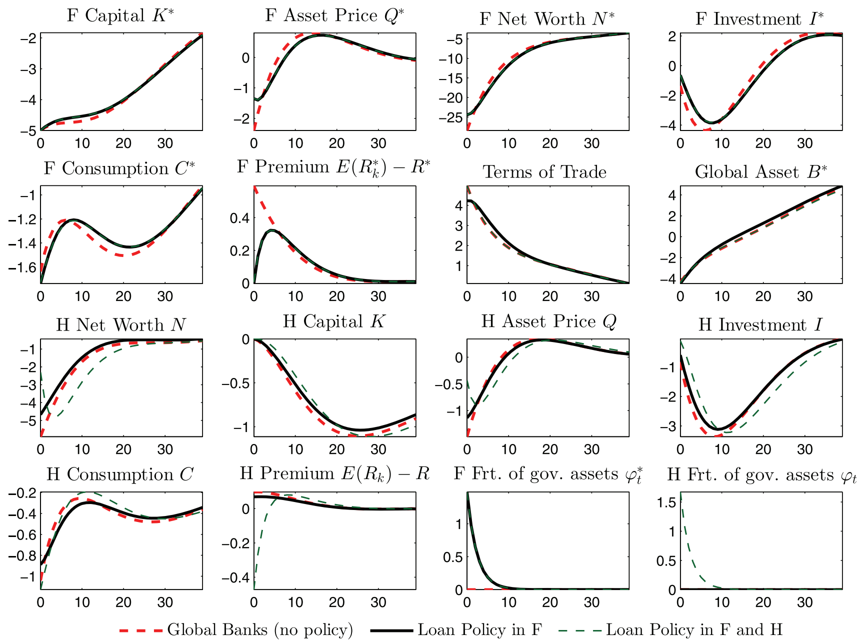
Figure 5. Case Study: The Great Recession: United States and Switzerland



bank determines the fraction of private credit to intermediate by following the difference between the risky and the risk-free interest rate and its stochastic steady-state value, as in equation (34).

Figure 6 shows a small set of variables with the results; figure A9 in online appendix 8 shows more variables. The thick dashed line is the model with financial frictions and financial openness without policy, the same as in the previous figures. The thick solid line is the model with direct intervention in the loan market carried out by the foreign central bank, and the thin dashed line corresponds to loan market intervention by both central banks. The policy parameter ν_g^* is set to be 2,000 and $\rho_{\tau_g^*} = 0.66$. The costs of issuing government loans follow Gertler, Kiyotaki, and Queralto (2012), and the fraction of government expenditure at the steady state matches the data for the United States and Switzerland.

Figure 6. Impulse Responses to a 5 Percent Decrease in Ψ_t^*, Unconventional Policies by Foreign (F) and Home (H) Central Bank



The foreign central bank intervention prompts a higher price of the domestic asset than under no intervention. The initial intervention is around 1.5 percent of total foreign assets. Higher asset price implies that foreign banks are less financially constrained. The foreign banks' net worth falls 5 percent less than under no policy. The asset price is also the price of investment; therefore, investment contraction is lower with the policy. Consumers pay the cost of the policy.

Because of asset market integration, the price of the global asset also falls less. Home banks are less financially constrained than under no policy, and the net worth of home banks drops only 4 percent on impact. Banks lend more to domestic firms; as a result, the home asset price decreases less with the foreign policy and the fall in investment is smoothed.

Therefore, with direct intervention in the foreign loan market, the foreign and the home economy get a smoother impact of the crisis. Although home banks do not have direct access to the policy, home profits through the higher prices in the interbank market. Home consumption and home total demand drop less than under no policy.

When I allow the home central bank also to intervene in the domestic loan market, the price of the domestic asset falls less, which prompts a lower impact on investment and the net worth of banks. However, the foreign economy variables do not change with respect to the intervention only by the foreign central bank because the home economy is relatively small. The fraction of assets that the authority puts on the market is the same as for the foreign central bank.

In conclusion, when only the foreign central bank intervenes, the foreign and home economies get a smoother impact of the crisis—even though the home economy does not have direct access to the policy. When I allow both authorities to intervene, the home economy presents a smoother reaction to the foreign shock, but the foreign economy's behavior does not change; this is a consequence of the relatively small open economy assumption and the fact that I do not allow foreign banks' lending to home banks. The interbank market transmits the financial crisis internationally but also the effects of the policies.

The full set of policies carried out by the foreign central bank are in figures A7 and A8. The three policies, up to a first-order approximation, show a similar effect on smoothing the initial shock. The results of equity injections evaluated in both countries are in figures A10 and A11, and they present a similar reaction to the loan policy carried out by both central banks.

The first-order approximation of the model is useful when studying the impact of an unexpected policy; however, it is not an adequate setup to study welfare. In the next subsection I evaluate the welfare implications of these policies by looking at the second-order approximation of the model.

5.4 Welfare Comparison

I introduce consumers' welfare to rank the policies presented above. The welfare criterion considered here is the one used by Gertler and

Karadi (2011) and developed by Faia and Monacelli (2007). The households' welfare function is given by

$$Welf_t = U(C_t, L_t) + \beta E_t Welf_{t+1}, \tag{38}$$

where the utility function is defined in equation (6). Welfare is defined as the lifetime utility of the consumers. I compare the different policies using the consumption equivalent, i.e., the fraction of household consumption that would be needed to equate the welfare under no policy to the welfare under policy intervention.

The stochastic steady state is defined as the mean of the second-order approximation of the model to a Monte Carlo simulation of the quality-of-capital shock.[11] The shock follows a Poisson process. The advantages of having a Poisson-distributed instead of a normal-distributed shock are twofold. First, I only study negative shocks, which is the nature of the quality-of-capital shock. According to equation (34), the government intervention is positive only with negative shocks; with positive shocks, the intervention would be negative because the spread would be negative. Positive quality-of-capital shocks would correspond to a transfer from the banking sector to the government. Second, the quality-of-capital shock does not occur in every period; instead, I set up the parameters to have a relatively "big" quality-of-capital shock every twenty-eight years. The occurrence of the shock matches Reinhart and Rogoff's (2008) estimate for banking crises in advanced economies; they report 7.2 banking crises between 1800 and 2008, as a world GDP-weighted average. The size of the shock is 0.015 and corresponds to a decrease in output, at the first order, of the economy directly hit by the shock of 1.2 percent from the steady-state level; this corresponds approximately to the drop in output from the peak of all banking crises noted by Boissay, Collard, and Smets (2013). This is an anticipated policy: there is no surprise regarding the intervention of the government; the agents know that every time there is a quality-of-capital shock in foreign, the policymaker intervenes.

Table 2 presents the results of the deterministic and the stochastic steady states of the model with and without policies. The first

[11]I simulate the model for 500 periods, 5,000 times, and drop the first fifty observations. I end up with 450 periods that equal 112 years.

Table 2. Deterministic and Stochastic Steady States Comparison with Policy in Foreign and in Home for Different Shocks

		No Policy		Loan Market		Interbank Market		Equity Injection	
	Determ.	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
UMP by the Foreign Central Bank: Stochastic Steady-State Ψ^* Shocks									
C	0.4697	0.4714	0.0036	0.4695	0.0012	0.4696	0.0012	0.4696	0.0012
L	0.2295	0.2286	0.0031	0.2290	0.0009	0.2290	0.0009	0.2290	0.0009
C^*	0.4430	0.4420	0.0022	0.4421	0.0022	0.4421	0.0022	0.4421	0.0022
L^*	0.2627	0.2628	0.0012	0.2628	0.0013	0.2628	0.0013	0.2628	0.0013
TOT	0.8274	0.8139	0.0149	0.8223	0.0057	0.8223	0.0056	0.8223	0.0057
CE				−0.8695		−0.8700		−0.8696	
CE^*				0.0170		0.0138		0.0132	
UMP by the Foreign Central Bank: Stochastic Steady-State Ψ, Ψ^*, A, A^*, G, and G^* Shocks									
C	0.4697	0.4691	0.0110	0.4672	0.0112	0.4673	0.0112	0.4673	0.0112
L	0.2295	0.2293	0.0138	0.2297	0.0139	0.2297	0.0139	0.2297	0.0139
C^*	0.4430	0.4418	0.0144	0.4418	0.0145	0.4419	0.0144	0.4419	0.0144
L^*	0.2627	0.2627	0.0205	0.2627	0.0204	0.2627	0.0205	0.2627	0.0205
TOT	0.8274	0.8240	0.0314	0.8324	0.0320	0.8325	0.0319	0.8325	0.0319
CE				−0.8802		−0.8802		−0.8801	
CE^*				0.0116		0.0141		0.0140	

(continued)

Table 2. (Continued)

		No Policy		Loan Market		Interbank Market		Equity Injection	
	Determ.	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
UMP by the Foreign and Home Central Banks: Stochastic Steady-State Ψ^* Shocks									
C	0.4697	0.4714	0.0036	0.4698	0.0015	0.4698	0.0015	0.4698	0.0015
L	0.2295	0.2286	0.0031	0.2289	0.0012	0.2289	0.0012	0.2289	0.0012
C^*	0.4430	0.4420	0.0022	0.4421	0.0022	0.4421	0.0022	0.4421	0.0022
L^*	0.2627	0.2628	0.0012	0.2628	0.0013	0.2628	0.0013	0.2628	0.0013
TOT	0.8274	0.8139	0.0149	0.8210	0.0068	0.8209	0.0069	0.8209	0.0069
CE				−0.7433		−0.7409		−0.7402	
CE^*				0.0120		0.0071		0.0065	

Notes: All the variables are in levels except for the consumption equivalents, which are in percentages. For the foreign central bank, $v_g^* = 100$ and for the home central bank, $v_g = 100$.

part of the table considers only quality-of-capital shocks in foreign and policies carried out by the foreign central bank. The second part of the table looks at the unconventional monetary policy by the foreign central bank with other shocks. The third part of the table presents only quality-of-capital shocks in the foreign economy with unconventional monetary policy carried out by both central banks. The second column shows the deterministic steady state, while the rest of the table presents the stochastic steady-state values. The policy parameters are $\nu_g^* = 100$ and $\rho_{\tau_g^*} = 0.66$, and similarly for home. The complete set of results are in online appendix 7, tables A4, A5, and A6, respectively.

Columns 3 and 4 are the mean and the standard deviation of the model without policy. In the stochastic steady state, quality-of-capital shocks in foreign prompt a lower stock of foreign capital with a decrease in its price. Foreign banks are more financially constrained. The lower price of the international asset and their lower value allow foreign banks to increase borrowing from home banks and to decrease deposits. Foreign households have a lower financial income, so they start to work more even though they face lower salaries. They cut down on consumption. The exchange rate depreciates for foreign because there is a higher flow of interbank market borrowing; when banks pay the return on the loans, the demand for foreign currency falls in comparison to the demand for the home currency.

Foreign real exchange rate depreciates; home real exchange rate appreciates. The net interest payments for home go up. In comparison to the deterministic steady state, home households consume more and work less, and consequently home consumers are better off. Households increase bank deposits; this funds the new loans that are made to foreign banks. Home banks substitute domestic capital with interbank market loans.

Columns 5–10 of table 2 show the mean and the standard deviation for the three different policies presented above. The three policies have similar welfare gains. The consumption equivalent gains (last two rows) show improvement in the case of any of these policies for foreign households but worsening for home ones. Three characteristics are important. First, by targeting the interest rate spread, the interventions increase the price of the assets. A higher price prompts a higher value of foreign banks than without policy. Banks increase domestic deposits and reduce borrowing from home banks; the borrowing constraint is less binding. The net interest payments received by home go down. The terms of trade improve foreign welfare. Second, the policies reduce the volatility of the variables with respect to the no-policy case, as in Dedola, Karadi, and Lombardo (2013). Third, the level of policy intervention is almost zero at the stochastic steady state.

The most effective domestic policy for foreign is loan market intervention; it presents the highest consumption equivalent for foreign households. This policy prompts the highest price of capital which helps relax the financing constraint of the banks. By injecting credit directly into the market in troubled times, the foreign central bank helps the domestic economy, while it hurts home households.

For robustness, I examine the model taking into account quality-of-capital, technology, and government expenditure shocks in both countries. This is shown in the second panel of table 2. The distribution of technology and government shocks follows Schmitt-Grohé and Uribe (2005). Technology shocks have an autoregressive coefficient of 0.8556 and a standard deviation of 0.0064; the autoregressive coefficient of government expenditure shocks and its standard deviation are 0.87 and 0.016, respectively. I assume that all the shocks except for the quality-of-capital shocks follow a normal process. Under this scenario, the results of intervening are very similar to the previous case. The policies carried out by the foreign central bank are effective in improving domestic consumers' welfare, but the gains for foreign households are smaller than in the case where there are only foreign quality-of-capital shocks.

The last part of table 2 shows the results when both countries intervene given the quality-of-capital shock in foreign. The policies are the same as before and to simplify, I assume that the policies carried out by the different policymakers are of the same type.

Comparing the results of both central banks intervening with the no-policy case, foreign consumers are better off, while home consumers are worse off; the result is similar to the one in which only the foreign central bank carries out a policy. The intervention of the home policymaker is still very small and is not able to reverse the sign of the consumption equivalent loss of their domestic households. However, home policy manages to reduce the loss of home consumers at the cost of decreasing the gain of the foreign households. The policies reduce the volatility of the variables, and the mean of the level of intervention is very low. The order of the policies from the foreign households remains the same: the largest gain comes from loan intervention, while the lowest comes from equity injections.

When the home central bank intervenes, the price of the asset goes up, in comparison to the case in which only foreign intervenes. The value of home banks is higher, so banks take more domestic deposits. The home banking system has more resources and the interest rate on the global asset is higher (because of the lower level of capital in foreign), so home banks increase how much they lend to foreign banks in the interbank market. The real exchange rate appreciates for home in comparison to only foreign intervening. Home consumers are better off with the policy at home and in foreign than with only the policy in foreign; foreign consumers are worse off.

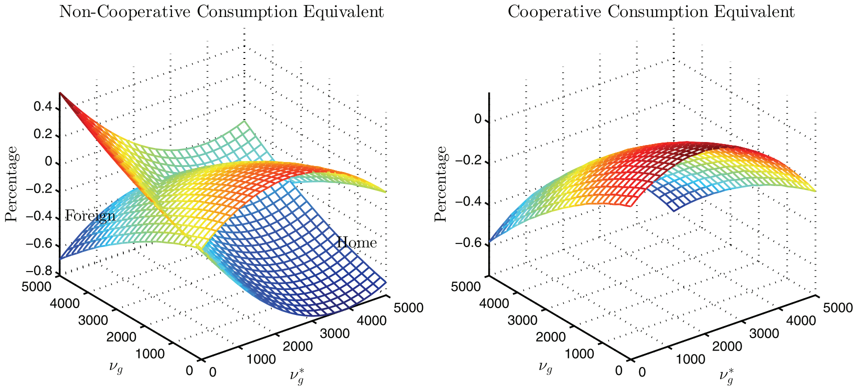
For a robustness check, in online appendix 6, I present the results for the unconditional welfare. The results are similar to the ones presented in this section.

The case of both countries intervening does not result in a Pareto improvement with respect to the baseline model; next, I study the non-cooperative outcome and if a coordinated policy that maximizes the weighted sum of the welfare of both countries can improve the outcome. In online appendix 5, I relax the assumption that foreign banks do not lend to home banks, and find that foreign policy also hurts home consumers but benefits foreign households. However, when both policymakers intervene, home and foreign consumers are better off in comparison to only foreign intervening, because both households benefit from the home intervention.

5.5 Non-Cooperative vs. Cooperative Policies

The left-side plot in figure 7 presents the home and foreign consumption equivalents as the percentage ratio of consumption when both central banks intervene with different policy parameters ν_g and ν_g^*. The range is between 0 and 5,000. The welfare level reported for each combination of ν_g and ν_g^* is the mean of 500 simulations of the model given the quality-of-capital shocks in foreign, Poisson

Figure 7. Non-Cooperative and Cooperative Consumption Equivalents under Quality-of-Capital Shocks in Foreign



distributed.[12] The best reaction of the home policymaker, given what the foreign central bank does, is always to intervene, and to do it to the greatest extent possible. For the range shown in the graph, the best response of home to the different values of ν_g^* is to set $\nu_g = 5{,}000$.

Taking as given what the home policymaker does, the foreign country experiences the highest welfare when $\nu_g^* = 2{,}200$. This is the optimal reaction for any value of ν_g. For the range shown in the graph, the non-cooperative equilibrium corresponds to $\nu_g^* = 2{,}200$ and $\nu_g = 5{,}000$. The consumption equivalents of this combination of parameters for home and for foreign households with respect to no policy are 0.0613 and 0.4036, respectively.

I define the cooperative policy as

$$Welf_t^{\text{coop}} = Welf_t m + Welf_t^*(1-m),$$

where m is the size of the home economy, while $Welf_t$ and $Welf_t^*$ are defined in equation (38).

The Nash outcome from the previous analysis says that both countries have incentives to intervene. When the policymaker of a country carries out a certain policy, that country is better off,

[12]Figure A5 in online appendix 6 presents a similar exercise with the unconditional utility. The results are robust.

while the other is worse off. As opposed to this, when it comes to cooperative welfare (the right-side plot in figure 7), the maximum level of welfare is achieved when the foreign policymaker intervenes ($\nu_g^* = 2{,}200$) and the home policymaker is inactive ($\nu_g = 0$). The consumption equivalents for home and for foreign for this combination are –0.4892 and 0.1939, respectively. The results are driven by the weight (based on the population) that I give to each country and by the range of the parameters; changing the size of the populations changes the implications.

It must be noted that the costs that I assume are very low. There are no microfoundations in the literature for these costs, and I employ the values used by Gertler, Kiyotaki, and Queralto (2012) in order to follow the previous literature. Raising the costs of issuing the policy implies a lower level of welfare; however, foreign consumers are still better off with the policy than without it.

The welfare implications are different from Dedola, Karadi, and Lombardo (2013). There are two main reasons. The first one is that since they assume that there is perfect integration across countries in the deposit and the loan markets, the interest rate spreads across countries are the same. When one country intervenes and cushions the interest rate spread, the other country's spread moves in exactly the same manner. This implies direct positive spillovers across countries from domestic policies. The second reason is that they abstract from real exchange rate effects. When one country's currency appreciates, their consumers are better off; the other country faces a depreciation and their households are worse off. The Nash equilibrium in their paper reflects the free-riding problem: intervention in one country reduces the incentives to intervene in the other country. In the model that I develop in this paper, there is no equalization of the spreads, which is a valid assumption for crisis periods; the purchases of private assets by a government generate negative spillovers in the other country. Moreover, in Dedola, Karadi, and Lombardo (2013) the cooperative welfare results in both countries intervening, while in my model, only the foreign central bank intervenes; this is a consequence of assuming that foreign banks cannot lend to home banks. As I explain in online appendix 5, relaxing this assumption prompts a cooperative equilibrium in which both central banks are active; the main difference is that when foreign banks lend to home banks, home intervention also benefits foreign consumers.

The Nash equilibrium in that model implies both central banks intervening.

6. Conclusion

I have presented a two-country DSGE model with financial intermediaries that captures the international transmission mechanism of the latest financial crisis. Banks in both countries are borrowing constrained on obtaining funds from households. Home can invest in the foreign economy through banks using a global asset (the global interbank market). The return of the international asset is equal to the return on capital of the foreign economy because there are no financial frictions in the international interbank market.

Comparing a model with financial frictions and in financial autarky with one with a global interbank market suggests that the latter generates a higher co-movement of the crisis that matches qualitatively the behavior seen in the data, as shown in the VAR analysis. When a quality-of-capital shock hits the foreign economy, foreign and home economies experience a crisis both in real and financial variables. The global interbank market prompts the international transmission. The net worth of home banks drops because the price of the international asset falls. Home banks face a reduction in their balance sheets, and they are more constrained on lending to domestic non-financial firms. The price of home asset drops, prompting a fall in investment, consumption, and total demand. The key aspect of the transmission mechanism is the equalization of returns across countries; this implies co-movement in asset prices and spreads between the risky and the risk-free interest rate.

I study the introduction of unconventional policies—in particular, direct lending of the foreign central bank to non-financial firms, direct lending in the interbank market, and equity injections into banks. I look at two cases. In the first case, only the foreign central bank carries out the policy. In the second, home and foreign central banks intervene using the same type of policy. Up to the first-order approximation, the policies are effective in mitigating the effects of the crisis not only in the domestic country but also abroad. When the home central bank intervenes, foreign variables are hardly affected, but the net worth of home banks falls less. Because of the equalization of loan returns across countries, when the foreign central bank intervenes to reduce the abnormal excess return, the price of foreign and global assets falls less than under no policy. As a result, home banks are less financially constrained. On impact, there is crowding out of consumption in the country that carries out the policy because of the costs of issuing the intervention.

I also evaluate the second-order approximation of the model. The quality-of-capital shock follows a Poisson distribution. When only the foreign central bank intervenes, foreign consumers have a welfare improvement as a result of the policies, whereas home consumers are worse off. If the home central bank also intervenes and is aggressive enough, it can improve home welfare and worsen the foreign one. However, if both policymakers behave along the same parameters, home consumers are worse off and foreign consumers are better off in comparison to the no-policy case. As opposed to this, when comparing the results with only the foreign central bank intervening, one can see that home consumers are better off, and foreign consumers are worse off.

The non-cooperative equilibrium implies an active central bank in each country, and the cooperative equilibrium implies that only the foreign central should carry out the policy, while the home central bank should do nothing. These results are subject to the assumption that foreign banks do not lend to home banks.

The paper focuses on one aspect of the unconventional policies that policymakers have carried out over the last few years. Banks that intermediate funds across borders and in different currencies encounter relevant challenges in terms of policy and regulation. In future research, I am planning to study different features of the unconventional policies. In particular, the Federal Reserve had coordinated actions with other central banks because of global banks. The Federal Reserve provided U.S. dollars to other central banks, such as the Swiss National Bank and the Bank of England. Then, these central banks provided liquidity to the banks in their jurisdiction to continue lending to U.S. institutions, thereby improving liquidity conditions in the United States. These arrangements are called foreign liquidity swaps.

In the model, home can only invest in foreign through the banks, and I only look at the net foreign asset position. In reality, the foreign exchange swaps and the interbank market, among other derivatives, make the relations across banking systems much more complicated.

I believe that this simple but relevant relationship between global banks helps us to understand some aspects of the international transmission of the crisis. Future research includes an extension of this model to include non-financial firms' international debt.

References

Backus, D., P. Kehoe, and F. Kydland. 1992. "International Real Business Cycles." *Journal of Political Economy* 100 (4): 745–75.

Bernanke, B., M. Gertler, and S. Gilchrist. 1999. "The Financial Accelerator in a Quantitative Business Cycle Framework." In *Handbook of Macroeconomics*, Vol. 1C, ed. J. B. Taylor and M. Woodford, 1341–93 (chapter 21). Elsevier.

Boissay, F., F. Collard, and F. Smets. 2013. "Booms and Systemic Banking Crises." ECB Working Paper No. 1514.

Cetorelli, N., and L. S. Goldberg. 2011. "Global Banks and International Shock Transmission: Evidence from the Crisis." *IMF Economic Review* 59 (1): 41–76.

Christiano, L. J., M. Eichenbaum, and C. L. Evans. 2005. "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." *Journal of Political Economy* 113 (1): 1–45.

Cole, H. 1993. "The Macroeconomic Effects of World Trade in Financial Assets." *Quarterly Review* (Federal Reserve Bank of Minneapolis) 17 (3, Summer): 12–21.

Cole, H., and M. Obstfeld. 1991. "Commodity Trade and International Risk Sharing: How Much Do Financial Markets Matter?" *Journal of Monetary Economics* 28 (1): 3–24.

Craig, S., B. Protess, and M. Saltmarsh. 2011. "UBS Faces Questions on Oversight After a Trader Lost $2 Billion." *New York Times*, September 16.

Cuche-Curti, N., H. Dellas, and J.-M. Natal. 2009. "DSGE-CH: A Dynamic Stochastic General Equilibrium Model for Switzerland." *Swiss National Bank Economic Studies* 5.

Dedola, L., P. Karadi, and G. Lombardo. 2013. "Global Implications of National Unconventional Policies." *Journal of Monetary Economics* 60 (1): 66–85.

Dedola, L., and G. Lombardo. 2012. "Financial Frictions, Financial Integration and the International Propagation of Shocks." *Economic Policy* 27 (70): 319–59.

Devereux, M., and A. Sutherland. 2011. "Evaluating International Financial Integration under Leverage Constraints." *European Economic Review* 55 (3): 427–42.

Devereux, M., and J. Yetman. 2010. "Leverage Constraints and the International Transmission of Shocks." *Journal of Money, Credit and Banking* 42 (s1): 71–105.

Faia, E. 2007. "Finance and International Business Cycles." *Journal of Monetary Economics* 54 (4): 1018–34.

Faia, E., and T. Monacelli. 2007. "Optimal Interest Rate Rules, Asset Prices, and Credit Frictions." *Journal of Economic Dynamics and Control* 31 (10): 3228–54.

Felkerson, J. 2011. "$29,000,000,000,000: A Detailed Look at the Fed's Bailout by Funding Facility and Recipient." Working Paper No. 698, Levy Economics Institute.

Gertler, M., and P. Karadi. 2011. "A Model of Unconventional Monetary Policy." *Journal of Monetary Economics* 58 (1): 17–34.

Gertler, M., and N. Kiyotaki. 2010. "Financial Intermediation and Credit Policy in Business Cycle Analysis." In *Handbook of Monetary Economics*, Vol. 3, ed. J. B. Taylor and M. Woodford, 547–99 (chapter 11). Elsevier.

Gertler, M., N. Kiyotaki, and A. Queralto. 2012. "Financial Crises, Bank Risk Exposure and Government Financial Policy." *Journal of Monetary Economics* 59 (Supplement): S17–S34.

Heathcote, J., and F. Perri. 2002. "Financial Autarky and International Business Cycles." *Journal of Monetary Economics* 49 (3): 601–27.

Helbling, T., R. Huidrom, M. A. Kose, and C. Otrok. 2011. "Do Credit Shocks Matter? A Global Perspective." *European Economic Review* 55 (3): 340–53, Special Issue: Advances in International Macroeconomics: Lessons from the Crisis.

Kalemli-Ozcan, S., E. Papaioannou, and F. Perri. 2013. "Global Banks and Crisis Transmission." *Journal of International Economics* 89 (2): 495–510.

Kamber, G., and C. Thoenissen. 2013. "Financial Exposure and the International Transmission of Financial Shocks." *Journal of Money, Credit and Banking* 45 (s2): 127–158.

Kilian, L. 2011. "Structural Vector Autoregressions." CEPR Discussion Paper No. 8515.

Kiyotaki, N. 2013. "Global Implications of National Unconventional Policies: A Comment." *Journal of Monetary Economics* 60 (1): 86–91.

Kollmann, R. 2013. "Global Banks, Financial Shocks, and International Business Cycles: Evidence from an Estimated Model." *Journal of Money, Credit and Banking* 45 (s2): 159–95.

Kollmann, R., Z. Enders, and G. Müller. 2011. "Global Banking and International Business Cycles." *European Economic Review* 55 (3): 407–26.

Krugman, P. 2008. "The International Finance Multiplier." Mimeo (October).

Mendoza, E., and V. Quadrini. 2010. "Financial Globalization, Financial Crises and Contagion." *Journal of Monetary Economics* 57 (1): 24–39.

Morgenson, G. 2007. "Crisis Looms in Market for Mortgages." *New York Times*, News Analysis section, March 11.

Reinhart, C. M., and K. S. Rogoff. 2008. "Banking Crises: An Equal Opportunity Menace." NBER Working Paper No. 14587.

Schmitt-Grohé, S., and M. Uribe. 2005. "Optimal Fiscal and Monetary Policy in a Medium-Scale Macroeconomic Model: Expanded Version." NBER Working Paper No. 11417.

Shin, H. S. 2012. "Global Banking Glut and Loan Risk Premium." *IMF Economic Review* 60 (2): 155–92.

Sutherland, A. 2005. "Incomplete Pass-Through and the Welfare Effects of Exchange Rate Variability." *Journal of International Economics* 65 (2): 375–99.

Swiss National Bank. 2013. "UBS Purchases StabFund from the SNB." Press Release, Swiss National Bank, November 8.

Ueda, K. 2012. "Banking Globalization and International Business Cycles: Cross-Border Chained Credit Contracts and Financial Accelerators." *Journal of International Economics* 86 (1): 1–16.

Appendix 1. Data and Sources

Real U.S. Loans: Loans and leases in bank credit, all commercial banks (in billions of dollars, seasonally adjusted), divided by consumer price index. Source: Federal Reserve Bank of St. Louis (FRED).

Real S&P 500: S&P 500 Stock Price Index (not seasonally adjusted). Source: FRED.

Real Swiss Domestic Demand: Domestic demand (in millions of Swiss francs, at prices of preceding year, chained values, reference year 2005, seasonally adjusted). Source: State Secretariat for Economic Affairs (SECO).

Real Swiss Loans Denominated in U.S. Dollars: Domestic and foreign assets, claims against banks plus claims against customers denominated in U.S. dollars for all banks (in millions of Swiss francs), divided by consumer price index. Source: Monthly Balance Sheets, Monthly Bulletin of Banking Statistics, Swiss National Bank (SNB) and SECO.

Real Swiss Net Interest Payments: Net labor and investment income (in billions of Swiss francs), divided by consumer price index. Source: Swiss Balance of Payments, SNB, and SECO.

Real SMI: Swiss market index (not seasonally adjusted). Source: Monthly Statistical Bulletin, SNB.

Appendix 2. The Model

Physical Setup

I present the equations for home; unless otherwise specified, foreign is symmetric and its variables are marked with an asterisk (*).

The physical setup is described by the production function, the law of motion for capital, the CES aggregator for the final good, and the resource constraint:

$$X_t = A_t K_t^{\alpha} L_t^{1-\alpha}, \quad \text{with } 0 < \alpha < 1 \tag{A1}$$

$$S_t = I_t + (1-\delta)K_t \tag{A2}$$

$$K_{t+1} = S_t \Psi_{t+1} \tag{A3}$$

$$Y_t = \left[\nu^{\frac{1}{\eta}} X_t^{H\,\frac{\eta-1}{\eta}} + (1-\nu)^{\frac{1}{\eta}} X_t^{F\,\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{A4}$$

$$Y_t = C_t + I_t \left[1 + f\left(\frac{I_t}{I_{t-1}} \right) \right] + G_t. \tag{A5}$$

Households

The problem of the households is

$$\max_{C_t, L_t, D_t^h} U(C_t, L_t) = E_t \sum_{t=0}^{\infty} \beta^t \left[\ln C_t - \frac{\chi}{1+\gamma} L_t^{1+\gamma} \right] \tag{A6}$$

$$\text{s.t.} \quad C_t + D_{t+1}^h = W_t L_t + R_t D_t^h + \Pi_t - T_t.$$

The first-order conditions are

$$L_t : \frac{W_t}{C_t} = \chi L_t^{\gamma} \tag{A7}$$

$$D_{t+1}^h : E_t R_{t+1} \beta \frac{C_t}{C_{t+1}} = E_t R_{t+1} \Lambda_{t,t+1} = 1, \tag{A8}$$

where $\Lambda_{t,t+1}$ is the stochastic discount factor.

Non-Financial Firms

Goods Producers

From the problem of the goods producers, the wage is defined by

$$W_t = (1-\alpha) P_t^H K_t^{\alpha} L_t{}^{-\alpha} \quad \text{with } P_t^H = \nu^{\frac{1}{\eta}} Y_t^{-1} \left(X_t^H \right)^{\frac{-1}{\eta}}. \tag{A9}$$

I define the gross return on capital as

$$Z_t = \alpha P_t^H K_t^{1-\alpha} L_t^{\alpha}. \tag{A10}$$

The demands faced by the intermediate competitive goods producers are

$$X_t^H = \nu \left[\frac{P_t^H}{P_t} \right]^{-\eta} Y_t \tag{A11}$$

and

$$X_t^{H*} = \nu^* \left[\frac{P_t^{H*}}{P_t^*} \right]^{-\eta} Y_t^*,$$

where P_t is the price of the home final good, P_t^H the price of home goods at home, and P_t^{H*} the price of home goods abroad. The price of the final good is

$$P_t = \left[\nu (P_t^H)^{1-\eta} + (1-\nu)(P_t^F)^{1-\eta} \right]^{\frac{1}{1-\eta}}$$
$$\frac{P_t}{P_t^H} = [\nu + (1-\nu)\tau_t^{1-\eta}]^{\frac{1}{1-\eta}},$$

where τ_t is the terms of trade, the price of imports relative to exports. Because of home bias in the final good production, $P_t \neq P_t^* NER_t$.

Capital Producers

Capital producers maximize their expected discounted utility

$$\max_{I_t} E_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau} \left\{ Q_\tau I_\tau - \left[1 + f\left(\frac{I_\tau}{I_{\tau-1}} \right) \right] I_\tau \right\}.$$

The first-order condition yields the price of capital goods, which equals the marginal cost of investment

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}} \right) + \frac{I_t}{I_{t-1}} f'\left(\frac{I_t}{I_{t-1}} \right) - E_t \Lambda_{t,t+1} \left[\frac{I_{t+1}}{I_t} \right]^2 f'\left(\frac{I_{t+1}}{I_t} \right). \tag{A12}$$

Banks

Home Banks

The problem of the bank is to maximize the value of the bank

$$V(s_{t-1}, b_{t-1}, d_{t-1}) = E_{t-1} \Lambda_{t-1,t} \left\{ (1-\sigma) n_t + \sigma \left[\max_{s_t, b_t, d_t} V(s_t, b_t, d_t) \right] \right\} \tag{A13}$$

subject to the borrowing constraint

$$V_t(s_t, b_t, d_t) \geq \theta(Q_t s_t + Q_{bt} b_t). \tag{A14}$$

I guess that the form of the value function of the Bellman equation is linear in assets and liabilities,

$$V(s_t, b_t, d_t) = \nu_{st} s_t + \nu_{bt} b_t - \nu_t d_t. \tag{A15}$$

Taking λ_t as the constraint multiplier, the problem yields the following first-order conditions:

$$s_t : \nu_{st} - \lambda_t(\nu_{st} - \theta Q_t) = 0$$
$$b_t : \nu_{bt} - \lambda_t(\nu_{bt} - \theta Q_{bt}) = 0$$
$$d_t : \nu_t - \lambda_t \nu_t = 0$$
$$\lambda_t : \theta(Q_t s_t + Q_{bt} b_t) - \{\nu_{st} s_t + \nu_{bt} b_t - \nu_t d_t\} = 0.$$

Rearranging terms yields

$$(\nu_{bt} - \nu_t)(1 + \lambda_t) = \lambda_t \theta Q_{bt} \tag{A16}$$

$$\left(\frac{\nu_{st}}{Q_t} - \frac{\nu_{bt}}{Q_{bt}}\right)(1 + \lambda_t) = 0 \tag{A17}$$

$$\left[\theta - \left(\frac{\nu_{st}}{Q_t} - \nu_t\right)\right] Q_t s_t + \left[\theta - \left(\frac{\nu_{bt}}{Q_{bt}} - \nu_t\right)\right] Q_{bt} b_t = \nu_t n_t. \tag{A18}$$

From equation (A17), I verify that the marginal value of lending in the international asset market is equal to the marginal value of assets in terms of the home final good. Let μ_t be the excess value of a unit of assets relative to deposits; equations (A16) and (A17) yield

$$\mu_t = \frac{\nu_{st}}{Q_t} - \nu_t.$$

Rewriting the incentive constraint (A18), I define the leverage ratio net of international borrowing as

$$\phi_t = \frac{\nu_t}{\theta - \mu_t}. \tag{A19}$$

Therefore, the balance sheet of the individual bank is written as

$$Q_t s_t + Q_{bt} b_t = \phi_t n_t. \tag{A20}$$

I verify the conjecture regarding the form of the value function using the Bellman equation (A13) and the guess (A15). For the conjecture to be correct, the cost of deposits and the excess value of bank assets have to satisfy

$$\nu_t = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{t+1} \tag{A21}$$

$$\mu_t = E_t \Lambda_{t,t+1} \Omega_{t+1} \left[R_{kt+1} - R_{t+1} \right], \tag{A22}$$

where the shadow value of net worth at $t+1$ is

$$\Omega_{t+1} = (1-\sigma) + \sigma(\nu_{t+1} + \phi_{t+1}\mu_{t+1}) \tag{A23}$$

and holds state by state. The gross rate of return on bank assets is

$$R_{kt+1} = \Psi_{t+1} \frac{Z_{t+1} + Q_{t+1}(1-\delta)}{Q_t}. \tag{A24}$$

From equation (A16),

$$\frac{\nu_{st}}{Q_t} = \frac{\nu_{bt}}{Q_{bt}},$$

which implies that the discounted rate of return on home assets has to be equal to the discounted rate of return on global loans

$$E_t \Lambda_{t,t+1} \Omega_{t+1} R_{kt+1} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{bt+1}, \tag{A25}$$

where R_{bt} is defined in the next section.

Foreign Banks

Let $V_t^*(s_t^*, b_t^*, d_t^*)$ be the maximized value of V_t^*, given an asset and liability configuration at the end of period t. The following incentive constraint must hold for each individual bank to ensure that a bank does not divert funds:

$$V_t^*(s_t^*, b_t^*, d_t^*) \geq \theta^*(Q_t^* s_t^* - Q_{bt}^* b_t^*). \tag{A26}$$

At the end of period $t-1$, the value of the bank satisfies the following Bellman equation:

$$V_t^*(s_{t-1}^*, b_{t-1}^*, d_{t-1}^*)$$
$$= E_{t-1}\Lambda_{t-1,t}^* \left\{(1-\sigma^*)n_t^* + \sigma^* \left[\max_{s_t^*, b_t^*, d_t^*} V^*(s_t^*, b_t^*, d_t^*)\right]\right\}. \tag{A27}$$

The problem of the bank is to maximize equation (A67) subject to the borrowing constraint, equation (A26).

I guess and verify that the form of the value function of the Bellman equation is linear in assets and liabilities,

$$V(s_t^*, b_t^*, d_t^*) = \nu_{st}^* s_t^* - \nu_{bt}^* b_t^* - \nu_t^* d_t^*. \tag{A28}$$

Maximizing the objective function (A67) with respect to (A26), with λ_t^* as the constraint multiplier, yields similar first-order conditions to the ones from home. If I rearrange the FOCs of the maximization problem of the foreign bank,

$$(\nu_{bt}^* - \nu_t^*)(1+\lambda_t^*) = \lambda_t^* \theta^* Q_{bt}^* \tag{A29}$$

$$\left(\frac{\nu_{st}^*}{Q_t^*} - \frac{\nu_{bt}^*}{Q_{bt}^*}\right)(1+\lambda_t^*) = 0 \tag{A30}$$

$$\left[\theta^* - \left(\frac{\nu_{st}^*}{Q_t^*} - \nu_t^*\right)\right] Q_t^* s_t^* - \left[\theta^* - \left(\frac{\nu_{bt}^*}{Q_{bt}^*} - \nu_t^*\right)\right] Q_{bt}^* b_t^* = \nu_t^* n_t^*. \tag{A31}$$

From the optimization problem of the foreign banks, the shadow value of global borrowing and domestic assets are equalized,

$$\frac{\nu_{st}^*}{Q_t^*} = \frac{\nu_{bt}^*}{Q_{bt}^*}; \tag{A32}$$

or, in terms of returns,

$$E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{kt+1}^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{bt+1}^*. \tag{A33}$$

Let μ_t^* be the excess value of a unit of assets (or international borrowing) relative to deposits,

$$\mu_t^* = \frac{\nu_{st}^*}{Q_t^*} - \nu_t^*. \tag{A34}$$

With Ω^*_{t+1} as the shadow value of net worth at date $t+1$, and R^*_{kt+1} as the gross rate of return on bank assets, after verifying the conjecture of the value function, I define the marginal value of deposits and the excess return on assets as

$$\nu^*_t = E_t \Lambda^*_{t,t+1} \Omega^*_{t+1} R^*_{t+1}$$
$$\mu^*_t = E_t \Lambda^*_{t,t+1} \Omega^*_{t+1} \left[R^*_{kt+1} - R^*_{t+1}\right]$$

with

$$\Omega^*_{t+1} = 1 - \sigma^* + \sigma^* \left(\nu^*_{t+1} + \phi^*_{t+1}\mu^*_{t+1}\right)$$
$$R^*_{kt+1} = \Psi^*_{t+1} \frac{Z^*_{t+1} + Q^*_{t+1}(1-\delta)}{Q^*_t}. \tag{A35}$$

Aggregate Bank Net Worth

Finally, aggregating across home banks, from equation (A20),

$$Q_t S_t + Q_{bt} B_t = \phi_t N_t. \tag{A36}$$

Capital letters indicate aggregate variables. From the previous equation, I define the households' deposits

$$D_t = N_t(1 - \phi_t). \tag{A37}$$

Furthermore,

$$N_t = (\sigma + \xi)\left\{R_{k,t} Q_{t-1} S_{t-1} + R_{b,t} Q_{b,t-1} B_{t-1}\right\} - \sigma R_t D_{t-1}. \tag{A38}$$

For foreign banks, the aggregation yields

$$N^*_t = (\sigma^* + \xi^*) R^*_{k,t} Q^*_{t-1} S^*_{t-1} - \sigma^* R^*_t D^*_{t-1} - \sigma^* R^*_{bt} Q^*_{bt-1} B^*_{t-1}, \tag{A39}$$

where R^*_{bt} equals R^*_{kt}, from equation (A33). The balance sheet of the aggregate foreign banking system can be written as

$$Q^*_t S^*_t - Q^*_{bt} B^*_t = \phi^*_t N^*_t. \tag{A40}$$

Global Interbank Market

The interest rate on the global interbank loan yields

$$R^*_{b,t+1} = \Psi^*_{t+1} \frac{Z^*_{t+1} + Q^*_{b,t+1}(1-\delta)}{Q^*_{bt}}. \tag{A41}$$

Equilibrium

To close the model, the different markets need to be in equilibrium:

$$Y_t = C_t + I_t \left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right] + G_t \tag{A42}$$

$$Y^*_t = C^*_t + I^*_t \left[1 + f\left(\frac{I^*_t}{I^*_{t-1}}\right)\right] + G^*_t \tag{A43}$$

$$X_t = X^H_t + X^{*H}_t \frac{1-m}{m} \quad \text{and} \quad X^*_t = X^F_t \frac{m}{1-m} + X^{*F}_t \tag{A44}$$

$$S_t = I_t + (1-\delta)K_t = \frac{K_{t+1}}{\Psi_{t+1}} \quad \text{and} \quad S^*_t = I^*_t + (1-\delta)K^*_t = \frac{K^*_{t+1}}{\Psi^*_{t+1}}$$

$$\chi L^\gamma_t = (1-\alpha)\frac{X_t}{L_t C_t} \quad \text{and} \quad \chi L^{*\gamma}_t = (1-\alpha)\frac{X^*_t}{L^*_t C^*_t}. \tag{A45}$$

If the economies are in financial autarky, the net exports for home are zero in every period; the current account results in

$$CA_t = 0 = \frac{1-m}{m} X^{H*}_t - \tau_t X^F_t. \tag{A46}$$

On the other hand, if there are global banks in the economy, the current account is

$$\begin{aligned} CA_t &= Q_{b,t}B_t - R_{bt}Q_{b,t-1}B_{t-1} \\ &= X^{*H}_t \frac{1-m}{m}\frac{P^H_t}{P_t} - X^F_t \tau_t \frac{P^H_t}{P_t} \end{aligned} \tag{A47}$$

$$B_t = B^*_t \frac{1-m}{m} \tag{A48}$$

$$D^h_t = D_t + \mathcal{D}_{gt} \quad \text{and} \quad D^{h*}_t = D^*_t + \mathcal{D}^*_{gt}. \tag{A49}$$

Appendix 3. Definition of Equilibria

Frictionless Economy

In a model without financial frictions, the competitive equilibrium is defined as a solution to the problem that involves choosing twenty-two quantities $(Y_t, X_t, L_t, C_t, I_t, X_t^H, X_t^{H*}, K_{t+1}, W_t, Z_t, S_t, Y_t^*, X_t^*, L_t^*, C_t^*, I_t^*, K_{t+1}^*, X_t^F, X_t^{F*}, W_t^*, Z_t^*, S_t^*)$, two interest rates (R_t, R_t^*), and five prices $(Q_t, P_t^H, Q_t^*, P_t^{F*}, \tau_t)$ as a function of the aggregate state $(I_{t-1}, K_t, A_t, \Psi_t, I_{t-1}^*, K_t^*, A_t^*, \Psi_t^*)$. There are twenty-nine variables and twenty-nine equations: equations (A1)–(A5), (A7)–(A12), and equation (A24) for home, where equation (A9) has two relations. These conditions also hold for foreign. I close the model with equations (A42–A44) and (A46).

Economy with Financial Frictions

The competitive banking equilibrium without government intervention is defined as a solution to the problem that involves choosing the same twenty-two quantities as in the frictionless economy (Y_t, X_t, L_t, C_t, I_t, X_t^H, $X_t^{H*}, K_{t+1}, W_t, Z_t, S_t, Y_t^*, X_t^*, L_t^*, C_t^*, I_t^*, K_{t+1}^*, X_t^F$, $X_t^{F*}, W_t^*, Z_t^*, S_t^*$) plus the fourteen variables related with banks (N_t, D_t, B_t, Ω_t, μ_t, ν_t, ϕ_t, N_t^*, D_t^*, B_t^*, Ω_t^*, $\mu_t^*, \nu_t^*, \phi_t^*$), five interest rates $(R_t, R_t^*, R_{kt}, R_{kt}^*, R_{bt}^*)$, and six prices $(Q_t, Q_{bt}^*, P_t^H, Q_t^*, P_t^{F*}, \tau_t)$ as a function of the aggregate state (I_{t-1}, K_t, A_t, Ψ_t, I_{t-1}^*, K_t^*, A_t^*, Ψ_t^*). There are forty-seven variables and forty-seven equations: equations (A1)–(A5) and (A7)–(A12) for home, where equation (A9) has two conditions. These twelve equations are equivalent for foreign. Equations (A19), (A21)–(A24), and (A36)–(A38) define part of the banking variables and interest rates and also hold for foreign. The equilibrium is completed with equations (A25), (A33), (A41), (A47), and (A48).

Appendix 4. Deterministic Steady State

In table A1, I show the comparison between the average of Swiss data for 2002–8 and the deterministic steady state of the home economy. The first part of the table presents the ratios of the main variables with respect to GDP, while the second part shows the ratios with

Table A1. Comparison between Swiss Data and Deterministic Steady State

		Data	**Model**
A. Ratios with Regard to GDP			
$X^{H^*}\frac{1-m}{m} - X^F$	Net exports	0.0777	−0.0516
C	Consumption	0.5933	0.6945
I	Investment	0.2146	0.2243
G	Gov. Consumption	0.1140	0.1300
B + K	Total Assets	5.7288	10.7368
B	Global Asset	1.0246	1.7658
B. Ratios with Regard to Final Domestic Demand			
$X^{H^*}\frac{1-m}{m} - X^F$	Net exports	0.0848	−0.0492
C	Consumption	0.6435	0.6622
I	Investment	0.2329	0.2138
G	Gov. Consumption	0.1236	0.1240
B + K	Total Assets	6.2245	10.2373
B	Global Asset	1.1135	1.6836

Notes: The Swiss data is HP filtered and evaluated between 2002 and 2008. See sources in appendix 1.

respect to the final domestic demand. In both cases the ratios of the deterministic steady state of the real variables match the data. There are two caveats. First, the net exports of the model are negative, while in the data they are positive. To model a small economy with a big financial sector, I need a net importer home country. If I only included the data for goods, the net exports of Switzerland would be negative. Second, the financial variables of the model (total assets and assets from home banks with foreign counterparties) almost double the data. However, the ratio of global assets over the total assets matches the data, which is most relevant for the results.

The deterministic steady state also matches the ratio between the Swiss and the U.S. economy. In particular, for the period 2002–8, the U.S. GDP is almost twenty-nine times bigger than the Swiss GDP. In the model, foreign production is twenty-seven times bigger than home production.

Appendix 5. When Foreign Banks Lend to Home Banks

In this section, I allow for symmetry in the portfolio of the banks: foreign banks lend to home banks, and home banks lend to foreign banks. However, there is still a positive net asset position for home banks. I only specify the new problem of home and foreign banks; the rest of the model remains the same.

The Model

Home Banks

For an individual home bank, the balance sheet implies that the value of the loans funded in that period, $Q_t s_t$ plus $Q_{bt} b_t$, where Q_{bt} is the price of loans made to foreign banks, has to equal the sum of the bank's net worth, n_t, home deposits, d_t, and loans made by foreign banks $Q_{jt} j_t$. Then, the balance sheet of a home bank reads

$$Q_t s_t + Q_{bt} b_t = n_t + d_t + Q_{jt} j_t. \tag{A50}$$

Let R_{bt} be the global asset's rate of return from period $t-1$ to period t and R_{jt} the one on foreign banks' loans. The net worth of an individual home bank at period t is the payoff from assets funded at $t-1$, net borrowing costs:

$$\begin{aligned} n_t = {} & [Z_t + (1-\delta)Q_t] s_{t-1} \Psi_t + R_{b,t} Q_{b,t-1} b_{t-1} - R_t d_{t-1} \\ & - R_{jt} Q_{j,t-1} j_{t-1}, \end{aligned}$$

where Z_t is the dividend payment at t on loans funded in the previous period.

At the end of period t, the bank maximizes the present value of future dividends, taking into account the probability of continuing being a banker in the next periods; the value of the bank is defined by

$$V_t = E_t \sum_{i=1}^{\infty} (1-\sigma) \sigma^{i-1} \Lambda_{t,t+i} n_{t+i}.$$

Following the previous literature, I introduce a simple agency problem to motivate the ability of the bank to obtain funds. After the bank obtains funds, it may transfer a fraction θ of assets back to its own household. Households limit the funds lent to banks.

If a bank diverts assets, it defaults on its debt and shuts down. Its creditors can reclaim the remaining $1-\theta$ fraction of assets. Let $V_t(s_t, b_t, d_t, j_t)$ be the maximized value of V_t, given an asset and liability configuration at the end of period t. The following incentive constraint must hold for each bank individually to ensure that the bank does not divert funds:

$$V_t(s_t, b_t, d_t, j_t) \geq \theta(Q_t s_t + Q_{bt} b_t - Q_{jt} j_t). \tag{A51}$$

The borrowing constraint establishes that for households to be willing to supply funds to a bank, the value of the bank must be at least as large as the benefits from diverting funds. In this case, diverted funds correspond to total assets minus what home banks borrowed from foreign banks; I assume that home banks cannot run away with money from foreign banks.

At the end of period $t-1$, the value of the bank satisfies the following Bellman equation:

$$\begin{aligned} &V(s_{t-1}, b_{t-1}, d_{t-1}, j_{t-1}) \\ &\quad = E_{t-1}\Lambda_{t-1,t}\left\{(1-\sigma)n_t + \sigma\left[\max_{s_t, b_t, d_t, j_t} V(s_t, b_t, d_t, j_t)\right]\right\}. \end{aligned} \tag{A52}$$

The problem of the bank is to maximize equation (A52) subject to the borrowing constraint, equation (A51). As in the baseline model, I assume that the value function is linear with respect to home and foreign loans, deposits, and foreign borrowing. Taking λ_t as the constraint multiplier, the problem yields the following first-order conditions:

$$\begin{aligned} &s_t : \nu_{st} - \lambda_t(\nu_{st} - \theta Q_t) = 0 \\ &b_t : \nu_{bt} - \lambda_t(\nu_{bt} - \theta Q_{bt}) = 0 \\ &d_t : \nu_t - \lambda_t \nu_t = 0 \\ &j_t : \nu_{jt} - \lambda_t(\nu_{jt} - \theta Q_{jt}) = 0 \\ &\lambda_t : \theta(Q_t s_t + Q_{bt} b_t - Q_{jt} j_t) - \{\nu_{st} s_t + \nu_{bt} b_t - \nu_t d_t - \nu_{jt} j_t\} = 0. \end{aligned}$$

Rearranging terms yields

$$(\nu_{bt} - \nu_t)(1 + \lambda_t) - \lambda_t \theta Q_{bt} = 0 \tag{A53}$$

$$\left(\frac{\nu_{st}}{Q_t} - \frac{\nu_{bt}}{Q_{bt}}\right)(1+\lambda_t) = 0 \tag{A54}$$

$$\left(\frac{\nu_{st}}{Q_t} - \frac{\nu_{jt}}{Q_{jt}}\right)(1+\lambda_t) = 0 \tag{A55}$$

$$\begin{aligned}\left[\theta - \left(\frac{\nu_{st}}{Q_t} - \nu_t\right)\right] Q_t s_t + \left[\theta - \left(\frac{\nu_{bt}}{Q_{bt}} - \nu_t\right)\right] Q_{bt} b_t \\ - \left[\theta - \left(\frac{\nu_{jt}}{Q_{jt}} - \nu_{jt}\right)\right] Q_{jt} j_t = \nu_t n_t.\end{aligned} \tag{A56}$$

From equation (A54), I verify that the marginal value of lending in the international asset market is equal to the marginal value of assets in terms of the home final good. Moreover, from equation (A55), the marginal cost of holding foreign debt is equal to the marginal benefit of domestic assets; this is the case because home banks cannot run away with money from foreign banks. Let μ_t be the excess value of a unit of assets relative to deposits; equations (A53) and (A54) yield

$$\mu_t = \frac{\nu_{st}}{Q_t} - \nu_t.$$

Rewriting the incentive constraint (A56), I define the leverage ratio net of international borrowing as

$$\phi_t = \frac{\nu_t}{\theta - \mu_t}. \tag{A57}$$

Therefore, the balance sheet of the individual bank is written as

$$Q_t s_t + Q_{bt} b_t - Q_{jt} j_t = \phi_t n_t. \tag{A58}$$

I verify the conjecture regarding the form of the value function using the Bellman equation (A52) and the guess:

$$V(s_t, b_t, d_t) = \nu_{st} s_t + \nu_{bt} b_t - \nu_t d_t - \nu_{jt} j_t, \tag{A59}$$

where ν_{st} is the marginal value of assets at the end of period t, ν_{bt} is the marginal value of global lending, ν_t is the marginal cost of deposits, and ν_{jt} is the marginal cost of holding foreign debt. For the conjecture to be correct, the cost of deposits and the excess value of bank assets have to satisfy

$$\nu_t = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{t+1} \tag{A60}$$

$$\mu_t = E_t \Lambda_{t,t+1} \Omega_{t+1} \left[R_{kt+1} - R_{t+1} \right], \tag{A61}$$

where the shadow value of net worth at $t + 1$ is

$$\Omega_{t+1} = (1 - \sigma) + \sigma(\nu_{t+1} + \phi_{t+1} \mu_{t+1}) \tag{A62}$$

and holds state by state. The gross rate of return on bank assets is

$$R_{kt+1} = \Psi_{t+1} \frac{Z_{t+1} + Q_{t+1}(1 - \delta)}{Q_t}. \tag{A63}$$

From equation (A53),

$$\frac{\nu_{st}}{Q_t} = \frac{\nu_{bt}}{Q_{bt}},$$

which implies that the discounted rate of return on home assets has to be equal to the discounted rate of return on global loans

$$E_t \Lambda_{t,t+1} \Omega_{t+1} R_{kt+1} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{bt+1}, \tag{A64}$$

where R_{bt} is defined in the next section.

And, from equation (A55),

$$\frac{\nu_{st}}{Q_t} = \frac{\nu_{jt}}{Q_{jt}},$$

which implies that the discounted rate of return on home assets has to be equal to the discounted rate on borrowing from foreign banks

$$E_t \Lambda_{t,t+1} \Omega_{t+1} R_{kt+1} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{jt+1} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{bt+1}. \tag{A65}$$

Equations (A57) and (A60)–(A64) are equal to the ones in the baseline model.

Foreign Banks

The problem of foreign banks is similar to the one of home banks, except that now the interbank market assets, b_t^*, are loans from home banks and are on the liability side, and j_t^* are loans to home banks and are on the asset side of foreign banks. The balance sheet for an individual foreign bank is

$$Q_t^* s_t^* + Q_{jt}^* j_t^* = n_t^* + d_t^* + Q_{bt}^* b_t^*.$$

The net worth of the bank can also be thought of in terms of payoffs; then, the total net worth is the payoff from assets funded at $t-1$, net of borrowing costs which include the international loans,

$$\begin{aligned} n_t^* = {} & [Z_t^* + (1-\delta)Q_t^*] s_{t-1}^* \Psi_t^* + R_{jt}^* Q_{jt-1}^* j_{t-1}^* \\ & - R_t^* d_{t-1}^* - R_{bt}^* Q_{bt-1}^* b_{t-1}^*. \end{aligned}$$

Let $V_t^*(s_t^*, b_t^*, d_t^*, j_t^*)$ be the maximized value of V_t^*, given an asset and liability configuration at the end of period t. The following incentive constraint must hold for each bank individually to ensure that a bank does not divert funds:

$$V_t^*(s_t^*, b_t^*, d_t^*, j_t^*) \geq \theta^*(Q_t^* s_t^* + Q_{jt}^* j_t^* - Q_{bt}^* b_t^*). \tag{A66}$$

At the end of period $t-1$, the value of the bank satisfies the following Bellman equation:

$$\begin{aligned} & V_t^*(s_{t-1}^*, b_{t-1}^*, d_{t-1}^*, j_{t-1}^*) \\ & \quad = E_{t-1}\Lambda_{t-1,t}^* \left\{ (1-\sigma^*) n_t^* + \sigma^* \left[\max_{s_t^*, b_t^*, d_t^*, j_t^*} V^*(s_t^*, b_t^*, d_t^*, j_t^*) \right] \right\}. \end{aligned} \tag{A67}$$

The problem of the bank is to maximize equation (A67) subject to the borrowing constraint, equation (A66).

I guess and verify that the form of the value function of the Bellman equation is linear in assets and liabilities,

$$V(s_t^*, b_t^*, d_t^*) = \nu_{st}^* s_t^* + \nu_{jt}^* j_t^* - \nu_{bt}^* b_t^* - \nu_t^* d_t^*. \tag{A68}$$

Maximizing the objective function (A67) with respect to (A66), with λ_t^* as the constraint multiplier, yields similar first-order conditions to the ones from home. Rearranging the FOCs of the maximization problem of the foreign bank,

$$(\nu_{bt}^* - \nu_t^*)(1+\lambda_t^*) - \lambda_t^* \theta^* Q_{bt}^* = 0 \tag{A69}$$

$$\left(\frac{\nu_{st}^*}{Q_t^*} - \frac{\nu_{bt}^*}{Q_{bt}^*}\right)(1+\lambda_t^*) = 0 \tag{A70}$$

$$\left(\frac{\nu_{st}^*}{Q_t^*} - \frac{\nu_{jt}^*}{Q_{jt}^*}\right)(1+\lambda_t^*) = 0 \tag{A71}$$

$$\begin{aligned}\left[\theta^* - \left(\frac{\nu_{st}^*}{Q_t^*} - \nu_t^*\right)\right] Q_t^* s_t^* + \left[\theta^* - \left(\frac{\nu_{jt}^*}{Q_{jt}^*} - \nu_t^*\right)\right] Q_{jt}^* j_t^* \\ - \left[\theta^* - \left(\frac{\nu_{bt}^*}{Q_{bt}^*} - \nu_t^*\right)\right] Q_{bt}^* b_t^* = \nu_t^* n_t^*.\end{aligned} \tag{A72}$$

From the optimization problem of the foreign banks, the shadow value of global borrowing and domestic assets are equalized,

$$\frac{\nu_{st}^*}{Q_t^*} = \frac{\nu_{bt}^*}{Q_{bt}^*}; \tag{A73}$$

or, in terms of returns,

$$E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{kt+1}^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{bt+1}^*. \tag{A74}$$

Similarly, the marginal value of an extra unit of domestic asset and the marginal value of an extra unit of home asset equalize,

$$\frac{\nu_{st}^*}{Q_t^*} = \frac{\nu_{jt}^*}{Q_{jt}^*}; \tag{A75}$$

or, in terms of returns,

$$E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{kt+1}^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{jt+1}^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{bt+1}^*. \tag{A76}$$

Let μ_t^* be the excess value of a unit of assets (or international borrowing) relative to deposits,

$$\mu_t^* = \frac{\nu_{st}^*}{Q_t^*} - \nu_t^*. \tag{A77}$$

With Ω_{t+1}^* as the shadow value of net worth at date $t+1$, and R_{kt+1}^* as the gross rate of return on bank assets, after verifying the conjecture of the value function, I define the marginal value of deposits and the excess return on assets as

$$\nu_t^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{t+1}^*$$
$$\mu_t^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* \left[R_{kt+1}^* - R_{t+1}^* \right]$$

with

$$\Omega_{t+1}^* = 1 - \sigma^* + \sigma^* \left(\nu_{t+1}^* + \phi_{t+1}^* \mu_{t+1}^* \right)$$
$$R_{kt+1}^* = \Psi_{t+1}^* \frac{Z_{t+1}^* + Q_{t+1}^*(1-\delta)}{Q_t^*}. \tag{A78}$$

The framework can be thought of as one with asset market integration because banks cannot divert funds financed by other banks. In particular, home banks can perfectly recover the interbank market loans. Foreign banks are only constrained on obtaining funds from foreign households.

Aggregate Bank Net Worth

Finally, aggregating across home banks, from equation (A58),

$$Q_t S_t + Q_{bt} B_t - Q_{jt} J_t = \phi_t N_t. \tag{A79}$$

Capital letters indicate aggregate variables. From the previous equation, I define the households' deposits,

$$D_t = N_t (1 - \phi_t). \tag{A80}$$

Furthermore,

$$N_t = \left(R_{k,t} Q_{t-1} S_{t-1} + R_{b,t} Q_{b,t-1} B_{t-1} \right) (\sigma + \xi)$$
$$- \sigma \left(R_t D_{t-1} + R_{jt} Q_{jt-1} J_{t-1} \right). \tag{A81}$$

The last equation specifies the law of motion of the home banking system's net worth. The first term in the brackets represents the return on loans made in the last period. The second term in the brackets is the return on funds that the household invested in the foreign economy. Both loans are scaled by the old bankers (that survived from the last period) plus the startup fraction of loans that young bankers receive. The last two terms in the equation are the total return on households' deposits that banks need to pay back and the total return on loans from foreign banks that home banks need to pay back, respectively.

For foreign banks, the aggregation yields

$$N_t^* = (\sigma^* + \xi^*)\left(R_{k,t}^* Q_{t-1}^* S_{t-1}^* + R_{j,t}^* Q_{j,t-1}^* J_{t-1}^*\right) \\ - \sigma^*(R_t^* D_{t-1}^* - R_{bt}^* Q_{bt-1}^* B_{t-1}^*), \tag{A82}$$

where R_{bt}^* equals R_{kt}^*, from equation (A74), and R_{jt}^* equals R_{kt}^*, from equation (A76). The balance sheet of the aggregate foreign banking system can be written as

$$Q_t^* S_t^* + Q_{jt}^* J_t^* - Q_{bt}^* B_t^* = \phi_t^* N_t^*. \tag{A83}$$

I define the deposits as in the original model:

$$D_t^* = N_t^*(1 - \phi_t^*). \tag{A84}$$

Moreover, $J_t^* n = J_t(1-n)$ and $B_t^* n = B_t(1-n)$.

Global Interbank Market

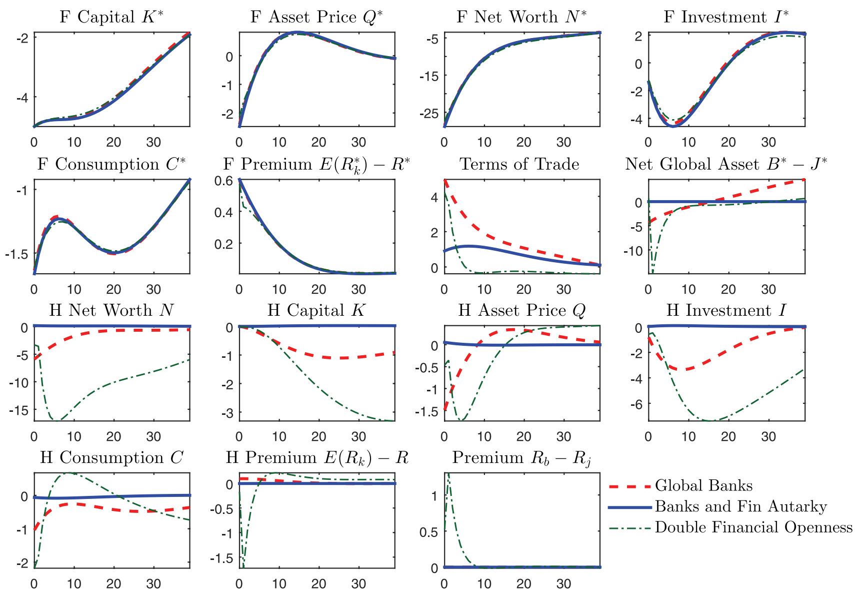
The return on loans to foreign banks made by home banks is $E_t(R_{bt+1}) = E_t(R_{bt+1}^* \frac{\varepsilon_{t+1}}{\varepsilon_t})$, and similarly for the return on loans from foreign to home banks, $E_t(R_{jt+1}) = E_t(R_{jt+1}^* \frac{\varepsilon_{t+1}}{\varepsilon_t})$. The rate on global loans is equalized to the return on loans to home firms, R_{kt}, in expected terms in equation (A65); home banks are indifferent between lending to home firms or to foreign banks. For foreign banks, equation (A76) equalizes the rate of return on global loans to the rate of return on foreign loans. The double equalization drives the asset market integration. In addition, the rate of return on the global asset market is related to the gross return on capital in the foreign country in the following way:

$$R_{b,t+1}^* = \Psi_{t+1}^* \frac{Z_{t+1}^* + Q_{b,t+1}^*(1-\delta)}{Q_{bt}^*}, \tag{A85}$$

which equalizes the returns on the international asset and the foreign lending. Moreover,

$$R_{j,t+1} = \Psi_{t+1} \frac{Z_{t+1} + Q_{j,t+1}(1-\delta)}{Q_{jt}}. \tag{A86}$$

Figure A1. Impulse Responses to a 5 Percent Decrease in Ψ_t^*, Models without Policy



Impulse Response Functions

I evaluate the model presented above up to a first-order approximation. The calibration is the same as in the baseline model. First, I compare the reaction of the model to the baseline framework when a quality-of-capital shock hits the economy. Second, I allow the policymakers to intervene; I let the central banks use direct lending and equity injections as explained in the main text.

No Policy

The results are in figure A1. The dashed line and the solid line are the same as in the main text, the model with global banks and with banks but in financial autarky, respectively. The dotted-dashed line is the model with double financial openness or double flows. The introduction of flows from foreign to home banks does not change the implications of the shock for foreign variables. However, because the foreign economy is relatively big for the home economy, this addition does change the spillover to the home economy.

I plot the net flows from home to foreign, $B_t - J_t$, under the global asset label. As in the previous model, the net flows decrease when foreign is hit by a negative quality-of-capital shock. Home banks decrease how much they lend to foreign because foreign banks are more financially constrained. The decrease in lending to foreign prompts a decrease in the net worth of home banks; it falls more than in the baseline model because net flows shrink more. Home banks are more financially constrained, foreign banks decrease lending to home banks, and this prompts the larger fall in the net international flows. Due to the further fall in home banks' net worth, loans and investment at home collapse. Consumption falls more on impact. Up to a first-order approximation, relaxing the assumption that foreign banks cannot hold claims on home banks prompts a larger spillover from foreign to home.

Policy Response—Unconventional Policy

As in the baseline model, I evaluate the consequences of introducing a central bank that carries out unconventional policy. First, I allow the foreign central bank to lend directly to non-financial firms or to inject equity into banks. The results are in figure A2. Second, I assume that both central banks carry out unconventional policy. The results are in figure A3.

In figure A2, the dotted-dashed line is the same model as in the previous figure: the model with double flows without policy. The dotted line is the model with loan policy carried out by the foreign central bank, and the solid line is the model with equity injections to the foreign banking system. The impact of the foreign policy in the big economy is similar to the baseline framework: the intervention reduces the impact of the shock on the asset price; the net worth of foreign banks falls less on impact and so does investment. Consumption, on the contrary, is hit more with the policy because households are paying for the policy. The home economy benefits from the policy through a lower drop, on impact, of the asset price; investment falls less on impact. The net global asset is also smoother due to the smaller reduction on lending from foreign to home, and so is the net worth. Consumption shows almost no changes.

Figure A2. Impulse Responses to a 5 Percent Decrease in Ψ_t^*, Double Flows Model with Policy by the F Central Bank

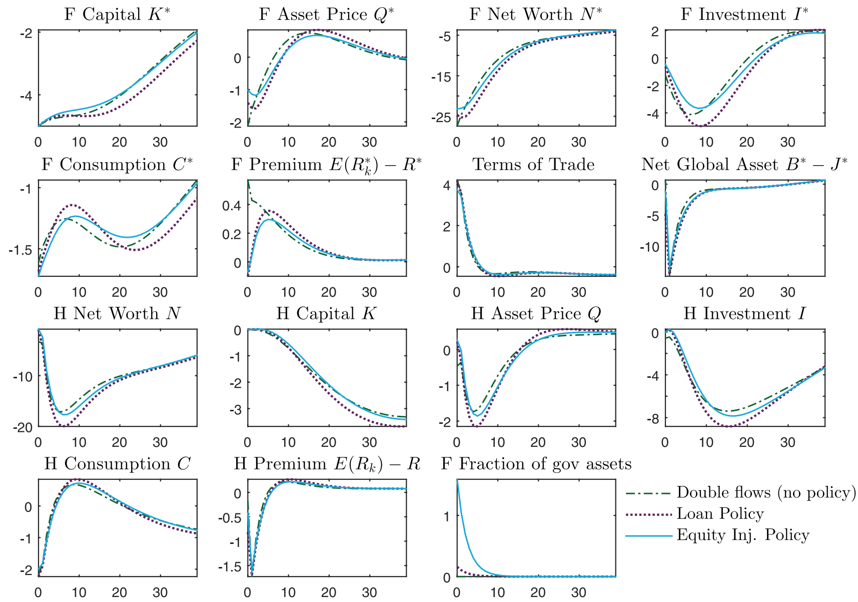
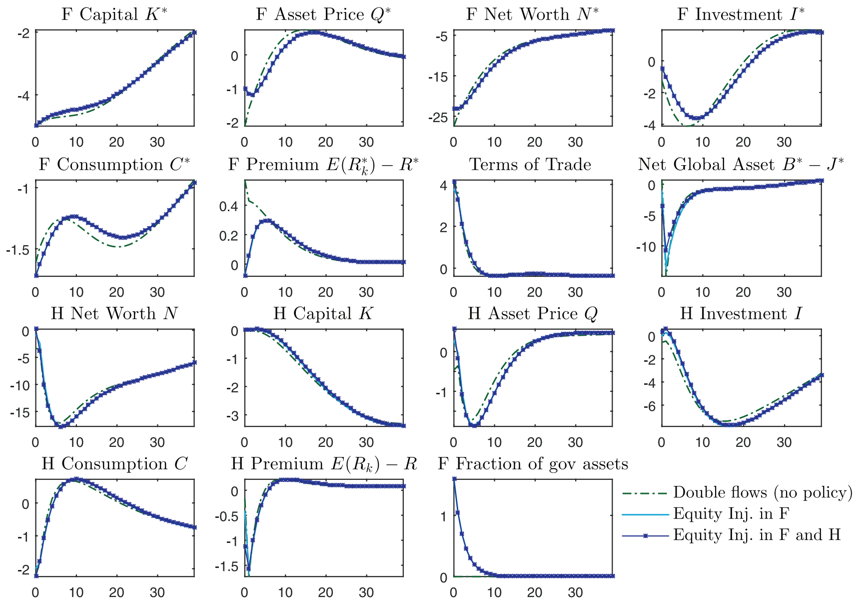


Figure A3 plots the case in which I allow both central banks to carry out unconventional policy—in particular, equity injections. The dotted-dashed and the solid lines are the same as before, the model without policy and with equity injections to the foreign banks, respectively. The solid line with asterisks is the model when both central banks intervene. The foreign economy adopts the policy and has the same reaction as in the previous figure. It seems that the home economy also behaves as in the previous policy, but this is not the case. The net global asset fall less due to a smoother behavior of the home asset price; the last effect also makes investment fall less on impact. Again, home consumption falls slightly more due to the intervention. The home economy presents a milder reaction to the shock when the home central bank carries out unconventional policy than when it does not; the foreign economy does not show major changes.

Figure A3. Impulse Responses to a 5 Percent Decrease in Ψ_t^*, Double Flows Model with Equity Injections by F and H Central Bank



Up to a first-order approximation, the model with double flows behaves in a similar fashion to the model with the assumption that foreign banks cannot hold claims on home banks. Unconventional policies are effective at reducing the impact on home and foreign of a negative quality-of-capital shock in foreign, but less effective than in the baseline model.

Welfare Analysis

As with the baseline model, I evaluate the second-order approximation of the model and the implications of loan market interventions. In this case, for simplicity, I only evaluate the unconditional welfare for one policy; I have shown that for the baseline model the simulations and the unconditional welfare give similar results.

The unconditional welfare results for the double flows model with unconventional policy are in table A2. As in the baseline model,

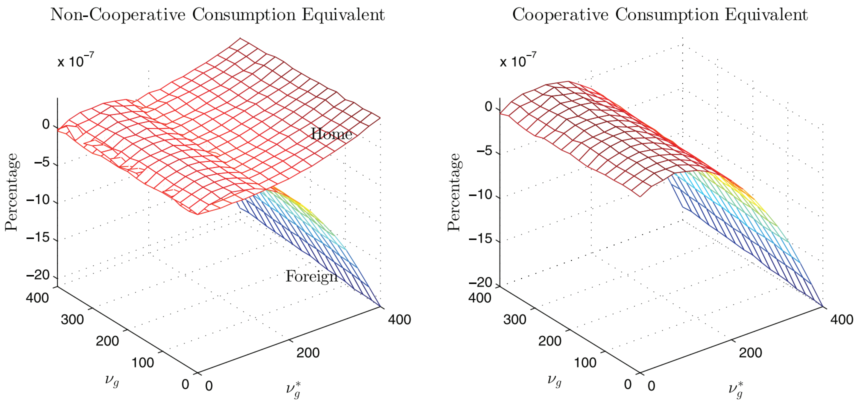
Table A2. Unconditional Moments: Deterministic and Stochastic Steady States Comparison, Policy in F and in H, $\upsilon_g^* = 0.25$ and $\upsilon_g = 0.25$

	Determ.	Stochastic Steady State Ψ*					
		No Policy		Loan Market F		Loan Market F H	
		Mean	SD	Mean	SD	Mean	SD
Y	0.6867	0.6866	0.0027	0.6866	0.0027	0.6867	0.0027
K	5.8471	5.8473	0.0055	5.8466	0.0055	5.8463	0.0055
C	0.4554	0.4553	0.0018	0.4553	0.0018	0.4554	0.0018
L	0.2283	0.2283	0.0028	0.2283	0.0028	0.2283	0.0028
Y^*	0.7622	0.7622	0.0022	0.7622	0.0022	0.7622	0.0022
K^*	6.6490	6.6489	0.0068	6.6489	0.0068	6.6490	0.0068
C^*	0.4436	0.4436	0.0024	0.4436	0.0024	0.4436	0.0024
L^*	0.2628	0.2628	0.0011	0.2628	0.0011	0.2628	0.0011
N	1.9811	1.9805	0.0190	1.9782	0.0190	1.9767	0.0190
N^*	1.6414	1.6412	0.0189	1.6412	0.0189	1.6412	0.0189
TOT	0.9519	0.9519	0.0017	0.9519	0.0017	0.9519	0.0017
Ψ^*	1.0000	1.0000	0.0013	1.0000	0.0013	1.0000	0.0013
B	1.3244	1.0729	0.6396	1.0636	0.6395	1.0652	0.6393
V^*	2.6838	2.6837	0.0065	2.6837	0.0065	2.6838	0.0065
J	0.0019	0.0000	18.0489	0.0000	18.0452	0.0000	18.0402
$\boldsymbol{\varphi}_g^*$				1.0000	0.0000	1.0000	0.0000
CE				−0.0010		−0.0009	
CE^*				0.0001		0.0004	

Notes: All the variables are in levels except for the consumption equivalents, which are in percentages. The first column, "Determ.," corresponds to the deterministic steady state; the third and fourth, "No Policy," are the mean and standard deviation of the stochastic steady state, respectively. The fifth and sixth, "Loan Market F," correspond to the loan market intervention in foreign. The last two columns, "Loan Market F H," are loan market interventions in foreign and home.

intervention implies a reduction in the standard deviation of the variables, which shows in the fifth digit. The intervention is zero at the steady state, and the shock has a very small standard deviation. The message from the intervention carried out only by the foreign central bank is similar to the baseline model: foreign consumers are better off and home consumers are worse off. The mechanism behind this is the same. However, when both central banks intervene, there is a Pareto improvement for the economy, with respect

Figure A4. Unconditional Utility: Non-Cooperative and Cooperative Consumption Equivalents under Quality-of-Capital Shocks in Foreign, Model with Flows from and to the Home Banking Sector



to only foreign intervening. The difference with the baseline model comes from relaxing the assumption that foreign banks cannot lend to home banks, even though in the model with the interventions these flows are reduced to almost zero. The intervention carried out by the home central bank does not hurt foreign consumers because they get the benefits from the loans that foreign banks hold in their balance sheet; the value of the foreign financial intermediaries, V^*, is higher when both central banks intervene.

Non-Cooperative vs. Cooperative Policies

Finally, I evaluate the cooperation across countries. In the baseline model, the Nash equilibrium resulted in both central banks intervening, while the cooperative equilibrium implied that only the foreign central bank would intervene, while the home policymaker would do nothing. However, this was not Pareto improvement.

The results regarding the consumption equivalent for different levels of intervention are in figure A4. On the one hand, home intervention does not affect much the welfare of either foreign or home consumers. Home consumption equivalent increases very little when home intervenes, and foreign consumption equivalent also increases with home policy; this is the difference with the baseline model, in which home intervention would benefit home consumers but hurt foreign households. In this model, home policy benefits both countries. On the other hand, foreign intervention is much more effective. With low values, foreign consumers' welfare improves. However, when the intervention is aggressive, the foreign consumption equivalent falls due to the costs. Home consumers take advantage of the foreign intervention and their welfare improves. Then, the Nash equilibrium results in both central banks intervening, as we can see in the left-hand-side panel of the figure. The cooperative equilibrium, the sum of both welfares weighted by the countries' population, implies an active foreign and home central bank. This result is different from the baseline model because now, home policy benefits foreign consumers.

Relaxing the assumption that foreign financial intermediaries are not allowed to lend to home banks does not change, in general terms, the non-cooperative result: both central banks are active. This is the case because the net international flows are positive for the home economy, as in the baseline model. The difference with Dedola, Karadi, and Lombardo (2013) comes from the assumption of a relatively small economy, rather than two economies of similar size, and the effects of the real exchange rate that they abstract from. Nevertheless, the cooperative equilibrium in this model is different from the baseline one.

Appendix 6. Unconditional Welfare

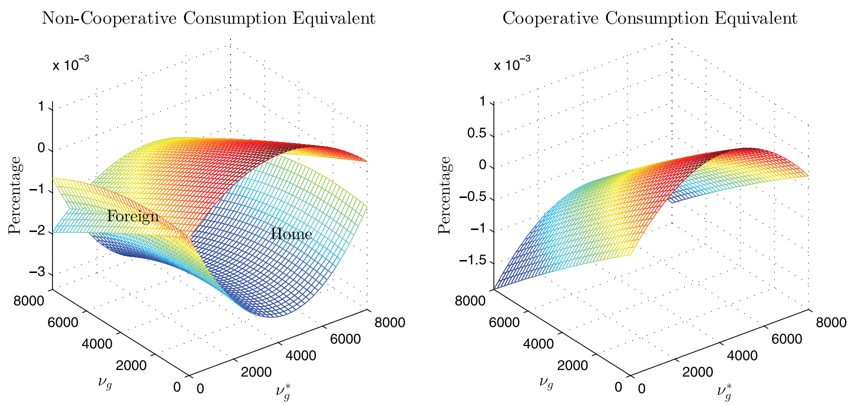
For comparison with the previous literature, I look at the unconditional moments of the second-order approximation of the model; the results are in table A3. Given that the volatility of the shock matches the volatility generated by the Poisson distribution, the size of the disturbance is very small and prompts a small reaction of the variables. In this case, it is the ergodic distribution of the variables' given positive and negative shocks which prompts negative and positive interventions, respectively. The government intervenes in every period using its unconventional policy. In comparison with the conditional moments, two aspects are relevant. First, the policies help reduce the volatility of the variables, as in the previous case. This is a very small difference that appears in the fifth digit. Second, the

Table A3. Unconditional Moments: Deterministic and Stochastic Steady States Comparison, Policy in F

	Determ.	Stochastic Steady State Ψ*							
		No Policy		Loan Market		Intb. Market		Equity Injections	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Y	0.7093	0.7124	0.0047	0.7124	0.0047	0.7123	0.0047	0.7123	0.0047
K	6.0671	6.0702	0.0018	6.0702	0.0018	6.0701	0.0018	6.0701	0.0018
C	0.4697	0.4723	0.0058	0.4723	0.0058	0.4722	0.0058	0.4722	0.0058
L	0.2295	0.2285	0.0048	0.2285	0.0048	0.2285	0.0048	0.2285	0.0048
Y^*	0.7612	0.7611	0.0022	0.7611	0.0022	0.7611	0.0022	0.7611	0.0022
K^*	6.6389	6.6393	0.0067	6.6393	0.0067	6.6393	0.0067	6.6393	0.0067
C^*	0.4430	0.4429	0.0024	0.4429	0.0024	0.4429	0.0024	0.4429	0.0024
L^*	0.2627	0.2628	0.0013	0.2628	0.0013	0.2628	0.0013	0.2628	0.0013
N	1.9806	2.0400	0.0317	2.0400	0.0317	2.0381	0.0317	2.0379	0.0317
N^*	1.6402	1.6381	0.0188	1.6381	0.0187	1.6382	0.0187	1.6382	0.0187
TOT	0.8274	0.8094	0.0232	0.8095	0.0232	0.8100	0.0232	0.8101	0.0232
Ψ^*	1.0000	1.0000	0.0013	1.0000	0.0013	1.0000	0.0013	1.0000	0.0013
B	1.1942	1.4604	0.2357	1.4602	0.2357	1.4502	0.2357	1.4490	0.2357
V^*		2.6785	0.0068	2.6785	0.0068	2.6786	0.0068	2.6786	0.0068
ϕ_g^*				1.0001	0.0000	1.0001	0.0000	1.0001	0.0000
CE				−0.0006		−0.0315		−0.0349	
CE^*				0.0001		0.0016		0.0017	

Notes: All the variables are in levels except for the consumption equivalents, which are in percentages.

Figure A5. Unconditional Utility: Non-Cooperative and Cooperative Consumption Equivalents under Quality-of-Capital Shocks in Foreign



ranking of the policies according to the consumption equivalent of foreign consumers is the opposite.

In the unconditional stochastic steady state, the policies prompt a higher price of the asset price, which is translated into a higher value of the foreign banks. This prompts an increase in domestic deposits and a reduction of loans from home banks. The terms of trade appreciate for foreign and depreciate for home. Then, foreign households consume more and work less; they are better off. Home households consume less and work more; they are worse off. These results are similar to the ones presented in the main text with the simulations.

I continue with the robustness checks. I plot the interactions between the two policymakers under the unconditional utility in figure A5. As in the results with the simulations, the Nash equilibrium implies active policymakers in both countries and the cooperative equilibrium where the foreign authority intervenes, while the home central bank does nothing.

Appendix 7. Additional Tables on Welfare

Table A4. Deterministic and Stochastic Steady States Comparison: Policy in F, $v_g^* = 100$

	Determ.	Stochastic Steady State Ψ^*							
		No Policy		Loan Market		Intb. Market		Equity Injections	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
K	6.0671	6.0569	0.0016	6.0260	0.0021	6.0261	0.0021	6.0261	0.0021
C	0.4697	0.4714	0.0036	0.4695	0.0012	0.4696	0.0012	0.4696	0.0012
L	0.2295	0.2286	0.0031	0.2290	0.0009	0.2290	0.0009	0.2290	0.0009
K^*	6.6389	6.6013	0.0063	6.6038	0.0063	6.6029	0.0062	6.6027	0.0062
C^*	0.4430	0.4420	0.0022	0.4421	0.0022	0.4421	0.0022	0.4421	0.0022
L^*	0.2627	0.2628	0.0012	0.2628	0.0013	0.2628	0.0013	0.2628	0.0013
N	1.9806	2.0349	0.0196	1.9514	0.0059	1.9520	0.0058	1.9521	0.0058
N^*	1.6402	1.6228	0.0183	1.6526	0.0189	1.6539	0.0186	1.6540	0.0186
TOT	0.8274	0.8139	0.0149	0.8223	0.0057	0.8223	0.0056	0.8223	0.0057
Ψ^*	1.0000	0.9999	0.0013	0.9999	0.0013	0.9999	0.0013	0.9999	0.0013
B	1.1942	1.5362	0.1474	1.2815	0.0384	1.2820	0.0385	1.2822	0.0386
V^*	2.6829	2.6627	0.0064	2.6709	0.0062	2.6705	0.0061	2.6704	0.0061
φ_g^*				1.0001	0.0003	1.0001	0.0003	1.0001	0.0003
CE				−0.8695		−0.8700		−0.8696	
CE^*				0.0170		0.0138		0.0132	

Notes: All the variables are in levels except for the consumption equivalents, which are in percentages.

Table A5. Deterministic and Stochastic Steady States Comparison: Technology, Government Expenditure, and Quality-of-Capital Shocks

	Determ.	**Stochastic Steady State Ψ, Ψ^*, A, A^*, G, and G^* Shocks**							
		No Policy		**Loan Market**		**Intb. Market**		**Equity Injections**	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
K	6.0671	6.0269	0.0247	5.9938	0.0248	5.9960	0.0247	5.9960	0.0247
C	0.4697	0.4691	0.0110	0.4672	0.0112	0.4673	0.0112	0.4673	0.0112
L	0.2295	0.2293	0.0138	0.2297	0.0139	0.2297	0.0139	0.2297	0.0139
K^*	6.6389	6.5836	0.0311	6.5843	0.0313	6.5853	0.0311	6.5853	0.0311
C^*	0.4430	0.4418	0.0144	0.4418	0.0145	0.4419	0.0144	0.4419	0.0144
L^*	0.2627	0.2627	0.0205	0.2627	0.0204	0.2627	0.0205	0.2627	0.0205
N	1.9806	1.9743	0.0632	1.8914	0.0641	1.8930	0.0641	1.8930	0.0641
N^*	1.6402	1.6176	0.0924	1.6466	0.0925	1.6490	0.0924	1.6490	0.0924
TOT	0.8274	0.8240	0.0314	0.8324	0.0320	0.8325	0.0319	0.8325	0.0319
Ψ^*	1.0000	0.9999	0.0013	0.9999	0.0013	0.9999	0.0013	0.9999	0.0013
B	1.1942	1.2559	0.0748	1.0466	0.0989	1.0458	0.0990	1.0459	0.0990
V^*	2.6829	2.6604	0.0299	2.6680	0.0301	2.6683	0.0299	2.6683	0.0299
ϕ_g^*				1.0001	0.0006	1.0001	0.0006	1.0001	0.0006
CE				−0.8802		−0.8802		−0.8801	
CE^*				0.0016		0.0141		0.0140	

Notes: All the variables are in levels except for the consumption equivalents, which are in percentages.

Table A6. Deterministic and Stochastic Steady States Comparison: Policy in F and H, $\upsilon_g^* = 100$ and $\upsilon_g = 100$

		Stochastic Steady State Ψ*							
		No Policy		Loan Market		Intb. Market		Equity Injections	
	Determ.	Mean	SD	Mean	SD	Mean	SD	Mean	SD
K	6.0671	6.0569	0.0016	6.0304	0.0020	6.0303	0.0019	6.0301	0.0019
C	0.4697	0.4714	0.0036	0.4698	0.0015	0.4698	0.0015	0.4698	0.0015
L	0.2295	0.2286	0.0031	0.2289	0.0012	0.2289	0.0012	0.2289	0.0012
K^*	6.6389	6.6013	0.0063	6.6043	0.0062	6.6027	0.0062	6.6025	0.0062
C^*	0.4430	0.4420	0.0022	0.4421	0.0022	0.4421	0.0022	0.4421	0.0022
L^*	0.2627	0.2628	0.0012	0.2628	0.0013	0.2628	0.0013	0.2628	0.0013
N	1.9806	2.0349	0.0196	1.9682	0.0074	1.9689	0.0075	1.9691	0.0075
N^*	1.6402	1.6228	0.0183	1.6525	0.0186	1.6535	0.0186	1.6536	0.0186
TOT	0.8274	0.8139	0.0149	0.8210	0.0068	0.8209	0.0069	0.8209	0.0069
Ψ^*	1.0000	0.9999	0.0013	0.9999	0.0013	0.9999	0.0013	0.9999	0.0013
B	1.1942	1.5362	0.1474	1.3174	0.0545	1.3187	0.0551	1.3190	0.0553
V^*	2.6829	2.6627	0.0063	2.6706	0.0061	2.6699	0.0061	2.6698	0.0061
φ_g^*				1.0001	0.0003	1.0001	0.0003	1.0001	0.0003
φ_g				1.0000	0.0001	1.0000	0.0001	1.0000	0.0001
CE				−0.7433		−0.7409		−0.7402	
CE^*				0.0120		0.0071		0.0065	

Notes: All the variables are in levels except for the consumption equivalents, which are in percentages.

Appendix 8. Additional Figures

Figure A6. Impulse Responses to a 5 Percent Decrease in Ψ_t^*, Comparison across Models without Policy Intervention, More Variables

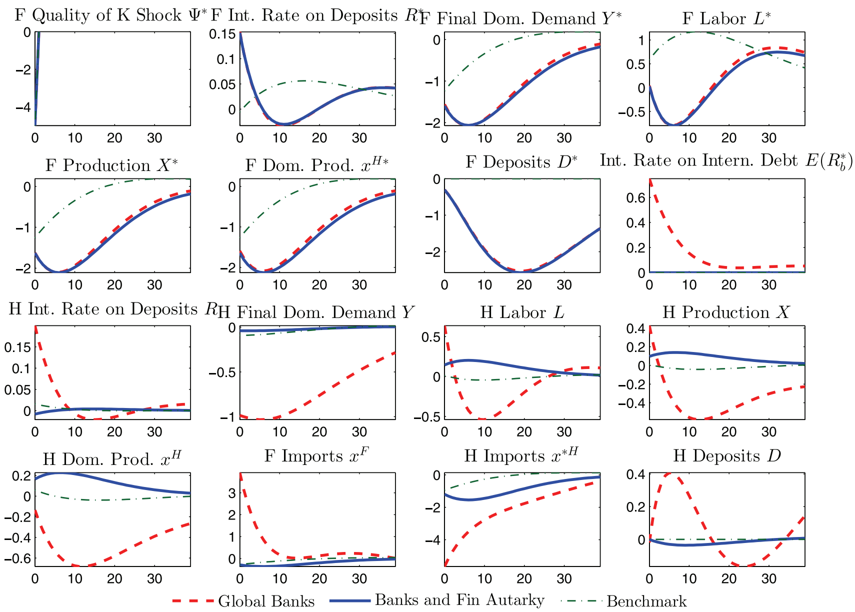


Figure A7. Impulse Responses to a 5 Percent Decrease in Ψ_t^*, Unconventional Policies by F Central Bank

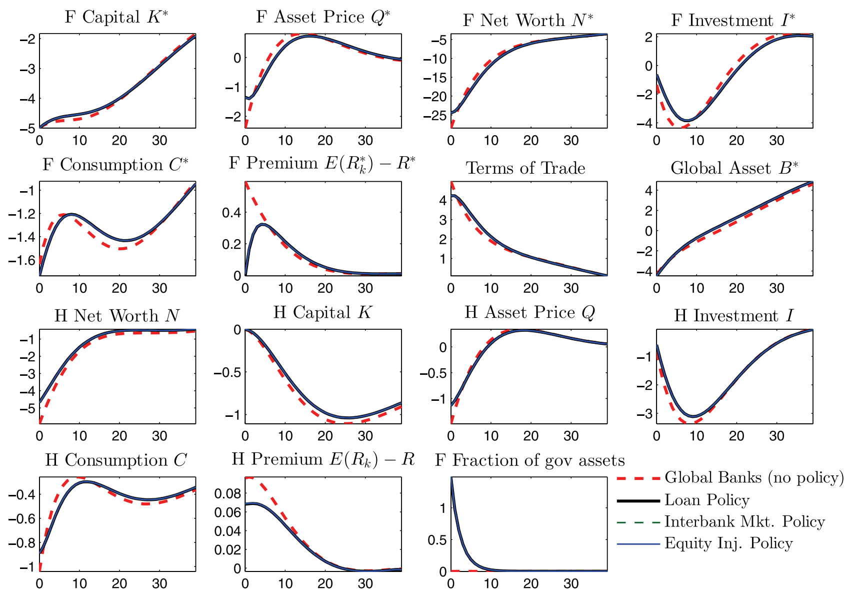


Figure A8. Impulse Responses to a 5 Percent Decrease in Ψ_t^*, Unconventional Policies by F Central Bank, More Variables

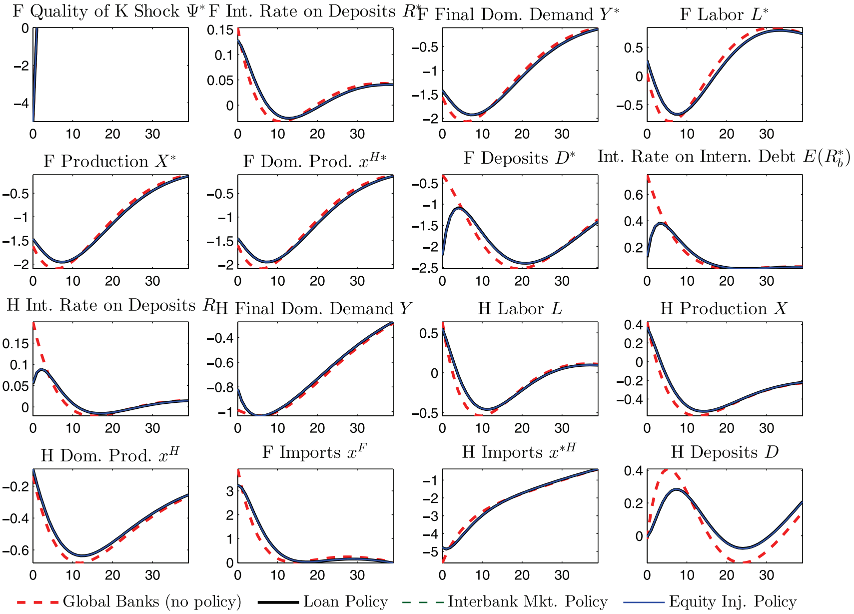


Figure A9. Impulse Responses to a 5 Percent Decrease in Ψ_t^*, Loan Market Intervention by F and H Central Bank

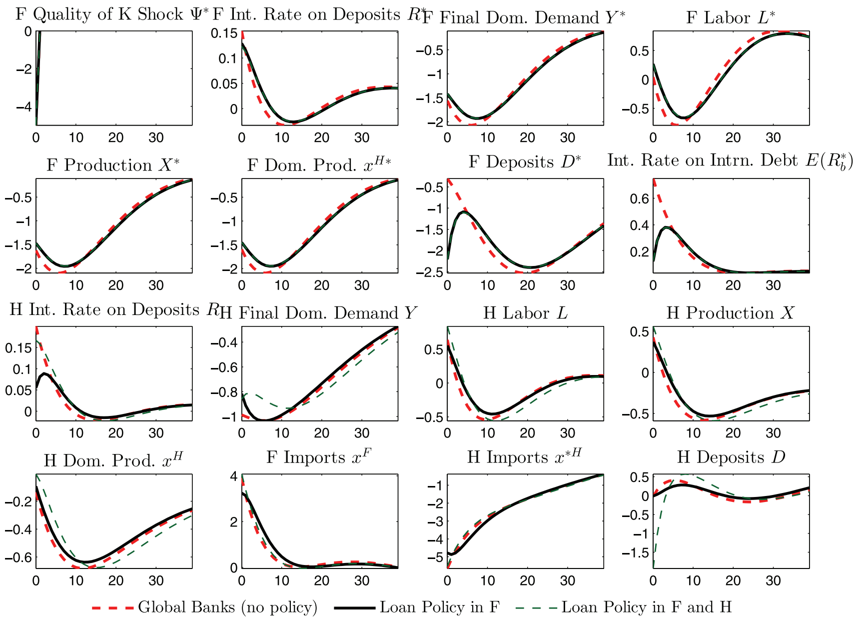


Figure A10. Impulse Responses to a 5 Percent Decrease in Ψ_t^*, Unconventional Policies by F and H Central Bank

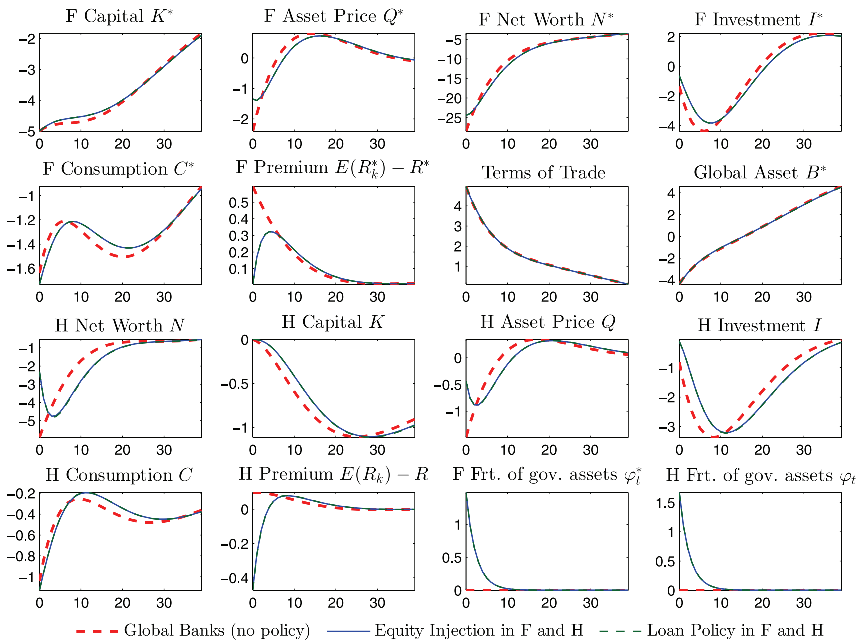


Figure A11. Impulse Responses to a 5 Percent Decrease in Ψ_t^*, Unconventional Policies by F and H Central Bank, More Variables

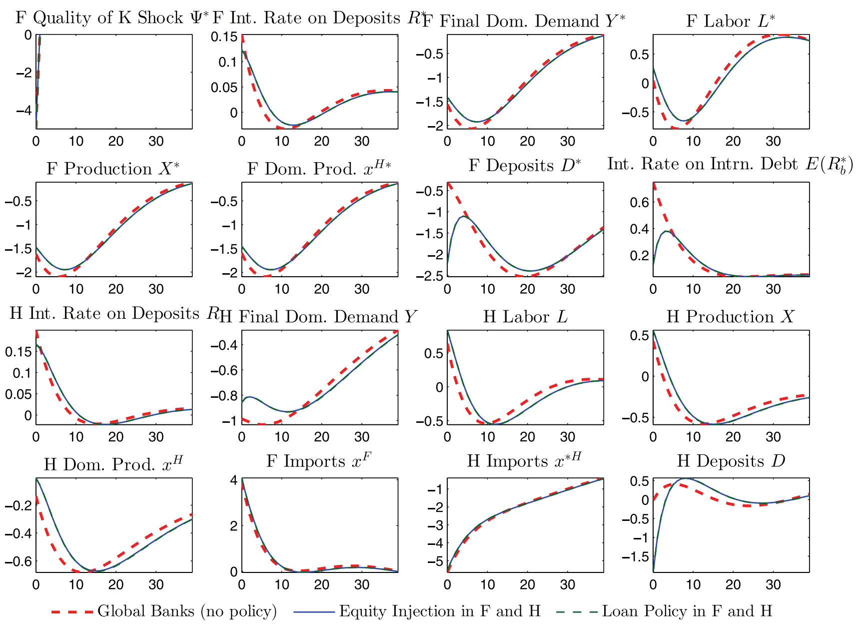
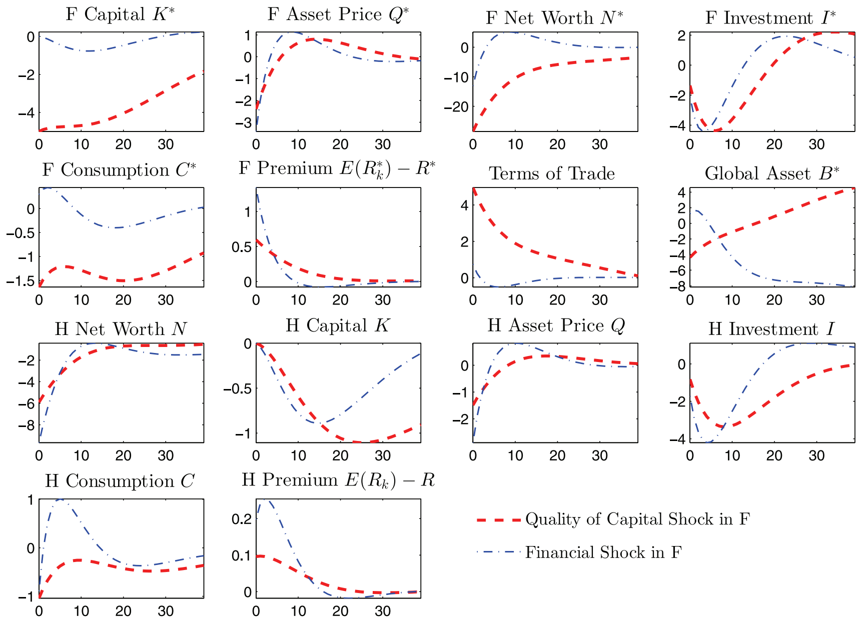


Figure A12. Comparison between a Quality-of-Capital Shock and a Financial Shock



Reference

Dedola, L., P. Karadi, and G. Lombardo. 2013. "Global Implications of National Unconventional Policies." *Journal of Monetary Economics* 60 (1): 66–85.

Discussion of "Financial Intermediation in a Global Environment"

Robert Kollmann
Université Libre de Bruxelles and CEPR

The 2007–09 global financial crisis has led to a rethinking of the role of financial intermediaries for economic fluctuations. Before the financial crisis, the workhorse macro models used by policy institutions and by academic researchers abstracted from banks (e.g., Christiano, Eichenbaum, and Evans 2005). The crisis has stimulated much research that incorporates banks into quantitative dynamic stochastic general equilibrium (DSGE) models. Given the global nature of the banking industry, and of the financial crisis, that research has frequently focused on open-economy models; see, e.g., Devereux and Sutherland (2011), Kollmann, Enders, and Müller (2011), Perri and Quadrini (2011), Ueda (2012), Dedola, Karadi, and Lombardo (2013), Kamber and Thoenissen (2013), Kollmann (2013), and Kollmann et al. (2013). In this new class of DSGE models, bank capital is a key state variable for real activity; negative shocks to bank capital are predicted to increase the spread between banks' lending and deposit rates, and to trigger a fall in bank credit, investment, and output; with a globalized banking system, losses on bank assets in one country can thus lead to a worldwide recession.

The paper by Victoria Nuguer makes a very interesting contribution to the new literature on open-economy DSGE models with banks. Her paper highlights the role of country asymmetries for the transmission of banking shocks and for the optimal policy response to those shocks. While most related studies assume symmetric countries, Victoria considers a world with two countries of vastly different sizes. The small country has a comparative advantage in banking, and its banks are thus larger than banks in the big country. The model is calibrated to data for Switzerland and the United States.

The non-financial aspects of the model follow the international real business cycle literature (Backus, Kehoe, and Kydland 1992).

Each country is specialized in the production of a tradable intermediate good. All markets are competitive; prices and wages are flexible. The modeling of banks in Victoria's paper is inspired by Gertler and Kiyotaki (2010) and Dedola, Karadi, and Lombardo (2013). Each country is inhabited by a representative family; a constant fraction of the family members are production workers, and the remaining members are bankers (there are random switches between these occupations). Workers cannot directly provide their savings to non-financial firms (that borrow to finance physical investment); instead, savings have to be channeled to firms via banks. To prevent embezzlement of bank assets by bankers, a minimum fraction of bank assets has to be funded with bankers' personal net worth (accumulated past profits). This capital requirement limits bank asset holdings. To ensure that the bank capital requirement is always binding, the model assumes that bankers have finite expected job spells, which restricts their net worth accumulation. Crucially, the model posits that bankers in the small country have longer expected job spells (than bankers in the big country); thus, the average small-country bank has more assets than a typical bank in the big country. Small-country banks hence hold a share of their assets abroad; the model assumes that foreign investment takes the form of loans to big-country banks (big-country banks only hold local assets). The interest rate on loans is assumed to equal the rate of return on physical capital in the borrowing country. The model postulates that the global interbank market is frictionless (there is no agency problem between banks).

The analysis in the paper centers on the effects of exogenous stochastic "capital quality" shocks in the big country. These shocks are non-positive, i.e., they may *destroy* a fraction of the big country's physical capital stock (the shocks are introduced to capture the fall in U.S. real estate prices that triggered the global financial crisis). The net worth of both big- and small-country banks drops in response to a negative capital quality shock in the big country. The model predicts that this induces a fall in bank lending, physical investment, and output in both countries. As mentioned above, qualitatively similar cross-country transmission effects (via global banks) have been discussed in previous studies that assume symmetric countries. Nevertheless, Victoria's analysis is interesting, as it shows that the transmission of foreign financial shocks is especially powerful to a small foreign country with large banks. The same intuitive point was previously made by Kamber and Thoenissen (2013), albeit in a banking model with a different structure. Victoria provides a statistical analysis (vector autoregressions) that supports the prediction of strong shock transmission from the United States to Switzerland, during the global financial structure.

A key property of the model, which is not discussed in the paper, is that the stochastic capital quality shocks in the big country *raise* the unconditional expected welfare of the small country, compared with welfare in the deterministic steady state of the world economy. This surprising prediction is important for interpreting the welfare effects of stabilization policy (see below). (Big-country unconditional welfare is lower in the presence of the stochastic big-country capital quality shocks, but this is not astonishing, as the shocks only take zero or negative values; in the stochastic economy, the mean big-country capital stock is thus smaller than in the deterministic steady state.) Tables 2 and 4 show that the higher small-country unconditional welfare (with stochastic shocks) reflects an increase in mean small-country net foreign asset holdings (compared with the deterministic steady state), which is accompanied by a rise in mean consumption and a fall in mean hours worked in the small country.[1] More research on these effects would be useful. I conjecture that the higher average small-country net foreign asset position (under stochastic shocks) might reflect an increase in the average return on physical capital in the big country, which raises the average return on the small country's foreign assets. Hence, the small-country unconditional welfare increase (induced by the foreign stochastic shocks) might hinge on two key assumptions: (i) the return on foreign loans made by small-country banks is indexed to the foreign physical capital return; (ii) the small country is a net lender. Welfare spillovers would change if standard unconditional bank loans were assumed. If the small country were structurally a net *debtor*, then big-country stochastic shocks might make the small country worse off, due to

[1] Using a second-order approximation of the utility function, I infer from the first and second moments of consumption and hours reported in table 2 that the rise in unconditional small-country welfare (due to big-country capital quality shocks) is equivalent to a permanent 0.79 percent consumption increase; the fall in big-country unconditional welfare is equivalent to a 0.27 percent permanent consumption cut.

a rise in the return on the country's foreign liabilities. Note also that adverse big-country shocks worsen the small country's terms of trade. A stronger terms-of-trade deterioration (than under the baseline calibration), due to greater complementarity between domestic and foreign tradables, also might imply a fall in small-country unconditional welfare.

An important contribution of Victoria's paper is the analysis of "unconventional" central bank policies in response to adverse capital quality shocks in the big country. Three types of policy interventions (by both countries) are considered: bank equity injections, central bank lending to non-financial firms, and central bank lending to foreign banks. These types of policies have similar effects. Importantly, the model assumes that central banks do not face a collateral constraint (capital requirement), i.e., central banks have an advantage over commercial banks in making loans. As might be expected, central bank intervention (in response to shocks that impair commercial banks) stabilizes credit, investment, and output, both in the domestic economy and abroad. Stabilization policy by the big country's central bank can markedly dampen the contraction of output in the small country (naturally, small-country central bank interventions have a much more muted stabilizing effect on the big country).

Rules-based stabilization policy (governed by policy feedback rules under full commitment) by a given country *raises* domestic *unconditional* expected welfare, but *lowers* foreign unconditional welfare. The negative effect on foreign unconditional welfare might seem astonishing. However, this effect is in line with the fact that, in this model, random adverse capital quality shocks in the big country *raise* small-country unconditional welfare (see above). This might help to understand why big-country policy interventions (that stabilize the domestic economy) reduce unconditional welfare in the small country. (However, it seems less clear why small-country stabilization policy lowers big-country unconditional welfare.)

An immediate implication of the *negative* foreign unconditional welfare effect of stabilization policy is that the non-cooperative policy equilibrium (Nash) implies excessively aggressive responses to financial shocks. Under Nash, unconditional welfare in both countries is lower than in the absence of any (domestic or foreign) policy response to financial shocks. In the model, coordinated stabilization policy that maximizes a (population-) weighted sum of the two countries' unconditional welfare implies that only the central bank of the big country intervenes.

This result is interesting; however, it seems at odds with observed policies during the recent global financial crisis. During the crisis, international policy coordination was intense, but big and *small* countries alike intervened aggressively to stabilize lending and bank equity.

The welfare and policy results in this paper differ starkly from the ones obtained by Dedola, Karadi, and Lombardo (2013) for a symmetric two-country model with banks. In that model, domestic stabilization policy raises foreign unconditional welfare, and thus there is too little intervention under Nash. A key insight of Victoria's paper is thus that the international spillovers of stabilization policy, and the global policy equilibrium, are sensitive to country asymmetries.

In my view, Victoria's paper suggests many interesting avenues for future research. For example, her model assumes a frictionless global interbank market (as mentioned above). Yet, the interbank market was severely impaired during the global financial crisis (sharp rise in interbank spreads). It would be useful to extend the model by allowing for frictions in the interbank market. A second useful research avenue would be to consider bigger shocks. The model calibration assumes that an adverse 1.5 percent capital quality shock in the big country occurs on average every twenty-eight years. The unconditional welfare cost of the assumed shock process is small. An adverse shock triggers a fall in the price of physical capital that is very modest when compared, for example, with the 40 percent fall in U.S. and European stock prices in 2008. The shocks assumed in the model do not threaten the solvency of the banking system. It would be very interesting to study the effect of bigger shocks that imperil the banking system. With bigger shocks, the welfare effects of unconventional policy might be much greater. However, analysis of big shocks would require the use of global numerical model solution methods instead of the local numerical approximations employed in the paper. A third research avenue would be to assume price or wage stickiness. With nominal rigidities, the fall in aggregate demand induced by adverse banking shocks can have a much greater effect on output than in a flex price/wage world; accordingly, unconventional central bank policies too would boost aggregate output much more, in a world with nominal rigidities (see Kollmann, Roeger, and in't Veld 2012 and Kollman et al. 2013 for New Keynesian models with banks, and bank rescue measures conducted by the government). Finally, it can be noted that the present model abstracts from conventional monetary and fiscal policy. During the global financial crisis, unconventional policies were combined with very large changes in conventional monetary and fiscal policy instruments. It would be fruitful to extend the model here by allowing for conventional macro policy tools; this would shed light on the optimal conventional/unconventional policy mix for coping with financial shocks.

In summary, Victoria Nuguer's paper provides important insights into the role of country asymmetries for the transmission of financial shocks and for optimal policy. Her paper also suggests fascinating avenues for future research.

References

Backus, D., P. Kehoe, and F. Kydland. 1992. "International Real Business Cycles." *Journal of Political Economy* 100 (4): 745–75.

Christiano, L., M. Eichenbaum, and C. Evans. 2005. "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." *Journal of Political Economy* 113 (1): 1–45.

Dedola, L., P. Karadi, and G. Lombardo. 2013. "Global Implications of National Unconventional Policies." *Journal of Monetary Economics* 60 (1): 66–85.

Devereux, M., and A. Sutherland. 2011. "Evaluating International Financial Integration under Leverage Constraints." *European Economic Review* 55 (3): 427–42.

Gertler, M., and N. Kiyotaki. 2010. "Financial Intermediation and Credit Policy in Business Cycle Analysis." In *Handbook of Monetary Economics,* Vol. 3A, ed. B. Friedman and M. Woodford, 547–99. Amsterdam: North-Holland.

Kamber, G., and C. Thoenissen. 2013. "Financial Exposure and the International Transmission of Financial Shocks." *Journal of Money, Credit and Banking* 45 (s2): 127–58.

Kollmann, R. 2013. "Global Banks, Financial Shocks and International Business Cycles: Evidence from an Estimated Model." *Journal of Money, Credit and Banking* 45 (s2): 159–95.

Kollmann, R., Z. Enders, and G. Müller. 2011. “Global Banking and International Business Cycles.” *European Economic Review* 55 (3): 407–26.

Kollmann, R., M. Ratto, W. Roeger and J. in’t Veld. 2013. “Fiscal Policy, Banks and the Financial Crisis.” *Journal of Economic Dynamics and Control* 37 (2): 387–403.

Kollmann, R., W. Roeger, and Jan in’t Veld. 2012. “Fiscal Policy in a Financial Crisis: Standard Policy vs. Bank Rescue Measures.” *American Economic Review: Papers and Proceedings* 102 (3): 77–81.

Perri, F., and V. Quadrini. 2011. “International Recessions.” NBER Working Paper No. 17201.

Ueda, K. 2012. “Banking Globalization and International Business Cycles: Cross-Border Chained Credit Contracts and Financial Accelerators.” *Journal of International Economics* 86 (1): 1–16.

Rule-of-Thumb Consumers and Labor Tax Cut Policy at the Zero Lower Bound*

Lorant Kaszab
Central Bank of Hungary

This paper shows that a labor tax cut can increase output in a model where the zero lower bound on the nominal interest rate binds due to a negative demand shock. The model is a basic New Keynesian one with non-Ricardian (also known as rule-of-thumb) households (along with the usual Ricardian ones) who spend the increase in their disposable income after the tax cut. Besides price rigidity, our result requires wage rigidity which attenuates the effect of the negative demand shock on the real wage. This finding stands in contrast to those of Eggertsson (2011) and Christiano, Eichenbaum, and Rebelo (2011), whose models support an increase in the labor tax. This paper departs from the assumption of balanced government budget with lump-sum taxes and introduces endogenous debt that is retired by taxes on labor income. It is shown that the tax-cut policy is most effective when debt is paid back far in the future.

JEL Codes: E52, E62.

*This paper is based on the first chapter of my PhD dissertation at Cardiff University. I am grateful to Gianluca Benigno, Pierpaolo Benigno, Mick Devreaux, Andrea Ferrero, Max Gillman, Patrick Minford, Panayiotis Pourpourides, Carlos Thomas, Mike Wickens, and John Williams for their extensive comments. Over the years I benefited from conversations with Helmuts Azacis, Alessia Campolmi, Lawrence Christiano, Huw Dixon, Roman Horvath, Csaba Kober, Istvan Konya, Henrik Kucsera, Robert Lieli, Ales Marsal, David Staines, Akos Valentinyi, and Balazs Vilagi. I thank seminar participants at Cardiff Business School, Central Bank of Hungary, QED in Vienna, RES Easter School, RES Job Market Conference, conferences of the Czech and Hungarian Economics Society, and the annual IJCB research conference. I acknowledge the support from the Grant Agency of the Czech Republic P402/12/G097. For the online appendix, see https://sites.google.com/site/lorantkaszab/research. Author contact: Research Directorate, 9 Szabadsag ter, 1054, Hungary. E-mail: kaszabl@mnb.hu.

1. Introduction

Following the enactment of the American Recovery and Reinvestment Act (ARRA) of 2009, which is a $787 billion fiscal package containing labor tax cuts[1] and various forms of government purchases, there has been discussion on the sign and magnitude of fiscal multipliers. On one hand, some influential papers using New Keynesian type models featuring price rigidity concluded that an increase in non-productive government spending can be very effective in stimulating the economy under the zero lower bound (ZLB) which is binding in the United States since the end of 2008 (see, e.g., Christiano, Eichenbaum, and Rebelo 2011; Eggertsson 2011; and Woodford 2011). On the other hand, these papers found that labor tax cuts can be contractionary when the zero lower bound on the nominal interest rate is binding.

This paper contributes to the literature on fiscal policy at the zero lower bound by showing that the incorporation of rule-of-thumb (or non-Ricardian) consumers into the baseline New Keynesian model can render labor tax cut policy expansionary when the nominal interest rate is zero. Non-Ricardian households behave in a Keynesian fashion—i.e., they are willing to raise their consumption expenditure in response to a rise in their disposable income following the tax cut[2]—whereas Ricardians recognize that the tax cut in the present is covered by taxes in the future and therefore their whole lifetime income on which they base their consumption decision is not affected. In this paper we reduce the employees' part of the labor taxes similar to what is prescribed by the U.S. stimulus package of 2009.

First, let us discuss what the baseline log-linear New Keynesian model with only price rigidity and a perfectly competitive labor market with flexible wages delivers in the absence of non-Ricardian

[1] In December 2011 President Obama announced that the payroll tax cut would be extended until the end of 2012.

[2] Rule-of-thumb households are excluded from the financial market. Hence, they have no consumption-savings trade-off (lack of Euler equation) and their decision problem is restricted to the optimal choice between consumption and leisure. The inclusion of rule-of-thumb households into dynamic stochastic general equilibrium (DSGE) models is a trivial way of generating incomplete asset markets.

consumers in response to a labor tax cut. As in Christiano, Eichenbaum, and Rebelo (2011), the zero lower bound on the nominal interest rate becomes binding due to a discount factor shock (i.e., a negative demand shock) which leads to deflation and a fall in output, consumption, and the marginal cost. In a similar model, Eggertsson (2011) shows that cutting the labor tax rate has effects similar to the discount factor shock, i.e., a random fraction of firms that can change their product price will lower the price because they face a reduction in their production costs, while other firms that cannot reset their price due to price stickiness will produce less and also decrease their demand for labor. When the nominal interest rate is zero, the deflationary effect of the labor tax cut is coupled with a rise in the real interest rate that depresses consumption. Also, Ricardian consumers associate the current tax cut with future rises in taxes and decrease their consumption to save up (Ricardian equivalence is valid). Thus, with only Ricardian consumers in the model, the tax cut cannot be stimulative.

However, the labor tax cut happens to be expansionary if we incorporate non-Ricardian consumers and wage rigidity into the model. Following the tax cut, non-Ricardian households consume the rise in their disposable income, generating a demand effect. Due to the higher consumption demand of non-Ricardian households, firms which cannot alter their price as a result of price rigidity will demand more labor to be able to produce more. In the absence of an imperfectly competitive labor market with nominal wage inertia,[3] the discount factor shock and the labor tax cut would lead to an enormous decline in the marginal cost (which equals the real wage due to the constant-returns-to-scale production function in the absence of productivity shocks and physical capital). But the introduction of wage rigidity into the model attenuates the reaction of real wage to the discount factor shock so that the real disposable income of non-Ricardians can rise following the tax cut. Hence, in our setting the effects of the negative demand shock are less severe if there

[3]To motivate imperfectly competitive labor markets, households (independently of whether they are of Ricardian or non-Ricardian origin) become members of unions which set wages for them. It is costly for the unions to change wages because of wage adjustment costs. Hence, we have nominal wage rigidity. See details in the main text.

is a simultaneous fall in the labor tax during the zero-lower-bound period. Our finding is completely in contrast to Christiano, Eichenbaum, and Rebelo (2011), who argue in favor of a labor tax rise at the zero lower bound using a middle-sized DSGE model without rule-of-thumb agents.

In this paper we consider two different ways of financing the labor tax cut. First, we maintain the simplest fiscal scenario whereby the government budget is balanced in each period by lump-sum taxes paid only by Ricardians. Secondly, we depart from a balanced budget and introduce endogenous government debt which is retired through labor income taxes levied uniformly on both types of households and collected either in the short or long run. In the first case, a labor tax cut stimulates the economy by construction. In the second case tax cut policy boosts economic activity only when debt is paid back in the long run so that non-Ricardians can enjoy higher disposable income due to the tax cut in the present. An alternative interpretation is that non-Ricardians receive a transfer from Ricardians in the present, which is followed by a transfer from non-Ricardians to Ricardians in the future.

Again it needs to be emphasized that the tax cut is stimulative in this paper because we reduce the employees' part of the labor taxes, which leads to an increase in non-Ricardians' income and a rise in labor demand. In general, it matters a lot whether we cut the employer's or the employee's part of the labor taxes. In the latter case an average labor tax cut acts like a traditional stimulus tax cut working through the labor demand while the labor supply is of reduced importance due to wage-setting frictions in the model (Christiano 2011). However, in the previous case the payroll tax cut directly affects the marginal cost and, as we argue below, acts like a further deflationary factor on the economy besides the negative demand shock. Therefore, in this paper, it is the employee's part of the average labor tax which is reduced.

Our findings are based on deterministic labor tax cut experiments conducted using the shooting algorithm of Christiano, Eichenbaum, and Rebelo (2011), who studied small and middle-sized New Keynesian models in log-linear form without non-Ricardian consumers. Thus, in our experiments the discount factor shock and the fiscal action (the labor tax cut) are on for a deterministic period of time. This modeling strategy received considerable attention in the recent literature. Here we touch upon two issues. First, Carlstrom, Fuerst, and Paustian (2012) assert that inflation and output impulse responses of a negative demand shock might exhibit unorthodox behavior—they rise instead of falling—depending on the number of periods for which the interest rate is fixed when there are state variables such as price indexation in the log-linear model. However, we do not encounter such a problem for our calibrated value of the length of the shock.[4] Second, a number of papers[5] raise concerns about the accuracy of the first-order perturbation in modeling the zero lower bound. However, Christiano and Eichenbaum (2012) present evidence that first-order perturbation remains to be a fairly good approximation to the non-linear model.

This work is closely related to several papers in the literature. One of them is Coenen et al. (2012), who simulate various middle-sized DSGE models including rule-of-thumb households. We differ from that paper for at least two reasons. First, the zero-lower-bound period in our paper is generated endogenously as a result of a negative demand shock instead of arbitrarily fixing the interest rate for a given time period as Coenen et al. (2012) and Cogan et al. (2010) did. Siemsen and Watzka (2013) describe why it is misleading to model the ZLB in a way that Coenen et al. (2012) did. Even with an increase in government spending output, consumption and inflation are below their steady-state values due to the negative demand shock that makes the zero lower bound binding in Christiano, Eichenbaum, and Rebelo (2011) and, thus, real activity and inflation remain depressed even after the zero-lower-bound period. However, the same variables in Coenen et al. (2012) are above their steady state even during the zero lower bound in the absence of the negative demand shock, and therefore monetary policy has to tighten outside the zero-lower-bound period as the Taylor rule, which engineers a sharp increase in real interest rates, is in operation. In contrast, economic activity in Christiano, Eichenbaum, and Rebelo

[4]Depending on the size and length of the discount factor and the fiscal shock (tax cut), the model endogenously generates the date at which the zero lower bound starts and ceases to bind.

[5]See, e.g., Braun and Körber (2011) who, using a non-linear model, argue that the ignorance of price adjustment cost in the aggregate feasibility constraint distorts the size and even the sign of fiscal multipliers obtained from the log-linear model in which the price adjustment cost is zero.

(2011) still remains weak in the aftermath of zero interest rates, and therefore monetary policy can be slack (real interest rates are low). Second, we employ simpler models than Coenen et al. (2012) so that we can provide intuition on what model features are needed in order for the labor tax cut policy to be expansionary.

Our paper is also closely related to Bilbiie, Monacelli, and Perotti (2012), who have shown that cuts in lump-sum taxes stimulate output and raise welfare in an economy featuring two types of households (savers and borrowers) and price rigidity, and which is constrained by the zero lower bound on the nominal interest rate. This paper is also related to the literature on models containing rule-of-thumb consumers, such as Bilbiie (2008) and Galí, Lopez-Salidó, and Vallés (2007). The model used in this paper is closest to Ascari, Colciago, and Rossi (2011) and Furlanetto (2011), who enrich the model of Galí, Lopez-Salidó, and Vallés (2007) with wage-setting frictions.

There is a growing empirical literature which finds labor tax cuts stimulative. In a well-known study, using a narrative approach, Romer and Romer (2010) found that tax increases are contractionary. Also, Mertens and Ravn (2012) found, using a new narrative account of federal tax liability changes to proxy tax shocks, that the short-run effects of a tax decrease on output are positive and large. Hall (2009) reviews several empirical studies arguing that households do respond with an increase in their consumption expenditures to a temporary cut in labor tax. Thus, there is enough empirical evidence in support of the positive effects of a labor tax cut.

The rest of the paper is organized as follows. Section 1 describes the agents in the model and their assumed behavior. Section 2 contains the calibration. In section 3 we conduct experiments in various models to investigate the effects of the labor tax cut. The last section concludes.

2. The Model

2.1 Households

2.1.1 Ricardians

There are two types of households: Ricardians and non-Ricardians. Ricardian households are able to smooth their consumption using state-contingent assets (risk-free bonds), while non-Ricardians cannot. The share of Ricardian and non-Ricardian households in the economy is $1-\lambda$ and λ, respectively. The instantaneous utility function of type $i \in \{o, r\}$ household, which can be Ricardian (optimizer (OPT), o) or non-Ricardian (rule-of-thumb (ROT), r), is given by

$$U_t^i = \frac{(C_t^i - h_i \bar{C}_{t-1}^i)^{1-\sigma} - 1}{1-\sigma} - \frac{(N_t^i)^{1+\varphi}}{1+\varphi}, \tag{1}$$

where $C_t^i(\bar{C}_t^i)$ denotes the time-t consumption (aggregate consumption) of type $i \in \{o, r\}$ household and parameter $h_i > 0$ governs the degree of habit formation in consumption. When $h_i = 0$, there is no habit formation. σ is the inverse of the intertemporal elasticity of substitution (IES), which measures the willingness of households' substituting consumption across time. Further σ stands for relative risk aversion. N_t^i is hours worked by household of type i. The second term on the right-hand side of equation (1) denotes the disutility of household i from working. The Frisch elasticity of labor supply is given by $1/\varphi$.

First, we discuss the problem of Ricardian households. They maximize their lifetime utility,

$$E_0 \sum_{t=0}^{\infty} \beta_t U_t^i, \tag{2}$$

where E_0 is the expectation operator representing expectations conditional on period-0 information and β is the discount factor. This maximization of the optimizer household is subject to a sequence of budget constraints[6]:

$$P_t C_t^o + R_t^{-1} B_{t+1}^o = (1-\tau_t^o) W_t N_t^o + D_t^o + B_t^o - P_t T_t^o - F_t - P_t S^o,$$

where P_t is the aggregate price level, W_t is the nominal wage, and N_t^o is hours worked by OPT. Thus, $W_t N_t^o$is the labor income received by the optimizer household. T_t^o are lump-sum taxes (or transfers, if

[6]For the rest of the paper, a variable without a time subscript denotes steady-state value.

negative) paid by the Ricardian household (hence, the superscript o). τ_t^o is a tax rate on labor income ($W_t N_t^o$). Profit income is denoted by D_t^o. Further, B_{t+1}^o is the amount of risk-free bonds and R_t is the gross nominal interest rate. Following Galí, Lopez-Salidó, and Vallés (2007) we assume, without loss of generality, that the steady-state lump-sum taxes (S^o) are chosen in a way that steady-state consumption of ROT and OPT households are equal in steady state. Hence, S^o is a steady-state lump-sum tax used to facilitate the equality of the steady-state consumptions of ROT and OPT households. F_t stands for a nominal union membership fee (see more on it below). For an alternative approach when steady-state consumptions are not equal, see Natvik (2012).

In summary, the optimizer household maximizes its lifetime utility with respect to its budget constraint.

The OPT household first-order conditions (FOCs) with respect to consumption (C_t^o) and bonds (B_{t+1}^o) are

$$\frac{\partial U_t^i}{\partial C_t^i} = (C_t^i - h_i \bar{C}_{t-1}^i)^{-\sigma} = \lambda_t, \text{ with } i = o, \tag{3}$$

$$\beta_{t+1} E_t \left(\lambda_{t+1} \frac{R_{t+1}}{\pi_{t+1}} \right) = \lambda_t, \tag{4}$$

where λ_t is the marginal utility of consumption. In all the above equations that contain expectations, we ignore covariance terms.

The linearized[7] version of equation (4) is the intertemporal Euler equation:

$$c_t^o = \frac{h_o}{1+h_o} c_{t-1}^o + \frac{1}{1+h_o} E_t c_{t+1}^o - \frac{1-h_o}{1+h_o} \frac{\beta}{\sigma} [dR_t - E_t \pi_{t+1} - r_t^*], \tag{5}$$

where $c_t^o \equiv \log(C_t^o/C), \pi_t \equiv \log(P_t/P_{t-1})$ is the time-t rate of inflation, and $dR_t \equiv R_t - R$, i.e., the deviation of nominal interest rate from its steady-state value. r_t^* can be interpreted as the discount

[7]The fact that Eggertsson (2011) log-linearizes while Christiano (2011) linearizes the same model does not affect the main conclusions. Here we follow the latter strategy.

factor shock.[8] Notice that $h_o = 0$ delivers the usual Euler equation without habit formation.

The labor supply of OPT household is determined by the union's problem (discussed below).

2.1.2 Non-Ricardians

Non-Ricardian households cannot invest in bonds. In other words, they are excluded from financial markets. Hence, this is the case of limited asset market participation. Therefore, ROT do not make consumption-savings decisions (i.e., the lack of consumption Euler equation). ROT households' consumption depends on their disposable income—i.e., the labor income after taxation, $(1 - \tau_t^r) W_t N_t^r$—which is reflected by their budget constraint:

$$\int_0^1 P_t(i) C_t^r(i) di = (1 - \tau_t^r) W_t N_t^r - P_t S^r, \tag{6}$$

where $C_t^r(i)$ and N_t^r are, respectively, the consumption of product i and hours worked by rule-of-thumb households. The steady-state lump-sum tax, S^r, ensures that the steady-state consumption of each type of household coincides.

ROT agents exploit relative price differences in the construction of their consumption basket and, in optimum, they obtain

$$P_t C_t^r = \int_0^1 P_t(i) C_t^r(i) di.$$

[8] Following the appendix of Christiano (2011), the time-varying discount factor is made equal to the inverse of the real interest rate (R_t^{real}):

$$\beta_t = \frac{1}{1 + R_t^{\text{real}}},$$

which can be linearized as

$$\beta \hat{\beta}_t = -\frac{1}{(1+r)^2} r_t^*,$$

where $\hat{\beta}_t \equiv (\beta_t - \beta)/\beta$ and $r_t^* \equiv R_t^{\text{real}} - R^{\text{real}}$. It follows by using the steady-state condition $\beta = 1/(1 + R^{\text{real}}) = 1/(1 + R)$ that

$$\hat{\beta}_t = -\beta r_t^*.$$

Thus, an ROT household maximizes its utility (equation (2) with $i = r$) with respect to its budget constraint (equation (6)).

The budget constraint of ROT households in equation (6) can be expressed in linear form as

$$c_t^r = w_t + n_t^r - \chi \hat{\tau}_t^r, \tag{7}$$

where $\hat{\tau}_t^r \equiv \tau_t^r - \tau^r$, $\chi \equiv 1/(1-\tau^r)$.

ROT households delegate their labor supply decision to unions.

2.2 Firms

The intermediary goods are produced by monopolistically competitive firms of which a randomly selected $1 - \xi^p$ fraction is able to set an optimal price each period as in Calvo (1983) while the remaining ξ^p fraction keep their price fixed. Intermediary good j, denoted as $Y(j)$, is produced by a one-to-one production function:

$$Y_t(j) = N_t(j), \tag{8}$$

where $N_t(j)$ is an aggregator of different labor varieties:

$$N_t(j) = \left(\int_0^1 [N_t(j,z)]^{\frac{\varepsilon_w - 1}{\varepsilon_w}} dz \right)^{\frac{\varepsilon_w}{\varepsilon_w - 1}},$$

where $N_t(j,z)$ stands for quantity of variety z labor employed by firm j. The one-to-one (constant-returns-to-scale) production function in equation (8) implies that the average (or economy-wide) marginal cost is equal to the economy-wide real wage in the absence of technology shocks.

There is a competitive firm which bundles intermediate goods into a single final good through the Kimball (1995) aggregator:

$$\int_0^1 \mathcal{G}(X_t(j))dj = 1, \tag{9}$$

where $X_t(j) \equiv Y_t(j)/Y_t$ is the relative demand and $\mathcal{G}$ is a function with properties $\mathcal{G}(1) = 1$, $\mathcal{G}' > 0$, and $\mathcal{G}'' < 0$. With Kimball specification, the elasticity of demand is increasing in the price ($P_t(j)$) set by an individual firm or, equivalently, decreasing in its relative output ($X_t(j)$). After linearization, it turns out that Kimball demand reduces the slope of the Phillips curve (see more below). The Kimball aggregator is also present in popular middle-sized DSGE models, such as the Smets-Wouters (2007) model.[9]

The profit-maximization problem of the perfectly competitive goods bundler (final goods producer) gives way to the relative demand for the product of firm j:

$$X_t(j) = \tilde{\mathcal{G}}\left(\frac{P_t(j)Y_t}{\mu_{f,t}}\right), \tag{10}$$

where $\tilde{\mathcal{G}} \equiv \mathcal{G}'^{-1}(.)$ and $\mu_{f,t}$ is the multiplier on the constraint (equation (9)) in the Lagrangean representation of the final goods producer's maximization problem (more details can be found in online appendix A at https://sites.google.com/site/lorantkaszab/research).

Intermediary firm z that last reset its price at time $T = 0$ maximizes its present and discounted future profits with the probability of not resetting its price:

$$\max_{P_t^*} \sum_{T=0}^{\infty} \left(\xi^p \beta\right)^T \Lambda_{t,t+T}\left[P_t^*(j)Y_{t+T}(j) - TC\left(Y_{t+T}(j)\right)\right], \tag{11}$$

where P_t^* is the optimal reset price at time t, ξ^p is the probability of not resetting the price, TC stands for the total cost of production, and $\Lambda_{t,t+T}$ is the stochastic discount factor defined as

$$\Lambda_{t,t+T} \equiv \left(\frac{C^o_{t+T} - h_o C^o_{t+T-1}}{C^o_{t+T+1} - h_o C^o_{t+T}}\right)^{\sigma} \frac{P_t}{P_{t+T}}.$$

This firm's maximization problem is subject to the production function in equation (8) and to the demand function of good z in equation (10).

The New Keynesian price Phillips curve in the case of Kimball demand can be written as

$$\pi_t = \beta E_t \pi_{t+1} + \kappa s_t \text{ with } \kappa \equiv A\frac{(1-\xi^p)(1-\beta\xi^p)}{\xi^p} \text{ and}$$

$$A \equiv \frac{1}{1+\mathcal{I}\frac{\epsilon}{\varepsilon_p - 1}}, \tag{12}$$

[9]There are several alternative ways to introduce strategic complementarity into price setting. In this paper we use the Kimball aggregator. Firm-specific labor is another possibility (see, e.g., chapter 3 in Woodford 2003).

where we can see that the slope of the Phillips curve (κ) is influenced beyond the Calvo parameter (ξ^p) and the discount factor (β) by the Kimball curvature parameter (ϵ) and the elasticity of demand (ε_p). The indicator variable $\mathcal{I}$ is equal to one when there is strategic complementarity in price setting (due to Kimball demand). The case of $\mathcal{I} = 0$ delivers the standard Phillips curve without Kimball demand. (For detailed derivation of the New Keynesian Phillips curve, see online appendix A.) In experiment 1 (see below), which utilizes the above model without wage stickiness, we found that real rigidity is necessary because it helps to avoid a non-uniqueness problem (for more on this, see footnote 18). Now we proceed to discuss the determination of labor supply.

2.3 Unions

To introduce wage stickiness into the model, one usually assumes that households have monopoly power in determining their wage as in Erceg, Henderson, and Levin (2000), who presume that each household can engage in perfect consumption smoothing. However, the presence of ROT households that cannot engage in intertemporal trade precludes the possibility of consumption smoothing. To motivate the wage-setting decision, we follow Galí, Lopez-Salidó, and Vallés (2007), whose model features a continuum of unions (on the unit interval), $z \in [0, 1]$, each representing a continuum of workers of which a fraction (λ) are members of rule-of-thumb and the remaining $(1 - \lambda)$ fraction consists of optimizing households. Each union employs one particular type of labor (independently of the type of households they originate from) that is different from the type of labor offered by other unions.

Each period, the union maximizes the weighted current and discounted future utility of its members:

$$E_t \sum_{T=0}^{\infty} \beta^T \left[\lambda U^r_{t+T} + (1 - \lambda) U^o_{t+T}\right]$$

subject to the labor demand function for labor of type z:

$$N_t(z) = \left(\frac{W_t(z)}{W_t}\right)^{-\varepsilon_w} N_t,$$

where $W_t(z)$ is the nominal wage set by the union z, ε_w is the elasticity of labor demand, and W_t is an aggregate of the wages set by unions:

$$W_t \equiv \left(\int_0^1 [W_t(z)]^{1-\varepsilon_w} \right)^{\frac{1}{1-\varepsilon_w}}.$$

Adjusting wages is costly, as in Rotemberg (1982), who originally applied it to model price adjustment. In particular, there is a wage adjustment cost which is a quadratic function of the change in the nominal wage and proportional to the aggregate wage bill. The presence of this wage adjustment cost is justified by the fact that unions have to negotiate wages each period and this activity consumes real resources. The larger is the increase in nominal wage achieved by the union, the higher is the effort associated with it. Each union member incurs an equal share of the wage adjustment cost. Thus, the nominal membership fee, F, paid by a generic union member z at time t is given by

$$F_t(z) = \frac{\phi_w}{2} \left(\frac{W_t(z)}{W_{t-1}(z)} - 1 \right)^2 W_t N_t,$$

where ϕ_w governs the size of the adjustment costs. In the special case of $\phi_w = 0$, the labor market features flexible wages.

The optimality condition from the union's problem can be derived by taking the FOC with respect to the wage, $\tilde{W}_t$:

$$\begin{aligned} 0 = &\left(\lambda \frac{\partial U_t^r}{\partial C_t^r} + (1-\lambda) \frac{\partial U_t^o}{\partial C_t^o} \right) (1-\tau_t) \tilde{W}_t [(\varepsilon_w - 1) + \phi_w (\Pi_t^w - 1) \Pi_t^w] \\ &- \varepsilon_w N_t^{\varphi} \\ &- \beta \left(\lambda \frac{\partial U_{t+1}^r}{\partial C_{t+1}^r} + (1-\lambda) \frac{\partial U_{t+1}^o}{\partial C_{t+1}^o} \right) \phi_w (\Pi_{t+1}^w - 1) \Pi_{t+1}^w \frac{W_{t+1}}{P_{t+1}} \frac{N_{t+1}}{N_t}, \end{aligned} \tag{13}$$

where $\Pi_t^w \equiv W_t / W_{t-1}$ is the wage inflation, $\tilde{W}_t \equiv W_t / P_t$ is the real wage, and $\frac{\partial U_t^i}{\partial C_t^i}$ is defined by equation (3) for $i \in \{o, r\}$. In deriving equation (13), we assumed that the labor taxes on Ricardian and non-Ricardian labor incomes are the same: $\tau_t = \tau_t^o = \tau_t^r$. Consumption differs between the two types of consumers outside the steady state. When making a decision on labor demand, the firm does not distinguish between different workers of type z. Thus, in the aggregate, $N_t^r = N_t^o = N_t$ holds, i.e., they work the same amount of hours. The linearization of equation (13) yields what we call the New Keynesian wage Phillips curve:

$$\pi_t^w = \beta E_t \pi_{t+1}^w - \kappa^w \left[w_t - mrs_t - \chi \hat{\tau}_t \right], \tag{14}$$

where $\pi_t^w \equiv \log(\Pi_t^w/\Pi^w)$, $w_t \equiv \log(\tilde{W}_t/\tilde{W})$, $\hat{\tau}_t \equiv \tau_t - \tau$, $\kappa^w \equiv \frac{\varepsilon_w - 1}{\phi_w}$,[10] and the linearized expression for the marginal rate of substitution is[11]

$$mrs_t = \chi_r (c_t^r - h_r c_{t-1}^r) + \chi_o (c_t^o - h_o c_{t-1}^o) + \varphi n_t, \tag{15}$$

where

$$\chi_r \equiv \sigma \frac{\lambda}{1 - h_r} \frac{(1 - h_o)^{-\sigma}}{\lambda (1 - h_r)^{-\sigma} + (1 - \lambda)(1 - h_o)^{-\sigma}},$$

$$\chi_o \equiv \sigma \frac{1 - \lambda}{1 - h_o} \frac{(1 - h_r)^{-\sigma}}{\lambda (1 - h_r)^{-\sigma} + (1 - \lambda)(1 - h_o)^{-\sigma}}.$$

Note that in case of $h_o = h_r = 0$, equation (15) boils down to the case of constant relative risk aversion (CRRA) utility without habits. Without loss of generality, we postulate, following Furlanetto and Seneca (2012), that $h_r = h_o = h$, implying $\chi_r \equiv \lambda/(1 - h)$ and $\chi_o \equiv (1 - \lambda)/(1 - h)$. The connection between the wage inflation (π_t^w), price inflation (π_t), and the real wage (w_t) can be expressed, in linear form, as

$$\pi_t^w = w_t - w_{t-1} + \pi_t. \tag{16}$$

---

[10] The slope of the Phillips curve under Calvo wage setting reads $\frac{(1-\xi^w)(1-\beta\xi^w)}{\xi^w} \frac{1}{1+\varphi\varepsilon_w}$, which is equivalent to the slope under Rotemberg wage setting, $\frac{\varepsilon_w - 1}{\phi_w}$. After assigning a value to ξ^w (probability of not resetting the wage), we can calculate ϕ_w.

[11] Note that we assume a tax policy that equates steady-state consumptions across household types (i.e., $C^r = C^o$).

2.4 Fiscal and Monetary Policy

2.4.1 Fiscal Policy

Similarly to Christiano (2011) and Christiano, Eichembaum, and Rebelo (2011), we consider a deterministic experiment: the tax rate is cut by the same amount in each period for the entire duration of the shock.

We operate with two markedly different fiscal scenarios in this paper. The first one assumes a uniform tax cut (lowering labor taxes for both types of households by the same proportion) that is financed by lump-sum taxes levied on Ricardian agents. Hence, non-Ricardians do not pay taxes. In this case the government budget is balanced in each period. This is the simplest possible fiscal scenario that can be built into the model. Therefore, our setup is different from Galí, Lopez-Salidó, and Vallés (2007), where non-Ricardians pay lump-sum taxes.

In the second fiscal scenario, we depart from a balanced budget and assume that a uniform tax cut is financed by government debt that is paid back through labor income taxes that are levied on both types of households.[12] With this latter arrangement, we relax the strong assumption that non-Ricardians do not bear the burden of the tax cut. In the experiments below we assume, in contrast to Galí, Lopez-Salidó, and Vallés (2007), that the steady-state level of debt is not zero. The government budget constraint which implicitly describes the evolution of debt (B) reads as

$$B_t + \tau_t W_t N_t = R_{t-1} B_{t-1} + P_t G_t,$$

which gives way after linearization to

$$b_t + \frac{\tau W N}{Y}\left(w_t + n_t + \frac{1}{\tau}\hat{\tau}_t\right) = \frac{1}{\beta} b_{t-1} + \gamma_b dR_{t-1} - \gamma_b \frac{1}{\beta}\pi_t + g_t,$$

where $b_t \equiv (B_t - B)/Y$, $dr_t \equiv r_t - r$, $y_t \equiv (Y_t - Y)/Y$, $g_t \equiv (G_t - G)/Y$, and γ_b is the government debt-to-GDP ratio. $\hat{\tau}_t$ and dR_t are defined above. For the rest of the paper we set $g_t = 0, \forall t$. When the steady-state debt-to-GDP ratio is positive $(\gamma_b > 0)$, the real interest rate

[12] Only Ricardians are entitled to profit income, as they are the owners of the firms.

$(dR_{t-1} - \frac{1}{\beta}\pi_t)$ has an effect on the dynamics of the debt. In particular, a rise in the real interest rate increases debt when $\gamma_b > 0$.

We propose a government revenue rule that is similar to the one in Leeper (1991):

$$\tau_t W_t N_t = \delta_0 + \delta_1 \frac{\tau Y}{B}(B_t - B) + \delta_2 \tau (Y_t - Y) + \varepsilon^{\tau}, \tag{17}$$

where $\delta_0 = 0$. As in Leeper (1991), there is no restriction on the values of δ_1 and δ_2. One usually refers to $\delta_2 > 0 (\delta_2 < 0)$ as procyclical (countercyclical) fiscal policy. Here we simply set $\delta_2 = 0$ so that public debt does not fluctuate along the business cycle. We depart from the specification in equation (17) in the sense that we consider the deviation of real government debt from its steady-state value relative to the steady-state of GDP, i.e., $b_t \equiv (B_t - B)/Y$. Exogenous shocks to the tax revenue are captured by ε^{τ}.

The latter revenue rule can be linearized to yield

$$\hat{\tau}_t = \delta_1 \frac{Y}{WN} b_t - \tau(w_t + n_t) + \{d\varepsilon^{\tau}\}_{t=\text{zlb start}}^{T=\text{zlb end}},$$

where $X = \{N, W, Y, \tau\}$ is the steady-state value of variable X and $d\varepsilon^{\tau} \equiv \varepsilon_t^{\tau} - \varepsilon^{\tau} = -0.1$ is the deterministic "tax cut shock" (a 10-percentage-points reduction) that is on for the duration of the zero-lower-bound period. "zlb start" and "zlb end" refer to the start and end dates, respectively, of the zero-lower-bound period. We investigate the robustness of our findings by setting different values for δ_1.

2.4.2 Monetary Policy

Monetary policy is described by the rule in Christiano, Eichenbaum, and Rebelo (2011):

$$R_t = \max(Z_t, 0), \tag{18}$$

where

$$Z_t = (1/\beta)(\Pi_t)^{\phi_1(1-\rho_R)}(Y_t/Y)^{\phi_2(1-\rho_R)}[\beta R_{t-1}]^{\rho_R} - 1, \tag{19}$$

where Z_t is the shadow nominal interest rate which can take on negative values as well. As usual, we assume that $\phi_1 > 1$, $\phi_2 \in [0, 1)$, and $0 < \rho_R < 1$. ϕ_1 controls how strongly monetary policy reacts to changes in inflation, while ϕ_2 governs the strength of the response of nominal interest to changes in output gap.[13] The main implication of the rule in equation (18) is that whenever the nominal interest rate becomes negative, the monetary policy sets it equal to zero; otherwise, it is set by the Taylor rule specified in equation (19). The parameter ρ_R measures how quickly monetary policy reacts to changes in inflation and output gap. Furthermore, inflation in steady state is assumed to be zero, which implies that steady-state net nominal interest rate is $1/\beta$.

The monetary policy rule above can be written, in linear form, as

$$dR_t = \begin{cases} dZ_t, & dZ_t \geq -\left(\frac{1}{\beta} - 1\right), \quad \text{“zero bound not binding”} \\ -\left(\frac{1}{\beta} - 1\right), & \text{otherwise}, \quad \text{“zero bound binding”} \end{cases}$$

$$dZ_t = \rho_R dR_{t-1} + (1 - \rho_R)\frac{1}{\beta}\left[\phi_1 \pi_t + \phi_2 y_t\right].$$

Hence, the ZLB on the nominal interest binds when $dR_t = -\left(\frac{1}{\beta} - 1\right)$. Otherwise, we set $dR_t = dZ_t$.

2.5 Aggregation, Market Clearing, and Equilibrium

The aggregate consumption is a composite of those of the two types of households:

$$C_t = \lambda C_t^r + (1 - \lambda)C_t^o. \tag{20}$$

The aggregate dividend payments are determined by $D_t = (1-\lambda)D_t^o$. The presence of unions implies that both types of households work the same number of hours and, thus, $N_t^r = N_t^o = N_t$ for all t.

It follows that equation (20) can be written in linear form as

$$c_t = \lambda c_t^r + (1 - \lambda)c_t^o, \tag{21}$$

[13]Precisely, the term Y_t/Y does not stand for the output gap, as the definition of the output gap contains the deviation of the actual GDP from its flexible-price level equivalent. Here we simply use the deviation of output from its steady-state value.

which is obtained by setting steady-state consumption and hours worked of each type equal in steady state ($C^r = C^o$) using a lump-sum tax appearing in the budget constraint of Ricardian households.

The goods market clearing is

$$Y_t = C_t + G_t,$$

which can be expressed in linear form as

$$y_t = \gamma_c c_t + g_t, \tag{22}$$

where for the rest of the paper we set $g_t \equiv (G_t - G)/Y = 0$ and $\gamma_c \equiv C/Y$ is calculated as $\gamma_c = 1 - \gamma_g$ with $\gamma_g \equiv G/Y$. After having laid out the building blocks, we are ready to define equilibrium of this model.

Definition 1. *The equilibrium is characterized by a sequence of endogenous quantities,* $\{N_t, C_t^o, C_t^r, C_t, Y_t\}_{t=0}^{\infty}$*; price sequences,* $\{\Pi_t, \Pi_t^w, W_t, R_t, Z_t, \tau_t\}_{t=0}^{\infty}$*; a given set of exogenous deterministic shocks,* $\{\beta_t, \epsilon_t^{\tau}\}_{t=0}^{\infty}$*; and initial values for debt that satisfy equilibrium conditions of the household, firms, unions, government, and monetary authority such that markets clear, the transversality conditions for the endogenous states are imposed, and the aggregate resource constraint is also satisfied.*

3. Parameterization

3.1 Households

The discount factor, β, is equal to 0.99, implying an annual real interest rate of 4 percent. The intertemporal elasticity of substitution (IES), σ, is set to one, implying log utility, which is a usual choice in the literature. Recently, Christiano, Trabandt, and Walentin (2010) argued that unitary Frisch elasticity is the most reasonable choice that is in line with both macro and micro evidence, so we select $\varphi = 1$. Similar to Christiano (2011), we set $\varepsilon_p = \varepsilon_w = 6$. For the habit formation parameter, h, Furlanetto and Seneca (2012) set a high value of 0.85, while Smets and Wouters (2007) employ a model with various frictions estimate a value of 0.6. Therefore, we consider a value in the middle range and set $h = 0.7$. The steady-state government spending-to-GDP ratio, γ_g, is set to 0.2, mimicking the post-war U.S. evidence. This implies a steady-state consumption-to-GDP ratio, γ_c, of 0.8. Furlanetto and Seneca (2009) calibrate the share of rule-of-thumb consumers (λ) to be between 29 percent and 35 percent after reviewing a couple of econometric studies. Based on this, we set $\lambda = 0.3$, which we think is more plausible empirically than the 0.5 used by Galí, Lopez-Salidó, and Vallés (2007). Parameterization is shown in table 1.

3.2 Fiscal and Monetary Policy

The steady-state quarterly debt-to-output ratio (B/Y) is 2.4, assuming that the yearly debt-to-output ratio is 60 percent. The steady-state labor tax rate (τ) in the model with a balanced budget is chosen to be 30 percent as in Christiano (2011), while it is 26.91 percent in the model with endogenous debt and pinned down by the discount factor, the debt-to-output ratio, and government spending-to-output ratio. In response to the discount factor shock, r_t falls to –0.01, which is close to the mode estimate (–0.0104) by Denes and Eggertsson (2009) using a model that contains only price rigidity and a specific labor market. The duration of the negative demand shock is ten periods,[14] which is in accordance with the modal estimate of Denes and Eggertsson (2009). The inflation coefficient in the Taylor rule, ϕ_1, is 1.5. Following Christiano (2011) and Christiano, Eichenbaum, and Rebelo (2011), there is neither interest rate smoothing ($\rho_R = 0$) nor a response to the output gap in the Taylor rule ($\phi_2 = 0$).

3.3 Firms

The mean posterior estimates of Smets and Wouters (2007) for the Calvo parameters, $\xi^p = 0.66$ ($\xi^w = 0.7$), imply an average price (wage) stickiness of around two (three) quarters. The reduced-form estimates (see Furlanetto and Seneca 2009 for references) on the

[14]Denes and Eggertsson (2009) and Eggertsson (2011) consider a stochastic experiment with a persistence estimate of $\mu = 0.9030$ for the discount factor shock process. This μ is easily translated into our deterministic experiment, knowing that the average duration of this AR(1) is $1/(1-\rho)$ which is roughly 10. For a similar argument, see appendix C of Carlstrom, Fuerst, and Paustian (2012).

Table 1. Parameterization for the Model Used in Experiment 4a except when Indicated Otherwise

Notation	Meaning	Value
	Households	
β	Discount factor	0.99
$1/\sigma$	Intertemporal elasticity of substitution (IES)	1
$1/\varphi$	Frisch elasticity	1
h	Habit formation	0.7
λ	Share of non-Ricardian households	0.3
γ_g	Government spending-to-GDP ratio	0.2
$\tau^{\text{out of ZLB}}$	Steady-state tax rate (experiments 1–3)	30%
$\tau^{\text{out of ZLB}}$	Steady-state tax rate	26.91%
r^{ZLB}	Interest rate at the zero lower bound	−0.0104
	Firms and Unions	
$\xi^p(\xi^w)$	Calvo parameter of price (wage) rigidity	0.66 (0.7)
ε_p	Elasticity of substitution between intermediary products	6
ε_w	Elasticity of substitution between labor types	6
ϵ	Kimball curvature (only experiment 1)	24.77
ϕ_w	Implied by β, ξ^w, ε_w, and φ	266.02
κ	Implied by β and ξ^p	0.1786
κ	Implied by β, ξ^p, and ϵ (only experiment 1)	0.03
	Fiscal and Monetary Authority	
B/Y	Debt-to-GDP ratio (in annual terms)	60%
δ_0	Intercept in the fiscal rule	0
δ_1	Coefficient on debt-to-GDP ratio in the fiscal rule	0.02
δ_2	Coefficient on output gap in the fiscal rule	0
ϕ_1	Response to price/wage inflation in the Taylor rule	1.5
ϕ_2	Response to output gap in the Taylor rule	0
ρ	Interest rate smoothing in the Taylor rule	0
Note: $\tau^{\text{out of ZLB}}$ refers to the tax rate out of the zero-lower-bound state.		

New Keynesian price Phillips curve imply $\kappa = 0.03$. Without real rigidity, such a value of κ would imply a very long period of price inertia ($\xi^p = 0.85$). In our baseline calibration without real rigidity (i.e., $\mathcal{I} = 0$), $\xi^p = 0.66$ implies $\kappa = .1786$. When $\mathcal{I} = 1$, the calibration of $\kappa = 0.03$ is achieved by setting an appropriate value for ϵ. The implied value of ϵ is 24.77, which is in the range of empirical estimates listed in Furlanetto and Seneca (2009).

4. Results

4.1 Experiment 1—Only Price Rigidity

Our experiments are in the spirit of Christiano (2011) and Christiano, Eichenbaum, and Rebelo (2011),[15] who assumed that the discount factor shock and the corresponding fiscal policy shock is on for a deterministic period of time. A discount factor shock (alternatively, savings or negative demand shock) hits the economy in period 1. The model is in deterministic steady state until $t = 1$. At $t = 1$ the discount rate drops from its steady-state value of 0.01 (per quarter) to $r = -0.01$ and remains low for $T = 10$ quarters.[16] From quarter 11 ($T+1$) on, the discount rate is back to its steady-state value. Note that all deterministic experiments below assume that the discount factor shock is on for ten periods. The deterministic simulations are executed using a standard shooting algorithm to handle the ZLB problem. The details of this algorithm are available in the appendix of Christiano (2011).[17] Briefly, the algorithm can be described as

[15]Note that sections 2 and 3 of Christiano, Eichenbaum, and Rebelo (2011) consider a stochastic experiment similar to those in Eggertsson (2011) and Woodford (2011), while sections 4 and 5 consider deterministic experiments that are accomplished by using a standard shooting algorithm. In the case of only price rigidity (or only wage rigidity), the system can be rewritten using the Eggertsson and Woodford (2003) type of methodology applicable if the system contains no state variable. The latter is not true in the case of the inclusion of both price and wage stickiness when one of the variables (potentially the real wage) becomes an endogenous state. Hence, we make use of the shooting algorithm of Christiano (2011).

[16]For comparison, Christiano (2011) considered a shock of similar size although a somewhat longer period ($T = 15$).

[17]In particular, we made use of some of the codes of Christiano (2011) and Christiano, Eichenbaum, and Rebelo (2011). The codes are available at Lawrence Christiano's website.

follows. Let t_1 and t_2 denote the guess values for dates of the start and the end, respectively, of the zero-lower-bound period, such that $1 \leq t_1 \leq t_2 \leq T$. Then taxes are decreased for period $t \in [t_1, t_2]$. Next check whether the zero lower bound binds for $t \in [t_1, t_2]$. If not, revise the guess for t_1 and t_2.

The steady-state level of labor tax in the model with a balanced government budget is 30 percent ($\tau = 0.3$). In the no-policy-response simulation, the labor tax rate is at its steady-state level for the entire simulation. In the alternative simulation (denoted with dashed line), the labor tax rate is decreased (in contrast to Christiano 2011 and Christiano, Eichenbaum, and Rebelo 2011, who considered a rise in the tax rate) to 20 percent for the time period in which the zero lower bound on the nominal interest rate is binding. The shooting algorithm determines endogenously the date at which the zero lower bound becomes binding and the date at which the zero lower bound ceases to bind. Thus we have at least two regimes. One of them is with a fixed interest rate (the zero-lower-bound period) and the other one is with a Taylor rule. In general there can be many regimes with either a fixed interest rate or with a Taylor rule operating. It is well known that there is indeterminacy in the New Keynesian model when the interest rate is fixed (see, e.g., Woodford 2011). However, inclusion of the Taylor rule in one of the regimes guarantees determinacy in the other regimes characterized by a fixed interest rate (see, e.g., Carlstrom, Fuerst, and Paustian 2012). We conduct four experiments, and elements of the models used in each experiment are listed in table 2.

Figure 1 shows experiment 1, featuring a model that includes two types of households and only price rigidity. In experiment 1 we assume that there is no wage rigidity in the economy (i.e., the wage Phillips curve in equation (14) is removed—equivalently, ξ^w is set close to zero). Therefore, wages are flexible in experiment 1.[18] For

[18]In this experiment we found numerically that there are two solutions to the shooting problem (hence no unique solution). Also we realized that the drop in output and inflation is extremely large in this simplest variant of the model (without habits and wage rigidity) containing two types of households. To avoid the non-uniqueness problem and to reduce the extreme negative impact of the shock, we introduce strategic complementarity into price setting in the way discussed above. In models containing wage rigidity (experiments 2–4) we do not encounter such non-uniqueness problem.

Table 2. Details of the Models Used in Experiments 1–4

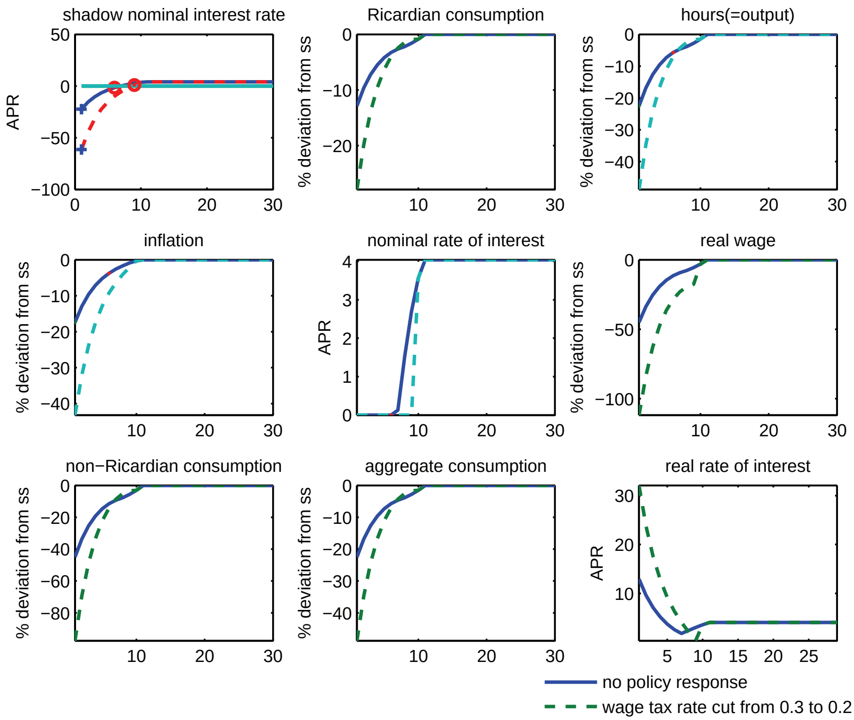
	Features of the Model Used
Experiment 1	Price rigidity
Experiment 2	Price and wage rigidity
Experiment 3	Price and wage rigidity, consumption habits
Experiment 4a	Price and wage rigidity, consumption habits, and government debt with $\delta_1 = 0.02$
Experiment 4b	See experiment 4a with $\delta_1 = 0.9$

Notes: All experiments contain both Ricardian and non-Ricardian households. Experiments 1, 2, and 3 assume a uniform tax cut that is financed by lump-sum taxes levied on Ricardian agents. Experiment 4a–b assume that the uniform tax cut is financed by government debt that is retired through income tax revenue collected from both types of household either in the short run (δ_1 is close to one) or in the long run (δ_1 is close to zero).

simplicity we also abstract from habit formation by setting $h = 0$ in experiment 1. The ZLB becomes binding in period 1 (denoted with + signs on the plot of the shadow nominal interest rate). In the absence of tax policy, the ZLB ends in period 6, while the presence of tax policy makes the ZLB bind for nine periods (denoted with circles). *One can observe that each of the variables except for nominal and real interest rates decline due to the negative demand shock in each experiment and, therefore, the question is always whether the tax cut is able to mitigate the negative effects of the demand shock or not.*

In experiment 1 consumption of non-Ricardians in the case of a decrease in labor taxes falls substantially more than without policy intervention. Therefore, the labor tax cut does not help alleviate the negative consequences of the demand shock (huge deflation and fall in output). Also note that the drop in real wage—which equals the marginal cost due to constant-returns-to-scale assumption—is considerable with or without a change in policy. When the zero lower bound ceases to bind, the Taylor rule becomes operational and monetary policy reacts to positive inflation emerging from expansionary fiscal policy (i.e., the labor tax cut) by raising the nominal interest rate. Thus, there is a large upward movement in the nominal interest rate following the zero-lower-bound period (see figure 1).

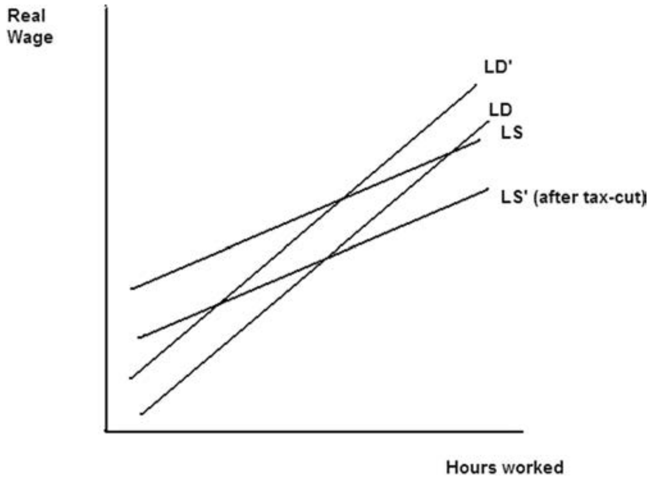
Figure 1. Experiment 1: Model that Includes Two Types of Households and Only Price Rigidity



Notes: The + signs indicate the date at which the zero lower bound on the nominal interest rate becomes binding, and circles appear on the date at which the zero lower bound ceases to bind. Consumption (both Ricardian and non-Ricardian), hours, output, real wage, price inflation, and wage inflation are expressed as a percentage deviation from their steady-state values (on the graphs it is indicated as "% deviation from ss") while the shadow, nominal, and real interest rates are expressed as annual percentage rate (APR). There are two shocks in this experiment: (i) strong negative demand shock with size that equals –0.01 in each period for ten quarters, which leads to a huge fall in all variables, and (ii) a labor tax cut of size –0.1 in each quarter during the zero-lower-bound period which does not necessarily last as long as the negative demand shock.

Similarly, the real interest rate jumps during the zero-lower-bound period because the nominal interest rate is fixed and there is huge deflation due to the negative demand shock. The real interest rate rises even more with a tax cut that is associated with a more

Figure 2. Labor Demand and Supply at the Zero Lower Bound Using the Stochastic Two-State Version of the Model in Experiment 1



pronounced fall in real wages and, hence, a bigger drop in inflation through the New Keynesian Phillips curve.

To provide intuition for experiment 1, let us study the labor market of the model. The effects of the tax cut are depicted in figure 2. The following proposition uses a simple two-state version of the model in experiment 1 with stochastic exit from the zero lower bound and establishes that the labor demand, which is steeper than the labor supply, has a positive slope.

PROPOSITION 1. *Both labor demand and supply are upward sloping at the zero lower bound such that the labor demand is steeper than the labor supply.*

Proof. See the proof in online appendix A.

The workings of the model with non-Ricardians is very similar to the model with only Ricardians in the absence of wage rigidity. The discount factor shock induces households to save more, which they cannot do without capital in equilibrium. The drop in real wage and hours worked, and the corresponding fall in aggregate consumption, ensures that savings are zero in equilibrium. Also importantly, with flexible wages the tax cut ($-\chi\hat{\tau}_t > 0$) is not strong enough to counteract the decline in real wages and hours worked due to the negative demand shock, so the disposable income of non-Ricardians' cannot rise.[19]

The labor supply shifts to the right from LS to LS' due to a decrease in the tax rate (see again figure 2), leading to a drop in wages and hours worked along labor demand, LD. Firms produce less due to the drop in aggregate demand shifting labor demand to the left from LD to LD'. For labor demand that is positively sloped at the zero lower bound, the rightward shift of the LS is contractionary such that hours worked finally drops even more with tax cut relative to the case of no policy intervention. The downward movement in the real wage directly translates to a fall in inflation through the New Keynesian Phillips curve.

In sum, the tax cut magnifies the deflationary effects described by Eggertsson (2011): *price deflation and the contraction in hours worked are more severe with the tax cut even after the inclusion of non-Ricardian households in the absence of wage rigidity.*

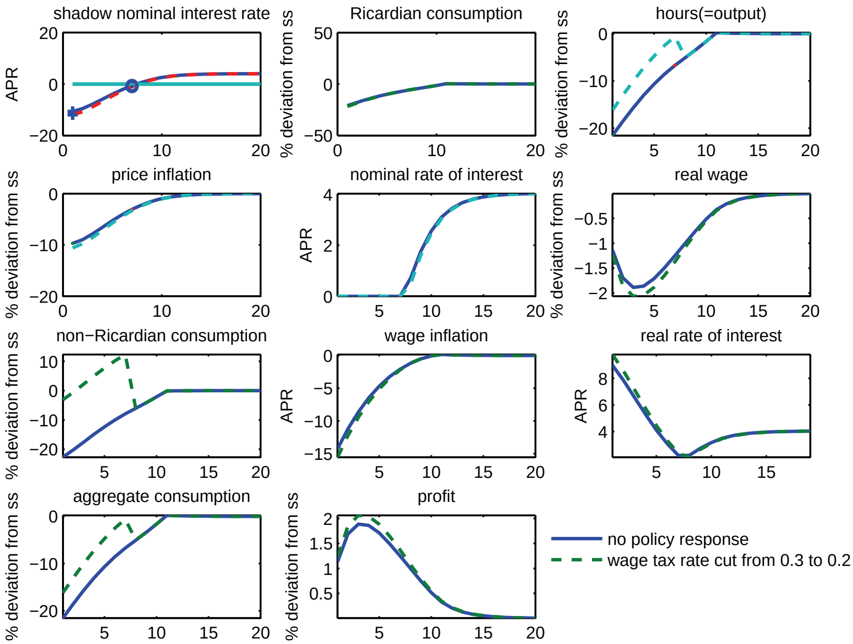
4.2 Experiment 2—Price and Wage Rigidity

Figure 3 shows an experiment similar to the first one, but this time we introduce wage stickiness into the model (experiment 2). The discount rate is set to -0.01 per quarter. The ZLB binds for period 1–6 with or without policy. Wages are set by unions and are assumed to remain fixed for about three quarters. The wage tax cut increases the disposable income of ROT households who consume it. *Again, the rise in the consumption of ROT households (and similarly for the other variables) in response to a labor tax cut should be read as the consumption of ROT households (and also other variables) falls less in the case of the tax cut than without the policy (see figure 3).*

Real wage does not fall dramatically due to the presence of wage stickiness, in sharp contrast to the previous experiment (the absence

[19] Based on the budget constraint of non-Ricardians (see equation (7)), c_t^r drops due to the fall in n_t and w_t, which are not neutralized by $-\chi\hat{\tau}_t^r > 0$.

Figure 3. Experiment 2: Wage Stickiness Introduced into the Model



Notes: The model used in experiment 1 is extended with wage rigidity. The + signs indicate the date at which the zero lower bound on the nominal interest rate becomes binding, and circles appear on the date at which the zero lower bound ceases to bind. "ss" means steady state. There are two shocks in this experiment: (i) a strong negative demand shock with size that equals –0.01 in each period for ten quarters, leading to a huge fall in all variables, and (ii) a labor tax cut of size –0.1 in each quarter during the zero-lower-bound period which does not necessarily last as long as the negative demand shock.

of wage rigidity). But, still, the tax cut remains deflationary (labor supply shifts slightly more to the right than labor demand) and real wage in the case of tax policy falls more than without policy. Observing the graph, we can also see that the wage deflation is higher than the price deflation, implying a fall in the real wage rate. With perfect wage stickiness (ξ^w is close to one)—which is not the case here but serves as a useful abstraction (see, e.g., the argument of Christiano 2011)—the labor supply would remain intact. Next we analyze the indirect reaction of labor demand to the tax cut.

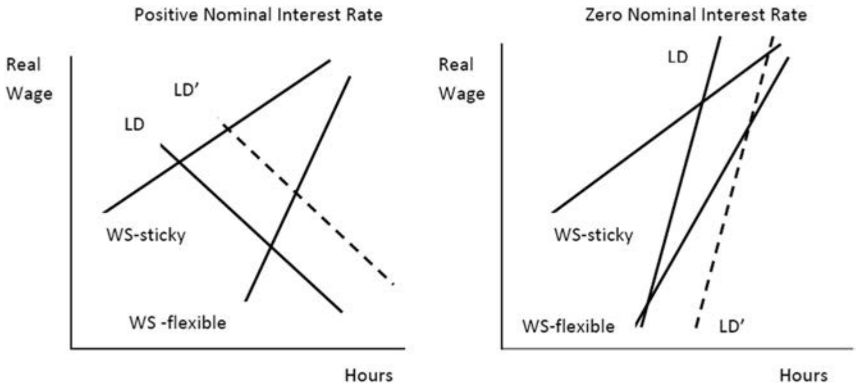
The higher consumption demand of non-Ricardian agents induces many of the firms which cannot charge a higher price due to price stickiness to increase their production. To produce more, firms demand more labor, i.e., the labor demand shifts out. As is well known, in sticky-price models a rise in aggregate demand—due to the higher consumption expenditures of ROT households—leads to a fall in the markup, which induces an outward shift in the labor demand. Below we discuss the reaction of labor supply following the tax cut.

On the one hand, the labor tax cut raises the pre-tax real wage, creating an incentive for the union to increase the labor supply (substitution effect). On the other hand, the labor tax cut has a strong negative wealth effect: Ricardians know that the present tax cut will be offset by higher lump-sum taxes in the future and, therefore, they decrease their demand for consumption and leisure. As the time frame is normalized to one, the fall in leisure implies spending more time working, i.e., Ricardians supply more labor. Due to unions, non-Ricardians work the same number of hours as Ricardians. Thus, both Ricardians and non-Ricardians satisfy higher labor demand by working more. In figure 3 the pre-tax real wage falls more for the tax cut scenario relative to the case of no policy change. Also, we observe that hours worked increases—i.e., it decreases less—with a tax cut. It follows that the labor supply must have increased more than the labor demand.

It also needs to be emphasized that wage stickiness implies that the labor supply (or wage schedule, WS) curve is flatter with rigid relative to flexible wages (Ascari, Colciago, and Rossi 2011) and the outward shift of labor demand in response to higher consumption expenditures of non-Ricardians is associated with more movement in hours worked (a drop) rather than real wage (a rise), which is apparent in figure 4.

The profit in figure 3 rises either with or without a tax cut. It is easy to show algebraically that this is always the case. In first-order log-linear terms, profit can be written as $profit_t = y_t - w_t - n_t$. Because of the constant-returns-to-scale assumption, $y_t = n_t$ and, therefore, $profit_t = -w_t$. The real wage always drops due to the negative demand shock, so it follows that profit has to increase. Profit income that accrues only to Ricardians has an important role in the model. It helps Ricardian consumers who are the owners of the firms

Figure 4. Comparison of Labor Markets under Positive and Zero Nominal Interest Rate



Notes: "WS-sticky" stands for the wage schedule under sticky wages, while "WS-flexible" means the wage schedule under flexible wages.
Source: The left-hand-side figure is a reproduction of Ascari, Colciago, and Rossi (2011, p. 12) while the right-hand-side one is based on figure 4 of Eggertsson (2011, p. 15).

to insulate themselves from the negative wealth effects of the future tax increases and also from the rise in the real interest rate that discourages them from further consumption in the present. Thus, profit income enables Ricardians to avoid larger cuts in consumption due to the future tax burden and the higher real rates.

4.2.1 Some Robustness Checks

The robustness of the finding in experiment 2 is examined in two ways. A detailed description and discussion of these experiments is available in online appendix B. We summarize the most important findings here. First, we examine what happens when the monetary authority follows strict inflation-targeting policy outside the ZLB. It is known that strict inflation targeting is the optimal policy in the basic closed-economy New Keynesian model (see, e.g., Woodford 2003).

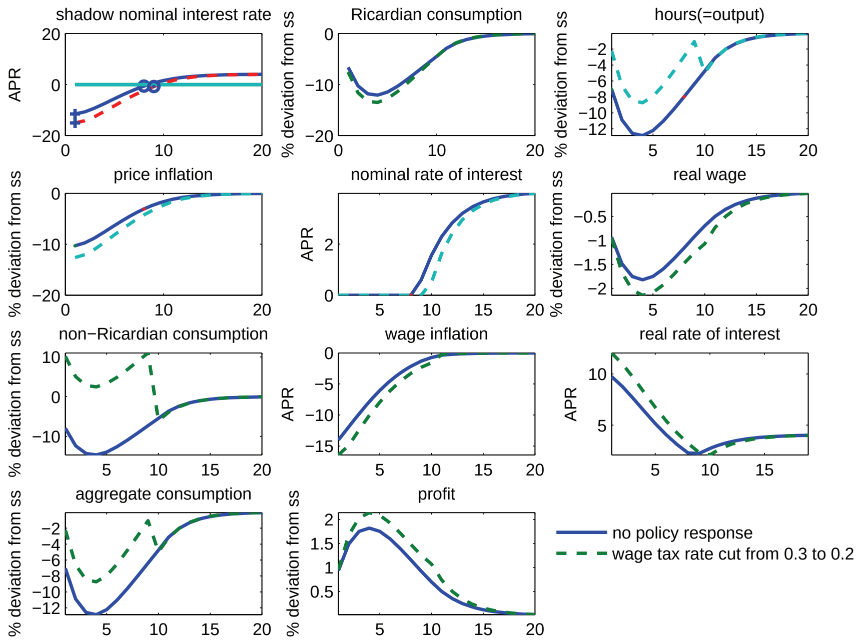
With strict inflation targeting, the Ricardian household expects the real interest rate to be very high after the ZLB period, and therefore it delays its savings to finance the tax cut for the period that is governed by the interest rate rule. Hence, there is scope for Ricardian consumption to decline less with the tax cut relative to the case of no policy intervention during the ZLB period with strict inflation targeting. Indeed, we observe that the real interest rate falls below its long-run level in the second half of the ZLB period, stimulating Ricardian consumption, and makes the stimulatory effect of the tax cut even more powerful. The extra boost from consumption makes it possible for the output not to fall below its steady state in the case of the tax cut in the second half of the ZLB period.

Second, we ask what is the impact of extending the labor tax cut beyond the ZLB period? We find that the extension of the tax cut until, for instance, period 15 has small additional stimulatory effects because the positive effects of the tax cut are weakened by the Taylor rule which is in operation outside the ZLB period.

4.3 Experiment 3—Price Rigidity, Wage Rigidity, and Consumption Habits

Experiment 3, which is shown in figure 5, makes use of the model in the previous simulation, but now it includes external habit formation in consumption as well. Due to the lagged consumption term, habit formation injects some endogenous persistence into the model and leads to hump-shaped impulse responses in consumption and hours. Habit formation is a well-known feature of middle-sized DSGE models, such as the one of Smets and Wouters (2007), and is found useful in matching the empirical VAR evidence. Also, habit formation is usually regarded as having some solid psychological foundation. The presence of habits mitigates the effects of the negative demand shock. This can be explained as follows. As argued above, it is the rise in the real interest rate that makes people delay their consumption expenditure. The introduction of habits reduces the sensitivity of consumption to changes in the real interest rate (this can be quickly verified by looking at equation (5), where the coefficient on the interest is smaller in the case of habits $[\frac{1-h_o}{1+h_o}\frac{\beta}{\sigma}]$ than it is for the standard CRRA case $[\beta/\sigma]$). The ZLB binds from period 1 to 8 (9) without (with) policy. Still output (hours) declines less when labor tax cut policy is applied.

Figure 5. Experiment 3: Model with External Habit Formation in Consumption

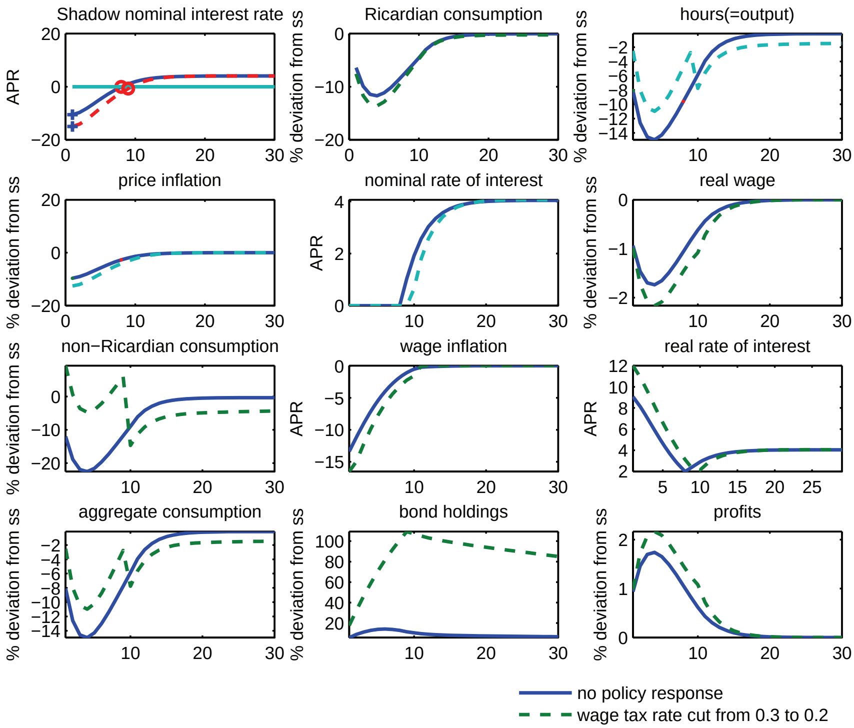


4.4 *Experiment 4—Price Rigidity, Wage Rigidity, Consumption Habits, and Government Debt*

In experiment 4 we assume more realistically that the tax cut is financed by government debt which is retired through an increase in labor tax revenue either in the short or long run. We allow for inherited debt from the past: that is, the steady-state debt-to-output ratio is positive, and interest payments on current debt affect the evolution of future debt. In previous experiments, only the Ricardians bear the burden of the tax cut. However, now, it is also the non-Ricardians who have to take part in settling the bill. Taxation is uniform: both types of households pay the same tax rate.

The parameter choice for δ_1 in the fiscal rule (equation (17)) turns out to be crucial for the outcome. When δ_1 is low, the tax cut is mainly financed with debt which is paid back in the distant

Figure 6. Experiment 4a: $\delta_1 = 0.02$



future (see, for instance, the impulse responses with $\delta_1 = 0.02$ in figure 6, where bond holdings refer to real debt). This case lends support for tax cut policy and is in accordance with the findings of Bilbiie, Monacelli, and Perotti (2012, 2013), who argue in favor of a (lump-sum) tax cut[20] as follows. When debt repayment happens far in the future, a uniform tax cut is pure redistribution (transfer) from Ricardians to non-Ricardians in the present, while it is a

[20]In this chapter we found that intuition in the case of a labor tax cut is similar to the lump-sum tax cut discussed by Bilbiie, Monacelli, and Perotti (2012), who assume the consolidation of debt in the form of higher lump-sum taxes. In this chapter, however, consolidation of debt is carried out through increases in labor taxes which distort the consumption-leisure trade-off, discourage from work, and depress output even more beyond the zero-lower-bound period.

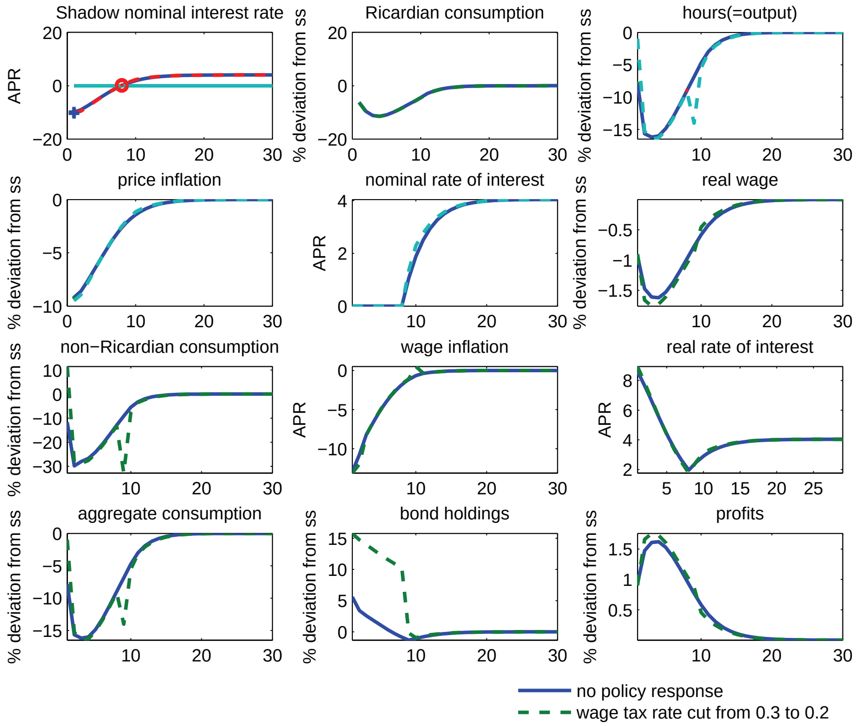
transfer from non-Ricardians to Ricardians in the future. The evolution of Ricardian consumption is totally consistent with our story. Ricardians pay attention to changes in their whole lifetime income (the present discounted value of income), which remains unaltered with temporary changes in taxes (see the straight and dashed lines overlap in figure 6).

Thus, the outcome of the policy in the case of endogenous debt with low δ_1 is very similar to the first fiscal scenario in which only Ricardians pay for the tax cut through lump-sum taxes. In particular, Ricardians do not react to the policy, while non-Ricardians enjoy the tax decrease, as it is not offset in the present by a rise in the labor tax. Also note that this tax cut policy leads to better outcome only in the zero-lower-bound period which coincides with the period of sharp accumulation in debt. As soon as the Taylor rule is operative again (from period 11), this type of tax cut policy is strictly worse—mainly because of its negative effects on the consumption of non-Ricardians. Indeed, from period 11, the tax cut is over and non-Ricardians also have to take part in settling the debt accumulated in the zero-lower-bound period. As a result, non-Ricardian consumption with fiscal policy beyond the zero-lower-bound period is below the one without fiscal policy.

On the contrary, when δ_1 is closer to one (see figure 7 for $\delta_1 = 0.9$), the tax cut in the present is counteracted by a tax rise and there is no rationale for such a policy. This is also confirmed by looking at the evolution of bonds in the same figure. In the first ten periods bond holdings are positive, but from period 11 on they are the same as in the case of no policy. This is markedly different from the previous experiment where the late repayment ensured that bond holdings are positive even beyond period 10 in the case of a tax cut relative to no policy intervention. Values of δ_1 that equal one or above are to be avoided, as they would render the path of debt explosive.

It deserves explanation why we observe a run-up of the debt in the zero-lower-bound period even without fiscal policy (see straight lines for bond holdings in figures 6 and 7). All the figures plot the evolution of real debt. In particular, increases in debt during the zero-lower-bound period (in the absence of fiscal policy) reflect the fact that the real value of debt increases due to deflation.

Figure 7. Experiment 4b: $\delta_1 = 0.9$



5. Robustness

The robustness of the tax cut policy to small changes in the parameters is assessed here. We shortly summarize the results of the robustness checks, which are more detailed in the online appendix C. Our baseline calibration considers unitary IES and Frisch elasticity. We find that the tax cut remains to be stimulative for the IES smaller than one and the Frisch elasticity higher than one (or when either (both) of them is (are) lower than one), which is suggested by empirical papers (see discussion in online appendix C). It turns out that the favorable effects of the tax cut do not survive if the share of non-Ricardians is lowered to 20 percent or the average duration of wage rigidity is reduced from 3.33 to 3 quarters. However, when IES is smaller than one and Frisch elasticity is higher or lower than one—calibrations which we argue are more plausible empirically—the tax cut policy is still better than the lack of policy even for either a lower share of non-Ricardians or a shorter duration of wage/price rigidity. The tax cut policy is also robust to the replacement of price inflation to wage inflation in the Taylor rule.

6. Conclusion

After augmenting the baseline New Keynesian model containing price and wage rigidity with rule-of-thumb (or non-Ricardian) households, we argued that a labor tax cut can partly offset the fall in output and deflation caused by a negative demand shock that made the zero lower bound on the nominal interest rate binding. Importantly, we assumed that we cut the labor tax rate that is levied upon the households and not upon the firms. Under such an arrangement the labor tax cut acts like a traditional fiscal stimulus that raises aggregate demand. We found that the tax cut policy is stimulative if it is financed by lump-sum taxes levied completely on Ricardian agents. We also explored a more realistic scenario when a tax cut is covered by long-term government debt which is settled by both types of households in the form of taxes on labor income. Still, the tax cut is found to have positive effects on output because non-Ricardians who do not take into consideration the future tax burden enjoy the increase in their disposable income by spending more. Finally, rule-of-thumb consumers can be thought of as a shortcut of modeling agents with borrowing constraint. Based on the logic of the model with rule-of-thumb households, our finding should remain valid in a model with savers and borrowers who face borrowing constraints.

References

Ascari, G., A. Colciago, and L. Rossi. 2011. "Limited Asset Market Participation, Sticky Wages and Monetary Policy." Mimeo.

Bilbiie, F. 2008. "Limited Asset Markets Participation, Monetary Policy and (Inverted) Aggregate Demand Logic." *Journal of Economic Theory* 14 (1): 162–96.

Bilbiie, F., T. Monacelli, and R. Perotti. 2012. "Tax Cuts vs. Spending Increases: Welfare at the Zero Lower Bound." Mimeo.

———. 2013. "Public Debt and Redistribution with Borrowing Constraints." *Economic Journal* 123 (566): F64–F98.

Braun, R. A., and L. M. Körber. 2011. "New Keynesian Dynamics in a Low Interest Rate Environment." *Journal of Economic Dynamics and Control* 35 (12): 2213–27.

Calvo, G. 1983. "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics* 12 (3): 383–98.

Carlstrom, C., T. Fuerst, and M. Paustian. 2012. "How Inflationary Is an Extended Period of Low Interest Rates?" Working Paper No. 1202, Federal Reserve Bank of Cleveland.

Christiano, L. 2011. "Comment on Eggertsson, 'What Fiscal Policy Is Effective at Zero Interest Rates?'" *NBER Macroeconomics Annual 2010*, Vol. 25, ed. D. Acemoglu and M. Woodford, 113–24. University of Chicago Press.

Christiano, L., and M. Eichenbaum. 2012. "Notes on Linear Approximations, Equilibrium Multiplicity and E-learnability in the Analysis of the Zero Lower Bound." Mimeo (March).

Christiano, L., M. Eichenbaum, and S. Rebelo. 2011. "When Is the Government Spending Multiplier Large?" *Journal of Political Economy* 119 (1): 78–121.

Christiano, L., M. Trabandt, and K. Walentin. 2010. "DSGE Models for Monetary Policy Analysis." In *Handbook of Monetary Economics,* ed. B. Friedman and M. Woodford, 285–367 (chapter 7). Elsevier.

Coenen, G., C. J. Erceg, C. Freedman, D. Furceri, M. Kumhof, R. Lalonde, D. Laxton, J. Lindé, A. Mourougane, D. Muir, S. Mursula, C. de Resende, J. Roberts, W. Roeger, S. Snudden, M. Trabandt, and J. in't Veld. 2012. "Effects of Fiscal Stimulus in Structural Models." *American Economic Journal: Macroeconomics* 4 (1): 22–68.

Cogan, J. F., T. Cwik, J. B. Taylor, and V. Wieland. 2010. "New Keynesian versus Old Keynesian Government Spending Multipliers." *Journal of Economic Dynamics and Control* 34 (3): 281–95.

Denes, M., and G. Eggertsson. 2009. "A Bayesian Approach to Estimating Tax and Spending Multipliers." Staff Report No. 403, Federal Reserve Bank of New York.

Eggertsson, G. 2011. "What Fiscal Policy Is Effective at Zero Interest Rates?" *NBER Macroeconomics Annual 2010,* Vol. 25, ed.

D. Acemoglu and M. Woodford, 59–112. University of Chicago Press.

Eggertsson, G., and M. Woodford. 2003. "The Zero Bound on Interest Rates and Optimal Monetary Policy." *Brookings Papers on Economic Activity* 1: 139–211.

Erceg, C. J., D. W. Henderson, and A. T. Levin. 2000. "Optimal Monetary Policy with Staggered Wage and Price Contracts." *Journal of Monetary Economics* 46 (2): 281–313.

Furlanetto, F. 2011. "Fiscal Stimulus and the Role of Wage Rigidity." *Journal of Economic Dynamics and Control* 35 (4): 512–27.

Furlanetto, F., and M. Seneca. 2009. "Fiscal Shocks and Real Rigidities." *B.E. Journal of Macroeconomics* 9 (1): 1–22 (Topics).

———. 2012. "Rule-of-Thumb Consumers, Productivity, and Hours." *Scandinavian Journal of Economics* 114 (2): 658–79.

Galí, J., D. Lopez-Salidó, and J. Vallés. 2007. "Understanding the Effects of Government Spending on Consumption." *Journal of European Economic Association* 5 (1): 227–70.

Hall, R. E. 2009. "By How Much Does GDP Rise if the Government Buys More Output?" *Brookings Papers on Economic Activity* (Fall): 183–231.

Kimball, M. 1995. "The Quantitative Analytics of the Basic Neomonetarist Model." *Journal of Money, Credit and Banking* 27 (4): 1241–77.

Leeper, E. 1991. "Equilibria Under 'Active' and 'Passive' Monetary and Fiscal Policies." *Journal of Monetary Economics* 27 (1): 129–47.

Mertens, K., and M. Ravn. 2012. "Empirical Evidence on the Aggregate Effects of Anticipated and Unanticipated U.S. Tax Policy Shocks." *American Economic Journal: Economic Policy* 4 (2): 145–81.

Natvik, G. 2012. "Government Spending Shocks and Rule-of-Thumb Consumers with Steady-State Inequality." *Scandinavian Journal of Economics* 114 (4): 1414–36.

Romer, D., and C. Romer. 2010. "The Macroeconomic Effects of Tax Changes: Estimates Based on a New Measure of Fiscal Shocks." *American Economic Review* 100 (3): 763–801.

Rotemberg, J. 1982. "Monopolistic Price Adjustment and Aggregate Output." *Review of Economic Studies* 49 (4): 517–31.

Siemsen, T., and S. Watzka. 2013. “Fiscal Multipliers and the Choice of Zero Lower Bound Modeling.” CESifo Working Paper No. 4342.

Smets, F., and R. Wouters. 2007. “Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach.” *American Economic Review* 97 (3): 586–606.

Woodford, M. 2003. *Interest and Prices: Foundations of a Theory of Monetary Policy.* Princeton University Press.

———. 2011. “Simple Analytics of the Government Expenditure Multiplier.” *American Economic Journal: Macroeconomics* 3 (1): 1–35.

Discussion of "Rule-of-Thumb Consumers and Labor Tax Cut Policy at the Zero Lower Bound"*

Kolver Hernandez
CEMLA

1. Introduction

Lorant Kaszab shows that a labor tax reduction can stimulate the economy when it is at the zero lower bound (ZLB)—due to demand shocks. In sharp contrast, Christiano, Eichenbaum, and Rebelo (2011) and Eggertsson (2011) recommend a labor tax increase in similar economic conditions. Kaszab's argument merits great attention in the literature.

To put my discussion in context, let me start by pointing out that Eggertsson and Christiano, Eichenbaum, and Rebelo show that in a New Keynesian model, when the economy hits the ZLB, a labor tax increase stimulates the economy. In their papers, the key tax policy channel works through the real interest rate. I call this the *real interest rate channel*. Kaszab introduces an additional channel closer in spirit to the traditional Keynesian view. In his model, a subset of consumers determine consumption exclusively based on their current disposable income, thus a labor tax reduction stimulates their consumption. I call this channel the *disposable income channel*. In sharp contrast to Eggertsson and Christiano, Eichenbaum, and Rebelo, Kaszab shows that at the ZLB, a labor tax reduction is desirable. In Kaszab's model these two channels are present and they act in opposite directions.

In my discussion, I will focus first on how the real interest channel works in the Eggertsson-Christiano (EC) model, based on Christiano (2010), and how the disposable income channel works in the Kaszab model. Then, I will modify Kaszab's experiment to consider

*Author contact: CEMLA, Research Department, Durango 54, Col. Roma 06700, Mexico City. Tel.: +52(55) 5061-6630. E-mail: khernandez@cemla.org.

a far more persistent demand shock and quantify and discuss the relevance of both channels in the model. I conclude that the disposable income channel faces important challenges when the economy remains at the ZLB for a prolonged period of time. However, when the ZLB binds for short periods of time, it can be the dominant channel for fiscal policy. Finally, I will show that the interest rate channel increases its power in an accelerated fashion with the duration of the fiscal stimulus, but the same does not apply to the disposable income channel. I will discuss why and then conclude.

2. The Tax Policy Channels in the Eggertsson-Christiano Model versus the Kaszab Model

To discuss Kaszab's model, first let me take one step back and talk about the tax multiplier in the Eggertsson-Christiano model.

2.1 The Eggertsson-Christiano Model

The Eggertsson-Christiano model discussed in Christiano (2010) consists of six endogenous variables and six equations: (i) a Euler equation of consumption, equation (1); (ii) a New Keynesian Phillips curve for prices, (2); (iii) a New Keynesian Phillips curve for wages, (3); (iv) a monetary policy rule, (4); (v) a fiscal rule, (5); and (vi) the law of motion of real wages, (6).

$$H_t = H_{t+1} - \beta \left\{ dR_t - \frac{1}{\beta}\pi_{t+1} - r_t^* \right\} \tag{1}$$

$$\pi_t = \beta\pi_{t+1} + \kappa w_t \tag{2}$$

$$\pi_t^w = \beta\pi_{t+1}^w - \kappa^w \left\{ w_t - (1+\phi)H_t - \frac{1}{1-\tau}\tau_t \right\} \tag{3}$$

$$dR_t = \begin{cases} 1.5\pi_t & \text{outside ZLB} \\ -(1/\beta - 1) & \text{at ZLB} \end{cases} \tag{4}$$

$$\tau_t = \begin{cases} 0\% & \text{outside ZLB} \\ +10\% & \text{at ZLB} \end{cases} \tag{5}$$

$$w_t = w_{t-1} + \pi_t^w - \pi_t. \tag{6}$$

Additionally, the economy features two exogenous shocks: a demand shock that enters the Euler equation as a perturbation to the real interest rate (see equation (1)) and a tax shock that increases wages on the producer side and thus increases marginal cost (see equation (3)). The nomenclature is output, H; inflation, π; wage inflation, π^w; tax rate, τ; interest rate, dR; and real wage, w. The exogenous shocks are the demand shock, r^*, and the tax shock. The calibration is as follows: $\beta = 0.99, \tau = 0.3, \phi = 1, \kappa = \frac{(1-\xi^p)(1-\beta\xi^p)}{\xi^p}, \xi^p = 0.75, \kappa^w = \frac{(1-\xi^w)(1-\beta\xi^w)}{\xi^w}$, and $\xi^w = 0.75$.

The experiment buffets the economy with contractionary demand shocks ($r_t^* = -0.02$ for $t = 1, \ldots, T$) for ten quarters ($T = 10$). The lower demand brings inflation and the interest rate down to the point at which the interest rate hits the zero lower bound. Once the economy is at the ZLB, the labor tax policy is introduced for the same quarters for which the economy is at the ZLB state. In particular, the tax policy increases the labor tax by 10 percentage points (equation (5)).

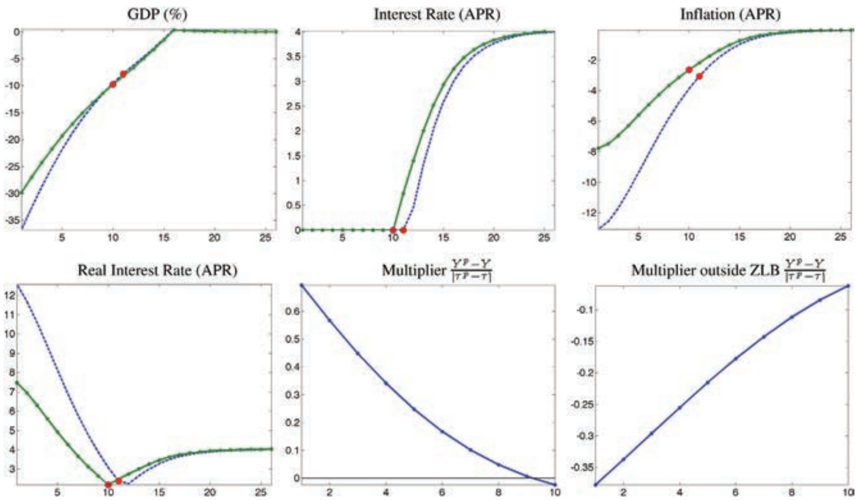
From the system of equations (1)–(6), note that the tax rate only enters in the Phillips curve for wages (6), so at the ZLB the tax policy affects consumption decisions through inflation and thus through the real interest rate.

Figure 1 shows the dynamics triggered by the EC experiment. The intuition for the outcome of the experiment is straightforward. At the ZLB, the tax rate hike lowers the deflation rate; thus this policy implies a lower real interest rate and a lower fall in output. The tax multiplier, calculated as the GDP with policy minus the GDP without policy and divided by the absolute change in the tax rate, is also shown in figure 1. The tax multiplier at the ZLB is positive and declines over time. Interestingly, the multiplier outside the ZLB state is negative; this is because outside the ZLB, the monetary authority can lower the real interest rate by lowering the policy rate; however, a tax increase is inflationary and makes the monetary policy less effective.

2.2 The Kaszab Model

As I mentioned before, the main contribution of the paper is to introduce an additional channel for fiscal policy into the model of Christiano, Eichenbaum, and Rebelo (2011) or that of Eggertsson

Figure 1. Simulated Eggertsson-Christiano Model



(2011). With that additional channel, Kaszab arrives at a sharply different policy recommendation.

The following summarizes the Kaszab model:

$$c_t^r = w_t + n_t - \frac{1}{1-\tau}\tau_t \tag{7}$$

$$c_t^o = c_{t+1}^o - \beta\{dR_t - \pi_{t+1} - r_t^*\} \tag{8}$$

$$\pi_t = \beta\pi_{t+1} + \kappa w_t \tag{9}$$

$$\pi_t^w = \beta\pi_{t+1}^w - \kappa^w \left\{ w_t - \left(1 + \frac{1}{\gamma^c}\right) n_t - \frac{1}{1-\tau}\tau_t \right\} \tag{10}$$

$$dR_t = \begin{cases} 1.5\pi_t & \text{outside ZLB} \\ -(1/\beta - 1) & \text{at ZLB} \end{cases} \tag{11}$$

$$\tau_t = \delta_1 \frac{Y}{WN} b_t - \tau w_t - \tau n_t + \begin{cases} 0\% & \text{outside ZLB} \\ -10\% & \text{at ZLB} \end{cases} \tag{12}$$

$$w_t = w_{t-1} + \pi_t^w - \pi_t. \tag{13}$$

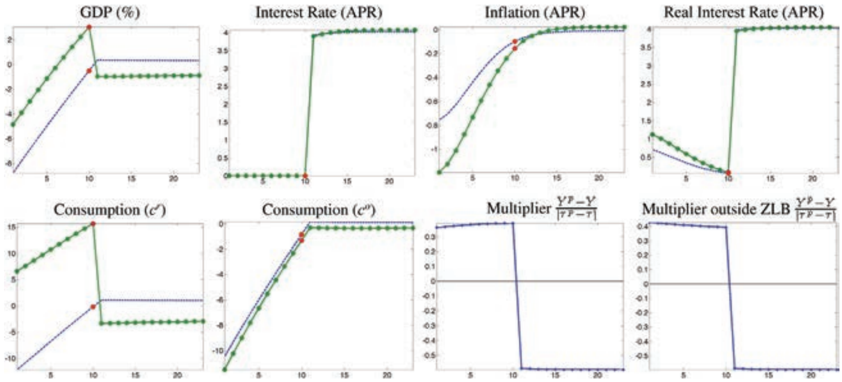
In addition to equations (7)–(13), the model also contains the law of motion of debt (15) and the equilibrium condition discussed below. The nomenclature is output and labor, n; inflation, π; wage inflation, π^w; tax rate, τ; interest rate, dR; real wage, w; Ricardian consumers, c^o; non-Ricardian consumers, c^r; and government debt, b. The exogenous shocks are the demand shock, r^*, and the tax shock. The calibration is as follows: $\beta = 0.99$, $\tau = 0.3$, $\kappa = \frac{(1-\xi^p)(1-\beta\xi^p)}{\xi^p}$, $\xi^p = 0.66$, $\kappa^w = \frac{(1-\xi^w)(1-\beta\xi^w)}{\xi^w}$, $\xi^w = 0.95$, $\gamma^c = 0.8$, $\delta_1 = 0.02$, and $\frac{WN}{Y} = 0.88$.

Equations (8)–(13) resemble the EC model. Those six equations are also present in the EC model, with small variations. Equation (8) is a Euler equation of consumption, equation (9) is a New Keynesian Phillips curve for prices, equation (10) is a New Keynesian Phillips curve for wages, equation (11) is a monetary policy rule, equation (12) is tax policy rule, and equation (13) is the law of motion of real wages. There are, however, two differences in the Kaszab model with respect to the EC model. The key difference is that the model also features a consumption decision equation (7) for non-Ricardian consumers. Equation (7) shows that those consumers determine their consumption based on their disposable income; thus, ceteris paribus a lower tax rate increases their consumption.

Note that, as in the EC model, the demand shock (r_t^*) only enters the Euler equation (8) and acts as a negative demand shock. However, in contrast to the EC model, the tax policy shock (τ_t) has two channels. First, as in the EC model, it factors into the Phillips curve of wages (equation (10)) and thus the model features a real interest rate channel precisely as in the EC model. However, the tax policy rate also enters in the consumption of the non-Ricardian consumer (equation (7)) and thus the model also features a disposable income channel. Note that these two channels act in opposite directions. As in the EC model, the real interest rate channel calls for a tax increase at the ZLB; however, the disposable income channel calls for a tax reduction.

Another small difference in the Kaszab model relative to the EC model is that the tax policy rate (12) is not purely exogenous. The tax policy reacts endogenously to government debt, wages and labor additionally to an exogenous component. Thus, to close the model we need two more equations: the law of motion of debt (15) discussed below and an equilibrium condition that relates total consumption

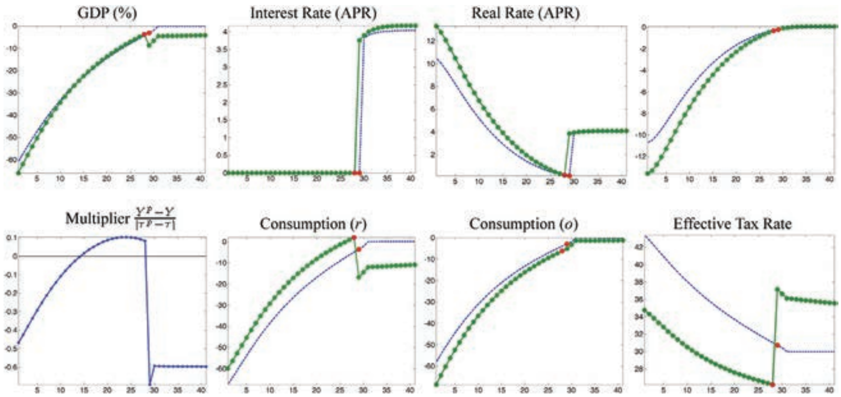
Figure 2. Simulated Kaszab Model



to total production $n_t = \gamma^c(\lambda c_t^r + (1-\lambda)c_t^o)$, where λ is the fraction of non-Ricardian consumers and γ^c is the share of consumption in GDP. To be clear, the model contains nine variables in nine equations.

Figure 2 shows the dynamics of the model. As in the EC exercise, the economy receives a contractionary demand shock ($r_t^* = -0.02$) for ten quarters ($t = 1, \ldots, 10$); however, it is different from the EC exercise because the tax rule (12) *reduces* its exogenous component by 10 percent. Due to the real interest rate channel, a tax reduction makes the deflation worse and the real interest rate higher, so the consumption of the Ricardian consumers (c^o) is worse with than without policy. On the other hand, the disposable income channel makes the non-Ricardian consumption much higher (c^r). The additional consumption of the non-Ricardian consumer more than compensates for the lower consumption of the Ricardian consumer, and the net effect is higher GDP. As shown, the multiplier is positive at the ZLB; however, it becomes negative when the interest rate exits the ZLB state. The abrupt change in sign of the multiplier is a feature of the specific calibration chosen in my illustrative exercise; however, we can allow for habit in consumption and show a multiplier with a "soft landing." It is worth noting that in contrast to the EC model, the multiplier in the Kaszab model is positive at the ZLB and outside the ZLB. That is, the tax policy recommendation does not change at the ZLB.

Figure 3. The Tax Policy Channels in a Highly Persistent Shock: Baseline Model with Persistent Shock



3. The Tax Policy Channels in a Highly Persistent Shock

The United States hit the ZLB on the first quarter of 2009 and has remained at the ZLB until the last quarter of 2015. What happens in Kaszab's economy when the contractionary demand shock is persistent enough to keep the ZLB state for an extended period of time? I repeat the experiment with a demand shock ($r_t^* = -.02$ for $t = 1, \ldots, T$) that lasts for thirty quarters ($T = 30$) and during the ZLB state the fiscal policy (12) stays in place—that is, I only replace $T = 10$ for $T = 30$.

Figure 3 shows that in those circumstances, the multiplier is negative. As before, the consumption of the non-Ricardian consumer is higher than without policy, but in this case, the consumption of the Ricardian consumer is much lower, and thus total consumption is lower. That is, when the economy faces a highly persistent demand shock and the economy stays at the ZLB for a prolonged period of time, the real interest rate channel dominates the disposable income channel.

Before exploring further the dominance of the real interest rate channel in the presence of highly persistent demand shocks, let me discuss Kaszab's policy experiment itself.

3.1 Closing the Model

Figure 3 shows that, when the demand shock is highly persistent (thirty quarters), the policy rule (equation (12)) calls for an effective tax rate higher than the pre-shock rate. The reason for this is the tax rule responds positively to government debt and, in this scenario, the accumulation of debt is so high that the effective tax rate increases despite the reduction by 10 percent in the exogenous component of the policy rule.

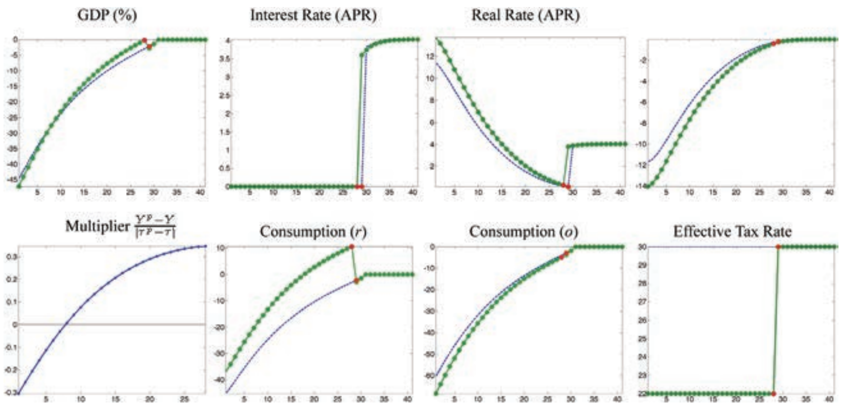
Kaszab motivates the use of the tax rule (equation (12) and reproduced below for convenience) based on the work of Leeper (1991). Leeper defines "active" and "passive" policies depending on their responsiveness to government debt; thus those policies inherently determine the existence and uniqueness of equilibria. To illustrate that point in a mechanical way, consider the tax policy rule and the law of motion of debt of the model shown below:

$$\tau_t = \delta_1 \frac{Y}{WN} b_t - \tau w_t - \tau n_t + \begin{cases} 0\% & \text{outside ZLB state} \\ -10\% & \text{at ZLB state} \end{cases} \tag{14}$$

$$b_t = -\tau \frac{WN}{Y} \left\{ w_t + n_t + \frac{1}{\tau}\tau_t \right\} + \frac{1}{\beta} b_{t-1} + \gamma^b dR_{t-1} - \gamma^b \frac{1}{\beta}\pi_t. \tag{15}$$

The law of motion of debt (equation (15)) contains a unit root because the coefficient of the autoregressive term equals the gross interest rate ($\frac{1}{\beta} = R > 1$). However, by adopting the tax rule (14), the coefficient δ_1 can be chosen so that after substituting the tax rule in the law of motion of debt, the resulting coefficient of the autoregressive term in the law of motion of debt is smaller than one. A similar issue arises naturally in *small open economies.* In those economies, the steady state of the model depends on the country's initial net foreign assets position, and thus foreign debt displays a unit root. Schmitt-Grohe and Uribe (2003) study the dynamic effects of alternative ways to deal with the unit root in small open economies. They compare the business-cycle dynamics of alternative ways to eliminate the unit root. Among those alternatives, they implement (i) an endogenous discount factor, (ii) a debt-elastic interest rate premium, (iii) convex portfolio adjustment costs, (iv) complete asset markets, and (v) a model without stationary-inducing features. They find that all versions of the model

Figure 4. The Tax Policy Channels in a Highly Persistent Shock: Purely Exogenous Tax with Persistent Shock



deliver very similar dynamics in terms of impulse responses and variances.

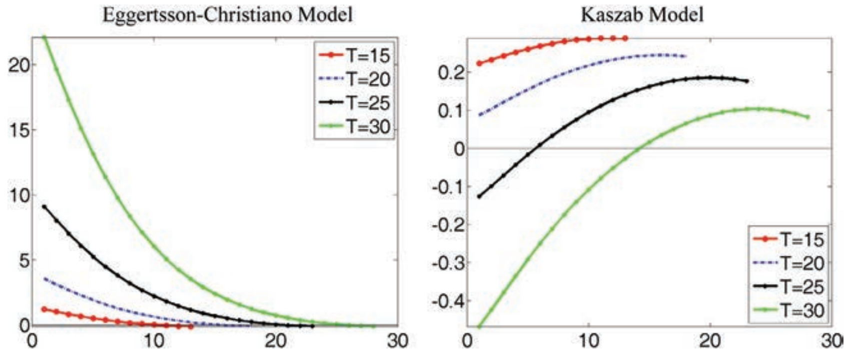
In light of the Schmitt-Grohe and Uribe (2003) results, it seems natural to consider the simplest tax policy rule in order to illustrate the role of the disposable income channel. Thus, as in the EC experiment, consider the tax rule

$$\tau_t = \begin{cases} 0\% & \text{outside ZLB state} \\ -8\% & \text{at ZLB state.} \end{cases} \tag{16}$$

Figure 4 shows the dynamic effects of the experiment described at the beginning of this section but with a purely exogenous tax rule (equation (16)).[1] The key result is that the resulting tax multiplier is negative on impact. As a matter of fact, consistent with Schmitt-Grohe and Uribe (2003), the dynamics under both tax rules (equations (14) and (16)) are very similar—except of course, for the dynamics of debt and the tax rate. However, the advantage of an exogenous tax rule is that the experiment is as transparent as possible.

[1] I choose a tax reduction of 8 percent as opposed to 10 percent to be consistent with the effective tax reduction in table 2.

Figure 5. The Tax Policy Channels in a Highly Persistent Shock: Robustness of CE and Kaszab Models to Shock Persistence



3.2 Robustness of EC and Kaszab Models to Persistent Shocks

How robust are the real interest rate and the disposable income channels? Figure 5 shows the multiplier in the EC model with demand shocks that last for fifteen, twenty, twenty-five, and thirty quarters. On impact, the multiplier grows in an accelerated fashion with the persistence of the shock in a range from around 1 to 4 to 9 to more than 20. The same panel also shows the multiplier in the Kaszab model under the same set of shocks. In sharp contrast, on impact, the multiplier decreases with the persistence of the demand shock.

Why is the real interest rate channel more powerful with persistent shocks and the disposable income channel is not? The answer is straightforward. The real interest rate channel works through the Phillips curve of the model (see equation (9)) and has a forward-looking nature, so current inflation will react to the full string of contemporaneous and future tax rates. Thus the initial effect on real interest rates is stronger when the tax policy stays in place for longer. On the other hand, the disposable income channel works through the consumption of the non-Ricardian consumer (see equation (7)), which only responds to the contemporaneous tax rate, and thus the initial effect is independent of the time duration of the policy rate.

4. Conclusions

Kaszab's model features two transmission channels for fiscal policy: the real interest rate channel and the disposable income channel. These channels act in opposite directions. For demand shocks of short enough duration, the disposable income channel dominates and a labor tax reduction is called for. The real interest rate channel, also featured in the model of Eggertsson (2011) and Christiano, Eichenbaum, and Rebelo (2011), is more powerful with persistent shocks because it works through the Phillips curve of the model, which has a forward-looking nature. Thus the initial impact compounds the longer duration of the fiscal policy and results in a stronger impact on the real interest rate. For persistent enough shocks, the Eggertsson-Christiano recommendation holds, i.e., a labor tax increase is called for in the Kaszab model as well. Finally, wage indexation is a feature regularly included in models to fit the data. Indexation moderates the forward-looking nature of the Phillips curve, and thus the inclusion of this feature in the model can reverse my conclusion on the effectiveness of the disposable income channel for persistent shocks.

References

Christiano, L., M. Eichenbaum, and S. Rebelo. 2011. "When Is the Government Spending Multiplier Large?" *Journal of Political Economy* 119 (1): 78–121.

Christiano, L. J. 2010. "Comment on Eggertsson, 'What Fiscal Policy Is Effective at Zero Interest Rates?'" Working Paper No. 10-06, Center for Quantitative Economic Research (November).

Eggertsson, G. B. 2011. "What Fiscal Policy Is Effective at Zero Interest Rates?" In *NBER Macroeconomics Annual 2010*, Vol. 25, ed. D. Acemoglu and M. Woodford, 59–112. University of Chicago Press and National Bureau of Economic Research, Inc.

Leeper, E. M. 1991. "Equilibria under 'Active' and 'Passive' Monetary and Fiscal Policies." *Journal of Monetary Economics* 27 (1): 129–47.

Schmitt-Grohe, S., and M. Uribe. 2003. "Closing Small Open Economy Models." *Journal of International Economics* 61 (1): 163–85.

Dynamic Stochastic General Equilibrium Models and Their Discontents*

Tamim Bayoumi
Peterson Institute for International Economics

The papers in this session all feature dynamic stochastic general equilibrium (DSGE) models that combine theory and empirics in a tractable manner. These models are an impressive response to the Lucas critique that reduced-form models cannot accurately respond to changes in fundamental behavior. However, because of the need to integrate many theoretical insights, DSGE models have some general characteristics that need to be taken into account when using the results in policy analysis. One concern is that it is difficult to move these models far from equilibrium because agents are highly forward looking and policymakers do the right thing, which makes it difficult to explain the length and depth of the current recession. This high degree of foresight also complicates the analysis of fiscal policy, as it tends to reduce the impact of Keynesian demand effects compared with classical supply responses. Finally, international spillovers are often underestimated, as these mainly come through financial links that are not well articulated in DSGE models. None of this implies that DSGE models should be abandoned, but it does suggest that their results should include a health warning.

JEL Codes: E32, E37, E62, F15.

1. Introduction

At first blush the papers in this session appear to be on quite different topics. The papers analyze fiscal issues (how effective are employer labor tax cuts in a currency union?), financial issues (can interbank markets explain real spillovers?), and monetary policy (the

*These views do not necessarily represent the views of any organizations to which I am affiliated.

effectiveness of forward guidance at the zero lower bound). To be sure, all three papers discuss important policy issues. But that alone would hardly be sufficient to justify including them in one session.

Rather than subject matter, the common link in this session is technique. All three papers come under the general rubric of dynamic stochastic general equilibrium models—DSGE models for short. More specifically, they all start from a theory-based model of the macroeconomy that involves maximizing consumers, producers, etc. These models have become extremely popular over time. The owe their origins to the original "Lucas critique" of the previous generation of more ad hoc models in which reduced-form equations were put together to create a description of the economy.[1] As Lucas correctly pointed out, reduced-form models have the disadvantage that if the nature of the deep shocks changes, then the responses of agents to those shocks may be wrong, as they ignore the deeper links implied by theory.

The Lucas critique spurred a huge intellectual effort to create theory-compatible models, including the three presented in this session. DSGE models are an astonishing intellectual achievement that have been built steadily over a long period.[2] They have evolved from the initial "real business cycle" models, which focused on economies with flexible prices and now more commonly include "New Keynesian" characteristics that acknowledge the existence of sticky prices. Indeed, the New Keynesian models have become a bedrock of large parts of monetary analysis as well as analysis other issues. They incorporate rational expectations, many agents (consumers, producers, governments, etc.), and deep theoretical parameters.

While I realize that the core DSGE models used in each of these papers are slightly different (for example, with regard to habit formation, rule-of-thumb consumers, etc.), I regard them as sufficiently similar to count them as coming from one root. In this commentary, I am therefore going to avoid concentrating on the specifics of the three papers presented in this session and instead discuss DSGE models in general. In particular, I am going to concentrate on three characteristics of these models which give me some concern. Slightly

[1] Lucas (1976).

[2] I was involved in supervising the creation of one of these models in the early 2000s. See Pesenti (2008) and Bayoumi et al. (2004).

unfairly, since I think all of the papers in this session are well done and make sensible points, I am going to use each paper as an example of my concerns.

My point of departure is that general equilibrium models produce results that involve all of their characteristics. That is their strength, but it is also their weakness. In particular, some of the general characteristics of such models need to be taken into account when using the results on specific policy issues.

2. Are DSGE Model Too Close to the Steady State?

My first concern is the speed at which a typical DSGE model comes back to its steady state. A (slightly jaundiced) way of describing the typical DSGE model is as follows. Everyone in the model understands perfectly how the economy works, the rules that policymakers follow, and that the economy will continue to work in the same way in the future.[3] In addition, because everyone understands the world perfectly, they discount the future very slowly (often at the real interest rate). Policymakers are following sensible rules that respond to the one major distortion in the economy (or economies), namely sticky prices. Since sticky prices are a relatively temporary phenomenon, it follows that sensible policy rules are extremely effective at driving the economy back to steady state in large part because low discount rates mean that future policy actions have a major impact on present behavior.

The result is that, even when hit by a large shock, the economy rapidly reverts to equilibrium. The paper in this session by Arce, Hurtado, and Thomas on the responses to prolonged deleveraging in the euro-area periphery is a good example of this property. The authors are interested in the impact of the zero bound on the euro-area economy. To do this, they hit the region with a shock about equal to that seen over the 2008/9 crisis. Notice, however, that in their base case the zero bound only holds for four quarters. And in the case where the monetary authorities extend the zero bound to support activity, this only lasts two quarters. Hence, even with good

[3]Indeed, such assumptions are basically a requirement of such a model because if this is not true, then it would be very difficult for agents to create rational expectations of the future.

policies, the zero bound is exited after six quarters. In the face of a large crisis (this paper is, after all, about responses to the euro-area crisis) the model comes out of the zero lower bound very fast. Also, the impact on activity in the core economies is small—although, to be fair, there is a prolonged impact on the periphery because of their addition to the standard DSGE setup of binding collateral constraints in the periphery.

Compare this model with the world we actually see. The U.S. Federal Reserve, the European Central Bank, the Bank of Japan, and the Bank of England were stuck at the zero bound for seven years. In addition, while the Federal Reserve has implemented one small hike and the Bank of England may lift rates soon, the other two major central banks look destined to stay at the zero bound for much longer. Turning to activity, in addition to a GDP slowdown in the periphery, there is also a marked slowdown in the core. While one could argue that other policies not included in the paper have put further downward pressure on output—budget cuts, possibly tighter financial regulation—it seems equally valid to point to policies that have supported output—quantitative easing and fiscal stimulus in the early days. In any case, it would take a huge policy shock to overcome the difference in timing at the zero bound between the real world and the model simulations.

So what went wrong? The answer is surely that in the real world people do not know exactly how the economy works now or in the future and in consequence are not sure of how policymakers will respond. Certainly, recent work by Del Negro, Giannoni, and Patterson (2012) suggests that ten-year bond yields had a more muted response to announcements of forward guidance than would be expected, consistent with future uncertainty. This points to issues such as bounded rationality and responses under uncertainty. All of these would be very difficult to put in a DSGE model that is built on rational expectations and policy rules. However, there would be one fix that could be tried, namely adding a higher discount rate of the type suggested by Blanchard (1985) and Yaari (1965).

Typically, even if such discount rates are applied, they follow the original paper in assuming that the additional discount rate reflects the likelihood of actual death and is therefore relatively small. However, it may be of interest to examine significantly higher discount rates, say in the range of 15 percent or so. This is the order of magnitude seen on credit card debt, the main source of unsecured lending for consumers which seems to be the equivalent to the discount rate in the Blanchard-Yaari model. A large discount rate of this type would create a much less forward-looking model, which might return to steady state more slowly. While this modification is difficult, it is not impossible (see Devereux 2010 for an application of the Blanchard-Yaari framework in a DSGE model) and the outcome could be much more realistic model characteristics.

3. Do DSGE Models Always Generate Sensible Behavior?

My second concern is that theory may not always produce sensible behavior. At first blush this sounds surprising. Wasn't the point of the Lucas critique that theory is a better guide to behavior than reduced forms? This is of course true in the abstract. However, when putting together a large theory-compatible model with multiple sectors, there can be significant constraints imposed by the need to use simple functional forms with simple solutions. A good example of this is the use of constant elastisticity of substitution for consumer preferences, which links the parameter on risk aversion with the parameter on intertemporal substitution. Similarly, monopolistic competition is modeled using a constant percentage markup because it is an easy functional form to manipulate. This is also why most DSGE models use representative consumers and producers, which makes consideration of financial intermediation—the essence of which is the transfer of resources from savers to borrowers—extremely difficult.

The paper in this session by Kaszab highlights another questionable theoretical property, namely Ricardian consumers and flexible wages. The paper notes that the earlier DSGE modeling has come up with the counterintuitive results that in the face of an asymmetric shock in a currency union, labor-tax cuts on employees can reduce activity. The reduction in taxes lowers consumption, as employees are Ricardian, so that there is no impact on aggregate demand, and the downward pressure on wages raises the real interest rate. In addition, firms that cannot cut prices in the face of lower wages are less competitive and reduce labor demand and output. The paper then shows that simply breaking Ricardian equivalence using rule-of-thumb consumers lowers but does not eliminate the downward impact on output in their model. It is also necessary to make wages sticky to produce the surely correct result that a cut in employee labor taxes will stimulate the economy.

The paper does a very nice job of creating the intuitive result. However, one has to wonder why such an odd result came out of such models in the first place and how many sophisticated "add-ons" to the core DSGE model are needed to create a "sensible" result. It might even lead one to think that a simpler reduced-form model that assumed that consumption was related to income, that post-tax wages rise by part of the cut in taxes, and that investment is related to profits might well be a better approximation to reality than typical core DSGE models—at least for this experiment.

4. Do DSGE Models Have Sufficient Spillovers?

My final area of concern is on the size of international spillovers in DSGE models. I take as my starting point the fact that a significant international business cycle exists—which seems to be the strong empirical evidence from factor models. Indeed, most policymakers regard international interlinkages as a major and rising concern.

In most DSGE models, however, spillovers come primarily from trade relationships.[4] Simple back-of-the-envelope calculations make clear why this is unlikely to produce significant international spillovers. With the exception of a few special cases (Canada to the United States, Netherlands to Germany), bilateral trade between countries is a quite limited percentage of GDP. Let us say, for example, that a country trades 5 percent of its GDP with another country—which would in most cases be a generous number. Let us also say that the elasticity on activity for such exports is two, again a generous estimate. Even in this case, the impact of a dollar reduction in real GDP in the recipient of these exports on the exporting country is only ten cents (5 percent times two).

[4]To be fair, this is not limited to DSGE models but is also true of most international macroeconomic models.

An obvious alternative is to look at financial relationships, as is done in the paper in this session by Nuguer. This paper focuses on one particularly close financial relationship, namely that between Swiss banks and the U.S. markets. The author produces a very nice model that shows how the impact of losses in U.S. markets could have been a major force for instability in the Swiss economy over the crisis. I completely agree, but unfortunately I suspect the example does not generalize. As shown in figure 1 of the paper, the importance of Swiss banks in the interbank market was huge compared with the size of the Swiss economy—it is the financial equivalent of looking at Canadian trade to the United States to examine international trade spillovers.

This and similar models use a financial accelerator to produce spillovers across economies. As a general matter, I do not think this generates large enough spillovers for similar reasons as for trade. For simplicity, let's focus on overall international asset holding rather than focusing on the interbank market and let us suppose the private sector of a country holds 10 percent of GDP of U.S. assets. This compares with U.S. holdings of U.S. assets of several hundred percent of GDP.[5] So by a similar logic to that discussed above, it is difficult to see how financial accelerator links through losses in foreign asset holding can generate large spillover in real activity. Like trade, the pipe through which the spillovers move from one country to another is simply too narrow.

So what *does* explain the international business cycle? Traditionally, the answer has been to argue that it represents some sort of global shock—often, for example, an international productivity shock. Outside of energy prices, however, it is difficult to see where such a shock could come from.

A more promising avenue is to examine why international asset prices are so closely correlated. As argued in Bayoumi and Vitek

[5]The sum of federal, municipal, government-sponsored enterprise (GSE), and corporate bonds plus corporate equities as a ratio to GDP has averaged more than 300 percent of GDP since 2000 according to the U.S. Flow of Funds. Even if some of these ratios are inflated by non-market instruments (equities average 150 percent of GDP, which is almost double the capital capitalization of the Wiltshire index), the ratio is clearly still well into three digits.

(2013), while typical DSGE models cannot explain the correlation of output across countries, models that include high asset price correlations can. Day in and day out, for example, a 1 percent change in U.S. equity prices is associated with a 0.6 percent change in (say) German stocks, while a 1-percentage-point change in ten-year bond yields is associated with a 0.4-percentage-point change in German bond yields. Furthermore, similar relationships are present across a wide range of countries and for lower frequencies. Such links can cause a significant spillover across economies, since both equity prices and bond yields have significant effects on activity. Producing a convincing theoretical explanation for why international asset prices are so closely correlated thus seems to me to be the key to explaining large spillovers in activity.

5. Final Thoughts

A not unreasonable reaction might be to say that this is all true but that DSGE models are still a useful tool for macroeconomists. I would completely agree that, when used properly, DSGE models are a great tool. All models are abstractions that help us think about the world. The concern is when models become seen as embodying fundamental truths. I would argue that something of this type happened over the Great Moderation. Mesmerized by models built in their own institutions that found that monetary policy was extremely effective, central bankers felt they could take a narrow focus and look only at activity and inflation, since policy could quickly "mop up" unexpected macroeconomic shocks. Indeed, there may be something of this type going on again with the debate about whether central banks should react to financial risks by leaning against the wind or should leave financial stability to macroprudential tools.

DSGE models are a great tool for any macroeconomist. They can provide important insights on topical issues, as the three papers in this session demonstrate. Nothing I have written here should be construed as saying that such models are not useful. That would be throwing the baby out with the bathwater. But it is essential to acknowledge that there is bathwater there, not just baby.

References

Bayoumi, T., D. Laxton, H. Faruqee, B. Hunt, P. Karam, J. Lee, A. Rebucci, and I. Tchakarov. 2004. "GEM: A New International Macroeconomic Model." IMF Occasional Paper No. 239.

Bayoumi, T., and F. Vitek. 2013. "Macroeconomic Model Spillovers and Their Discontents." IMF Working Paper No. 13/4 (January).

Blanchard, O. 1985. "Debt, Deficits, and Finite Horizons." *Journal of Political Economy* 93 (2): 223–47.

Del Negro, M., M. Giannoni, and C. Patterson. 2012. "The Forward Guidance Puzzle." Staff Report No. 574, Federal Reserve Bank of New York.

Devereux, M. 2010. "Fiscal Deficits, Debt, and Monetary Policy in a Liquidity Trap." Working Paper No. 44, Federal Reserve Bank of Dallas Globalization and Monetary Policy Institute.

Lucas, R. 1976. "Econometric Policy Evaluation: A Critique." In *The Phillips Curve and Labor Markets,* ed. K. Brunner and A. Meltzer, 19–46. Carnegie-Rochester Conference Series on Public Policy 1. New York: American Elsevier.

Pesenti, P. 2008. "The Global Economy Model: Theoretical Framework." *IMF Staff Papers* 55 (2): 243–84.

Yaari, M. 1965. "Uncertain Lifetime, Life Insurance, and the Theory of the Consumer." *Review of Economic Studies* 32 (2): 137–50.