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Fiscal Consolidation in a Small Euro-Area Economy*

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This article focuses on macroeconomic impacts and welfare effects of a fiscal consolidation process in a small euro-area economy. Fiscal consolidation is defined as a permanent decline in the ratio of public debt to GDP. The analysis is based on PESSOA, a New Keynesian general equilibrium model with non-Ricardian agents. The results suggest that a reduction in public expenditure leads in the long run to sizable increases in output and tends to improve welfare, specifically because it allows for a sustainable decrease in the labor income tax rate. However, output and consumption decline in the short run, and current generations are likely to experience welfare losses. This situation might well provide a rationale for the frequent lack of political will to move in this direction. The results are robust to alternative paths for fiscal consolidation.

JEL Codes: E62, F41, H63.

1. Introduction

The Great Recession triggered massive fiscal stimulus in many economies. The injection of public funds in troubled financial institutions assumed a crucial role in bringing systemic risk under control, against a background characterized by tight financing conditions around the globe. Public debt levels increased substantially in many developed economies, including some in the euro area, raising

*We are indebted to Michael Kumhof and Douglas Laxton. This article would not exist without their inspiration and contribution. We would also like to thank the two anonymous referees for their comments and suggestions, as well as the participants in the Working Group on Econometric Modelling of the Eurosystem for the valuable discussions.

sustainability concerns and bringing debt sustainability and fiscal consolidation to center stage in the policy debate.

The international financial and economic crisis also highlighted the heterogenous nature of euro-area economies. Indeed, countries revealing larger structural fragilities, specifically larger fiscal imbalances or asset-price bubbles, found themselves singled out in international wholesale credit markets, with resultant severe impact on domestic financing conditions and on economic activity. In this context, ensuring debt sustainability, evaluating the benefits of fiscal consolidation in the long run, and creating conditions for a successful consolidation process became a focus for the economic literature (Barrios, Langedijk, and Pench 2010; Mulas-Granados, Baldacci, and Gupta 2010; Rother, Schuknecht, and Stark 2010).

This article focuses on the impacts on economic activity, demand conditions, and welfare during a period of fiscal consolidation in a small euro-area economy. Fiscal consolidation is defined as a permanent decline in the ratio of public debt to GDP. The analysis is based on PESSOA, a New Keynesian general equilibrium model with non-Ricardian agents. The results suggest that a reduction in public expenditure leads to sizable output increases in the long run and is likely to be welfare improving. This outcome is obtained after an a priori evaluation of the main transmission channels of alternative fiscal instruments (transfers to households, government consumption, and taxes on wage income and consumption). More precisely, a benchmark fiscal consolidation strategy was set out, based on expenditure cuts (government consumption and transfers to households), where the tax burden on wage income adjusts endogenously. The robustness of the results is evaluated for alternative paces of fiscal tightening.

This article adds to the existing literature on expansionary fiscal consolidations. Kumhof et al. (2011) acknowledge that an important driving force behind the long-run gains in worldwide fiscal consolidation is that the increase in the world savings rate creates room for a drop in real interest rates and this boosts economic activity. The results documented in this article show that the long-run gains are preserved in the case of a small open economy (SOE) without independent monetary policy and with no influence in world real interest rates. This case is of paramount importance for Southern European economies currently under stress in sovereign debt markets.

The results of this article are subject to some caveats. Firstly, the model is silent on the interaction between fiscal consolidation and financing conditions. This is particularly relevant against an international environment shaped by sovereign debt crises. Moreover, the model assumes perfect credibility of fiscal policy, while the impact of alternative consolidation strategies on financing prospects may also depend on credibility issues. Secondly, the model does not account for income inequality, which plays a key role in fiscal policy strategies and may also interact with financial stability. Some recent literature suggests that income inequality may have played a part in triggering the financial crisis (Kumhof and Rancière 2010; Kumhof et al. 2012), though some empirical evidence suggests that this may not represent a general relationship (Bordo and Meissner 2012).

The structure of the article is as follows. The model is presented in section 2. Section 3 addresses the costs and benefits of fiscal consolidation, including alternative paces of fiscal tightening. Section 4 concludes and draws some policy implications.

2. A Model for a Small Euro-Area Economy

This section briefly presents PESSOA, the New Keynesian dynamic general equilibrium model behind the analysis of the macroeconomic impacts of a fiscal consolidation process.[1] The model features an SOE integrated in a fully fledged monetary union (MU)—in this case, the euro area. We assume from the outset that the rest of the MU is immune to domestic shocks. Hence, developments in foreign interest rates are orthogonal to domestic developments as in Adolfson et al. (2007) and domestic interest rates can only deviate from the MU reference rate by a risk premium. Contrary to most general equilibrium models in the literature on SOEs, PESSOA has intrinsic non-Ricardian features based on the International Monetary Fund's (IMF's) Global Integrated Monetary and Fiscal model (Kumhof et al. 2010): (i) finitely lived households in line with the stochastic finite lifetime framework (Yaari 1965; Blanchard 1985; Buiter 1988; Weil 1989); (ii) distortionary taxation on household

[1] A more detailed description of the model can be found in Almeida, Castro, and Félix (2010).

consumption, labor, and capital income; and (iii) hand-to-mouth households (Galí, López-Salido, and Vallés 2007).

It is well known that breaking the Ricardian equivalence is important to generate realistic private consumption responses to government expenditure shocks (Blanchard 1985; Galí, López-Salido, and Vallés 2007). The stochastic finite lifetime framework may generate sizable wealth effects from public debt issuance, which are absent in the workhorse infinitely lived agent framework (Frenkel and Razin 1996; Kumhof and Laxton 2009b). In the Blanchard-Yaari-Buiter-Weil world, households strongly prefer debt issuance to tax financing of government expenditure, since future generations will bear some of the tax burden (Buiter 1988). In addition, this framework allows for the endogenous determination of the net foreign asset position of the economy, since finite lifetimes limit the amount of assets/debt that a household can accumulate (Harrison et al. 2005). This represents an appealing feature for the simulation of permanent fiscal shocks, since it generates a positive correlation between public debt and the net foreign debt position.[2] The link between fiscal consolidation and the current account balance has been assessed in IMF (2011).

Since PESSOA is designed for an SOE integrated in an MU, the economy's adjustment mechanism to domestic shocks is rather different from the standard SOE model. The dynamic stability of the model is ensured by an active role of the real exchange rate, which has sizable impacts on competitiveness, trade, and, thus, on the net foreign asset/debt position of the economy. In a context in which foreign prices are independent of domestic shocks, it is the real exchange rate that pins down the domestic price level.

Finally, the monopolistic structure in labor and product markets yields market power to both workers and firms. This, in combination with a number of nominal rigidities that imply staggered wage and price inflation adjustment, creates room for an active macroeconomic stabilization policy. On the real side, external habit formation in

[2]On the contrary, in the infinitely lived agents model, the steady-state net foreign asset position is pinned down exogenously (Schmitt-Grohe and Uribe 2003), implying that changes in steady-state public debt are fully offset by changes in private savings and are, by assumption, uncorrelated with the net foreign debt.

private consumption and quadratic adjustment costs on investment and on the import content of final demand are featured.

2.1 Households

Households evolve according to the overlapping-generations scheme first proposed in Blanchard (1985). All households are subject to stochastic finite lifetimes, facing an equal constant instant probability of death $1-\theta$.[3] The overall size of the population, N, is constant, implying that in each period $N(1-\theta)$ households die and the same number are born. Two types of households coexist: asset holders (type $\mathcal{A}$) that smooth out their consumption over their lifetime by trading in assets, and hand-to-mouth households à la Galí, López-Salido, and Vallés (2007) (type $\mathcal{B}$) that do not trade assets and consume all their income in each and every period. The share of type $\mathcal{B}$ households is constant at ψ, implying that in each period there exist $N(1-\psi)$ asset holders and $N\psi$ hand-to-mouth households.

A representative household of type $H \in \{\mathcal{A}, \mathcal{B}\}$ with age a derives utility from consumption, $C^H_{a,t}$, and leisure, $1 - L^H_{a,t}$, according to a constant relative risk aversion (CRRA) utility function.[4] Expected lifetime utility is given by

$$E_t \sum_{s=0}^{\infty} (\beta\theta)^s \frac{1}{1-\gamma} \left[\left(\frac{C^H_{a+s,t+s}}{Hab^H_{a+s,t+s}} \right)^{\eta^H} (1 - L^H_{a+s,t+s})^{1-\eta^H} \right]^{1-\gamma}, \quad (1)$$

where E_t is the expectation operator, $0 \leq \beta \leq 1$ stands for the standard time discount factor, $\gamma > 0$ is the coefficient of risk aversion, and $0 \leq \eta^H \leq 1$ is a distribution parameter. Hab^H_t stands for external habits, defined in terms of per capita consumption $[C^{\mathcal{A}}_{t-1}/(N(1-\psi))]^v$ and $[C^{\mathcal{B}}_{t-1}/(N\psi)]^v$ for type $\mathcal{A}$ and $\mathcal{B}$ households, respectively, with parameter $0 \leq v \leq 1$ controlling for the

[3] Probability $1-\theta$ can also be interpreted as a probability of "economic death" or a degree of "myopia" (Blanchard 1985; Frenkel and Razin 1996; Harrison et al. 2005; Bayoumi and Sgherri 2006).

[4] $L^H_{a,t}$ stands for hours worked as a percentage of households' full time endowment.

degree of habit persistence.[5] Note that government consumption is not included in equation (1) and therefore does not contribute directly to household utility, as in Kumhof et al. (2011), which is acknowledged to be an extreme case.

Type $\mathcal{A}$ households trade in both domestic ($B_{a,t}$) and foreign government bonds ($B^*_{a,t}$), which yield gross nominal interest rates i_t and i^*_t, respectively. Interest is assumed to be disbursed at the beginning of period $t+1$. Type $\mathcal{A}$ households earn labor income at a wage rate, W_t, adjusted by the household's age-specific productivity level, $\Phi_a = k\chi^a$ (k is a scaling factor and $0 \leq \chi \leq 1$ is the labor productivity rate of decay), roughly mimicking a life-cycle income profile. In addition, asset holders receive dividends from firms and labor unions, $D^{\mathcal{A}}_{a,t}(x)$. Finally, households pay consumption and labor income taxes ($\tau_{C,t}$ and $\tau_{L,t}$ are the respective average tax rates) and receive transfers from both the government ($TRG^{\mathcal{A}}_t$) and abroad ($TRX^{\mathcal{A}}_t$).

The asset holders' optimization problem consists in setting the path of consumption, labor, and domestic and foreign asset holdings, which maximizes (1) subject to the following budget constraint:

$$\begin{aligned} P_t C^{\mathcal{A}}_{a,t} + B_{a,t} + B^*_{a,t} \leq{} & \frac{1}{\theta}\left[i_{t-1}B_{a-1,t-1} + i^*_{t-1}\Psi_t B^*_{a-1,t-1}\right] \\ & + W_t \Phi_a L^{\mathcal{A}}_{a,t}(1-\tau_{L,t}) \\ & + \sum_{\substack{x=\mathcal{N},\mathcal{T},\mathcal{C},\\ \mathcal{G},\mathcal{I},\mathcal{X},\mathcal{U}}} D^{\mathcal{A}}_{a,t}(x) + TRG^{\mathcal{A}}_t + TRX^{\mathcal{A}}_t, \end{aligned} \tag{2}$$

where $P_t = (1+\tau_{C,t})P^C_t$ is the after-tax price of the final consumption good and is taken as the numeraire price, while P^C_t is the before-tax price.

Type $\mathcal{A}$ households are not indifferent as to financing government expenditure with tax levies or debt issuance (i.e., future taxes). Non-Ricardian behavior (namely, finite lifetimes amplified by the life-cycle income profile) imply that asset holders strongly prefer debt financing, since they take part of the government bond holdings as

[5] Aggregation across generations is feasible only under multiplicative habits. However, it is recognized that this formulation generates lower consumption persistence than additive habits.

net wealth. Indeed, in the case of debt financing, current generations purchase a share of the newly issued debt that exceeds the present discounted value of corresponding future tax liabilities, since future taxes will be charged largely on yet-to-be born generations. Hence, part of the debt held by current generations can be used to finance private consumption expenditure during their lifetime, instead of being used to face future tax liabilities. These effects are magnified by the above-mentioned life-cycle income profile, which implies that the further apart in time taxes are levied, the lower the labor income tax payments of current generations. In this framework, households tend to be more shortsighted than in infinitely lived agents models.

The lack of access to asset markets by type $\mathcal{B}$ households is an additional source of non-Ricardian behavior. The objective function of these households is also given by the utility function (1), though they cannot smooth consumption by trading in assets, being instead constrained to consume at most, in each period, their current income (that is, the after-tax wage income plus all transfers from both the government and abroad). The optimization problem is to maximize (1) subject to the following budget constraint:

$$P_t C^{\mathcal{B}}_{a,t} \;\leq\; W_t \Phi_a L^{\mathcal{B}}_{a,t}(1-\tau_{L,t}) + D^{\mathcal{B}}_{a,t}(\mathcal{U}) + TRG^{\mathcal{B}}_t + TRX^{\mathcal{B}}_t. \quad (3)$$

The households' maximization problem delivers a condition for each type of household that yields their optimal consumption-labor allocation and a consumption function that depends on current income in the case of hand-to-mouth households (which represents all their wealth in each period) and on human and financial wealth in the case of asset holders. Human wealth corresponds to the present discounted value of labor and dividend income accruing in the future, while financial wealth corresponds to current domestic and foreign asset holdings. In the case of asset holders, an interest rate parity condition resulting from portfolio optimization defines the equilibrium in the bonds market. This implies that domestic interest rates depart from foreign interest rates by a risk premium, Ψ_t, which is modeled as an exogenous process.

2.2 Unions

There is a continuum of labor unions in the economy $h \in [0, 1]$. Unions transform homogenous labor services into differentiated varieties, $U_t(h)$. Labor varieties are bundled and then sold to manufacturers at an aggregate wage, V_t, higher than the households' wage, W_t. Labor differentiation yields market power, which is used by labor unions to charge a markup, reflecting limited substitutability among labor varieties in the bundle purchased by manufacturer $j, U_t(j)$.

Each manufacturer demands a specific labor bundle. Aggregating across manufacturers, the demand for labor variety h is given by

$$U_t(h) = \left(\frac{V_t(h)}{V_t}\right)^{-\sigma_{U,t}} U_t, \tag{4}$$

where $V_t(h)$ represents the variety h wage and $0 \leq \sigma_{U,t} \leq \infty$ the elasticity of substitution across labor varieties determining the wage markup in the steady state.

Wage adjustments are costly, with abrupt changes in $V_t(h)$ being more costly than smooth adjustments. It is assumed that labor unions incur quadratic wage adjustment costs, $\Gamma_t^{\mathcal{U}}(h)$, as in Ireland (2001) and Laxton and Pesenti (2003).[6]

Labor union h solves the following dividend-maximization problem:

$$\max_{V_t(h)} E_t \sum_{s=0}^{\infty} \tilde{R}_{t,s} D_{t+s}^{\mathcal{U}}(h) \tag{5}$$

with

$$\tilde{R}_{t,s} = \prod_{l=1}^{s} \frac{\theta}{i_{t+l-1}} \text{ for } s > 0 (1 \text{ for } s = 0)$$

subject to labor demand (4) and quadratic adjustment costs $\Gamma_t^{\mathcal{U}}(h)$. $\tilde{R}_{t,s}$ stands for the subjective nominal discount factor and i_t is the nominal interest rate. Labor unions are owned by households and managed under the preferences of finitely lived agents. Therefore, the subjective discount factor in the maximization problem of labor unions and firms incorporates the survival rate θ.

[6] More specifically, quadratic adjustment costs are specified as $\Gamma_t^{\mathcal{U}}(h) = \frac{\phi_{\mathcal{U}}}{2} T_t U_t (\frac{V_t(h)/V_{t-1}(h)}{V_{t-1}/V_{t-2}} - 1)^2$, where T_t is labor-augmenting technical progress. A number of real and nominal variables are subject to this type of costs in PESSOA and follow similar formulations.

Period t dividends, $D_t^{\mathcal{U}}(h)$, are defined as

$$D_t^{\mathcal{U}}(h) = (1 - \tau_{L,t}) \left[(V_t(h) - W_t) U_t(h) - P_t \Gamma_t^{\mathcal{U}}(h) \right]. \tag{6}$$

2.3 Firms

Two types of firms are featured: manufacturers and distributors. Manufacturers produce differentiated tradable ($\mathcal{T}$) and non-tradable ($\mathcal{N}$) intermediate goods, using a constant elasticity of substitution (CES) technology. Manufacturers hire labor from unions and manage a capital stock by purchasing new capital from the distributor who produces investment goods. In turn, distributors combine domestic intermediate goods (both tradable and non-tradable) with imports to produce differentiated final goods that fulfill final demand.

2.3.1 Manufacturers

For each type of intermediate good $J \in \{\mathcal{T}, \mathcal{N}\}$, there is a continuum of manufacturers $j \in [0, 1]$. Each manufacturer produces a variety, $Z_t^J(j)$, combining capital, $K_t^J(j)$, and labor, $U_t^J(j)$, through a CES production function with labor-augmenting technology, which is the source of real growth in the model. Manufacturers sell variety j at a price $P_t^J(j)$, which corresponds to a markup over marginal costs, reflecting the market power yielded by the limited substitutability between intermediate goods varieties.

Capital accumulation by manufacturer j follows a standard accumulation condition, $K_{t+1}^J(j) = (1 - \delta^J) K_t^J(j) + I_t^J(j)$, where $I_t^J(j)$ stands for the new capital goods purchased in period t that will start operating in $t + 1$, and $0 \leq \delta^J \leq 1$ is the constant depreciation rate of type J firms.

To obtain smooth responses to shocks, capital and labor services are subject to quadratic real adjustment costs ($\Gamma_t^{\mathcal{I}J}(j)$ and $\Gamma_t^{\mathcal{U}J}(j)$, respectively). Furthermore, realistic inflation persistence in the intermediate goods price is ensured by quadratic inflation adjustment costs, $\Gamma_t^{PJ}(j)$, as in Rotemberg (1982).

In this framework, each distributor sets the demand for variety j of the intermediate good that is cost minimizing. Aggregating across distributors, the demand for variety j is given by

$$Z_t^J(j) = \left(\frac{P_t^J(j)}{P_t^J} \right)^{-\sigma_{J,t}} Z_t^J, \tag{7}$$

where $P_t^J(j)$ represents the variety j price and $0 \leq \sigma_{J,t} \leq \infty$ the elasticity of substitution between type J good varieties.

Manufacturer j solves the following dividend-maximization problem:

$$\max_{P_t^J(j), I_t^J(j), U_t^J(j), K_{t+1}^J(j)} \quad E_t \sum_{s=0}^{\infty} \tilde{R}_{t,s} D_{t+s}^J(j) \tag{8}$$

subject to the constraints imposed by the CES technology, capital accumulation condition, quadratic adjustment costs, and the demand curve (7).

Period t dividends, $D_t^J(j)$, are defined as

$$\begin{aligned} D_t^J(j) = {} & (1 - \tau_{K,t}) \\ & \times \left[P_t^J(j) Z_t^J(j) - (1 + \tau_{SP,t}) V_t U_t^J(j) - \text{ adj. \& fixed costs} \right] \\ & - P_t^{\mathcal{I}} I_t^J(j) + \tau_{K,t} P_t^{\mathcal{I}} q_t^J \delta^J K_t^J(j). \end{aligned}$$

Dividends before corporate income tax correspond to sales revenues, $P_t^J(j) Z_t^J(j)$, net of labor costs, $(1 + \tau_{SP,t}) V_t U_t^J(j)$ (where $\tau_{SP,t}$ is firms' payroll tax rate), adjustment and fixed costs,[7] and investment spending, $P_t^{\mathcal{I}} I_t^J(j)$. The expression $\tau_{K,t} P_t^{\mathcal{I}} q_t^J \delta^J K_t^J(j)$ accounts for the corporate income tax rebate of capital depreciation, where $\tau_{K,t}$ is the corporate income tax rate and q_t^J stands for Tobin's Q, which is the shadow price of a unit of installed capital in terms of new capital goods. It should be noted that corporate income tax is charged on net operational profits, implying that, in contrast with investment spending, capital depreciation is tax rebatable.

2.3.2 Distributors

There is a continuum of distributors $f \in [0, 1]$ producing each type of final good $F \in \{\mathcal{C}, \mathcal{G}, \mathcal{I}, \mathcal{X}\}$. Each type of final good is demanded by a unique type of customer: consumer goods $(\mathcal{C})$ are demanded by households, new capital goods $(\mathcal{I})$ are demanded by manufacturers, government consumption goods $(\mathcal{G})$ are demanded by the

[7] A real fixed-cost term is used to ensure that economic profits arising from monopolistic competition are largely depleted in the steady state and, therefore, no firm enters or leaves the market. The fixed-cost term is defined as a constant share of nominal output, ensuring that it does not vanish along the inflationary balanced growth path of the economy.

public sector, and export goods ($\mathcal{X}$) are demanded by foreign customers. Each distributor sells its good variety f at price $P_t^F(f)$, which is set as a markup over marginal costs (reflecting the imperfect substitutability across each type of final goods).

Each distributor uses a two-stage CES production technology. In the first stage, distributor f uses a CES technology to obtain an assembled good, $Y_t^{\mathcal{A}F}(f)$, through the combination of domestic tradable goods, $Z_t^{\mathcal{T}F}(f)$, with imported goods, $M_t^F(f)$. To change the import content of the assembled good, the distributor incurs quadratic real adjustment costs $\Gamma_t^{\mathcal{A}F}(f)$. In the second stage, the distributor combines the assembled good with domestic non-tradable goods, $Z_t^{\mathcal{N}F}(f)$, using also a CES technology, to produce the variety f of the final good, $Y_t^F(f)$.[8]

As with manufacturers, distributors also face quadratic inflation adjustment costs, $\Gamma_t^{PF}(f)$, which generate realistic inflation dynamics.

In this framework, each customer sets the demand for variety f of the final good that is cost minimizing. Aggregating across customers, the demand for variety f is given by

$$Y_t^F(f) = \left(\frac{P_t^F(j)}{P_t^F}\right)^{-\sigma_{F,t}} Y_t^F, \tag{9}$$

where $0 \leq \sigma_{F,t} \leq \infty$ is the elasticity of substitution between varieties of the type F good.

Each final goods producer f solves the following dividend-maximization problem:

$$\max_{P_t^F(f), Z_t^{\mathcal{T}F}(f), Z_t^{\mathcal{N}F}(f), M_t^F(f)} E_t \sum_{s=0}^{\infty} \tilde{R}_{t,s} D_{t+s}^F(f) \tag{10}$$

subject to the constraints imposed by the CES technology, adjustment costs, and demand curve (9). Period t dividends, $D_t^F(j)$, are defined as

$$\begin{aligned} D_t^F(f) = (1 - \tau_{K,t}) \big[& P_t^F(f) Y_t^F(f) - P_t^{\mathcal{T}} Z_t^{\mathcal{T}F}(f) \\ & - P_t^{\mathcal{N}} Z_t^{\mathcal{N}F}(f) - P_t^* M_t^F(f) - \text{ adj. \& fixed costs} \big]. \end{aligned}$$

[8]The production technology can be formalized as a sector-specific nested CES production function, $Y_t^F(f) = CES_2\{CES_1[Z_t^{\mathcal{T}F}(f), M_t^F(f)], Z_t^{\mathcal{N}F}(f)\}$.

Dividends before corporate income tax correspond to sales, $P_t^F(f)Y_t^F(f)$, net of input costs, $P_t^{\mathcal{T}} Z_t^{\mathcal{T}F}(f) + P_t^{\mathcal{N}} Z_t^{\mathcal{N}F}(f) + P_t^* M_t^F(f)$, and adjustment and fixed costs. Finally, P_t^* is the price of imported goods set by foreign suppliers.

Finally, it should be mentioned that public capital stock, resulting from the accumulation of public investment, is not explicitly modeled and therefore plays no role in the production function of firms. The model is therefore silent on the role played by some public policies, such as the development of infrastructures that are used by the private sector. Nevertheless, it should also be noted that many projects are developed by private firms in the context of public-private partnerships and public concessions.

2.4 The Government

The fiscal block of the model is detailed enough to allow for the assessment of macroeconomic impacts of alternative fiscal policy strategies. The government finances expenditure through tax levies and manages a public debt stock.

The government consumes a specific final good, $P_t^{\mathcal{G}} G_t$ ($P_t^{\mathcal{G}}$ is the price charged by distributors for the government consumption good) and performs lump-sum transfers to households, TRG_t. In addition, the government pays debt interest outlays, $(i_{t-1} - 1)B_{t-1}$, to asset holders.

Government spending is financed by taxes on households' labor income and consumption, on manufacturers' payroll, and on corporate income.[9] Note that the average tax rates that have an impact on wage income are the labor income tax paid by employees, $\tau_{L,t}$, and the payroll taxes paid by employers, $\tau_{SP,t}$. Taken together, they represent what will henceforth be called the "tax burden on wage income."

The government issues one-period bonds, paying interest outlays at the beginning of period t on the stock held from $t-1$. Is is assumed that all government debt is held by domestic asset holders (i.e., full home bias is assumed). However, these households can borrow in

[9]The possibility of government expenditures being partly financed by transfers from the rest of the MU is also considered, but it does not play an active role in this article.

international debt markets to buy domestic government bonds.[10] The issuance of public debt allows for the postponement of the tax levies required to finance expenditure in each period, implying that the public-sector account does not need to be balanced in each and every period. This has a non-trivial impact on household decisions, since part of the public debt is taken as net wealth by asset holders.

To ensure that public debt follows a non-explosive path, a fiscal policy rule is introduced, with the imposition that the ratio of public debt to GDP, B_t/GDP_t, and the ratio of fiscal balance to GDP, SG_t/GDP_t, converge to predetermined (target) steady-state levels. The fiscal rule implies that at least one fiscal instrument adjusts endogenously. In line with Kumhof and Laxton (2009a), the following rule is considered:

$$\left(\frac{SG}{GDP}\right)_t = \left(\frac{SG}{GDP}\right)_t^{target} + d_1\left(\frac{RV_t - RV_t^{ss}}{GDP_t^{ss}}\right) + d_2\left(\frac{B_t}{GDP_t^{ss}} - \left(\frac{B}{GDP}\right)_t^{target}\right), \tag{11}$$

where RV_t^{ss} is the structural overall tax revenue (i.e., the tax revenue that is collected when tax bases stand at their steady-state levels), and GDP_t and GDP_t^{ss} are the observed and the steady-state GDP levels. The response to business-cycle fluctuations and the speed of convergence to the public debt target depend on parameters d_1 and d_2, respectively. Parameter d_1 controls for the response to the tax revenue gap and parameter d_2 controls for the government (in)tolerance to deviations from the debt target. In the steady state, both the tax revenue gap and the debt gap are zero.

At this point, the fiscal instrument that becomes endogenous remains to be defined. A common option relies on the use of the labor income tax rate as the endogenous fiscal policy instrument (Kilponen and Ripatti 2005; Kumhof and Laxton 2007; Kumhof et al. 2010). Nevertheless, other possibilities are available in PESSOA, among them using one of the remaining taxes, lump-sum transfers

[10] In an environment without financial frictions, the assumption of full home bias in public debt holding is likely to be neutral. The absence of financial frictions is an acknowledged fragility of the model.

to households, government consumption, or a combination of these instruments.

Finally, a word of caution is needed. Although the above-mentioned fiscal block is suited to implement several fiscal simulations, the model remains a simplification of reality. As already mentioned, government consumption and investment are assumed not to generate any externalities and, therefore, do not affect the marginal utility of consumption and leisure or firms' productivity level. The only tangible impact of government consumption is on the demand conditions for a specific final good, which is particularly intensive in non-tradable intermediate goods and has a low import content. The model is thus silent on other roles played by the government—in particular, as a large-scale employer and investor—or on the externalities associated with alternative fiscal policies. Note also that the model does not feature unemployment benefits explicitly, since the labor market is not explicitly modeled.

2.5 The Rest of the World

In PESSOA, the rest of the world (RoW) corresponds to the rest of the euro area. Without loss of generality, the nominal effective exchange rate is irrevocably set to unity.

As for trade flows, the demand for imports by domestic distributors results from the cost-minimization problem presented in section 2.3 and reflects final demand conditions and competitiveness. Domestic exports are essentially determined by the foreign distributors' imports demand. Foreign distributors are assumed to be identical to domestic ones, and therefore their demand for domestic economy exports results from their cost-minimization problem subject to a CES technology. The representative foreign distributor produces a final good variety, $Y_t^*(f^*)$, by assembling domestic economy exports (i.e., foreign economy imports), $X_t(f^*)$, and intermediate goods produced by foreign manufacturers, $Z_t^*(f^*)$.

Aggregating across foreign final goods producers and export good varieties, the demand for domestic exports is given by

$$X_t = \alpha^* \left(\frac{P_t^X}{P_t^*} \right)^{-\xi^*} Y_t^*, \tag{12}$$

where P_t^X is the aggregate export price charged by domestic distributors, P_t^* is the price of the foreign good, and Y_t^* is foreign output level. Parameter α^*, the CES quasi-share, is of key importance in determining the steady-state export market share. In turn, ξ^* is the elasticity of substitution between home exports and foreign goods.

Equation (12) is fundamental to render the model dynamically stable. In particular, a large real exchange rate elasticity of exports is required. The model operates like a fixed nominal exchange rate model under perfect credibility, in which domestic price levels are pinned down by the external constraint that uniquely sets the real exchange rate in the steady state.[11] Like the remaining foreign variables, both P_t^* and Y_t^* are assumed to be independent of domestic developments.

Regarding financial flows, the SOE approach relies on the assumption that changes in the domestic economy net foreign asset position have negligible impacts on euro-area aggregates and on policy decisions.

2.6 Market Clearing Conditions and GDP Definition

The model is closed by a set of conditions imposing market clearing for each and every period for labor, intermediate, and final goods. In a frictionless international financial environment, the modeling of financial flows becomes trivial and is fully determined by national saving decisions at the prevailing interest rate and by the following market clearing condition where changes in net foreign asset holdings must be identical to the current account balance:

$$B_t^* - i_{t-1}^* \Psi B_{t-1}^* = P_t^X X_t - P_t^* M_t + TRX_t. \tag{13}$$

Nominal GDP is defined as

$$GDP_t = P_t C_t + P_t^G G_t + P_t^I I_t + P_t^X X_t - P_t^* M_t. \tag{14}$$

Real GDP is aggregated by the Fisher formula.

[11] In the standard SOE model, monetary policy is actively managed and the adjustment of the real interest rate supplements the real exchange rate in rendering the model dynamically stable. In an SOE in an MU, the absence of monetary policy implies that real interest rate dynamics tend to amplify business-cycle fluctuations.

2.7 Calibration

PESSOA was calibrated to fit the Portuguese economy, using actual data and additional information from studies on the Portuguese and euro-area economies. The model parameters are presented in detail in the appendix.

There is a relatively large set of parameters and assumptions behind the model, and from these it is worth mentioning that the steady-state real GDP growth was assumed to be identical in the entire MU, ensuring the existence of a balanced growth path. The labor-augmenting productivity annual growth was set to 2 percent, which is consistent with the available estimates for the potential output growth in the euro area (Musso and Westermann 2005; Proietti and Musso 2007). This figure also seemed reasonable for Portugal (Almeida and Félix 2006).

Regarding inflation, the steady state was solved under the assumption that foreign inflation stands at 2 percent per year. The euro-area nominal interest rate in the steady state was set to 4.5 percent (Coenen, McAdam, and Straub 2007).

The parameters related to the Blanchard-Yaari households' behavior—specifically, the instant probability of death and the decay in productivity over the lifetime—were calibrated as in Kumhof et al. (2010). The elasticities of substitution in the production functions of manufacturers and distributors, the parameters governing wage and price markups, adjustment costs, and the fiscal rule parameters also follow Coenen, McAdam, and Straub (2007), Kumhof et al. (2010), and estimates for Portugal, whenever available.

2.8 Welfare Analysis

The utility function presented in equation (1) can also be used to conduct welfare analysis of alternative policy actions. This analysis can be seen as a metric stressing the role of consumption and leisure in households' utility, instead of simply focusing on output.

Some key issues arise in the computation of welfare in an overlapping-generations model with asset holders and rule-of-thumb households. Firstly, the impact of policy changes on welfare differs across current generations. Following Ganelli (2005) and Kumhof, Laxton, and Leigh (2010), consumption and leisure of households of type $H \in \{\mathcal{A}, \mathcal{B}\}$ with age a in the utility function (1) is replaced by the corresponding average per capita values across all generations. Secondly, the impact of policy changes on welfare also differs between current and future generations. In an overlapping-generations framework, the discount rate (henceforth defined as Υ) determines the weight attached to current versus future generations in the overall welfare assessment. The higher the Υ, the larger the relative weight of current in comparison with future generations and the higher the weight attached to the transitional dynamics. Hence, the choice of Υ is not a straightforward matter and a variety of rates have been used in the literature. Ramsey (1928) and Stern (2007) advocate that all generations should be treated identically and therefore the future should not be discounted at all, which is tantamount to assessing welfare in the initial and in the final steady state and to attaching a negligible weight to the welfare implication in the transitional dynamics (this is assessed by setting, respectively, $\Upsilon = 0.0$ percent and $\Upsilon = 0.1$ percent in table 2). In turn, Kaplow (2007) advocates the optimality of using the market rate of return to capital ($\Upsilon = 2.8$ percent), while Marini and Scaramozzino (2000) favor a discount rate identical to productivity growth ($\Upsilon = 2.0$ percent). Besides the previous rates, it is also considered the households' discount rate ($\Upsilon = 6.8$ percent), which accounts for the finitely lived nature of households.

The welfare impacts are expressed in consumption good units using the compensating variation of consumption, that is, the percentage increase in the initial steady-state consumption that yields the same welfare as the policy change, while keeping the amount of leisure at the initial steady-state level. The aggregate value is obtained as a weighted average of compensating consumption variations of type $\mathcal{A}$ and $\mathcal{B}$ households, using their respective weights, $1 - \psi$ and ψ. A recent application using this type of household can be found in Kumhof et al. (2011).

Finally, it should be acknowledged that welfare analysis is conditioned by the working assumptions that government consumption does not directly affect households' utility or have any impact on factor productivity. Thus, any fiscal consolidation based on government consumption is perceived as less welfare harming than otherwise. A key issue in this context is whether this type of good is valued separably or not in the utility function. If government consumption enters the utility function in a non-separable fashion, it affects the marginal rate of substitution between consumption and leisure. If this type of good enters in a separable fashion, the utility level is affected, as in Kumhof, Laxton, and Leigh (2010), but the households' decisions remain unchanged. The absence of these effects implies that the welfare impacts, arising from cuts in government consumption, should best be seen as upper-limit estimates. In turn, if the reduction in this type of government spending is achieved through higher efficiency in the provision of goods and services actually valued by households or by elimination of spending negligibly valued, then the absence of government consumption in equation (1) is more negligible.

3. The Costs and Benefits of Fiscal Consolidation

This section assesses the macroeconomic effects of a fiscal consolidation process in a small euro-area economy. Fiscal consolidation is defined as a permanent reduction in the public debt ratio and is implemented through an initial fiscal tightening. Over time, debt falls and so do government interest outlays, allowing for a larger primary deficit and creating room either for lower taxes or higher primary expenditure in the final steady state. More precisely, the fiscal consolidation process is implemented through equation (11) and takes the form of a permanent reduction in the fiscal deficit of 1 percent of the initial steady-state GDP. Given the assumptions for nominal interest rates and GDP growth, this leads to a decline in the public debt ratio of around 25 percentage points in the final steady state.

Before discussing the costs and benefits of a specific fiscal consolidation strategy, sub-section 3.1 presents in detail the impact and the main transmission channels for each fiscal instrument (transfers to households, government consumption, tax burden on wage income, and consumption taxes). Based on these results, a benchmark fiscal consolidation package is defined. This package considers mainly expenditure cuts (government consumption and transfers to households), and the fiscal room created by lower interest outlays in the final steady state is used to cut the tax burden on wage income. Sub-section 3.2 presents the macroeconomic impacts of different paces of the consolidation process. More specifically, three alternative scenarios are considered: a slow consolidation scenario, a medium-pace scenario ("central scenario"), and a fast consolidation scenario.

The simulations presented in sub-sections 3.1 and 3.2 assume perfect foresight and full credibility of the fiscal authority. Therefore, the risk premium on public debt is assumed not to be affected by the chosen consolidation strategy.

3.1 Impact of Alternative Instruments

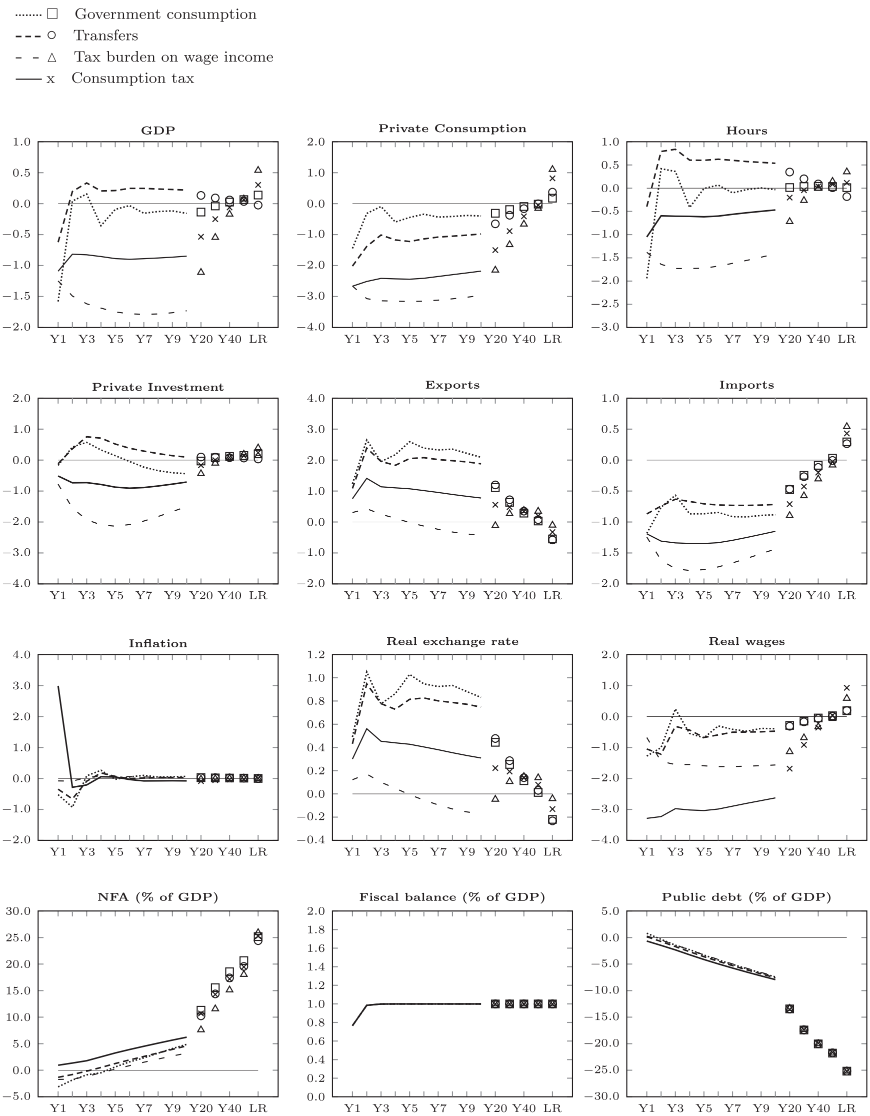
This sub-section investigates the short-, medium-, and long-run impacts of each fiscal instrument—namely transfers to households, government consumption, tax burden on wage income, and the consumption tax—and clarifies the main transmission channels of these instruments.[12]

All policy actions share the objectives of reaching a reduction in the fiscal deficit equal to 1 percent of the initial steady-state GDP (more than 90 percent of the reduction is assumed to be reached after one year) and a decrease in the public debt ratio of around 25 percentage points of GDP in the long run. The fiscal rule parameters in equation (11) are set to zero, implying that the endogenous fiscal instrument adjusts as much as needed to ensure that the fiscal balance matches the new target level in each and every period. This feature implies identical fiscal balances across all instruments and a very slow fiscal consolidation pace. Alternative fiscal consolidation paces will be discussed in the next sub-section.

To design the benchmark fiscal package, three different simulation exercises were implemented. The first simulation assumes that the fiscal instrument used to implement the initial tightening is the same one that is used to take advantage of the fiscal room created by lower interest outlays at longer horizons. Simulation results, in percentage deviations from the initial steady state, are presented in figure 1.

[12]Though lump-sum taxes are not explicitly considered, a cut in transfers can be reinterpreted as an increase in lump-sum taxes. The labor income tax and the firm payroll tax, defined in section 2 as the tax burden on wage income, are adjusted in identical magnitudes in terms of percentage-point changes in their average rates.

Figure 1. Macroeconomic Impacts Using One Fiscal Instrument



Notes: Values are expressed as percentage deviation from steady-state levels. Inflation, NFA, fiscal balance, and public debt deviations are in percentage points. The remaining variables are in percentages. A higher real exchange rate implies depreciation. "LR" refers to a long-run outcome. Note that while the first ten years are shown by lines, longer horizons are represented by markers. In each simulation, there is only one fiscal instrument being used at a time (which implies a unique instrument behind both the initial fiscal tightening and the fiscal rule that ensures a fiscal balance consistent with a stable debt path).

The results suggest that fiscal policy instruments operate through different channels. A fiscal consolidation based on a cut in transfers to households affects macroeconomic outcomes mainly through the impact on households' wealth and on the resulting responses of hours worked and private consumption. A reduction in transfers has significantly negative wealth effects, leading to a drop in consumption and leisure and, thus, to an increase in hours worked.[13] Households with no access to asset markets cut their consumption and simultaneously increase hours worked to partially compensate forgone income. The consumption of asset holders is less affected, reflecting improved dividend prospects and the ability to smooth consumption. Moreover, the upward shift in hours leads to lower real wages and to a decrease in firms' marginal costs, implying a drop in domestic prices and a real exchange rate depreciation.

A fiscal consolidation process based on a cut in government consumption implies a reduction in hours worked. Government consumption is extremely intensive in domestic non-tradable intermediate goods, which, in turn, are significantly labor intensive. As a consequence, real wages decline, as well as households' wealth and, consequently, private consumption. Hence, a cut in government consumption depresses domestic demand, thereby contributing to a decrease in domestic prices and, thus, to international competitiveness gains through a real exchange rate depreciation. The cut in government consumption ends up releasing resources that can be allocated to other sectors—in particular, to the production of tradable goods.

An expenditure-based fiscal tightening implies a reduction in demand pressures, promotes a real exchange rate depreciation, and improves the international competitiveness of domestic firms. The increase in competitiveness stimulates domestic production and factor demand and improves the external account, partly offsetting the recessive impact of fiscal consolidation. In contrast, the fall in expected inflation raises the real interest rate, exacerbating the

[13]In PESSOA, a cut in transfers induces a shift in labor supply. In practice, however, a part of the transfers is received by pensioners who do not actively supply labor. This feature is not captured and may significantly limit labor-supply impacts.

decline in aggregate demand and amplifying the short-run recessive effects of the fiscal consolidation measures.[14]

In turn, the results suggest that a fiscal tightening based on tax increases implies a protracted decline in output, private consumption, and investment to levels below the initial steady state. An increase in the labor income tax (one of the components of the tax burden on wage income) affects the economy mainly through its impact on the marginal rate of substitution between consumption and leisure. Hence, a rise in the labor income tax discourages workers, and this implies a decrease in labor supply. At the same time, an increase in firms' payroll taxes (the second component of the tax burden) leads to an increase in the marginal costs of firms, inducing an increase in capital intensity and a reduction in labor demand. Therefore, a rise in the tax burden on wage income implies a decrease in hours worked and an increase in domestic prices, gradually leading to a real exchange rate appreciation.

The consumption tax increase is less distortionary of the consumption/leisure allocation than the tax burden on wage income. Changes in the consumption tax affect the economy mainly through the price transmission channel, reducing the real value of households' wealth. This induces households to supply more labor in order to limit the impact of the negative wealth effects on consumption, leading to a smaller decline in hours worked than in the case of a higher tax burden on wage income.

In the first year, the most negative effect on output comes from a cut in government consumption, which is a result also obtained in several models (Coenen et al. 2012). From the second year onwards, tax-based policies are likely to involve higher losses in terms of GDP, while consolidation strategies based on transfers and government consumption are less penalizing. In the cases of consumption and investment, this result is valid even in the first year. These results suggest that fiscal consolidations should be initially biased towards spending cuts rather than tax hikes. This conclusion is further analyzed below. Theoretical analysis favoring fiscal consolidation based

[14]In models with autonomous monetary policy, the policy interest rate response plays a key role during the transition period. In this type of model, the contractionary short-term impact of fiscal consolidation is partly offset by a reduction in nominal interest rates in the case when the zero lower bound is not binding.

on spending cuts, following a fiscal stimulus, have been suggested by Corsetti et al. (2010). This policy option also seems appealing in the European context, since taxes are already at high levels in some economies and the recent period has been characterized by a rise in government spending. Expenditure cuts are nevertheless likely to imply reforms that take time to implement. Thus, in the short run, taxes may help to speed up the fiscal consolidation.

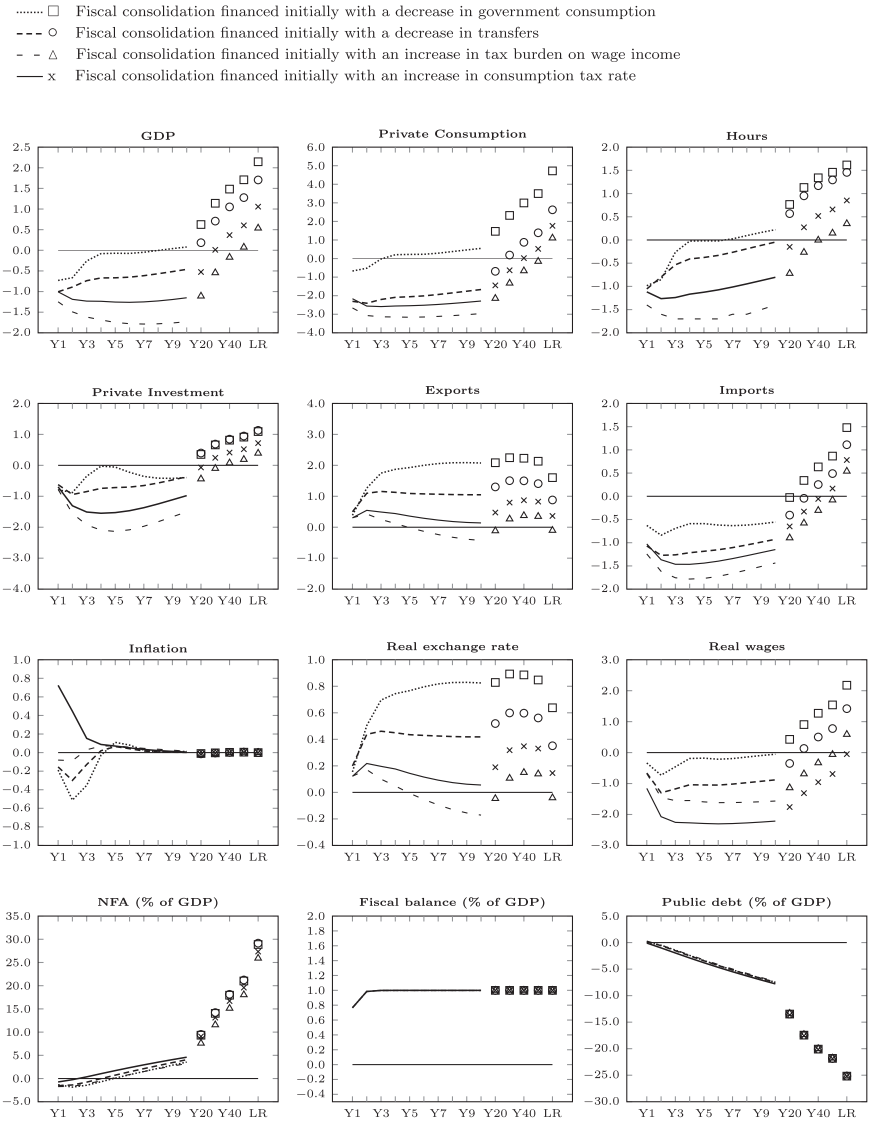
The results in figure 1 also illustrate that each fiscal instrument has different impacts over different time horizons. More specifically, the most adequate instrument in the short run is not necessarily the most effective in boosting economic activity in the long run.

To ensure that the previous finding (fiscal consolidations should be initially biased towards spending cuts) is not conditional on the instrument that adjusts endogenously in the fiscal rule, a second simulation is implemented. As before, the fiscal rule parameters are set to zero and the initial tightening is based on a single instrument at a time. However, the fiscal rule is now based on a unique instrument across all experiments—specifically, the tax burden on wage income, which according to the results presented in figure 1 is the most effective in boosting output in the long run. These taxes are thus the only instrument that adjusts to ensure that the fiscal balance is always on target. The results of the second simulation are presented in figure 2.

The conclusion that an expenditure-based fiscal tightening is preferable to tax increases is confirmed by the results of this simulation. In addition, the outcome suggests that the design of the fiscal package can benefit from the utilization of different instruments at different horizons. In comparison with a strategy in which the tax burden on wage income is used in the fiscal tightening phase, a fiscal consolidation policy initially biased towards government spending cuts is less costly in terms of forgone output (as measured by GDP) and households' consumption.

To design the benchmark fiscal package, the third simulation focuses exclusively on long-run impacts and introduces a welfare analysis of the alternative policy actions. The initial fiscal tightening is based on permanent cuts in government consumption and in transfers to households, each contributing 0.5 percent of initial steady-state GDP, while the fiscal room in the long run is used to either cut taxes or increase spending. The results are summarized in table 1.

Figure 2. Macroeconomic Impacts Using Two Fiscal Instruments



Notes: This figure reports the macroeconomic impacts of using one instrument at a time, but only to implement the initial tightening. The second instrument is always the tax burden on wage income, which is endogenously determined by the fiscal rule. For further information, see the notes presented in figure 1.

Table 1. Long-Run Impacts from the Lower Interest Rate Burden

	Lower Interest Burden Used to:			
	Reduce $\tau_L + \tau_{SP}$	**Reduce** τ_C	**Raise** G	**Raise** TRG
GDP	2.4	1.3	0.5	−0.3
Private Consumption	4.4	3.0	−0.2	0.8
Private Investment	1.5	0.7	0.6	−0.3
Exports	1.7	0.7	−0.5	−0.6
Imports	1.6	1.0	0.4	0.2
Hours	2.1	0.9	0.4	−0.6
Real Wage Rate	2.2	3.9	0.2	0.2
Real Exchange Rate	0.7	0.3	−0.2	−0.3
Welfare Analysis:				
CV in % of Initial SS Consumption	3.1	2.3	−0.5	1.2

Notes: Values are expressed as percentage deviation from steady-state levels. $\tau_L + \tau_{SP}$ represent the tax burden on wage income, τ_C is the consumption tax, G is government consumption, and TRG are lump-sum transfers to all households. "SS" stands for steady state and "CV" for compensating variation. Welfare analysis in this table treats all generations alike, following Ramsey (1928).

The results are in line with the standard view of relative distortionary features of the various fiscal instruments. In the long run, tax cuts have the larger GDP impact. The welfare analysis also points in the same direction. The consumption compensating variation varies between –0.5 percent and 3.1 percent, the latter delivered by the reduction of the tax burden on wage income. This policy option can thus be rationalized in terms of being welfare maximizing.

A fiscal strategy based on higher government consumption in the long run also delivers a positive impact on GDP, whereas an increase in transfers leads to a marginally negative impact. This negative impact is due to the fact that transfers are defined as lump-sum payments to households that may flexibly adjust their labor supply. Therefore, if the fiscal room is used to increase transfers, households reduce their labor supply in view of higher income and the possibility of higher consumption. In this case, the higher level of wages that is required to motivate households to supply enough labor leads to a loss in competitiveness and to a drop in exports. This negative effect more than offsets the positive impact on consumption in the long run, implying a marginal negative impact on GDP.

3.2 The Benchmark Fiscal Consolidation under Alternative Timings

This sub-section assesses the costs and benefits of the benchmark fiscal consolidation strategy considering alternative paces of consolidation. The simulations are implemented by changing the calibrated fiscal parameters in equation (11) and by allowing the instrument that is endogenously determined by the fiscal rule to react to tax revenue gaps and to public debt deviations from target. In the previous sub-section, fiscal rule parameters were set to zero and this implied a slow and identical consolidation pace across all simulations (see figures 1 and 2). In this sub-section, the rule is calibrated to allow for alternative paces.

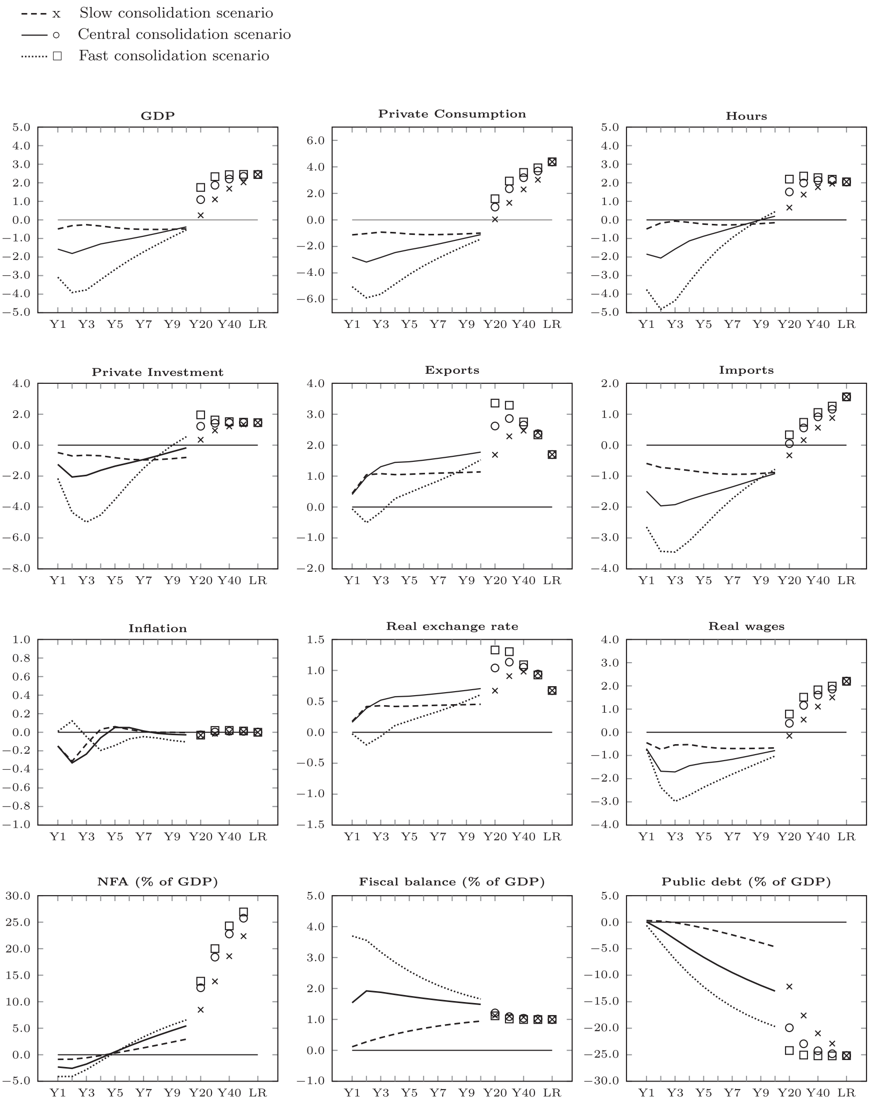
The benchmark fiscal consolidation strategy is defined as a permanent cut in government consumption and in transfers to households, each contributing with 0.5 percent of initial steady-state GDP. These measures are furthermore assumed to be gradually factored in over a period of two years. In the short run, the adjustment to a lower deficit level requires a slight increase in the tax burden, and this speeds up the convergence to a lower public debt level. However, as public debt declines, interest payments shrink and savings are used to reduce the tax burden on wage income, since this instrument is the most distortionary and this reduction enhances the medium- and long-run impacts on GDP and welfare.

This sub-section starts by analyzing the macroeconomic impacts of a fiscal policy that features half of the envisaged decline in the public debt ratio in eight years. This policy is referenced as the "central consolidation scenario" and the results are presented in figure 3.

In the short run, the central scenario implies a fall in real GDP, which reaches a trough in the second year (around 2 percent below the initial steady state) and makes a gradual recovery thereafter.[15]

[15] A sensitivity analysis was conducted in order to assess the impact of changing the parameter that defines the percentage of rule-of-thumb consumers in the results. Simulation results do not depend significantly on this parameter and, therefore, conclusions are robust to alternative calibrations of the parameter ψ in the range of realistic values.

Figure 3. Macroeconomic Impacts of Alternative Fiscal Consolidation Paces



Notes: For further information, see the notes presented in figure 1.

Nevertheless, this scenario leads to a protracted period of below-steady-state real GDP. Private consumption decreases steeply in the short run, due not only to the direct impact of fiscal measures on households' wealth but also to the increase in the real interest rate. Indeed, the return on savings increases, measured in terms of future consumption, implying a further disincentive to current consumption. The negative impact on consumption and investment is partly offset in the short run by more favorable future wealth prospects due to expected lower distortionary taxes. In turn, the short-run decrease in the price level leads to gains in international competitiveness, and this implies both an increase in export market share and a decline in the import content of domestic output. Thus, in the short run, fiscal consolidation leads to an improvement in the ratio of trade balance to GDP.

In the central scenario, the tax burden on wage income declines 3.2 percentage points in the final steady state. Hence, households' after-tax real wage increases, raising the opportunity cost of leisure and thereby leading to an upward shift in labor supply. Simultaneously, firms' payroll tax falls and labor demand increases, leading to a rise in the marginal product of capital and fostering capital accumulation. The increase in households' wealth, due to the increase in wage and capital income prospects, boosts consumption and investment and, consequently, GDP. In the final steady state, GDP is 2.4 percent above the initial steady state.

The fiscal consolidation leads to a permanent improvement in the net foreign asset position. Hence, on the one hand, the income balance improves permanently, since interest rates are held constant by assumption, but on the other hand, imports also increase permanently, due to higher global demand in the long run. Therefore, the above-mentioned improvement in the trade balance, resulting from the real exchange rate depreciation, vanishes gradually, leading to a larger trade deficit than in the initial steady state.

Table 2 presents the impact of the central scenario on households' welfare, considering alternative discount rates. The results show that welfare impacts are conditional on the discount rate Υ. More precisely, the welfare gains are enhanced for lower Υ. In this scenario, the compensating variation of consumption ranges from –0.8 percent to +3.1 percent.

Table 2. Welfare Assessment of Alternative Scenarios

	Discount Rate (Υ)				
	0.0%	**0.1%**	**2.0%**	**2.8%**	**6.8%**
Slow Consolidation	3.1	3.0	0.9	0.5	−0.5
Central Consolidation	3.1	3.0	1.0	0.5	−0.8
Fast Consolidation	3.1	3.0	0.9	0.4	−1.3

Note: Values in percent of initial steady-state consumption. The welfare impacts are expressed in consumption good units using the compensating variation of consumption.

Despite the short-run costs of fiscal consolidation, it can be concluded that a lower ratio of public debt to GDP has positive long-run impacts on economic activity, private consumption, investment, and exports, as shown in Coenen, Mohr, and Straub (2008). It also increases households' welfare and significantly improves the net foreign asset position. The short-term pain and long-run gains of permanent deficit reductions are fully in line with Kumhof et al. (2011). There are, however, some significant qualifications that are worth emphasizing. In particular, figure 3 shows that the main driving forces behind a fiscal consolidation process remain intact even if a particular country does not have an active monetary policy and does not affect worldwide real interest rates.

Figure 3 also illustrates the impact on the main macroeconomic variables of alternative paces of fiscal consolidation. Besides the central fiscal consolidation scenario, there are two additional scenarios that differ on the speed of convergence towards the new public debt target: the "slow consolidation scenario," which ensures that half of the reduction of the public debt ratio is achieved in twenty years, and the "fast consolidation scenario," in which half of the public debt ratio decline is achieved after five years.

A front-loaded fiscal tightening—the fast consolidation scenario—implies a deep recession, with significant losses in output, consumption, and investment, and lower hours worked in the short run. On the other hand, a slow fiscal consolidation scenario, with a longer transition period, implies lower output, consumption, and investment losses and a smaller reduction in hours worked in the short and medium run, but a more protracted period of below initial steady-state GDP. Moreover, medium-run improvements in the competitiveness of domestic firms are more limited in the last scenario.

Table 2 also presents the welfare costs and benefits for the slow and fast fiscal consolidation scenarios. Results show that for the highest discount rate, the slow consolidation scenario is the strategy that implies smaller welfare losses, and therefore current generations may prefer a more gradual approach, a result that is in line with the literature pointing to the optimality of tax smoothing (Caprioli, Rizza, and Tommasino 2010). As the discount rate decreases, the difference between the alternative fiscal consolidation paces in terms of costs and benefits narrows.

The above results suggest that the slower the fiscal consolidation, the lower is the decrease in output and domestic demand in the short and medium run. However, the slower the consolidation, the longer is the time period to reap its full benefits. Regardless of the fiscal consolidation pace, a protracted time period of below initial steady-state GDP seems warranted. This might well provide a rationale for the frequent lack of political will to move in this direction.

4. Conclusions

A credible fiscal consolidation strategy seems necessary in many euro-area countries. Some economies have been facing a surge in sovereign debt spreads and are now being forced to take immediate and rapid measures to ensure access of the public sector to the sovereign debt markets. In this context, evaluating the costs and benefits of fiscal consolidation and creating the conditions for a successful consolidation process became a topical policy issue.

This article analyzes the impact of alternative fiscal consolidation strategies on the macroeconomic scenario and on welfare, using a dynamic general equilibrium model with non-Ricardian features (PESSOA). Under the assumption of full credibility and unchanged sovereign risk premium, the simulations suggest that fiscal consolidation, in general, implies a trade-off between the short-run costs and the long-run benefits. In the short run, debt reduction is painful, especially for slow-growing economies, since it implies a reduction in economic activity. In contrast, lowering debt and thus reducing interest rate payments on outstanding government debt brings long-run benefits, among them sizable increases of output.

The welfare analysis conducted in the article suggests that the costs and benefits of a credible fiscal consolidation strategy are conditional on the discount rate and therefore on the relative weight attached to current versus future generations. A consolidation strategy is likely to be more welfare improving the larger the weight attached to future generations. This analysis is conditioned by the assumption that government consumption does not directly affect households' utility or factor productivity. Thus, the welfare impacts of government spending cuts should be interpreted as resulting from reforms aimed at increasing government efficiency in the provision of services and/or at eliminating services negligibly valued by households.

Consolidation strategies based on transfers to households and government consumption cuts are relatively less penalizing than tax hikes for real GDP from the second year onwards. In the case of private consumption and investment, this result is valid even in the short run. Moreover, an expenditure-based fiscal tightening brings about a bigger real exchange rate depreciation than tax hikes and improves the international competitiveness of domestic firms. In turn, long-term gains from fiscal consolidation are enhanced if the fiscal room created by lower public interest outlays is used to cut distortionary taxes—in particular, the tax burden on wage income. Well-designed strategies could therefore minimize the costs and enhance the benefits of fiscal consolidation. Nevertheless, a protracted period of below initial steady-state GDP seems warranted and might well provide a rationale for the frequent lack of political will to move in this direction.

Additionally, a front-loaded fiscal consolidation process implies a deeper recession, with significant short-term losses in output, when compared with more gradual strategies. Thus a credible slow fiscal adjustment is more appealing. However, the slower the implementation, the longer is the time period to reap the full benefits of fiscal consolidation. Finally, welfare analysis suggests that, as the discount rate increases, the slow consolidation scenario is likely to become the preferred strategy, as it implies smaller welfare losses. As the weight of current and future generations becomes the same, all strategies deliver welfare gains and the difference between them becomes negligible.

Appendix

Table 3 reports the main parameters of the model and table 4 the steady-state key ratios, including a comparison with actual data, when available.

The calibration of households' parameters is largely based on Fagan, Gaspar, and Pereira (2004), Harrison et al. (2005), and Kumhof and Laxton (2007). Parameters $\eta_{\mathcal{A}}$ and $\eta_{\mathcal{B}}$ were calibrated so as to ensure a unitary elasticity of labor supply to real wage. The coefficient of relative risk aversion was set to calibrate the intertemporal elasticity of substitution to 0.2. The share of liquidity-constrained households was set to 40 percent, broadly in line with the estimates for Portugal presented in Castro (2006).

The steady-state wage markup of labor unions was set at 25 percent. Although relatively high, the tightly regulated Portuguese labor market may even justify a higher number. Nominal wage rigidity was calibrated to ensure that wages adjust to the new equilibrium in six quarters, a value slightly above euro-area estimates published in Coenen, McAdam, and Straub (2007) but still in the range usually found in the literature.

Turning to firms, the depreciation rate was assumed to be identical across manufacturers and was calibrated by taking into account actual data on investment-to-GDP ratio. The elasticity of substitution between capital and labor in the production function was assumed to be unitary and takes into account the actual labor income share. The steady-state price markup of tradable and non-tradable goods was calibrated using OECD product market regulation indicators and the correlation between tradable and non-tradable goods markups and product market regulation indicators found in Høj et al. (2007). The price markup of the non-tradable goods was set at 20 percent, in line with low competition levels in this sector. As for real rigidities, capital adjustment costs were calibrated so as to ensure plausible investment responses. Regarding nominal rigidities, price-growth adjustment costs were calibrated to match average adjustment time spans, in which the adjustment of prices in the non-tradable goods sector is slightly slower than in the tradable goods sector. The elasticity of substitution between domestic tradable goods and imports was assumed to be identical across firms and set above unity (Erceg, Henderson, and Levin 2000; Harrison

Table 3. Main Parameters

	Parameter	Value
Monetary Union Parameters		
Euro-Area Interest Rate (annualized)	i^*	1.05
Euro-Area Labor-Augmenting Prod. Growth (annualized)	g	1.02
Euro-Area Inflation Target (annualized)	π^*	1.02
Euro-Area EoS between Domestic and Imported Goods	ξ^*	2.50
Households and Unions		
Households' Discount Rate (annualized)	β	0.97
Intertemporal Elasticity of Substitution	$\frac{1}{\gamma}$	0.20
Households' Instant Probability of Death (annualized)	$1-\theta$	0.04
Households' Habit Persistence	ν	0.20
Consumption Share—Type $\mathcal{A}$ Households	$\eta_{\mathcal{A}}$	0.74
Consumption Share—Type $\mathcal{B}$ Households	$\eta_{\mathcal{B}}$	0.66
Lifetime Productivity Decline Rate (annualized)	$1-\chi$	0.04
Share of Type $\mathcal{B}$ Households	ψ	0.40
Wage Markup	$\frac{\sigma_U}{\sigma_U-1}$	1.25
Wage Rigidity—Adjustment Cost	ϕv	200
Manufacturers		
Depreciation Rate (annualized)	δ	0.09
EoS between Capital and Labor	ξ_J	0.99
Price Markup—Tradables	$\frac{\sigma_T}{\sigma_T-1}$	1.10
Price Markup—Non-Tradables	$\frac{\sigma_N}{\sigma_N-1}$	1.20
Capital Adjustment Cost	ϕ_{IJ}	10
Labor Adjustment Cost	ϕ_{UJ}	5
Price Adjustment Cost	ϕ_{PJ}	200
Quasi Labor Income Share—Tradables	α_T	0.56
Quasi Labor Income Share—Non-Tradables	α_N	0.60
Distributors		
EoS Domestic Tradable/Imported Good	ξ_{AF}	1.50
EoS Assembled/Non-Tradable Good	ξ_F	0.50
Price Markup (domestic distributors)	$\frac{\sigma_F}{\sigma_F-1}, F \neq X$	1.05
Price Markup (exporters)	$\frac{\sigma_X}{\sigma_X-1}$	1.03
Import Content Adjustment Cost	ϕ_{AF}	2
Price Adjustment Cost	ϕ_{PF}	200

(continued)

Table 3. (Continued)

	Parameter	Value
Government		
Labor Income Tax Rate	τ_L	0.23
Consumption Tax Rate	τ_C	0.31
Capital Income Tax Rate	τ_K	0.17
Firms' Payroll Tax Rate	τ_{SP}	0.19
Debt-to-GDP Ratio (annualized)	$\frac{b}{gdp}$	0.53
Fiscal Stance Parameter	d_1	1.00
Speed Adjustment towards the Target Debt Ratio Parameter	d_2	0.10

Table 4. Steady-State Key Ratios

	Data	Model
Expenditure (as a % of GDP)		
Private Consumption	0.64	0.60
Government Consumption and GFCF	0.23	0.23
Private Investment	0.21	0.21
Exports	0.30	0.29
Imports	0.38	0.33
Labor Income Share (as a % of overall income)	0.58	0.57
Tradable Goods	0.54	0.55
Non-Tradable Goods	0.59	0.59
Capital-Output Ratio (as a % of output)	*NA*	2.34
Tradable Goods	*NA*	2.53
Non-Tradable Goods	*NA*	2.21
Government (as a % of GDP)		
Debt Stock	0.58	0.53
Fiscal Balance	−0.03	−0.02
Overall Revenues	0.42	0.43
Overall Expenditure	0.45	0.45
External Account (as a % of GDP)		
Net Foreign Assets	−0.64	−1.44
Current Account	−0.08	−0.06
Trade Balance	−0.08	−0.04

Note: *NA* stands for non-available data.

et al. 2005; Coenen, McAdam, and Straub 2007; Kumhof et al. 2010), while the combination of assembled goods with non-tradable goods was assumed to feature a low substitutability (Mendoza 2005; Kumhof et al. 2010). These production functions were also calibrated in line with the National Accounts import contents and the non-tradable goods content of each type of final good. The degree of monopolistic competition among distributors was assumed to be lower than among manufacturers, with the steady-state markup being set to 5 percent, except in the case of exporters, where fiercer competition justifies a lower markup. In terms of price stickiness, it was assumed that prices take two quarters to fully adjust for all distributors except exporters, whose prices are assumed to adjust faster. Real rigidities related to the import content adjustment costs were set to ensure a smooth adjustment of import contents to real exchange rate fluctuations.

The steady-state tax rates, as well as transfers from the rest of the MU, government consumption and investment, and government transfers, were calibrated to match actual data. The fiscal policy rule was calibrated to ensure smooth tax adjustments. The target debt was set to 53 percent of GDP, implying a fiscal balance of −2.1 percent in line with the fiscal target set in the European Union.

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Transmission Lags of Monetary Policy: A Meta-Analysis*

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The transmission of monetary policy to the economy is generally thought to have long and variable lags. In this paper we quantitatively review the modern literature on monetary transmission to provide stylized facts on the average lag length and the sources of variability. We collect sixty-seven published studies and examine when prices bottom out after a monetary contraction. The average transmission lag is twenty-nine months, and the maximum decrease in prices reaches 0.9 percent on average after a 1-percentage-point hike in the policy rate. Transmission lags are longer in developed economies (twenty-five to fifty months) than in post-transition economies (ten to twenty months). We find that the factor most effective in explaining this heterogeneity is financial development: greater financial development is associated with slower transmission.

JEL Codes: C83, E52.

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1. Introduction

Policymakers need to know how long it takes before their actions fully transmit to the economy and what determines the speed of transmission. A common claim about the transmission mechanism of monetary policy is that it has "long and variable" lags (Friedman 1972; Batini and Nelson 2001; Goodhart 2001). This view has been embraced by many central banks and taken into account during their decision making: most inflation-targeting central banks have adopted a value between twelve and twenty-four months as their policy horizon (see, for example, Bank of England 1999; European Central Bank 2010). Theoretical models usually imply transmission lags of similar length (Taylor and Wieland 2012), but the results of empirical studies vary widely.

In this paper we quantitatively survey studies that employ vector autoregression (VAR) methods to investigate the effects of monetary policy shocks on the price level. We refer to the horizon at which the response of prices becomes the strongest as the transmission lag, and collect 198 estimates from sixty-seven published studies. The estimates of transmission lags in our sample are indeed variable, and we examine the sources of variability. The meta-analysis approach allows us to investigate both how transmission lags differ across countries and how different estimation methodologies within the VAR framework affect the results. Meta-analysis is a set of tools for summarizing the existing empirical evidence; it has been regularly employed in medical research, but its application has only recently spread to the social sciences, including economics (Stanley 2001; Disdier and Head 2008; Card, Kluve, and Weber 2010; Havranek and Irsova 2011). By bringing together evidence from a large number of studies that use different methods, meta-analysis can extract robust results from a heterogeneous literature.

Several researchers have previously investigated the cross-country differences in monetary transmission. Ehrmann (2000) examines thirteen member countries of the European Union and finds relatively fast transmission to prices for most of the countries: between two and eight quarters. Only France, Italy, and the United Kingdom exhibit transmission lags between twelve and twenty quarters. In contrast, Mojon and Peersman (2003) find that the effects of monetary policy shocks in European economies are much more delayed, with the maximum reaction occurring between sixteen and twenty quarters after the shock. Concerning cross-country differences, Mojon and Peersman (2003) argue that the confidence intervals are too wide to draw any strong conclusions, but they call for further testing of the heterogeneity of impulse responses. Boivin, Giannoni, and Mojon (2009) update the results and conclude that the adoption of the euro contributed to lower heterogeneity in monetary transmission among the member countries.

Cecchetti (1999) finds that for a sample of advanced countries, transmission lags vary between one and twelve quarters. He links the country-specific strength of monetary policy to a number of indicators of financial structure but does not attempt to explain the variation in transmission lags. In a similar vein, Elbourne and de Haan (2006) investigate ten new EU member countries and find that the maximum effects of monetary policy shocks on prices occur between one and ten quarters after the shock. These papers typically look at a small set of countries at a specific point in time; in contrast, we collect estimates of transmission lags from a vast literature that provides evidence for thirty different economies during several decades. Moreover, while some of the previous studies seek to explain the differences in the strength of transmission, they remain silent about the factors driving transmission speed.

In this paper we attempt to fill this gap and associate the differences in transmission lags with a number of country and study characteristics. Our results suggest that the transmission lags reported in the literature really do vary substantially: the average lag, corrected for misspecification in some studies, is twenty-nine months, with a standard deviation of nineteen months. Post-transition economies in our sample exhibit significantly faster transmission than advanced economies, and the only robust country-specific determinant of the length of transmission is the degree of financial development. In developed countries, financial institutions have more opportunities to hedge against surprises in monetary policy stance, causing greater delays in the transmission of monetary policy shocks. Concerning variables that describe the methods used by primary studies, the frequency of the data employed matters for the reported transmission lags. Our results suggest that researchers who use monthly data instead of quarterly data report systematically faster transmission.

The remainder of the paper is structured as follows. Section 2 presents descriptive evidence concerning the differences in transmission lags. Section 3 links the variation in transmission lags to thirty country- and study-specific variables. Section 4 contains robustness checks. Section 5 summarizes the implications of our key results.

2. Estimating the Average Lag

We attempt to gather all published studies on monetary transmission that fulfill the following three inclusion criteria. First, the study must present an impulse response of the price level to a shock in the policy rate (that is, we exclude impulse responses of the inflation rate). Second, the impulse response in the study must correspond to a 1-percentage-point shock in the interest rate, or the size of the monetary policy shock must be presented so that we can normalize the response. Third, we only include studies that present confidence intervals around the impulse responses—as a simple indicator of quality. The primary studies fulfilling the inclusion criteria are listed in table 1. More details describing the search strategy can be found in a related paper (Rusnak, Havranek, and Horvath 2013), examining which method choices are associated with reporting the "price puzzle" (the short-term increase in the price level following a monetary contraction).

After imposition of the inclusion criteria, our database contains 198 impulse responses taken from sixty-seven previously published studies and provides evidence on the monetary transmission mechanism for thirty countries, mostly developed and post-transition economies. The database is available in the online appendix (http://meta-analysis.cz/lags/index.html). For each impulse response, we evaluate the horizon at which the decrease in prices following the monetary contraction reaches its maximum. The literature reports two general types of impulse responses, both of which are depicted in figure 1. The left-hand panel shows a hump-shaped (also called U-shaped) impulse response: prices decrease and bounce back after some time following a monetary policy shock; the monetary contraction stabilizes prices at a lower level or the effect gradually dies out. The dashed line denotes the maximum effect, and we label the corresponding number of months passed since the monetary contraction as the transmission lag. In contrast, the right-hand panel shows a strictly decreasing impulse response: prices neither stabilize

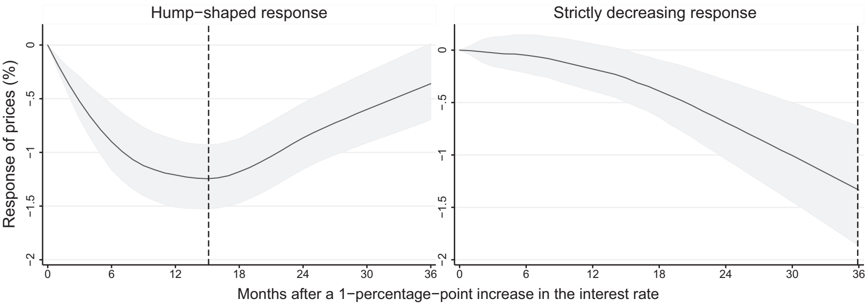
Table 1. List of Primary Studies

Andries (2008)	Jang & Ogaki (2004)
Anzuini & Levy (2007)	Jaroncinski (2010)
Arin & Jolly (2005)	Jarocinski & Smets (2008)
Bagliano & Favero (1998, 1999)	Kim (2001, 2002)
Banbura, Giannone, & Reichlin (2010)	Krusec (2010)
Belviso & Milani (2006)	Kubo (2008)
Bernanke, Boivin, & Eliasz (2005)	Lagana & Mountford (2005)
Bernanke, Gertler, & Watson (1997)	Leeper, Sims, & Zha (1996)
Boivin & Giannoni (2009)	Lange (2010)
Borys, Horvath, & Franta (2009)	Li, Iscan, & Xu (2010)
Bredin & O'Reilly (2004)	McMillin (2001)
Brissimis & Magginas (2006)	Mertens (2008)
Brunner (2000)	Minella (2003)
Buckle et al. (2007)	Mojon (2008)
Cespedes, Lima, & Maka (2008)	Mojon & Peersman (2001)
Christiano, Eichenbaum, & Evans (1996, 1999)	Mountford (2005)
Cushman & Zha (1997)	Nakashima (2006)
De Arcangelis & Di Giorgio (2001)	Normandin & Phaneuf (2004)
Dedola & Lippi (2005)	Oros & Roocea-Turcu (2009)
Eichenbaum (1992)	Peersman (2004, 2005)
Eickmeier, Hofmann, & Worms (2009)	Peersman & Smets (2001)
Elbourne (2008)	Peersman & Straub (2009)
Elbourne & de Haan (2006, 2009)	Pobre (2003)
European Forecasting Network (2004)	Rafiq & Mallick (2008)
Forni & Gambetti (2010)	Romer & Romer (2004)
Fujiwara (2004)	Shioji (2000)
Gan & Soon (2003)	Sims & Zha (1998)
Hanson (2004)	Smets (1997)
Horvath & Rusnak (2009)	Sousa & Zaghini (2008)
Hulsewig, Mayer, & Wollmershauser (2006)	Vargas-Silva (2008)
	Voss & Willard (2009)
	Wu (2003)

Notes: The search for primary studies was terminated on September 15, 2010. A list of excluded studies, with reasons for exclusion, is available in the online appendix.

nor bounce back within the time frame reported by the authors (impulse response functions are usually constructed for a five-year horizon). In this case the response of the price level becomes the strongest in the last reported horizon, so we label the last horizon as the transmission lag.

Figure 1. Stylized Impulse Responses

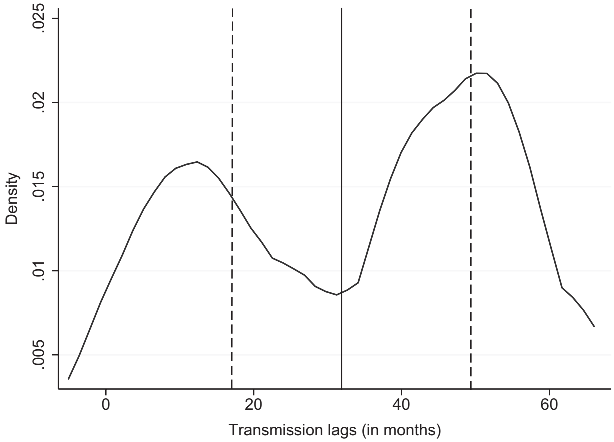


Notes: The figure depicts stylized examples of the price level's response to a 1-percentage-point increase in the policy rate. The dashed lines denote the number of months to the maximum decrease in prices.

Researchers often discuss the number of months to the maximum decrease in prices in the case of hump-shaped impulse responses. On the other hand, researchers rarely interpret the timing of the maximum decrease in prices for strictly decreasing impulse responses, as the implied transmission lag often seems implausibly long. Moreover, a strictly decreasing response may indicate non-stationarity of the estimated VAR system (Lütkepohl 2005). Nevertheless, we do not limit our analysis to hump-shaped impulse responses since both types are commonly reported: in the data set we have 100 estimates of transmission lags taken from hump-shaped impulse responses and 98 estimates taken from strictly decreasing impulse responses. We do not prefer any particular shape of the impulse response and focus on inference concerning the average transmission lag, but we additionally report results corresponding solely to hump-shaped impulse responses.

Figure 2 depicts the kernel density plot of the collected estimates; the figure demonstrates that the transmission lags taken from hump-shaped impulse responses are, on average, substantially shorter than the lags taken from strictly decreasing impulse response functions. Numerical details on summary statistics are reported in table 2. The average of all collected transmission lags is 33.5 months, but the average reaches 49.1 months for transmission lags taken from strictly decreasing impulse responses and 18.2 months for hump-shaped impulse responses. In other words, the decrease in prices

Figure 2. Kernel Density of the Estimated Transmission Lags



Notes: The figure is constructed using the Epanechnikov kernel function. The solid vertical line denotes the average number of months to the maximum decrease in prices taken from all the impulse responses. The dashed line on the left denotes the average taken from the hump-shaped impulse responses. The dashed line on the right denotes the average taken from the strictly decreasing impulse response functions.

Table 2. Summary Statistics of the Estimated Transmission Lags

Variable	Obs.	Mean	Median	Std. Dev.	Min.	Max.
Estimates from all Impulse Responses	198	33.5	37	19.4	1	60
Hump-Shaped Impulse Responses	100	18.2	15	14.1	1	57
Strictly Decreasing Impulse Responses	98	49.1	48	8.6	24	60

following a monetary contraction becomes the strongest, on average, after two years and three quarters. Our data also suggest that the average magnitude of the maximum decrease in prices following a 1-percentage-point increase in the policy rate is 0.9 percent (for a

Table 3. Transmission Lags Differ across Countries

Economy	Average Transmission Lag
Developed Economies	
United States	42.2
Euro Area	48.4
Japan	51.3
Germany	33.4
United Kingdom	40.4
France	51.3
Italy	26.6
Post-Transition Economies	
Poland	18.7
Czech Republic	14.8
Hungary	17.9
Slovakia	10.7
Slovenia	17.6

Notes: The table shows the average number of months to the maximum decrease in prices taken from all the impulse responses reported for the corresponding country. We only show results for countries for which the literature has reported at least five impulse responses.

detailed meta-analysis of the strength of monetary transmission at different horizons, see Rusnak, Havranek, and Horvath 2013).

The average of 33.5 is constructed based on data for thirty different countries. To investigate whether transmission lags vary across countries, we report country-specific averages in table 3 (we only show results for countries for which we have collected at least five observations from the literature). We divide the countries into two groups: developed economies and post-transition economies.[1] From the table it is apparent that developed countries display much longer transmission lags than post-transition countries. The developed country with the fastest transmission of monetary policy actions is

[1]The definition of the two groups is somewhat problematic. The Czech Republic, for example, has been considered a developed economy by the World Bank since 2006. We include the country in the second group because pre-2006 time series constitute the bulk of the data used by studies in our sample.

Italy: the corresponding transmission lag reaches 26.6 months. The slowest transmission is found for Japan and France, with a transmission lag equal to 51.3 months. In general, the transmission lags for developed countries seem to vary between approximately twenty-five and fifty months. These values sharply contrast with the results for post-transition countries, where all reported transmission lags lie between ten and twenty months. The result is in line with Jarocinski (2010), who investigates cross-country differences in transmission and finds that post-communist economies exhibit faster transmission than Western European countries. We examine the possible sources of the cross-country heterogeneity in the next section.

3. Explaining the Differences

Two general reasons may explain why the reported transmission lags vary: First, structural differences across countries may cause genuine differences in the speed of transmission. Second, characteristics of the data and other aspects of the methodology employed in the primary studies, such as specification and estimation characteristics, may have a systematic influence on the reported transmission lag.

We collected thirty-three potential explanatory variables. Several structural characteristics that may account for cross-country differences in the monetary transmission mechanism have been suggested in the literature (Dornbusch et al. 1998; Cecchetti 1999; Ehrmann et al. 2003). Therefore, to control for these structural differences we include *GDP per Capita* to represent the country's overall level of the development, *GDP Growth* and *Inflation* to reflect other macroeconomic conditions in the economy, *Financial Development* to capture the importance of the financial structure, *Openness* to cover the exchange rate channel of the transmission mechanism, and *Central Bank Independence* to capture the influence of the institutional setting and credibility on monetary transmission. These variables are computed as averages over the periods that correspond to the estimation periods of the primary studies. The sources of the data for these variables are Penn World Tables, the World Bank's World Development Indicators, and the International Monetary Fund's International Financial Statistics; the central bank independence index is extracted from Arnone et al. (2009). We also include variables that control for data, methodology, and publication characteristics of the primary studies. The definitions of the variables are provided in table 4 together with their summary statistics.

Rather than estimating a regression with an ad hoc subset of explanatory variables, we formally address the model uncertainty inherent in meta-analysis (in other words, many method variables may be important for the reported speed of transmission, but no theory helps us select which ones). There are at least two drawbacks to using simple regression in situations where many potential explanatory variables exist. First, if we put all potential variables into one

Table 4. Description and Summary Statistics of Explanatory Variables

Variable	Description	Mean	Std. Dev.
	Country Characteristics		
GDP per Capita	The logarithm of the country's real GDP per capita.	9.880	0.415
GDP Growth	The average growth rate of the country's real GDP.	2.644	1.042
Inflation	The average inflation of the country.	0.078	0.145
Financial Dev.	The financial development of the country measured by (domestic credit to private sector)/GDP.	0.835	0.408
Openness	The trade openness of the country measured by (exports + imports)/GDP.	0.452	0.397
CB Independence	A measure of central bank independence (Arnone et al. 2009)	0.773	0.145
	Data Characteristics		
Monthly	= 1 if monthly data are used.	0.626	0.485
No. of Observations	The logarithm of the number of observations used.	4.876	0.661
Average Year	The average year of the data used (2000 as a base).	−9.053	7.779

(continued)

Table 4. (Continued)

Variable	Description	Mean	Std. Dev.
Specification Characteristics			
GDP Deflator	= 1 if the GDP deflator is used instead of the consumer price index as a measure of prices.	0.172	0.378
Single Regime	= 1 if the VAR is estimated over a period of a single monetary policy regime.	0.293	0.456
No. of Lags	The number of lags in the model, normalized by frequency: lags/frequency.	0.614	0.373
Commodity Prices	= 1 if a commodity price index is included.	0.626	0.485
Money	= 1 if a monetary aggregate is included.	0.545	0.499
Foreign Variables	= 1 if at least one foreign variable is included.	0.444	0.498
Time Trend	= 1 if a time trend is included.	0.131	0.339
Seasonal	= 1 if seasonal dummies are included.	0.146	0.354
No. of Variables	The logarithm of the number of endogenous variables included in the VAR.	1.748	0.391
Industrial Prod.	= 1 if industrial production is used as a measure of economic activity.	0.429	0.496
Output Gap	= 1 if the output gap is used as a measure of economic activity.	0.030	0.172
Other Measures	= 1 if another measure of economic activity is used (employment, expenditures).	0.121	0.327
Estimation Characteristics			
BVAR	= 1 if a Bayesian VAR is estimated.	0.121	0.327
FAVAR	= 1 if a factor-augmented VAR is estimated.	0.051	0.220
SVAR	= 1 if non-recursive identification is employed.	0.313	0.465
Sign Restrictions	= 1 if sign restrictions are employed.	0.152	0.359

(continued)

Table 4. (Continued)

Variable	Description	Mean	Std. Dev.
Publication Characteristics			
Strictly Decreasing	The reported impulse response function is strictly decreasing (that is, it shows the maximum decrease in prices in the last displayed horizon).	0.495	0.501
Price Puzzle	The reported impulse response exhibits the price puzzle.	0.530	0.500
Study Citations	The logarithm of [(Google Scholar citations of the study)/(age of the study) + 1].	1.875	1.292
Impact	The recursive RePEc impact factor of the outlet.	0.900	2.417
Central Banker	= 1 if at least one co-author is affiliated with a central bank.	0.424	0.495
Policymaker	= 1 if at least one co-author is affiliated with a Ministry of Finance, IMF, OECD, or BIS.	0.061	0.239
Native	= 1 if at least one co-author is native to the investigated country.	0.449	0.499
Publication Year	The year of publication (2000 as a base).	4.894	3.889

Note: The sources of data for country characteristics are Penn World Tables, the World Bank's World Development Indicators, and the International Monetary Fund's International Financial Statistics.

regression, the standard errors get inflated since many redundant variables are included. Second, sequential testing (or the "general-to-specific" approach) brings about the possibility of excluding relevant variables.

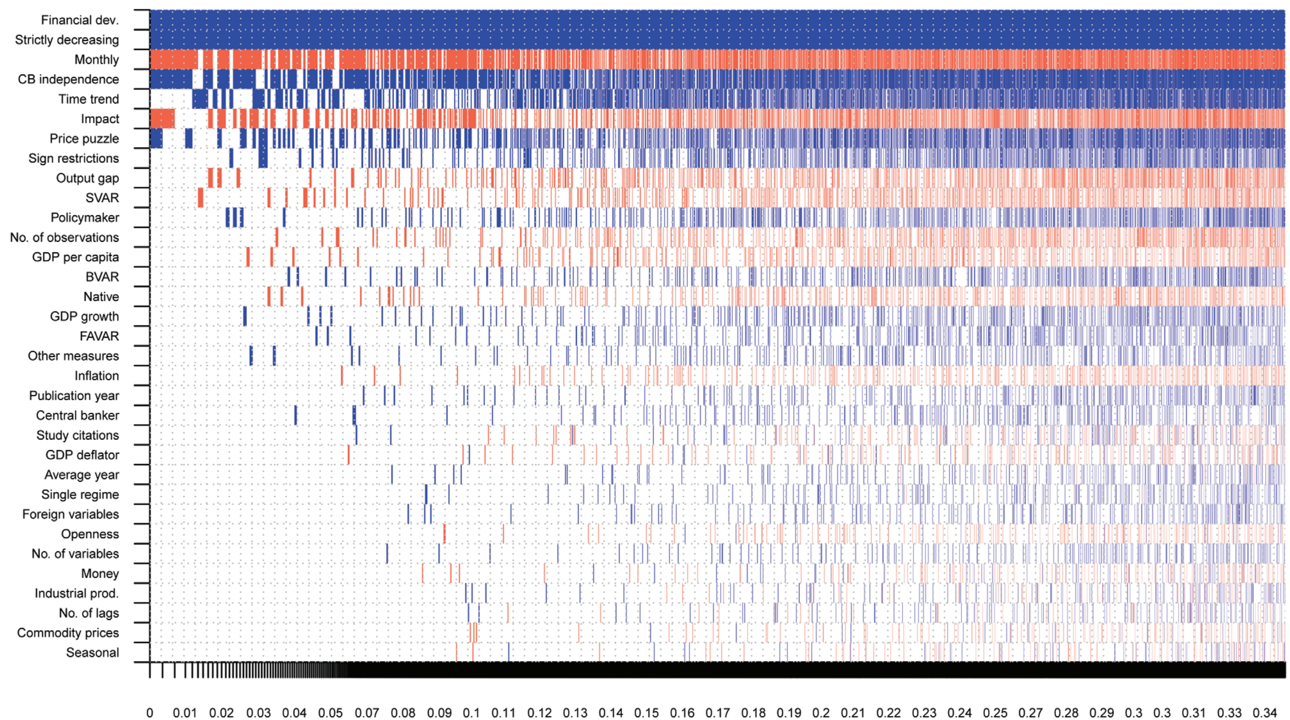
To address these issues, Bayesian model averaging (BMA) is employed frequently in the literature on the determinants of economic growth (Fernandez, Ley, and Steel 2001; Sala-I-Martin, Doppelhofer, and Miller 2004; Durlauf, Kourtellos, and Tan 2008; Feldkircher and Zeugner 2009; Eicher, Papageorgiou, and Raftery 2011). Recently, BMA has been used to address other questions as well (see Moral-Benito 2011 for a survey). The idea of BMA is to go through all possible combinations of regressors and weight them according to their model fit. BMA thus provides results robust to model uncertainty, which arises when little or nothing is known ex ante about the correct set of explanatory variables. An accessible introduction to BMA can be found in Koop (2003); technical details concerning the implementation of the method are provided by Feldkircher and Zeugner (2009).

Because we consider thirty-three potential explanatory variables, it is not technically feasible to enumerate all 2^{33} of their possible combinations; on a typical personal computer this would take several months. In such cases, Markov chain Monte Carlo methods are used to go through the most important models. We employ the priors suggested by Eicher, Papageorgiou, and Raftery (2011), who recommend using the uniform model prior and the unit information prior for the parameters, since these priors perform well in forecasting exercises. Following Fernandez, Ley, and Steel (2001), we run the estimation with 200 million iterations, ensuring a good degree of convergence. Appendix 1 provides diagnostics of our BMA estimation; the online appendix provides R and Stata codes.

The results of the BMA estimation are reported graphically in figure 3. The columns represent individual regression models where the transmission lag is regressed on variables for which the corresponding cell is not blank. For example, the explanatory variables in the first model from the left are *Financial Development*, *Strictly Decreasing*, *Monthly*, *CB Independence*, *Impact*, and *Price Puzzle*. The width of the columns is proportional to the so-called posterior model probabilities; that is, it captures the weight each model gets in the BMA exercise. The figure only shows the 5,000 models with the highest posterior model probabilities. The best models are displayed on the left-hand side and are relatively parsimonious compared with those with low posterior model probabilities. Explanatory variables in the figure are displayed in descending order according to their posterior inclusion probabilities (the sum of the posterior probabilities of the models they are included in). In other words, the variables at the top of the figure are robustly important for the explanation of the variation in transmission lags, whereas the variables at the bottom of the figure do not matter much.

The color (shading in the print version of this paper) of the cell corresponding to each variable included in a model represents

Figure 3. Bayesian Model Averaging, Model Inclusion



Notes: Response variable: transmission lag (the number of months to the maximum decrease in prices taken from the impulse responses). Columns denote individual models; variables are sorted by posterior inclusion probability in descending order. Blue color (darker in grayscale) = the variable is included and the estimated sign is positive. Red color (lighter in grayscale) = the variable is included and the estimated sign is negative. No color = the variable is not included in the model. The horizontal axis measures cumulative posterior model probabilities. Only the 5,000 models with the highest posterior model probabilities are shown.

the estimated sign of the regression parameter. Blue (darker in grayscale) denotes a positive sign, and red (lighter in grayscale) denotes a negative sign. For example, in the first model from the left the estimated regression sign is positive for *Financial Development*, positive for *Strictly Decreasing*, negative for *Monthly*, positive for *CB Independence*, negative for *Impact*, and positive for *Price Puzzle*. As can be seen from the figure, variables with high posterior inclusion probabilities usually exhibit quite stable regression signs. Nevertheless, for a more precise discussion of the importance of individual variables (analogous to statistical significance in the frequentist case), we need to turn to the numerical results of the BMA estimation, reported in table 5.

Table 5 shows the posterior means (weighted averages of the models displayed in figure 3) for all regression parameters and the corresponding posterior standard deviations. According to Masanjala and Papageorgiou (2008), variables with the ratio of the posterior mean to the posterior standard deviation larger than 1.3 can be considered effective (or "statistically significant" in the frequentist case). There are only three such variables: *Financial Development*, *Monthly*, and *Strictly Decreasing*. First, our results suggest that a higher degree of financial development in the country is associated with slower transmission of monetary policy shocks to the price level. Moreover, when researchers use monthly data in the VAR system, they are more likely to report shorter transmission lags. The BMA exercise also corroborates that the transmission lags taken from strictly decreasing impulse responses are much longer than the lags taken from hump-shaped impulse responses; the difference is approximately twenty-six months.

While many of the method characteristics appear to be relatively unimportant for the explanation of the reported transmission lags, a few (for example, *Sign Restrictions* or *Output Gap*) have moderate posterior inclusion probabilities. Because some of the method choices are generally considered misspecifications in the literature, we use the results of the BMA estimation to filter out the effects of these misspecifications from the average transmission lag. In other words, we define an ideal study with "best-practice" methodology and maximum publication characteristics (for example, the impact factor and the number of citations). Then we plug the chosen values of the

Table 5. Why Do Transmission Lags Vary?

Variable	PIP	Posterior Mean	Posterior Std. Dev.	Standardized Coef.
Country Characteristics				
GDP per Capita	0.099	−0.447	1.647	−0.0096
GDP Growth	0.087	0.111	0.444	0.0059
Inflation	0.053	−0.337	1.918	−0.0025
Financial Dev.	**1.000**	**12.492**	**3.166**	**0.2630**
Openness	0.029	−0.056	0.631	−0.0011
CB Independence	0.705	13.370	10.412	0.1002
Data Characteristics				
Monthly	**0.730**	**−4.175**	**3.036**	**−0.1045**
No. of Observations	0.127	−0.362	1.136	−0.0123
Average Year	0.032	0.003	0.030	0.0012
Specification Characteristics				
GDP Deflator	0.035	−0.052	0.584	−0.0010
Single Regime	0.031	0.039	0.395	0.0009
No. of Lags	0.023	0.014	0.436	0.0003
Commodity Prices	0.022	−0.009	0.246	−0.0002
Money	0.026	−0.011	0.286	−0.0003
Foreign Variables	0.030	0.039	0.385	0.0010
Time Trend	0.472	3.681	4.480	0.0643
Seasonal	0.020	−0.004	0.307	−0.0001
No. of Variables	0.028	0.036	0.400	0.0007
Industrial Prod.	0.025	0.008	0.352	0.0002
Output Gap	0.189	−1.464	3.566	−0.0130
Other Measures	0.059	0.199	1.038	0.0034
Estimation Characteristics				
BVAR	0.096	0.337	1.278	0.0057
FAVAR	0.068	0.304	1.444	0.0034
SVAR	0.153	−0.468	1.303	−0.0112
Sign Restrictions	0.200	0.954	2.232	0.0177

(continued)

Table 5. (Continued)

Variable	PIP	Posterior Mean	Posterior Std. Dev.	Standardized Coef.
Publication Characteristics				
Strictly Decreasing	**1.000**	**26.122**	**1.798**	**0.6757**
Price Puzzle	0.383	1.359	1.999	0.0351
Study Citations	0.039	−0.005	0.205	−0.0003
Impact	0.423	−0.305	0.414	−0.0381
Central Banker	0.044	0.075	0.497	0.0019
Policymaker	0.149	0.858	2.426	0.0106
Native	0.091	−0.221	0.865	−0.0057
Publication Year	0.048	0.011	0.070	0.0022
Constant	1.000	7.271	NA	0.3752

Notes: Estimated by Bayesian model averaging. Response variable: transmission lag (the number of months to the maximum decrease in prices taken from impulse responses). PIP = posterior inclusion probability. The posterior mean is analogous to the estimate of the regression coefficient in a standard regression; the posterior standard deviation is analogous to the standard error of the regression coefficient in a standard regression. Variables with posterior mean larger than 1.3 posterior standard deviations are typeset in bold; we consider such variables effective (following Masanjala & Papageorgiou 2008).

explanatory variables into the results of the BMA estimation and evaluate the implied transmission lag.

For the definition of the "ideal" study we prefer the use of more observations in the VAR system (that is, we plug in the sample maximum for variable *No. of Observations*), more recent data (*Average Year*), the estimation of the VAR system over a period of a single monetary policy regime (*Single Regime*), the inclusion of commodity prices in the VAR system (*Commodity Prices*), the inclusion of foreign variables (*Foreign*), the inclusion of seasonal dummies (*Seasonal*), the inclusion of more variables in the VAR (*No. of Variables*), the use of the output gap as a measure of economic activity (*Output Gap*; *Industrial Production* and *Other Measures* are set to zero), the use of Bayesian VAR (*BVAR*), the use of sign restrictions (*Sign Restrictions*; *FAVAR* and *SVAR* are set to zero), more citations of the study (*Study Citations*), and a higher impact factor (*Impact*). All other variables are set to their sample means.

The average transmission lag implied by our definition of the ideal study is 29.2 months, which is less than the simple average by approximately 4 months. The estimated transmission lag hardly changes when FAVAR or SVAR are chosen for the definition of best-practice methodology; the result is also robust to other marginal changes to the definition. On the other hand, the implied transmission lag decreases greatly if one prefers hump-shaped impulse responses: in this case the estimated value is only 16.3 months. Moreover, if one prefers impulse responses that do not exhibit the price puzzle, the implied value diminishes by another month. In sum, when the effect of misspecifications is filtered out and one does not prefer any particular type of impulse response, our results suggest that prices bottom out approximately two-and-a-half years after a monetary contraction.

4. Robustness Checks and Additional Results

Our analysis, based on the results of BMA, attributes the differences in transmission lags between (and within) developed and post-transition countries to differences in the level of financial development. The BMA exercise carried out in the previous section controls for methodology and other aspects associated with estimating impulse responses. Nevertheless, it is still useful to illustrate that the differences in results between developed and post-transition countries are not caused by differences in the frequency of reporting strictly decreasing impulse responses or impulse responses showing the price puzzle. To this end, we replicate table 3 but only focus on the sub-samples of impulse responses that are hump shaped (table 6) or that do not exhibit the price puzzle (table 7).

The tables show that developed countries exhibit longer transmission lags even if strictly decreasing impulse responses or impulse responses showing the price puzzle are disregarded. But the difference is smaller for the sub-sample of hump-shaped impulse responses, where some developed countries (for example, Italy) exhibit shorter transmission lags than some post-transition countries (for example, Poland). There are two potential explanations of this result. First, compared with table 3, now we only have approximately half the number of observations, and for some countries we are even

Table 6. Transmission Lags Differ across Countries (hump-shaped impulse responses)

Economy	**Average Transmission Lag**
Developed Economies	
United States	23.2
Euro Area	39.5
Japan	40.5
Germany	19.4
United Kingdom	10.0
France	24.0
Italy	9.2
Post-Transition Economies	
Poland	15.4
Czech Republic	14.8
Hungary	14.4
Slovakia	5.0
Slovenia	13.0

Notes: The table shows the average number of months to the maximum decrease in prices taken from the impulse responses reported for the corresponding country. Strictly decreasing impulse responses are omitted from this analysis.

left with less than five impulse responses, which makes the average number imprecise. Second, strictly decreasing impulse responses, which are associated with longer transmission lags, are more often reported for developed economies than for post-transition economies. The reason is that shorter data spans are available for post-transition countries, which makes researchers often choose monthly data. Since monthly data are associated with shorter reported lags, researchers investigating monetary transmission in post-transition countries are less likely to report strictly decreasing impulse responses. Nevertheless, in the BMA estimation we control for data frequency as well as for the shape of the impulse response, and financial development still emerges as the most important factor causing cross-country differences in transmission lags.

In our baseline model from the previous section we combine data from hump-shaped and strictly decreasing impulse response

Table 7. Transmission Lags Differ across Countries (responses not showing the price puzzle)

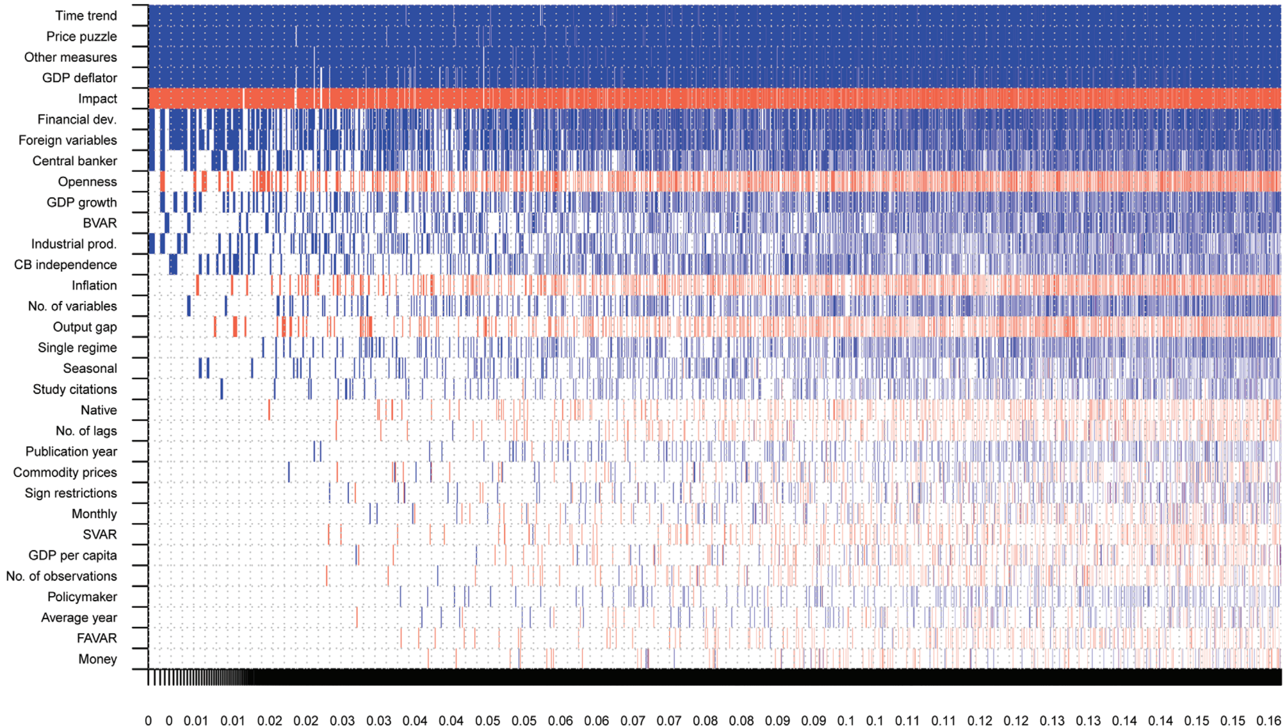
Economy	Average Transmission Lag
Developed Economies	
United States	40.5
Euro Area	49.2
Japan	57.0
Germany	34.5
United Kingdom	10.0
France	52.8
Italy	30.0
Post-Transition Economies	
Poland	14.0
Czech Republic	8.8
Hungary	15.4
Slovakia	10.7
Slovenia	17.8

Notes: The table shows the average number of months to the maximum decrease in prices taken from the impulse responses reported for the corresponding country. Impulse responses exhibiting the price puzzle are omitted from this analysis.

functions. For strictly decreasing impulse responses, however, our definition of the transmission lag (the maximum effect of a monetary contraction on prices) is influenced by the reporting window chosen by researchers. To see whether the result concerning financial development is robust to omitting data from strictly decreasing impulse response functions, we repeat the BMA estimation from the previous section using a sub-sample of hump-shaped impulse responses.

The results are presented graphically in figure 4. The variable corresponding to financial development retains its estimated sign from the baseline model and still represents the most important country-level factor explaining the differences in monetary transmission lags. Compared with the baseline model, in this specification additional method variables seem to be important. The use of other measures than GDP, the output gap, or industrial production as a proxy for economic activity is associated with slower reported transmission.

Figure 4. Bayesian Model Averaging, Model Inclusion (hump-shaped impulse responses)



Notes: Response variable: transmission lag (the number of months to the maximum decrease in prices taken from the impulse responses). Only transmission lags from hump-shaped impulse responses are included in the estimation. Columns denote individual models; variables are sorted by posterior inclusion probability in descending order. Blue color (darker in grayscale) = the variable is included and the estimated sign is positive. Red color (lighter in grayscale) = the variable is included and the estimated sign is negative. No color = the variable is not included in the model. The horizontal axis measures cumulative posterior model probabilities. Only the 5,000 models with the highest posterior model probabilities are shown.

The choice to represent prices by the GDP deflator instead of the consumer price index on average translates into longer transmission lags. Also, the inclusion of foreign variables in the VAR system makes researchers report slower transmission.

By excluding all strictly decreasing impulse responses, however, we lose half of the information contained in our data set. For this reason we consider a second way of taking into account the effect of the reporting window: censored regression. The reporting window of primary studies is often set to five years, so we use sixty months as the upper limit and estimate the regression using the Tobit model. (Changing the upper limit to three or four years, the amount of time sometimes used as the reporting window, does not qualitatively affect the results.) Unfortunately, it is cumbersome to estimate Tobit using BMA. Thus, we estimate a general model with all potential explanatory variables and then employ the general-to-specific approach. The general model is reported in table 12 in appendix 2. The inclusion of all potential explanatory variables, many of which may not be important for explanation of the differences in transmission lags, inflates the standard errors of the relevant variables. Hence, in the next step we eliminate the insignificant variables one by one, starting from the least significant variable. As mentioned before, the general-to-specific approach is far from perfect—but in this case it represents an easy alternative to BMA.

The results presented in table 8 and table 12 corroborate that, even using this methodology, financial development is highly important for the explanation of transmission lags; in both specifications it is significant at the 1 percent level. The use of monthly data is associated with faster reported transmission, which is also consistent with the baseline model. In line with our results from the previous sections, table 8 suggests that impulse responses exhibiting the price puzzle are likely to show longer transmission lags. In contrast to the baseline model, some other variables seem to be important as well: *GDP per Capita*, *Inflation*, and *Openness*, among others. Because, however, the results concerning these variables are not confirmed by other specifications, we do not want to put much emphasis on these variables. The variable *Strictly Decreasing*, which was crucial for the baseline BMA estimation, is omitted from the present analysis because it defines the censoring process.

Table 8. Censored Regression, Specific Model

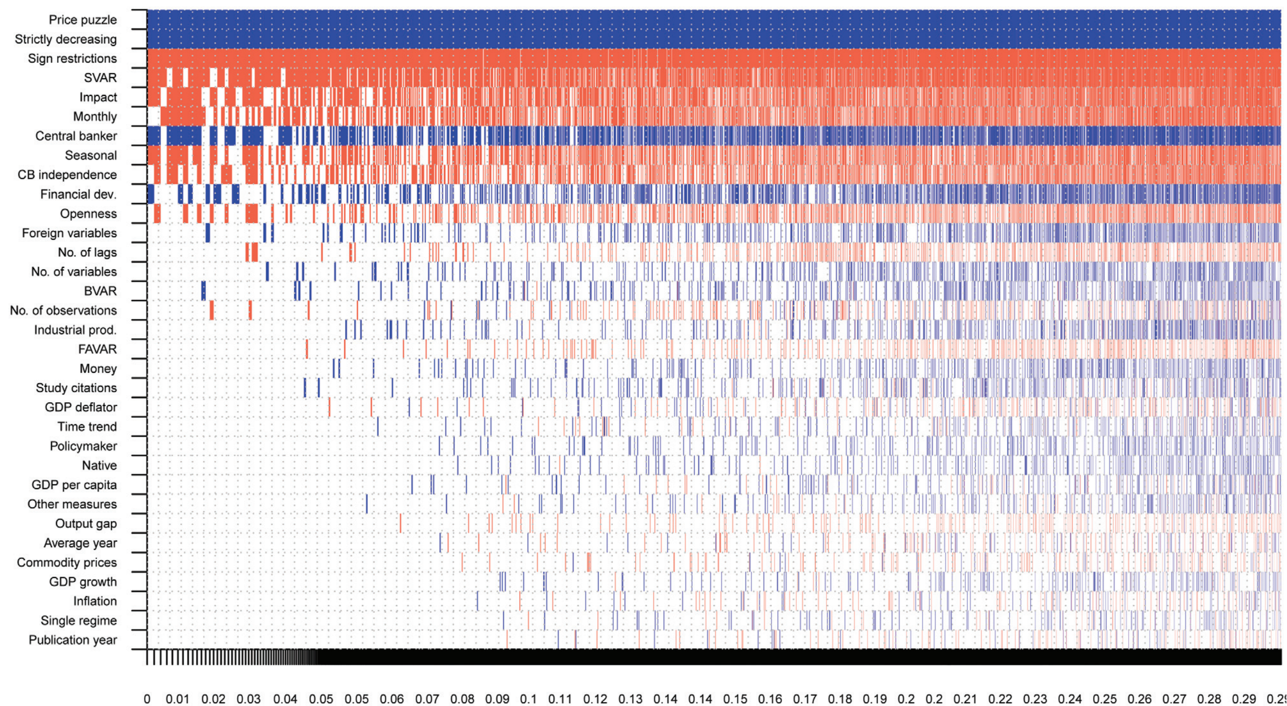
Response Variable: Transmission Lag		
GDP per Capita	−11.48**	(4.793)
Price Puzzle	4.667**	(2.343)
Inflation	−17.25**	(8.739)
Financial Dev.	21.61***	(5.375)
Openness	−12.67***	(4.670)
CB Independence	29.38***	(10.64)
Monthly	−12.04***	(3.821)
No. of Observations	6.526**	(2.951)
Policymaker	12.37**	(5.012)
Constant	86.58**	(43.69)
Observations	198	

Notes: Standard errors in parentheses. Estimated by Tobit with the upper limit for transmission lags equal to sixty months. The specific model is a result of the backward stepwise regression procedure applied to the general model, which is reported in appendix 2 (the cut-off level for p-values was 0.1). ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

So far we have analyzed the time it takes before a monetary contraction translates into the maximum effect on the price level. The extent of the maximum effect, however, varies a lot across different impulse responses. Therefore, as a complement to the previous analysis, we collect data on how long it takes before a 1-percentage-point increase in the policy rate leads to a decrease in the price level of 0.1 percent. This number was chosen because most of the impulse response functions in our sample (173 out of 198) reach this level at some point. In contrast, if we chose a value of 0.5 percent, for example, we would have to disregard almost two-thirds of all the impulse responses.

The results of the BMA estimation using the new response variable are reported in figure 5. Again, the shape of the impulse response and the frequency of the data used in the VAR system seem to be associated with the reported transmission lag. Financial development still belongs among the most important country-level variables, together with central bank independence and trade openness. According to this specification, monetary transmission is faster in countries that are more open to international trade and that have

Figure 5. Bayesian Model Averaging, Model Inclusion (time to –0.1 percent decrease in prices)



Notes: Response variable: the number of months to a –0.1 percent decrease in prices following a 1-percentage-point increase in the policy rate. Columns denote individual models; variables are sorted by posterior inclusion probability in descending order. Blue color (darker in grayscale) = the variable is included and the estimated sign is positive. Red color (lighter in grayscale) = the variable is included and the estimated sign is negative. No color = the variable is not included in the model. The horizontal axis measures cumulative posterior model probabilities. Only the 5,000 models with the highest posterior model probabilities are shown.

a more independent central bank; these results may point at the importance of the exchange rate and expectation channels of monetary transmission. Additionally, some method variables matter for the estimated transmission lag: for example, the use of sign restrictions, structural VAR, and seasonal adjustment. Our results also suggest that articles published in journals with a high impact factor tend to present faster monetary transmission.

5. Concluding Remarks

Building on a sample of sixty-seven previous empirical studies, we examine why the reported transmission lags of monetary policy vary. Our results suggest that the cross-country variation in transmission is robustly associated with differences in financial development. To explain the variation of results between different studies for the same country, the frequency of the data used is important: the use of monthly data makes researchers report transmission faster by four months, holding other things constant. This is in line with Ghysels (2012), who shows that responses from low- and high-frequency VARs may indeed differ due to mixed-frequency sampling or temporal aggregation of shocks. The shape of the impulse response matters as well. Strictly decreasing impulse responses, which may suggest that the underlying VAR system is not stationary, exhibit much longer transmission lags.

The key result of our meta-analysis is that a higher degree of financial development translates into slower transmission of monetary policy. The finding can be interpreted in the following way. If financial institutions lack opportunities to protect themselves against unexpected monetary policy actions (due to either low levels of capitalization or low sophistication of financial instruments provided by the undeveloped financial system), they need to react immediately to monetary policy shocks, thus speeding up the transmission. In financially developed countries, in contrast, financial institutions have more opportunities to hedge against surprises in monetary policy stance, causing greater delays in the transmission of monetary policy shocks.

More generally, our results imply that monetary transmission may slow down as the financial system of emerging countries develops, since financial innovations allow banks to protect better against surprise shocks in monetary policy.

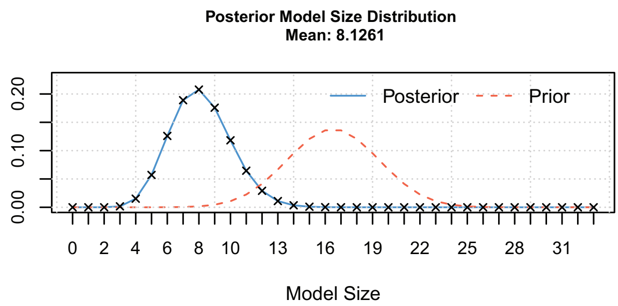
Appendix 1. Diagnostics of Bayesian Model Averaging

Table 9. Summary of BMA Estimation (baseline model)

Mean No. Regressors	*Draws*	*Burn-Ins*	*Time*
8.1261	$2 \cdot 10^8$	$1 \cdot 10^8$	11.88852 hours
No. Models Visited	*Modelspace*	*Visited*	*Topmodels*
83,511,152	$8.6 \cdot 10^9$	0.97%	34%
Corr. PMP	*No. Obs.*	*Model Prior*	*g-Prior*
0.9999	198	Uniform/16.5	UIP
Shrinkage Stats			
Av. = 0.995			

Note: UIP = unit information prior, PMP = posterior model probability.

Figure 6. Model Size and Convergence (baseline model)



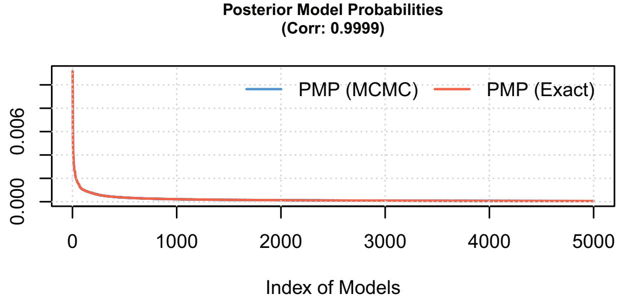


Table 10. Summary of BMA Estimation (hump-shaped impulse responses)

Mean No. Regressors	*Draws*	*Burn-Ins*	*Time*
10.7143	$2 \cdot 10^8$	$1 \cdot 10^8$	12.15215 hours
No. Models Visited	*Modelspace*	*Visited*	*Topmodels*
104,093,439	$4.3 \cdot 10^9$	2.4%	16%
Corr. PMP	*No. Obs.*	*Model Prior*	*g-Prior*
0.9997	100	Uniform/16	UIP
Shrinkage Stats			
Av. = 0.9901			

Note: UIP = unit information prior, PMP = posterior model probability.

Figure 7. Model Size and Convergence (hump-shaped impulse responses)

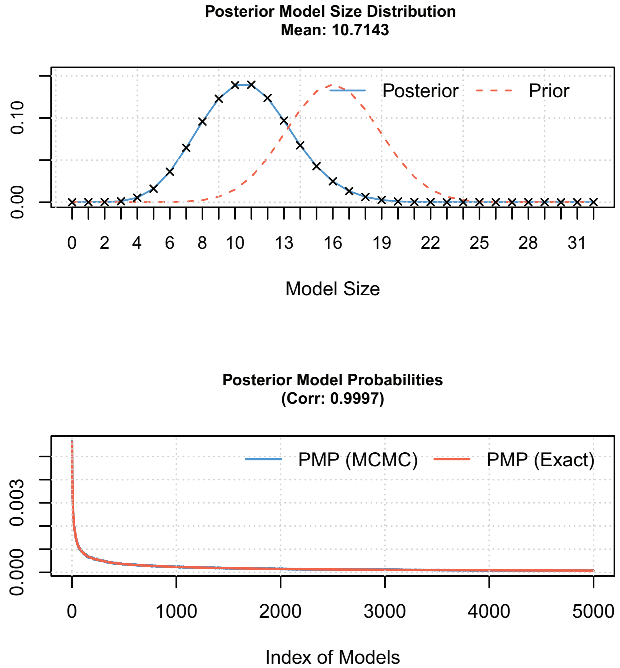
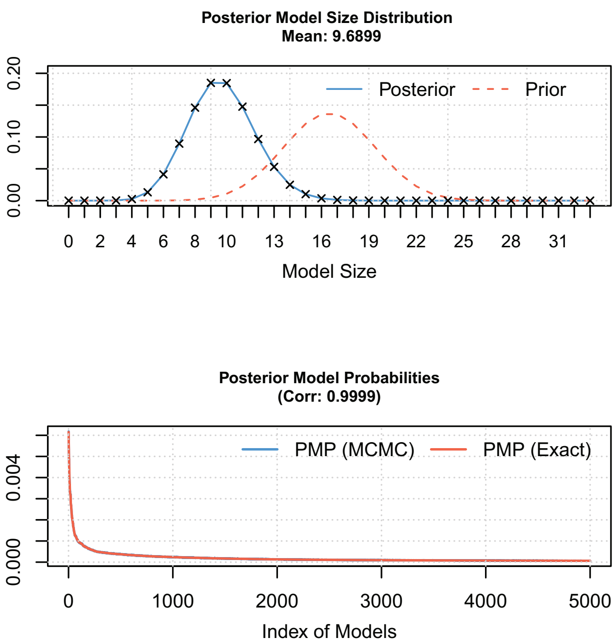


Table 11. Summary of BMA Estimation (time to −0.1 percent decrease in prices)

Mean No. Regressors	*Draws*	*Burn-Ins*	*Time*
9.6899	$2 \cdot 10^8$	$1 \cdot 10^8$	12.0976 hours
No. Models Visited	*Modelspace*	*Visited*	*Topmodels*
87,125,827	$8.6 \cdot 10^9$	1%	30%
Corr. PMP	*No. Obs.*	*Model Prior*	*g-Prior*
0.9999	173	Uniform/16.5	UIP
Shrinkage Stats			
Av. = 0.9943			

Note: UIP = unit information prior, PMP = posterior model probability.

Figure 8. Model Size and Convergence (time to –0.1 percent decrease in prices)



Appendix 2. Results of Censored Regression

Table 12. Censored Regression, General Model (all variables are included)

Response Variable: Transmission Lag		
Country Characteristics		
GDP per Capita	−9.792*	(5.192)
GDP Growth	1.512	(1.346)
Inflation	−17.41**	(8.695)
Financial Dev.	22.17***	(6.084)
Openness	−11.16**	(5.595)
CB Independence	30.20**	(12.27)
Data Characteristics		
Monthly	−4.402	(6.920)
No. of Observations	4.287	(5.186)
Average Year	−0.168	(0.367)
Specification Characteristics		
GDP Deflator	5.102	(4.281)
Single Regime	4.143	(3.497)
No. of Lags	8.132*	(4.744)
Commodity Prices	−1.284	(2.861)
Money	1.768	(2.949)
Foreign Variables	4.102	(3.400)
Time Trend	2.700	(5.791)
Seasonal	7.231*	(4.057)
No. of Variables	1.352	(3.536)
Industrial Prod.	−6.785*	(3.904)
Output Gap	−10.41	(7.681)
Other Measures	−6.246	(5.017)
Estimation Characteristics		
BVAR	−1.147	(5.094)
FAVAR	14.53**	(6.525)
SVAR	−4.243	(3.008)
Sign Restrictions	−3.270	(5.163)

(continued)

Table 12. (Continued)

Response Variable: Transmission Lag		
Publication Characteristics		
Price Puzzle	3.651	(2.537)
Study Citations	−0.717	(1.734)
Impact	−0.742	(0.699)
Central Banker	5.313	(3.633)
Policymaker	9.024	(6.137)
Native	−1.996	(3.043)
Publication Year	0.0475	(0.453)
Constant	62.32	(50.10)
Observations	198	

Notes: Standard errors in parentheses. Estimated by Tobit with the upper limit for transmission lags equal to sixty months. ***, **, and * denote significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

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The Safety of Cash and Debit Cards: A Study on the Perception and Behavior of Dutch Consumers*

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This paper investigates the impact of the perceived payment safety on debit card and cash usage. It provides a conceptual framework of safety perception and payment behavior, which is empirically tested using 2008 consumer survey data. The results show that consumers' payment preferences are strongly influenced by their views on the safety of payment instruments. These views are determined mainly by consumers' perception of the likelihood that payment incidents may occur. The seriousness of possible incidents is also considered, though to a much lesser degree. Personal characteristics and experiences of payment incidents are shown to play a significant role here.

JEL Codes: C42, D12, E41.

1. Introduction

Debit cards have grown rapidly into widely used payment instruments at points of sale (POS) in the Netherlands since their introduction in the late 1980s. In 2010, around 58 percent of total sales and 32 percent of total transactions were paid by debit card versus 38 percent and 65 percent in cash (Jonker, Kosse, and Hernandéz 2012). The increasing acceptance and usage of the debit card has

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made it progressively susceptible to fraud—in particular, skimming fraud.[1] Total skimming losses have increased materially over the past few years, from under EUR 4 million in 2005 to EUR 20 million in 2010 (Currence 2011). The scale of skimming fraud is still relatively small compared with the size of the Dutch debit card market,[2] yet the impact on society as a whole could be much larger. Incidents of fraud receive a fair amount of media attention, which is directed at not only the victims but also the entire population. This might affect overall payment behavior inasmuch as consumers may lose confidence in their debit card and shift to other means of payment. Kosse (2013), for example, shows that news about card fraud significantly depresses same-day card usage. Since earlier studies have shown that the debit card is often a fast and cheap payment method (Brits and Winder 2005; McKinsey & Company 2006; EIM 2011), this could eventually harm the efficiency of the entire retail payment system.

In light of this, it is important to have a clear understanding of how consumers assess the safety of payment instruments and of how this affects their payment choices. Understanding the mechanism of safety perception and payment behavior might help policymakers and central bankers preserve consumers' confidence in the safety of the payment system and in cost-efficient payment instruments in particular. A reasonable amount of research has already been carried out in the field of retail payments to better understand market participants' behavior and their underlying motivations.[3] Research into

[1]Total card fraud is often grouped into four main categories: mail non-receipt fraud (the physical card sent by the bank through the mail is intercepted), lost-and-stolen-card fraud (cards being lost or stolen), card-not-present fraud (fraud related to remote payments such as Internet transactions), and skimming fraud (the data on the magnetic stripe of the card is copied and the personal identification number (PIN) is captured in order to produce a counterfeit card).

[2]In 2009, around 0.3 percent of all debit cards were copied, 0.4 percent of all automated teller machines (ATMs) and POS terminals were sabotaged, and total fraud losses amounted to 0.03 percent of total debit card sales (Currence 2011; De Nederlansche Bank 2011).

[3]The many references include Baxter 1983; Stavins 2001; Rochet and Tirole 2003; Wright 2004; Bounie and Abel 2006; Keinonen 2007; Rysman 2007; Bolt, Humphrey, and Uittenbogaard 2008; Borzekowski and Kiser 2008; Klee 2008; Hyytinen and Takalo 2009; Zinman 2009; Ching and Hayashi 2010; and Kosse and Jansen 2013.

consumers' attitudes towards risks and the impact of safety perception on payment behavior, however, is scarce and does not provide a unanimous answer. Several theories and findings suggest that safety is one of the factors considered when choosing how to pay.[4] Others, however, find no evidence of safety playing a role.[5] Therefore, the aim of this paper is to analyze further consumers' payment behavior in relation to safety. More precisely, the objective is to assess the determinants of consumers' safety perception and to examine the impact of perceived safety on the usage of cash and debit cards.

To this end, 2008 consumer survey data is used for various empirical analyses. These analyses depart from the idea that consumers' safety perception of payment instruments is influenced by both their perception of the probability of incidents occurring when carrying or using a particular instrument and their perception of the severity of these incidents. Until now, this two-step approach of separating the probability of losses (PL) and the severity given losses (SGL) has not been considered in retail payments research. It is, however, commonly used in other research fields, such as in economics and finance and in food sciences.[6] The conceptual framework underlying the empirics in this paper further assumes that consumers' views on probabilities and consequences are heterogeneous, varying with personal characteristics and personal experiences.[7] People who have been involved in negative payments-related incidents are assumed to have different views on the likelihood and seriousness of incidents than those who have not. As a final step, the framework presupposes a negative relationship between consumers' safety perception and

[4]See, e.g., Baumol 1952; Humphrey, Pully, and Vesala 1996; Cheney 2006; Benton et al. 2007; Jonker 2007; Bolt and Chakravorti 2008; Borzekowski, Kiser, and Ahmed 2008; He, Huang, and Wright 2008; Alvarez and Lippi 2009; Kahn and Roberds 2009; and Kosse 2013.

[5]See, e.g., Yin and DeVaney 2001 and Schuh and Stavins 2010.

[6]In economics and finance, PD (probability of default) and LGD (loss given default) are often used when modeling credit risks (e.g., Bank for International Settlements 2005). The two-step approach is also found to be useful when modeling risk perception and behavior in fields such as food sciences, environmental sciences, and marketing (e.g., Royal Society 1992; UK Department of the Environment 1995; Rundmo 1996; and Yeung and Morris 2001).

[7]Wildavsky and Dake (1990) and Sapp (2003), for example, find that personal characteristics strongly affect risk perception when examining food technology adoption and risk perception.

their payment choices. Overall, the non-payments-related literature agrees that consumers' overall safety assessment negatively influences behavior; the higher the probability and impact of potential incidents, the higher the probability of consumers seeking risk relief (e.g., Huang 1993; Weinstein 1993; Eom 1994; Yeung and Morris 2001).

The empirical results presented in this paper first demonstrate that consumers' safety perception is influenced mainly by consumers' views on the likelihood that incidents may occur. Consumers who believe that the risk of falling victim to payment loss or fraud is high are more likely to believe that the corresponding means of payment are unsafe. As hypothesized by the conceptual framework, the seriousness of these incidents is also considered, though to a much lesser degree. Second, consumers' beliefs of the likelihood and impact of possible safety incidents are shown to be influenced strongly by experiences and personal characteristics. Generally, people who have been involved in negative payment incidents, women, people living in urbanized areas, and lower-educated and lower-income people think more seriously about the risks and consequences of payment incidents. Finally, this paper demonstrates that consumers' daily payment behavior is significantly influenced by how consumers assess the safety level of the different means of payment. People who perceive particular payment instruments to be unsafe are found to use them less often, reverting to alternative ways of paying. These findings are robust to the inclusion of a variety of consumer characteristics.

This paper proceeds as follows: Section 2 describes the survey methodology and data used for the empirical analyses. Section 3 analyzes the factors influencing consumers' safety perception, while section 4 reports the results on the role of safety in consumers' payment choices. Section 5 concludes and discusses policy implications.

2. Survey Methodology and Data Description

In order to examine the determinants of consumers' safety perception and the role of safety in consumers' payment behavior, an extensive payments survey was conducted in April 2008 among more than 2,000 Dutch consumers. These consumers were drawn from the CentERpanel, a representative panel of Dutch households, managed by the CentERdata research institute, which is closely affiliated with Tilburg University. The objective of the survey was to collect information about consumers' personal backgrounds, payment habits, and subjective judgments on the safety of POS payment instruments. The data were merged with data from the 2008 De Nederlansche Bank (DNB) Household Survey (DHS) to construct a risk-aversion indicator for each respondent. The DHS is a yearly questionnaire collecting information on assets, liabilities, work, housing, mortgages, health, and income and many subjective measures such as expectations as well as investment and savings motives.

The payments survey was answered in full by 1,672 individuals, corresponding to a 65 percent response rate. Table 1 presents an overview of the key survey statistics. Because men, the elderly, and higher-educated people were slightly overrepresented in the sample, the data was weighted by age, gender, and education in order to represent the entire Dutch population. First, the survey data confirm that cash and debit cards are the major POS payment instruments used in the Netherlands, with the majority of the population paying with cash as well as a debit card at least once a week. The electronic purse (e-purse)[8] and credit cards are used less often. Second, the data indicates that, on average, Dutch consumers are positive about the safety of the various POS payment instruments. They were asked to rate the safety of cash, the debit card, the credit card, and the e-purse on a scale from 1 (very unsafe) to 7 (very safe). A distinction was made between using and carrying the payment instruments. Remarkably, the data shows small but significant differences between both aspects. Consumers feel less secure carrying any of the payment instruments than they do in using them for ATM withdrawals or POS payments. In general, they feel most secure carrying the e-purse or a debit card, while cash and the e-purse are perceived to be the

[8]The Dutch national e-purse called Chipknip is a smartcard-based prepaid instrument that provides instant and irrevocable offline transactions at the POS. The chip on the card is loaded via a transfer from a bank account with a maximum of EUR 500 and can then be used at designated POS terminals. Since e-purse transactions do not require the cardholder to enter a PIN, the e-purse is mainly used for small-value payments at, for example, vending and parking machines.

Table 1. Key Survey Statistics

	Total (1)	Cash (2)		Debit Card (3)		E-Purse (4)		Credit Card (5)		ATM (6)
Frequency of Use:										
Every Day		14%		10%		4%		0%		
A Few Times a Week		48%		54%		10%		2%		
Once a Week		20%		15%		7%		2%		
A Few Times a Month		11%		10%		14%		9%		
Once a Month		3%		4%		8%		9%		
Less than Once a Month		3%		4%		24%		45%		
Never		1%		3%		34%		32%		
		Carry	**Use**	**Carry**	**Use**	**Carry**	**Use**	**Carry**	**Use**	**With-drawals**
Perceived Safety Level:										
Mean on a 1–7 Scale		4.89	5.37	5.26	5.31	5.29	5.39	4.93	5.07	4.91
% Unsafe		9%	2%	3%	4%	4%	3%	9%	6%	10%
No. of Obs.		1,664	1,664	1,630	1,624	823	793	869	812	1,656
Perceived Likelihood (Mean on a 1–5 Scale):										
Pickpockets		2.76		2.76		2.76		2.76		
Violent Robbery		2.47		2.47		2.47		2.47		
Loss		2.66		2.66		2.66		2.66		
Falsification			2.56							
Too Little Change			2.43							
Skimming					2.25		2.07		2.38	2.49
PIN Spying					2.68					2.57
Erroneous Debits					1.91		1.78		2.07	

(continued)

Table 1. (Continued)

	Total (1)	Cash (2)		Debit Card (3)		E-Purse (4)		Credit Card (5)		ATM (6)
		Carry	Use	Carry	Use	Carry	Use	Carry	Use	With-drawals
Perceived Consequences (Mean on a 1–5 Scale):										
Pickpockets		3.41		3.61		3.03		3.92		
Violent Robbery		3.96		4.26		3.68		4.19		
Loss		3.17		3.22		2.86		3.60		
Falsification			3.27							
Too Little Change			2.60							
Skimming					3.73		2.96		3.80	3.79
PIN Spying					3.49					3.50
Erroneous Debits					3.16		2.91		3.27	
Personal Experiences:										
Pickpockets	16%									
Violent Robbery	3%									
Loss	31%									
Falsification		12%								
Too Little Change		55%								2%
Skimming					2%				4%	5%
PIN Spying					8%					
Erroneous Debits					5%		2%		10%	

Notes: This table summarizes the information collected by the survey on consumers' payment habits and safety perception. The survey data shown is weighted by age, gender, and education. Percentages represent shares of respondents. Perceived safety levels are shown as means of the scores given by the respondents on a scale from 1 (very unsafe) to 7 (very safe). All means significantly differ from each other at a 1 percent significance level. The results of the two-sample t-tests are available upon request. "% Unsafe" shows the percentage of respondents who gave a score of 1 (very unsafe), 2 (unsafe), or 3 (a little unsafe). Perceived likelihoods and consequences are shown as means of the scores given by the respondents on a scale from 1 (very low) to 5 (very high).

safest instruments with which to pay. There is relatively considerable dissatisfaction with the safety of using and carrying credit cards, carrying cash, and making ATM withdrawals, with about 10 percent of respondents perceiving these payment aspects to be unsafe.

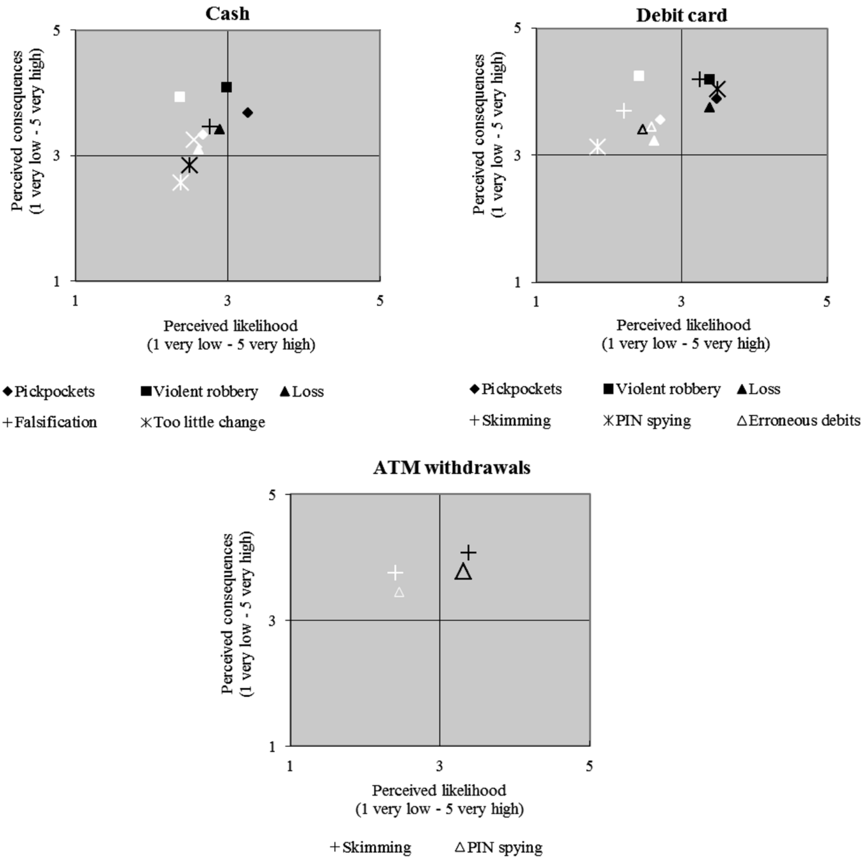
The respondents were also asked to rate the likelihood as well as the seriousness of possible payment incidents, on a scale from 1 (very low) to 5 (very high). The survey results presented in table 1 show that, on average, consumers believe that the chance of falling victim to payment incidents is relatively small. The consequences, however, are perceived to be rather serious. This also holds for the consequences of skimming fraud, which is generally compensated by banks. Another remarkable finding is that consumers have a certain perception of both the likelihood and the consequences of e-purse skimming fraud, whereas in fact this type of fraud does not exist. These findings hint at a certain lack of information and knowledge among consumers on the actual probabilities and consequences of payments-related safety incidents. Finally, table 1 shows that only a few respondents have ever been involved in a payments-related safety incident themselves. The incidents most experienced relate to carrying payment instruments (e.g., loss or theft). With the exception of receiving too little change, only a few respondents have ever been the victim of an incident resulting from an ATM withdrawal or a POS payment, such as of erroneous debits or skimming fraud.

3. Results: Factors Affecting Consumers' Safety Perception

In order to examine the factors influencing consumers' safety perception, the 2008 survey data was employed for various empirical analyses, using the conceptual framework laid out in the introduction as a starting point. Given the limited usage of the e-purse and credit cards in the Netherlands, the focus is on cash and debit cards only.

First, to assess the relationship between overall feelings of payment (un)safety on the one hand and perceptions of probabilities and consequences on the other, figure 1 presents three scatter plots showing the average "likelihood" and "consequence" scores given by the respondents for various cash, debit card, and ATM incidents.

Figure 1. Perceived Likelihoods and Consequences



Notes: This figure presents the average "likelihood" and "consequence" scores given by the respondents for various cash, debit card, and ATM incidents. The black symbols refer to the average scores given by the respondents who rated the safety level of the corresponding payment instrument with a score of 1 (very unsafe), 2 (unsafe), or 3 (a little unsafe). The white symbols refer to those who gave a score of 4 (neutral), 5 (a little safe), 6 (safe), or 7 (very safe). The black/white distinction in the cash graph for pickpockets, violent robbery, and loss is based on consumers' overall safety assessment of carrying cash. For falsification and too little change, the distinction is based on the overall safety assessment of using cash. The black/white distinction in the debit card graph for pickpockets, violent robbery, and loss is based on the overall safety assessment of carrying a debit card. For skimming, PIN spying, and erroneous debits, the distinction is based on the overall safety assessment of using a debit card. The black/white distinction in the ATM graph is based on consumers' overall safety assessment of ATM withdrawals.

Each plot makes a distinction between the average scores given by respondents who feel generally unsafe in either using or carrying (depending on the safety incident concerned) the corresponding payment instrument (the black symbols) and the average scores of those who felt safe (the white symbols).[9] A comparison of the black and white symbols shows that respondents feeling unsafe perceive not only the likelihood of the incidents as higher but also the consequences as more serious compared with those who felt safe. The largest difference, however, is in their probability assessment. This suggests that consumers' overall safety assessment is mainly influenced by their views on the likelihood of loss and fraud and, to a lesser extent, by their views on the possible consequences of it.

In order to examine this issue more formally, three ordered logit models were estimated, with the overall perceived safety level of cash (CASHSAFE), debit cards (DCSAFE), and ATM withdrawals (ATMSAFE) being the dependent variables. The perceived safety level of ATM withdrawals was taken directly from the survey. However, since the respondents were asked to provide two separate scores for cash and debit cards—one for using it and one for carrying it—the overall safety levels of cash and debit cards were calculated by averaging the usage and carrying scores and rounding that average up to the nearest integer. As a result, all three dependent variables take on a value ranging from 1 (very unsafe) to 7 (very safe). They are regressed upon a vector of two dummies, indicating whether consumers perceived the likelihood of related incidents to be high and whether they perceived the possible consequences to be serious. Both dummies take on a value of one when the average likelihood and consequences scores given by the respondents for related payment incidents, rounded up to the nearest integer, equal 4 (high) or 5 (very high). The model also includes an interaction term of both dummies to account for the possibility that perceived probabilities might only play a role when the consequences are thought to be serious and vice versa. In addition, an indicator of risk aversion

[9]The black symbols refer to the respondents who rated the safety level of the respective payment aspect with a score of 1 (very unsafe), 2 (unsafe), or 3 (a little unsafe). The white symbols refer to those who gave a score of 4 (neutral), 5 (a little safe), 6 (safe), or 7 (very safe).

Table 2. Impact of Perceived Likelihood and Consequences on Overall Safety Assessment

	CASHSAFE	DCSAFE	ATMSAFE
Perceived Likelihood (0 = low, 1 = high)	−0.782***	−0.646**	−1.362***
Perceived Consequences (0 = low, 1 = high)	−0.211*	−0.063	−0.028
Likelihood*Consequences	0.118	−0.670**	−0.038
Risk Aversion	0.013	−0.073	0.004
No. of Obs.	1,672	1,672	1,656
Pseudo R2	0.0129	0.0339	0.0333
Log-Likelihood	−2411.358	−2468.5358	−2476.1525

Notes: This table presents the parameter estimates of the three ordered logit regressions, with CASHSAFE, DCSAFE, and ATMSAFE being the dependent variables reflecting the overall perceived safety level of cash, debit cards, and ATM withdrawals, respectively, taking on a value ranging from 1 (very unsafe) to 7 (very safe). The dummy variables "Perceived Likelihood" and "Perceived Consequences" take on a value of one if the average of, respectively, the likelihood and consequences scores given by the respondents for related payment incidents, rounded up to the nearest integer, equal 4 (high) or 5 (very high), and zero otherwise. The interaction dummy "Likelihood*Consequences" takes on a value of one if both the likelihood and consequences of related payment incidents are perceived to be high, and zero otherwise. ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.

is incorporated into the model to account for the fact that people might differ in their attitudes towards risks.[10]

Table 2 shows the parameter estimates of the ordered logit analyses. The results confirm the conclusion drawn from the scatter plots that consumers' safety perception is influenced mainly by their views on the likelihood that incidents may occur. In the cash, the debit card, and the ATM model, the likelihood dummy has a significant negative sign, meaning that consumers who believe the chance of falling victim to cash, debit card, or ATM incidents is high are more

[10]This indicator was taken from the DHS questionnaire, in which respondents were presented with the following statement: "I would never consider investments in shares because I find this too risky." The answers to this question were coded on a scale from 1 (totally disagree) to 7 (totally agree). For the purpose of this study, this variable is transformed into a dummy variable of one if respondents agreed to the statement.

likely to perceive these means of payment to be unsafe. The results demonstrate that the perceived consequences of possible incidents are also considered by consumers, though to a much lesser degree. The likelihood dummy has a significant negative effect in the cash model, but at the 10 percent significance level only. In the debit card model, it only appears through the significant interaction term, meaning that perceived consequences play a role only when the risks are perceived to be high. So, as long as consumers believe that the chance of falling victim to a debit card incident is small, the magnitude of the possible consequences is of no significant importance. Finally, the risk-aversion indicator has no significant impact in any of the three models. This shows that people who are less fond of taking risks in general are not more likely to believe that cash, debit cards, and ATM withdrawals are unsafe, irrespective of how they assess the likelihood of incidents occurring and the consequences.[11]

In the next step, three bivariate probit models were estimated to assess the role of personal experiences and personal characteristics in consumers' subjective assessment of probabilities and consequences. Each model contains two dependent variables: a dummy variable indicating whether consumers perceived the likelihood of related payment incidents to be high (i.e., LLHCASH, LLHDC, and LLHATM) and a dummy variable indicating whether they perceived the consequences of related incidents to be serious (i.e., IMPCASH, IMPDC, and IMPATM). In fact, these are the same dummies as the ones used as explanatory variables in the ordered logit analyses. In each model, the two dependent dummy variables are simultaneously regressed upon a vector of dummies indicating whether consumers had ever experienced similar payment incidents and various personal characteristics, such as gender, age, living environment, income, and education. The results presenting both parameter estimates and marginal effects are shown in table 3.

The findings support strongly the assumption laid out in the conceptual framework. That is, personal experiences of payments-related incidents influence one's beliefs about the likelihood of incidents occurring and the impact of these incidents. Negative cash

[11]The correlation coefficients between risk aversion, perceived likelihood, and perceived consequences were small. Therefore, the three variables could be incorporated into the model simultaneously.

Table 3. Impact of Personal Experiences and Demographics

	Cash			Debit Card			ATM Withdrawals		
	LLHCASH	**IMPCASH**	**dy/dx**	**LLHDC**	**IMPDC**	**dy/dx**	**LLHATM**	**IMPATM**	**dy/dx**
Constant	−0.261	0.318		−0.279	0.356		−0.336	0.252	
Exp. ATM Incident	0.325***	−0.153	0.054	0.587***	0.138	0.178***	0.824***	0.017***	0.194***
Exp. Cash Incident	0.346***	0.260***	0.132***	−0.033	0.499	0.036	−0.107	0.479***	0.013
Exp. Debit Card Incident	−0.015	−0.024	0.007	0.279***	0.044***	0.067**	0.119	0.038	0.035
Gender	0.162**	0.312***	0.085***	0.203***	0.326***	0.097***	0.204***	0.253***	0.083***
Age:									
25–34 Years	−0.291	0.181	−0.059	−0.165	−0.102	−0.054	−0.038	0.167	0.008
35–44 Years	−0.195	0.378**	−0.018	−0.078	0.187	−0.002	−0.033	0.393**	0.030
45–54 Years	−0.323*	0.237	−0.064	−0.167	−0.058	−0.050	−0.037	0.154	0.007
55–64 Years	−0.269	0.358**	−0.041	−0.169	0.086	−0.037	0.083	0.158	0.041
65 Years and Over	−0.170	0.153	−0.029	−0.012	−0.007	−0.004	0.083	0.037	0.026
Living Environment:									
Enormously Urbanized	0.265**	0.104	0.086**	0.158	−0.064	0.033	0.067	−0.047	0.011
Strongly Urbanized	0.264**	0.105	0.085**	0.188*	0.019	0.053	0.154	0.087	0.051
Moderately Urbanized	0.279**	0.051	0.081**	0.249**	0.053	0.074**	0.162	0.145	0.061
Little Urbanized	0.185*	−0.047	0.040	0.208*	0.124	0.074**	0.093	−0.066	0.014
Income:									
EUR 1151–EUR 1800	−0.548***	−0.549***	−0.174***	−0.336**	−0.267	−0.110**	−0.602***	−0.116	−0.145***
EUR 1801–EUR 2600	−0.330**	−0.436***	−0.126***	−0.184	−0.206	−0.070	−0.425***	−0.002	−0.102**
More than EUR 2600	−0.415***	−0.521***	−0.150***	−0.331**	−0.292*	−0.112**	−0.648***	−0.129	−0.154***

(continued)

Table 3. (Continued)

	Cash			Debit Card			ATM Withdrawals		
	LLHCASH	**IMPCASH**	**dy/dx**	**LLHDC**	**IMPDC**	**dy/dx**	**LLHATM**	**IMPATM**	**dy/dx**
Education:									
Lower Sec.	0.011	−0.003	0.002	−0.080	0.162	−0.005	0.017	−0.002	0.004
Higher General	−0.221	0.091	−0.048	−0.363**	0.143	−0.084*	−0.352**	0.066	−0.081
Intermediate Voc.	−0.010	0.160	0.015	−0.164	0.322**	−0.017	−0.021	0.133	0.009
Higher Voc.	−0.313**	−0.060	−0.085*	−0.426***	0.193	−0.098**	−0.164	0.008	−0.040
University	−0.313*	−0.073	−0.086*	−0.664***	0.236	−0.153***	−0.409**	0.093	−0.093*
No. of Obs.	1,672			1,672			1,672		
Wald chi2	149.72			195.24			211.42		
Prob. > chi2	0.0000			0.0000			0.0000		
Log-Likelihood	−1984.17			−1772.74			−1635.01		
Rho	0.3767			0.4128			0.4311		
Test rho = 0 Prob. > chi2	0.0000			0.0000			0.0000		
Prob. (LLH = 1 & IMP = 1)	0.3034			0.3086			0.2842		

Notes: This table presents the parameter estimates and marginal effects of the three bivariate probit regressions, with each model containing two dependent variables: a dummy indicating whether the likelihood of related incidents is perceived to be high (i.e., LLHCASH, LLHDC, and LLHATM) and a dummy indicating whether the consequences of related incidents are perceived to be serious (i.e., IMPCASH, IMPDC, and IMPATM). Both dummies are created by averaging the scores given by the respondents for the related payment incidents, rounded up to the nearest integer, and take on a value of one if this average equals 4 (high) or 5 (very high) and zero otherwise. The dummy variables "Exp. ATM Incident," "Exp. Cash Incident," and "Exp. Debit Card Incident" take on a value of one if the respondents have ever experienced a cash, debit card, or an ATM incident themselves, and zero otherwise. In all three models, the reference category is a man, younger than twenty-five years, living in a non-urbanized area, earning less than EUR 1150 per month, and only having primary education. Prob. (LLH = 1 & IMP = 1) reflects the predicted probability that a person from this reference category with no prior experiences with cash, debit, or ATM incidents perceives both the likelihood and the impact of possible incidents to be high. The marginal effects (dy/dx) reflect the change in this probability for a discrete change of the dummy variables from 0 to 1, holding all other variables constant at their reference points. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

experiences affect strongly and significantly consumers' views on the probability and impact of possible cash incidents, whereas negative debit card and ATM experiences have significant repercussions on consumers' perceptions about the likelihood and consequences of debit card and ATM incidents. People who have been involved in cash-related incidents are 13 percent more likely to perceive both the probability and consequences of cash incidents to be high compared with people having no such experiences. Similarly, those who have ever fallen victim to a debit card or an ATM incident are 7 percent and 19 percent more likely to think that the risks and consequences of these incidents are high. Interestingly, past experiences with cash incidents do not influence consumers' views about the safety of debit cards, and vice versa. Apparently, consumers see cash and debit cards as two distinct means of payment. With respect to ATM withdrawals, however, the results do point to a significant interaction with the other two payment instruments; those who have been involved in a cash incident are more likely to perceive the consequences of ATM incidents as severe. At the same time, those who have been involved in an ATM incident are more likely to perceive the probability of possible cash or debit card incidents as high. This might indicate that consumers perceive a strong association and overlap between ATM withdrawals on the one hand and both cash and debit cards on the other. This may be explained by the fact that ATM withdrawals are necessary for carrying and using cash and that, in order to withdraw money, a debit card is needed.[12]

Personal characteristics are shown to have a strong and significant impact on consumers' assessment of probabilities and consequences too. First, women are nearly 10 percent more likely than men to perceive as high and serious the likelihood and consequences of incidents relating to cash, debit cards, and ATMs. Second, people between the ages of 35 and 44 and between the ages of 55 and 64 are more likely than those younger than 25 years to believe that the consequences of cash and ATM incidents are more serious. The marginal effects, however, are insignificant. Third, compared with people from the lowest income category, higher-income people tend to think less

[12]This is the case, at least, in the Netherlands, where most cash is withdrawn at ATMs and where consumers are able to use their debit card instead of a special ATM card for withdrawing money.

seriously about the likelihood and consequences of cash incidents and about the likelihood of debit card and ATM incidents. In addition, the perceived chance of being involved in a cash or debit card incident significantly increases with the urbanization degree of people's living environment, with marginal effects of around 8 percent. Last, education seems to play a role, with higher-educated people tending to rate the likelihood and impact of incidents significantly lower than less-educated people.

4. Results: Impact of Safety on Payment Behavior

To assess the final step laid out in the conceptual framework—i.e., the impact of consumers' views on safety on their daily payment behavior—three types of consumers are identified: (i) frequent cash users who pay more frequently in cash than by debit card (CASHPREF), (ii) frequent debit card users who pay more often by debit card than in cash (DCPREF), and (iii) consumers who have no particular preference and use cash and debit cards to the same extent (NOPREF). One-third of all respondents turn out to be frequent cash users, 30 percent prefer to pay by debit card, and 38 percent have no particular preference (NOPREF). Since there is no natural ordering between the different types of consumers, a multinomial logistic model was estimated with the type of consumer being the dependent variable taking on three outcomes: CASHPREF, DCPREF, or NOPREF. As explanatory variables, dummy variables are used to indicate whether consumers perceived cash, debit cards, and ATM withdrawals to be unsafe,[13] and to account for personal characteristics, dummies are added for gender, age, education, income, and living environment. The results are summarized in table 4. As NOPREF is used as the base outcome, the coefficients of the CASHPREF and DCPREF equations should be interpreted as changes relative to the NOPREF alternative.

[13]The dummy variable "ATM Unsafe" takes on a value of one if the safety of ATM withdrawals was rated with a score of 1 (very unsafe), 2 (unsafe), or 3 (a little unsafe), and zero otherwise. The dummies "Debit Card Unsafe" and "Cash Unsafe" both take on a value of one if the average of the safety scores given for using and carrying the instrument concerned rounded up to the nearest integer equals 1 (very unsafe), 2 (unsafe), or 3 (a little unsafe), and zero otherwise.

Table 4. Impact of Safety Perception on Cash and Debit Card Usage

	CASHPREF		DCPREF	
	Coefficient	**dy/dx**	**Coefficient**	**dy/dx**
Constant	0.891**		−0.379	
ATM Unsafe (no = 0, yes = 1)	0.398*	0.038	0.510**	0.031
Debit Card Unsafe (no = 0, yes = 1)	−0.069	0.056	−1.049***	−0.098**
Cash Unsafe (no = 0, yes = 1)	−0.563**	−0.211***	0.611**	0.180***
Gender	0.115	0.039	−0.125	−0.027
Age:				
25–34 Years	−0.953***	−0.269***	0.353	0.168**
35–44 Years	−0.552*	−0.170**	0.302	0.112**
45–54 Years	−0.211	−0.044	−0.081	0.009
55–64 Years	−0.071	−0.035	0.169	0.033
65 Years and Over	0.223	0.037	0.156	−0.001
Living Environment:				
Enormously Urbanized	0.204	0.077*	−0.348	−0.058**
Strongly Urbanized	0.048	0.032	−0.231	−0.033
Moderately Urbanized	−0.049	0.014	−0.292	−0.033
Little Urbanized	−0.081	0.008	−0.306	−0.032
Income:				
EUR 1151–EUR 1800	−0.448*	−0.091	−0.205	0.013
EUR 1801–EUR 2600	−0.772***	−0.176***	−0.152	0.051
More than EUR 2600	−0.697***	−0.161***	−0.118	0.050

(continued)

The results show that consumers' daily payment behavior is strongly influenced by consumers' views on the safety level of the different means of payment. Changes in the perceived safety level of cash significantly affect consumers' preferences for cash. Those who believe that paying in cash is unsafe are 21 percent less likely to be frequent cash users. Similarly, people who believe that debit cards are unsafe are 10 percent less likely to be frequent debit card users. The results also point to a strong and highly significant substitution effect from cash to debit cards. People who think that cash is unsafe are more likely to prefer paying by debit card, with the probability of being a frequent debit card user increasing by 18 percent. These

Table 4. (Continued)

	CASHPREF		DCPREF	
	Coefficient	**dy/dx**	**Coefficient**	**dy/dx**
Education:				
Lower Sec.	−0.250	−0.108*	0.410	0.096*
Higher General	−0.223	−0.125*	0.590*	0.129**
Intermediate Voc.	−0.345	−0.127**	0.373	0.101*
Higher Voc.	−0.439	−0.147**	0.340	0.101**
University	−0.517*	−0.129*	−0.017	0.050
Prob. (CASHPREF = 1)		0.5914		
Prob. (DCPREF = 1)				0.166
No. of Obs.				1,672
LR chi2(46)				127.01
Prob. > chi2				0.0000
Log-Likelihood				−1763.3951

Notes: This table presents the parameter estimates and marginal effects of the multinomial logistic regression, with the dependent variable taking on three outcomes: CASHPREF, DCPREF, and NOPREF, with CASHPREF being one for frequent cash users, DCPREF being one for frequent debit card users, and NOPREF being one for those having no particular preference for either cash or debit. The results of the CASHPREF and DCPREF equations should be interpreted as changes relative to the NOPREF alternative. The reference category is a man, younger than twenty-five years, living in a non-urbanized area, earning less than EUR 1150 per month, and only having primary education. Prob. (CASHPREF = 1) and Prob. (DCPREF = 1) reflect the predicted probabilities that a person from this reference category that perceives neither cash nor debit cards nor ATM withdrawals to be unsafe is classified as being a frequent cash or debit card user. The marginal effects (dy/dx) reflect the change in this probability for a discrete change of the dummy variables from 0 to 1, holding all other variables constant at their reference points. The dummy variable "ATM Unsafe" takes on a value of one if the safety of ATM withdrawals was rated with a score of 1 (very unsafe), 2 (unsafe), or 3 (a little unsafe), and zero otherwise. The dummies "Debit Card Unsafe" and "Cash Unsafe" both take on a value of one if the average of the safety scores given for using and carrying the instrument concerned rounded up to the nearest integer equals 1 (very unsafe), 2 (unsafe), or 3 (a little unsafe), and zero otherwise. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

findings are robust to the inclusion of various personal characteristics. Here, the estimation results confirm the conclusions drawn in earlier payment studies—that younger, more-educated consumers with higher incomes are more likely to pay by card instead of cash (see, for example, Kosse and Jansen 2013 and references therein).

5. Conclusions and Policy Implications

The key finding of this paper is that consumers' payment preferences are strongly affected by their perceptions of safety, which in turn are primarily influenced by views on the probability of possible safety incidents occurring when using or carrying a payment instrument. The economic significance of the role of consumers' safety perception, and of their views on risks in particular, provides several meaningful messages. First, it shows that the current levels of safety and efficiency of retail payment systems could be maintained or even improved by minimizing in particular the risks of safety incidents occurring. This underlines the importance of all stakeholders being constantly ready to reduce to a minimum fraud and safety risks in payments. Conversely, measures undertaken to reduce the severity of the consequences of safety incidents, such as fraud compensation, are likely to be of lesser value. Second, by demonstrating the importance of *perceptions* of safety, this paper emphasizes that it is essential to realize that perceptions may not always reflect *reality.* Consumers may wrongly perceive certain payment instruments to be unsafe and, therefore, wrongfully avoid them. Similarly, consumers may *underestimate* the risks of payments-related safety incidents and, consequently, inadequately protect themselves. Therefore, it is crucial that the public receive clear communication on the measures taken by the different actors and on the steps that consumers can take to minimize retail payment risks. This communication should not make the public feel insecure. However, done in a suitable way, it should improve the perceived level of retail payments safety, stimulating consumers to pay efficiently and safely in all circumstances.

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Commitment vs. Discretion in the UK: An Empirical Investigation of the Monetary and Fiscal Policy Regime*

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This paper investigates the conduct of monetary and fiscal policy in the post-ERM period in the United Kingdom. Using a simple DSGE New Keynesian model of non-cooperative monetary and fiscal policy interactions under fiscal intraperiod leadership, we demonstrate that the past policy in the United Kingdom is better explained by optimal policy under discretion than under commitment. We estimate policy objectives of both policymakers. We demonstrate that fiscal policy plays an important role in identifying the monetary policy regime.

JEL Codes: E52, E61, E63.

1. Introduction

It has long been known in the literature on monetary policy that if policymakers can precommit to a stabilization plan, then they can achieve a significant welfare gain. This is relative to the case of discretionary policy and in an environment where the current decisions

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of the forward-looking private sector are largely determined by their expectations.[1]

A policymaker who can commit chooses a policy plan once and then follows this policy at all dates in the future. This policy is the best from today's perspective, provided that the precommitment is credible. However, the policy is time inconsistent, and with the passage of time the policymaker will have an incentive to renege. Only a policymaker whose promises are perfectly credible can precommit.

In contrast, a discretionary policy is time consistent and, as such, is perfectly credible. It is known that the policymaker reoptimizes every period. In the resulting equilibrium, given an opportunity to renege on the expected policy for the next period, the policymaker will find it optimal to choose the same policy for that period. The private sector believes all promises, as there are no incentives to renege on them.

A credible commitment policy is able to take advantage of the forward-looking behavior of the agents by allowing them to understand how the policy will react to all circumstances in future periods. It can be formulated in terms of a contingent *intertemporal plan*, and the plan is linked to the initial date and has clear relations between consequent periods. This reflects the ability of the policymaker to manipulate the expectations in a desired way and convince the private sector to coordinate at the best possible intertemporal outcome, linked to the date of precommitment. In contrast, a discretionary policy can rather be described as a set of *intratemporal contingent rules*; the forward-looking private sector recognizes this feature and also reacts optimally, but it reacts only to the current state, as past promises are ignored.

Although the different properties of these two benchmark policies having been known for decades, the issue of practical implementation of such policies remains controversial. Most discussions concern *monetary policy.* Although there is little doubt that major central banks are able to precommit to a target—as, for example, an inflation target—the way they actually manage the *expectations of policies* to achieve the target remains underexplored. The key problem with the acceptance of the theoretical concept of commitment

[1]See Kydland and Prescott (1977), Currie and Levine (1993), and Woodford (2003a), among many others.

policy as a practical option has always been its time inconsistency. It is well understood that the policymaker will have an incentive to renege at *every* consequent period. This is because the private sector will have done part of the "work" of the policymaker by setting its expectations in a particular way. From this perspective the policymaker would gain from exploiting the expectations of the private sector. Also, it is because the policymaker may have some additional and sudden "distractions," like the task of maintaining financial stability. Issues with financial stability may require sudden monetary loosening regardless of the inflation record at the time.

Despite the well-understood difficulties with the ability of a central bank to precommit to a policy plan, the statements of major central banks about their practices differ widely. The early statements do not suggest that banks precommit to a plan which is chosen once and forever. In particular, after the Bank of England gained its independence, King (1997) proclaimed a regime of "constrained discretion." In these statements the word "discretion," which does not typically assume an ability to manipulate expectations over time, has rather been used to acknowledge inevitable "distractions." On the other hand, the word "constrained" was meant to mean that the "distractions" will not dominate. The Bank of England would, therefore, not pursue a short-term gain at the expense of mid-term inflation stability. This was meant to improve the credibility of the policy in the eyes of the private sector. Nothing in King (1997) suggests that the word "discretion" is meant to exclude the possibility that the Bank of England would not be able to manipulate the private sector's expectations and use information from a longer period of time rather than just within the current period. Bernanke and Mishkin (1997) give similar arguments to describe the U.S. monetary policy as discretionary. Coroneo, Corradi, and Santos Monteiro (2012) and Givens (2012) estimate that the Volker-Bernanke period in the United States is best described by the discretionary monetary regime.

More recently, the statements of some European central banks have either described their current monetary policy as policy under commitment or have come very close to doing so. The intertemporal feature of a commitment policy is being communicated as a "predictable response pattern." See Bergo (2007) for the view of the Norges Bank and Svensson (2009) for policy recommendations for the Riksbank to follow in the footsteps of Norges Bank by generating policy projections as optimal projections. Using medium-scale macro models, Bache, Brubakk, and Maith (2010) for Norges Bank and Adolfson et al. (2011) for the Riksbank, find that the past policy of these banks is better explained as optimal policy under commitment than as simple rules.

The recent documents may imply that the Bank of England takes a similar view on the issue (Tucker 2006; Stockton 2012). A clear target and a public commitment to anchor inflation expectations in line with this target, together with being understood to be willing to do whatever is necessary to achieve this goal, not just in the current period but in all periods, is critical to achieving credibility. Once credibility is achieved, a central bank that wants to maintain the credibility of its promises would then clearly recognize that reneging on past promises would lead to a loss of credibility. One might interpret this statement as indicating that, in effect, the Bank of England was able to *precommit to the policy* and then chose not to renege on its previously chosen *intertemporal* policy. It is an empirical question, however, whether the Bank of England was able to manage the private sector's expectations as if the Bank could not renege on its promises under any circumstances.

Fiscal policy arrangements are much less discussed in the literature, although they may play an important role in identifying the monetary policy regime as well as parameters of the model. Partly because of institutional arrangements, it is believed that fiscal policy is too inflexible to be used for active stabilization. However, recent developments in the world, recent episodes of using fiscal policy as a stabilization device, have shown that there might be a more active role for fiscal policy.[2] A more focused discussion on the institutional design of stabilizing fiscal policy may not be too far into the future.

The main focus of this paper is the identification of the degree of policy precommitment in the United Kingdom. We work with the standard microfounded model of a small open economy.[3] We use

[2]Recent examples include the Economic Stimulus Act of 2008 and the American Recovery and Reinvestment Act of 2009 in the United States, and the establishment of the Office of Budget Responsibility in the United Kingdom. See Osborne (2008); see also Wyplosz (2005) and Kirsanova, Leith, and Wren-Lewis (2006) for a more formal discussion.

[3]We build on models in Galí and Monacelli (2005, 2008), Lubik and Schorfheide (2006, 2007), and Justiniano and Preston (2010a, 2010b).

the theoretical framework of *non-cooperative* monetary and fiscal discretionary interactions, as in Fragetta and Kirsanova (2010) and Blake and Kirsanova (2011), and we also develop the appropriate theoretical framework for non-cooperative commitment. The policymakers are assumed to minimize the microfounded social welfare loss function except that they can change the relative weight on inflation stabilization and introduce an additional penalty on the excess volatility of policy instruments. We estimate structural parameters of the model and weights of policy objectives under two alternative assumptions about the policymakers' degree of precommitment using the Bayesian approach (see, e.g., An and Schorfheide 2007).

We demonstrate that the monetary and fiscal policy regime in the United Kingdom under the assumption of fiscal leadership can best be described by a regime of optimal policy under discretion: the probability that the actual data were generated by a model with optimal commitment policy, rather than by a model with optimal discretionary policy, is less than 1.0 percent. Both policymakers put a smaller weight on inflation stabilization than is socially optimal, and the fiscal policymaker pays much less attention to inflation stabilization than the monetary policymaker. We assess the empirical fit of an optimizing microfounded model based on first- and second-order moments and use DSGE-VAR methodology (Del Negro and Schorpfheide 2004) to investigate the degree of misspecification of the model under different policies. In particular, we show that the DSGE model imposes useful restrictions to improve the in-sample predictive properties of the Bayesian VAR model. Finally, we demonstrate that the fiscal solvency constraint plays an important role as an identifying restriction for both fiscal and monetary policy reactions as well as model parameters: excluding the fiscal block from the system leads to a greater degree of misspecification of the pure monetary model.

The focus of this paper is different from the one of Fragetta and Kirsanova (2010). We identify the degree of policy precommitment, while Fragetta and Kirsanova (2010) identify the degree of leadership and work with a discretionary model only.[4] Unlike Givens (2012), we

[4]In contrast to the model in Fragetta and Kirsanova (2010), our model accounts for habit persistence and inflation inertia.

use a microfounded model, and account for non-cooperative monetary and fiscal policy interactions, which allows a more complete description of the UK macroeconomic policy regime. Finally, in contrast to Fragetta and Kirsanova (2010) and Givens (2012), we process the data in a different way: following Lubik and Schorfheide (2006), we introduce a non-stationary worldwide technology shock which substantially reduces the model misspecification.

This paper is organized as follows. In the next section we outline the model and describe policy interactions under commitment and discretion. Section 3 explains the empirical methodology, the choice of priors, and the data. The results are discussed in section 4, and section 5 concludes. Appendices contain details of derivations and the theoretical framework for the two policy regimes in a general rational expectations linear-quadratic framework.

2. The Model

We build on models by Galí and Monacelli (2005, 2008), Lubik and Schorfheide (2006, 2007), and Justiniano and Preston (2010a, 2010b) modified to include fiscal policy. The following section presents key structural equations of a small open-economy model, which allows for habit formation and price indexation.

2.1 Households

The economy is populated by a unit-continuum representative household, by a unit-continuum monopolistically competitive firm, and by two policymakers: the government and the central bank.

Each household k maximizes the following objective:

$$W = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left(\frac{(X_t^k / A_{Wt})^{1-\sigma}}{1-\sigma} + \chi \frac{(G_t / A_{Wt})^{1-\sigma}}{1-\sigma} - \frac{{N_t}^{1+\varphi}}{1+\varphi} \right). \quad (1)$$

Here $X_t^k = C_t^k - h\varkappa C_{t-1}$ is the habit-adjusted consumption, $C_{t-1} \equiv \int_0^1 C_{t-1}^k dk$ is the cross-sectional average of consumption, N_t is labor supply of a representative household, and G_t is consumption of public goods. Parameter $0 \leq h \leq 1$ measures the degree of habit persistence, parameter β is the household discount rate, φ is the elasticity of labor supply, and σ is the coefficient of relative risk aversion. Parameter χ is the scaling factor for the utility of consuming public goods. In order to guarantee that the model has a balanced growth path, we assume that households derive utility from effective consumption relative to the worldwide level of technology, A_{Wt}. The technology shock A_{Wt} is non-stationary, with growth rate $z_t = A_{Wt}/A_{Wt-1}$. Parameter $\varkappa$ is the steady-state value of z_t.

Household k's consumption, C_t^k, is an aggregate of the continuum of goods $i \in [0,1]$ produced in the home country (indexed H) and abroad (indexed F),

$$C_t = \left((1-\alpha)^{\frac{1}{\eta}} C_{Ht}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{Ft}^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}},$$

where $0 \leq \alpha < 1$ is the import share and $\eta > 0$ is the intratemporal elasticity of substitution between home and foreign consumption goods. C_H is a composite of domestically produced goods given by

$$C_{Ht} = \left(\int_0^1 C_{Ht}(z)^{\frac{\epsilon-1}{\epsilon}} dz\right)^{\frac{\epsilon}{\epsilon-1}}, \tag{2}$$

where z denotes the good's type or variety and ϵ is the intratemporal substitution between domestically produced goods. Similarly, the aggregate C_{Ft} is an aggregate across overseas countries i,

$$C_{Ft} = \left(\int_0^1 C_{it}^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon}{\epsilon-1}},$$

where C_{it} is an aggregate similar to (2). Households allocate aggregate expenditures based on the demand functions:

$$C_{Ht} = (1-\alpha)\left(\frac{P_{Ht}}{P_t}\right)^{-\eta} C_t \text{ and } C_{Ft} = \alpha\left(\frac{P_{Ft}}{P_t}\right)^{-\eta} C_t,$$

where P_{Ht}, P_{Ft} are domestic and foreign goods price indices and

$$P_t = \left((1-\alpha)P_{Ht}^{1-\eta} + \alpha P_{Ft}^{1-\eta}\right)^{\frac{1}{1-\eta}}$$

is the consumption-based price index.

Consumers face the following aggregated budget constraint:

$$P_t C_t^k + \mathbb{E}_t\{Q_{t,t+1} A_{t+1}^k\} = A_t^k + (1-\tau_t)\left(W_t N_t^k + \Upsilon_t^k\right) + T_t,$$

where A_{t+1}^k is the nominal payoff of portfolio held at the end of period t, W_t is wages, τ_t is the income tax rate, Υ is profits, and T_t is lump-sum transfers paid by the government. $Q_{t,t+1}$ is the stochastic discount factor for one-period-ahead payoffs.

In the maximization problem, households take the processes for C_{t-1}, W_t, T_t, and the initial asset position A_{-1}^k as given. The optimization produces the standard first-order conditions

$$\frac{1}{1+i_t} = \beta \mathbb{E}_t \left(\frac{P_t A_{Wt}}{P_{t+1} A_{Wt+1}} \left(\frac{X_t / A_{Wt}}{X_{t+1}/A_{Wt+1}} \right)^{\sigma} \right) \tag{3}$$

$$\frac{W_t}{P_t} = A_{Wt} \frac{\left(X_t / A_{Wt}\right)^{\sigma} N_t{}^{\varphi}}{(1-\tau_t)}, \tag{4}$$

where $1 + i_t = \left(\mathbb{E}_t\{Q_{t,t+1}\}\right)^{-1}$ is the gross return on a riskless one-period bond paying off a unit of domestic currency in period $t+1$. We omit superscript k, as all households are identical.

2.2 Firms

Domestic differentiated goods are produced by monopolistically competitive firms, which use labor as the only factor of production. The production technology is given by

$$Y_t(i) = A_{Wt} A_{Ht} N_t(i), \tag{5}$$

where $Y_t(i)$ is the amount of output produced by firm i in period t, $N_t(i)$ is the amount of labor employed by firm i in period t, and A_{Ht} is the home-specific stationary technology shock.

We assume the familiar Calvo-type price setting (Calvo 1983). A firm will not reset the price the next period with given probability θ. When firm i does not reset price, the price is costlessly adjusted with steady-state rate of inflation Π. When firm i resets price, with probability $1-\zeta$ it chooses price P_{Ht}^f, which maximizes

$$\max_{P_{Ht}^f(i)} \sum_{k=0}^{\infty} \theta^k Q_{t,t+k} \left(Y_{t+k}(i) P_{Ht}^f(i) \Pi^k - W_{t+k} N_{t+k}(i) \right)$$

subject to demand system

$$Y_{t+k}(i) = \left[\frac{p_{Ht}(i)\,\Pi^k}{P_{Ht+k}}\right]^{-\epsilon} Y_{t+k}$$

and production function (5). The solution to this optimization problem is given by

$$\frac{P^f_{Ht}}{P_{Ht}} = \frac{\epsilon}{\epsilon-1}\frac{K_{1t}}{K_{2t}}, \tag{6}$$

where K_{1t} and K_{2t} satisfy

$$\gamma\beta K_{1t+1}\left(\frac{P_{Ht+1}}{\Pi P_{Ht}}\right)^{\epsilon} = K_{1t} - \left(\frac{X^k_t}{A_{Wt}}\right)^{-\sigma}\frac{Y_t}{A_{Wt}}\frac{W_t}{P_t A_{Wt} A_{Ht}}, \tag{7}$$

$$\gamma\beta K_{2t+1}\left(\frac{P_{Ht+1}}{\Pi P_{Ht}}\right)^{\epsilon-1} = K_{2t} - \left(\frac{X^k_t}{A_{Wt}}\right)^{-\sigma}\frac{P_{Ht}}{P_t}\frac{Y_t}{A_{Wt}}. \tag{8}$$

When a firm resets price, then with probability ζ it chooses the new price P^b_{Ht} according to a simple rule of thumb

$$P^b_{Ht} = P^*_{Ht-1}\Pi_{Ht-1}, \tag{9}$$

where the index of the reset prices P^*_{t-1} is given by

$$P^{*1-\epsilon}_{Ht} = (1-\zeta)\left(P^f_{Ht}\right)^{1-\epsilon} + \zeta\left(P^b_{Ht}\right)^{1-\epsilon}. \tag{10}$$

With share θ of firms keeping last period's price and share $(1-\theta)$ of firms setting a new price, the law of motion of aggregate price index P_{Ht} is

$$P^{1-\epsilon}_{Ht} = (1-\theta)\left(P^*_{Ht}\right)^{1-\epsilon} + \theta\left(\Pi P_{Ht-1}\right)^{1-\epsilon}. \tag{11}$$

Finally, the evolution of price dispersion $\Delta_t = \int_0^1 (\frac{p_{Ht}(i)}{P_{Ht}})^{-\epsilon} di$ is given by

$$\Delta_t = (1-\theta)(1-\zeta)\left(\frac{P^f_{Ht}}{P_{Ht}}\right)^{-\epsilon} + (1-\theta)\zeta\left(\frac{P^b_{Ht}}{P_{Ht}}\right)^{-\epsilon} + \theta\left(\frac{P_{Ht}}{P_{Ht-1}}\right)^{\epsilon}\Delta_{t-1}. \tag{12}$$

2.3 Risk-Sharing, Market Clearing, and Private-Sector Equilibrium

The bilateral terms of trade measure foreign country goods prices relative to home goods prices. The effective terms of trade S_t are given by

$$S_t = \frac{P_{Ft}}{P_{Ht}},$$

and the real exchange rate $\mathcal{Q}_t$ is defined as

$$\mathcal{Q}_t = \frac{P_t^* \mathcal{E}_t}{P_t},$$

where $\mathcal{E}_t$ is the nominal exchange rate. Assuming that the home country is small and the law of one price holds, we obtain

$$S_t \equiv \frac{P_{Ft}}{P_{Ht}} = \frac{P_t^* \mathcal{E}_t}{P_{H,t}} = \frac{P_t}{P_{H,t}} \frac{P_t^* \mathcal{E}_t}{P_t} = \frac{P_t}{P_{H,t}} \mathcal{Q}_t.$$

The Euler equation for the rest of the world can be written as

$$\frac{1}{1+i_t^*} = \beta \mathbb{E}_t \left(\frac{X_t^*/A_{Wt}}{X_{t+1}^*/A_{Wt+1}} \right)^{\sigma} \left(\frac{P_t^*}{P_{t+1}^*} \right).$$

Combining two consumption Euler equations with the uncovered interest rate parity

$$\frac{1+i_t}{1+i_t^*} = \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}$$

yields the international risk-sharing relationship

$$\frac{X_t/A_{Wt}}{X_t^*/A_{Wt}} \mathcal{Q}_t^{-\frac{1}{\sigma}} = \frac{X_{t+1}/A_{Wt+1}}{X_{t+1}^*/A_{Wt+1}} \mathcal{Q}_{t+1}^{-\frac{1}{\sigma}}.$$

Goods market clearing requires

$$Y_t(j) = C_{Ht}(j) + \int_0^1 C_t^i(j) di + G_t(j),$$

where

$$C_{Ht}^{i}(j) = \alpha \left(\frac{P_{Ht}(j)}{P_{Ht}}\right)^{-\epsilon} \left(\frac{P_{Ht}}{\mathcal{E}_{it} P_t^i}\right)^{-1} C_t^i.$$

The allocation of government spending across goods is determined by the minimization of total costs,

$$G_t(j) = \left(\frac{p_{Ht}(j)}{P_{Ht}}\right)^{-\epsilon} G_t.$$

Substituting everything into the market clearing condition yields

$$Y_t(j) = \left(\frac{P_{Ht}(j)}{P_{Ht}}\right)^{-\epsilon} \left[(1-\alpha)\frac{P_t C_t}{P_{Ht}} + \alpha \int_0^1 \frac{\mathcal{E}_{it} P_t^i C_t^i}{P_{Ht}} di + G_t\right].$$

Aggregation, using $Y_t = (\int_0^1 Y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj)^{\frac{\epsilon}{\epsilon-1}}$, yields the aggregate demand equation

$$Y_t = (1-\alpha)\frac{P_t}{P_{Ht}} C_t + \alpha C_t^* + G_t. \tag{13}$$

Similarly, aggregation of production function (5) yields the aggregate production function

$$Y_t = A_{Wt} A_{Ht} \frac{N_t}{\Delta_t}. \tag{14}$$

We assume that all public debt consists of riskless one-period bonds. Therefore, the nominal value of end-of-period public debt $\mathcal{B}_t$ evolves according to the following law of motion:

$$\mathcal{B}_t = (1 + i_{t-1})\, \mathcal{B}_{t-1} + P_{Ht} G_t - \tau_t P_{Ht} Y_t. \tag{15}$$

For analytical convenience, we define $B_t = \frac{(1+i_{t-1})\mathcal{B}_{t-1}}{P_{t-1} A_{Wt}}$ as a measure of real government debt. Because A_{Wt} and B_t are observed at the beginning of period t, equation (15) can be rewritten as

$$B_{t+1} \frac{A_{Wt+1}}{A_{Wt}} = (1 + i_t) \left(B_t \frac{P_{Ht-1}}{P_{Ht}} - \tau_t \frac{Y_t}{A_{Wt}} + \frac{G_t}{A_{Wt}}\right). \tag{16}$$

Finally, the private-sector equilibrium $\{\frac{X_t}{A_{Wt}}, \frac{W_t}{P_t}, N_t, Y_t, K_{1t}, K_{2t}, p_{Ht}^f, P_t^b, P_t^*, \Pi_t, \Delta_t, B_t\}$ is determined by equations (3), (4), (6), (7), (8), (9), (10), (11), (12), (13), (14), and (16).

2.4 Linearization

We proceed by log-linearizing the model equations around the balanced growth path. Our model imposes common steady-state real interest rates, inflation rates, growth rates, and technologies. Because the model contains a non-stationary component, the worldwide technology shock A_{Wt}, we detrend the affected variables by their specific growth components beforehand.

We denote by lowercase letters the stationary transformation of corresponding variables, by dividing them by a common numeraire, A_{Wt}. Therefore, we denote $x_t = \frac{X_t}{A_{Wt}}$, $y_t = \frac{Y_t}{A_{Wt}}$, $g_t = \frac{G_t}{A_{Wt}}$, $c_t = \frac{C_t}{A_{Wt}}$. We present the model in a form where all variables are in log-deviations from the steady state, and for any variable u_t with steady state $\bar{u}$ we denote $\hat{u}_t = \log\left(\frac{u_t}{\bar{u}}\right)$.

The linearized system which describes the evolution of the economy can be written as

$$\hat{\pi}_{Ht} = \beta\frac{\theta}{\Phi}\mathbb{E}_t\hat{\pi}_{Ht+1} + \frac{\zeta}{\Phi}\hat{\pi}_{Ht-1} + \frac{\lambda}{\Phi}\left(\sigma\hat{x}_t + \varphi\hat{y}_t + \alpha\hat{S}_t - (\varphi+1)\hat{A}_{Ht}\right) + \eta_{\pi t} \tag{17}$$

$$\hat{x}_t = \mathbb{E}_t\hat{x}_{t+1} - \frac{1}{\sigma}\left(\hat{\imath}_t - \mathbb{E}_t\hat{\pi}_{Ht+1} + \alpha\hat{S}_t - \alpha\mathbb{E}_t\hat{S}_{t+1} - \mathbb{E}_t\hat{z}_{t+1}\right) \tag{18}$$

$$\hat{S}_t = \frac{\sigma}{(1-h)(1-\alpha)}\left(\hat{c}_t - h\hat{c}_{t-1} - \hat{c}^*_t + h\hat{c}^*_{t-1}\right) \tag{19}$$

$$\hat{x}_t = \frac{1}{(1-h)}(\hat{c}_t - h\hat{c}_{t-1}) + \frac{h}{(1-h)}\hat{z}_t \tag{20}$$

$$\hat{y}_t = \alpha(2-\alpha)\eta\hat{S}_t + (1-\alpha)\hat{c}_t + \alpha\hat{c}^*_t + \frac{\bar{g}}{\bar{c}}\hat{g}^y_t \tag{21}$$

$$\tilde{b}_{t+1} = \frac{1}{\beta}\left(\tilde{b}_t - \frac{\bar{B}}{\bar{y}\Pi}\hat{\pi}_{Ht} + \frac{\bar{g}}{\bar{y}}\hat{g}^y_t - \left(\tau - \frac{\bar{g}}{\bar{y}}\right)\hat{y}_t\right) + \frac{\bar{B}}{\bar{y}\Pi}\hat{\imath}_t - \frac{\bar{B}}{\bar{y}\Pi}\mathbb{E}_t\hat{z}_{t+1} \tag{22}$$

$$\Psi_t = \hat{y}_t - \hat{y}_{t-1} + \hat{z}_t \tag{23}$$

$$\Omega_t = \hat{g}^y_t - \hat{g}^y_{t-1} + \eta_{gt}. \tag{24}$$

Here $\hat{g}^y_t = \hat{g}_t - \hat{y}_t$ is spending-to-output ratio, or the government share, and $\tilde{b}_t = \frac{\bar{B}}{\bar{y}\Pi}\log\left(\frac{B_t}{\bar{B}}\right)$ is a measure of real debt. Variables

Ψ_t and Ω_t are the growth rate of output and of the government share correspondingly. Parameters are $\Phi = \zeta + \theta - \zeta\theta + \theta\beta\zeta$, $\lambda = (1-\theta)(1-\theta\beta)(1-\zeta)$. All microfounded shocks are assumed to follow an AR(1) process:

$$\hat{A}_{Ht} = \rho_a \hat{A}_{Ht-1} + \eta_{at} \tag{25}$$

$$\hat{c}_t^* = \rho_c \hat{c}_{t-1}^* + \eta_{ct} \tag{26}$$

$$\hat{z}_t = \rho_z \hat{z}_{t-1} + \eta_{zt}, \tag{27}$$

where η_{at}, η_{ct}, and η_{zt} are i.i.d. Note that additional to three microfounded shocks, $\hat{A}_{Ht}$, $\hat{z}_t$, and $\hat{c}_t^*$, we have added shocks $\eta_{\pi t}$ and η_{gt} into the final specification of the system. Shock $\eta_{\pi t}$ captures inefficient variations in markups. It is assumed to be i.i.d. to allow easier identification of the degree of inflation inertia. Shock η_{gt} captures the non-systematic part of fiscal policy, the discrepancy between the observed government share and the unobservable policy instrument. As a measurement error, η_{gt} is assumed to be i.i.d.

2.5 Policy

2.5.1 Social Welfare

The aggregated household utility (1) implies the following social welfare loss function:

$$W = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left(\pi_{Ht}^2 + \frac{\zeta}{\theta(1-\zeta)} (\pi_{Ht} - \pi_{Ht-1})^2 \right. \\ \left. + L\left(\hat{x}_t, \hat{c}_t, \hat{y}_t , \hat{g}_t^y, \hat{A}_{Ht}, \hat{c}_t^*, \hat{c}_{t-1}^* \right) \right),$$

where $L(\hat{x}_t, \hat{c}_t, \hat{y}_t , \hat{g}_t^y, \hat{A}_{Ht}, \hat{c}_t^*, \hat{c}_{t-1}^*)$ is a collection of quadratic terms which can be rearranged to describe "gap" targets; see appendix 1.

2.5.2 Policy Objectives

It is often suggested that realistic policymakers are not benevolent. There are some theoretical reasons for introducing additional objectives and for distorting social weights of a *discretionary* policymaker. A discretionary monetary policymaker can reduce the "stabilization bias"[5] in several ways. For example, Woodford (2003b) demonstrates that if the discretionary monetary policymaker adopts an additional interest rate smoothing target, then the policy becomes "history dependent" and the dynamics of the economy under discretion is similar to the one under commitment policy, with a higher level of social welfare attained. A similar result is demonstrated in Vestin (2006): introducing the price-level target into the monetary policymaker's objectives improves the social welfare too. Also, following the famous result of Barro and Gordon (1983), Clarida, Galí, and Gertler (1999) show that the discretionary monetary authority which puts higher than socially optimal weight on the inflation stabilization target can achieve the same level of welfare as under the optimal precommitment-to-rules policy.[6]

The policymakers may not be benevolent because of some institutional restrictions, both under commitment and discretion. For example, fiscal instrument smoothing may result from fiscal policy being "delayed." All spending decisions should pass the Parliament scrutiny. In order to avoid large changes in inappropriate times, it may be optimal to propose only relatively small changes. In our framework, such policy can be described by introducing a penalty on the change of fiscal instrument. Similarly, a debt target can reflect some international agreements. It can also help to avoid large risk premiums, which cannot be described by this model.

To account for possible delegation schemes and institutional restrictions, we assume a more general form of the monetary policymakers' objective function in our empirical part of the paper:

$$W^M = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left(\Phi_{\pi M} \left(\hat{\pi}_{Ht}^2 + \frac{\zeta}{\theta\left(1-\zeta\right)} \left(\hat{\pi}_{Ht} - \hat{\pi}_{Ht-1}\right)^2 \right) \right.$$
$$\left. + L\left(\hat{x}_t, \hat{c}_t, \hat{y}_t\ , \hat{g}_t^y, \hat{A}_{Ht}, \hat{x}_t^*, \hat{c}_t^*\right) + \Phi_{\Delta I}\left(\Delta \hat{\imath}_t\right)^2 \right).$$

Here we add additional interest rate smoothing weight $\Phi_{\Delta I}$ and allow for "inflation conservatism" $\Phi_{\pi M}$.

[5]See Svensson (1997).

[6]For other policy delegation proposals, see, e.g., Svensson (1997), Walsh (2003), and Woodford (2003b).

We adopt the same general form of policy objectives for fiscal policy:

$$W^F = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left(\Phi_{\pi F} \left(\hat{\pi}_{Ht}^2 + \frac{\zeta}{\theta\left(1-\zeta\right)} \left(\hat{\pi}_{Ht} - \hat{\pi}_{Ht-1}\right)^2 \right) \right.$$
$$\left. + L\left(\hat{x}_t, \hat{c}_t, \hat{y}_t\ , \hat{g}_t^y, \hat{A}_{Ht}, \hat{x}_t^*, \hat{c}_t^*\right) + \Phi_{\Delta G}\left(\Delta \hat{g}_t^y\right)^2 + \Phi_B b_t^2 \right),$$

where we account for "inflation conservatism" $\Phi_{\pi F}$ and instrument smoothing $\Delta\hat{g}_t^y$, but also add debt target Φ_B. Both policymakers are not assumed to modify social "gap" targets $L(\hat{x}_t, \hat{c}_t, \hat{y}_t\ , \hat{g}_t^y, \hat{A}_{Ht}, \hat{x}_t^*, \hat{c}_t^*)$; their change might move us too far from the original microfounded criterion and might not allow us to make a simple interpretation of results.[7]

2.5.3 Strategic Interactions

We assume that the monetary policymaker uses the nominal interest rate, i_t, as its instrument, and the fiscal policymaker uses the government share, g_t^y.[8] Both policymakers act *non-cooperatively* in order to stabilize the economy against shocks.

We assume that the fiscal policymaker acts as an intraperiod leader and the monetary authority acts as an intraperiod follower. (Fragetta and Kirsanova 2010 show that the model of fiscal leadership gives better fit to the UK data than the model of simultaneous moves under discretion.) This assumption implies that the leader, the fiscal authority, knows the reaction function of the monetary authority and takes it into account when formulating policy.

If both policy authorities are benevolent, and the steady-state level of debt is not too high, then in the resulting equilibrium the optimizing monetary policymaker reacts to inflation nearly in the

[7]See Dennis (2006), Ilbas (2010), and Givens (2012) who directly estimate the relative weights of the authority's ad hoc loss function.

[8]We follow Galí and Monacelli (2005, 2008) in the choice of fiscal instrument. The empirical evidence in Taylor (2000), Auerbach (2003), and Favero and Monacelli (2005), for example, also suggests that government spending does move.

same way as if the debt accumulation problem were not part of the problem, and the optimizing fiscal policymaker adjusts the fiscal instrument to keep debt under control; see, e.g., Blake and Kirsanova (2011). Moreover, the level of debt is optimally brought back only slowly—under commitment it is just not allowed to explode—so the optimal volatility of fiscal instrument is relatively small. This optimal "division of responsibilities," where the burden of economic stabilization is optimally carried by the monetary policymaker, describes the standard case of benevolent policymakers.[9]

Once the policy objectives are made distinct, the optimizing policymakers may engage in a fight, each trying to offset the harm done by the other. This fight, however, is more likely to happen if the authorities move simultaneously; see Dixit and Lambertini (2003) and Blake and Kirsanova (2011). The regime of fiscal leadership considered here is likely to mitigate the conflict. If the fiscal policymaker has lesser need to stabilize inflation but prefers faster stabilization of the output gap than the monetary policymaker does, it knows that an increase in government spending will not produce higher output but just higher interest rate, so the fiscal policymaker optimally refrains from moving the fiscal instrument excessively and concentrates on debt stabilization. If the fiscal authority is able to conduct itself as an intraperiod leader, then it will willingly allow the monetary authority to carry out almost all of the required macroeconomic stabilization.

Policymakers who act under commitment are able to manipulate expectations of the private sector along the whole dynamic path. The monetary policymaker takes the state of fiscal policy as given and precommits to policy taking into account the forward-looking behavior of the private sector and the evolution of predetermined states. The fiscal policymaker also takes into account the forward-looking behavior of the private sector and the evolution of predetermined states, but it also takes into account the reaction function of the monetary policymaker. Both policymakers precommit once, in the initial period, and then follow their (initially optimal) plans. The

[9]See the discussion in Kirsanova, Leith, and Wren-Lewis (2009). If both policymakers are benevolent and there is a unique equilibrium, then the leadership does not matter, of course.

private sector's expectations are among the policymakers' choice variables so that the best-at-point-of-precommitment outcome is achieved. The formal treatment of non-cooperative optimization under commitment is relegated to appendix 2.

In contrast, discretionary policymakers reoptimize (or change office) every period, and the forward-looking sector knows this. As a result, all agents choose their optimal reactions as functions of current predetermined states only.[10] The optimal reaction rule of the private sector feeds back on all observed states, including policy. The monetary policymaker takes into account this reaction function of the private sector, as well as predetermined states and fiscal policy. The fiscal policymaker takes into account reaction rules of the monetary policymaker and the private sector. Although the policymakers cannot affect expectations of the private sector to the extent available under commitment, they can influence the endogenous predetermined state, the evolution of which is taken into account by the private sector. Similarly, the expectations of the monetary policymaker are affected by actions of the fiscal policymaker through their effect on endogenous predetermined states. The formal treatment of non-cooperative optimization under discretion is presented in Blake and Kirsanova (2011).

Solving the optimization problem yields the following policy reaction functions:

$$\begin{aligned}\hat{\imath}_t &= r_z\eta_{z,t} + r_a\eta_{a,t} + r_{y^*}\eta_{y0^*,t} + r_{y1^*}\eta_{y^*,t-1} + r_r\hat{\imath}_{t-1} + r_g\hat{g}^y_{t-1} \\ &\quad + r_\pi\hat{\pi}_{Ht-1} + r_c\hat{c}_{t-1} + r_b\tilde{b}_t + r_\Lambda\Lambda_{mt} \qquad (28)\\ \hat{g}^y_t &= g_z\eta_{z,t} + g_a\eta_{a,t} + g_{y^*}\eta_{y0^*,t} + g_{y1^*}\eta_{y^*,t-1} + g_r\hat{\imath}_{t-1} + g_g\hat{g}^y_{t-1} \\ &\quad + g_\pi\hat{\pi}_{Ht-1} + g_c\hat{c}_{t-1} + g_b\tilde{b}_t + g_\Lambda\Lambda_{ft}, \qquad (29)\end{aligned}$$

where all coefficients are non-linear functions of structural and policy parameters. Terms $r_\Lambda\Lambda_{mt}$ and $g_\Lambda\Lambda_{ft}$ are linear functions of predetermined Lagrange multipliers and are only included in case of commitment; see appendix 2, proposition 1.

[10] We assume no memory.

3. Estimation Strategy and Empirical Implementation

3.1 Empirical Specification and Data

Using the Dynare toolkit (Juillard 2005), we estimate the model using Bayesian techniques that have been developed to estimate and evaluate DSGE models (see, e.g., An and Schorfheide 2007).

The empirical specification of the system for estimation consists of equations (17)–(27) and two policy rules in the form of (28)–(29). The observable variables are domestic inflation, $\hat{\pi}_{Ht}$; the growth rate of output, Ψ_t; nominal interest rate, $\hat{\imath}_t$; terms of trade, $\hat{S}_t$; and the growth rate of government share, Ω_t. Government debt is treated as an unobservable variable.[11] In the case of commitment, the set of unobservable endogenous variables also includes predetermined Lagrange multipliers. We keep very tight restrictions on the number of shocks being equal to the number of observed variables; this allows us to assess possible misspecifications using the DSGE-VAR approach as in Del Negro and Schorpfheide (2004). The estimation of commitment assumes that the commitment policy was announced at some point that predates the sample, at a date which we do not have to identify in estimation. Therefore, we chose to initialize the predetermined Lagrange multipliers to their steady-state values when we start the Kalman filter.[12]

In order to approximate variables $\hat{\pi}_{Ht}, \hat{\imath}_t, \hat{S}_t, \Psi_t$, and Ω_t, we use seasonally adjusted quarterly data on real GDP, the GDP deflator, nominal interest rates on three-month Treasury bills, current government spending on goods and services, and the data on exports and imports of goods and services at current market prices and as chained volume measures. All data series are obtained from the Office for National Statistics (ONS) database.[13] Home inflation rates are defined as log-differences of the GDP deflator and multiplied by 100 to obtain quarterly percentage rates. The data on the terms of

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[11]The model is formulated in terms of quarterly debt. Because of the data availability on the very short-term debt, we treat this variable as unobservable.

[12]Alternatively, Ilbas (2010) and Adolfson et al. (2011) use a presample to initialize the Lagrange multipliers. Both approaches give very similar results.

[13]The ONS codes for the data series are GZSN, YBHA, AJRP, YBGB, IKBI, IKBH, IKBL, and IKBK.

trade are constructed as the relative price of export and import. The estimation is based on demeaned data.

We study the post-ERM period 1992:Q1–2008:Q2. During this period the United Kingdom maintained a flexible exchange rate regime, with explicit inflation targeting in the post-1997 period. We, therefore, effectively assume that during the whole sample period, the monetary authorities—whether independent or as part of the government—were trying to maintain stability of the economy as described by low and stable inflation and low unemployment. Although the period covers several governments, we nevertheless estimate the fiscal regime "on average." Being the intraperiod leader, the fiscal policymaker is expected to remain relatively inactive, concentrating on keeping the debt accumulation under control.

3.2 Priors

We keep a number of parameters fixed, as some of them are related to steady-state values and cannot be estimated from a log-linearized demeaned model. We calibrate the discount factor, β, to be 0.99, which implies an annual steady-state interest rate of about 4 percent. The steady-state tax rate is set to 0.35, the steady-state government share is set to 0.2, and the steady-state debt-to-GDP ratio is set to 0.1, as the UK data suggest.[14] We set the intratemporal substitution elasticity $\eta = 1$, as did Lubik and Schorfheide (2007).

Table 1 summarizes prior distributions for structural parameters, policy objectives, and shocks. They are consistent with priors used in, e.g., Smets and Wouters (2003) and Lubik and Schorfheide (2006). We set relatively wide priors for all parameters which affect persistence of the propagation mechanism: the price indexation parameter ζ is beta-distributed with mean 0.5 and standard error of 0.25, and the habit persistence parameter h is beta-distributed with mean 0.5 and standard error of 0.10. Priors for elasticities σ and φ are consistent with, e.g., Adjemian, Paries, and Moyen (2008), Justiniano and Preston (2010a), and Liu and Mumtaz (2011).

Parameters $\Phi_{\pi M}$, $\Phi_{\Delta I}$, $\Phi_{\pi F}$, $\Phi_{\Delta G}$, and Φ_B measure the extent of deviation of the empirical policy objectives from those microfounded.

[14] We work with one-period debt stock; its proportion in the total debt stock is relatively small over the observed period.

Table 1. Priors for Structural Parameter and Policy Weights

		Domain	Dist.	p(1)	p(2)
Structural Parameters					
Home Techn.	ρ_a	[0,1)	B	0.8	0.05
World Output	ρ_{y*}	[0,1)	B	0.8	0.05
World Techn.	ρ_z	[0,1)	B	0.8	0.05
Calvo Param.	θ	[0,1)	B	0.6	0.05
Habit Persist.	h	[0,1)	B	0.5	0.10
Inflation Inertia	ζ	[0,1)	B	0.5	0.25
Openness	α	[0,1)	B	0.3	0.03
CRRA	σ	$\mathbb{R}$	G	1.5	0.10
Inverse Frisch	φ	$\mathbb{R}$	G	2.0	0.25
Monetary Policy Parameters					
Conservatism	$\Phi_{\pi M}$	$\mathbb{R}^+$	G	1	0.25
Smoothing	$\Phi_{\Delta I}$	$\mathbb{R}^+$	G	0.75	0.25
Fiscal Policy Parameters					
Conservatism	$\Phi_{\pi F}$	$\mathbb{R}^+$	G	0.5	0.40
Debt	Φ_B	$\mathbb{R}^+$	G	1×10^{-3}	9×10^{-4}
Smoothing	$\Phi_{\Delta G}$	$\mathbb{R}^+$	G	0.1	0.09
Smoothing	ρ_g	[0,1)	B	0.8	0.05
Standard Deviation of Shocks					
World Techn.	σ_z	$\mathbb{R}^+$	I	0.2	4
Home Techn.	σ_a	$\mathbb{R}^+$	I	0.5	4
World Output	σ_{y^*}	$\mathbb{R}^+$	I	0.5	4
Cost-Push	σ_π	$\mathbb{R}^+$	I	0.1	4
Spending	σ_g	$\mathbb{R}^+$	I	2.0	4

Notes: B stands for beta, G for gamma, and I for inverted gamma distributions. Parameters p(1) and p(2) list the means and standard deviations for all distributions.

We set gamma distributions for the "conservatism" parameters, $\Phi_{\pi M}$ and $\Phi_{\pi F}$. The mean prior of $\Phi_{\pi M}$ is set to 1.0, and the mean prior of $\Phi_{\pi M}$ is set to 0.5 to reflect our belief that the monetary policymaker is likely to prioritize inflation stabilization, while the fiscal policymaker may consider inflation stabilization less of a priority. However, both prior distributions are very wide and allow both posterior means to exceed one.

The interest rate smoothing target weight $\Phi_{\Delta I}$ can be interpreted as a measure of importance of this target relative to the inflation stabilization target. It is widely accepted that the monetary authorities consider the inflation target to be most important, and it might be difficult to justify the mean posterior of $\Phi_{\Delta I}$ if it exceeds one. Note, however, that $\Phi_{\Delta I}$ directly affects the instrument inertia in the implied policy reaction function. The empirical reaction function may not be fully determined by either commitment or discretion; it may have some non-strategic components which we cannot identify within this framework. The presence of such non-strategic components may imply a large estimate of $\Phi_{\Delta I}$. Following Dennis (2006) and Ilbas (2010), we do not constrain $\Phi_{\Delta I}$ to be less than one. We choose gamma distribution with mean 0.75 and standard error of 0.25; this gives us a very wide prior.

There is no wide agreement that the policy weight on instrument smoothing in fiscal objectives should not dominate the inflation target. However, because we remove the stochastic trend from the government share over the observed period, we do not expect to find a great deal of the fiscal instrument smoothing. We do not expect to find an important debt stabilization target either, given the observed high and persistent debt-to-output ratio in the United Kingdom. To reflect these beliefs, we choose gamma distribution with mean 0.1 and standard error of 0.09 for $\Phi_{\Delta G}$ and choose gamma distribution with mean 1×10^{-3} and standard error of 9×10^{-4} for Φ_B.

All shock variances are assumed to be distributed as inverted gamma distribution. Their means are taken from similar studies, predominantly from Dennis (2006), Lubik and Schorfheide (2006), Ilbas (2010), and Givens (2012).

Finally, some priors are more dispersed than others. Note that more-diffuse priors do not necessarily deliver higher marginal data density. While the in-sample fit improves slightly, wider priors relax some of the parameter restrictions, and this leads to a larger penalty for model complexity. The second effect can outweigh the first one, and this leads to an overall fall in the marginal data density. We therefore make a prior more concentrated when such effect is evident.

4. Empirical Results

4.1 Parameter Estimates

Markov chain Monte Carlo methods, described in, e.g., Lubik and Schorfheide (2006), are used to generate draws from the posterior distribution of model parameters. We present the summary statistics in tables 2–4.

Overall, the estimates of the structural parameters fall within plausible ranges, consistent with most of the literature, and are similar for commitment and discretion; see table 2.

The estimate of the Calvo parameter θ implies that prices remain fixed between two and three quarters. The price indexation parameter ζ is estimated rather moderately: when firms adjust the price, less than half of them change prices optimally rather than adopt a rule of thumb and index the growth rate of prices to the past observed inflation rate. These estimates are consistent with those obtained in Lubik and Schorfheide (2006).

We do not find evidence of substantial habit persistence, measured by parameter h; this is similar to findings in Liu and Mumtaz (2011) for the United Kingdom and in Justiniano and Preston (2010b) for New Zealand. The estimate of the preference parameter α is lower than the UK import share, and this is consistent with much of the open-economy literature; see, e.g., Lubik and Schorfheide (2007) and Justiniano and Preston (2010a). The inverse of the intertemporal elasticity of substitution, σ, is consistent with those obtained in the literature, e.g., Justiniano and Preston (2010a, 2010b).

These results are interrelated and are the consequence of fitting equation (19) to the data. If we treat the terms of trade as a non-observable variable, then the tension between the prior and posterior for α, σ, and h is greatly reduced.

The marginal data density is relatively flat in the inverse elasticity of labor supply, ϕ, as the posterior distribution of ϕ is not much different from the prior.

All priors for policy parameters do not conflict with the data; see table 3. The mean posterior of $\Phi_{\pi M}$ is only slightly less than the mean prior, and the posterior distribution is only slightly more concentrated than the prior distribution. It implies that the weight

Table 2. Estimated Structural Parameters and Shocks

		Monetary-Fiscal Model		Monetary Model	
		Discretion	**Commitment**	**Discretion**	**Commitment**
Structural Parameters					
Home Techn.	ρ_a	0.83 [0.77,0.89]	0.84 [0.77,0.90]	0.87 [0.82,0.92]	0.87 [0.81,0.93]
World Output	ρ_{y*}	0.84 [0.79,0.90]	0.83 [0.78,0.89]	0.83 [0.77,0.90]	0.82 [0.75,0.88]
World Techn.	ρ_z	0.87 [0.82,0.92]	0.88 [0.83,0.93]	0.85 [0.79,0.91]	0.85 [0.79,0.91]
Calvo Param.	θ	0.64 [0.58,0.70]	0.62 [0.54,0.67]	0.70 [0.64,0.76]	0.63 [0.57,0.70]
Habit Persist.	h	0.09 [0.05,0.12]	0.10 [0.05,0.14]	0.08 [0.05,0.11]	0.08 [0.05,0.11]
Inflation Inertia	ζ	0.64 [0.52,0.77]	0.75 [0.61,0.88]	0.79 [0.69,0.90]	0.76 [0.60,0.91]
Openness	α	0.26 [0.21,0.30]	0.26 [0.22,0.31]	0.27 [0.22,0.32]	0.27 [0.22,0.32]
CRRA	σ	1.23 [1.10,1.36]	1.22 [1.09,1.35]	1.19 [1.06,1.32]	1.19 [1.05,1.32]
Inverse Frisch	ϕ	2.03 [1.64,2.42]	2.03 [1.63,2.42]	1.87 [1.50,2.15]	1.92 [1.54,2.26]
Standard Deviation of Shocks					
World Techn.	σ_z	0.18 [0.15,0.22]	0.23 [0.18,0.28]	0.25 [0.19,0.30]	0.29 [0.23,0.36]
Home Techn.	σ_a	0.38 [0.32,0.45]	0.41 [0.34,0.49]	0.92 [0.75,1.08]	0.89 [0.73,1.04]
World Output	σ_{y^*}	1.15 [0.97,1.34]	1.17 [0.97,1.37]	1.30 [1.10,1.50]	1.30 [1.10,1.51]
Cost-Push	σ_π	0.14 [0.12,0.16]	0.14 [0.12,0.16]	0.14 [0.12,0.16]	0.14 [0.12,0.16]
Spending	σ_g	2.25 [1.92,2.59]	2.28 [1.92,2.61]	2.23 [1.90,2.57]	2.24 [1.90,2.57]

Notes: Mean and posterior percentiles are from eight chains of 100,000 draws generated using the random-walk Metropolis algorithm, where we discard the initial 50,000 draws. Convergence diagnostics were assessed using trace plots.

Table 3. Estimated Structural Parameters and Weights

		Monetary-Fiscal Model		Monetary Model	
		Discretion	**Commitment**	**Discretion**	**Commitment**
Monetary Policy Parameters					
Conservatism	$\Phi_{\pi M}$	0.91 [0.55,1.27]	0.92 [0.56,1.25]	0.78 [0.45,1.11]	0.90 [0.52,1.26]
Smoothing	$\Phi_{\Delta I}$	0.90 [0.49,1.27]	0.80 [0.43,1.14]	1.09 [0.64,1.52]	0.92 [0.53,1.25]
Fiscal Policy Parameters					
Conservatism	$\Phi_{\pi F}$	0.39 [0.01,0.79]	0.35 [0.04,0.66]	—	—
Debt	Φ_B	0.00 [0.00,0.00]	0.00 [0.00,0.00]	—	—
Smoothing	$\Phi_{\Delta G}$	0.01 [0.00,0.03]	0.01 [0.00,0.03]	—	—
Smoothing	ρ_g	—	—	0.85 [0.80,0.90]	0.85 [0.80,0.90]

Table 4. Data Density

		Type of Policy Regime	Type of BVAR Prior	Data Density	Hyper-parameter $\hat{\lambda}$
Monetary-Fiscal Model	DSGE	Discretion	—	−226.25	—
	DSGE	Commitment	—	−231.65	—
	BVAR	—	Discretion	−183.37	0.98 [0.70,1.24]
	BVAR	—	Commitment	−182.20	0.98 [0.72,1.23]
Monetary Model	DSGE	Discretion	—	−288.37	—
	DSGE	Commitment	—	−289.52	—
	BVAR	—	Discretion	−203.45	0.76 [0.60,0.92]
	BVAR	—	Commitment	−205.05	0.74 [0.72,1.23]

on inflation stabilization is consistent with the microfounded weight and is relatively large. There is no tension between the prior and posterior of $\Phi_{\Delta I}$: although the mean posterior is slightly higher than the mean prior, it remains below one and the confidence interval is not too wide.

The policy priorities of the fiscal policymaker are described by relative weights $\Phi_{\pi F}$, $\Phi_{\Delta G}$, and Φ_B. The posterior of the conservatism weight, $\Phi_{\pi F}$, is more concentrated than the (very wide) prior, with the mean shifted towards zero. This implies that the relative weight on the inflation target is lower than the microfoundations suggest. The fiscal smoothing weight $\Phi_{\Delta G}$ is very small; this is likely to be a consequence of the chosen detrending method. We did not find any evidence that the fiscal policymakers have the debt target, Φ_B.

The estimates of standard errors of structural shocks are in line with those obtained in most of the literature; see, e.g., Smets and Wouters (2003) and Lubik and Schorfheide (2007) for equally stylized models. Standard errors of technology and cost-push shocks are relatively low and, similar to results in Lubik and Schorfheide (2007), the standard error of the foreign demand shock is relatively high. The foreign demand shock is likely to accumulate various misspecifications of our simple model.

4.2 Commitment vs. Discretion

If we allow for policy delegation, then the dynamics of the economy under discretion can be made very similar to the one under commitment.[15] Additionally, if the private sector is predominantly backward looking, then the difference between the dynamics of the economy under commitment and discretion is small. Our model has both these features. First, we have estimated some degree of habit persistence and inflation inertia. Second, we have also estimated different parameters of policy objectives of the two policymakers. It might become difficult to distinguish between the two policy regimes.

Nevertheless, there are some differences between the estimated parameters under discretion and commitment. First, to fit the same

[15]Interest rate smoothing, price-level targeting, and speed-limit policy are all designed to approximate the commitment equilibrium in a simple New Keynesian model. In models with optimizing fiscal policy, such result may be less clear if the policymakers choose to engage in a fight.

data, the price setters under commitment reset prices more frequently, but most of these changes are based on the rule of thumb rather than on optimality. The mean share of the rule-of-thumb setters under commitment is 10 percent greater than under discretion. Second, the monetary policymaker under discretion has a bigger penalty on the interest rate smoothing target than the policymaker under commitment. In this model, given the same policy objectives and parameters of the model for commitment and discretion, the optimal policy under commitment generates lower volatility of inflation and higher volatility of interest rate. At the same time, inflation is found to be more sensitive to interest rate changes under commitment than under discretion. Therefore, in order to fit both models to the same data on interest rate and inflation, we have to have a lower weight on interest rate smoothing under commitment. An increase in this weight under commitment generates lower volatility of interest rate and much higher volatility of inflation, which is rejected by the data.

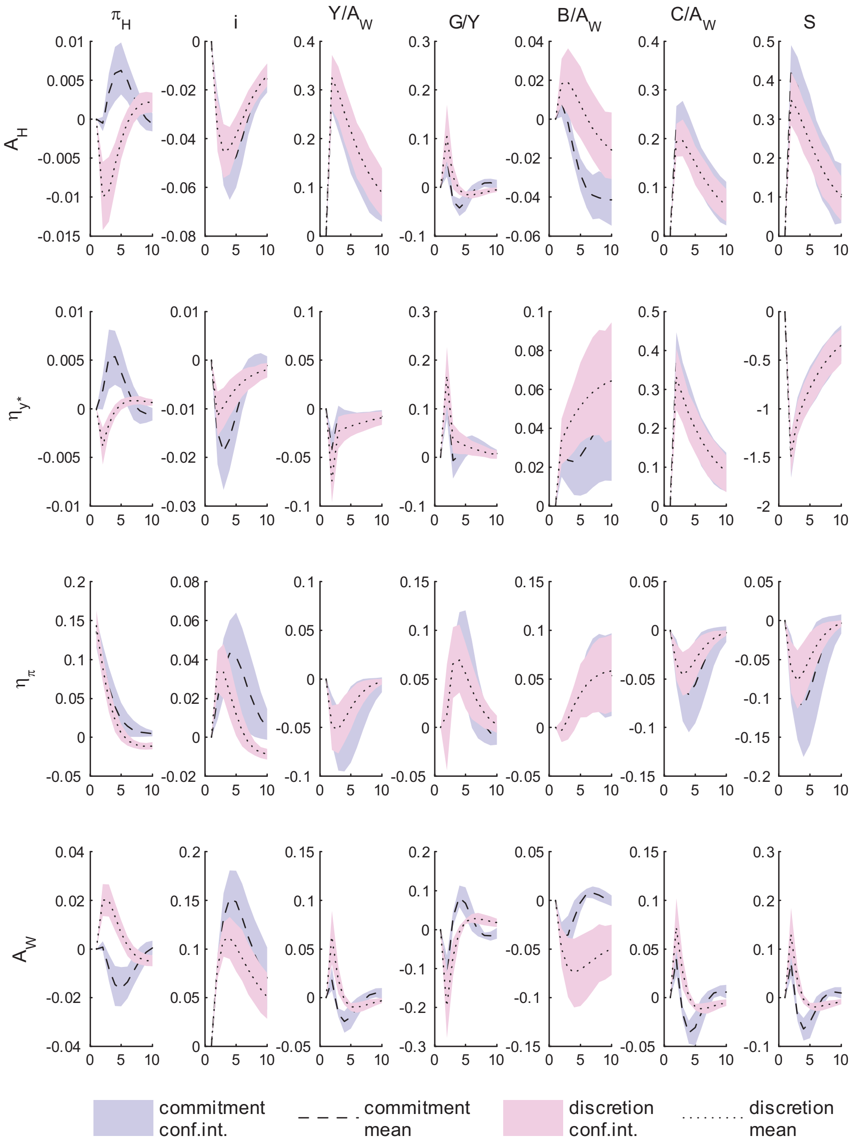
In order to improve our understanding of the dynamics of economy under the two policies, we compute impulse response functions. Figure 1 reports the responses of endogenous variables to one-standard-deviation shocks. Each sub-plot plots results for commitment and discretion together and shows mean responses of observable variables together with 5th and 95th percentiles. We only plot the first ten quarters, as all variables converge back to their base lines in the long run.[16]

A positive home technology shock A_H reduces the marginal cost and drives inflation down. The monetary policymaker reduces the interest rate so consumption and output rise. The real exchange rate depreciates. The fiscal policymaker increases spending such that the government share rises. Under commitment, the interest rate is reduced by more, which leads to higher consumption, inflation overshooting, and a reduction in government debt.

An increase in the world output η_{y^*} increases foreign demand for both home and foreign goods. This results in an appreciation of the real exchange rate. Because of the risk-sharing assumption, consumers increase consumption of foreign goods, which leads to an

[16]Because the debt target $\Phi_B \neq 0$, although very small, the debt under commitment is not a unit-root variable.

Figure 1. Impulse Responses to One-Standard-Deviation Structural Shocks



initial reduction in domestic output. Inflation falls and the interest rate is reduced. The interest rate under commitment is reduced by more, resulting in inflation overshooting and lower debt. Fiscal policy increases spending and the government share.

A positive cost-push shock η_π increases inflation, and optimal monetary policy raises the interest rate in response. This leads to lower consumption and output and a consequent reduction in inflation. Fiscal policy reduces spending. The real exchange rate appreciates. Under commitment, the interest rate is raised by more, which leads to greater appreciation of the real exchange rate and a greater fall in consumption. The resulting reduction in marginal cost is insufficiently strong to outweigh the inflation persistence and deliver the same speed of reduction in inflation as under discretion. The government share rises because of the bigger fall in consumption and output.

A positive worldwide productivity shock A_W results in the real exchange rate depreciation. The productivity-adjusted output rises. The initial impact on habit-adjusted consumption is positive because of the increase in real wage following the shock. The higher marginal cost drives inflation up. The optimal interest rate is raised. Government spending has to be lower to control the accumulation of debt. Interest rate under commitment rises higher than under discretion. This ensures quick reduction in inflation with overshooting.

4.3 Model Fit

Table 4 reports the marginal data density for both policy regimes. This is a measure of relative fit and allows one to compare different specifications of the model. A comparison of marginal data densities leads to the conclusion that the regime of fiscal leadership in the United Kingdom can be best described as discretion. The difference between the log-marginal data densities can be interpreted as log-posterior odds under the assumption that the two specifications have equal prior probabilities. Our finding suggests that the probability that the actual data was generated by a model with optimal commitment policy, rather than by a model with optimal discretionary policy, is less than 1 percent. In interpretation of Kass and Raftery (1995), there is a "substantial" evidence in favor of discretion over commitment.

While the data density provides a measure of relative fit, we also present root mean squared errors (RMSEs) and second-order moments which measure absolute fit; see, e.g., Justiniano and Preston (2010b) and Rabanal and Tuesta (2010). Table 5 reports RMSEs and second-order moments for the data and the corresponding statistics implied by the estimated models. We report means with standard errors in parentheses.

The DSGE model under discretion produces good fit of standard deviations of all variables—in particular, of interest rate and inflation. The volatility of the output growth rate Ψ_t is slightly overestimated under both discretion and commitment. The volatility of interest rate is substantially overestimated under commitment. Namely, these properties produce most of the differences in impulse responses between the two models in figure 1.

Empirical autocorrelation of inflation is best captured by the commitment model, while the discretion model underestimates it. Both models overestimate the autocorrelation of the growth rate of output and underestimate the autocorrelation of the government share. The autocorrelation of the terms of trade is captured reasonably well.

Further, table 6 reports autocorrelations up to the fifth order. The autocorrelations generated by the model of discretion are close to the data autocorrelations for all variables. However, both discretion and commitment models are able to match empirical autocorrelations closely.

To assess the degree of model fit, we also report marginal data densities for reduced-form vector autoregressions with four lags, estimated under different Minnesota-type priors. More specifically, following Del Negro and Schorpfheide (2004), Lubik and Schorfheide (2006), and Adjemian, Paries, and Moyen (2008), we populate the original data sample with additional artificial data generated by the DSGE model. The relative importance of the prior information can be measured by parameter $\hat{\lambda} = N/T$, where N is the size of the artificial sample and T is the size of the data sample. We estimate the optimal weight, $\hat{\lambda}$, of either commitment or discretion DSGE prior in the BVAR model. Following Del Negro and Schorpfheide (2004), we call it the DSGE-VAR or BVAR model interchangeably. The relative importance of the prior information is a measure of the degree of misspecification of the model. If $\hat{\lambda}$ is estimated to be high,

Table 5. RMSEs and Moments Implied by the Data and Models

	Data	Monetary-Fiscal Model				Monetary Model			
		DSGE with Type of Policy		BVAR with Type of Prior		DSGE with Type of Policy		BVAR with Type of Prior	
		Discr.	Comm.	Discr.	Comm.	Discr.	Comm.	Discr.	Comm.
RMSE									
π_H		0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
i_t		0.08	0.08	0.10	0.10	0.08	0.08	0.11	0.11
Ψ_t		0.39	0.37	0.43	0.42	0.63	0.63	0.75	0.77
S_t		1.28	1.27	1.28	1.25	1.27	1.26	1.25	1.24
Ω_t		2.27	2.30	2.30	2.32	2.33	2.33	2.34	2.33
Standard Deviations									
π_H	*0.20*	0.18	0.20	0.12	0.15	0.20	0.20	0.13	0.12
		(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
i_t	*0.25*	0.31	0.41	0.20	0.26	0.37	0.46	0.20	0.23
		(0.03)	(0.04)	(0.02)	(0.03)	(0.03)	(0.04)	(0.02)	(0.02)
Ψ_t	*0.37*	0.53	0.59	0.37	0.39	1.15	1.20	0.48	0.51
		(0.03)	(0.05)	(0.03)	(0.04)	(0.06)	(0.07)	(0.03)	(0.03)
S_t	*2.40*	2.68	2.66	1.41	1.38	3.38	3.31	1.41	1.40
		(0.19)	(0.20)	(0.18)	(0.17)	(0.19)	(0.18)	(0.15)	(0.15)
Ω_t	*2.22*	2.28	2.29	1.37	1.39	2.32	2.32	0.94	0.94
		(0.16)	(0.17)	(0.15)	(0.15)	(0.18)	(0.18)	(0.10)	(0.09)
Autocorrelations									
π_H	*0.69*	0.61	0.71	0.69	0.80	0.69	0.68	0.78	0.73
		(0.00)	(0.00)	(0.0027)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
i_t	*0.92*	0.94	0.96	0.93	0.95	0.95	0.96	0.93	0.94
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Ψ_t	*0.28*	0.44	0.60	0.38	0.52	0.07	0.11	0.14	0.19
		(0.05)	(0.05)	(0.07)	(0.07)	(0.03)	(0.04)	(0.06)	(0.06)
S_t	*0.82*	0.82	0.82	0.79	0.79	0.84	0.83	0.81	0.80
		(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)
Ω_t	*−0.16*	−0.01	−0.00	−0.01	−0.01	−0.07	−0.07	−0.10	−0.10
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Table 6. Autocorrelations Implied by the Data and Models

Lag	Data	DSGE		BVAR	
		Type of Policy		Type of Prior	
		Discretion	Commitment	Discretion	Commitment
Inflation, π_H					
1	0.69	0.61 (0.00)	0.71 (0.00)	0.69 (0.00)	0.80 (0.00)
2	0.23	0.42 (0.00)	0.41 (0.00)	0.57 (0.00)	0.50 (0.00)
3	0.01	0.21 (0.00)	0.22 (0.00)	0.40 (0.00)	0.33 (0.00)
4	0.03	0.05 (0.00)	0.11 (0.00)	0.25 (0.00)	0.21 (0.00)
5	0.07	−0.06 (0.00)	0.06 (0.00)	0.14 (0.00)	0.14 (0.00)
Output Growth Rate, Ψ_t					
1	0.28	0.44 (0.05)	0.60 (0.05)	0.38 (0.07)	0.52 (0.07)
2	0.08	0.06 (0.02)	0.10 (0.03)	0.10 (0.03)	0.14 (0.04)
3	0.09	0.06 (0.02)	0.10 (0.03)	0.10 (0.03)	0.13 (0.04)
4	0.04	0.06 (0.02)	0.09 (0.03)	0.09 (0.03)	0.12 (0.04)
5	−0.01	0.05 (0.02)	0.09 (0.03)	0.08 (0.03)	0.11 (0.03)
Interest Rate, i_t					
1	0.92	0.94 (0.00)	0.96 (0.00)	0.93 (0.00)	0.95 (0.00)
2	0.80	0.85 (0.00)	0.86 (0.00)	0.81 (0.00)	0.82 (0.00)
3	0.64	0.74 (0.00)	0.74 (0.00)	0.68 (0.01)	0.67 (0.01)
4	0.51	0.63 (0.00)	0.62 (0.00)	0.55 (0.01)	0.52 (0.01)
5	0.42	0.53 (0.00)	0.52 (0.00)	0.43 (0.01)	0.41 (0.01)

(continued)

Table 6. (Continued)

Lag	Data	DSGE		BVAR	
		Type of Policy		Type of Prior	
		Discretion	Commitment	Discretion	Commitment
Terms of Trade, S_t					
1	0.08	0.82	0.82	0.79	0.79
		(0.00)	(0.00)	(0.00)	(0.00)
2	0.76	0.71	0.70	0.68	0.67
		(0.01)	(0.01)	(0.00)	(0.00)
3	0.64	0.61	0.59	0.58	0.56
		(0.00)	(0.01)	(0.00)	(0.00)
4	0.57	0.52	0.49	0.48	0.46
		(0.01)	(0.01)	(0.00)	(0.01)
5	0.53	0.44	0.42	0.41	0.39
		(0.01)	(0.01)	(0.00)	(0.01)
Growth Rate of Government Share, Ω_t					
1	−0.16	−0.01	−0.00	−0.01	−0.01
		(0.00)	(0.00)	(0.00)	(0.00)
2	−0.00	−0.06	−0.06	−0.08	−0.08
		(0.00)	(0.00)	(0.00)	(0.00)
3	−0.02	−0.06	−0.05	−0.06	−0.06
		(0.00)	(0.00)	(0.00)	(0.00)
4	0.42	−0.05	−0.04	−0.05	−0.05
		(0.00)	(0.00)	(0.00)	(0.00)
5	−0.06	−0.04	−0.04	−0.04	−0.04
		(0.00)	(0.00)	(0.00)	(0.00)

then it means that the DSGE model imposes useful restrictions to improve the (in-sample) predictive properties of the BVAR model. Conversely, if $\hat{\lambda}$ is estimated to be low, then the DSGE model is not coherent with the data. Finding $\hat{\lambda} \simeq 1.0$ suggests that the DSGE models do impose some useful restrictions: Del Negro et al. (2007) and Adjemian, Paries, and Moyen (2008) demonstrate that $\hat{\lambda} = 0.35$ is close to the point where the DSGE provides no useful information, while $\hat{\lambda} > 0.6$ demonstrates some coherence of the DSGE model with the data.

Notably, the marginal data densities for both BVARs are almost identical; see table 4. Both commitment and discretion DSGE models impose similarly useful restrictions. A comparison of DSGE and BVARs can help us to identify the tightest restrictions imposed by the DSGE models. Table 5 demonstrates that both BVARs improve the fit of the growth rate of output and interest rate but at the expense of the fit of other variables. Figure 2 compares impulse responses of DSGE and DSGE-VAR models under discretion. It is apparent that the dynamics of inflation, interest rate, and the terms of trade is less volatile as implied by the BVAR, but at the same time we do not observe any big differences in direction of responses and in their persistence which is implied by this correction.

Finally, figure 3 reports the historic and the one-step-ahead predicted data under the two policy regimes. Both policy regimes result in very similar estimates.

4.4 Role of Fiscal Policy

We have estimated fiscal policy to be relatively inactive: although there is a general consistency of the data with microfounded policy objectives, fiscal policy does very little to stabilize the economy. Under our assumption of fiscal intraperiod leadership, this is the optimal outcome, as the fiscal policymaker leaves the stabilization work to the monetary policymaker. The monetary policymaker, however, observes fiscal variables and takes them into account when formulating policy. In this section we argue that the state of fiscal stance does play a role in identification of the model.

The evolution of the government debt and fiscal spending are among the identifying restrictions for the model. To assess the importance of these restrictions, we reestimate the model excluding the government solvency constraint and treating the government share as following an AR(1) process with coefficient ρ_g. The monetary policymaker is assumed to act either under discretion or commitment. The results of estimation are given in table 2, in the last two columns.

Some of the key structural parameters appear to be different when the fiscal problem is excluded. In particular, the Calvo reset

Figure 2. Impulse Responses under Discretion

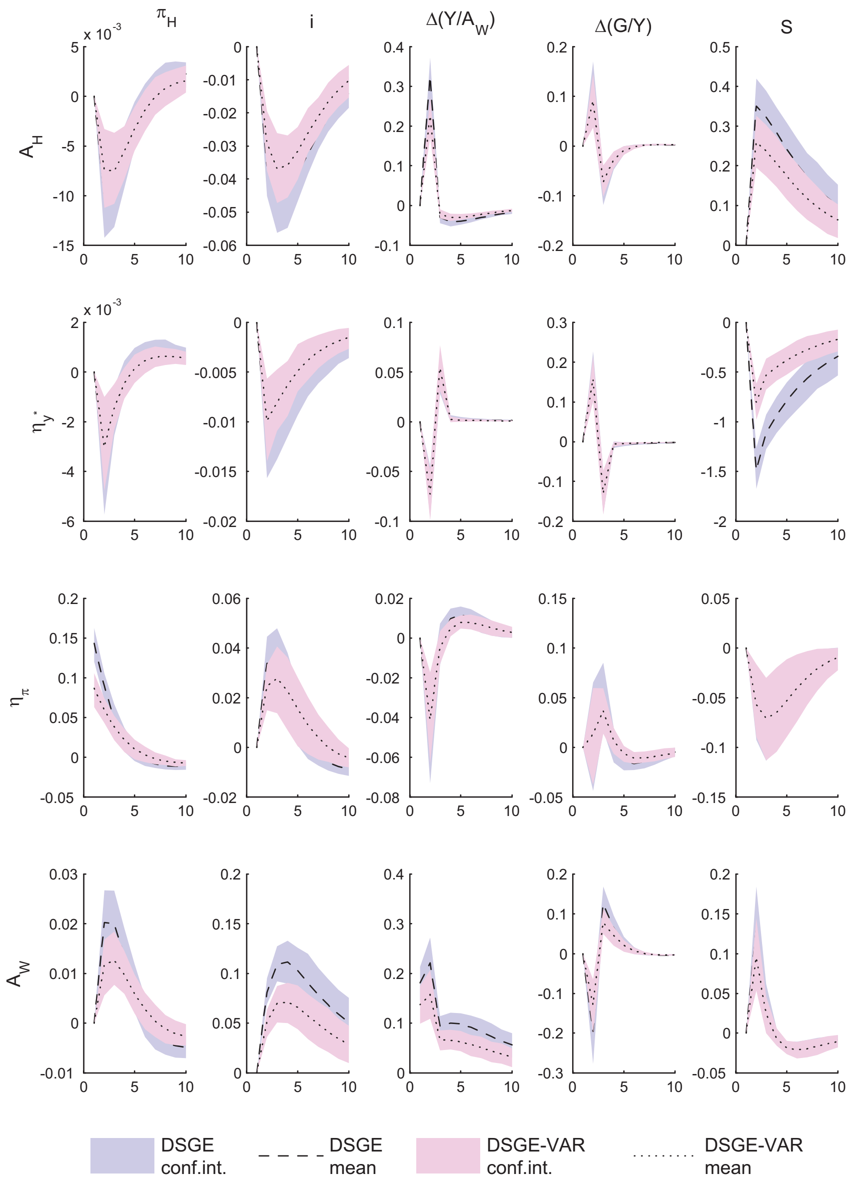
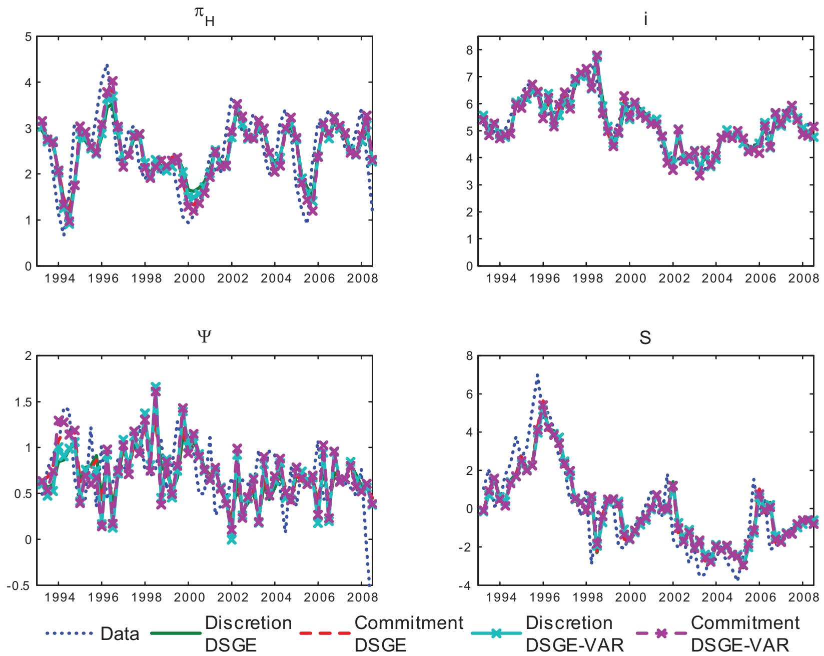


Figure 3. The Data and One-Step-Ahead Forecast



probability, the degree of inflation inertia, and volatility of home technology shocks are larger when the fiscal block is ignored; the difference is particularly large for the preferred specification of the optimal discretion. The monetary policy parameters are affected too once the fiscal block becomes exogenous: the monetary policymaker is less inflation conservative and operates with greater interest rate smoothing. All these changes in estimated parameters are required to generate greater endogenous persistence observed in the data.

Table 4 demonstrates that the monetary model leads to lower marginal data density. (There is also much less difference between commitment and discretion.) The absolute fit is assessed in table 5. Standard deviations of interest rate, terms of trade, and the growth rate of output are substantially overestimated. The autocorrelation of the growth rate of output is underestimated and there is a big increase in RMSE for this variable. At the same time, the autocorrelation of the government share is much less underestimated.

To understand these results, we look at the role of the government debt accumulation equation in the model.

First, the debt accumulation process is highly persistent under both commitment and discretion. Its persistence propagates through the whole system; in particular, in the case of discretion where all reaction functions are time invariant and can be written as linear functions of predetermined states, the speed of convergence of all variables, including debt, is the same. If we remove the government budget constraint from the system, then in order to fit the same persistent data, we require more inflation inertia and a higher penalty on policy instrument movements. This role of debt process as persistent process might be played by some other “slow” processes, like the capital accumulation process, which are omitted from our simple model.

Second, the debt accumulation process is potentially explosive. All economic agents are aware of this and should make decisions that are compatible with non-explosiveness of debt dynamics. In particular, the fiscal policymaker may optimally prefer to feed back on debt strong enough in order to allow the monetary policymaker to concentrate on inflation stabilization tasks. The monetary-fiscal model estimation results are consistent with non-explosiveness of debt. Once the government budget constraint is removed and the dynamics of fiscal instrument is approximated by an AR(1) exogenous process, the monetary policymaker does not take into account whether the problem of debt stabilization is resolved or not. This yields higher volatility of interest rate to fit the volatility of inflation in the data. Higher penalty on the instrument smoothing terms would result in higher volatility of inflation, inconsistent with the data. This role of the debt accumulation process as a potentially explosive process may not be played by an intrinsically stable process like the capital accumulation process.

One can argue that the monetary policymaker alone can precommit to the chosen plan, while if we estimate monetary and fiscal interactions jointly, then discretionary policy of fiscal policymakers results in the overall dominance of discretion. Indeed, we find that the gap between discretion and comment reduced once we excluded the fiscal sector from the economy. However, the smaller difference can also be a result of higher estimated persistence of the economy and the smaller role of expectations.

Finally, results from corresponding DSGE-VAR models suggest that there is a reduction in $\hat{\lambda}$, so the monetary DSGE model imposes tighter restrictions on the data. The BVAR marginal data density values improve by about eighty units and are closer to those obtained in more general monetary-fiscal DSGE-VAR models. Also, the first- and second-order moments are not as closely matched as in the monetary-fiscal model.

5. Conclusions

This paper identifies the degree of precommitment in monetary and fiscal policy interactions in the United Kingdom. We specify a small-scale structural general equilibrium model of a small open economy and estimate it using Bayesian methods. Unlike most of the existing empirical research, we explicitly take into account the solvency constraint faced by the fiscal authorities. We also assume that the authorities act non-cooperatively and may have different objectives.

We find that the model of discretionary policy explains the data better than the model of commitment policy. We find that both policymakers put smaller weight on inflation stabilization than is socially optimal. The fiscal policymaker pays much less attention to inflation stabilization than the monetary policymaker. The presence of fiscal block in the model plays the important role in identification of monetary policy and structural parameters.

Appendix 1. Social Welfare

Social welfare is written as

$$W = \sum_{t=0}^{\infty} \beta^t \left(\frac{x_t^{1-\sigma}}{1-\sigma} + \chi \frac{g_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right).$$

Linearization yields

$$W = \sum_{t=0}^{\infty} \beta^t \left(x^{1-\sigma} \left(\hat{x}_t + \frac{1}{2}(1-\sigma)\hat{x}_t^2 \right) + \chi g^{1-\sigma} \left(\hat{g}_t + \frac{1}{2}(1-\sigma)\hat{g}_t^2 \right) \right.$$
$$\left. - N^{1+\varphi} \left(\hat{N}_t + \frac{1}{2}(1+\varphi)\hat{N}_t^2 \right) \right) + tip(3),$$

where $tip(3)$ includes terms independent of policy of the third order and higher. Production function (14) yields the exact relationship $\hat{N}_t = \hat{\Delta}_t + \hat{y}_t - \hat{A}_{Ht}$. We substitute $\hat{N}_t$ out and use

$$\sum_{t=0}^{\infty} \beta^t \hat{\Delta}_t = \frac{\theta}{1-\theta\beta}\hat{\Delta}_{-1} + \frac{1}{2}\sum_{t=0}^{\infty}\beta^t \frac{\epsilon\theta(1-\zeta)}{\lambda} \times \left(\pi_{Ht}^2 + \frac{\zeta}{\theta(1-\zeta)}(\pi_{Ht}-\pi_{Ht-1})^2\right)$$

to yield

$$W = \sum_{t=0}^{\infty}\beta^t \left(x^{1-\sigma}\left(\hat{x}_t + \frac{1}{2}(1-\sigma)\hat{x}_t^2\right) + \chi g^{1-\sigma}\left(\hat{g}_t + \frac{1}{2}(1-\sigma)\hat{g}_t^2\right) - \chi_N N^{1+\varphi}\left(\hat{y}_t + \frac{1}{2}\frac{\epsilon\theta(1-\zeta)}{\lambda}\left(\pi_{Ht}^2 + \frac{\zeta}{\theta(1-\zeta)}(\pi_{Ht}-\pi_{Ht-1})^2\right) + \frac{1}{2}(1+\varphi)\hat{N}_t^2\right)\right) + tip(3).$$

The linearized-up-to-second-order national income identity and the international risk-sharing condition yield

$$\hat{y}_t + \frac{1}{2}\hat{y}_t^2 = (1-\alpha)\frac{c}{y}\left(\hat{c}_t + \alpha\eta\hat{S}_t + \frac{1}{2}\alpha\eta(-\eta+2\alpha\eta+1-\alpha)\hat{S}_t^2 + \frac{1}{2}\hat{c}_t^2 + \alpha\eta\hat{S}_t\hat{c}_t\right) + \frac{g}{y}\left(g_t + \frac{1}{2}g_t^2\right) + \alpha\frac{c}{y}\left(\eta\hat{S}_t + \hat{c}_t^* + \frac{1}{2}\eta^2\hat{S}_t^2 + \frac{1}{2}\hat{c}_t^{*2} + \eta\hat{S}_t\hat{c}_t^*\right)$$

$$\sigma\hat{x}_t + \frac{1}{2}\sigma^2\hat{x}_t^2 = (1-\alpha)\hat{S}_t + \sigma\hat{x}_t^* + \frac{1}{2}\frac{(\eta\alpha-2\alpha+1)}{(1-\alpha)}(1-\alpha)^2\hat{S}_t^2 + \frac{1}{2}\sigma^2\hat{x}_t^{*2} + \sigma(1-\alpha)\hat{S}_t\hat{x}_t^*.$$

Combining them allows us to substitute out the terms of trade:

$$\hat{y}_t = \frac{c}{y}(1-\alpha)\hat{c}_t + \frac{g}{y}g_t + \frac{c}{y}\frac{\alpha\eta(2-\alpha)\sigma}{(1-\alpha)}\hat{x}_t + \frac{c}{y}\frac{1}{2}\frac{\alpha\eta(2-\alpha)\sigma^2}{(1-\alpha)}\hat{x}_t^2 + \frac{c}{y}\frac{1}{2}\alpha\eta\left(\alpha(\eta-\alpha\eta+1)-(1-\alpha)^2\right)\frac{\sigma^2}{(1-\alpha)^2}(\hat{x}_t-\hat{x}_t^*)^2$$

$$
-\frac{c}{y}\frac{\alpha\eta\left(2-\alpha\right)\sigma^{2}}{\left(1-\alpha\right)}\left(\hat{x}_{t}-\hat{x}_{t}^{*}\right)\hat{x}_{t}^{*}+(1-\alpha)\frac{c}{y}\frac{\alpha\eta\sigma}{\left(1-\alpha\right)}\left(\hat{x}_{t}-\hat{x}_{t}^{*}\right)\hat{c}_{t}
+\frac{c}{y}\frac{\alpha\eta\sigma}{\left(1-\alpha\right)}\left(\hat{x}_{t}-\hat{x}_{t}^{*}\right)\hat{c}_{t}^{*}+\frac{g}{y}\frac{1}{2}g_{t}^{2}-\frac{1}{2}\hat{y}_{t}^{2}+(1-\alpha)\frac{c}{y}\frac{1}{2}\hat{c}_{t}^{2}.
$$

Using

$$
\sum_{t=0}^{\infty}\beta^{t}\hat{x}_{t}=-\frac{h}{(1-h)}\hat{c}_{-1}+\frac{(1-\beta h)}{(1-h)}\sum_{t=0}^{\infty}\beta^{t}\hat{c}_{t},
$$

we arrive at

$$
W=\sum_{t=0}^{\infty}\beta^{t}\mathcal{W}_{t},
$$

where

$$
\begin{aligned}
\mathcal{W}_{t}=&\left(-\frac{x^{1-\sigma}}{N^{1+\varphi}}\frac{(1-\beta h)}{(1-h)}+\frac{\alpha\eta\left(2-\alpha\right)\sigma\left(1-\beta h\right)}{\left(1-\alpha\right)\left(1-h\right)}\frac{c}{y}+(1-\alpha)\frac{c}{y}\right)\hat{c}_{t}\\
&+\left(\frac{g}{y}-\frac{\chi g^{1-\sigma}}{N^{1+\varphi}}\right)\hat{g}_{t}+\frac{1}{2}\left(\frac{c}{y}\frac{\alpha\eta\left(2-\alpha\right)\sigma^{2}}{\left(1-\alpha\right)}-\frac{x^{1-\sigma}}{N^{1+\varphi}}(1-\sigma)\right)\hat{x}_{t}^{2}\\
&+\frac{1}{2}\frac{\epsilon\theta\left(1-\zeta\right)}{\lambda}\left(\pi_{Ht}^{2}+\frac{\zeta}{\theta(1-\zeta)}\left(\pi_{Ht}-\pi_{Ht-1}\right)^{2}\right)\\
&+\frac{c}{y}\frac{1}{2}\frac{(\alpha\left(\eta-\alpha\eta+1\right)-\left(1-\alpha\right)^{2})\alpha\eta\sigma^{2}}{(1-\alpha)^{2}}\left(\hat{x}_{t}-\hat{x}_{t}^{*}\right)^{2}\\
&+\frac{c}{y}\alpha\eta\sigma\left(\hat{x}_{t}-\hat{x}_{t}^{*}\right)\hat{c}_{t}-\frac{c}{y}\frac{\left(2-\alpha\right)\alpha\eta\sigma^{2}}{\left(1-\alpha\right)}\left(\hat{x}_{t}-\hat{x}_{t}^{*}\right)\hat{x}_{t}^{*}\\
&+\frac{c}{y}\frac{\alpha\eta\sigma}{\left(1-\alpha\right)}\left(\hat{x}_{t}-\hat{x}_{t}^{*}\right)\hat{c}_{t}^{*}+\frac{1}{2}(1+\varphi)(\hat{y}_{t}-\hat{A}_{Ht})^{2}\\
&+\frac{1}{2}(1-\alpha)\frac{c}{y}\hat{c}_{t}^{2}+\frac{1}{2}\left(\frac{g}{y}-\frac{\chi g^{1-\sigma}}{N^{1+\varphi}}(1-\sigma)\right)\hat{g}_{t}^{2}-\frac{1}{2}\hat{y}_{t}^{2}+tip(3).
\end{aligned}
$$

We are interested in comparing stabilization performance of different policies; therefore, we assume that a time-invariant labor subsidy offsets monopolistic distortions, $\frac{x^{1-\sigma}}{N^{1+\varphi}}=\frac{c}{y}(\frac{\sigma\alpha\eta(2-\alpha)}{(1-\alpha)}+\frac{(1-h)(1-\alpha)}{(1-\beta h)})$. We chose χ so that $\frac{g}{y} = \chi\frac{g^{1-\sigma}}{N^{1+\varphi}}$. This yields the quadratic approximation to the social welfare loss in the form

$$\begin{aligned}\mathcal{W}_t &= \pi_{Ht}^2 + \frac{\zeta}{\gamma(1-\zeta)}(\pi_{Ht} - \pi_{Ht-1})^2 + \frac{\lambda\sigma(1-\theta)}{\epsilon\gamma(1-\zeta)}\hat{g}_t^2 \\ &\quad + \frac{\lambda\varphi}{\epsilon\gamma(1-\zeta)}\left(\hat{y}_t^2 - \frac{(1+\varphi)}{\varphi}\hat{A}_{Ht}\right)^2 \\ &\quad + \frac{2\theta\lambda}{\epsilon\gamma(1-\zeta)}\left(\frac{1}{2}\Psi_x\hat{x}_t^2 + (1-\alpha)\hat{c}_t^2 - \frac{\alpha\eta\sigma^2\left(\alpha\eta - \alpha^2\eta + 1\right)}{(1-\alpha)^2}\hat{x}_t\hat{x}_t^* \right. \\ &\quad \left. + \alpha\eta\sigma\hat{x}_t\hat{c}_t + \frac{\eta\alpha\sigma}{(1-\alpha)}\hat{x}_t\hat{c}_t^* - \alpha\eta\sigma\hat{x}_t^*\hat{c}_t\right) + tip(3),\end{aligned}$$

where $\Psi_x = \frac{\sigma\alpha\eta}{(1-\alpha)}((2-\alpha)(2\sigma-1) + \frac{((1-\alpha)\eta+1)\alpha\sigma}{(1-\alpha)}) - \frac{(1-h)(1-\alpha)(1-\sigma)}{(1-\beta h)} - \alpha\eta\sigma^2$.

Appendix 2. Theoretical Framework

Our model belongs to the class of non-singular linear stochastic rational expectations models of the type described by Blanchard and Kahn (1980), augmented by a vector of control instruments.

We label the two policymakers as leader (L) and follower (F), and denote them with index i, $i \in \{L, F\}$. (In this paper the leader is the fiscal policymaker and the follower is the monetary policymaker.)

The evolution of the economy is explained by the following system:

$$\begin{aligned}\begin{bmatrix} \mathsf{y}_{t+1} \\ \mathcal{E}_t\mathsf{x}_{t+1} \end{bmatrix} &= \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}\begin{bmatrix} \mathsf{y}_t \\ \mathsf{x}_t \end{bmatrix} \\ &\quad + \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix}\begin{bmatrix} \mathsf{u}_t^L \\ \mathsf{u}_t^F \end{bmatrix} + \begin{bmatrix} \epsilon_{t+1} \\ \mathsf{0} \end{bmatrix}, \end{aligned} \tag{30}$$

where y_t is a vector of predetermined variables with initial conditions y_0 given, $\mathsf{y}_t = [a_t, y_t^*, \varepsilon_t^\pi, b_t]'$, x_t is a vector of non-predetermined (or jump) variables, and $\mathsf{x}_t = [\pi_{Ht}, x_t]'$ where $x_t \equiv y_t - g_t$. u_t^F and u_t^L are the two vectors of policy instruments of the two policymakers, named F and L. $\mathsf{u}_t^F = i_t$ and $\mathsf{u}_t^L = g_t$ in the model. ϵ_t is a vector of i.i.d. shocks.

Each of the two policymakers has the following loss functions:

$$J_t^j = \frac{1}{2}\mathcal{E}_t \sum_{s=t}^{\infty} \beta^{s-t}(G_s' \mathcal{Q}^j G_s), \tag{31}$$

where $j = \{L, F\}$ and G_s^j is a vector of goal variables of policymaker i, which is a linear function of state variables and instruments, $G_s^j = \mathcal{C}^j \left[\mathsf{y}_s', \mathsf{x}_s', \mathsf{u}_s^{L\prime}, \mathsf{u}_s^{F\prime}\right]'$.

Commitment policy means that each policymaker is able to commit, with full credibility, to a policy *plan* (Currie and Levine 1993). Thus, the policy plan has to specify the desired levels of the target variables (e.g., inflation, the output gap, etc.) at all current and future dates and states of nature.

Assumption 1. *At each time t the follower observes the current decision of the leader u_t^L. The private sector observes both decisions u_t^L and u_t^F.*

Assumption 2. *At any time t both policymakers know assumption 1.*

The follower observes policy of the leader and reacts to it. The leader knows the follower reacts to its policy and is able to exploit it.

Assumption 3. *Suppose at time t the private sector and the policymakers only responds to the current state*

$$\begin{bmatrix} \mathsf{x}_t \\ \mathsf{u}_t^L \\ \mathsf{u}_t^F \end{bmatrix} = -\begin{bmatrix} \mathsf{N}^d \\ F_1^L \\ F_2^F \end{bmatrix} \mathsf{y}_t. \tag{32}$$

Assumption 4. *At each time t, the private sector observes the current policy decisions u_t^L, u_t^F and expects that future policymakers will reoptimize, and will apply the same decision process and implement decision $[F_1^{L\prime}, F_2^{F\prime}]'$. At each time t the follower observes the current policy decision of the leader u_t^L and expects that future leaders will reoptimize, and will apply the same decision process and implement decision F_1^L.*

PROBLEM 1 (Leadership under Commitment). *Under commitment policy the follower solves*

$$\min_{\{u_s^F\}_{s=t}^{\infty}} \frac{1}{2}\mathcal{E}_t \sum_{s=t}^{\infty} \beta^{s-t}(G_s^{F\prime}\mathcal{Q}^F G_s^F) \tag{33}$$

subject to constraint (30).

The leader solves

$$\min_{\{u_t^L\}_{s=t}^{\infty}} \frac{1}{2}\mathcal{E}_t \sum_{s=t}^{\infty} \beta^{s-t}(G_s^{L\prime}\mathcal{Q}^L G_s^L) \tag{34}$$

subject to constraint (30) and to the system of first-order conditions of the follower's optimization problem.

Policy determined by $[F_1^{L\prime}, F_2^{F\prime}]'$ is commitment policy if both policymakers find it optimal to follow $[F_1^{L\prime}, F_2^{F\prime}]'$ each time $s > t$, given assumptions 1–2.

Discretionary policy means that the policymaker treats its optimal policy problem, as described above, as one of "sequential optimization," i.e., without committing to any future course of action, it makes the decision that is optimal within that period only.

PROBLEM 2 (Leadership under Discretion). *Under discretion the follower solves*

$$\min_{u_t^F} \frac{1}{2}\mathcal{E}_t \sum_{s=t}^{\infty} \beta^{s-t}(G_s^{F\prime}\mathcal{Q}^F G_s^F) \tag{35}$$

subject to constraint (30).

The leader solves

$$\min_{u_t^L} \frac{1}{2}\mathcal{E}_t \sum_{s=t}^{\infty} \beta^{s-t}(G_s^{L\prime}\mathcal{Q}^L G_s^L) \tag{36}$$

subject to constraint (30) and to the system of first-order conditions of the follower's optimization problem.

Policy determined by $[F_1^{L\prime}, F_2^{F\prime}]'$ is discretionary if both policymakers find it optimal to follow $[F_1^{L\prime}, F_2^{F\prime}]'$ each time $s > t$, given assumptions 1–4.

Finally, we prove the following proposition.

PROPOSITION 1 (First-Order Conditions). *A solution to both commitment and discretionary leadership problems can be written in the following dynamic form:*

$$\mathsf{z}_{t+1} = \mathsf{M}\mathsf{z}_t, \tag{37}$$

$$\mathsf{v}_t = -\mathsf{N}\mathsf{z}_t, \tag{38}$$

where variable $\mathsf{z}_t \equiv \mathsf{y}_t$ *under discretion and* $\mathsf{z}_t \equiv [\mathsf{y}_t', \lambda_t']'$ *under commitment and* λ_t *are predetermined Lagrange multipliers; variable* $\mathsf{v}_t = [\mathsf{x}_t', \mathsf{u}_t^{L\prime}, \mathsf{u}_t^{F\prime}]'$. *Matrices* M *and* N *are functions of policy objectives* $\mathcal{Q}^L$ *and* $\mathcal{Q}^F$ *and of the system matrices* A *and* B.

Proof. We first solve the problem under commitment. The minimization problem of the follower can be presented by the following intraperiod Lagrangian:

$$\begin{aligned}
H_s^F = \frac{1}{2}\beta^{s-t}(&\mathsf{x}_s' Q_{22}^F \mathsf{x}_s + 2\mathsf{y}_s' Q_{12}^F \mathsf{x}_s + \mathsf{y}_s' Q_{11}^F \mathsf{y}_s + 2\mathsf{u}_s^L P_{11}^{F\prime} \mathsf{y}_s + 2\mathsf{u}_s^L P_{21}^{F\prime} \mathsf{x}_s \\
&+ 2\mathsf{u}^F P_{12}^{F\prime} \mathsf{y}_s + 2\mathsf{u}_s^F P_{22}^{F\prime} \mathsf{x}_s + \mathsf{u}_s^L R_{11}^F U_s^L + 2\mathsf{u}_s^L R_{12}^F \mathsf{u}_s^F + \mathsf{u}_s^F R_{22}^F v_s^F \\
&+ \lambda_{s+1}^{Fy\prime}(A_{11}\mathsf{y}_s + A_{12}\mathsf{x}_s + D_1 \mathsf{u}_s^L + B_1 \mathsf{u}_s^F - \mathsf{y}_{s+1}) \\
&+ \lambda_{s+1}^{Fx\prime}(A_{21}\mathsf{y}_s + A_{22}\mathsf{x}_s + D_2 \mathsf{u}_s^L + B_2 \mathsf{u}_s^F - \mathsf{x}_{s+1})),
\end{aligned}$$

where Lagrange multipliers λ^{Fy} are non-predetermined (as those on predetermined variables) with terminal conditions and λ^{Fx} are predetermined with initial conditions. The first-order conditions are

$$\begin{aligned}
0 &= Q_{22}^F \mathsf{x}_s + Q_{21}^F \mathsf{y}_s + P_{21}^F \mathsf{u}_s^L + P_{22}^F \mathsf{u}_s^F + \beta A_{12}' \lambda_{s+1}^{Fy} + \beta A_{22}' \lambda_{s+1}^{Fx} - \lambda_s^{Fx} \\
0 &= Q_{12}^F \mathsf{x}_s + Q_{11}^F \mathsf{y}_s + P_{11}^F \mathsf{u}_s^L + P_{12}^F \mathsf{u}_s^F + \beta A_{11}' \lambda_{s+1}^{Fy} + \beta A_{21}' \lambda_{s+1}^{Fx} - \lambda_s^{Fy} \\
0 &= P_{12}^{F\prime} \mathsf{y}_s + P_{22}^{F\prime} \mathsf{x}_s + R_{12}^{F\prime} \mathsf{u}_s^L + R_{22}^F \mathsf{u}_s^F + \beta B_1' \lambda_{s+1}^{Fy} + \beta B_2' \lambda_{s+1}^{Fx}.
\end{aligned}$$

The minimization problem of the leader or fiscal policymaker,

$$\begin{aligned}
H_s^L = \frac{1}{2}\beta^{s-t}\big(&\mathsf{x}_s' Q_{22}^L \mathsf{x}_s + 2Y_s' Q_{12}^L \mathsf{x}_s + \mathsf{y}_s' Q_{11}^L \mathsf{y}_s + 2\mathsf{u}^L P_{11}^{L\prime} \mathsf{y}_s \\
&+ 2\mathsf{u}^L P_{21}^{L\prime} \mathsf{x}_s + 2\mathsf{u}^F P_{12}^{L\prime} \mathsf{y}_s + 2\mathsf{u}_s^F P_{22}^{L\prime} \mathsf{x}_s + \mathsf{u}_s^L R_{11}^L \mathsf{u}_s^L + 2\mathsf{u}_s^L R_{12}^L \mathsf{u}_s^F \\
&+ \mathsf{u}_s^F R_{22}^L \mathsf{u}_s^F + \lambda_{s+1}^{Ly\prime}(A_{11}\mathsf{y}_s + A_{12}\mathsf{x}_s + D_1 \mathsf{u}_s^L + B_1 \mathsf{u}_s^F - \mathsf{y}_{s+1})
\end{aligned}$$

$$
\begin{aligned}
&+ \nu_s^{Lx\prime}(\beta A_{12}' \lambda_{s+1}^{Fy} + \beta A_{22}' \lambda_{s+1}^{Fx} - \lambda_s^{Fx} + \mathcal{Q}_{22}^F \mathsf{x}_s + \mathcal{Q}_{21}^F \mathsf{y}_s \\
&+ P_{21}^F \mathsf{u}_s^L + P_{22}^F \mathsf{u}_s^F) \\
&+ \lambda_{s+1}^{Lx\prime}(A_{21}\mathsf{y}_s + A_{22}\mathsf{x}_s + D_2 \mathsf{u}_s^L + B_2 \mathsf{u}_s^F - \mathsf{x}_{s+1}) \\
&+ \nu_s^{Ly\prime}\Big(A_{11}'\beta\lambda_{s+1}^{Fy} + A_{21}'\beta\lambda_{s+1}^{Fx} - \lambda_s^{Fy} + \mathcal{Q}_{12}^F \mathsf{x}_s + \mathcal{Q}_{11}^F \mathsf{y}_s \\
&+ \ P_{11}^F \mathsf{u}_s^L + P_{12}^F \mathsf{u}_s^F\Big) \\
&+ \nu_s^{Lu\prime}(P_{12}^{L\prime}\mathsf{y}_s + P_{22}^{L\prime}\mathsf{x}_s + R_{12}^{F\prime}\mathsf{u}_s^L + R_{22}^F \mathsf{u}_s^F + \beta B_1' \lambda_{s+1}^{Fy} \\
&+ \beta B_2' \lambda_{s+1}^{Fx})),
\end{aligned}
$$

where Lagrange multipliers λ^{Ly} are non-predetermined (as those on predetermined variables) with terminal conditions and λ^{Lx} are predetermined with initial conditions. The first-order conditions are

$$
\begin{aligned}
0 &= Q_{22}^L \mathsf{x}_s + Q_{21}^L \mathsf{y}_s + P_{21}^L \mathsf{u}_s^L + P_{22}^L \mathsf{u}_s^F + \mathcal{Q}_{12}^{F\prime}\nu_s^{Ly} + \mathcal{Q}_{22}^{F\prime}\nu_s^{Lx} + P_{22}^F \nu_s^{Lu\prime} \\
&\quad + \beta A_{12}' \lambda_{s+1}^{Ly} + \beta A_{22}' \lambda_{s+1}^{Lx} - \lambda_s^{Lx}, \\
0 &= Q_{12}^L \mathsf{x}_s + Q_{11}^L \mathsf{y}_s + P_{11}^L \mathsf{u}_s^L + P_{12}^L \mathsf{u}_s^F + \mathcal{Q}_{11}^{F\prime}\nu_s^{Ly} + \mathcal{Q}_{21}^{F\prime}\nu_s^{Lx} + P_{12}^F \nu_s^{Lu} \\
&\quad + \beta A_{11}' \lambda_{s+1}^{Ly} + \beta A_{21}' \lambda_{s+1}^{Lx} - \lambda_s^{Ly}, \\
0 &= P_{11}^{L\prime}\mathsf{y}_s + P_{21}^{L\prime}\mathsf{x}_s + R_{11}^L \mathsf{u}_s^L + R_{12}^L \mathsf{u}_s^F + P_{11}^{F\prime}\nu_s^{Ly} + P_{21}^{F\prime}\nu_s^{Lx} + R_{12}^F \nu_s^{Lu} \\
&\quad + \beta D_1' \lambda_{s+1}^{Ly} + \beta D_2' \lambda_{s+1}^{Lx}, \\
0 &= P_{12}^{L\prime}\mathsf{y}_s + P_{22}^{L\prime}\mathsf{x}_s + R_{12}^{L\prime}\mathsf{u}_s^L + R_{22}^L \mathsf{u}_s^F + P_{12}^{F\prime}\nu_s^{Ly} + P_{22}^{F\prime}\nu_s^{Lx} + R_{22}^{F\prime}\nu_s^{Lu} \\
&\quad + \beta B_1' \lambda_{s+1}^{Ly} + \beta B_2' \lambda_{s+1}^{Lx}, \\
0 &= A_{11}\nu_s^{Ly} - \nu_{s+1}^{Ly} + A_{12}\nu_s^{Lx} + B_1 \nu_s^{Lu}, \\
0 &= A_{21}\nu_s^{Ly} + A_{22}\nu_s^{Lx} - \nu_{s+1}^{Lx} + B_2 \nu_s^{Lu}, \\
0 &= A_{11}\mathsf{y}_s + A_{12}\mathsf{x}_s + D_1 \mathsf{u}_s^L + B_1 \mathsf{u}_s^F - \mathsf{y}_{s+1}, \\
0 &= A_{21}\mathsf{y}_s + A_{22}\mathsf{x}_s + D_2 \mathsf{u}_s^L + B_2 \mathsf{u}_s^F - \mathsf{x}_{s+1}.
\end{aligned}
$$

The system of first-order conditions to both optimization problems can be written as

$$
G\begin{bmatrix} K_{s+1} \\ L_{s+1} \end{bmatrix} = D\begin{bmatrix} K_s \\ L_s \end{bmatrix},
$$

where $K_s = (\mathsf{y}'_s, \mu_s^{x\prime})'$ is a predetermined variable and $L_s = (\mathsf{u}'_s, \mathsf{x}'_s, \mu_s^{y\prime})'$ is a non-predetermined variable, and $\mu_s^{y\prime}$ and $\mu_s^{x\prime}$ collect corresponding Lagrange multipliers. Matrix G can be singular, so using singular form decomposition (see Söderlind 1999), we find the solution of the system in the form

$$\begin{bmatrix} Y_{s+1} \\ \mu_{s+1}^x \end{bmatrix} = Z_{11} S_{11}^{-1} T_{11} Z_{11}^{-1} \begin{bmatrix} Y_s \\ \mu_s^x \end{bmatrix}, \begin{bmatrix} \mathsf{u}_s \\ X_s \\ \mu_s^y \end{bmatrix} = Z_{21} Z_{11}^{-1} \begin{bmatrix} Y_s \\ \mu_s^x \end{bmatrix}, \tag{39}$$

where matrices Z, S, and T are obtained when solving the generalized eigenvalue problem. Note that S_{11} and Z_{11} have to be invertible, but T_{11} does not need to be. Moreover, if D has any zero roots, then any transformations with Hermitian matrices leave them zero, and they are collected in the top left part of T, such that $T_{ii}/S_{ii} < 1$.

Denote $\mathsf{M} = Z_{11} S_{11}^{-1} T_{11} Z_{11}^{-1}$, $N = -Z_{21} Z_{11}^{-1}$, and matrix N contains first $k_F + k_F + n_2$ rows of matrix N. Then, system (39) is written in the form of (37)–(38).

We now prove the proposition for discretion.

Solution to a discretionary problem in any time t gives a value function for each policymaker i, $i \in \{L, F\}$, which is quadratic in the state variables,

$$W_t^i = \frac{1}{2} \mathsf{y}'_t S^i \mathsf{y}_t, \tag{40}$$

a linear relation between the forward-looking variables

$$\mathsf{x}_t = -N \mathsf{y}_t, \tag{41}$$

and a linear policy reaction function

$$\mathsf{u}_t^F = -F^F \mathsf{y}_t - L \mathsf{u}_t^L, \tag{42}$$

$$\mathsf{u}_t^L = -F^L \mathsf{y}_t, \tag{43}$$

where $L = -\partial \mathsf{u}_t^F / \partial \mathsf{u}_t^L$: in a leadership equilibrium the follower treats the leader's policy instrument parametrically.

We seek solution in the class of matrices with time-invariant coefficients. Given y_0 and system matrices A and B, matrices N, F^F, F^L, and L define the trajectories $\{\mathsf{y}_s, \mathsf{x}_s, \mathsf{u}_s\}_{s=t}^{\infty}$ in a unique way and vice versa: if we know that $\{\mathsf{y}_s, \mathsf{x}_s, \mathsf{u}_s\}_{s=t}^{\infty}$ solve the discretionary optimization problem, then, by construction, there are unique time-invariant linear relationships between them which we label N, F^F, F^L, and L. Matrix S^i defines the cost to go for a policymaker i along a trajectory. Given the one-to-one mapping between equilibrium trajectories and $\{\mathsf{y}_s, \mathsf{x}_s, \mathsf{u}_s\}_{s=t}^{\infty}$ and the sextuple of matrices $\mathcal{T} = \{N, F^F, F^L, L, S^F, S^L\}$, it is convenient to continue with definition of policy equilibrium in terms of $\mathcal{T}$, not trajectories. This approach has become standard since Oudiz and Sachs (1985) and Backus and Driffill (1986).

The first-order conditions on $\mathcal{T}$ are derived in Blake and Kirsanova (2011). We substitute (43) into (42) and obtain equation (38) with $\mathsf{N} = [N', (F^F - LF^L)', F^{L\prime}]'$. We substitute (41), (42), and (43) into system (30) and obtain the dynamic system, in which first n_1 equations are written in the form of matrix equation (37) with $M = A_{11} - A_{12}N - B_{11}F^L - B_{12}(F^F - LF^L)$.

Appendix 3. System Matrices

System (17)–(27) can be brought to the form

$$\hat{\pi}_{Ht} = \beta\frac{\theta}{\Phi}\mathbb{E}_t\hat{\pi}_{Ht+1} + \frac{\zeta}{\Phi}\hat{\pi}_{Ht-1} + \frac{\lambda}{\Phi}\left(\pi_c\hat{c}_t - \pi_{c1}\hat{c}_{t-1} + \pi_g\hat{g}_t^y + \pi_{c^*}\hat{c}_t^* \right.$$

$$\left. + \pi_{c1^*}\hat{c}_{t-1}^* + \frac{\sigma h}{(1-h)}\hat{z}_t - (\varphi+1)\,\hat{a}_{Ht}\right)$$

$$\hat{c}_t = \frac{1}{(1+h)}\mathbb{E}_t\hat{c}_{t+1} + \frac{h}{(1+h)}\hat{c}_{t-1} - \sigma_c\left(\hat{r}_t - \mathbb{E}_t\hat{\pi}_{Ht+1}\right) + c_{c^*}\hat{c}_t^*$$

$$- \frac{h\alpha}{(1+h)}\hat{c}_{t-1}^* - c_z\hat{z}_t$$

$$\hat{b}_{t+1} = \frac{1}{\beta}\left(\hat{b}_t - \frac{b}{y}\hat{\pi}_{Ht} + b_g\hat{g}_t^y + b_c\hat{c}_t - b_{c1}\hat{c}_{t-1} + b_{c^*}\hat{c}_t^* + b_{c1^*}\hat{c}_{t-1}^*\right)$$

$$+ \frac{b}{y}\hat{r}_t - \frac{b}{y}\rho_z\hat{z}_t$$

$$\hat{y}_t = y_c\hat{c}_t - y_{c1}\hat{c}_{t-1} + y_{c^*}\hat{c}_t^* + y_{c1^*}\hat{c}_{t-1}^* + \frac{g}{c}\hat{g}_t^y,$$

where

$$\pi_c = \frac{\sigma}{(1-h)(1-\alpha)}\left(1 + \varphi\frac{(1-h)}{\sigma_\alpha}\right), \pi_{c1} = \frac{\sigma h\,(1+(2-\alpha)\,\alpha\eta\varphi)}{(1-h)(1-\alpha)}$$

$$\pi_g = \varphi \frac{g}{c}, \pi_{c^*} = \left(\varphi \left(1 - \frac{(2-\alpha)\,\eta\sigma}{(1-h)\,(1-\alpha)} \right) - \frac{\sigma}{(1-h)\,(1-\alpha)} \right) \alpha$$

$$\pi_{c1^*} = \frac{\alpha\sigma h\,(1+(2-\alpha)\,\eta\varphi)}{(1-h)\,(1-\alpha)}, b_g = (1-\tau)\,\frac{g}{c}, b_c = \frac{(\frac{g}{y}-\tau)\sigma}{(1-\alpha)\sigma_\alpha}$$

$$b_{c1} = \left(\frac{g}{y} - \tau \right) \frac{(2-\alpha)\,\alpha\eta\sigma}{(1-h)\,(1-\alpha)} h,$$

$$b_{c^*} = \left(\frac{g}{y} - \tau \right) \alpha \left(1 - \frac{(2-\alpha)\,\eta\sigma}{(1-h)\,(1-\alpha)} \right)$$

$$b_{c1^*} = \left(\frac{g}{y} - \tau \right) \frac{\alpha\,(2-\alpha)\,\eta\sigma}{(1-h)\,(1-\alpha)} h, \sigma_\alpha = \frac{\sigma}{(1-\alpha+\alpha\omega)}$$

$$\omega = \frac{(2-\alpha)\,\sigma\eta}{(1-h)} - (1-\alpha)\,, \sigma_c = \frac{(1-h)\,(1-\alpha)}{(1+h)\,\sigma},$$

$$c_{c^*} = \left(1 - \frac{\rho_{c^*}}{(1+h)} \right) \alpha, c_z = (1-\rho_z)\,\frac{(1-\alpha)}{(1+h)} h,$$

$$y_c = \frac{\alpha\,(2-\alpha)\,\eta\sigma}{(1-h)\,(1-\alpha)} + (1-\alpha), y_{c1} = \frac{\alpha\,(2-\alpha)\,\eta\sigma h}{(1-h)\,(1-\alpha)},$$

$$y_{c^*} = \alpha - \frac{\alpha\,(2-\alpha)\,\eta\sigma}{(1-h)\,(1-\alpha)}, y_{c1^*} = \frac{\alpha\,(2-\alpha)\,\eta\sigma h}{(1-h)\,(1-\alpha)}.$$

Therefore, system (30) can be written in the following matrix form:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \beta\frac{\theta}{\Phi} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \sigma_c & \frac{1}{(1+h)} \end{bmatrix} \begin{bmatrix} z_{t+1} \\ \hat{a}_{Ht+1} \\ \hat{c}^*_{t+1} \\ \hat{c}^*_t \\ \hat{r}_t \\ \hat{g}_{H,t} \\ \hat{b}_{t+1} \\ \pi_{Ht} \\ \hat{c}_t \\ \mathbb{E}_t\pi_{Ht+1} \\ \mathbb{E}_t\hat{c}_{t+1} \end{bmatrix}$$

$$
= \begin{bmatrix}
\rho_z & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \rho_a & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \rho_{c^*} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\frac{b\rho_z}{y} & 0 & \frac{b_{c^*}}{\beta} & \frac{b_{c1^*}}{\beta} & 0 & 0 & \frac{1}{\beta} & 0 & -\frac{b_{c1}}{\beta} & -\frac{b}{\beta y} & \frac{b_c}{\beta} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
-\frac{\lambda\sigma h}{\Phi(1-h)} & \frac{\lambda(\varphi+1)}{\Phi} & -\frac{\lambda\pi_{c^*}}{\Phi} & -\frac{\lambda\pi_{c1^*}}{\Phi} & 0 & 0 & 0 & -\frac{\zeta}{\Phi} & \frac{\lambda\pi_{c1}}{\Phi} & 1 & -\frac{\lambda\pi_c}{\Phi} \\
c_z & 0 & -c_{c^*} & \frac{\alpha h}{(1+h)} & 0 & 0 & 0 & 0 & -\frac{h}{(1+h)} & 0 & 1
\end{bmatrix}
$$

$$
\times \begin{bmatrix} z_t \\ \hat{a}_{Ht} \\ \hat{c}_t^* \\ \hat{c}_{t-1}^* \\ \hat{r}_{t-1} \\ \hat{g}_{H,t-1}^y \\ \hat{b}_t \\ \pi_{Ht-1} \\ \hat{c}_{t-1} \\ \pi_{Ht} \\ \hat{c}_t \end{bmatrix}
+ \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \\ 0 \\ \frac{b}{y} \\ 0 \\ 0 \\ 0 \\ \sigma_c \end{bmatrix} \hat{r}_t
+ \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 1 \\ \frac{1}{\beta} b_g \\ 0 \\ 0 \\ -\frac{\lambda}{\Phi}\pi_g \\ 0 \end{bmatrix} \hat{g}_t^y;
$$

The vector of goal variables can be written as follows:

$$
\begin{aligned}
G_t &= \left[\ x_t^* \quad \hat{c}_t^* \quad \hat{g}_t \quad x_t \quad \hat{c}_t \quad \hat{y}_t - \hat{A}_{Ht} \quad \hat{y}_t \quad \pi_{Ht} - \pi_{Ht-1} \quad \pi_{Ht}\ \right]' \\
&= T \left[\ z_t \ \hat{a}_{Ht} \ \hat{c}_t^* \ \hat{c}_{t-1}^* \ r_{t-1} \ \hat{g}_{t-1}^y \ b_t \ \pi_{Ht-1} \ \hat{c}_{t-1} \ \pi_{Ht} \ \hat{c}_t \ \hat{g}_t^y \ r_t \ \right],
\end{aligned}
$$

where

$$
T = \begin{bmatrix}
\frac{h}{(1-h)} & 0 & \frac{1}{(1-h)} & -\frac{h}{(1-h)} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & y_{c^*} & y_{c1^*} & 0 & 0 & 0 & 0 & -y_{c1} & 0 & y_c & \frac{y}{c} & 0 \\
\frac{h}{(1-h)} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\frac{h}{(1-h)} & 0 & \frac{1}{(1-h)} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & -1 & y_{c^*} & y_{c1^*} & 0 & 0 & 0 & 0 & -y_{c1} & 0 & y_c & \frac{g}{c} & 0 \\
0 & 0 & y_{c^*} & y_{c1^*} & 0 & 0 & 0 & 0 & -y_{c1} & 0 & y_c & \frac{g}{c} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0
\end{bmatrix}.
$$

The social welfare objective matrix can be written as follows:

$$\mathcal{Q}^{L,F} = \begin{bmatrix} 0 & 0 & 0 & q & -\frac{c}{y}\alpha\eta\sigma & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{c}{y}\frac{\eta\alpha\sigma}{1-\alpha} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{g}{y}\sigma & 0 & 0 & 0 & 0 & 0 & 0 \\ q & \frac{c}{y}\frac{\eta\alpha\sigma}{1-\alpha} & 0 & \frac{c}{y}\Psi_x & \frac{c}{y}\alpha\eta\sigma & 0 & 0 & 0 & 0 \\ -\frac{c}{y}\alpha\eta\sigma & 0 & 0 & \frac{c}{y}\alpha\eta\sigma & (1-\alpha)\frac{c}{y} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1+\varphi & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{\epsilon\zeta}{\lambda} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{\epsilon\theta(1-\zeta)}{\lambda} \end{bmatrix},$$

where $q = -\frac{c}{y}\frac{\alpha\eta\sigma^2\left(\alpha\eta-\alpha^2\eta+1\right)}{(1-\alpha)^2}$.

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A Retrospective Analysis of the House Price Macro-Relationship in the United States*

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This study provides empirical evidence on the strengthening of the impact of house prices on the U.S. macroeconomy. The stability of the house price macro-link is tested in a small-dimensional vector autoregressive model over the last fifty years. The estimated break points are used to split the sample into different segments, and a multivariate time-series analysis is performed within sub-samples. The paper finds a robust structural break in the mid-80s. In addition, time-series analysis across segments provides evidence that the effect of house prices, not only on private consumption but also on economic activity, has intensified since the mid-80s.

JEL Codes: C32, E20, E44, R30.

1. Introduction

A decade ago, Alan Greenspan (2002) suggested in his testimony to the Joint Economic Committee of the U.S. Congress that the strong appreciation of house prices after the crash of the stock market in 2001 might have helped save the U.S. economy from a more serious

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recession, a point of view shared by most of the economists at that time. A few years later, a large crash in housing prices triggered—in all likelihood—a financial and economic crisis. Inevitably, both events have contributed to the consensus among economic practitioners and many researchers that fluctuations in housing prices are a key factor in the U.S. business cycle.

The question of the extent to which the deep transformation of mortgage markets in recent years has modified the house price macro-relationship arose naturally. A consensus rapidly emerged in the literature that the effect of house prices on the macroeconomy has intensified since the mid-80s, a time when important deregulations took place in the mortgage market along with the development of secondary markets and the increasing role of the government-sponsored enterprises (GSEs) in mortgage financing.[1]

Consequentially, a persistent fall in mortgage transaction costs occurred along with a strong relaxation of credit conditions. Homeowners were allowed to easily extract equity from their houses and loan-to-value ratios associated with mortgage loans rose, increasing the ability of landlords to borrow against their real estate.[2]

In the literature, theoretical models showing how a relaxation of credit constraints on the mortgage sector amplifies the effect of housing prices on the macroeconomy have been developed by Miles (1992), Kiyotaki and Moore (1997), Iacoviello (2005), and Iacoviello and Neri (2010), among others. The primary mechanism of these models is that a reduction of credit constraints allows economic agents to increase the amount that they are able to borrow against their home equity and use these additional resources to finance extra consumption and investment. Thus, because of the multiple signs of a relaxation in credit conditions in the United States, we can expect that the impact of house prices on the macroeconomy has become stronger over time.

[1]See Gerardi, Rosen, and Willen (2010) for a brief review on the modifications of the U.S. mortgage market in the last forty years.

[2]Taking data from the Federal Home Loan Mortgage Corporation, we calculate a substantial fall in fees and points for a regular thirty-year fixed-rate mortgage. We obtain an average of 2.3 for the 1980s, 1.5 for the 1990s, and 0.7 for the 2000s. Greenspan and Kennedy (2008) find a sustained increase in both their gross and net equity-extraction measures (relative to disposable income) since the beginning of the 1990s.

The important role of housing prices in the U.S. business cycle in recent years does not provide sufficient evidence to conclude that the house price effect in the macroeconomy has strengthened. Indeed, one should take into consideration the magnitude of the last boom and bust in house prices; according to the Case-Shiller Home Price Index, the boom and bust in house prices has been the largest at least since the end of the nineteenth century. Although time-series and micro-econometric evidence largely show that housing prices have a positive impact on the U.S. economy (see, for example, Green 1997; Case, Shiller, and Quigley 2005; Haurin and Rosenthal 2006; Bostic, Gabriel, and Painter 2009; and Miller, Peng, and Sklarz 2011), only a few papers provide empirical evidence on the strengthening of the effect of house prices on the macroeconomy over time. Muellbauer (2008), using a structural single-equation estimation, finds that before the U.S. credit market liberalization in the 1980s, there was no significant housing wealth effect on consumption; however, since then, the effect has become positive. Altissimo et al. (2005) estimate a marginal propensity to consume (MPC) out of wealth from aggregate U.S. data. Their results suggest that the MPC appears not to have statistically changed since the beginning of the 1970s. They find, however, a big increase in the MPC at the end of the 1960s.

In this paper, we provide empirical evidence of the strengthening of impact of house prices on the U.S. macro-variables. We proceed in two steps. First, we test the stability of the house price macro-link in the United States during the last fifty years. A recursive vector autoregressive (VAR) model including gross domestic product (GDP) or private consumption, interest rates, and house prices is chosen to account for the house price macro-relationship. The methodology developed in Qu and Perron (2007) is applied to identify breaks in our multivariate system. In this method, the dates and the number of breaks are entirely determined by the algorithm, rather than being imposed ex ante like most of the methods used in the time-series literature.[3] Thus, this methodology does not require us to set a priori the mid-80s—a period systematically found as a

[3]Bai and Perron (1998) also develop a methodology to detect multiple breaks occurring at unknown dates, but the method only considers the case of a single linear equation.

structural break in the literature on the “Great Moderation”—as a unique break point in the house price macro-link. Indeed, a rupture in this relationship could have occurred as early as the end of the 1960s, when the privatization of the Federal National Mortgage Association (“Fannie Mae”) in 1968 and the creation of the Federal Home Loan Mortgage Corporation (“Freddie Mac”) in 1970 established the foundation of what would become the renovated U.S. mortgage market. A break might also be found as recently as the early 2000s, when a deepening of markets for securitized contracts and derivatives occurred and sub-prime mortgage loans developed at a very strong pace. Furthermore, the method allows us to consider the fact that the reduction in credit constraints has been a gradual process and that the modification in the house price macro-link did not occur all at once. The implication of this hypothesis is that the aforeproposed break dates are not exclusive and that more than one break could exist in the link. In the second step, we use the break points estimated to split the sample into different segments, and on each sub-sample, multivariate time-series analysis, including impulse response and Granger causality tests, are performed.

Our results can be summarized as follows: the application of Qu and Perron’s methodology in a VAR with linear restrictions concludes that there are two break points in the house price macro-relationship when GDP is introduced in the VAR specification: one at the end of the 1960s and the second in the mid-80s, the latest rupture being the strongest among the two break dates. We also find that there is only one structural break in the link when private consumption is included in the multivariate system, in the mid-80s. Time-series analysis across sub-samples finds that the overall impact of house prices, not only on private consumption but also on economic activity, has intensified since the mid-80s. Our results give support to the hypothesis that the modification of the real-estate market in the mid-80s seems to have been a key factor in the strengthening of the effect of house prices on the macroeconomy.[4]

[4]Generally, the “Great Moderation” literature finds reduced responses of GDP to different shocks in the period after the mid-80s (see Stock and Watson 2003 for a survey), not increased responses as in this paper. However, the papers related to that literature do not provide evidence of a change on the effect of house price shocks on the economy.

The paper is organized as follows. In section 2, we present Qu and Perron's methodology, which is used to detect breaks. Section 3 applies this methodology to a small-dimensional VAR model using U.S. macro-data. In section 4, we split the initial sample into different segments using the identified break points. We then perform impulse response and Granger causality tests in each of the segments from the initial VAR model specification. Section 5 contains the concluding remarks and proposes avenues of future research.

2. Testing Structural Changes in a Multivariate Model

The various methods of identifying structural changes in a single regression model have been well documented in the literature. However, in the multivariate case, only a few papers have dealt with structural breaks. Qu and Perron (2007) consider issues related to estimation, inference, and computation when multiple structural changes occur at unknown dates in a system of equations including a vector autoregressive model. The changes here can pertain to the regression coefficients and/or the covariance matrix of the errors. This section presents a brief description of Qu and Perron's method before proceeding to an application in a VAR model using U.S. macro-data in the next section.

2.1 The Model and Estimator

In the presentation below, we consider a VAR model with three components, $y_t = (y_{1t}, y_{2t}, y_{3t})'$, and one lag, as in our application in section 3. This can be extended to a general VAR model without any major difficulties. The dates and the number of structural changes in the parameters are unknown. We use m to denote the total number of structural changes and T to denote the sample size. The unknown break dates are denoted by the m vector $\Gamma = (T_1, \ldots, T_m)$ and we use the convention that $T_0 = 1$ and $T_{m+1} = T$. Hence there are $m+1$ unknown sub-periods, $T_{j-1} + 1 \leq t < T_j, j = 1, \ldots, m+1$. The model can be written as

$$y_t = \pi_{j0} + \pi_{j1} y_{t-1} + \varepsilon_t, \;\; t = T_{j-1} + 1, \ldots, T_j, \tag{1}$$

where $y_t = (y_{1t}, y_{2t}, y_{3t})'$. In each sub-period $T_{j-1} + 1 \leq t < T_j$: $\pi_{j0} = (\pi_{j0}^{(i)})_{i=1,\ldots,3}$ is the vector of constant parameters;

$\pi_{j1} = (\pi_{j1}^{(kl)})_{k=1,\ldots,3;l=1,\ldots,3}$ indicates the 3x3 matrices of the VAR parameters; and ε_t is the vector of the residuals with mean O and covariance matrix denoted by Σ_j. Here we are interested in the estimation of $\Lambda = \{\widehat{m}, \widehat{T}_1, \ldots, \widehat{T}_m, \widehat{\Sigma}_{j=1,\ldots,m+1}\}$. We suppose in this paragraph that m is known, and will discuss later the estimation of m. For the estimation of model (1) it is convenient to rewrite the model as

$$y_t = x_t' \beta_j + \varepsilon_t, \tag{2}$$

where $x_t' = (I_3 \otimes (1, y_{1t-1}, y_{2t-1}, y_{3t-1}))$ and $\beta_j = (\pi_{j0}^{(1)}, \pi_{j1,}^{(11)} \pi_{j1}^{(12)}, \pi_{j1}^{(13)}, \ldots, \pi_{j0}^{(3)}, \pi_{j1,}^{(31)} \pi_{j1}^{(32)}, \pi_{j1}^{(33)})'$. The estimation method we consider is restricted quasi-maximum likelihood. Conditional on the given break dates $\Gamma = (T_1, \ldots, T_m)$, the Gaussian quasi-likelihood ratio is

$$LR_\Gamma = \frac{\Pi_{j=1}^{m+1} \Pi_{t=T_{j-1}+1}^{T_j} f\left(y_t | x_t; \beta_j, \Sigma_j\right)}{\Pi_{j=1}^{m+1} \Pi_{t=T_{j-1}^0+1}^{T_j^0} f\left(y_t | x_t; \beta_j^0, \Sigma_j^0\right)}, \tag{3}$$

where $f\left(y_t | x_t; \beta_j, \Sigma_j\right) = (2\pi)^{-n/2} \left|\Sigma_j\right|^{-1/2} \exp\{-\frac{1}{2}\left[y_t - x_t'\beta_j\right]' \Sigma_j^{-1} \left[y_t - x_t'\beta_j\right]\}$ and $n = 3$ is the number of equations in the VAR model. $\Gamma^0 = (T_1^0, \ldots, T_m^0)$, β_j^0, and Σ_j^0 indicate the true unknown parameters. Qu and Perron's (2007) approach introduces a restriction in $\beta = (\beta_1', \ldots, \beta_{m+1}')'$ and $\Sigma = (\Sigma_1, \ldots, \Sigma_{m+1})$. For example, we obtain a partial structural-change model when the restriction imposes that a particular subset of β_j is the same for all j. We denote by $g\left(\beta, vec(\Sigma)\right) = 0$ the form of the restrictions in β and (or) Σ, where $g(.)$ is an r-dimensional vector and r the number of restrictions. Hence the restricted log-likelihood ratio is given by

$$rlr_\Gamma = \log(LR_\Gamma) + \lambda' g\left(\beta, vec(\Sigma)\right) \tag{4}$$

and the estimates are

$$\{\widehat{T}_1, \ldots, \widehat{T}_m, \widehat{\beta}, \widehat{\Sigma}\} = \arg\ \max_{(T_1,\ldots,T_m,\beta,\Sigma)} rlr_\Gamma. \tag{5}$$

The maximization (5) is taken over all partitions $\Gamma = (T_1, \ldots, T_m)$ such that $|T_j - T_{j-1}| \geq [\varepsilon T]$ and $T_m \leq [T(1-\varepsilon)]$, where ε is an arbitrarily small positive number and [] denotes the integer part of the argument. The parameter ε plays a trimming role and imposes a minimal length for each regime. One important result is that under more general assumptions the estimates of the break dates $\Gamma = (T_1, \ldots, T_m)$ and the coefficients (β, Σ) are asymptotically independent and valid restrictions on the latter do not affect the distribution of the former. Qu and Perron (2007) also discuss a method based on the principle of dynamic programming which searches for the optimal partition $\Gamma = (T_1, \ldots, T_m)$, i.e., the partition that yields the optimal value of the log-likelihood rlr_Γ. They argue that this method is efficient, as it only requires least-squares calculations of order $O(T)$ and matrix inversions of order $O(n)$.

2.2 Selection of the Number of Breaks

To determine the number of breaks m, we can appeal to the likelihood-ratio test of no change versus some specific number of changes, k. As proposed by Qu and Perron (2007), this statistic can be constructed as follows:

$$\sup LR_T\left(k, p_b, n_{bd}, n_{bo}, \varepsilon\right) = 2\left[\log \widehat{L}_T\left(\widehat{T}_1, \ldots, \widehat{T}_k\right) - \log \widetilde{L}_T\right].$$

Here $\log \widehat{L}_T(\widehat{T}_1, \ldots, \widehat{T}_k)$ is the maximum of the log-likelihood obtained with the optimal partition $\{\widehat{T}_1, \ldots, \widehat{T}_k\}$; $\log \widetilde{L}_T$ is the maximum of the log-likelihood under the null hypothesis of no structural change; p_b is the total number of coefficients that are allowed to change (not including the coefficients of the variance-covariance matrix); and n_{bd} and n_{bo} indicate, respectively, the number of parameters that are allowed to change amongst the diagonal and off-diagonal coefficients of the variance-covariance matrix. As noted above, ε is a parameter that allows us to impose a minimal length for each regime. The limiting distribution of $\sup LR_T$ is discussed in detail by the authors and depends on the aforementioned parameters. It is important to note that this testing procedure is particularly flexible. The test can be used with respect to many cases of structural change: (i) changes only in the coefficients of the conditional mean $(n_{bd} = 0, n_{bo} = 0)$; (ii) changes only in the coefficients of the covariance matrix of the residuals $(p_b = 0)$; and (iii) changes in all of the coefficients $(p_b \neq 0, n_{bd} \neq 0, n_{bo} \neq 0)$.

The test for no change versus an unknown number of breaks can also be considered given some upper-bound M for k. These types of tests are called double maximum tests, and the statistic is defined for some fixed weights $W = \{a_1, \ldots, a_M\}$ as

$$D \ \max \ LR_T(M) = \max_{1 \leq k \leq M} \ [a_k \sup LR_T \left(k, p_b, n_{bd}, n_{bo}, \varepsilon\right)].$$

For uniform weights, i.e., $a_i = 1, i = 1, \ldots, M.$, the statistic is always denoted by $UD\max\ LR_T(M)$. The second test is noted by $WD\max$ $LR_T(M)$ and applies weights to the individuals tests such that the marginal p-values are equal across values of m. Bai and Perron (1998) provide more discussion of this class of tests and their critical values.

We can also consider the sequential test based on the null hypothesis of, say, l break dates versus $l + 1$ breaks. The general form of this statistic is

$$SEQ_T \left(l + 1|l\right) = \max_{1 \leq j \leq l+1} \ \sup_{\tau \epsilon \Lambda_{j,\varepsilon}} lr_T \left(\widehat{T}_1, \ldots, \widehat{T}_{j-1}, \tau, \widehat{T}_j, \ldots, \widehat{T}_l\right) \\ - lr_T \left(\widehat{T}_1, \ldots, \widehat{T}_l\right).$$

Here $lr_T(.)$ denotes the log of the likelihood, $\{\widehat{T}_1, \ldots, \widehat{T}_l\}$ denotes the optimal partition if l breaks are supposed, and $\Lambda_{j,\varepsilon} = \{\tau; \widehat{T}_{j-1} + (\widehat{T}_j - \widehat{T}_{j-1})\varepsilon \leq \tau \leq \widehat{T}_j - (\widehat{T}_j - \widehat{T}_{j-1})\varepsilon\}$. In addition, the limiting distribution of the test depends on the number of coefficients that are allowed to change.

In practice, the preferred strategy to determine the number of breaks is first to look at the $UD\max\ LR_T(M)$ or $WD\max\ LR_T(M)$ tests to see if at least one structural break exists. We can then decide the number of breaks based on the $SEQ_T\ (l + 1|l)$ statistic. We select m breaks such that the $SEQ_T\ (l + 1|l)$ tests are insignificant for any $l \geq m$. Bai and Perron (2003) conclude that this method leads to the best results, and they recommend it for empirical applications. However, in the case of a VAR with restrictions on the coefficients, Qu and Perron (2007) consider only the $SupLR_T$ test to obtain the number and the location of the breaks.

2.3 Method of Lag Selection

The presence of structural changes in multivariate models introduces non-linearity. As such, the usual model-selection criteria (Akaike and

Bayesian information criteria, AIC and BIC) are not applicable. One practical result in Qu and Perron (2007) is that the limited distribution of the estimates of the break points is not affected by the imposition of valid restrictions on the parameters. Hence, a non-linear VAR model with a number of lags, say p, can be considered as a valid restriction of a non-linear VAR model with $p + 1$ lags, if the break dates in the two models are significantly unchanged. We use this result to decide on the number of lags in the application section.[5]

3. House Price Macro-Link in the United States: Evidence of Instability

Under this section we apply Qu and Perron's algorithm to the U.S. macro-data. We consider a VAR model with three endogenous variables—real gross domestic product (GDP) or real private consumption (C), real house prices (HP), and the federal funds rate (I)—as a proxy for the monetary policy stance. Closed specifications accounting for the house price macro-relationship have been used by Iacoviello (2005), Goodhart and Hoffman (2007, 2008), Oikarinen (2009), and Calza, Monacelli, and Stracca (2013), among others.

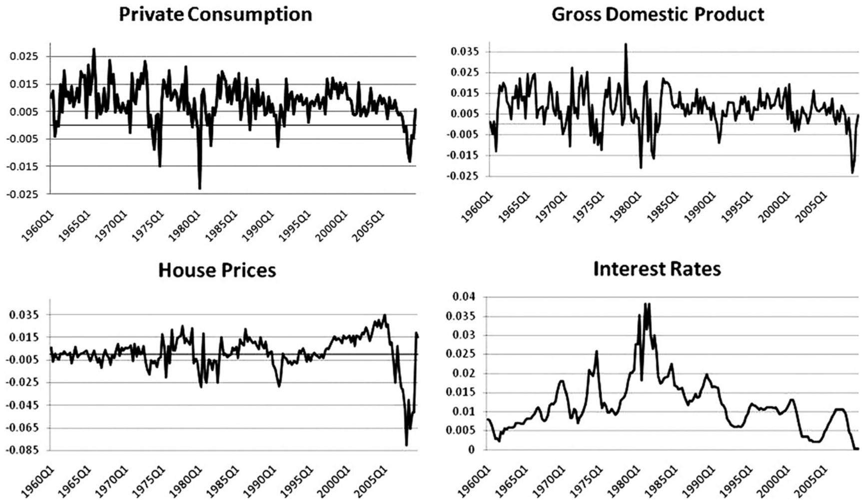
We work with two different VAR specifications, one including GDP and the other private consumption, to examine whether the reduction in credit constraints in the United States could have modified only the impact of housing prices on consumption and not their effect on overall economic activity.

Our data is in quarterly frequency from 1960:Q1 to 2009:Q3. GDP, private consumption, and house prices are measured in logarithms, with the log-values detrended via the first-differencing filter.[6] Private consumption and house prices are deflated using the consumer price index. The federal funds rate is the average value in the

[5]An alternative method of lag selection in a non-linear VAR is proposed in Kurozumi and Tuvaandorj (2011). The authors discuss a modified AIC and BIC to be used in the case of a multivariate model with multiple structural changes.

[6]We use the first-differencing filter instead of a two-sided moving-average filter (for example, Hodrick-Prescott or Baxter-King) in order to test for Granger causality in section 4. Indeed, it is well known in the econometric literature that the use of a two-sided moving-average filter biases the Granger causality test towards a false finding of Granger causation (see, for instance, Cogley 2008).

Figure 1. Data Series



first month of each quarter. The house price series comes from the Case-Shiller Home Price Index. Figure 1 shows the data series used.

3.1 Application of Qu and Perron's Algorithm in a VAR with No Linear Constraints

Qu and Perron's procedure to identify breaks is applied to the following model:

$$y_t = \pi_{j0} + \pi_{j1} y_{t-1} + \varepsilon_t$$
$$\text{and } t = T_{j-1} + 1, \ldots, T_j, j = 1, \ldots, m+1,$$

where $y_t = (\Delta X_t, \Delta HP_t, \Delta I_t)'$ and m denotes the unknown breaks. In each unknown sub-period $T_{j-1} + 1 \leq t < T_j, \pi_{j0} = (\pi_{j0}^{(i)})_{i=1,\ldots,3}$ is the vector of constant parameters; $\pi_{j1} = (\pi_{j1}^{(kl)})_{k=1,\ldots,3;l=1,\ldots,3}$ indicates the 3x3 matrices of the VAR parameters; and ε_t is the vector of the residuals with mean O and a constant covariance matrix. Thus, we only consider the case of a structural change in the conditional mean of the coefficients. X represents either GDP or private consumption. Δ is the delta operator. All the tests are carried out

Table 1. *WD*max Test for up to Four Breaks: VAR with no Linear Restrictions

	VAR with X = GDP	VAR with X = C
*WD*max Statistic	54.13	50.75
Critical Value at 5%: 30.62		

by fixing $m = 4$ and a trimming value of $\varepsilon = 0.02$.[7] We start by applying the tests considering a lag fixed at $p = 1$.

Let us first consider X = GDP. Table 1 shows the results of the $WD\max\ LR_T(M)$ test, where the null hypothesis is rejected at the 5 percent level. The value of the $WD\max\ LR_T(M)$ statistic is 54.13, whereas the critical value at the 5 percent level is 30.62. Hence, there is at least one structural break in the VAR model. The $SEQ_T\,(l+1|l)$ test allows us to reject the null hypothesis of one break against the alternative of two breaks, as $Seq(2|1) = 40.84$ with the 5 percent critical value being 32.60. The $SEQ_T\,(l+1|l)$ test allows us also to reject the null hypothesis of two breaks against the alternative of three breaks, as $Seq(3|2) = 37.88$ with the 5 percent critical value being 33.96. Finally, the null hypothesis of three breaks against four breaks is not rejected, as $Seq(4|3) = 0.00$ where the 5 percent critical value is 34.89. The performed tests thus lead us to conclude that there are three structural breaks in the considered VAR system which includes a GDP variable: 1969:Q3, 1982:Q4, and 1999:Q1. Table 2 shows the results of the $SEQ_T\,(l+1|l)$ test along with the estimated break dates with their 95 percent confidence intervals.

Next we apply the procedure setting $X = C$. The $WD\max LR_T(M)$ statistic allows us to reject the null hypothesis at the 5 percent level (table 1). The value of the $WD\max\ LR_T(M)$ statistic is 50.75, whereas the critical value at the 5 percent level is 30.62. We conclude then that there is at least one structural

[7]The parameter ϵ imposes a minimal length for each segment, and the limiting distributions of the different tests are affected by this value. As a robustness exercise, we experiment with three different values of ϵ: 0.015, 0.02, and 0.03. These values are considered in many empirical papers and Monte Carlo simulations. We find that results do not differ statistically. Results of this robustness exercise are not presented in the paper but are available by request.

Table 2. The $SEQ_T(l+1|l)$ Test for a VAR with no Linear Restrictions with X = GDP

	Statistic	Critical Value at 5% Level	Significant Break
$Seq(2\|1)$	40.84	32.60	—
$Seq(3\|2)$	37.88	33.96	1969:Q3 (1968:Q1–1971:Q1); 1982:Q4 (1981:Q2–1984:Q2); & 1999:Q1 (1997:Q1–2001:Q1)
$Seq(4\|3)$	0.00	34.89	—

Table 3. The $SEQ_T(l+1|l)$ Test for a VAR with no Linear Restrictions with X = C

	Statistic	Critical Value at 5% Level	Significant Break
$Seq(2\|1)$	39.32	32.60	—
$Seq(3\|2)$	38.82	33.96	1970:Q2 (1967:Q4–1972:Q4); 1985:Q1 (1983:Q4–1986:Q2); & 1999:Q1 (1998:Q2–1999:Q4)
$Seq(4\|3)$	0.000	34.89	—

break in the considered VAR model. The $SEQ_T\ (l+1|l)$ test allows us to reject the null hypothesis of one break against the alternative of two breaks, as $Seq(2|1) = 39.32$ with the 5 percent critical value being 32.60. Moreover, $SEQ_T\ (l+1|l)$ also allows us to reject the null hypothesis of two breaks against the alternative of three breaks, as $Seq(3|2) = 37.88$ with the 5 percent critical value being 33.96. Nevertheless, the null hypothesis of three breaks against four breaks is not rejected, as $Seq(4|3) = 0.00$ where the 5 percent critical value is 34.89. Thus, the performed tests allow us to conclude that there are three structural breaks in the considered VAR specification which includes a private consumption variable: 1970:Q2, 1985:Q1, and 1999:Q1. Table 3 shows the 95 percent confidence intervals for each break.

Afterwards, we apply the tests using a VAR with a lag fixed at $p = 2$. The number and location of the break dates remain significantly unchanged.[8] In both cases, the VAR model with one lag can then be considered as a valid and parsimonious restriction of the VAR model with two lags.

3.2 Application of Qu and Perron's Algorithm in a VAR with Linear Constraints

The estimated break dates in the first part of this section are submitted to a robustness exercise in this sub-section. We would like to dismiss the possibility that the breaks found are not primarily driven by changes in the effect of house prices on the macroeconomy. For instance, the new monetary policy paradigm of the Federal Reserve—nominal policy interest rates reacting more than proportionally to inflation rate changes—could be the main factor causing the rupture detected in the mid-80s. To avoid this issue, we constrain our VAR to only allow a change in the set of parameters related directly to the impact of house prices in the macro-variables. Thus, Qu and Perron's algorithm is applied to the following VAR model:

$$\begin{cases} \Delta X_t = \beta_1 + \beta_2 \Delta X_{t-1} + \beta_{3j} \Delta HP_{t-1} + \beta_4 I_{t-1} + \epsilon_{t1} \\ \Delta HP_t = \beta_5 + \beta_6 \Delta X_{t-1} + \beta_{7j} \Delta HP_{t-1} + \beta_8 I_{t-1} + \epsilon_{t2} \\ \Delta I_t = \beta_9 + \beta_{10} \Delta X_{t-1} + \beta_{11j} \Delta HP_{t-1} + \beta_{12} I_{t-1} + \epsilon_{t3} \end{cases}$$

$$\text{and } t = T_{j-1} + 1, \ldots, T_j, j = 1, \ldots, m+1,$$

where m denotes the unknown breaks and ϵ_t=$\{\epsilon_{t1}, \epsilon_{t2}, \epsilon_{t3}\}$ is the error term with mean 0 and a constant variance-covariance matrix. Then, in the above VAR with linear restrictions, only the parameters β_{3j}, β_{7j}, and β_{11j} are allowed to change. As proposed by Qu and Perron (2007), the $SupLR_T$ test is performed to obtain the number and the location of breaks in a VAR with linear constraints.

Let us consider the case of a VAR with X = GDP. The null hypothesis of no break is tested against the previously estimated three breaks. Results (table 4) show that the $SupLR_T$ test does not allow us to reject the null hypothesis of no structural break against the alternative of three breaks, as the value of the $SupLR_T$ statistic is 29.92 while the critical value at the 5 percent level is 33.71. Thus,

[8]The test results are not reported because of space considerations but are available by request.

Table 4. The $SupLR_T$ Test for a VAR with no Linear Restrictions with X = GDP

	Statistic	Critical Value at 5% Level	Significant Break
$SupLR_T$ Test (1|0)	25.08	21.37	1984:Q4 (1981:Q4–1987:Q4)
$SupLR_T$ Test (2|0)	29.54	28.17	1971:Q2 (1968:Q2–1973:Q2); 1983:Q1 (1980:Q2–1985:Q4)
$SupLR_T$ Test (3|0)	29.92	33.71	—

we cannot associate each of the three previously detected breaks as structural changes in the effect of house prices on the macroeconomy. We proceed to examine if two of the estimated breaks are robust to the imposed restrictions. The $SupLR_T$ test allows us to reject the null hypothesis of no structural break against the alternative of two breaks, as the value of the $SupLR_T$ statistic is 29.54 while the critical value at the 5 percent level is 28.17. The test gives us 1971:Q2 and 1983:Q1 as structural breaks. The confidence intervals associated with these two breaks, 1968:Q2–1973:Q2 and 1980:Q2–1985:Q4, cover the first two break points obtained in the non-restricted VAR (1969:Q3 and 1982:Q4). We can then conclude that only the break dates 1969:Q3 and 1982:Q4 can be associated with a change in the impact of house prices on the macroeconomy, when GDP is included in the VAR specification. In a final step, we use the $SupLR_T$ test to detect the location of the strongest rupture in the system during the considered period. To do this, we apply the $SupLR_T$ test with the null hypothesis of no structural break against the alternative of one break. The $SupLR_T$ test allows us to reject the null hypothesis of no structural break against the alternative of one break, as the value of the $SupLR$ statistic is 25.08 while the critical value at the 5 percent level is 21.37. The test gives us 1984:Q4 as a break point, and the confidence interval associated with this break, 1981:Q4–1987:Q4, covers the second break date obtained in the non-restricted VAR (1982:Q4). Thus, we conclude that the strongest rupture in the house price macro-link, for the considered VAR specification, occurred in the mid-80s.

We now test the robustness of the three break dates estimated in a VAR including private consumption as an endogenous variable (i.e., X = C). Results (table 5) show that the $SupLR_T$ test does not

Table 5. The $SupLR_T$ Test for a VAR with no Linear Restrictions with $X = \mathbf{C}$

	Statistic	Critical Value at 5% Level	Significant Break
$SupLR_T$ Test (1|0)	23.05	21.37	1984:Q3 (1981:Q1–1988:Q1)
$SupLR_T$ Test (2|0)	24.24	28.17	—
$SupLR_T$ Test (3|0)	24.40	33.70	—

allow us to reject the null hypothesis of no structural break against the alternative of three breaks, as the value of the $SupLR_T$ statistic is 24.40 while the critical value at the 5 percent level is 33.70. The $SupLR_T$ test also does not allow us to reject the null hypothesis of no structural break against the alternative of two breaks, as the value of the $SupLR_T$ statistic is 24.24 while the critical value at the 5 percent level is 28.17. Finally, the $SupLR_T$ test allows us to reject the null hypothesis of no structural break against the alternative of one break. The test gives us 1984:Q3 as the only break in the system. The confidence interval associated with this break, 1981:Q1–1988:Q1, covers the second break point obtained in the non-restricted VAR (1985:Q1). We can then conclude that only the break point 1985:Q1 can be associated with a change in the effect of house prices on the macroeconomy when private consumption is included in the VAR system.

Results in this section suggest that the housing prices' impact on the selected U.S. macro-aggregates experienced an important rupture in the mid-80s. Even though the economic agents experienced a progressive relaxation on credit constraints, especially during the last thirty years, the modification of the housing market in the mid-80s seems to have been a determining factor of the change of the house price macro-relationship.[9]

[9]Our results also suggest that the break estimated at the end of the 1960s is not due to a change in house prices' effect on consumption, but it would be mainly driven by changes in the impact of house prices on investment. The increase in the competition on the secondary market due to the creation of Freddie Mac (in 1970) could have played a role in the modification of the link between housing investment and house prices; however, more work would be needed to clarify this issue.

4. Multivariate Time-Series Analysis within Sub-Samples

In section 3 we have shown that the impact of house prices on the macroeconomy changed in the mid-80s. In this section we look for time-series evidence to find in which direction the house prices macro-link has moved. More specifically, we seek evidence that the effect of house prices on economic activity and on private consumption has been reinforced after the break. In this aim, we split the sample into two segments using the break date estimated in the mid-80s. Impulse response and Granger causality tests are performed for both sub-samples. The VAR specification used to identify the breaks in the previous section is also considered in each sub-period.[10]

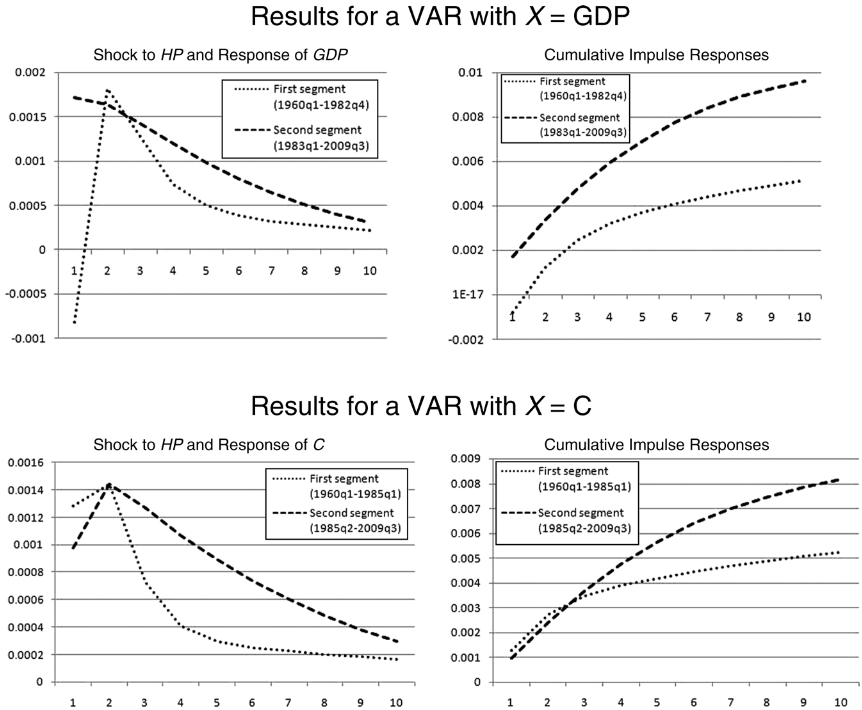
4.1 Generalized Impulse Response Functions

In order to analyze the dynamics of a VAR system, most of the empirical papers in the literature use the "orthogonalized" impulse responses, where the underlying shocks are orthogonalized using the Cholesky decomposition methodology. The main problem with this method is that in practice, when the order of the variables in the VAR is modified, the responses are often significantly different. To avoid the issue of potentially different results, we apply the generalized impulse responses (GIRs) proposed by Pesaran and Shin (1998), which are invariant to the ordering of the variables in the VAR. For each of the VAR specifications, either including GDP or consumption, we perform GIRs and cumulative GIRs for each of the two sub-periods (figure 2). Shocks represent an exogenous increase of 1 percent in the house price variable.[11]

[10] In the previous section we have found that a VAR with one lag is a valid and parsimonious restriction of a VAR with two lags. This result allows us to estimate for this section a VAR with either one or two lags. We choose a VAR with one lag for the sake of preserving an adequate number of degrees of freedom for the estimation.

[11] Because the housing price series has been log-transformed and first-differentiated, an increase of 1 percent of this variable represents an increase of 1 percent in the growth rate of house prices. The same is true for the responses of GDP and private consumption.

Figure 2. Generalized Impulse Responses



Notes: The y-axis measures percent deviations from the baseline, while the x-axis represents quarters after shock.

4.1.1 First Case: GIRs for a VAR Including GDP

First Segment (1960:Q1–1982:Q4). The effect of an increase in house prices by 1 percent has an immediate negative effect on GDP; however, it becomes positive after one quarter and then decreases steadily in the next quarters. The cumulative impulse responses for a ten-quarter horizon suggests that the accumulated effect of a 1 percent increase in housing prices on GDP after ten quarters is around 0.5 percent for this segment.

Second Segment (1983:Q1–2009:Q3). For this sub-period, we find a stronger effect of house prices on GDP compared with the effect found in the first segment for all the periods but one. Moreover, the cumulative impulse responses show that the accumulated effect of a rise of 1 percent in house prices on GDP is around 1 percent after ten quarters for this sub-period, which is approximately 100 percent stronger than the accumulated effect estimated for the first segment.

4.1.2 Second Case: GIRs for a VAR Including Private Consumption

First Segment (1960:Q1–1985:Q1). The effect of a 1 percent increase in the house price variable increases private consumption by approximately 0.1 percent in the first quarter. The shock appears to be absorbed rapidly, implying that a change in housing prices has little influence on private consumption after two quarters. The cumulative impulse responses for a ten-quarter horizon suggests that the accumulated effect of an increase in housing prices of 1 percent on consumption after ten quarters is around 0.5 percent for this sub-period.

Second Segment (1985:Q2–2009:Q3). For this segment, the rise in private consumption following a house price increase of 1 percent is very close in the short run to the response estimated in the first sub-period. Nevertheless, the disturbance appears to impact consumption long after the initial impact. Moreover, the cumulative impulse responses show that the accumulated effect of a rise of 1 percent in house prices on private consumption is around 0.8 percent after ten quarters for this sub-period, which is more than 50 percent stronger than the accumulated effect found for the first segment.

In sum, generalized impulse responses show that the effect of house prices on the economic activity and on aggregate private consumption has substantially increased since the mid-80s.

4.2 Granger Causality Test of Block Exogeneity

Under this short sub-section, multivariate Granger causality of block exogeneity Wald tests are performed for each of the VAR specifications, including either GDP or private consumption, and for each sub-period (see table 6).

Granger causality tests show that before the mid-80s, there is no unidirectional Granger causality running either from house prices to

Table 6. Granger Causality Tests

		Chi-square	**P-value**
Results for a VAR with X = GDP			
First Segment	$HP \nRightarrow GDP$	0.81	0.37
(1960:Q1–1982:Q4)	$GDP \nRightarrow HP$	0.01	0.93
Second Segment	$HP \Rightarrow GDP$	10.86	0.00
(1983:Q1–2009:Q3)	$GDP \nRightarrow HP$	3.32	0.07
Results for a VAR with X = C			
First Segment	$HP \nRightarrow C$	1.16	0.28
(1960:Q1–1985:Q1)	$C \nRightarrow HP$	1.00	0.31
Second Segment	$HP \Rightarrow C$	20.74	0.00
(1985:Q2–2009:Q3)	$C \nRightarrow HP$	0.66	0.42

Notes: The null hypothesis is the non-Granger causality. The $\Rightarrow$ and $\nRightarrow$ symbols denote the Granger causality and the non-Granger causality, respectively, at the 5 percent significance level.

GDP or consumption, or in the opposite direction. However, a clear unidirectional Granger causality running from house prices to the economic activity and to private consumption is detected since the mid-80s.

5. Conclusion

This paper provides empirical evidence on the strengthening of the impact of house prices on the macroeconomy in the United States. First, Qu and Perron's methodology is applied to identify breaks in a VAR model. The choice of this method is guided by its key advantages compared with the alternative methods used in the literature: the method allows us to detect a break at unknown dates and it allows for multiple breaks. Second, the estimated break points are used to split the sample into different segments, and the generalized impulse responses proposed by Pesaran and Shin (1998) as well as Granger causality tests are performed within the sub-samples.

Using macro-data from the last fifty years, this study finds that there is a robust structural break in the mid-80s in the house price effect on the macroeconomy, which is obtained when either GDP or private consumption is included in the multivariate specification. The paper also finds time-series evidence that the overall impact of house prices on consumption and on economic activity has intensified since the mid-80s. Results in this study support the widespread hypothesis in the theoretical literature that the deep transformation in the mortgage market during the mid-80s is the main cause of the intensification of the impact of housing prices, not only on household expenditures decisions but also on the economic activity as a whole.

Future research could be focused on the consequences of the Dodd-Frank Act on credit conditions and to what extent it will affect the house price macro-link. Indeed, a tightening in credit constraints could be expected following Title XIV of the Dodd-Frank Act—"Mortgage Reform and Anti-Predatory Lending Act"—since its main objective is the imposition of restrictions on mortgage originators to only provide lending to borrowers who are likely to repay their loans.

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The Transmission of Monetary Policy Through Conventional and Islamic Banks*

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We investigate the differences in banks' responses to monetary policy shocks across bank size, liquidity, and type—i.e., conventional versus Islamic—in Pakistan between 2002:Q2 and 2010:Q1. We find that following a monetary contraction, small banks with liquid balance sheets cut their lending less than other small banks. In contrast, large banks maintain their lending irrespective of their liquidity positions. Islamic banks, though similar in size to small banks, respond to monetary policy shocks as large banks. Hence, ceteris paribus, the credit channel of monetary policy may weaken when Islamic banking grows in relative importance.

JEL Codes: E5, G2.

1. Introduction

Islamic banking is one of the fastest growing segments of the global financial sector. It is currently expanding at a rate of approximately 20 percent annually. In some countries the share of the Islamic financial sector has now reached a size and a level of development such that the financial arrangements it offers are a full-fledged alternative to those in the conventional financial sector. The countries where this has happened include Malaysia, Iran, and the Gulf Cooperation Council countries, i.e., Bahrain, Kuwait, Oman, Qatar, Saudi

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Arabia, and the United Arab Emirates. Some Asian countries like Bangladesh, Pakistan, and Indonesia are also experiencing a phenomenal increase in Islamic finance. Moreover, a number of Western countries are now facilitating Islamic banking. To tap into this growing market, large conventional banks that have opened Islamic windows include Barclays, BNP Paribus, Citi Group, Deutsche Bank, Standard Chartered, and the Royal Bank of Scotland.

The total volume of Islamic finance was estimated to roughly equal $1 trillion in 2010 (Standard & Poor's 2010). Commercial banking comprised the largest share, i.e., 74 percent (International Financial Services London 2010). Investment banking accounted for 10 percent. The remaining part consists of *sukuk* (Islamic bonds) and *takaful* (Islamic insurance). Assets of the largest 500 Islamic banks increased by 29 percent to $822 billion in 2009. Around the same time, the rest of the world's financial system contracted, and many of the financial institutions deleveraged their positions. The reason for this starkly different development resides in the fact that Islamic banking tenets do not allow the banks to charge interest and to be involved in the sales of debt instruments. Therefore, Islamic banks did not invest in the kind of instruments that were badly affected during the financial crises, namely derivatives, conventional securities, and toxic assets. Banning short-selling of shares after the crisis is a further reflection of Islamic finance, as it stops dealers from selling assets which they do not own. A key question this brisk growth poses to academics and policymakers alike is whether the transmission of monetary policy through the so-called bank lending channel will be altered in strength when the Islamic segment of the banking sector becomes even more important.[1] Indeed, the

[1] This bank balance sheet channel may be operational because of agency problems between banks and their providers of funds, depositors, other debt holders, and equity holders (Bernanke 2007). Gertler and Kiyotaki (2011) formalize this channel, modeling financial intermediation as in Gertler and Karadi (2011) but including liquidity risk as in Kiyotaki and Moore (2012). Similarly, the agency problems between banks and their borrowers (firms and households) give rise to the firm balance sheet channel (Lang and Nakamura 1995; Bernanke, Gertler, and Gilchrist 1996, 1999). Gertler and Gilchrist (1993) and Oliner and Rudebusch (1996), for example, find that, following the dates of monetary contractions identified in Romer and Romer (1989), the ratio of bank loans to small versus large manufacturing firms falls. Gertler and Gilchrist (1994) show that, even after controlling for differences in sales between these firms, the differences in the behavior of small and large firm debt remain there. If bank loans are imperfectly substitutable with public financing for firms, and prices adjust imperfectly, monetary policy affects real activity through the so-called credit channel.

potency of the bank lending channel crucially depends on the ability of the central bank to affect bank loan supply, i.e., whether banks cannot attract (time) deposits perfectly elastically or they do not consider the loans granted and securities held in portfolio as perfect substitutes.

Islamic banks may be, on the one hand, unable or unwilling to "buy" wholesale time deposits at a fixed rate and—à la socially responsible investors—may not consider their Islamic loans substitutable for any securities they would hold in their portfolio. This may make the transmission of monetary policy shocks through the Islamic segment of the banking sector more potent. On the other hand, Islamic banks singularly attract deposits and lend under interest-free arrangements, likely entered into for religious reasons by depositors and borrowers (Baele, Farooq, and Ongena 2012; Khan and Khanna 2012). These contractual and motivational features, on both their liability and asset sides, may allow Islamic banks to shield themselves from monetary policy shocks (see section 3). Consequently, whether Islamic banks transmit monetary policy differently than conventional banks is an empirical question, which we aim to address in this paper.

Following Bernanke and Blinder (1992), who find that a monetary contraction is followed by a significant decline in aggregate bank lending, Kashyap and Stein (2000) analyze if there are important cross-sectional differences in the way that banks respond to monetary policy shocks. In this way, controlling for loan demand, they find that following a monetary contraction, small banks with liquid balance sheets cut their lending less than other small banks. Brissimis, Kamberoglou, and Simigiannis (2003), de Haan (2003), Kaufmann (2003), Loupias, Savignac, and Sevestre (2003), Worms (2003), and Gambacorta (2005), for example, also find that liquidity positions of banks play a significant role in banks' response to a monetary shock in various European countries. Jayaratne and Morgan (2000), Kishan and Opiela (2000), Ashcraft (2006), and Black, Hancock, and Passmore (2009) similarly examine the differentiation across bank capitalization, core deposits, bank holding company status, and bank business strategies.

We follow the seminal paper by Kashyap and Stein (2000) and investigate the cross-sectional differences in the way that banks respond to monetary policy shocks, not only across bank size and liquidity but also across bank type—i.e., conventional versus Islamic—in Pakistan between 2002:Q2 and 2010:Q1.[2] The country and sample period provide a unique setting to analyze this differential response. Pakistan may be one of the few countries where both well-developed conventional and Islamic banking sectors have coexisted for a considerable period, formally since 2002 when Islamic banking was reintroduced in Pakistan. Out of forty banks that grant business loans, six banks are licensed by the Banking Policy and Regulation Department of the State Bank of Pakistan as *shariah*-compliant full-fledged Islamic banks.

As in Kashyap and Stein (2000), we find that following a monetary contraction, small banks with liquid balance sheets cut their lending less than other small banks, and large banks maintain their lending irrespective of their liquidity positions. The main contribution of our paper is to show that Islamic banks, though similar in size to small banks, respond to monetary policy shocks much like large banks. Hence, ceteris paribus, the expected growth in the Islamic segment of the banking sector in many countries may lead to a weakening in the potency of the credit channel of monetary policy.

In this respect, our paper contributes to the rapidly growing literature on socially responsible investment that shows that fund portfolio allocation and the resultant firms' cost of capital, and ultimately their performance, may be affected by the pursuit of social or ethical objectives by decision makers—in particular, by investors (Renneboog, Ter Horst, and Zhang 2008; Hong and Kacperczyk 2009; Hong and Kostovetsky 2012). Our results show that even the transmission of monetary policy may be affected by the religion-inspired objectives pursued by a set of bank managers and their clients.

[2]Khwaja and Mian (2008) also analyze lending by banks in Pakistan. They examine the drop in lending by different banks to similar firms following shocks to banks' liquidity induced by unanticipated nuclear tests that took place in 1998 in Pakistan. They find that banks pass their liquidity shortages to firms, but firms with strong business or political ties can turn to alternative sources in the credit market. In contrast, we focus on the monetary policy shocks responding to foreign capital inflows that followed this period and assess the differential transmission through the conventional and Islamic segments of the banking sector. Other studies that focus on the banking sector in Pakistan include Khwaja and Mian (2005), Mian (2006), Zia (2008), and Baele, Farooq, and Ongena (2012), for example.

The remainder of this paper is organized as follows. Section 2 discusses the institutional framework in Pakistan after 2001 and its relevance for the lending channel. Section 3 describes the data and introduces the econometric specification, and section 4 discusses the results. Section 5 concludes.

2. Pakistan after 2001

2.1 Monetary Conditions

Following 9/11 there was a substantial inflow of capital in Pakistan. Workers' remittances, especially from the United States, the United Kingdom, the United Arab Emirates, and Saudi Arabia, increased tremendously. Spurred by the privatization of major public-sector corporations by the Government of Pakistan, foreign direct investment (FDI) also boomed.

The growing inflow of remittances and FDI caused an appreciation in the local currency, the Pakistan rupee (PKR), against most other currencies. Prior to 2001, Pakistan had faced severe shortages in foreign reserves because of the nuclear tests in 1998 (Khwaja and Mian 2008). The inflow of foreign capital was therefore welcomed initially. The State Bank of Pakistan (SBP), the nation's central bank, reacted to the inflow of foreign funds by purchasing U.S. dollars and by increasingly accumulating these and other foreign reserves. Its aim was also to curb the appreciation of the rupee against most other currencies to safeguard the competitiveness of Pakistan's exports. The purchase of dollars by the central bank almost inevitably caused the money supply to expand, despite the attempts to sterilize the increase in money supply through open-market sales of government securities.

As a result, the financial markets in Pakistan became saturated with excess liquidity, and in August 2003 the interest rate on government securities dropped to as low as 1.27 percent. It is only after 2005 that monetary policy started to tighten in response to inflation, inexorably following the relentless monetary expansion during the preceding years.

Since monetary policy during most of the analyzed time period simply responded to this unique and large external shock—i.e., the concurrent inflow of remittances and FDI—our analysis will rely on the changes in the three-month Treasury-bill rate as the most straightforward indicator of monetary policy. The use of variations in the short-term interest rate as a measure that proxies the change in the stance of monetary policy is fully in line with the literature analyzing the credit channel at the micro level.[3] The use of a three-month interest rate was followed by many articles in Angeloni, Kashyap, and Mojon (2003), for example, that analyze European data. Replacing the changes in the three-month interest rate with the changes in the overnight interbank interest rate or with the changes in the six-month Treasury-bill rate yields very similar results, maybe not surprisingly, as the correlation between all interest rate series is very high.

2.2 Islamic Banks

In principle, Islamic banking is equity, rather than fixed-interest, based on profit and loss sharing on both the liability and asset sides of a bank's balance sheet. Depositors in Islamic banks are, for all practical purposes, shareholders that receive no guarantee with respect to the face value of their "deposits." In principle, they fully share in the profits and losses of the bank in which they have their deposits. Similarly, on their asset side, Islamic banks deploy an array of deferred sales, operational leases, and profit-and-loss-sharing arrangements to finance household consumption or firm investment. In many respects, Islamic banks are not unlike conventional mutual fund banks (e.g., Cowen and Kroszner 1990).

Islamic banks seek funding through transaction deposits and investment accounts. *Transaction deposits* are similar to conventional banks' demand deposits; i.e., cash can be withdrawn at any time by writing a check or by accessing an automated teller machine (ATM), and the bank guarantees the nominal value of the deposit. However, Islamic banks cannot lend the funds to projects that are

[3]See Jayaratne and Morgan (2000), Kashyap and Stein (2000), Kishan and Opiela (2000), Ashcraft (2006), and Black, Hancock, and Passmore (2009), among others. On the other hand, Bernanke and Blinder (1992) and Christiano, Eichenbaum, and Evans (1996) use vector autoregressions to identify monetary policy shocks. However, Kashyap and Stein (2000) find very similar results using either the variation in the federal funds rate, the Boschen and Mills (1995) index, or the Bernanke and Mihov (1998) measure.

haram—i.e., not permissible under Islamic jurisprudence (*Shariah*) and related to alcohol, pork, sex, etc.—or that deal with interest payments (*riba*), gambling (*maysar*), or excessive uncertainty (*garrar*). In general, Islamic banks aspire to be more conservative in lending.

Investment accounts are the equivalent of the conventional savings accounts plus time deposits. However, these accounts do not offer a fixed interest rate, but rather involve profit and loss sharing between bank and depositors. Although consequently the face value of the investment deposits is not ensured, Islamic banks invariably observe due diligence in financing various projects.

Joint venture financing arrangements constitute the most principled form of financing households and firms. However, in the early stages of their development, Islamic banks often adopt asset-backed fixed-return arrangements, mainly deferred payment sales (*murabahah*) and operational leases (*ijarah*), to finance household consumption, car purchases, and real estate. In Pakistan these two types cover approximately 80 percent of the total financing provided by Islamic banks (as of December 2004), which has decreased to about 60 percent over time (as of December 2009).[4]

2.3 Monetary Conditions and Islamic Banks

The first Islamic bank in Pakistan was established in 2002 as a response to the—until then—unmet market demand for Islamic financial products (State Bank of Pakistan 2004). Islamic banking quickly observed a sharp growth, as new and established banks entered the market by designing and offering suitable contracts to collect deposits from and extend credit to households and enterprises.

The main problem immediately faced by the Islamic banks was the absence of a government security designed in accordance with Islamic principles, for use as a safe investment or to fulfill the liquidity requirements set by the SBP. In the absence of such an Islamic government security, Islamic banks had no immediate base rate to

[4]These two products are mainly replaced by another fixed-return scheme called diminishing *musharikah* (i.e., "diminishing partnership"), in which the partner in an asset (a house, for example) not only pays rental payments to the bank but over time also buys the share owned by the bank.

price their *murabahah* and *ijarah* contracts. Instead, they used the Karachi Interbank Offered Rate (KIBOR) (State Bank of Pakistan 2009). However, the KIBOR is largely determined by the rate on short-term government securities such as the three-month Treasury bill, which is set in fortnightly auctions. Because fixed-return modes cover a large part of the total financing that is provided by Islamic banks, for the estimation of the strength of a lending channel the three-month Treasury bill rate can also be used as an indicator of the monetary policy stance.

The balance sheet data in table 1 provide a first glimpse of the crucial differences between small and large conventional banks and Islamic banks in terms of liquidity. A large bank is defined as a bank with more than 200 billion PKR (around 2.5 billion U.S. dollars; 80 PKR = 1 USD) in assets. According to this definition there are six large banks, representing around 60 percent of all banking assets. We label the remaining banks as small banks. By assets, all Islamic banks are small banks.

Liquidity is defined as the sum of cash, balances with Treasury banks, and balances with other banks (as in Loupias, Savignac, and Sevestre 2003, for example). Although the cash reserve requirement for both conventional and Islamic banks remained the same throughout the entire sample period, liquidity varies noticeably across bank type. On average, small conventional banks were more liquid than large conventional banks during the period of easy monetary policy in 2003. However, the situation is reversed during the period of tight monetary policy after 2005. Hence, contractionary monetary policy creates more liquidity problems for small banks than for large banks. This is due to the fact that the large banks have relatively more options for non-reversible financing like debt or equity instruments.

In comparison with conventional banks, Islamic banks have the higher fraction of their assets in cash and balances with Treasury and other banks. This is also the case in many other countries where Islamic banks are present (Beck, Demirgüç-Kunt, and Merrouche 2013). The explanation may be straightforward: In the early stages of their existence, Islamic banks had fewer immediate investment opportunities in comparison with their conventional counterparts.

Most of their liquidity remained in the form of cash and balances with other financial institutions. This is mainly due to the absence

Table 1. Balance Sheet Items for Conventional Banks and Islamic Banks (as percentage of assets and liabilities, and indicated items)

	Conventional Banks				Islamic Banks	
	Small Banks		Large Banks			
	2003	**2009**	**2003**	**2009**	**2003**	**2009**
Assets						
Cash and Balances with Treasury Banks	9	6	10	10	12	8
Balances with Other Banks	4	2	4	3	12	7
Lending to Financial Institutions	11	4	7	3	0	16
Call Money	14	*13*	8	*11*	0	*0*
Repurchase Agreements	75	*66*	86	*84*	0	*2*
Other	11	*21*	6	*6*	0	*98*
Investments—Net	22	31	36	25	7	16
Market Treasury Bills	49	*67*	69	*51*	0	*5*
Pakistan Investment Bonds	43	*14*	19	*9*	0	*2*
Other	8	*19*	12	*40*	100	*93*
Advances—Net	50	45	37	52	64	44
Other Assets	5	12	6	8	4	9
Liabilities						
Borrowing from Financial Institutions	22	17	5	6	12	4
Deposits and Other Accounts	66	64	84	78	69	80
Time Deposits	23	*38*	18	*28*	42	*42*
Saving Deposits	54	*33*	50	*36*	46	*31*
Current Accounts	23	*28*	31	*36*	12	*26*
Subordinated Loans	1	1	0	1	0	0
Other Liabilities	6	7	5	4	4	5
Equity	6	10	5	10	15	10

Source: Annual audited bank accounts.

of a *shariah*-compliant instrument called *sukuk* (Islamic bond). Islamic banks initially did not have any alternative investment option in securities. This is evident from the low fraction of their assets in investments in 2003 (table 1). The first *shariah*-compliant instrument was issued by a public-sector enterprise only in 2005, but

Table 2. Statutory Cash and Liquidity Reserve Requirements (as percentage of time and demand deposits)

Dates	Cash Requirements	Liquidity Requirements	
	All Banks	Conventional Banks	Islamic Banks
Until 2006	5	15	6
Feb. 15, 2006	5	15	8
July 18, 2006	5	15	8
July 18, 2006	7	18	8
June 31, 2008	8	18	8
May 22, 2008	9	19	9
Oct. 17, 2008	6	19	9
Nov. 1, 2008	5	19	9

it could not fulfill the large investment appetite of Islamic banks. So until 2008, in the absence of any Islamic government security, Islamic banks held cash to fulfill the statutory liquidity requirement (SLR) and cash reserve requirements (CRRs).

Holding only cash resulted in higher opportunity costs for Islamic banks than for conventional banks. Realizing that Islamic banks were at a cost disadvantage compared with conventional banks in meeting the SLR, the SBP relaxed it for Islamic banks. While their CRRs are the same, Islamic banks, on average, have been required to hold 10 percent less in SLR than conventional banks. During the period under study, Islamic banks need to hold 9 percent of the total demand and time deposits for SLR purposes, whereas conventional banks are liable to maintain 19 percent of demand and time deposits (table 2). Therefore, and in order to make our analysis comparable across bank type, we take the liquidity variable equal to the first two liquidity items—i.e., cash and balances with Treasury and other banks—for which the requirements and the opportunities are most likely similar for conventional and Islamic banks.

In the absence of a risk-free Islamic instrument, Islamic banks also benchmarked their fixed-return contracts, *murabahah* and *ijarah*, to the conventional interest rate charged in the interbank market, which is usually based on the Treasury-bill rate. However, the loan supply of Islamic banks is less likely to react to changes in monetary policy because, as mentioned earlier, they have fewer investment opportunities and are more likely to sit on a lot of spare liquidity. In addition, since Islamic banks assets are only indirectly linked to the policy rate, Islamic banks may be less affected by the changes in monetary policy.

2.4 Bank Lending Channel in Pakistan

The structure of a country's banking system is likely to determine the strength of the banks' lending response to monetary policy shocks. The size of the banking sector and its market concentration, the fraction of banking assets that are liquid, and the banks' capitalization could be crucial in establishing the potency of the bank lending channel.

State and foreign ownership of domestically operating banks will also be important in determining the impact of domestic monetary policy on the banks' loan supply. State-owned banks, which are mostly publicly guaranteed, likely attract new funds elastically to offset the impact of monetary contractions, for example (Ehrmann et al. 2003). Similarly, foreign banks with close links to their parent institutions and global bank networks are likely to absorb the impact of domestic monetary policy without altering their domestic loan supply (foreign banks with most of their funding in their home country may contract lending relatively more following contractionary monetary policy in their home country).

This section presents salient features of the banking system in Pakistan, such as the importance of banks within the financial system and corporate finance, the market structure, the heterogeneity of the banks, their overall performance, and the role of the state in the banking system. Each of these features may determine the potency of the bank lending channel. Tables 3 and 4 provide, for conventional and Islamic banks, many of the statistics we now discuss, while table 5 summarizes how the various characteristics we discuss determine the potency of the bank lending channel in Pakistan through the conventional and Islamic segment of the banking sector, respectively.

Table 3. Financial Intermediation in Pakistan in 2002–09

Year:	2002	2003	2004	2005	2006	2007	2008	2009
As Percent of Total Assets of the Financial Sector								
Microfinance Institutions	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2
Non-Bank Financial Institutions	6.2	6.6	7.0	7.6	7.8	8.0	7.6	5.3
Insurance	3.8	3.8	3.8	3.9	4.1	4.6	4.4	4.4
Central Directorate of National Savings Institutions	24.9	25.0	21.7	18.0	16.1	14.6	14.8	16.6
All Banks	65.0	64.5	67.3	70.4	71.9	72.7	73.0	73.5
As Percent of Gross Domestic Product								
Microfinance Institutions	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Non-Bank Financial Institutions	4.6	4.9	5.2	5.6	5.7	5.9	5.0	3.4
Insurance	2.8	2.9	2.8	2.9	3.0	3.4	2.9	2.8
Central Directorate of National Savings Institutions	18.2	18.8	16.1	13.3	11.7	10.8	9.8	10.8
All Banks	47.7	48.3	50.1	51.8	52.4	53.9	48.1	47.6
As Percent of Total Assets of All Banks								
All	73.3	75.0	74.4	73.7	72.9	74.1	66.0	64.7
Private-Sector Credit	18.0	19.9	22.6	26.3	27.8	28.5	27.6	22.8

Source: State Bank of Pakistan.

Table 4. Banking Structure in Pakistan in 2002–09

Year:	2002	2003	2004	2005	2006	2007	2008	2009
Public Debt and Stock Market Financing								
Domestic Debt Securities Issued by the Corporate Sector, in % of GDP	0.19	0.05	0.08	0.16	0.04	0.07	0.25	0.02
Domestic Debt Securities Issued by the Corporate Sector, in % of Bank Loans to Corporate Sector	1.5	0.3	0.4	0.6	0.2	0.3	0.9	0.1
Stock Market Capitalization, in % of GDP	14	20	30	42	36	49	14	20
Measures of Banking-Sector Concentration								
Herfindahl-Hirschman Index	973	912	850	762	745	739	736	712
Coefficient of Variation	1.7	1.6	1.5	1.4	1.4	1.4	1.4	1.4
Assets of Five Largest Banks, in % of Total Bank Assets	61	59	56	54	52	52	52	51
Assets of Large Banks (Assets > 200 billion PKR), in % of Total Bank Assets	n/a	n/a	65	64	60	58	59	57
State Ownership								
Assets of the Public-Sector Banks, in % of Total Bank Assets	52	49	27	26	26	27	25	26

(continued)

Table 4. (Continued)

Year:	2002	2003	2004	2005	2006	2007	2008	2009
Bank Performance, Conventional Banks (all values are in %)								
Capital Asset Ratio	6.3	5.8	6.3	3.8	6.7	5.5	−0.1	−2.5
Fixed Asset to Total Asset	1.6	2.0	1.8	1.9	3.0	3.1	4.6	4.4
Lending Rate	8.0	5.1	4.4	6.8	7.5	8.4	9.7	10.2
Non-Deposit Funding to Total Funding	25.3	24.9	27.3	26.5	24.8	22.3	20.9	22.2
Non-Loan Earning Assets to Total Earning Assets	50.5	51.1	45.7	44.1	40.6	41.3	35.0	45.0
Non-Performing Loans to Total Assets	13.1	12.3	11.8	11.7	8.5	9.3	12.0	13.8
ROA	0.6	0.9	1.4	1.0	1.0	0.3	0.1	1.0
Islamic Banks								
Capital Asset Ratio	19.0	14.7	12.7	13.0	28.4	27.2	21.2	17.0
Cost Income Ratio	69.2	66.2	69.4	63.6	179.4	99.9	101.4	101.0
Fixed Asset to Total Asset	0.4	0.5	0.7	0.7	5.1	5.0	5.6	4.7
Lending Rate	7.1	4.5	3.8	6.5	6.2	7.1	10.0	10.7
Non-Deposit Funding to Total Funding	11.8	16.4	17.9	12.8	8.8	3.8	5.3	6.4
Non-Loan Earning Assets to Total Earning Assets	30.5	22.8	23.5	27.0	43.6	43.6	35.4	44.9
Non-Performing loans to Total Assets	2.5	1.4	1.0	1.3	0.5	0.3	1.1	3.8
ROA	2.4	1.5	1.1	1.9	−1.0	0.0	−0.3	−1.1

Source: State Bank of Pakistan.

Table 5. Factors Determining the Potency of the Bank Lending Channel

This table provides the factors that determine the potency of the bank lending channel and the direction of their impact in general and with respect to the specific status of conventional and Islamic banks in Pakistan. A positive sign (+) means that there is a positive impact of that factor on the potency of the bank lending channel, and vice versa if the sign is negative (–). The last four columns state the relevance of these factors with respect to status of both the conventional banks and Islamic banks in Pakistan. For example, borrowing/financing from conventional banks is very high in Pakistan, so it strengthens the lending channel through these banks, whereas for Islamic banks the share is much smaller, so the factor weakens the channel through Islamic banks (see section 2.4).

		Relevancy for Status Banking System in Pakistan			
		Conventional Banks		Islamic Banks	
Factor	**Impact on Potency of Bank Lending Channel**	**Strengthening**	**Weakening**	**Strengthening**	**Weakening**
Importance of the Banking Sector					
Importance of Bank Financing	+	√			√
Investors Protection and Capital Markets	–	√		√	
Bank Dependence	+	√			√
Structure of the Banking System					
Concentration and Size	–		√	√	
Financial Strength	–	√		√	
State Influence	–	√		√	
Foreign Ownership and Bank Networks	–	√		√	
Regulatory Requirements					
Capital Adequacy	–		√		√
Deposit Insurance	–	√		√	
Bank Failures	+	√			√

2.4.1 Importance of Banks within the Financial System

Banks play a central and still expanding role in the financial system of Pakistan. In the wake of reforms that started during the 1990s—such as bank privatizations and interest rate liberalization, for example—the total assets of the banking system increased during the last decade, both in absolute value and as a share of the total assets of the financial system, from 65 percent in 2002 to 74 percent in 2009.[5]

In contrast, the share of non-bank financial institutions and the Central Directorate of National Savings decreased from 6.2 to 5.6 and from 25 to 17 percent, respectively. The latter category of financial institutions comprises various national saving schemes through which the government mobilizes household savings by offering various debt instruments at varying maturities and constitutes a major source of non-bank borrowing for the government. The minute share of microfinance and insurance institutions increased slightly.

In general, global macroeconomic and political developments remain favorable to the Pakistani banking sector. Yet, total private-sector credit granted by banks over gross domestic product (GDP) expanded briskly until 2005, then leveled off and, for the first time, dropped in 2007, corresponding to the tightening of monetary conditions. This fact is suggestive of the existence of a lending channel in Pakistan. The share of Islamic banks' assets in total assets of the banking sector is still small, though increasing over time.

2.4.2 Importance of Banks for the Financing of Corporations

Banks around the world are very important in fulfilling the financing needs of the corporate sector. For most firms and even in financially well-developed countries, public debt and equity play only a minor role in financing corporate activities.

Debt and equity markets are often found to be less developed and subject to more intense market imperfections in emerging economies. This is also the case in Pakistan. The issuance of public debt is very limited, and small firms especially rely heavily on bank debt. Bond

[5]The banks also own shares in non-bank financial institutions, insurance companies, brokerage houses, and financial advisory services, further underlining their central role in the financial system (State Bank of Pakistan 2007–08).

market capitalization has even decreased over time in nominal terms. Stock markets continue to play a modest role in corporate-sector funding. Stock market capitalization has shown an upward trend, but still the market is relatively thin, dominated by a handful of commercial banks' stocks and mainly driven by the demand from foreign investors.

In sum, banks play a dominant role as financial intermediaries in Pakistan. If the supply of bank loans to firms changes following changes in monetary policy, firms will likely be affected, as financing alternatives are not readily available for most firms.

2.4.3 Performance of the Banking Sector

The transmission of monetary policy also depends on the performance of the banks. A stronger banking sector results in a weaker effect of monetary policy on the loan supply (Cecchetti 1999). The financial strength of the banking system can be measured through asset quality, capital adequacy, liquidity, and the earnings of the banking system.

The first half of the sample period is characterized by an increase in the stability and expansion of the banking system. Banking business remained profitable and return on equity (ROE), for example, grew until 2006. Similarly, the cost-income ratio dropped until the same year.

However, after the tightening of monetary policy started in 2005, performance of the banking sector weakened, and in subsequent years there was a rise in non-performing loans and a resultant erosion of capital. The banking sector in Pakistan is clearly not immune to contractionary monetary policy shocks, as bank balance sheets are affected by the increasing interest rates.

2.4.4 Relationship Lending

A strong relationship with a bank may insulate an individual firm to some extent from the cut in bank lending that follows a contractionary monetary policy. This shielding may not only be cross-sectional—i.e., vis-á-vis other firms that have no relationship—but also across time if banks would intertemporally "subsidize."

If firms engage multiple banks, firms can switch if one bank is affected more by contractionary monetary policy than the others

(Detragiache, Garella, and Guiso 2000). Large firms are mostly immune from any type of financing shortage by switching among banks when needed (Khwaja and Mian 2008). Small firms, however, are often unable to substitute between banks, or between bank and other types of financing.

2.4.5 Market Concentration and Size Structure

Informational frictions in the banking sector are important for the lending channel to operate. If market players in the interbank markets are facing significant informational asymmetries, then distributional effects are likely to occur between banks that are confronted with informational issues to various degrees. Size criterion is used as standard in literature as a proxy to measure the opaque informational situation of the banks. Small banks, in general, are considered to be more exposed to informational frictions than large banks. Therefore, the external finance premium for the former category is probably higher than for the latter group.

The banking market in Pakistan is characterized by a steadily decreasing concentration during the sample period. The Herfindahl-Hirschman Index (i.e., the sum of market shares squared) decreased from 973 in 2002 to 736 in 2008, while the group of the largest banks (with total assets more than 200 billion PKR) slipped from 65 percent in 2004 to 52 percent in 2008. As concentration dropped, competition may have intensified, possibly making the bank lending channel more potent, particularly for small banks.

2.4.6 State Influence in the Banking Sector

Before the financial reforms in the 1990s, the Pakistani financial system was mainly characterized by high government borrowing, bank-level credit ceilings, directly controlled interest rates, and directed and subsidized loan supply.

Public ownership of banks was introduced in the 1970s and lasted until the early 1990s, making the state dominant in the banking sector. In 1990 there was not a single domestic private bank. However, due to additional privatization of state-owned banks during the sample period studied, the influence of the state remained waning. The fraction of assets of state-owned banks over total assets of the banking system halved from 52 percent in 2002 to 26 percent in 2009, potentially strengthening the bank lending channel of monetary policy transmission.

2.4.7 Deposit Insurance

There is no deposit insurance in Pakistan. Rather, deposits are in principle indirectly insured only by the continuous supervision by the regulatory authority. Detailed prudential regulations have been issued to avoid different types of risks a bank could be exposed to. Moreover, stringent liquidity requirements are in place to restrain banks from taking excess leverage.

Therefore, in absence of explicit deposit insurance, the lending channel may be more potent, because the lack of certainty about the nominal value of deposits makes depositors feel unsafe about their money. Consequently, following a tightening of monetary policy, deposits may be withdrawn and banks compelled to cut lending.

2.4.8 Bank Failures

There were few bank failures in Pakistan during the 1990s. Some institutions became involved in scandals and failed due to imprudent banking. The Mehran Bank scandal is well known, for example. Some banks were involved in a few scandals, causing depositors to feel insecure. Furthermore, some cooperative societies also collected deposits from the people with a promise of higher returns than the ongoing market rates. These societies inevitably failed and caused a loss to their depositors.

Due to these incidents in the past, there may be a higher occurrence of rumors and an abrupt contraction in deposits following a tighter monetary policy. Furthermore, fraud and forgeries independently affect deposits, which in turn affect lending of the banks. Data related to such cases indicate a significant increase in such cases during the last few years (State Bank of Pakistan 2008–09).

2.4.9 Foreign Banks and Bank Networks

In case any liquidity problem arises, due to a decrease in demandable deposits, foreign banks and banks in networks can resort to their head office or holding company to cover the liquidity shortage.

Under this scenario, the potency of the bank lending channel of domestic monetary policy transmission becomes weaker. The role of foreign banks has been limited in Pakistan, as they account for only 10 percent of total banking-sector assets. There are some implicit bank networks in Pakistan in that ownership of some banks is common. There is also foreign ownership in some large banks. However, evidence strongly suggests that the banks in Pakistan do pass shocks to their borrowers subject to their liquidity position (Khwaja and Mian 2008). This evidence, combined with the weak role of foreign banks and bank networks, makes it more likely that tight monetary policy eventually leads to the loss of deposits by all the banks and a contraction in lending.

3. Data and Econometric Specification

The main source of data is the Quarterly Report of Condition (QRC) of all banks submitted to the State Bank of Pakistan (SBP). The data set covers the whole population of banking institutions that are operational in the financial system and incorporates their QRCs' figures. The time period is from 2002:Q2 to 2010:Q1 at a quarterly basis. There are forty banks, of which six are Islamic banks.

We lose observations because (i) some banks start operating after 2002:Q2; (i) we employ up to four lags of quarterly growth rates; (iii) some banks merge and, following Kashyap and Stein (2000), we remove banks' observations in any quarter in which they are involved in a merger; (iv) we remove observations for which the loan growth rate is more than three standard deviations from its sample mean; and (v) there are missing values in the data set. We are left with 756 bank year:quarter observations that can be used in the estimations. See table 6.

For our analysis of the bank lending channel, we use the theoretical model of Ehrmann et al. (2001), which is for our purposes a relevant version of the Bernanke and Blinder (1988) model. There is no fundamental change in the model when it is applied to Islamic banks. We explain the model with respect to conventional banks compared with Islamic banks. The money-market equilibrium can be described as follows:

$$M = D = -\psi r + \chi, \tag{1}$$

Table 6. Descriptive Statistics

This table provides the definitions, means, standard deviations, minimum, and maximum of all variables used in the estimations. All variables are expressed in percent. The number of bank year:quarter observations equals 756. 80 PKR = 1 USD.

Variable Name	Definition	Number of Banks	Mean	Standard Deviation	Min.	Max.
Small Bank	= 1 if the bank has average total assets below 200 billion PKR and is a conventional bank, = 0 otherwise	28	0.70	0.46	0	1
Large Bank	= 1 if the bank has average total assets exceeding 200 billion PKR and is a conventional bank, = 0 otherwise	6	0.15	0.36	0	1
Islamic Bank	= 1 if the bank is classified as an Islamic bank, = 0 otherwise	6	0.15	0.36	0	1
Islamic Share	= 100 if the bank is classified as an Islamic bank, = 0 if the bank is a pure conventional bank, and varies between 0 and 100 (by asset share) if the bank is a mixed bank					
Small Banks	Six are Islamic, fifteen are pure conventional, and thirteen are mixed	34	18.19	37.97	0	100
Large Banks	One is pure conventional and five are mixed	6	1.33	3.04	0	13.38

(continued)

Table 6. (Continued)

Variable Name	Definition	Bank Type	Mean	Standard Deviation	Min.	Max.
$\Delta \log(L_{it})$	Change in the log of private-sector loans	All Banks	4.2	12.6	−57.7	140.8
		Small Banks	17.4	14.3	−23.6	55.3
		Large Banks	22.5	10.6	7.0	48.0
		Islamic Banks	4.0	13.8	−57.7	140.8
$\sum_{j=1}^{4} \Delta \log(L_{it-j})$	Change in the log of private-sector loans, sum of last four quarters	All Banks	20.4	36.0	−95.7	280.6
		Small Banks	18.5	38.0	−95.7	280.6
		Large Banks	3.8	7.7	−10.7	31.1
		Islamic Banks	5.9	10.7	−12.4	63.0
X_{it-1}	Liquid assets to total assets	All Banks	16.0	14.8	3.0	92.2
		Small Banks	16.1	16.7	3.0	92.0
		Large Banks	12.3	3.3	5.8	25.5
		Islamic Banks	22.5	10.6	7.0	48.0
ΔR_{t-j}	Change in three-month Treasury-bill rate		0.4	0.7	−0.7	2.5
$\sum_{j=0}^{4} \Delta R_{t-j}$	Change in three-month Treasury-bill rate, sum of last four quarters		1.7	2.0	−4.4	5.5
ΔLSM_t	Change in the large-scale manufacturing index		3.0	15.3	−30.7	33.6
$\sum_{j=0}^{4} \Delta LSM_{t-j}$	Change in the large-scale manufacturing index, sum of last four quarters		11.9	15.3	−27.6	40.0

where deposits (D), considered as money (M), depend negatively on the risk-free government bonds' interest rate being the opportunity cost of holding money. Due to the religious motivations, ψ is expected to be much lower for Islamic banks than for conventional banks (Khan and Khanna 2012).

The demand for loans (L_i^d) which a bank faces is assumed to depend on the interest rate on loans (r_l):

$$L_i^d = \varphi_1 r_l. \tag{2}$$

Equation (2) can also apply to Islamic banks, as Islamic banks indirectly use the government Treasury-bill rate as a benchmark for their products for financing (State Bank of Pakistan 2009).[6]

The supply of bank loans (L_i^s) depends on the amount of money (or deposits) available and interest rate on loans. L_i^s also depends (negatively) on the monetary policy rate directly, as the same is considered to be the opportunity cost of bank loans on their assets side as well as the cost of interbank financing on the liability side of the banks' balance sheet. The function remains the same, as Islamic banks are expected to behave like conventional banks—i.e., loans are positively related to the markup/profit rate and negatively related to conventional policy rate:

$$L_i^s = \mu_i D_i + \varphi_2 r_l - \varphi_3 r. \tag{3}$$

It is also assumed that the impact of change of monetary policy through deposits is lower, the higher the bank liquidity (x_i) is:

$$\mu_i = \mu_0 - \mu_1 x_i. \tag{4}$$

In comparison with conventional banks, Islamic banks are more liquid because of the limited financing avenues in the initial stage of their operations.

Inserting (1) and (4) into (3), we get

$$L_i^s = (\mu_0 - \mu_1 x_i)(-\psi r + \chi) + \varphi_2 r_l - \varphi_3 r. \tag{3a}$$

[6]In our specifications and to control for demand-side effects, we also include the large-scale manufacturing index as a proxy for GDP.

Also from (2), we get r$_l$:

$$r_l = \frac{-L_i^d}{\varphi_1}. \tag{2a}$$

We substitute (2a) into (3a) to get

$$L_i^s = (\mu_0 - \mu_1 x_i)(-\psi r + \chi) + \frac{\varphi_2(-L_i^d)}{\varphi_1} - \varphi_3 r. \tag{3b}$$

Since in equilibrium $L_i^d = L_i^s = L_i$, we replace the values accordingly and solve for L_i:

$$L_i = (\mu_0 - \mu_1 x_i)(-\psi r + \chi) + \frac{\varphi_2(-L_i)}{\varphi_1} - \varphi_3 r \tag{3c}$$

$$L = \frac{-(\mu_0\psi + \varphi_3)\varphi_1 r + \varphi_1\mu_1\psi x_i r - \varphi_1\mu_1\chi x_i + \varphi_1\mu_0\chi}{\varphi_1 + \varphi_2}. \tag{3d}$$

Hence,

$$L_i = constant + c_0 r + c_1 r x_i + d x_i, \tag{3e}$$

where $c_1 = \frac{\varphi_1\mu_1\psi}{\varphi_1+\varphi_2}$ is the coefficient on the interaction term of liquidity and the policy rate, and it captures the banks' response to a monetary shock depending upon their liquidity position. A statistically significant and economically relevant c_1 implies that monetary policy does affect the loan supply.[7] The identification requires that the interest rate sensitivity of loan demand observed by a bank is uncorrelated with its liquidity (x_i), i.e., φ_1 is the same for all banks. However, in our robust estimation we control for the demand-side impact as well by including the large-scale manufacturing index (LSM) and interacting the same with liquidity. This is equivalent to allowing for different values of φ_1 across various bank sizes and types with different liquidity. A priori, large banks are less likely to react to a

[7]We also replace the large bank dummy with "size" (total assets) and interact it with liquidity and the monetary policy measure, as robustness of the baseline specification (in which small and large bank dummies are interacted with liquidity and the monetary policy measure). The premise is that large banks, regardless of their liquidity position, can insulate themselves from a monetary shock through funding from capital markets and issuance of wholesale deposits.

monetary impulse, as these banks face fewer informational problems and resultant market frictions. Therefore, due to easier access to capital market and the issuance of wholesale deposits, large banks are *less* likely to cut their lending, irrespective of their liquidity position. Similarly, Islamic banks will not be responsive to monetary policy conditions because of (i) the religiosity of their depositors, and (ii) their strong liquidity position. For estimation, we introduce some dynamics in the final equation and closely follow Kashyap and Stein (2000). The methodology, in general, is based on an assessment of the differences in the response of individual banks to a monetary policy shock according to their liquidity positions.

In sum, we estimate the following equation (5):

$$\begin{aligned}\Delta\log(L_{it}) = c_i + \sum_{j=1}^{m}\alpha_j\Delta\log(L_{it-j}) + \sum_{j=0}^{m}\mu_j\Delta R_{t-j} + \Theta T_t \\ + \sum_{k=1}^{m}\rho_k\, Quarter_{kt} + X_{it-1}\left(\eta + \sum_{j=0}^{m}\varphi_j\Delta R_{t-j}\right) + \varepsilon_{it},\end{aligned} \tag{5}$$

where c_i is the bank i specific fixed effect;[8] $\Delta\log(L_{it-j})$ is the quarterly change in the logarithm of the total amount of the loans granted to the private sector by bank i in year:quarter $t-j$; ΔR_{t-j} is the quarterly change in the three-month Treasury-bill rate in year:quarter $t-j$; T_t is the time trend; $Quarter_{kt}$ is the dummy for quarter k in year:quarter t; and X_{it-1} is liquid assets (i.e., cash and balances with the banks) over total assets of bank i in year:quarter t. m is set to equal four, i.e., one calendar year. This corresponds to the number of lags used in other papers assessing the potency of the credit channel in other countries.

The cross-sectional and time-series derivatives of equation (5) explain the correspondence we assess in the data. The cross-sectional derivative, $\frac{\partial \dot{L}_{it}}{\partial X_{it-1}}$, determines the sensitivity of bank i's lending to its *liquidity position* in the last quarter. The time-series derivative, $\frac{\partial \dot{L}_{it}}{\partial \dot{R}_t}$, captures the sensitivity of lending of bank i to *monetary impulses*. This derivative establishes the direct responsiveness of

[8] Our main results are unaffected if we exclude the set of bank fixed effects.

bank lending to monetary policy on average, irrespective of individual bank characteristics.

We want to test how the sensitivity of bank lending to monetary policy of an individual bank depends on its liquidity position, which can be captured through a second cross partial derivative, $\frac{\partial^2 \dot{L}_{it}}{\partial X_{it-1} \cdot \partial \dot{R}_t}$. Instead, the second cross partial derivative, $\frac{\partial^2 \dot{L}_{it}}{\partial \dot{R}_t \cdot \partial X_{it-1}}$, measures the sensitivity of bank credit to monetary policy, and the hypothesis is that this sensitivity is higher for banks with weak liquidity positions. Both these derivatives use the cross-sectional *and* the time-series properties of the data.

The main hypothesis is that contractionary monetary policy affects the small illiquid banks more than the liquid banks, as the latter can offset any decrease in deposits by reducing their liquid assets. Consequently, our main coefficient of interest is the sum of interaction terms of liquidity X_{it-1} with the monetary policy measure ΔR_{t-j}, i.e., $\sum \varphi$. The correctness of the aforementioned hypothesis requires this coefficient to be positive and statistically significant, i.e., lending by small liquid banks is less sensitive to a monetary shock than lending by other small banks.[9]

Equation (5) is first estimated for the entire banking sector to evaluate the potency of the aggregate bank lending channel. Large banks are possibly less influenced than small banks by monetary shocks because of their ability to raise funds from capital markets and issue wholesale deposits, which—irrespective of their internal liquidity positions—would make their lending less dependent on monetary policy shocks. Islamic banks may also be less affected. Therefore, we also estimate equation (5) including dummies both for large banks and Islamic banks. Both dummies are interacted then with all coefficients, except the trend, quarter, and province shares. We also replace the bank-specific effects with these province shares, which are constructed by calculating for each bank the relative number of branches it has in each province.

[9]For large banks, the interaction term is equivalent to evaluating the hypothesis $\frac{\partial^3 \dot{L}_{it}}{\partial X_{it-1} \partial \dot{R}_t \partial Size_{it-1}} < 0$, i.e., the impact that more-liquid banks decrease their lending less than other banks decreases as the size of the banks increases. This means that the liquidity constraint is not effective for the largest banks, as they can easily raise funds from capital markets and issue wholesale deposits. Therefore, these banks are more likely to maintain their lending after a monetary shock, regardless of their liquidity positions.

In robustness, and to further control for the business cycle and loan demand, we also include change in the large-scale manufacturing index (LSM). Equation (6) equals

$$\begin{aligned}\Delta\log(L_{it}) = c_i &+ \sum_{j=1}^{m}\alpha_j\Delta\log(L_{it-j}) + \sum_{j=0}^{m}\mu_j\Delta R_{t-j} \\ &+ \sum_{j=0}^{m}\pi_j LSM_{t-j} + \Theta T_t + \sum_{k=1}^{3}\rho_k Quarter_{kt} \\ &+ X_{it-1}\left(\eta + \sum_{j=0}^{m}\varphi_j\Delta R_{t-j} + \sum_{j=0}^{m}\gamma_j LSM_{t-j}\right) + \varepsilon_{it}.\end{aligned} \tag{6}$$

4. Results

4.1 All Banks

Table 7 presents the results of the preliminary regression—i.e., equation (5)—estimated using the observations for all banks. The purpose is to assess the potency of the bank lending channel for the overall banking sector. The table shows the sum of the estimated coefficients. The coefficients for provinces, quarter dummies, individual liquidity, and time trend are not shown. All estimates are in percentage terms and we report White (1980) heteroskedasticity-consistent standard errors that are clustered at the year:quarter level (we also check estimates when standard errors are clustered at the bank level, but the significance levels are mostly unaffected).

The estimated coefficients confirm that the bank lending channel is operational in Pakistan. The sum of the estimated coefficients on the changes in the three-month Treasury-bill rate equals -5.83^{***}.[10] Hence, an increase in the interest rate by 1 percentage point decreases loan growth by 5.83 percentage points.

To identify that this decrease in loan growth actually represents a contraction in the supply of credit and not a reduction in the demand for credit, we interact the measure for bank-specific liquidity with

[10] As in the tables, we star (the sum of) the estimated coefficients according to their significance levels. *** denotes significance at 1 percent, ** significance at 5 percent, and * significance at 10 percent.

Table 7. Loan Growth, All Banks

This table reports the sum of the estimated coefficients for specifications with the dependent variable $\Delta \log(L_{it})$, which is the quarterly change in the logarithm of the total amount of the loans granted to the private sector by bank i in year:quarter t. The independent variables are $\Delta \log(L_{it-j})$, which are j lags of the dependent variable, ΔR_{t-j} is the quarterly change in the three-month Treasury-bill rate in year:quarter $t-j, X_{it-1}$ is the liquid assets (i.e., cash and balances with the banks) over total assets of bank i in year:quarter t, and ΔLSM_{t-j} is the quarterly change in the large-scale manufacturing index in year:quarter $t-j$. The estimations use 756 bank year:quarter observations. Standard errors are heteroskedasticity consistent and clustered at the year:quarter level. *** denotes significance at 1 percent, ** significance at 5 percent, and * significance at 10 percent.

(Sum of) Estimated Coefficients	**Preliminary (1)**	**GMM/2SLS (2)**	**R = KIBOR (3)**	**With Bank Province Shares (4)**	**With Large-Scale Manufacturing Index (5)**
$\sum_{j=1}^{4} \Delta \log(L_{it-j})$	0.34^{***}	0.25^{*}	0.36^{***}	0.40^{***}	0.35^{***}
$\sum_{j=0}^{4} \Delta R_{t-j}$	-5.83^{***}	-5.8^{***}	-3.69^{***}	-5.95^{***}	-5.56^{***}
$X_{it-1} * \sum_{j=0}^{4} \Delta R_{t-j}$	20.71^{*}	21.72	15.01	19.22	25.42
$\sum_{j=0}^{4} \Delta LSM_{t-j}$					0.32^{*}
Quarter Dummies, Trend	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects	Yes	Yes	Yes	No	Yes
Bank Province Shares	No	No	No	Yes	No

the interest rate (as in Kashyap and Stein 2000).[11] The sum of the estimated coefficients on this interaction term equals 20.71*. Consequently, banks with a higher level of liquidity contract lending less following a monetary shock (we discuss the economic relevancy of similar estimates in the next table).

A fixed-effects model may create a correlation between lagged dependent variable ΔL_{it-1} and the error term, causing the "Nickel bias" as described, for example, in Verbeek (2008). However, this bias is expected to be negligible if the time period is substantial (Judson and Owen 1999). In our case it is thirty-two quarters, which is sufficiently large. Nevertheless, to ensure the validity of our results we also estimate equation (5) using a two-stage least-squares method (first-stage GMM). Specifically, we employ in model (2) the Arellano and Bover (1995) approach (with the second lag of the dependent variable in level as an instrument, which is valid according to a Sargan 1958 test). There is only a very small change in results.

To further check the robustness of these estimates, we replace the three-month Treasury-bill rate with the KIBOR in model (3) and the six-month Treasury bill (results not shown). The sum of the estimated coefficients on the changes in the interest rates equals −3.69*** and −5.12***, respectively, while the sum of the estimated coefficients on the interaction term with liquidity equals 20.71 and 15.42. Individual liquidity coefficients are insignificant for all specifications.

To control better for regional effects, model (4) replaces the bank fixed effects with bank province shares—i.e., for each bank, the number of branches it has in each province divided by the total number of branches it has. To control better for business cycle and loan demand, model (5) includes the change in LSM. Estimates are mostly unaffected.

4.2 Large and Islamic Banks

We now assess the role played by large and small (conventional) banks and Islamic banks in the bank lending channel. We interact

[11]We also use liquid assets to deposits as a liquidity measure instead of liquid assets to total assets. This measure incorporates the changes in the deposits as a result of monetary policy impulses. The new estimates corroborate the earlier findings.

dummies for large and Islamic banks with all independent variables (except with the trend, season, and province shares). Table 8 exhibits the results for various specifications. Panel A provides the sum of the estimated coefficients, while panel B provides for the baseline model (1) the estimated *individual* coefficients for the included lags (which are, as in Kashyap and Stein 2000, broadly in line with the sums).

The baseline model (1) indicates that the small banks especially make the bank lending channel operational, a finding also present in Kashyap and Stein (2000). An increase in the three-month Treasury-bill rate of 1 percentage point decreases the loan growth of small banks by 7.17*** percentage points in a year. The sum of the estimated coefficients on the interaction terms of liquidity and interest rates equals 25.06**.

To assess if the estimated coefficients also have economically relevant implications, we need to calculate the response in lending by similar-sized banks, but with different liquidity positions, to a monetary policy shock. Using the liquidity distribution of small banks in 2010:Q1, we consider a bank at the ninth decile a "liquid" bank and at the first decile an "illiquid" bank. The liquidity ratios according to this criterion are 24 and 5 percent, respectively. Under this scenario, a 1-percentage-point increase in the interest rate reduces the lending by an illiquid bank 4.5 percentage points more than the lending by a liquid bank over a one-year time period. This is calculated through multiplying $\sum \varphi$ by the liquidity differential of the liquid and illiquid banks, i.e., $25.06 \times (0.24 - 0.05)$.

The estimated results for the large banks are different. The sum of the estimated coefficients on the change in interest rate is positive—i.e., 7.06*—but only marginally significant. Hence, large banks are not sensitive to changes in monetary policy due to their ability to fund their lending from the capital market (other than from demand deposits). The sum of the interaction terms of liquidity and the interest rate is now negative, as in Kashyap and Stein (2000), but insignificant. Using the difference between small banks' and large banks' coefficients, there is a 12.2 percent gap in the level of lending across liquid and illiquid small banks one year after a monetary shock.

All in all, these findings are very similar to those in Kashyap and Stein (1995), i.e., tight monetary policy decreases the loan growth of small banks but may actually increase credit granted by large

Table 8. Loan Growth, Across Bank Type

This table reports the sum of the estimated coefficients for specifications with the dependent variable $\Delta \log(L_{it})$, which is the quarterly change in the logarithm of the total amount of the loans granted to the private sector by bank i in year:quarter t. The independent variables are $\Delta \log(L_{it-j})$, which are j lags of the dependent variable, ΔR_{t-j} is the quarterly change in the three-month Treasury-bill rate in year:quarter $t-j$, ΔLSM_{t-j} is the quarterly change in the large-scale manufacturing index in year:quarter $t-j$, and X_{it-1} is the liquid assets (i.e., cash and balances with the banks) over total assets of bank i in year:quarter t. The estimations use 756 bank year:quarter observations. Standard errors are heteroskedasticity consistent and clustered at the year:quarter level. *** denotes significance at 1 percent, ** significance at 5 percent, and * significance at 10 percent.

A. Sum of Estimated Coefficients						
(Sum of) Estimated Coefficients	**Bank Type**	**Baseline (1)**	**GMM/2SLS (2)**	**R = KIBOR (3)**	**With Bank Province Shares (4)**	**With Large-Scale Manufacturing Index (5)**
$\sum_{j=1}^{4} \Delta \log(L_{it-j})$	Small	0.36***	0.26**	0.39***	0.43***	0.37***
	Large	0.15	−0.03	0.29**	0.15	0.09
Difference from	Islamic	0.08	0.10	0.06	0.21***	0.06
Small Banks	*Large*	*−0.21*	−0.29	*−0.10*	*−0.28***	−0.28
	Islamic	*−0.28**	−0.15	*−0.33***	*−0.23*	−0.30*
$\sum_{j=0}^{4} \Delta R_{t-j}$	Small	−7.17***	−7.33***	−4.26***	−7.12***	−7.21***
	Large	7.06*	7.97	4.99	4.43	11.13***
Difference from	Islamic	2.05	3.91*	3.85	−2.95	−3.38
Small Banks	*Large*	*14.23****	15.30***	*−9.25***	*−11.60****	18.34***
	Islamic	*9.22**	11.24*	*−8.12***	4.17	3.83

(continued)

Table 8. (Continued)

A. Sum of Estimated Coefficients						
(Sum of) Estimated Coefficients	**Bank Type**	**Baseline (1)**	**GMM/2SLS (2)**	**R = KIBOR (3)**	**With Bank Province Shares (4)**	**With Large-Scale Manufacturing Index (5)**
$X_{it-1} * \sum_{j=0}^{4} \Delta R_{t-j}$	Small	25.06**	26.90*	18.24*	22.88*	31.05*
	Large	−39.20	−41.35	−28.83	−17.40	−62.24***
Difference from	Islamic	−31.83	−36.32	−27.29*	−19.90	−0.42
Small Banks	*Large*	*−64.26***	−68.25**	*−47.08*	*−40.28**	−93.28***
	Islamic	*−56.90****	−63.22**	*−45.54***	*−42.78***	−31.47
$\sum_{j=0}^{4} \Delta LSM_{t-j}$	Small					0.20
	Large					0.87**
Difference from	Islamic					0.99
Small Banks	*Large*					0.67
	Islamic					0.79
$X_{it-1} * \sum_{j=0}^{4} \Delta LSM_{t-j}$	Small					−0.81
	Large					−5.17**
Difference from	Islamic					−4.35*
Small Banks	*Large*					−4.36
	Islamic					−3.54
Quarter Dummies, Trend		Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects		Yes	Yes	Yes	No	Yes
Bank Province Shares		No	No	No	Yes	No

(continued)

Table 8. (Continued)

B. Baseline Specification (1)						
(Sum of) Estimated Coefficients	**Bank Type**	***Lags: j = 0***	***j = 1***	***j = 2***	***j = 3***	***j = 4***
$\Delta\log(L_{it-j})$	Small		−0.05	0.23***	0.22***	−0.04
	Large		−0.03	−0.25***	−0.25***	0.33***
Difference from Small Banks	*Islamic*		−0.11	−0.01	−0.21***	0.04
ΔR_{t-j}	Small	−1.16	−3.86***	−0.03	−0.81	−1.31***
	Large	6.04***	8.59***	−2.67	0.58	1.69
Difference from Small Banks	*Islamic*	7.19**	1.55	−4.18*	6.39**	−1.72
$X_{it-1} * \Delta R_{t-j}$	Small	18.18**	5.57	−17.74	10.29***	8.76*
	Large	−32.94**	−42.13**	28.76	−11.52	−6.44
Difference from Small Banks	*Islamic*	−33.39**	−16.71	36.54**	−40.86**	−2.48

banks in the short run. Romer and Romer (1990), Bernanke and Blinder (1992), and Christiano, Eichenbaum and Evans (1996) also show that credit reacts sluggishly or initially even expands following a monetary tightening. In Pakistan this effect is also present due to the response of the large banks.

Islamic banks are equivalent to small banks in terms of asset size, and as Islamic banks use the conventional interest rate as a key benchmark, one can expect that the bank lending channel will also operate through Islamic banks. However, since Islamic banks were expanding during the sample period, their deposit growth may have been less affected by tight monetary policy. Also, their share of fixed deposits to total deposits is higher than that of conventional banks. Using panel data of bank deposits across all commercial banks in Pakistan, Khan (2010) also found that Islamic banks enjoy substantially higher deposit growth rates than other banks, including the crises period of 2008. Moreover, the liquidity position of Islamic banks makes them less susceptible to a change in the interest rate.

The results indeed show that the loan growth of Islamic banks is not affected by changes in the interest rate. The sum of the estimated coefficients equals 2.05, positive but not statistically significant. Similarly, the sum of the estimated coefficients on the interaction terms of bank liquidity and changes in the interest rate equals −31.83, negative and insignificant. In both cases, Islamic banks are statistically different from small banks—with an estimated difference that equals 9.22* for the changes in the interest rate and 56.90*** for the interaction term—but similar to the large banks.

As before, and to check the robustness of these estimates, we use Arellano and Bover (1995) in model (2), replace the three-month Treasury-bill rate with the KIBOR in model (3) and the six-month Treasury-bill rate (results not shown), and introduce bank province shares and the change in large-scale manufacturing in models (4) and (5). Results are mostly unaffected and show that even though Islamic banks are small (in terms of asset size), their response in lending to a monetary policy shock is similar to that of the large banks in the sample. We further test whether there is any significant difference in lending response of banks to contractionary and expansionary monetary policy. The unreported results show that the difference in banks' lending response to both phases of monetary policy is insignificant.

4.3 Robustness

Clienteles and their demand could still differ between bank types—i.e., small and large conventional and Islamic—in a way that is not identifiable by the strategy in Kashyap and Stein (2000). In table 9 we therefore "horserace" other bank characteristics capturing specific clientele demand with bank type. In particular, the following bank characteristics are introduced "side by side" with bank type dummies in all relevant terms in the baseline model (i.e., model (1) from table 8): (i) *Non-Performing Loans* (non-performing loans over total assets), (ii) *Non-Lending Business* (non-lending-based earning assets over total earning assets), (iii) *Non-Deposit Funding* (funding by other than deposits over total funding), (iv) *Lending Rate* (interest income on loans granted to the private sector over average loans granted to the private sector), (v) *ROA* (return on assets), and (vi) *Fixed Assets* (fixed assets over total assets). Results are mostly unaffected, suggesting that it is bank type per se and not clientele and/or other bank characteristics that determines our findings.

In addition to the six banks (out of forty) that are licensed by the Banking Policy and Regulation Department of the State Bank of Pakistan as (*shariah*-compliant) full-fledged Islamic banks, five large and eight small banks are licensed to operate Islamic branches as well as conventional ones. These so-called "mixed" banks actually keep two separate balance sheets for their conventional and Islamic branches, respectively. In table 10 we therefore also study the impact through the Islamic share (by assets) of the banks in panel A and through the Islamic branches of the large and small mixed banks (adding their conventional branches to the set of small and large conventional banks) in panel B. We again turn to the baseline model (i.e., model (1) from table 8) augmented by the respective additional variables.

In panel A of table 10, the results confirm our findings so far. Indeed, take the interaction terms of bank liquidity and changes in the interest rate for the pure conventional small banks. The estimated coefficient equals 25.16^{**}. For the (pure) Islamic small banks, the estimated coefficient then equals $25.16^{**} + (100 \times -0.61^{***}) = -35.84$, which is not different from the estimated coefficient for the pure conventional large banks, which equals -55.84^{***}.

In panel B the estimates on the coefficients for Islamic banks remain similar, even though now the benchmark category is

Table 9. Loan Growth, Across Bank Type: Baseline Specification Augmented with Additional Bank Characteristics

This table reports the sum of the estimated coefficients for baseline specifications with the dependent variable $\Delta\log(L_{it})$, which is the quarterly change in the logarithm of the total amount of the loans granted to the private sector by bank i in year:quarter t. The independent variables are $\Delta\log(L_{it-j})$, which are j lags of the dependent variable, ΔR_{t-j} is the quarterly change in the three-month Treasury-bill rate in year:quarter $t-j$, X_{it-1} is the liquid assets (i.e., cash and balances with the banks) over total assets of bank i in year:quarter t, and B_{it-1} is the additional bank characteristic which varies by column: Non-Performing Loans is the amount of non-performing loans over total assets, Non-Lending Business is the non-lending-based earning assets over total earning assets, Non-Deposit Funding is the funding other than deposits over total funding, the Lending Rate is the interest income on loans granted to the private-sector over average loans granted to the private sector, ROA is return on assets, and Fixed Assets is the fixed assets over total assets. The estimations use 756 bank year:quarter observations. Standard errors are heteroskedasticity consistent and clustered at the year:quarter level. *** denotes significance at 1 percent, ** significance at 5 percent, and * significance at 10 percent.

(Sum of) Estimated Coefficients	Additional Bank Characteristic/ Bank Type	Non-Performing Loans (1)	Non-Lending Business (2)	Non-Deposit Funding (3)	Lending Rate (4)	ROA (5)	Fixed Assets (6)
$\sum_{j=1}^{4}\Delta\log(L_{it-j})$	Small	0.33***	0.42***	0.32***	0.39***	0.39***	0.35***
	Large	0.15	0.14	0.15	0.08	0.20	0.16
	Islamic	0.05	0.15	0.10	0.06	0.06	0.13
Difference from Small Banks	*Large*	−0.18	−0.28*	−0.16	−0.31**	−0.19	−0.19
	Islamic	−0.28*	−0.27*	−0.22	−0.33**	−0.33*	−0.21
$\sum_{j=0}^{4}\Delta R_{t-j}$	Small	−8.03***	−8.62***	−10.65***	−5.04*	−6.61***	−6.27***
	Large	5.42	3.61	6.29	9.59*	5.05	8.07
	Islamic	2.03	−0.75	0.46	5.12	1.53	1.95
Difference from Small Banks	*Large*	13.45***	12.23***	16.94***	14.63***	11.66***	14.35***
	Islamic	10.06**	7.88	11.10**	10.15**	8.14	8.22**

(continued)

Table 9. (Continued)

(Sum of) Estimated Coefficients	Additional Bank Characteristic/ Bank Type	Non-Performing Loans (1)	Non-Lending Business (2)	Non-Deposit Funding (3)	Lending Rate (4)	ROA (5)	Fixed Assets (6)
$X_{it-1} * \sum_{j=0}^{4} \Delta R_{t-j}$	Small	28.42^{**}	78.69^{***}	44.89^{*}	17.75	20.89	24.22^{*}
	Large	−27.75	28.73	−36.58	−46.92	−23.03	−44.61
Difference from	Islamic	−32.33	33.73	−21.95	−39.13	−27.30	-29.42^{*}
Small Banks	*Large*	−56.17	−49.96	-81.46^{***}	-64.67^{**}	−43.92	-68.83^{**}
	Islamic	-60.75^{***}	-44.96^{*}	-66.83^{***}	-56.87^{***}	-48.19^{*}	-53.64^{***}
B_{it-1}		−0.07	0.00	-0.21^{***}	0.09	−0.25	−0.05
$B_{it-1} * X_{it-1} * \sum_{j=0}^{4} \Delta R_{t-j}$		−0.78	-1.79^{***}	−0.70	2.21	−10.03	1.18
$B_{it-1} * \sum_{j=0}^{4} \Delta R_{t-j}$		0.12^{*}	0.12	0.14^{**}	−0.62	1.27	−0.33
$B_{it-1} * X_{it-1}$		−0.87	1.54^{***}	0.41	−0.03	5.95	3.28
Quarter Dummies, Trend		Yes	Yes	Yes	Yes	Yes	Yes
Bank Fixed Effects		Yes	Yes	Yes	Yes	Yes	Yes

Table 10. Loan Growth, Across Bank Branch Type: Augmented Baseline

This table reports the sum of the estimated coefficients for a baseline specification with the dependent variable $\Delta \log(L_{it})$, which is the quarterly change in the logarithm of the total amount of the loans granted to the private sector by bank i in year:quarter t. The independent variables are $\Delta \log(L_{it-j})$, which are j lags of the dependent variable, ΔR_{t-j} is the quarterly change in the three-month Treasury-bill rate in year:quarter $t-j$, and X_{it-1} is the liquid assets (i.e., cash and balances with the banks) over total assets of bank i in year:quarter t. In panel A, we also perform an exercise where we use a continuous measure of Islamic share. For pure Islamic banks, the value "Islamic Share" is 100, for pure conventional banks this is 0, and for mixed banks the measure varies between 0 and 100. In panel B, we split the balance sheet of the thirteen mixed banks, five of which are large and eight of which are small, into their conventional and Islamic branches. The estimations therefore use 982 bank (branch type) year:quarter observations. Standard errors are heteroskedasticity consistent and clustered at the year: quarter level. *** denotes significance at 1 percent, ** significance at 5 percent, and * significance at 10 percent.

A. Baseline Specification Augmented by Islamic Share			
(Sum of) Estimated Coefficients	**Bank Type**	**Augmented Baseline**	
		Conventional	**Islamic Share**
$\sum_{j=1}^{4} \Delta \log(L_{it-j})$	Small Banks	0.36^{***}	0.003^{***}
	Large Banks	-0.06^{***}	-0.03
Difference from Small Conventional Banks	*Large Banks*	*-0.42^{***}*	
$\sum_{j=0}^{4} \Delta R_{t-j}$	Small Banks	-7.23^{***}	0.10^{**}
	Large Banks	11.73^{***}	-17.42^{***}
Difference from Small Conventional Banks	*Large Banks*	*18.96^{***}*	
$X_{it-1} * \sum_{j=0}^{4} \Delta R_{t-j}$	Small Banks	25.16^{**}	-0.61^{***}
	Large Banks	-55.84^{***}	113.60^{***}
Difference from Small Conventional Banks	*Large Banks*	*-81.00^{***}*	

(continued)

Table 10. (Continued)

B. Baseline Specification Augmented by Islamic Branches			
(Sum of) Estimated Coefficients	**Bank Type**	**Augmented Baseline**	
		Small	**Large**
$\sum_{j=1}^{4} \Delta \log(L_{it-j})$	Conventional Banks and Conventional Branches of Mixed Banks	0.35***	0.08
Difference from Small	Islamic Branches of Mixed Banks	−0.22	0.71***
Conventional Banks and	Islamic Banks	0.06	
Conventional Branches of Small Mixed Banks	*Conventional Banks and Conventional Branches of Mixed Banks*		−0.28**
	Islamic Branches of Mixed Banks	−0.58***	0.36*
	Islamic Banks	−0.29*	
$\sum_{j=0}^{4} \Delta R_{t-j}$	Conventional Banks and Conventional Branches of Mixed Banks	−6.43***	3.40*
Difference from Small	Islamic Branches of Mixed Banks	−3.91	0.11
Conventional Banks and	Islamic Banks	1.54	
Conventional Branches of Small Mixed Banks	*Conventional Banks and Conventional Branches of Mixed Banks*		9.83***
	Islamic Branches of Mixed Banks	2.52	6.54**
	Islamic Banks	7.96*	

(continued)

Table 10. (Continued)

B. Baseline Specification Augmented by Islamic Branches			
(Sum of) Estimated Coefficients	**Bank Type**	**Augmented Baseline**	
		Small	**Large**
$X_{it-1} * \sum_{j=0}^{4} \Delta R_{t-j}$	Conventional Banks and Conventional Branches of Mixed Banks	24.27*	−18.34
	Islamic Branches of Mixed Banks	1.82	21.38
	Islamic Banks	−29.56	
Difference from Small Conventional Banks and Conventional Branches of Small Mixed Banks	*Conventional Banks and Conventional Branches of Mixed Banks*		−42.61**
	Islamic Branches of Mixed Banks	−22.45	−2.89
	Islamic Banks	−53.83***	
Quarter Dummies, Trend		Yes	
Bank Fixed Effects		Yes	

somewhat altered (i.e., it no longer comprises the Islamic branches of the small mixed banks). The estimates on the coefficients of the Islamic branches of large mixed banks and the Islamic branches of small mixed banks, and their difference from the benchmark category of small conventional banks and conventional branches of small mixed banks, are also very interesting. The estimates suggest a similar though more muted reaction from Islamic branches (of mixed banks) than from Islamic banks, even though the estimates (and their differences from the benchmark category) are not always statistically significant. There is one mixed bank that is public; it is also small. So in unreported regressions we further split the Islamic branches of the small mixed banks into private and public but find no further differences.

Next we investigate the results for different levels of interest rates, i.e., to assess across bank type the existence of any nonlinearity in the impact of monetary conditions (e.g., Thoma 1994; Weise 1999). In table 11 we show the estimates for the baseline model ((1) in table 8) that also includes dummies for high and low Treasury-bill rates (above and below median). The table reports the sum of the estimated coefficients from this one specification in the first two adjacent columns, while the third column reports the difference and its statistical significance based on a Wald test of the High – Low = 0 equality restriction. The estimates suggest that there are statistically no differences in the reaction to monetary conditions for small banks between periods with high and low Treasury-bill rates. However, the differential impact of liquidity is stronger for these banks during the time of low interest rates than in the period of high interest rates. The potential explanation for this difference is that when the interest rates are low, the changes (increase) in interest rates are more consistent and higher than when interest rates are high. Also, reactions of the large Islamic banks in times of low interest rates are stronger than when interest rates are high.

Finally, we investigate the impact of monetary conditions on the interest rate charged by banks (lending rate). We calculate the lending rate as the interest income on loans granted to the private sector over average loans granted to the private sector. In table 12 we introduce (the quarterly change of) this new dependent variable in the baseline model (i.e., model (1) from table 8). Recall that in principle Islamic banks do not charge any interest, so for these banks

Table 11. Loan Growth, Across Bank Type: For the Baseline Regression Banks' Response at High and Low Level of the Policy Rate

This table reports the sum of the estimated coefficients for the baseline specification with the dependent variable $\Delta\log(L_{it})$, which is the quarterly change in the logarithm of the total amount of the loans granted to the private sector by bank i in year:quarter t. The specification also includes dummies for high and low Treasury-bill rates (above and below median). The table reports the sum of the estimated coefficients from this one specification in two adjacent columns. Column 3 reports the difference and its statistical significance based on a Wald test of the High – Low = 0 equality restriction. The independent variables are $\Delta\log(L_{it-j})$, which are j lags of the dependent variable, ΔR_{t-j} is the quarterly change in the three-month Treasury-bill rate in year:quarter $t-j$, and X_{it-1} is the liquid assets (i.e., cash and balances with the banks) over total assets of bank i in year:quarter t. The estimations use 756 bank year:quarter observations. Standard errors are heteroskedasticity consistent and clustered at the year:quarter level. *** denotes significance at 1 percent, ** significance at 5 percent, and * significance at 10 percent.

(Sum of) Estimated Coefficients	Bank Type	High Treasury-Bill Rate	Low Treasury-Bill Rate	Wald Test: High − Low = 0
$\sum_{j=1}^{4}\Delta\log(L_{it-j})$	Small	0.37***		
	Large	0.28*		
	Islamic	0.07		
Difference from Small Banks	*Large*	−0.10		
	Islamic	−0.30**		

(continued)

Table 11. (Continued)

(Sum of) Estimated Coefficients	**Bank Type**	**High Treasury-Bill Rate**	**Low Treasury-Bill Rate**	**Wald Test: High − Low = 0**
$\sum_{j=0}^{4} \Delta R_{t-j}$	Small	−8.52***	−8.53***	0.01
	Large	3.06	8.09**	−5.03***
Difference from Small Banks	Islamic	1.01	7.86	1.01*
	Large	11.58***	16.62***	−5.04***
	Islamic	9.53***	16.39***	−6.86***
$X_{it-1} * \sum_{j=0}^{4} \Delta R_{t-j}$	Small	18.73	29.02**	−10.29**
	Large	−19.25	−51.99*	32.74***
Difference from Small Banks	Islamic	−46.61**	−55.02**	8.41
	Large	−37.97	−81.01***	43.03***
	Islamic	−65.33***	−84.03***	18.70*
Quarter Dummies, Trend		Yes	Yes	Yes
Bank Fixed Effects		Yes	Yes	Yes

Table 12. Change in the Lending Rate, Across Bank Type

This table reports the sum of the estimated coefficients for the baseline specification with the alternative dependent variable $\Delta LRATE_{it}$, which is the quarterly change in the net interest income on loans granted to the private sector over total loans granted to the private sector by bank i in year:quarter t. The independent variables are $\Delta\log(LRATE_{it-j})$, which are j lags of the dependent variable, ΔR_{t-j} is the quarterly change in the three-month Treasury-bill rate in year:quarter $t-j$, X_{it-1} is the liquid assets (i.e., cash and balances with the banks) over total assets of bank i in year:quarter t, and B_{it-1} is the bank characteristics, which varies in each column and mentioned in the first row of the table. The estimations use 756 bank year:quarter observations. Standard errors are heteroskedasticity consistent and clustered at the year:quarter level. *** denotes significance at 1 percent, ** significance at 5 percent, and * significance at 10 percent.

(Sum of) Estimated Coefficients	**Bank Type**	**Without Liquidity Interaction**	**With Liquidity Interaction**
$\sum_{j=1}^{4}\Delta\log(LRATE_{it-j})$	Small	-1.69^{***}	-1.73^{***}
	Large	-2.04^{***}	-2.04^{***}
	Islamic	-1.50^{***}	-1.51^{***}
Difference from Small Banks	*Large*	-0.35	-0.31
	Islamic	0.19	0.22
$\sum_{j=0}^{4}\Delta R_{t-j}$	Small	1.02^{***}	0.95^{***}
	Large	1.40^{***}	1.53^{*}
	Islamic	1.38^{***}	1.75^{**}
Difference from Small Banks	*Large*	0.38	0.58
	Islamic	0.35^{**}	0.81
$X_{it-1} * \sum_{j=0}^{4}\Delta R_{t-j}$	Small		0.96
	Large		-2.01
	Islamic		-2.08
Difference from Small Banks	*Large*		-2.97
	Islamic		-3.04
Quarter Dummies, Trend		Yes	Yes
Bank Fixed Effects		Yes	Yes

the interest income is a markup which has to be calculated on the basis of all outstanding contracts (that may often have equity-like features). Despite the difficulties of the comparison involved, the estimates (though not always statistically significant) are consistent with those on the quantity side.

5. Conclusion

The fast growth of Islamic banking and finance across the world raises an important question to academics and policymakers alike: Will the transmission of monetary policy through the bank lending channel be altered when the Islamic segment of the banking sector becomes significantly larger? The bank lending channel importantly depends on the ability of the central bank to affect bank loan supply. For that it matters whether banks can or cannot attract (time) deposits perfectly elastically at interest rates outside the control of the central bank and whether they consider the loans granted and securities held in portfolio as perfect substitutes.

Islamic banks may, on the one hand, be unable or unwilling to issue wholesale time deposits at a fixed rate and may not consider their Islamic loans substitutable for any of the securities they would alternatively hold in their portfolio. This may make the transmission of monetary policy shocks through the Islamic segment of the banking sector more potent. On the other hand, Islamic banks singularly attract deposits and lend under interest-free arrangements, likely entered into for religious reasons by depositors and borrowers (Baele, Farooq, and Ongena 2012; Khan and Khanna 2012). These contractual and motivational features on both their liability and asset sides may allow Islamic banks to shield themselves from monetary policy shocks. Thus, in the end, whether Islamic banks transmit monetary policy differently than conventional banks is an empirical question, which we address in this paper.

We investigate the differences in banks' responses to monetary policy shocks across bank size, liquidity, and type—i.e., conventional versus Islamic—in Pakistan between 2002:Q2 and 2010:Q1. We find that following a monetary contraction, small banks with liquid balance sheets cut their lending less than other small banks. In contrast, large banks maintain their lending irrespective of their liquidity positions. Islamic banks, though similar in size to small banks, respond to monetary policy shocks like large banks. Hence the credit channel of monetary policy is likely to weaken when Islamic banking grows in relative importance, assuming of course that the characteristics of Islamic banks will not change as the sector grows larger.

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