International Trade Finance and the Cost Channel of Monetary Policy in Open Economies*

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This paper studies the role of international trade finance in the transmission mechanism of monetary policy in a two-country dynamic stochastic general equilibrium (DSGE) framework. The model shows that trade finance can both amplify or mitigate the impact of shocks, depending on the degree to which countries differ in price stickiness and dependence on trade finance. The model is estimated with Bayesian techniques using macroeconomic data from the United States and the euro zone and reveals the impact of trade finance to be quantitatively important, especially for spillover effects of shocks across countries. It significantly alters the interpretation of the sources and propagation of business cycles. In particular, accounting for trade finance makes external shocks much less important for business cycles in the euro area. At the same time, spillover effects of U.S. monetary policy on euro-area output are much larger.

JEL Codes: F44, F41, E44, E52.

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1. Introduction

While the literature on trade finance is extensive,[1] the implications of trade finance for business cycle fluctuations in macroeconomic models remain understudied. This omission is conspicuous given the fact that open-economy models that are commonly used for policy analysis and forecasting typically give a central role to international trade. Indeed, trade is the primary and in some cases the only channel through which shocks can be transmitted across countries in these models.[2] This paper studies business cycle implications of trade finance through the lens of an estimated two-country New Keynesian dynamic stochastic general equilibrium (DSGE) model.

The term "trade finance" is used in the literature to describe a number of different financing arrangements. These include direct lending by banks to the exporter and/or the importer, interfirm trade credit, open account (i.e., post-delivery payment), or cash in advance.[3] Recognizing that all these mechanisms involve at least one of the parties engaging in borrowing at an interest rate that is potentially affected by changes in monetary policy, trade finance in the paper is introduced by augmenting the cost channel of monetary policy. While there exists a sizable literature that studies different aspects of the cost channel of monetary policy, including extensions to open-economy settings (see, for instance, Gertler, Gilchrist, and Natalucci 2007 and Gilchrist 2003), these models do not distinguish between the external finance dependence of international and intranational trade, a distinction that the international trade literature has strongly emphasized. This paper models this distinction and shows that it is important not only quantitatively but also qualitatively in terms of the sign of the effects that the cost channel of monetary policy can generate.

[1] Bekaert and Hodrick (2017) identify trade finance as the "fundamental problem in international trade." According to the estimates of the Committee on the Global Financial System (CGFS), \$6.5–8 trillion worth of bank-intermediated trade finance was provided during the year 2011, which, at around 10 percent of global gross domestic product (GDP) and 30 percent of global trade, is a fairly sizable number in itself, even though it does not include letters of credit and other forms of trade finance not explicitly involving bank loans.

[2] See, for instance, Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2003).

[3] See Ahn, Amiti, and Weinstein (2011) and Schmidt-Eisenlohr (2013).

The standard cost channel of monetary policy typically amplifies the output effect of domestic shocks that hit the economy.[4] On the other hand, this paper shows that the cost channel when combined with trade finance can either amplify or mitigate the effects of shocks. Consider a monetary contraction in the home economy, which leads to a fall in domestic aggregate demand and prices. If importing firms are constrained to borrow at their respective home interest rates, then foreign imports into the home country become more expensive, whereas imports into the foreign country (i.e., home exports) become cheaper for foreign consumers, leading to a higher demand for the latter and a lower demand for the former. As a result, the trade finance plays the role of cushioning the effect of the original monetary contraction on home output. If on the other hand exporting firms (instead of importing firms) are financially constrained and borrow in their domestic interest rate, then the trade finance constraints can amplify the effect of the monetary contraction on home GDP in the example just described.

Elaborating on these points, the first part of the paper focuses on studying the impact of trade finance on the transmission mechanism of monetary policy shocks through simulations under alternate scenarios. It illustrates how the effect depends critically on parameters characterizing the trade sector in the model, including the degree of price stickiness (and asymmetry across countries in this parameter) and parameters quantifying the external finance dependence of trade flows. Various sources of this asymmetry are identified and their implications are explored. Moreover, because monetary policy has both an exogenous and endogenous component, these additional features not only affect the propagation of monetary policy shocks themselves but also the propagation of all other shocks via the endogenous component of monetary policy.

The general nature of the implications that emerge from the model can be summarized under two polar scenarios depending on whether the countries are symmetric with respect to each other in regard to their external sectors. External sectors could differ due to the degree of external finance dependence, price flexibility, and

[4] See, for instance, Barth and Ramey (2002).

currency denomination of trade finance contracts, all of which in turn could be functions of the nature of export bundles of countries. When the external sectors are symmetric across countries, incorporation of trade finance leads to sharp movements in trade volumes but has negligible impact on GDP. When global interest rates are high, international trade becomes more expensive, which leads to higher import prices for both countries. Both countries shift away from imports and towards their respective domestically produced goods in such a way that the net effect on the GDP of both countries is minimal. On the other hand, when countries are asymmetric in any of these dimensions, the demand shifts do not offset one another, and trade finance can significantly alter the response of GDP to various shocks that hit the economy.

Given that these parameters play a critical role in affecting business cycle fluctuations and for the most part extant literature is not very informative on their values, uncovering values of these parameters and relative differences across trading partners is likely to be a fruitful avenue for future research. The second part of the paper takes the first step in this direction by estimating a two-country DSGE model with trade finance using data from two regions that constitute one of the largest trading relationships in the world—the United States and the euro zone (EZ). The focus of the estimation exercise is threefold: (i) parameter estimation, (ii) model comparison, and (iii) a quantitative analysis of the role played by trade finance in business cycle fluctuations. Regarding parameter estimation, the estimates reveal asymmetries in the degree of price stickiness in imports between the United States and the European Union (EU). In particular, retail prices of U.S. imports are found to be more flexible than their European counterparts.

While open-economy macro models typically give a central role to international trade, by omitting trade finance they ignore an important feature of international trade which has been shown to be important in the trade literature. How significant is this omission, and should there be a move towards incorporating models involving trade finance? To this end, estimation of different versions of the model (in particular, ones with and without trade finance) provide strong evidence in favor of models incorporating trade finance and show that trade finance is indeed quantitatively important in accounting for business cycle fluctuations.

The model makes the simplifying assumption that exporters and importers are not allowed to switch between sources of funding in response to shocks. While there is an extensive literature documenting that firms' sources of funding are sticky, some recent studies focusing specifically on international trade finance have found that that exporters and importers do indeed change their sources of funding in response to shocks.[5] The implications of such switching are discussed below, while modeling optimal funding choice remains a fruitful avenue for future research.

The remainder of this paper is organized as follows. Section 2 begins with a brief literature review. Section 3 lays out the main features of the model and discusses the equilibrium conditions. Section 4 presents a calibration- and simulation-based exercise to illustrate different features of the model. Section 5 undertakes Bayesian estimation of the model, and section 6 concludes.

2. Related Literature

This paper is linked to several different strands in the literature at the intersection of macroeconomics, monetary economics, and international trade. The incorporation of credit constraints in this paper is motivated by the extensive empirical literature on trade finance and its link to monetary policy. This literature has documented—across countries and time—the higher reliance of international trade on external finance compared with intranational trade. Ju, Lin, and Wei (2013) employ a large bilateral sector-level trade data set for the years 1970–2000 to study the effect of monetary policy tightening on export behavior. They find that the sectors relying more on external finance are disproportionally largely affected by monetary tightening, and that the exporting behavior is affected more than domestic sales. Using monthly data on U.S. imports, Chor and Manova (2012) find that the United States imported less from countries with higher interest rates and tighter credit conditions. Using a panel of 91 countries from 1980 to 1997, Manova (2008) shows that equity market liberalizations are positively associated with higher exports. Manova, Wei, and Zhang (2011) report similar results using

[5]See, for instance, Antràs and Foley (2015), Demir and Javorcik (2018), and Garcia-Marin, Justel, and Schmidt-Eisenlohr (2019).

firm-level data from China. Based on survey data from Italian manufacturing firms, Minetti and Zhu (2011) report that credit rationing affects international sales more than domestic sales. Using a detailed matched firm-level data set for banks and firms in Japan, Amiti and Weinstein (2009) find that the health of the banking sector is much more influential in determining exporting behavior of firms compared with their domestic sales.

On the theoretical front, several explanations for this phenomenon have been explored in the literature. The most common explanation hinges on the fact that international shipments take more time than domestic shipments (both travel time and time taken for documentation and clearances),[6] which implies that producers have to incur costs of production much before revenues are obtained. Feenstra, Li, and Yu (2014) provide a theoretical model incorporating these ideas. International trade is also likely to be more intensive in external finance because of higher information asymmetries associated with cross-border transactions.

Recognizing the need for trade finance, there is also a growing literature on the optimal financing arrangement. In theoretical frameworks, Ahn (2014) and Schmidt-Eisenlohr (2013) study how the optimal financing arrangement depends on the financial market characteristics of both the source and the destination country. Ahn, Khandelwal, and Wei (2011), Hoefele, Schmidt-Eisenlohr, and Yu (2016), and Niepmann and Schmidt-Eisenlohr (2017) test the occurrences of different financing arrangements in the data against these theories and find the evidence to be broadly consistent. Custom data suggest that open account is the dominant financing form, with a share of around 80 percent of trade reported for Turkey, Chile, and Colombia in Ahn, Khandelwal, and Wei (2011) and Demir and Javorcik (2018).[7] For the United States, Antràs and Foley (2015) also find a large role for cash in advance when looking at the transaction-level data from a U.S. exporter of frozen and refrigerated food products.

[6]See Djankov, Freund, and Pham (2006) and Hummels and Schaur (2013).

[7]This share, although high, is still less than estimates of the share of open account in domestic transactions in advanced economies. Ellingsen, Jacobson, and von Schedvin (2016), for instance, find the open account share to be close to 100 percent for domestic transactions in Sweden.

An alternative to bank-intermediated trade finance is trade credit, or the direct extension of credit between buyers and suppliers. Although the two are substitutes and one would expect firms to turn from bank-intermediated trade finance to trade credits, the evidence supporting this hypothesis is mixed.[8]

In its exploration of the role of the cost channel of monetary policy in open-economy settings, the paper has several precedents in the closed-economy literature. Using industry-level data from the United States, Barth and Ramey (2002) provide compelling evidence in favor of the cost channel of monetary policy. Dedola and Lippi (2005) report similar conclusions based on a richer data set containing information on 21 manufacturing sectors from five OECD countries. Ravenna and Walsh (2006) highlight the presence of the cost channel on the basis of parameters estimates based on their estimation of the Phillips curve for the United States. They also provide a characterization of the optimal monetary policy problem in the presence of these cost side effects. In advanced economies monetary policy is primarily conducted via open market operations which affect the balance sheets of banks directly. If cost side effects of monetary policy are present, one would expect countries with bank-based systems to be more sensitive to monetary policy shocks. This is exactly what Cecchetti (1999) and Kashyap and Stein (1997) find. Moreover, based on joint BIS-IMF-OECD-World Bank statistics on external debt, Auboin (2007) documents that 80 percent of the providers of trade finance are private banks.[9]

The paper also builds on ideas developed in the literature on vertical specialization and multiple-stage production. Huang and Liu (2001, 2007) and Wong and Eng (2013) are among the many papers that have used these features to explain various empirical stylized facts that standard models have difficulty accounting for. This paper builds a model that would allow multiple-stage trade intermediation to act as an amplification mechanism for shocks due to borrowing constraints. Similar ideas incorporating liquidity constraints have

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[8]See Asmundson et al. (2011) and Choi and Kim (2005) as two examples of the mixed evidence.

[9]In the Lehman bankruptcy 6 of the 30 largest unsecured claims against Lehman were letters of credit.

been applied in a closed-economy setting by Bigio and La'O (2013) and Kalemli-Ozcan et al. (2013).

3. Model

The model in this paper builds on the framework used in Galí and Monacelli (2005) and Lubik and Schorfheide (2006), which in turn fit into the New Open Economy Macroeconomics (NOEM) paradigm of Obstfeld, Rogoff, and Wren-Lewis (1996).[10] In particular, it builds on Lubik and Schorfheide (2006) by modeling a cost channel of monetary policy and allowing for trade finance and multiple stages in production of exports. Apart from these features (which are limited to the import-export sector), the rest of the model is identical to Lubik and Schorfheide (2006).

The world economy is assumed to comprise two countries of equal size. Households have preferences over domestic and foreign goods and supply labor to firms. There are two sets of firms in each economy—production firms and trade firms. Prices are assumed to be sticky in both the domestic and import sector. The monetary authority uses the short-term nominal interest rate as its instrument. For brevity, only the home economy is described in detail below. The foreign economy is assumed to be isomorphic.

3.1 Households

The household side of the economy is characterized by a representative consumer with preferences over consumption and leisure given by the following utility function:

$$U(C_t^h, H_t^h, N_t^h) = \frac{1}{1-\sigma_c}\left(\frac{C_t^h - H_t^h}{A_t}\right)^{1-\sigma_c} - \frac{1}{1+\sigma_L} N_t^{h1+\sigma_L}. \quad (1)$$

Here C_t^h is consumption, N_t^h is the labor supply, and H_t^h $(=\chi C_{t-1}^h)$ is the habit stock going into period t. A_t is a nonstationary worldwide productivity shock which evolves according to

$$A_t = Z_t\left(\gamma A_{t-1}\right). \quad (2)$$

[10]See Lane (2001) for a survey of the NOEM literature.

Z_t is an exogenous component and γ denotes the trend growth rate of world productivity. Agents are thus assumed to derive utility from effective consumption relative to the level of global technology.[11] Preferences are characterized by internal habits.[12]

There is a constant elasticity of substitution (CES) aggregator for C_t^h:

$$C_t^h = \left[(1-\alpha)^{\frac{1}{\eta}}\left(C_t^{hh}\right)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}}\left(C_t^{fh}\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}. \tag{3}$$

Here C_t^{hh} and C_t^{fh} denote the home- and foreign-produced components in the consumption bundle of country h. η is the elasticity of substitution between domestic and foreign aggregates and α parameterizes the home bias in consumption. The associated price index, which is also the consumer price index (CPI) in the home country, is given by

$$P_t^{h,cpi} = \left[(1-\alpha)\left(P_t^{hh}\right)^{1-\eta} + \alpha\left(P_t^{fh}\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}, \tag{4}$$

where P_t^{hh} and P_t^{fh} denote the domestic and import price indexes for the home country. The bundles C_t^{hh} and C_t^{fh} in turn are CES aggregates combining different home- and foreign-produced varieties,

$$C_t^{hh} = \left[\int_j C_t^{hh}(j)^{\frac{\epsilon-1}{\epsilon}} dj\right]^{\frac{\epsilon}{\epsilon-1}}, C_t^{fh} = \left[\int_j C_t^{fh}(j)^{\frac{\epsilon-1}{\epsilon}} dj\right]^{\frac{\epsilon}{\epsilon-1}}, \tag{5}$$

where ϵ is the elasticity of substitution across different varieties produced in the same country.

The associated price indexes are as follows:

$$P_t^{hh} = \left[\int_j P_t^{hh}(j)^{1-\epsilon} dj\right]^{\frac{1}{1-\epsilon}}, P_t^{fh} = \left[\int_j P_t^{fh}(j)^{1-\epsilon} dj\right]^{\frac{1}{1-\epsilon}}. \tag{6}$$

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[11] This assumption is made to ensure that the model has a balanced growth path along which hours worked are stationary, as is the case in the data.

[12] With a representative agent, internal and external habit formulations yield almost identical dynamics. Using micro data, Ravina (2007) argues that the evidence in favor of internal habits is stronger than external habits.

$P_t^{hh}(i)$ and $P_t^{fh}(j)$ denote the prices paid by home consumers for imported varieties i and j, respectively. Markets are assumed to be complete, so that households can trade in a complete set of state-contingent securities in order to smooth consumption fluctuations. While the complete-markets assumption is a strong one, it is used extensively in the literature, and incomplete markets have been shown to generate only minor departures from the complete-markets benchmark (see, for instance, Schmitt-Grohé and Uribe 2003.)

In the presence of complete markets, the household budget constraint is as follows:

$$P_t^{h,cpi} C_t^h + \int_s \mu_{t,t+1}(s) D_{t+1}^h(s) \leq W_t^h N_t^h + D_t^h + T_t^h. \qquad (7)$$

D_{t+1} denotes the amount of state-contingent securities purchased by households at price $\mu_{t,t+1}(s)$ which yield one unit of nominal payoff at time $t+1$ if state s is realized. W_t is the nominal wage, and T_t denotes lump-sum transfers to households. These comprise net transfers from the government as well as dividends from firms and financial intermediaries.

Although as a simplification I model a cashless economy with no explicit mention of money, implicitly there is assumed to be a time-invariant one-to-one relationship between the nominal interest rate and money demand which the central bank can exploit to set the desired nominal interest rate by changing money supply.

As a further simplification, wages are assumed to be flexible and the monetary non-neutrality is induced solely via price stickiness. In a closed-economy setting, Smets and Wouters (2007) show that price stickiness is more important in explaining fluctuations in the U.S. data compared with wage stickiness. Wage stickiness is nevertheless introduced in standard models to provide a "cost-push shock." In this model, however, the working capital constraints on firms play that role. That said, the main results of the model are robust to the introduction of wage stickiness.[13]

[13] Appendix A extends the model with sticky wages. The main empirical results are unaffected by this extension. It is pertinent to note that the decision to ignore stickiness in wages is made explicitly based on its limited contribution to a model like the one that is being built here. There is strong evidence in favor of wage

The first-order conditions characterizing the household problem are as follows:

$$A_t\lambda_t^h = \left(\frac{(C_t^h - H_t^h)}{A_t}\right)^{-\sigma_c} - \chi\gamma\beta\mathbb{E}_t\left[\frac{A_t}{A_{t+1}}\left(\frac{(C_{t+1}^h - H_{t+1}^h)}{A_{t+1}}\right)^{-\sigma_c}\right] \tag{8}$$

$$(N_t^h)^{\sigma_L} = \lambda_t^h \frac{W_t^h}{P_t^{h,cpi}} \tag{9}$$

$$\beta\mathbb{E}_t\left[\frac{\lambda_{t+1}^h}{\lambda_t^h}\frac{P_t^{h,cpi}}{P_{t+1}^{h,cpi}}\right] = \frac{1}{R_t^h} = \mu_{t,t+1}. \tag{10}$$

λ_t^h is the Lagrange multiplier associated with the budget constraint, which also captures the marginal utility of consumption. Equation (8) is the standard Euler equation with internal habits in consumption. Equation (9) is the labor supply condition which equates the marginal disutility from work to the increase in income, and equation (10) gives the price of state-contingent bonds, which also equals the inverse of the equilibrium gross nominal interest rate. Note that equation (10) uses the assumption that the state-contingent bonds are denominated in the home currency. This is without loss of generality, and the corresponding equation for the foreign country is given by

$$\beta\mathbb{E}_t\left[\frac{\lambda_{t+1}^h}{\lambda_t^h}\frac{P_t^{f,cpi}}{P_{t+1}^{f,cpi}}\frac{E_t}{E_{t+1}}\right] = \frac{1}{R_t^f} = \mu_{t,t+1}. \tag{11}$$

E_t denotes the nominal exchange rate, i.e., the price of foreign currency in terms of home currency.[14] Equations (10) and (11) can

stickiness in the form of downward nominal rigidity, and this has first-order implications for open economies—see, for instance, Schmitt-Grohé and Uribe (2011). However, the solution technique used in this paper involves linearization around a deterministic steady state and is neither equipped to deal with large shocks nor with asymmetries like one-sided wage rigidity, so these considerations are beyond the scope of the present paper.

[14]Note that as defined here, an increase in the nominal exchange rate corresponds to a depreciation of the home currency.

be used to show that the uncovered interest rate parity condition holds up to a first order.

$$R_t^h = R_t^f \mathbb{E}_t \left(\frac{E_{t+1}}{E_t} \right) \tag{12}$$

3.2 Firms

The production side of the economy is characterized by a continuum of atomistic firms, each of which produces a differentiated product. Labor is the only input in production and the production function of the generic firm is given by[15]

$$Y_t^h(j) = A_t A_t^h N_t^h(j). \tag{13}$$

Here A_t is a common worldwide technology component and A_t^h is a country-specific stationary technology shock. Following Christiano, Eichenbaum, and Evans (2005), I assume that firms operate under a working capital constraint and are required to borrow funds at the nominal interest rate to pay a fraction of their wage bill.[16] The cost function of the firm is thus given by

$$\Xi_t^h(j) = R_{L,t}^h W_t^h Y_t^h(j), \tag{14}$$

where R_{Lt}^h is the firm's total interest rate factor. I assume that a fraction u_L^h of the wage bill has to be financed by intraperiod borrowing, which gives the following relationship defining the external financial dependence of goods-producing firms:

$$R_{L,t}^h = \left(u_L^h R_t^h + 1 - u_L^h \right). \tag{15}$$

[15]The model abstracts from capital mainly for simplicity. This assumption is not uncommon in the New Keynesian literature. Another reason for excluding capital is that the introduction of cost side effects of monetary policy on investment interferes with stability and model indeterminacy as emphasized by Aksoy, Basso, and Martinez (2012).

[16]This is a standard channel via which a cost channel for monetary policy can be introduced. See Barth and Ramey (2002) for intra-industry evidence on the cost channel and Ravenna and Walsh (2006) for a theoretical exploration and more empirical evidence.

$u_L^h = 0$ corresponds to the case with no working capital constraints, whereas $u_L^h = 1$ corresponds to the case that is considered in most papers that model the cost channel, including Christiano, Eichenbaum, and Evans (2005) and Ravenna and Walsh (2006).

The market structure is assumed to be monopolistically competitive. Each producer producing a distinct good faces an elasticity of demand ϵ. Prices are assumed to be sticky and pricing contracts are staggered according to the mechanism in Calvo (1983).[17] In each period each firm has the opportunity to reoptimize and set its price with probability $(1 - \theta_h)$. The firms that do not optimize their price are assumed to keep their price unchanged from the previous period.[18] Conditional on having the opportunity to reset its price in period t, firm j would reset its price in order to maximize a discounted value of its lifetime future expected profits conditional on the prices remaining the same. The associated maximization problem is given by

$$P_t^h(j)^* = Argmax\mathbb{E}_t \left[\sum_{k=0}^{\infty} (\theta^h)^k \Omega_{t,t+k} \left[P_t^h(j)^* Y_{t+k}^h(j) - \Xi_{t+k}^h(j) \right] \right], \tag{16}$$

where the demand function for each firm is as follows:

$$Y_t^h(j) = \left(\frac{P_t^h(j)^*}{P_t^h} \right)^{-\epsilon} Y_t^h. \tag{17}$$

[17]Alternatively, the more realistic quadratic adjustment costs as proposed in Rotemberg (1982) can be assumed. However, the model is solved by considering a first-order approximation around a deterministic steady state, and it can be shown that the dynamics implied by these two mechanisms are identical up to a first-order approximation. In particular, they both lead to the same Phillips curve derived below.

[18]Alternatively, one could allow for prices to be indexed to past inflation. As shown by Adolfson et al. (2007) and Smets and Wouters (2007), adding this assumption does not change much in terms of the fit of the model. This is also consistent with the single-equation estimates of Galí, Gertler, and López-Salido (2001).

The first-order conditions associated with this problem yield the following expression for the optimal price conditional on reoptimization:

$$P_t^h(j)^* = \mathbb{E}_t \left[\frac{\sum_{k=0}^{\infty} (\theta^h)^k \Omega_{t,t+k} \left(\frac{\epsilon}{\epsilon-1}\right) P_{t+k}^h MC_{t+k}^h Y_{t+k}^h}{\sum_{k=0}^{\infty} (\theta^h)^k \Omega_{t,t+k} Y_{t+k}^h} \right], \tag{18}$$

where $MC_t^h = \frac{R_L^h W_t^h}{A_t A_t^h P_t^h}$ denotes the real marginal cost facing each firm. The log-linearized version of equation (18) around the symmetric steady state reads[19]

$$p_t^h(j)^* = (1 - \beta\theta^h) \sum_{k=0}^{\infty} (\beta\theta^h)^k \mathbb{E}_t(mc_{t+k}^h). \tag{19}$$

This leads to the following forward-looking Phillips curve for PPI inflation:[20]

$$\pi_t^h = \beta \mathbb{E}_t \pi_{t+1}^h + \frac{(1-\beta\theta^h)(1-\theta^h)}{\theta^h} mc_t^h. \tag{20}$$

3.3 Import-Export Sector

In order to introduce a role for trade finance, an import-export sector characterized by the presence of trade firms is explicitly introduced in the model. This international trade sector, which is assumed to be credit constrained, generates a role for trade finance constraints to influence real variables in the economy in addition to incomplete pass-through. In particular, like the domestic firms, the trade firms too are assumed to be credit constrained and are required to borrow to pay for an exogenous (and time-invariant) fraction of their costs. For simplicity, I assume that the trade firms do not employ any labor.

Sequential trade and vertical fragmentation are key features in the trade data that have been successful in explaining many empirical stylized facts.[21] Following this literature, the import sector is

[19] Throughout the paper, lowercase letters are used to denote log-deviations from steady state, i.e., $x_t = logX_t - log(\bar{X})$.

[20] The derivation is standard; see, for instance. Galí (2009).

[21] See, for instance, Huang and Liu (2001, 2007) and Wong and Eng (2013).

assumed to be characterized by a sequence of firms that operate at different stages. Each firm has a production function which transforms the input into output one for one. Each firm however is credit constrained and is required to finance a part of its purchase by borrowing at the risk-free rate. Multiple processing stages in the import sector thus play the role of amplifying the cost effects of monetary policy.

Incorporating these features, the import-export sector is modeled as an n-stage sequential setup. At each stage k, a continuum of atomostic firms operate with the following production technology:

$$Y_{k,t}^{fh}(j) = Y_{k-1,t}^{fh}(j), k \in \{1, 2, \ldots, n\}, j \in (0, 1). \tag{21}$$

Note that for simplicity it is assumed that these firms neither employ labor, nor are they subject to productivity shocks as is the case with goods-producing firms. The cost function of each firm is given by

$$\varXi_{k,t}^{fh}(j) = R_t^{fh}(k) P_{k-1,t}^{fh}. \tag{22}$$

Similar to the goods-producing firms, R_t^{fh} is the gross interest factor which characterizes the external finance dependence of the sector. Moreover, in order to allow for incomplete pass-through of exchange rate into import prices, firms at the final stage (n) in the import-export sector are assumed to operate under monopolistic competition like the goods-producing firms. Under these assumptions, the real marginal cost of the import-export sector as a whole can be written as follows:

$$\varPhi_t^{fh} = \frac{E_t P_t^f R_t^{fh}}{P_t^{fh}}. \tag{23}$$

Here P_t^{fh} denotes the local currency price of foreign goods that are sold to home consumers. This real marginal cost term can also be interpreted as a law of one price gap. This gap comprises not only incomplete pass-through because of price stickiness but also an additional effect coming from trade finance, which implies that in this model there can be deviations from law of one price even in the absence of market power and flexible prices on the part of the importing firms.

The gross interest rate factor in equation (23) can be written as follows:

$$R_t^{fh} = \left[u^{fh} R_t^c + (1 - u^{fh})\right]^n, \tag{24}$$

where n is the number of processing stages and $0 < u^{fh} < 1$ is the fraction of the purchases that have to be financed by external borrowing at each stage.[22] R_t^c is the interest rate that is used in trade finance. It would be the home interest rate (R_t^f), the foreign interest rate R_t^f, or a convex combination of the two. While firms are allowed to split their borrowing across domestic and foreign sources, this split is assumed to be time invariant. While this simplifying assumption is potentially restrictive—as it does not allow for optimal choice of funding by firms in response to shocks—the fact that firm's sources of funding are sticky has been well documented in the literature.[23]

Log-linearizing equation (24) yields the following approximate relationship between the number of processing stages, external finance dependence in each stage, and the nominal interest rate:

$$r_t^{fh} \approx n u^{fh} r_t^h. \tag{25}$$

As is evident from equation (25), the impact of changes on nominal interest rate on trade finance depends on both the external finance dependence (u^{fh}) and the number of processing stages (n). The equation also makes it clear however that with this specification it is not possible to identify these two parameters separately in the data. Moreover, the relationship between the risk-free interest rate and the marginal cost of the retail sector may depend on other factors that are not modeled explicitly but may nevertheless play a role. Since the goal of the paper is to study the consequences of this relationship rather than its microfoundations, the model is parameterized in terms of an aggregate parameter (δ^{fh}) which can be understood as the elasticity of marginal cost of import retailers with respect to the risk-free rate, i.e.,

$$r_t^{fh} = \delta^{fh} r_t^h, \tag{26}$$

[22] For simplicity, this parameter is assumed to be independent of n as well as t.

[23] See, for instance, Degryse et al. (2019), Jiménez et al. (2012), and Khwaja and Mian (2008).

where $\delta^{fh} = f(n, u^{fh}, Z)$ is a function of n, u^{fh}, and other characteristics Z that are not explicitly modeled. Trade finance in the real world (both domestic and international) is operationalized in a number of different ways, including direct lending by banks to the exporter and/or the importer, interfirm trade credit, open account (i.e., post-delivery payment), or cash in advance.[24] To the extent that all these mechanisms involve at least one of the parties engaging in borrowing at an interest rate that is directly affected by changes in monetary policy (as captured by equation (26)), it is important to emphasize that even with this parsimonious specification of external finance dependence, the model is general enough to capture all the different trade finance arrangements.

Similar to the case of goods-producing firms, the optimal pricing decisions of the importing firms lead to the following forward-looking Phillips curve for import consumer prices:

$$\pi_t^{fh} = \beta E_t \pi_{t+1}^{fh} + \frac{(1-\beta\theta^{fh})(1-\theta^{fh})}{\theta^{fh}}\phi_t^{fh}. \tag{27}$$

As $\theta^{fh} \to 0$, we have the benchmark case of complete pass-through, with the difference from the standard model being that in addition to exchange rate pass-through, there is also "interest rate pass-through," a novel channel not considered in the literature so far.

For future reference, the CPI inflation in the home country is given by a weighted sum of π_t^{fh} and π_t^h. In particular,

$$\pi_t^{fh} = (1-\alpha)\pi_t^h + \alpha\pi_t^{fh}. \tag{28}$$

3.4 Government

There is a government which finances current expenditure by imposing lump-sum taxes on households. For simplicity, I do not allow for government borrowing or lending and all expenditures are financed based on current-period receipts. The government consumption good is assumed to follow the same aggregator as that for the households.

[24]See Ahn, Amiti, and Weinstein (2011) and Schmidt-Eisenlohr (2013).

The overall government spending process is stochastic and driven by persistent shocks.

$$g_t^h = \rho_g^h g_{t-1}^h + \epsilon_{gt}^h \tag{29}$$

Note that although neither the lump-sum tax nor the assumption of same consumption bundle for households and the government is realistic,[25] the sole aim for introducing the government in this model is to have a source for exogenous demand shocks.

3.5 Central Bank

The central bank is assumed to set interest rates according to a modified version of the Taylor rule postulated in Taylor (1993). In particular, I allow for interest rate smoothing and the possibility of nominal exchange rate stabilization in the central bank's reaction function.[26]

The central bank's reaction function is thus given by

$$i_t^h = \rho_R^h i_{t-1}^h + (1-\rho_R^h)\left[\phi_\pi^h \pi_t^h + \phi_y^h \triangle y_t^h + \phi_e^h \triangle e_t\right] + \epsilon_{rt}^h, \tag{30}$$

where i_t^h denotes the nominal interest rate ($R_t^h = 1 + i_t^h$), $\triangle y_t^h$ denotes the growth rate of output, and $\triangle e_t$ denotes the rate of (nominal) depreciation. ϵ_t^h is an idiosyncratic white-noise process to be interpreted as a monetary policy shock.

Finally, the model is closed by imposing the following market clearing condition for each firm in equilibrium:

$$Y_t^h(j) = C_t^{hh}(j) + G_t^{hh}(j) + G_t^{hf}(j) + C_t^{hf}(j) \forall j \in (0,1). \tag{31}$$

3.6 Terms of Trade and Real Exchange Rate

Terms of trade for a country is defined as the ratio of the price of domestically produced goods at home relative to the price of

[25] In particular, government consumption is likely to be concentrated towards nontradables and therefore exhibit a higher home bias than households. See Lane (2010) for a discussion of this point.

[26] The estimation allows for the responses of the central bank to nominal exchange rates to differ across the two countries. Backus et al. (2010) show that this asymmetry can go a long way in explaining the uncovered interest rate parity puzzle.

imported goods.[27] In particular, the terms of trade for the home country is defined as follows:

$$tot_t^h = \frac{P_t^h}{P_t^{fh}}. \tag{32}$$

Analogously, terms of trade for the foreign country is defined as

$$tot_t^f = \frac{P_t^f}{P_t^{hf}}. \tag{33}$$

Using equation (23) and its foreign-country counterpart along with (32) and (33) gives

$$\phi_t^{fh}\phi_t^{hf} = tot_t^h tot_t^f R_t^{fh} R_t^{hf}. \tag{34}$$

This equation shows that even under the assumption of perfect competition (so that $\phi_t^{hf} = \phi_t^{fh} = 1$), the home and foreign terms of trade do not equal each other (inversely). In this case, the law of one price gap still exists, but depends only on terms relating to international trade finance.

The real exchange rate (RER) between home and foreign currencies is defined in the standard way by weighting the nominal exchange rate by the ratio of the consumer price indexes in the two countries.

$$S_t = \frac{E_t P^{f,CPI}}{P^{h,CPI}} \tag{35}$$

As with the nominal exchange rate, the real exchange rate is defined in such a way that an increase corresponds to a depreciation of the home currency. Typically in open-economy models, the real exchange rate as defined above is used as a gauge of competitiveness, i.e., a falling RER denotes lower competitiveness of home goods and vice versa. As the next section shows, however, this interpretation of the RER can be flawed in the presence of frictions like trade finance constraints, and the terms of trade is more relevant as a measure of competitiveness.

[27]Note that typically terms of trade is defined as the ratio of the price of exports to imports. The distinction ceases to matter since most models typically have the feature that export prices are equal to domestic prices. This however is not the case in this model due to imperfect competition as well as trade finance.

3.7 Equilibrium and Solution Method

The equilibrium conditions characterized above along with the shock processes comprise a dynamic system with a unique nonstochastic steady state.[28] The model is solved by log-linearizing the equilibrium conditions characterizing the model around this nonstochastic steady state. In addition to the monetary policy, productivity, and government spending shocks, the model also features a shock to the labor supply equation and the nominal exchange rate process.

4. Calibration and Model Simulations

This section discusses simulation results based on a calibrated version of the model to outline the dynamics of the key model variables and how they are affected by the presence and degree of trade finance dependence in the wake of exogenous shocks. The model is calibrated to a symmetric two-country case with most parameter values picked from the previous literature—in particular, Lubik and Schorfheide (2006) and Smets and Wouters (2003, 2007)—but the values are kept the same for both home and foreign countries so as to illustrate the mechanics in the model more clearly.[29]

4.1 Calibration

Table 1 shows the values used in the calibration exercise. Although most of the values are standard, there are a couple of parameters that merit further discussion. The intratemporal elasticity of substitution between home and foreign goods is a parameter that, despite extensive empirical research, has failed to yield a consensus, leading to the "elasticity puzzle" (see Ruhl 2008). Typically, the elasticity estimates are found to fall with the level of aggregation, as documented in Disdier and Head (2008) and Hummels (1999). While

[28] All parameter restrictions required for uniqueness, including the Taylor principle proposed in Woodford and Walsh (2005), are imposed to allow a unique solution. In the estimation, priors are confined to the region so that the posterior distribution also continues to satisfy these constraints.

[29] These restrictions will be lifted in the empirical section and most parameters will be estimated without imposing these symmetry restrictions.

Table 1. Parameter Calibration for Simulation Exercises

θ^h	0.7	σ_c	2
θ^f	0.7	σ_L	2
θ^{hf}	**{0.1,0.7}**	h	0.7
θ^{fh}	**{0.1,0.7}**	η	1
ϕ_π	1.5	α	0.15
ϕ_y	0.5	β	0.99
ϕ_e	0	δ	**{0,2}**
ρ_R	0.7		

calibrated models typically rely on evidence from the trade literature and pick values greater than 1,[30] estimates based on macro data typically yield much lower values, most often less than 1.[31] Although this paper too finds estimates of elasticity to be small in line with the macro literature, these estimates could be susceptible to the downward aggregation bias discussed in Imbs and Méjean (2012), who show that when elasticities are heterogenous, aggregation leads to a downward bias. Indeed, the evidence on heterogeneity of elasticities is substantial, as documented in Broda and Weinstein (2006). The value chosen for the simulation results is $\eta = 1$. It is a compromise between the estimate obtained from the micro and macro literatures and is more in line with the latter.[32] The main mechanisms highlighted in this paper are not dependent on this choice.

The only asymmetries introduced in the calibration are in the external sectors in the two countries in order to study their interaction with trade finance constraints. The external sectors of the two countries can be asymmetric along several dimensions. Firstly, they could differ in the degree of their external finance dependence, i.e., $\delta^{fh} \neq \delta^{hf}$. As argued above, this implies that the asymmetry is either in the average external finance dependence per stage or in the

[30]See, for instance, Obstfeld and Rogoff (2005). For micro studies that typically yield values greater than 2, see Broda and Weinstein (2006), Feenstra (1994), and Soderbery (2010).

[31]See, for instance, Justiniano and Preston (2010) and Lubik and Schorfheide (2006).

[32]Recently, Drozd, Kolbin, and Nosal (2014) have shown how allowing for dynamic elasticities (i.e., different elasticity in the short versus long run) can help reconcile the business cycle and trade literatures.

number of stages involved in transporting the good from one country to another. For instance, Amiti and Weinstein (2011) find that external finance dependence is much higher for goods shipped by sea than for those shipped by air. Secondly, countries could differ in the degree of their import price pass-throughs, which could be a function of the nature of goods themselves. For instance, Peneva (2009) shows that prices of labor-intensive goods are stickier than those of capital-intensive goods. If countries export goods with substantially different factor intensities, this could lead to an asymmetry in import prices. Lastly, countries can also differ in the interest rate/currency that they are constrained to borrow in. The first two asymmetries are likely to be linked to differences in export bundles of countries. A country exporting high-end luxury products is likely to have lower competitiveness, higher markups, and hence lower price flexibility in its prices than a commodity-exporting country that exports a homogenous product. The third source of asymmetry, the currency denomination of debt, is likely to be an institutional feature that I assume is fixed in the short run.[33] The two parameters governing import price stickiness are varied in the simulations to show how they affect the propagation mechanism of shocks.

In order to determine plausible values for the external finance dependence parameters, I rely on two separate approaches, which yield similar ballpark estimates. Firstly, I consider the model's predication regarding the fall in trade-to-GDP ratios in response to a trade finance shock. Eaton et al. (2011) argue that about 80 percent of the 20–30 percent fall in trade-to-GDP ratio can be accounted for by demand-side effects and heterogeneity in traded versus nontraded goods. This leaves 20 percent of the collapse, or about 4–6 percent fall in trade-to-GDP ratios, unexplained. The first calibration strategy for δ involves matching this response of the trade-to-GDP ratio to an interest rate shock that is simulated in the model. Table 2 shows the peak response of trade-to-GDP ratios under different assumptions on elasticity of substitution and import

[33]A large fraction of international trade is conducted in U.S. dollars and hence the dollar is the primary currency not only for settling trade transactions but also in facilitating trade finance. However, local-currency debt in countries like Europe and Japan is also fairly likely—see, for instance, Amiti and Weinstein (2011) and Gopinath, Itskhoki, and Rigobon (2010).

Table 2. Peak Response of Trade-to-GDP Ratio to an Interest Rate Spread Shock of 300 Basis Points

$\boldsymbol{\eta = 2}$	$\boldsymbol{\delta = 2}$	$\boldsymbol{\delta = 4}$
$\theta^{hf} = \theta^{hf} = 0.1$ $\theta^{hf} = \theta^{hf} = 0.7$	−10.0366 −2.8278	−23.0467 −5.8697
$\boldsymbol{\eta = 0.5}$	$\boldsymbol{\delta = 2}$	$\boldsymbol{\delta = 4}$
$\theta^{hf} = \theta^{hf} = 0.1$ $\theta^{hf} = \theta^{hf} = 0.7$	−2.5092 −0.707	−5.7617 −1.467

price flexibility in the model. The size of the shock is 300 basis points, to roughly match the increase in the TED spread during the peak of the 2008 financial crisis. Since there is no consensus on the value of elasticity of substitution (although values closer to and even below 1 are typically preferred by the macro data), a value of δ around 2 seems to be a plausible (if somewhat conservative) value for this parameter. It generates a maximum response of –10 percent, which is on the higher side, but neither this elasticity ($\eta = 2$) nor this pass-through specification seems plausible and is rejected by the data below. Based on the rest of the numbers, it seems to be a conservative estimate, accounting for a decline of trade-to-GDP ratio of less than 3 percent, which is close to but below the 4–6 percent target.

As discussed above, the parameter δ captures not just external financial dependence of sectors but also the number of stages involved in the process from actual production to eventual consumption. The second calibration strategy leverages this interpretation by looking at average propagation lengths (APLs) in the data. The APL between A and B measures the number of stages it takes for the good produced in A to reach B. As an example, consider a world in which global trade comprises an upstream country (say Japan) exporting intermediate goods to a downstream country (say China) which in turn exports them to the consuming country (say the United States). In this simple example, the APL between Japan and the United States would be 2, while the APL between Japan and China would be 1.

More generally, APLs can be computed using input-output tables using the procedure outlined in Dietzenbacher and Romero (2007).

Table 3. Average Propagation Length: Summary Statistics for Benchmark Year 2007

A. Average Propagation Length (APL) Summary Statistics			
Country-Level APL		**Country-Sector-Level APL**	
No. of Countries	41	No. of Country-Sectors	1,435
Mean APL	2.8465	Mean APL	3.61
Median APL	2.7396	Median APL	3.62
Std. Dev.	0.5	Std. Dev.	0.9
B. APL for Select Country Pairs			
	United States	**Germany**	**China**
United States	1.70	2.85	3.65
Germany	2.83	1.62	3.54
China	3.42	3.53	2.48

Source: World Input Output Database (http://www.wiod.org) and author calculations.

Table 3 displays summary statistics for APLs computed at the country and country-sector level using detailed intercountry input-output data from the World Input-Output Database for the benchmark year 2007.[34] While the country-level APLs are likely to be biased downwards since they ignore within-country flows and the heterogeneity is substantial, the values in the range 2 to 5 seem to be reasonable based on these statistics, which are also in line with the range of plausible values obtained using the behavior of trade-to-GDP ratios.

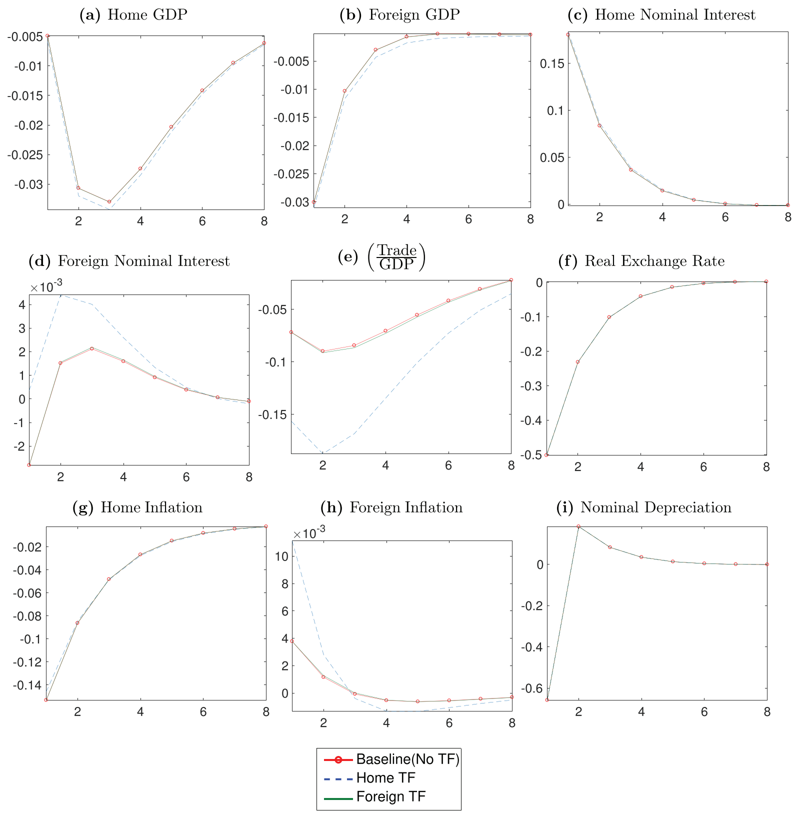
4.2 Model Simulations

Figure 1 shows the impulse response of key macroeconomic variables to a contractionary monetary policy shock (in the form of a 25 basis point increase in the nominal interest rate) in different versions of the model.[35] These versions differ only along one dimension—the

[34]See Timmer and Erumban (2012) for a detailed description of the database and Dietzenbacher and Romero (2007) for a detailed discussion of APL.

[35]The contractionary monetary shock corresponds to a surprise increase in the nominal interest rate due to a positive shock to ϵ_{rt}^{h} in equation (30). The instantaneous response of the nominal interest rate is less than 25 basis points (the size

Figure 1. Impulse Response to a Home Monetary Contraction: $\theta^{fh} = 0.7, \theta^{hf} = 0.7$



Notes: The impulse responses to a positive 25 basis point shock to the nominal interest rate are computed through simulations using the values in table 1. The horizontal axis measures time in quarters. The vertical axis units are deviations from the unshocked path. Inflation and nominal interest rate are given in annualized percentage points. The other variables are in percentages.

interest rate relevant for trade finance. The blue (dashed) lines correspond to the specification where all borrowing costs related to international trade finance are linked to the home policy rate, whereas the

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of the shock), due to the endogenous response of the nominal interest rate to the shock via the interest rate rule (see, for instance, Galí 2009, chapter 3).

green (solid) lines denote the opposite scenario in which borrowing costs are linked to the policy rate of the foreign economy. For comparison, red (solid with dots) lines corresponding to a model without trade finance are also shown.[36] The two economies are assumed to be symmetric in all dimensions, including the degree of price stickiness in the import sector ($\theta^{fh} = 0.7, \theta^{hf} = 0.7$).

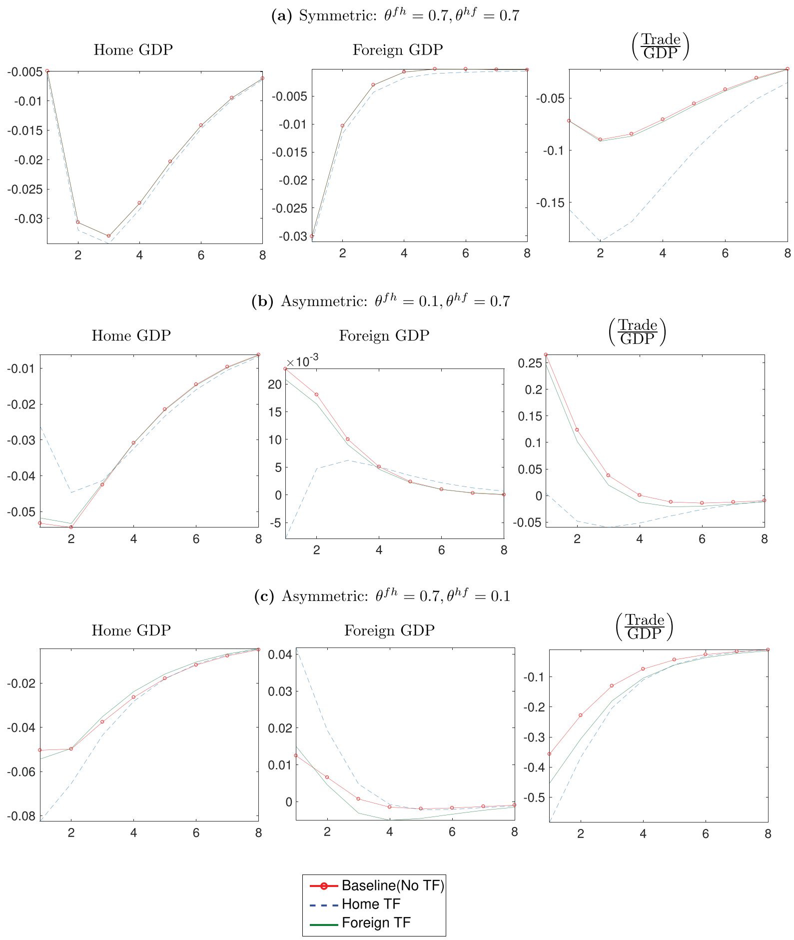
Compared with the model without trade finance, the model in which trade finance is tied to home monetary conditions displays a sharp fall in trade, as captured by the decline in trade-to-GDP ratio (blue dashed line).[37] This is a direct consequence of trade becoming more expensive due to a rise in borrowing costs that are linked to the home nominal interest rate. Interestingly, however, the response of both home and foreign GDP is virtually identical under the different models. This reflects the confluence of two effects brought about by the introduction of trade finance which offset one another. As trade becomes more expensive, consumers shift away from imports and towards domestically produced goods. While the former leads to a fall in aggregate demand due to a decline in demand for exports, the latter leads to a rise in aggregate demand due to increased demand for domestically produced goods by consumers in each country as they shift consumption away from imports. On net, these two effects offset each other, such that the impact of trade finance on the response of GDP to monetary shocks remains muted in both the home and the foreign economy.

As shown in figure 2, the symmetry across the two countries is important for this lack of impact of trade finance on GDP. Panel A shows the response of GDP and trade under symmetric price stickiness across countries ($\theta^{fh} = 0.7, \theta^{hf} = 0.7$), the same as in figure 1. Panel B shows how when home import prices are more flexible than foreign prices (a feature that is uncovered in the data in the following section), trade finance begins to significantly alter the impact of home and foreign GDP to home monetary shocks.

[36]For figures in color, see the online version of the paper, available at http://www.ijcb.org.

[37]The trade-to-GDP ratio is defined as the ratio of total trade divided by total GDP, both measured in nominal terms in a common currency.

Figure 2. Comparison of Impulse Responses to a Home Monetary Contraction under Different Price Stickiness Assumptions



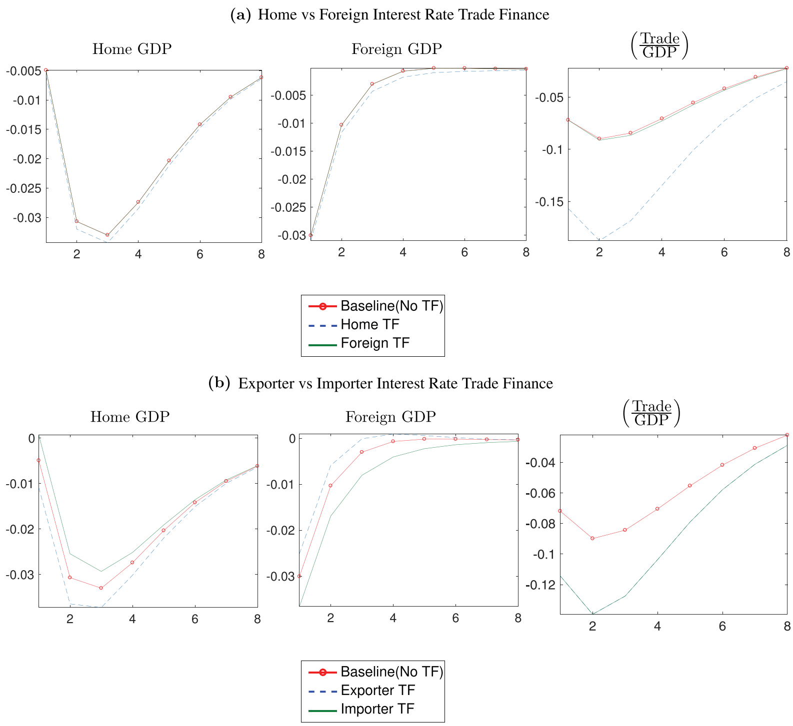
Notes: The impulse responses to a positive 25 basis point shock to the nominal interest rate are computed through simulations using the values in table 1. The horizontal axis measures time in quarters. The vertical axis units are percentage deviations from the unshocked path.

As before, the rise in home interest rates, which govern the borrowing costs for importers worldwide, leads to a sharp rise in the marginal costs of import firms. Since home import prices are more flexible, home importers pass on this rise to consumers in the form of higher import prices to a larger extent than foreign importers, whose retail prices are stickier. The net result is a sharp fall in the demand for imports in the home economy, which, unlike in the case of symmetric import price stickiness, is not matched by a corresponding fall in demand for home exports coming from the foreign country. Therefore, compared with the baseline model without trade finance, the model with trade finance generates a positive impact on home GDP (which consequently declines by less in response to the monetary shock) and a larger fall in GDP in the foreign economy.

The opposite is true if the price asymmetry is reversed such that the foreign retail price of imports is more flexible than home, as in panel C. In this case, in comparison with the baseline model in response to a home monetary shock, the introduction of trade finance has a positive impact on home GDP and a negative impact on foreign GDP.

Differences in the degree of price stickiness are just one source of asymmetry across countries (albeit an important one for which the following sections provide evidence). In principle, asymmetries in other dimensions can also break the offsetting effects that make trade finance constraints irrelevant as far as GDP is concerned. Panel B in figure 3 shows an example where price stickiness is the same across countries, but they differ in the interest rate that is used to finance international trade (panel A, for reference, is the same as in the previous two figures). The blue lines correspond to the model in which exporters are financially constrained and need to borrow working capital at a cost linked to the risk-free rate of the exporting country. In this case, when home interest rates rise as a consequence of the monetary contraction, foreign imports (home exports) become more expensive for consumers due to the higher borrowing costs of home exporters. This is not offset by a corresponding rise in the price of home imports, since marginal costs of foreign exporters, which are linked to the foreign risk-free rate, do not rise. As a result, compared with the baseline model without trade finance, home GDP falls more, and foreign GDP less, in response to a home monetary contraction. The opposite is true when importers who have working capital requirements that need to be financed at borrowing costs linked to their domestic risk-free rate (green lines).

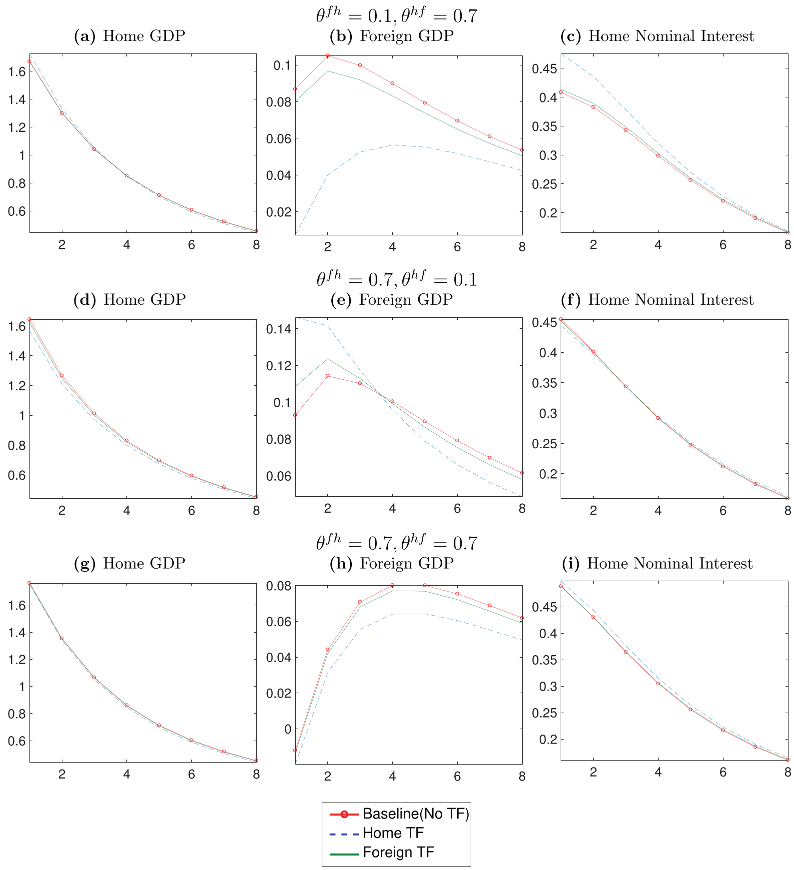
Figure 3. Comparison of Impulse Responses to a Home Monetary Contraction under Different Financing Arrangements



Notes: The impulse responses to a positive 25 basis point shock to the nominal interest rate are computed through simulations using the values in table 1. The price stickiness parameters are fixed at $\theta^{fh} = 0.7, \theta^{hf} = 0.7$ across all sets of simulations reported in this figure. The horizontal axis measures time in quarters. The vertical axis units are percentage deviations from the unshocked path.

To summarize, the main insight from simulation results is that when countries are completely symmetric in terms of their price stickiness and trade financing needs, the introduction of trade finance matters only as far as trade prices and total trade volumes are concerned, but offsetting effects imply that its impact on the response of home and foreign GDP is limited. On the other hand, when countries are asymmetric along any of these dimensions, trade finance exerts a significant influence on the response of home and foreign GDP to shocks.

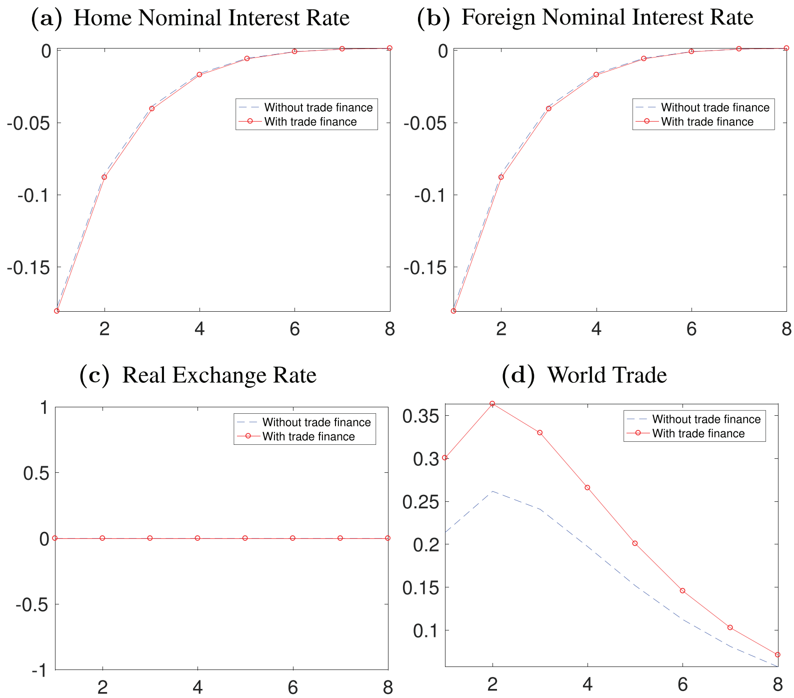
Figure 4. Home Government Spending Shock



Notes: Impulse response to a positive government spending shock in the home country. The vertical axis units are deviations from the unshocked path. Inflation and nominal interest rate are given in annualized percentage points. The other variables are in percentages.

It is important to emphasize that while the impact is most visible in the case of monetary shocks, to the extent that most other shocks generate an endogenous response of the risk-free rate in the economy, the impact of trade finance extends to all other business cycle shocks. Figure 4, for instance, illustrates this for a positive home government spending (demand) shock.

Figure 5. Competitive Devaluations and Trade



Notes: The figure shows impulse responses to a simultaneous interest rate cut by both central banks. The impulse responses are computed through simulations using the values in table 1 ($\theta^{fh} = 0.7, \theta^{hf} = 0.7$). The horizontal axis measures time in quarters. The vertical axis units are deviations from the unshocked path. Inflation and nominal interest rate are given in annualized percentage points. The other variables are in percentages.

4.3 Application: Impact of Competitive Devaluations on Trade

This section discusses the implications of trade finance for competitive devaluations. Figure 5 considers a competitive devaluation scenario in which both the home and the foreign central bank engage in simultaneous interest rate cuts of equal magnitude—a "competitive devaluation" or "currency war" scenario. Panels A and B indicate this action. As is evident from panel C, the actions of the two central banks cancel each other as far as the impact on the exchange rate is concerned and lead to no change in the real (or nominal) exchange rate. However, as shown in panel D, in a world where trade finance is important, the boost to international trade volumes is much more pronounced. While trade rises in both cases due to the increased aggregate demand in each country which also spills over into demand for imports, the fact that the financing constraints on importers and exporters are loosened in a world in which trade finance is present leads to the much sharper boost in trade. This finding is particularly relevant in an environment where trade conflicts are depressing the outlook for trade. These results show that to the extent that international trade policymakers care about trade over and above its impact on contemporaneous output,[38] even if devaluations are matched competitively by trade partners, the boost to exports can be substantially larger than that inferred from models that do not incorporate a role for trade finance.

5. Estimation

As is evident in section 4.2, the role of trade finance in business cycle fluctuations depends critically on parameters characterizing the export-import sectors of countries, and in particular on differences across the two countries. This section uses Bayesian techniques to estimate the model using macroeconomic time-series data from two large open economies—the United States and euro zone.[39] Following Smets and Wouters (2003) and others, a full-information likelihood-based estimation procedure is used.

5.1 Data

The model is matched to the data by treating the United States and euro zone as the two countries comprising the world economy. The sample period is 1983:Q1–2007:Q4.[40] Table 4 lists the variables used

[38]One reason why this may be so is because there is an extensive literature documenting the productivity gains from trade—see, for instance, De Loecker (2013).

[39]See appendix B for a brief description of Bayesian estimation and the model comparison exercise.

[40]Since the subsequent period has been characterized by zero and negative interest rates, the monetary policy stance is not well captured by the policy rate.

Table 4. Observables and Data Sources

Interest Rates	
R^{US}	Effective Federal Funds Rate
R^{EU}	Euro-Area Nominal Interest Rate
Prices	
$\pi^{US,CPI}$	CPI Inflation, US
$\pi^{US,GDP}$	GDP Deflator Inflation, US
$\pi^{EU,CPI}$	CPI Inflation, EU
$\pi^{EU,GDP}$	GDP Deflator Inflation, EU
Exchange Rate	
$\%\Delta E$	Nominal Depreciation Rate of U.S. Dollar against Euro[a]
Output	
ΔY^{US}	GDP Growth Rate, US
ΔY^{EU}	GDP Growth Rate, EU

[a]Before 2000, a GDP-weighted exchange rate is used from Lubik and Schorfheide (2006)'s publicly available database.

as observables in the estimation (a more detailed description along with data sources can be found in appendix E). These comprise short-term nominal interest rates, the euro-dollar nominal exchange rate, GDP growth rates, and various inflation rates for the two countries.[41] Compared with previous studies like Lubik and Schorfheide (2006) that have used only one measure of prices (namely the CPI inflation), both CPI- and GDP-deflator-based inflation measures are used. This is done in order to make the likelihood of the model more informative regarding the new features and parameters introduced in the model, and to sharpen the identification of domestic price stickiness parameters (θ^h and θ^f) on the one hand, and import price stickiness parameters (θ^{hf} and θ^{fh}) on the other. The U.S. data are taken from the Bureau of Economic Analysis, and the European data are taken from the European Central Bank's Area Wide Model (AWM) database. Prior to estimation, all the data are seasonally adjusted.

[41]Robustness checks also use bilateral trade as well as import price data, and the results are qualitatively similar.

Table 5. Classification of 11 Shocks Used in Benchmark Estimation

U.S. Shocks	Monetary Policy, Productivity, Government Spending, Labor Supply
EU Shocks	Monetary Policy, Productivity, Government Spending, Labor Supply
Common/Global Shocks	Productivity, UIP, Trade Finance

5.2 Shocks

The benchmark estimation allows for 11 shocks. As shown in table 5, the shocks can be classified into three broad categories: U.S. shocks, euro-area shocks, and common or global shocks.[42]

5.3 Priors

The first five columns of table 6 describe the priors used in the estimation prices. Most of the priors are based on priors and estimates from Lubik and Schorfheide (2006) and Smets and Wouters (2003, 2007). There are two parameters that quantify trade finance dependence which are new in the paper (δ^{hf} and δ^{fh}). The prior mean for these is set equal to 2, based on the calibration exercises in section 4. A fairly high standard deviation is allowed in the prior in order to reflect parameter uncertainty. For the elasticity of substitution (η), a prior of 1 is assumed as a compromise between the macro and micro evidence regarding the magnitude of this parameter as argued before.

5.4 Estimation Results

5.4.1 Parameter Estimates and Model Comparison

Tables 6 and 7 summarize the prior and posterior distribution of the estimated parameters for the model in which all trade is financed by

[42]The depreciation shock (also labeled “UIP shock”) is common in the literature and is needed to match the dynamics of the nominal exchange rate, which are not explained well by this class of models. This is a standard limitation of models of this type (see, for instance, De Walque, Smets, and Wouters 2005 and Lubik and Schorfheide 2006).

Table 6. Summary of Prior and Posterior Prior and Posterior Distribution of Estimated Parameters

Parameter	Description	Prior			Posterior		
		Distribution	Mean	Std. Dev.	Mean	90% C.I.	
θ^{US}	Calvo Domestic	Beta	0.7	0.05	0.837	0.8	0.874
$\theta^{\text{US Import}}$	Calvo Import	Beta	0.5	0.1	0.377	0.229	0.518
$\theta^{\text{EU Import}}$	Calvo Import	Beta	0.5	0.1	0.872	0.726	0.986
θ^{EU}	Calvo Domestic	Beta	0.7	0.05	0.75	0.695	0.807
σ_c	Intertemporal Consumption Elasticity	Gamma	1	0.25	4.512	3.309	5.751
σ_L	Labor Supply Elasticity	Gamma	2	0.5	1.541	0.966	2.092
h	Habit Parameter	Beta	0.5	0.1	0.547	0.395	0.697
η	Intratemporal Elasticity	Gamma	1	0.3	0.408	0.25	0.558
ϕ_π^{US}	Taylor-Rule Parameter	Gamma	1.5	0.25	1.926	1.591	2.232
ϕ_y^{US}	Taylor-Rule Parameter	Gamma	0.5	0.25	0.452	0.206	0.68
ϕ_e^{US}	Taylor-Rule Parameter	Gamma	0.1	0.05	0.031	0.01	0.051
ϕ_π^{EU}	Taylor-Rule Parameter	Gamma	1.5	0.25	1.862	1.524	2.219
ϕ_y^{EU}	Taylor-Rule Parameter	Gamma	0.5	0.25	0.546	0.246	0.845
ϕ_e^{EU}	Taylor-Rule Parameter	Gamma	0.1	0.05	0.03	0.008	0.05
ρ_A^{US}	U.S. TFP Persistence	Beta	0.8	0.1	0.996	0.992	0.999
ρ_R^{US}	U.S. Interest Rate Smoothing	Beta	0.5	0.2	0.821	0.789	0.856
ρ_G^{US}	U.S. Government Spending Persistence	Beta	0.8	0.1	0.963	0.941	0.985
ρ_A^{EU}	EU TFP Persistence	Beta	0.6	0.2	0.574	0.259	0.906
ρ_R^{EU}	EU Interest Rate Smoothing	Beta	0.5	0.2	0.867	0.843	0.892
ρ_G^{EU}	EU Government Spending Persistence	Beta	0.8	0.1	0.93	0.891	0.971
ρ_Z	Global Productivity Persistence	Beta	0.66	0.15	0.461	0.258	0.661
$\delta^{EU\rightarrow US}$	Trade Finance Parameter: US	Gamma	2	0.75	2.27	0.991	3.423
$\delta^{US\rightarrow EU}$	Trade Finance Parameter: US	Gamma	2	0.75	1.837	0.735	2.909
ρ_N^{US}	U.S. Labor Supply Shock Persistence	Beta	0.85	0.1	0.81	0.743	0.878
ρ_N^{EU}	EU Labor Supply Shock Persistence	Beta	0.85	0.1	0.894	0.849	0.939

Notes: The results are based on 200,000 MCMC draws (split across two chains) after burn-in with the posterior mode used as the starting value for each parameter. The list of observables is given in table 4.

Table 7. Summary of Priors and Posterior Distributions of Standard Deviations of Shocks

Shock	Prior Distribution	Mean	Std. Dev.	Posterior Mean	90% C.I.	
A^h	Invg.	1.253	0.655	1.167	0.873	1.463
G^h	Invg.	1.253	0.655	0.526	0.451	0.6
R^h	Invg.	0.501	0.262	0.161	0.139	0.183
A^f	Invg.	0.501	0.262	0.464	0.224	0.707
G^f	Invg.	1.253	0.655	0.502	0.432	0.569
R^f	Invg.	0.251	0.131	0.138	0.12	0.156
Z	Invg.	0.627	0.328	0.337	0.236	0.434
ΔE	Invg.	4.387	2.293	4.166	3.673	4.643
N^h	Invg.	0.101	0.262	1.563	1.355	1.755
N^f	Invg.	2	0.5	2.608	1.722	3.472

Notes: "Invg." denotes the inverse gamma distribution. The last two rows correspond to measurement errors of the corresponding observed variables. h denotes the home country (United States) and f denotes the foreign country (European Union).

borrowing at the U.S. interest rate. (This is the model that is most preferred by the data, i.e., has the highest Bayes factor, as will be discussed later.)

The posterior estimates of the price stickiness parameters imply that the data support a model in which there is asymmetry in the pass-through into import prices across the two countries. While the pass-through into EU import prices is quite low ($\theta^{\text{EU Import}}$ has a posterior mean of 0.87), the corresponding value for the United States is fairly high (posterior mean of $\theta^{\text{US Import}}$ is 0.38).

Given the importance of the import price stickiness parameters in driving the results of the model, table 8 reports additional robustness checks on the estimated values. It imposes priors that imply exactly the opposite price stickiness pattern to the one estimated in the data (table 6), and finds that the results are robust to this change in the priors.

These results are in line with estimates from Lubik and Schorfheide (2006), who also find evidence in favor of this asymmetry. Table 9 shows a comparison of the posterior means for the Calvo parameters from table 6. In their case this difference may also

Table 8. Alternate Priors for Import Price Stickiness

Parameter	Description	Prior			Posterior		
		Distribution	**Mean**	**Std. Dev.**	**Mean**	**90% C.I.**	
Benchmark Estimation (Table 6)							
$\theta^{\text{US Import}}$	Calvo Import	Beta	0.5	0.1	0.377	0.229	0.518
$\theta^{\text{EU Import}}$	Calvo Import	Beta	0.5	0.1	0.872	0.726	0.986
Estimation Results under Alternate Prices							
$\theta^{\text{US Import}}$	Calvo Import	Beta	0.9	0.15	0.336	0.160	0.523
$\theta^{\text{EU Import}}$	Calvo Import	Beta	0.1	0.15	0.963	0.927	0.997

Notes: The results are based on 200,000 MCMC draws (split across two chains) after burn-in with the posterior mode used as the starting value for each parameter. The list of observables is given in table 4.

Table 9. Comparison of Calvo Parameters with Lubik and Schorfheide (2006)

		Lubik and Schorfheide (2006)		
	Posterior Mean	**Posterior Mean**	**90% C.I.**	**Prior Month**
θ^{US}	0.83	0.62	[0.49, 0.77]	0.5
$\theta^{\text{US Import}}$	0.38	0.45	[0.17, 0.72]	0.5
$\theta^{\text{EU Import}}$	0.87	0.9	[0.82, 1.00]	0.75
θ^{EU}	0.75	0.61	[0.43, 0.81]	0.75

be partly driven by the choice of their prior distribution, which is asymmetric and implies higher price flexibility in the United States than in the EU for both domestic and import prices.[43] This paper on the other hand does not impose this asymmetry ex ante.

Notwithstanding the fact that the estimates of the price stickiness parameters are in line with the estimates of Lubik and Schorfheide (2006), at first sight they seem to be at odds with the extensive literature on pass-through into import prices which has found the pass-through (in particular, with regard to the nominal exchange rate) into U.S. import prices to be low, pointing to a very low import price flexibility for the United States.[44] Although a thorough exploration of this apparent discrepancy would require detailed examination of micro data and is beyond the scope of this paper, two possible explanations can be conjectured. Firstly, while the trade literature has focused for the most part on exchange rate pass-through, the asymmetry revealed here is with regard to pass-through of marginal costs into prices more generally, including other components of marginal costs apart from the nominal exchange rate. Secondly, while the trade literature has focused on import prices at the dock, the estimates in the model correspond to the retail price of imports. Understanding the journey of imports from the dock to eventual retail outlets, including the characteristics of the different

[43]They rely on Angeloni et al. (2006) and Bils and Klenow (2004) to impose a high prior mean for Europe and a lower one for the United States.

[44]See, for instance, Gopinath, Itskhoki, and Rigobon (2010).

markets and intermediaries involved, would be an important part of interpreting these findings.

With regard to δ, the other parameter which governs the strength of the trade finance channel, table 6 shows that the posterior means are 2.27 and 1.87 for $\delta^{EU \rightarrow US}$ and $\delta^{US \rightarrow EU}$, respectively. These are broadly in line with the calibrated values used in section 4.[45]

In terms of the reduced-form interpretation of equation (25), this estimate implies that the elasticity of the trade finance rate with respect to the risk-free rate is around 2, implying that a 1 percentage point increase in the risk-free rate leads to about a 2 percentage point increase in the total cost of trade finance. While the magnitudes are again roughly consistent with the average propagation lengths estimates in the data, the 90 percent interval includes values high enough to imply an inferred external finance dependence greater than 1. This suggests that there remains scope for alternative microfoundations of the parameter δ.

Table 10 reports the log marginal density for various specifications of the model that are estimated, along with the Bayes factor for each model in comparison with the model without trade finance. Assuming the prior probabilities to be the same across models, numbers in each column (i.e., estimates based on the same number of observables) can be interpreted as measures of the posterior odds ratios, with higher numbers (lower absolute values) indicating higher posterior odds for the corresponding model.[46] The last column reports Bayes factors computed with respect to the baseline model with no trade finance, which by construction has a Bayes factor of 1 with respect to itself. Bayes factors greater than 1 indicate that the respective model is more preferred by the data than the baseline model. According to Jeffreys (1998), a Bayes factor greater than 30 is "very strong " and a Bayes factor greater than 20 is "decisive" evidence.

The table shows that the models with trade financing with U.S. interest rates and importer interest rates carry the highest posterior probability and Bayes factors. The first of these is not surprising,

[45]Given the importance of the δ and θ parameters, appendix C presents some additional robustness checks on the estimates.

[46]Note that this comparison is valid as long as the prior is proper, which is the case throughout this paper.

Table 10. Marginal Likelihood for Different Models

Model	Marginal Data Density	Bayes Factor wrt No Trade Finance
1 No Trade Finance	−1236.04	1
2 Trade Finance: Both Interest Rates	−1233.71	10
3 U.S. Interest Rate Trade Finance	−1227.37	5,825
4 EU Interest Rate Trade Finance	−1236.15	0.9
5 Importer Interest Rate Trade Finance	−1227.42	5,541
6 Exporter Interest Rate Trade Finance	−1232.34	40

Note: The second model, "Trade Finance: Both Interest Rates," allows for trade finance to be dependent on both home and foreign interest rates.

given the central role that U.S. monetary policy plays in the global economy and given the fact that the dollar is also the primary vehicle currency in which international trade is conducted.[47] The higher posterior marginal data density of the model with importer interest rate trade finance on the other hand is less easier to motivate, given that the majority of the empirical literature in trade finance has documented the link between exporter monetary policy and volume of exports. However, a close examination of the arguments given for these apply equally to the link between imports and interest rates as well. In fact, in his empirical analysis Schmidt-Eisenlohr (2013) finds the role of importer interest rate to be as important as the exporter one.

What these results indicate in conjunction is that in the data, the trade finance channel seems to be governed by the interaction of U.S. interest rates with U.S. imports. Since European imports play a limited role due to their low price flexibility, the models with U.S. interest rate and importer interest rate financing both seem to be consistent, and the data are not clearly able to distinguish between the two.

[47]For evidence regarding the latter, see Goldberg and Tille (2008).

5.4.2 Variance Decompositions[48]

The simulation results in section 4 show that incorporation of trade finance has a disproportionately large effect on the spillover effects of shocks, as opposed to the effect on the domestic economy. This raises a queston of how much the proposed model fundamentally changes our understanding of the importance of U.S. shocks for euro-area business cycles. Table 11 provides a comparison of the variance decomposition of euro-area variables at two horizons for two categories of shocks according to the classification in table 5—domestic U.S. shocks and all external shocks which include U.S. shocks and the global shocks in table 5. The numbers in the table denote the difference between the share (out of 1) of the variance of the row variable explained by the model with trade finance and the one without. Positive numbers therefore convey that U.S. and external shocks are more important in the model with trade finance for the particular variable, whereas negative numbers indicate the opposite.[49]

The differences in the long-run variance decomposition (horizon = ∞) are unanimous in suggesting that ignoring trade finance overstates the importance of U.S. shocks as well as external shocks more generally for the euro area. Indeed, the differences are negative for all the euro-area variables. The results are less clear-cut in the case of short-run variance decompositions (horizon = one quarter), where the model with trade finance does give a higher weight to external shocks for most euro-area quantity variables such as output, consumption, and imports, but not to price variables such as inflation and the real exchange rate.

To summarize, the model with trade finance suggests that while external shocks are more important in explaining the short-run variance of some variables such as output and consumption, overall, external shocks including U.S. domestic shocks are much less

[48] Appendix D provides additional comparisons between the model with and without trade finance based on posterior predictive moments.

[49] For example, the number corresponding to the row "Imported Inflation" and column "Domestic U.S. Shocks" under the "Horizon = ∞" panel shows that for euro-area imported inflation, domestic U.S. shocks account for 0.46 (out of 1) more variance according to the model without trade finance, compared with the one with trade finance, i.e., for example, if in the model without trade finance, U.S. shocks account for 0.8 (or 80 percent) of the variance of euro-area import inflation, they account for only only 0.34 (or 34 percent) of the variance in the model with trade finance.

Table 11. Variance Decomposition for Euro Area: Difference between Models with and without Trade Finance

	Domestic U.S. Shocks	All External Shocks	Domestic U.S. Shocks	All External Shocks
Variable (Euro Area)	**Horizon = ∞**		**Horizon = 1**	
GDP	−0.001	−0.001	0.00	0.114
Inflation	−0.006	−0.478	−0.003	−0.161
Imported Inflation	−0.009	−0.416	−0.008	−0.12
Consumption	−0.006	−0.006	−0.019	0.408
Nominal Interest Rate	−0.037	−0.046	−0.004	−0.004
Imports	−0.459	−0.456	−0.562	0.141
Exports	−0.017	−0.018	−0.115	−0.009
Terms of Trade	−0.1	−0.1	−0.196	−0.19
Real Exchange Rate	−0.11	−0.114	−0.232	−0.36
Nominal Depreciation	−0.013	−0.11	−0.016	−0.095

Notes: The numbers in the table denote the difference between the share of the variance of the row variable explained by the model with trade finance and the one without. Positive numbers therefore convey that the model with trade finance explains a higher share of the variance of the variable, whereas negative numbers indicate the opposite.

important for euro-area business cycles. This is an important takeaway for policymakers, as the role of external versus domestic shocks in driving business cycle fluctuations has different implications for their policy frameworks.

5.4.3 Comparison to an Atheoretical Benchmark: DSGE-VAR

This section uses the DSGE-VAR approach to assess the fit of the model with respect to an atheoretical benchmark—an unrestricted VAR.[50]

The approach exploits the fact that estimating a DSGE model is akin to estimating a VAR with cross-equation restrictions, and allows for the extent to which the restrictions can be imposed or relaxed. In particular, there is a hyperparameter $\lambda \geq 0$ such that the DSGE model restrictions are strictly imposed if $\lambda = \infty$, whereas the restrictions are completely ignored if $\lambda = 0$. Estimation of the VAR uses a prior that is centered at the DSGE-model-implied restrictions. The hyperparameter λ scales the covariance matrix of the prior. If it is large, most of the variance is centered around the DSGE model. The prior is combined with the likelihood to obtain the posterior of λ.[51]

Table 12 summarizes the estimation results for λ. The fact that the posterior of λ shifts towards zero compared with the prior indicates that some of the restrictions in the model are at odds with the data. This is in line with the results obtained in Lubik and Schorfheide (2006) and Smets and Wouters (2003), and highlights that estimated DSGE models are typically worse than some VAR specifications. That said, the posterior of λ, as well as the marginal likelihood, is higher in the case of the model with trade finance than without. This suggests that even when evaluated against an atheoretical benchmark like an unconditional VAR, the model with trade finance continues to provide a better fit to the data, and the data relaxes less of its cross-equation restrictions compared with the model that lacks a role for trade finance.

[50] For a detailed description of the procedure see, for instance, Del Negro et al. (2007) and Del Negro and Schorfheide (2004, 2006).

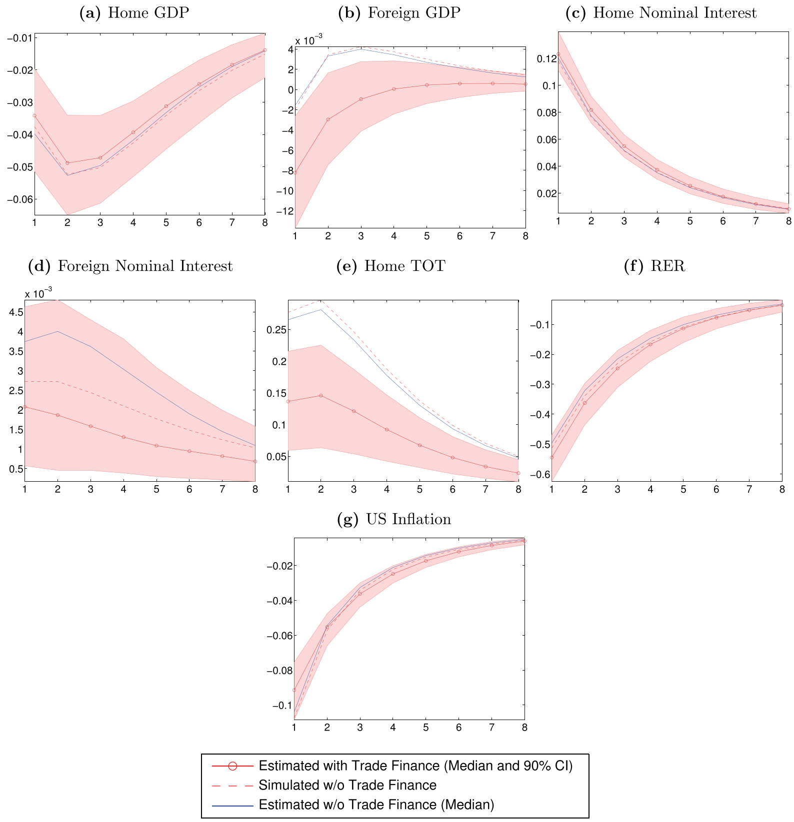
[51] The parameters of the DSGE model are also estimated simultaneously in the procedure by projecting the parameters of the estimated VAR back onto the DSGE parameter space.

Table 12. Comparison of the Fit of the Estimated DSGE Model with Unrestricted VAR

Prior and Posterior for DSGE-VAR Hyperparameter λ				
		Posterior		
Model	**Prior (Mean = 1)**	**Mean**	**90% C.I.**	**Marginal Likelihood**
Without Trade Finance	Uniform [0,2]	0.589	[0.560, 0.615]	−1,799.3
With Trade Finance	Uniform [0,2]	0.661	[0.619, 0.706]	−1,732.9

Notes: The table summarizes the prior and the posterior means of the DSGE-VAR hyperparameter λ which quantifies the extent to which the restrictions of the DSGE model are rejected by the data. The model is estimated with four lags using the nine observables in table 4. See Del Negro and Schorfheide (2006) for a description of the DSGE-VAR procedure.

Figure 6. U.S. Monetary Contraction



Note: Baseline model (dotted line) assumes U.S. interest rate trade finance.

5.4.4 Comparison of Shock Propagation Mechanism across Estimated Versions of the Model

This section illustrates the differences in propagation mechanisms using estimated impulse responses from the model. Figure 6 shows the impulse response of a one-standard-deviation U.S. monetary contraction (median and 90 percent confidence bands) using the estimated model with U.S. trade finance (the model with the higher posterior probability than the standard model). For comparison, the figure also shows two impulse responses corresponding to the standard model. One of these (labeled "Estimated w/o Trade

Finance (Median)") corresponds to the estimated model without trade finance constraints, and the second (labeled "Simulated w/o Trade Finance") corresponds to the impulse response from the simulated model with all parameters at the posterior mean from the model with trade finance constraints except the trade finance dependence parameters themselves, which are set to zero. These are two alternate ways of comparing the results with the estimated model with trade finance. Qualitatively, the results in figure 6 are broadly in line with the simulation results. Quantitatively, the figure shows that while the models generate similar predications for the response of domestic GDP, they differ appreciably in the response of foreign GDP and terms of trade.

One implication of this is that for a large open economy like the United States whose business cycle fluctuations are mostly driven by domestic shocks, excluding trade finance from models might be an innocuous omission. On the other hand, if the object of interest is to study spillover effects from foreign shocks (as would typically be the case for a small open economy), ignoring trade finance constraints can lead to severe misrepresentation of the important transmission channels in the model. This is due to the fact that trade finance exerts its influence on shock propagation by affecting terms of trade, which translates into changes in trade volumes. As far as the domestic economy is concerned, it is therefore best seen as an additional channel, while the main effects of the shock are likely to come from the direct domestic impact of shock. On the other hand, as far as the foreign economy and spillover effects are concerned, the entire effect of the domestic shock is transmitted through the external sector, which in turn is affected by trade finance. As a result, incorporation of trade finance matters more for spillover effects of shocks as opposed to domestic effects.

6. Conclusion

An extensive literature in international trade has documented the heavy reliance of international trade flows on external finance and has shown that external financing matters more for international trade as opposed to intranational trade. This paper assesses how this feature affects aggregate business cycle fluctuations and the transmission mechanism of monetary policy. It does so by modeling the link between trade finance and the cost channel of monetary policy in a two-country New Keynesian model. Unlike the domestic component of the cost channel of monetary policy which has been studied extensively in the literature, the paper shows that the cost channel when combined with trade finance has much richer implications for business cycles, both qualitatively and quantitatively. More specifically, it shows that when external sectors are symmetric across countries, trade finance constraints lead to sharp movements in trade prices and volumes, but do not significantly alter the response of GDP to shocks in either the home country or abroad, due to offsetting effects. On the other hand, if external sectors are asymmetric, trade finance constraints significantly change the response of GDP to both monetary and nonmonetary shocks. The paper identifies various sources of such asymmetry (including differences in import price flexibility) and studies their implications. The parameter estimates provide compelling evidence for asymmetry in import price flexibility across the two countries. In particular, U.S. retail import prices are found to be more flexible than their European counterpart.

Using Bayesian techniques, the paper estimates a two-country DSGE model with macroeconomic time-series data from the United States and the euro zone, two regions which share one of the largest bilateral trade relationships in the world. Based on model comparison exercises, models that appropriately incorporate trade finance constraints are shown to be preferred by the data. Furthermore, trade finance is found to have a larger impact on spillover effects of shocks rather than the effects on the country of origin. For example, euro-zone output contracts sharply in response to U.S. monetary contractions once the model is allowed to appropriately account for the trade finance channel, while the impact is indistinguishable from zero in the model without trade finance. In addition, appropriately accounting for trade finance in the model significantly reduces the importance of external (including domestic U.S.) shocks for euro-area business cycles. This is an important takeaway for policymakers, as the role of external versus domestic shocks in driving business cycle fluctuations has different implications for their policy frameworks. These results also carry important implications for the theory of competitive devaluations. By relaxing financing constraints on exporters and importers worldwide, devaluations are likely to boost trade volumes even more strongly than inferred by standard models.

An important limitation of this paper that future research warrants addressing is with respect to the rigidity in modeling the choice of trade finance by firms. Firms in the model are not allowed to switch between sources of funding in response to shocks. While this assumption is well grounded in the large body of empirical work documenting the stickiness in firms' funding sources (Degryse et al. 2019, Jiménez et al. 2012, and Khwaja and Mian 2008), and may be justifiable for the sample period considered in the paper which coincides with the great moderation period when the shocks hitting the economy were not too large, an extension of the model to endogenize firms' funding choices is bound to provide a more comprehensive understanding of the role of trade finance for business cycle fluctuations.[52] If firms could switch instantaneously, completely, and costlessly from one funding source to another, then the impact of trade finance on business cycles could be mitigated. The mitigation would be particularly pronounced, and may even lead to a rise in trade, if the interest rates of the two countries move in opposite directions in response to a shock, since in that case exporters and importers would benefit from a decrease in the cost of financing by switching to the lower interest rate. The fact that the data overwhelmingly find a role for trade finance is indicative that while firms may switch between funding sources, it may not be reasonable to assume that this switch is instantaneous and costless.

Appendix A. Model with Sticky Wages

The household problem is to maximize utility given by

$$\max \sum_{j=0}^{\infty} (\beta\theta_w^h)^j E_t(U_{t+j}(C_{t+j}, H_{t+j}, N_{t+j}(h)) \tag{A.1}$$

subject to the per-period budget constraint given by

$$P_t^{cpi} C_t + \int_s \mu_{t,t+1}(s) D_{t+1}(s) \leq W_t N_t + D_t + T_t \tag{A.2}$$

[52]Indeed, recent empirical work looking specifically at exporting firms has found that many of them do in fact switch sources of funding in response to shocks—see, for instance, Antràs and Foley (2015), Demir and Javorcik (2018) and Garcia-Marin, Justel, and Schmidt-Eisenlohr (2019).

and the labor demand schedule given by

$$N_t(j) = \left(\frac{W_t(j)}{W_t^h}\right)^{-\eta} N_t \forall t. \quad \text{(A.3)}$$

Here $(1 - \theta_w)$ denotes the time-invariant probability of re-adjusting wages in a given period.

The first-order condition implies the following expression for the wage negotiated by households who optimize in a given period:

$$W_t^* = \frac{\sum_j (\beta\theta_w)^j E_t \left(N_{t+j}(h) U_N(t+j)\right)}{\sum_j (\beta\theta_w)^j E_t \left(N_{t+j}(h) U_C(t+j) \left(\frac{\eta-1}{\eta}\right) \frac{1}{p_{c,t+j}}\right)}, \quad \text{(A.4)}$$

which linearizes to

$$\hat{w_t^*} = (\beta\theta_w) E_t(\hat{w_{t+1}^*}) + (1 - \beta\theta_w)\left(\hat{U_N}(t) - \hat{U_c}(t) + \hat{p_c}(t)\right). \quad \text{(A.5)}$$

The aggregate wage evolves according to the following equation:

$$\hat{w}_t = (1 - \theta_w)\hat{w_t^*} + \theta_w \hat{w}_{t-1}. \quad \text{(A.6)}$$

Combining (A.5) and (A.6), we can write the Phillips-curve analogue of real wage inflation as follows:

$$\hat{w}_t = \frac{\beta\theta_w}{1 + \beta\theta_w^2} E_t \hat{w}_{t+1} + \frac{\theta_w}{1 + \beta\theta_w^2} \hat{w}_{t-1} + \frac{(1 - \beta\theta_w)(1 - \theta_w)}{1 + \beta\theta_w^2} (\hat{U_N}(t) - \hat{U_c}(t) + \hat{p_c}(t)).$$

Appendix B. Bayesian Estimation Preliminaries

Let $\mathbb{M}$ denote a generic model and let $\theta_{\mathbb{M}}$ be the vector of parameters associated with it. Let $\mathbb{Y}$ denote the data that is used to estimate the model (note that $\mathbb{Y}$ does not have an $\mathbb{M}$ subscript, i.e., it is assumed that the data used is the estimation routine is constant across models). Bayesian estimation proceeds by specifying a prior distribution over $\theta_{\mathbb{M}}$ which is denoted here by $\mathbb{P}(\mathbb{M}, \theta_{\mathbb{M}})$. The prior is then combined with the likelihood computed using the data to form the posterior distribution of parameters as follows:

$$\mathbb{P}(\theta_{\mathbb{M}}|\mathbb{M}, \mathbb{Y}) \propto \mathbb{P}(\mathbb{Y}|\mathbb{M}, \theta_{\mathbb{M}})\mathbb{P}(\mathbb{M}, \theta_{\mathbb{M}}). \quad \text{(B.1)}$$

Draws from the posterior distribution are generated by applying the Gibbs sampler using standard Markov chain Monte Carlo (MCMC) techniques.[53]

B.1 Model Selection

The marginal density of the data given the model $\mathbb{M}$ is given by

$$\mathbb{P}(\mathbb{Y}|\mathbb{M}) = \int_{\theta_{\mathbb{M}}} \mathbb{P}(\mathbb{Y}|\mathbb{M}, \theta_{\mathbb{M}})\mathbb{P}(\mathbb{M}, \theta_{\mathbb{M}}). \tag{B.2}$$

This quantity has the interpretation of being the probability of observing the data given the true model is $\mathbb{M}$. In order to compare two models $\mathbb{M}_1$ and $\mathbb{M}_2$, first the prior odds are specified for both models. These are then combined with the marginal densities to obtain posterior odds ratios which are used for the purpose of model comparison.

$$PO_{1|2} = \frac{\mathbb{P}(\mathbb{Y}|\mathbb{M}_1)\mathbb{P}(\mathbb{M}_1)}{\mathbb{P}(\mathbb{Y}|\mathbb{M}_2)\mathbb{P}(\mathbb{M}_2)} \tag{B.3}$$

One advantage of the Bayesian framework is that the models do not have to be nested.[54] Throughout this paper, a non-informative prior is assumed on the models ($\mathbb{P}(\mathbb{M}_1) = \mathbb{P}(\mathbb{M}_2) = 0.5$) so that the ratio of marginal data densities is equal to the posterior odds ratio, which in this case is also equal to the frequently quoted statistic called the Bayes factor.

Appendix C. Bayesian Estimation Robustness Checks

The parameters quantifying import price flexibility as well as the elasticity of marginal cost with respect to the risk-free rate are critical in determining the role played by trade finance in propagation of business cycle shocks. This section conducts a series of robustness checks with regard to these parameters. Table C.1 reports posterior

[53] See Koop, Poirier, and Tobias (2007) for an overview of MCMC techniques.

[54] Note however that in order for the data densities to be comparable, the data used in estimating the two models should be the same and the priors should be proper (i.e., they should define a valid distribution that integrates to one). These conditions will be imposed throughout the paper in order to keep the model comparisons valid.

Table C.1. Posterior Means of Key Parameters under Different Model Assumptions/Restrictions

	θ^{US} Import	θ^{EU} Import	$\delta^{EU \rightarrow US}$	$\delta^{US \rightarrow EU}$
$\sigma_c = 1$	0.31	0.72	2.02	1.68
$\eta = 1$	0.33	0.96	2.40	1.94
Domestic Cost Channel	0.33	0.84	2.36	1.89
Sticky Wages	0.37	0.84	2.12	1.79

Note: The prior mean and standard deviation of the parameters is the same as that in the benchmark case (table 6) except when indicated in the first column.

means of these parameters under different variations of the model. For each of the cases reported in table C.1, the prior mean and standard deviation of the parameters is the same as that in the benchmark case (table 6) except when indicated in the first column.

Since the elasticity of intertemporal substitution is estimated to be somewhat higher in comparison with the literature in the baseline case, the first row considers a model with log utility. The second row considers another restriction on the model by fixing the intratemporal elasticity of substitution between domestic and foreign bundles. As argued before, there is little consensus in the value of this parameter in the literature, and a value of 1 can be considered a compromise between the trade and business cycle literatures.[55] The third row considers a model in which the cost channel of monetary policy is operational even in the domestic sector, i.e., even the goods-producing firms are required to borrow in order to finance their wage bill. This is typically how the cost channel of monetary policy has been modeled in the literature so far.[56] As is evident from the results reported in the table, the estimates of the main parameters of interest are robust to all these departures from the baseline version of the model.

[55]A more thorough approach would be to allow for dynamic elasticities as discussed in Crucini and Davis (2013) and Drozd, Kolbin, and Nosal (2014). However, this approach is not undertaken since the main message of the paper is robust to the value of the elasticity used.

[56]See, for instance, Barth and Ramey (2002), Christiano, Eichenbaum, and Evans (2005), and Ravina (2007).

Table D.1. Comparison of Data- and Model-Generated Variances

		Data	Model with Trade Finance	Model without Trade Finance
1	$\pi^{US,CPI}$	1.55	0.85	1.2
2	$\pi^{EU,CPI}$	2.78	4.92	2.75
5	ΔY^{US}	0.31	0.39	0.4
6	ΔY^{EU}	0.22	0.34	0.31
7	$\%\Delta E$	19.99	18.58	21.42

Appendix D. Posterior Predictive Moments

The estimation results in the main text show that the model with trade finance provides a better fit to the data, as measured by the marginal density. To help shed some light on which moments of the data the two models help match better, this section discusses some of the posterior predictive moments generated by the two models and compares them with their counterparts in the data.[57] Table D.1 presents a comparison of the variances of output and inflation for the two countries as well as the nominal exchange rate depreciation. While the model with trade finance yields variances for U.S. output and the nominal exchange rate depreciation that are closer to the data, the model without trade finance performs better with respect to the other variances. The model with trade finance begins to outperform the model without trade finance more systematically when going to higher order and cross-moments. As an example, table D.2 presents a comparison of the autocorrelations of the different variables generated by the two models with the data. An entry of "1" indicates that the corresponding value of the model with trade finance was closer to the data, while "0" indicates that the value for the model without trade finance is closer to the corresponding value in the data. In total, the model with trade finance generates moments that are closer to the data in 42 out of the 72 possible instances.

[57]See An and Schorfheide (2007) for a similar approach.

Table D.2. Comparison of Autocorrelations between Models with and without Trade Finance and the Data

Lags↓	$\pi^{US,CPI}$	$\pi^{EU,CPI}$	R^{US}	R^{EU}	ΔY^{US}	ΔY^{EU}	$\%\Delta E$	$\pi^{EU,GDP}$	$\pi^{US,GDP}$
1	0	0	0	0	0	1	0	1	0
2	0	1	0	0	0	1	0	1	1
3	1	1	0	0	0	1	1	1	1
4	1	1	0	0	0	1	1	1	1
5	1	1	0	0	1	1	1	0	1
6	1	1	1	0	1	1	0	1	1
7	1	0	1	0	1	1	1	1	1
8	1	0	1	0	0	1	0	0	1

Note: "1" indicates that the corresponding value of the model with trade finance was closer to the data, while "0" indicates that the value for the model without trade finance was closer to the corresponding value in the data.

Appendix E. Data

E.1 Correlations and Plots

This appendix provides the details and sources for the data used in the empirical part of the paper. Unless otherwise mentioned, the data are at quarterly frequency from 1983:Q1–2007:Q4. They are seasonally adjusted and demeaned before estimation.

U.S. Data:

- R^{US}: Effective federal funds rate, nominal, annualized, percentage
- $\triangle Y^{US}$: Quarter-to-quarter growth rate of GDP per capita computed as follows:

$$\triangle Y_t^{US} = 100\left[log\left(\frac{GDP_t}{POP_t}\right) - log\left(\frac{GDP_{t-1}}{POP_{t-1}}\right)\right]$$

  Note: Nominal GDP is converted to real using the GDP deflator.
- CPI Inflation:

$$\pi_t^{CPI,US} = 400\left[log\left(CPI_t\right) - log\left(CPI_{t-1}\right)\right]$$

- GDP Deflator Inflation:

$$-\pi_t^{GDP,US} = 400\left[log\left(GDPDEF_t\right) - log\left(GDPDEF_{t-1}\right)\right]$$

- Import Price Inflation (used only in robustness checks, not used in benchmark estimation)

$$-\pi_t^{IM,US} = 400\left[log\left(P_{IM,t}\right) - log\left(P_{IM,t-1}\right)\right]$$

Data Sources: The data for the U.S. block are taken from the Bureau of Economic Analysis (BEA) National Income and Product Accounts (NIPA). The data on population are taken from Ramey (2011)'s publicly available data set.

EU Data:

- R^{EU}: Effective federal funds rate, nominal, annualized, percentage

- $\triangle Y^{EU}$: Quarter-to-quarter growth rate of GDP per capita computed as follows:

$$\triangle Y_t^{EU} = 100\left[log\left(\frac{GDP_t}{POP_t}\right) - log\left(\frac{GDP_{t-1}}{POP_{t-1}}\right)\right]$$

  Note: Nominal GDP is converted to real using the GDP deflator.

- CPI Inflation:

$$\pi_t^{CPI,EU} = 400\left[log\left(CPI_t\right) - log\left(CPI_{t-1}\right)\right]$$

- GDP Deflator Inflation:

$$-\pi_t^{GDP,EU} = 400\left[log\left(GDPDEF_t\right) - log\left(GDPDEF_{t-1}\right)\right]$$

- Nominal Exchange Rate Depreciation:

$$-\triangle E_t = log(E_t) - log(E_{t-1})$$

Data Sources: The data for the EU block are taken from the European Central Bank (ECB) Area Wide Model (AWM) database. The nominal effective exchange rate series before 2000 is taken from Lubik and Schorfheide (2006)'s publicly available database.

Trade Data:

- Bilateral trade data between the United States and the European Union at quarterly frequency are taken from the International Monetary Fund's (IMF's) Direction of Trade Statistics (DOTS). The database only covers merchandise trade and is used in this paper as a proxy for total trade.

$$\triangle\frac{trade}{GDP} = 100\left[log\left(\frac{Exports_t + Imports_t}{GDP_t^{US}}\right)\right.$$
$$\left.-log\left(\frac{Exports_{t-1} + Imports_{t-1}}{GDP_{t-1}^{US}}\right)\right] \quad \text{(E.1)}$$

$$\triangle\frac{Import}{GDP} = 100\left[log\left(\frac{Imports_t}{GDP_t}\right) - log\left(\frac{Imports_{t-1}}{GDP_{t-1}^{US}}\right)\right] \quad \text{(E.2)}$$

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