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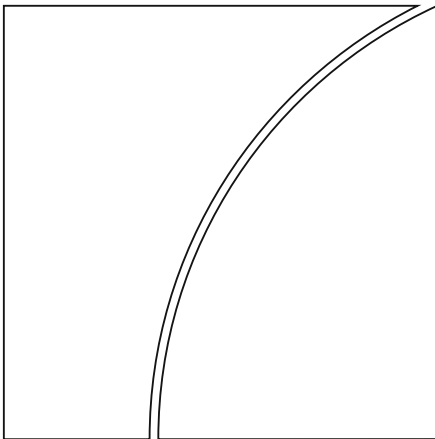
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International Trade Finance and the Cost Channel of Monetary Policy in Open Economies

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Keywords: Trade Finance, monetary policy, DSGE

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

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Abstract

This paper models the interaction between international trade finance and monetary policy in open economies and shows that trade finance affects the propagation mechanism of all macroeconomic shocks that are identified to be drivers of business cycles in advanced economies. The model is estimated with Bayesian techniques using output, price and bilateral trade data from the US and the Eurozone. The estimation exercise shows that trade finance conditions, which in turn are driven by US interest rates, are critical in explaining economic fluctuations. Quantitatively, trade finance has a larger impact on spillover effects of shocks to foreign countries, implying that incorporation of trade finance is particularly important when modeling small open economies.

Keywords: Trade Finance, monetary policy, DSGE.

JEL Classification: 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 cycles—in particular its link to monetary policy and its role in transmitting business cycle fluctuations across countries—have not been studied to date. This omission is surprising given the fact that standard open economy models commonly used in academia and by central banks and policy institutions typically give a central role to international trade, which is the primary and in some cases the only channel through which shocks can be transmitted across countries in these models.

This paper addresses this void by studying business cycle implications of trade finance through the lens of a calibrated and an estimated two-country New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model. Trade finance is modeled by augmenting the cost channel of monetary policy, and is consistent with a variety of different trade finance arrangements that have been identified in the trade literature, including direct lending by banks to the exporter and/or the importer, inter-firm trade credit, trading on open account (i.e. post delivery payment) and cash in advance.² While the cost channel has been studied extensively both in closed and open economy settings, this is the first paper to model the distinction between international and intra-national trade vis-à-vis the cost channel in a theoretical setting, a feature which has extensive empirical support in the trade literature reviewed in the next section.

The main theoretical contribution of the paper is to highlight how trade finance can have different implications on the effects of the same shock depending on how external sectors in the two countries are oriented, and to what extent they differ across countries. External sectors, or sectors in an economy which interact directly with the rest of the world through exports and imports, can differ across countries in several dimensions including the degree of passthrough (or price stickiness), time lags associated with transactions and the degree of intermediation involved as well as the interest rate they face when accessing financial markets for working capital loans.³

As an illustration of the main mechanism, consider the role played by trade finance

¹Bekaert et al. (2009) identify trade finance as the “fundamental problem in international trade”. According to the estimates of the Committee on the Global Financial System, \$6.5–8 trillion worth of bank-intermediated trade finance was provided during the year 2011, which, at around 10 percent of global 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

²See Ahn et al. (2011) , Antràs and Foley (2014) and Schmidt-Eisenlohr (2013).

³All these could more primitively be linked to heterogeneity in export and import bundles across countries, although these heterogeneities are not explicitly modeled in the paper.

in the transmission of monetary policy shocks in a model in which external sectors in the two countries are perfectly symmetric except potentially with respect to the degree of price stickiness. With high interest rates, the cost of imports increases in both countries. If price stickiness is symmetric across countries, then this affects import prices symmetrically, leading to a switch towards domestically produced goods in both countries. While this leads to a sharp fall in trade, the effect on GDP is minimal, since the loss in demand for exports is compensated by the rise coming from domestic consumers who face an increase in import prices. If on the other hand price stickiness is not symmetric across countries, then expenditure switching in one country is not offset by the other, and trade finance begins to significantly affect not only trade volumes and prices but also GDP.

Taking the US and Eurozone as the two countries, the model is estimated with Bayesian techniques using data on several macroeconomic time series including GDP, inflation and bilateral trade. Key findings from this empirical exercise can be summarized as follows. Firstly, based on formal model comparison exercises, models incorporating trade finance are found to significantly outperform models which ignore this feature. Secondly, US monetary policy and interest rates are found to be the key determinant of trade finance conditions. Thirdly, import retail prices in the US are found to be more flexible than in the Eurozone, a distinction which, as argued above, has first-order implications for the importance of trade finance in affecting transmission of business cycle shocks. Fourthly, trade finance is found to have a larger impact on spillover effects of shocks to the foreign country compared to its effect on the country of origin of the shock.

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 to intra-national trade. [Ju et al. \(2013\)](#) 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. Given their rich dataset, they are able to exploit cross-sectional differences and find that sectors relying more on external finance are disproportionately affected by monetary tightening, and that the

exporting behavior is affected more than domestic sales even after controlling for endogeneity. Using monthly data on US imports, [Chor and Manova \(2012\)](#) also document the impact on interest rates on trade. In particular, they find that the US 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 et al. \(2011\)](#) report similar results using 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 transaction-level data from a US exporter of frozen and refrigerated food products, [Antràs and Foley \(2014\)](#) report cash in advance to be the most common form of payment reported by US exporters from foreign importers. Using a detailed matched firm-level dataset 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 to 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),⁴ which implies that producers have to incur costs of production much before revenues are obtained. [Feenstra et al. \(2011\)](#) 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.⁵

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 US, [Barth III 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 dataset 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 US. 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

⁴See [Hummels and Schaur \(2013\)](#) and [Djankov et al. \(2006\)](#).

⁵See [Schmidt-Eisenlohr \(2013\)](#) for a theoretical exploration of this point.

external debt, [Auboin \(2007\)](#) documents that 80 percent percent of the providers of trade finance are private banks.⁶

The paper also builds on ideas developed in the literature on vertical specialization and multiple stage production. [Huang and Liu \(2007\)](#), [Huang and Liu \(2001\)](#) and [Wong and Eng \(2012\)](#) are among the many papers that have used these features to explain various empirical stylized facts that standard models have difficulty in accounting for. This paper will build 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 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 [Gali and Monacelli \(2005\)](#) and [Lubik and Schorfheide \(2006\)](#), which in turn fit into the New Open Economy Macroeconomics (NOEM) paradigm of [Obstfeld et al. \(1996\)](#).⁷ The world economy is assumed to consist of two countries of equal size. Households have preferences over domestic and foreign goods and supply labor to firms elastically. There are two sets of firms in each economy— production firms and trade firms. Prices are assumed to be sticky and consequently money is not neutral in the short run. The monetary authority is assumed to conduct monetary policy by using the short-term nominal interest rate as its instrument. The following sections describe each of the sectors in the model in detail. For brevity, only the home economy is described in detail. The foreign economy is assumed to be isomorphic.

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.

$$U(C_t^h, H_t^h, N_t^h) = \frac{1}{1 - \sigma_c} \left(\frac{C_t^h - H_t^h}{A_t} \right)^{1 - \sigma_c} - \frac{1}{1 + \sigma_L} N_t^{h1 + \sigma_L} \quad (3.1)$$

⁶In the Lehman bankruptcy six of the thirty largest unsecured claims against Lehman were letters of credit.

⁷See [Lane \(2001\)](#) for a survey of the NOEM literature.

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 non-stationary world-wide productivity shock which evolves according to:

$$A_t = Z_t (\gamma A_{t-1}) \quad (3.2)$$

Here 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.⁸ Preferences are characterized by internal habits.⁹

I assume a constant elasticity of substitution (CES) aggregator for C_t^h :

$$C_t^h = \left[(1 - \alpha)^{\frac{1}{\eta}} (C_t^{hh})^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} (C_t^{fh})^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \quad (3.3)$$

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 parametrizes the home bias in consumption. The associated price index, which is also the consumer price index (CPI) of the home country is given by

$$P_t^{h,cpi} = \left[(1 - \alpha) (P_t^{hh})^{1-\eta} + \alpha (P_t^{fh})^{1-\eta} \right]^{\frac{1}{1-\eta}} \quad (3.4)$$

where P_t^{hh} and P_t^{fh} denote the domestic and import price indices 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,

$$C_t^{hh} = \left[\int_j C_t^{hh}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}}, C_t^{fh} = \left[\int_j C_t^{fh}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}} \quad (3.5)$$

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

The associated price indices are as follows:

$$P_t^{hh} = \left[\int_j P_t^{hh}(j)^{1-\epsilon} dj \right]^{\frac{1}{1-\epsilon}}, P_t^{fh} = \left[\int_j P_t^{fh}(j)^{1-\epsilon} dj \right]^{\frac{1}{1-\epsilon}} \quad (3.6)$$

⁸This 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.

⁹With a representative agent internal and external habit formulations yield almost identical dynamics. Using micro data [Ravina \(2007\)](#) establishes that the internal habit is stronger than external. Note, however that although habits are internal, they are not “Deep habits” in the sense considered by [Ravn et al. \(2006\)](#). As is shown in [Ravn et al. \(2006\)](#), [Ravn et al. \(2010\)](#) and [Ravn et al. \(2012\)](#), the move from internal to deep habits leads to more drastic changes and is beyond the scope of the present paper.

Here $P_t^{hh}(i)$ 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:

$$P_t^{h,cpi} C_t^h + \int_s \mu_{t,t+1}(s) D_{t+1}^h(s) \leq W_t^h N_t^h + D_t^h + T_t^h \quad (3.7)$$

Here 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 include net transfers from the government as well as dividends from firms and financial intermediaries. Each of these components will be described in detail in the following sections.

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 the money supply.

As a 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 US data compared to 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.

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

$$A_t \lambda_t^h = \left(\frac{(C_t^h - H_t^h)}{A_t} \right)^{-\sigma_c} - \chi \gamma \beta \mathbb{E}_t \left[\frac{A_t}{A_{t+1}} \left(\frac{(C_{t+1}^h - H_{t+1}^h)}{A_{t+1}} \right)^{-\sigma_c} \right] \quad (3.8)$$

$$(N_t^h)^{\sigma_L} = \lambda_t^h \frac{W_t^h}{P_t^{h,cpi}} \quad (3.9)$$

$$\beta \mathbb{E}_t \left[\frac{\lambda_{t+1}^h \frac{P_t^{h,cpi}}{P_{t+1}^{h,cpi}}}{\lambda_t^h \frac{P_t^{h,cpi}}{P_{t+1}^{h,cpi}}} \right] = \frac{1}{R_t^h} = \mu_{t,t+1} \quad (3.10)$$

λ_t^h is the Lagrange multiplier associated with the budget constraint, which also captures the marginal utility of consumption. Equation (3.8) is the standard Euler equation with

internal habits in consumption. (3.9) is the labor supply condition which equates the marginal disutility from work to the increase in income. (3.10) Gives the price of state-contingent bonds, which also equals the inverse of the equilibrium gross nominal interest rate. Note that (3.10) 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

$$\beta \mathbb{E}_t \left[\frac{\lambda_{t+1}^h \frac{P_t^{f,cpi}}{P_{t+1}^{f,cpi}} \frac{E_t}{E_{t+1}}}{\lambda_t^h \frac{P_t^{f,cpi}}{P_{t+1}^{f,cpi}} \frac{E_t}{E_{t+1}}} \right] = \frac{1}{R_t^f} = \mu_{t,t+1} \quad (3.11)$$

where E_t denotes the nominal interest rate, i.e the price of foreign currency in terms of home currency.¹⁰ (3.10) and (3.11) can be used to show that uncovered interest rate parity condition holds up to a first-order.

$$R_t^h = R_t^f \mathbb{E}_t \left(\frac{E_{t+1}}{E_t} \right) \quad (3.12)$$

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:¹¹

$$Y_t^h(j) = A_t A_t^h N_t^h(j) \quad (3.13)$$

Here A_t is a common worldwide technology component and A_t^h is a country-specific stationary technology shock. Following [Christiano et al. \(2005\)](#) 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.¹² The cost function of the firm is thus given by:

$$\Xi_t^h(j) = R_{L,t}^h W_t^h Y_t^h(j) \quad (3.14)$$

¹⁰Note that as defined here, an increase in the nominal exchange rate corresponds to a depreciation of the home currency.

¹¹I abstract from capital mainly for simplicity. This assumption is not uncommon in the New Keynesian literature—see for instance [Lubik and Schorfheide \(2006\)](#). Another less innocuous reason, however, for excluding capital is that the introduction of cost side effects of monetary policy on investment has non-trivial implications for stability and model indeterminacy as emphasized by [Aksoy et al. \(2012\)](#).

¹²This is a standard channel via which a cost channel for monetary policy can be introduced. See [Barth III and Ramey \(2002\)](#) for intra industry evidence on the cost channel and [Ravenna and Walsh \(2006\)](#) for a theoretical exploration and more empirical evidence.

where $R_{L,t}^h$ 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 intra-period borrowing, which gives the following relationship defining the external financial dependence of goods-producing firms:

$$R_{L,t}^h = (u_L^h R_t^h + 1 - u_L^h) \quad (3.15)$$

$u_L^h = 0$ 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 et al. \(2005\)](#) and [Ravenna and Walsh \(2006\)](#). goods-producing firms are constrained to borrow at the domestic interest rate (i.e they cannot borrow in foreign currency).

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 \(1983\)](#).

In each period each firm has the opportunity to re-optimize 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.¹³ 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:

$$P_t^h(j)^* = \text{Argmax} \mathbb{E}_t \left[\sum_{k=0}^{\infty} (\theta^h)^k \Omega_{t,t+k} [P_t^h(j)^* Y_{t+k}^h(j) - \Xi_{t+k}^h(j)] \right] \quad (3.16)$$

where the demand function for each firm is as follows:

$$Y_t^h(j) = \left(\frac{P_t^h(j)^*}{P_t^h} \right)^{-\epsilon} Y_t^h \quad (3.17)$$

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

$$P_t^h(j)^* = \mathbb{E}_t \left[\frac{\sum_{k=0}^{\infty} (\theta^h)^k \Omega_{t,t+k} \left(\frac{\epsilon}{\epsilon-1} \right) P_{t+k}^h MC_{t+k}^h Y_{t+k}^h}{\sum_{k=0}^{\infty} (\theta^h)^k \Omega_{t,t+k} Y_{t+k}^h} \right] \quad (3.18)$$

$$(3.19)$$

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

¹³Alternatively, 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 [Gali et al. \(2001\)](#).

version of (3.18) around the symmetric steady state reads:¹⁴

$$p_t^h(j)^* = (1 - \beta\theta^h) \sum_{k=0}^{\infty} (\beta\theta^h)^k \mathbb{E}_t(m c_{t+k}^h) \quad (3.20)$$

This leads to the following forward-looking Phillips curve for PPI inflation:¹⁵

$$\pi_t^h = \beta \mathbb{E}_t \pi_{t+1}^h + \frac{(1 - \beta\theta^h)(1 - \theta^h)}{\theta^h} m c_t^h \quad (3.21)$$

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, as in [Lubik and Schorfheide \(2006\)](#) and [Monacelli \(2005\)](#). While these papers introduce the import sector purely to generate the scope for incomplete passthrough of exchange rate fluctuations into import prices, the international trade sector in this model, 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 passthrough. 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 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.¹⁶ Following this literature I model the import sector as characterized by a sequence of firms that operate at different stages. Each firm has a trivial 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 a sequence of firms in n stages. At each stage k , a continuum of atomistic firms operate with the following production technology:

$$Y_{k,t}^{fh}(j) = Y_{k-1,t}^{fh}(j), k \in \{1, 2, \dots, n\}, j \in (0, 1) \quad (3.22)$$

¹⁴Throughout the paper, lower case letters are used to denote log deviations from steady state, i.e $x_t = \log X_t - \log(\bar{X})$

¹⁵The derivation is standard, see for instance [Galí \(2009\)](#).

¹⁶See for instance [Wong and Eng \(2012\)](#), [Huang and Liu \(2001\)](#) and [Huang and Liu \(2007\)](#)

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:

$$\Xi_{k,t}^{fh}(j) = R_t^{fh}(k)P_{k-1,t}^{fh} \quad (3.23)$$

where, 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 passthrough 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:

$$\Phi_t^{fh} = \frac{E_t P_t^f R_t^{fh}}{P_t^{fh}} \quad (3.24)$$

Here P_t^{fh} denotes the local currency price of foreign goods that are sold to home consumers. Note that similar to [Lubik and Schorfheide \(2006\)](#), this real marginal cost term can be interpreted as a law of one price gap. However, in this paper this gap comprises not only of incomplete passthrough 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 [3.24](#) can be written as follows:

$$R_t^{fh} = [u^{fh} R_t^c + (1 - u^{fh})]^n \quad (3.25)$$

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.¹⁷ R_t^c is the interest rate that is used in trade finance. It would be either the home interest rate (R_t^f) or the foreign interest rate R_t^f

Log linearizing equation [\(3.25\)](#) yields the following approximate relationship between the number of processing stages, external finance dependence in each stage and the nominal interest rate

$$r_t^{fh} \approx n u^{fh} r_t^h \quad (3.26)$$

As is evident from [\(3.26\)](#), the impact of changes in nominal interest rates on trade finance depends on both the external finance dependence (u^{fh}) and the number of processing stages

¹⁷For simplicity this parameter is assumed to be independent of n as well as t .

(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.¹⁸ Since the goal of the paper is to study the consequences of this relationship rather than its micro-foundations, the model is parametrized 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

$$r_t^{fh} = \delta^{fh} r_t^h \quad (3.27)$$

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, inter-firm trade credit, open account (i.e post delivery payment) or cash-in advance.¹⁹ 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 3.27), 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.

$$\pi_t^{fh} = \beta E_t \pi_{t+1}^{fh} + \frac{(1 - \beta \theta^{fh})(1 - \theta^{fh})}{\theta^{fh}} \phi_t^{fh} \quad (3.28)$$

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

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

$$\pi_t^{fh} = (1 - \alpha) \pi_t^h + \alpha \pi_t^{fh} \quad (3.29)$$

¹⁸ Amplification effects coming via a financial accelerator type mechanism is an example of one such scenario

¹⁹ See [Ahn et al. \(2011\)](#), [Antràs and Foley \(2014\)](#) [Schmidt-Eisenlohr \(2013\)](#).

Financial Intermediaries

As emphasized above, a key feature in this model is that firms are liquidity-constrained. In particular, they are constrained to finance (partly or fully) their input purchases (or wages as the case may be) by borrowing at the risk free rate. This financing could be assumed to be intermediated by banks, which rebate their profits to domestic households.²⁰

Government

The remaining aspects of the model are standard. There is a government which finances current expenditure by imposing lump sum taxes on households. For simplicity, government borrowing or lending is not allowed, and all expenditures are financed based on current period receipts.²¹

The government consumption good is assumed to follow the same aggregator as that for the households. The overall government spending process is stochastic and driven by persistent shocks.

$$g_t^h = \rho_g^h g_{t-1}^h + \epsilon_{gt}^h \quad (3.30)$$

Note that although neither the lump sum tax nor the assumption of same consumption bundle for households and the government is realistic,²² the goal for introducing the government in this model is to have a source for exogenous demand shocks. The paper is not aimed at studying the effects of fiscal policy per se.

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 banks reaction function.²³

The central bank's reaction function is thus given by:

²⁰This forms part of the term T_t^h in equation 3.7 along with other dividend payments from goods-producing and trade firms

²¹With optimizing households, Ricardian equivalence holds and allowing for government borrowing will not alter the results.

²²In particular, government consumption is likely to be concentrated towards non-tradable and therefore exhibit a higher home bias than households. See [Lane \(2010\)](#) for a discussion of this point.

²³In particular, I allow the responses of the central bank to nominal exchange rates to differ across the two countries. As is shown by [Backus et al. \(2010\)](#), this asymmetry can go a long way in explaining the uncovered interest rate parity puzzle, a robust feature of the data.

$$i_t^h = \rho_R^h i_{t-1}^h + (1 - \rho_R^h) [\phi_\pi^h \pi_t^h + \phi_y^h \Delta y_t^h + \phi_e^h \Delta e_t] + \epsilon_{rt}^h \quad (3.31)$$

where i_t^h denotes the nominal interest rate ($R_t^h = 1 + i_t^h$), Δy_t^h denotes the growth rate of output and Δe_t denotes the rate of (nominal) depreciation. ϵ_{rt}^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:

$$Y_t^h(j) = C_t^{hh}(j) + G_t^{hh}(j) + G_t^{hf}(j) + C_t^{hf}(j) \forall j \in (0, 1) \quad (3.32)$$

Terms of Trade and Real Exchange Rate

Terms of trade for a country is defined as the ratio of the price of domestically produced good at home relative to the price of imported goods.²⁴ In particular, the terms of trade for the home country is defined as follows:

$$tot_t^h = \frac{P_t^h}{P_t^{fh}} \quad (3.33)$$

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

$$tot_t^f = \frac{P_t^f}{P_t^{hf}} \quad (3.34)$$

Using (3.24) and its foreign country counterpart along with (3.33) and (3.34) give:

$$\phi_t^{fh} \phi_t^{hf} = tot_t^h tot_t^f R_t^{fh} R_t^{hf} \quad (3.35)$$

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 indices in the two countries.

²⁴Note 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.

$$S_t = \frac{E_t P^{f,CPI}}{P^{h,CPI}} \quad (3.36)$$

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.

Equilibrium and Solution method

The equilibrium conditions characterized above along with the shock processes comprise a dynamic system with a unique non-stochastic steady state.²⁵ The model is solved by log-linearizing the equilibrium conditions characterizing the model around this non-stochastic 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 Assessment of the Role of External Finance

This section discusses some simulation results based on a symmetrically 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 external finance dependence in the wake of exogenous shocks. The model is calibrated to a symmetric two-country case with most parameter values picked

²⁵All parameter restrictions required for uniqueness, including the Taylor principle proposed in [Woodford and Walsh \(2005\)](#) are imposed to allow a unique solution. (The focus of the paper is not on indeterminacy and sunspot equilibria. See [Aksoy et al. \(2012\)](#) for a summary of these issues in the presence of cost channel of monetary policy). Steps will be taken to restrict priors to the region so that the posterior distribution also continues to satisfy these constraints.

from the previous literature—in particular [Lubik and Schorfheide \(2006\)](#), [Smets and Wouters \(2003\)](#) and [Smets and Wouters \(2007\)](#), but the values are kept the same for both home and foreign countries so as to illustrate the mechanics in the model more clearly.²⁶

Table 3 shows the values used in the calibration exercise. Although most of the values are standard, there are a few parameters that merit further discussion. The intra-temporal 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 calibrated models typically rely on evidence from the trade literature and pick values greater than one,²⁷ estimates based on macro data typically yield much lower values, most often less than one.²⁸ 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 heterogeneous, aggregation leads to a downward bias. Indeed the evidence on heterogeneity of elasticities is substantial, as documented in [Patel et al. \(2014\)](#) and [Broda and Weinstein \(2006\)](#) among others. The value chosen for the simulation results $\eta = 1$ is a compromise between the estimated obtained from the micro and macro literatures and is more in line with the latter.²⁹

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 and/or the 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 compared to those shipped by air. Secondly, countries could differ in the degree of their import price passthroughs, 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 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

²⁶These restrictions will be lifted in the empirical section and most parameters will be estimated without imposing these symmetry restrictions.

²⁷See 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 \(2010\)](#).

²⁸See for instance [Justiniano and Preston \(2010\)](#) and [Lubik and Schorfheide \(2006\)](#).

²⁹Recently, [Drozd et al. \(2014\)](#) have shown how allowing for dynamic elasticities (i.e. different elasticity in the short vs long run) can help reconcile the business cycle and trade literatures.

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 competition, higher markups and hence lower price flexibility in its prices compared to 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.³⁰ The two parameters governing import price stickiness will be 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 different approaches. Firstly, I consider the model’s prediction regarding the fall in trade to GDP ratios in response to a trade finance shock, which in the context of this paper is best understood as a shock to the interest rate spread. Table 1 shows the peak response of trade to GDP ratio. The corresponding number in the data is of the order of 20 to 30 percent. Eaton et al. (2011) argue that about 80 percent of the fall in trade to GDP ratio can be accounted for by demand side effects and heterogeneity in traded vs non-traded goods. This leaves 20 percent of the collapse, or about 4-6 percent fall in trade to GDP ratios unexplained. Table 1 shows the peak response of trade to GDP ratios under different assumption on elasticity of substitution and import price flexibility. 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.³¹

As discussed above, the parameter δ captures not just external financial dependence of sectors but rather also the number of stages involved in the process from actual production to eventual consumption. Regarding this interpretation, one can get a sense of the length of the chain by considering a statistic like the average propagation length (APL). 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 of 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 US). In this simple example, the APL between Japan and the US would be 2, which 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 2 displays summary statistics for APLs computed at the country and country-sector level using detailed inter-country input output

³⁰A large fraction of international trade is conducted in US 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 are also fairly likely—see for instance Gopinath et al. (2010) and Amiti and Weinstein (2011).

³¹The maximum response it generates is -10 percent which seems a bit high, but neither this elasticity nor this passthrough specification seems plausible and is rejected by the data. Based on the other three numbers, it seems to be a conservative estimate.

Table 1 – Peak Response of trade to GDP ratio to an interest rate spread shock of 300 basis points

$\eta = 2$	$\delta = 2$	$\delta = 4$
$\theta^{hf} = \theta^{hf} = 0.1$	-10.0	-23.0
$\theta^{hf} = \theta^{hf} = 0.7$	-2.8	-5.8

$\eta = 0.5$	$\delta = 2$	$\delta = 4$
$\theta^{hf} = \theta^{hf} = 0.1$	-2.5	-5.7
$\theta^{hf} = \theta^{hf} = 0.7$	-0.7	-1.4

Table 2 – Average Propagation Length: Summary Statistics For Benchmark Year 2007

(a) Average Propagation Length (APL) Summary Statistics

Country Level APL		Country-Sector Level APL	
Number of countries	41	Number of Country-Sectors	1435
Mean APL	2.8465	Mean APL	3.61
Median APL	2.7396	Median APL	3.62
St. Dev	0.5	St. Dev	0.9

(b) APL for select Country Pairs

	US	Germany	China
US	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 (wiod.org) and author calculations.

Table 3 – 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		

data from the World Input Output Database for the benchmark year 2007.³² 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 a 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.

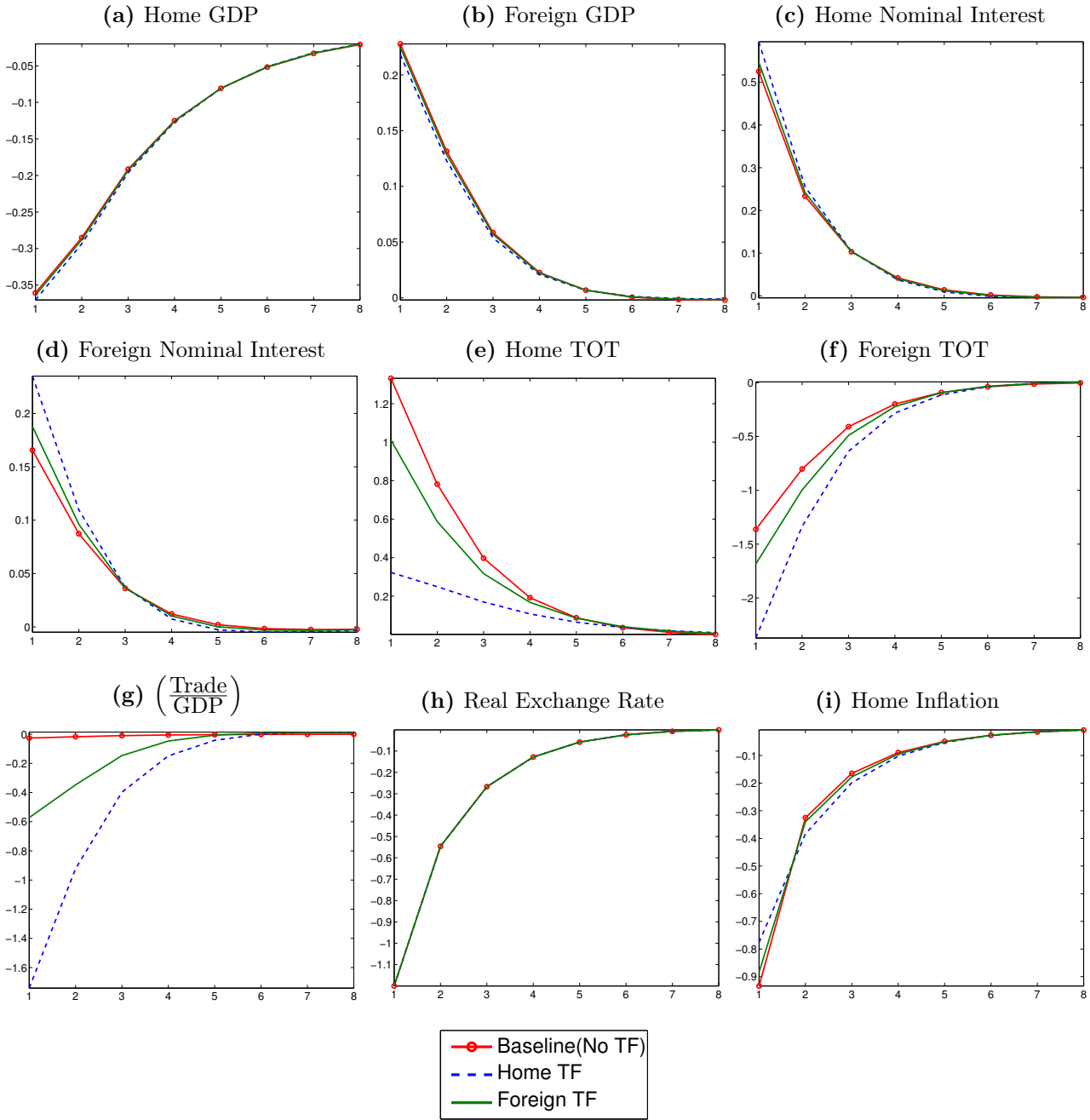
5 Model Simulations

Monetary Shocks

Figure 5.1 plots impulse responses of nine endogenous variables to a contractionary home monetary policy shock in the symmetric case where both home and foreign import price exhibit high flexibility ($\theta^{hf} = \theta^{fh} = 0.1$). The three lines correspond to models without trade finance, the model in which all trade finance is driven by home interest rates and a model in which all trade finance is driven by foreign interest rates respectively. As the figure shows, as far as foreign GDP is concerned, in all these three cases the expenditure switching effect dominates the aggregate demand effect and a monetary contraction leads to an increase in foreign GDP. As is also evident from the diagrams, the net effect of trade finance constraints on home and foreign GDP is minimal. This is a consequence of two opposing effects which

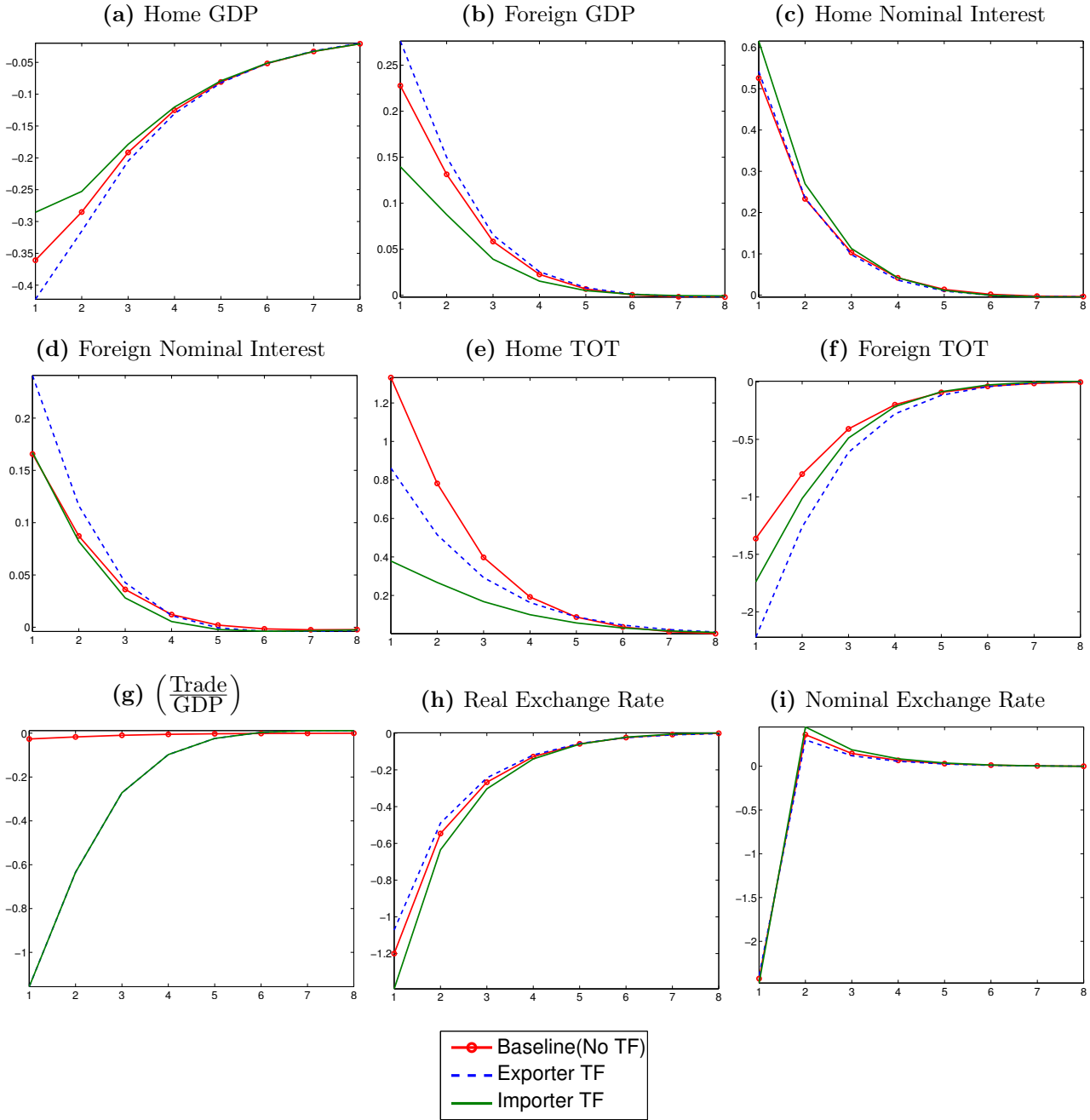
³²See [Timmer and Erumban \(2012\)](#) for a detailed description of the database and [Dietzenbacher and Romero \(2007\)](#) for a detailed discussion of APL.

Figure 5.1 – Home Monetary Contraction: $\theta^{hh} = \theta^{hf} = 0.1$



Notes: The impulse responses are computed through simulations using the values in table 3. 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.

Figure 5.2 – Home Monetary Contraction: $\theta^{fh} = \theta^{hf} = 0.1$



Notes: The impulse responses are computed through simulations using the values in table 3. 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.

tend to cancel each other out in this symmetric setting. Since global interest rates are high, the external finance channel makes imports more expensive for both countries, leading to a shift towards domestically produced goods by both home and foreign consumers. The two sides of this shift imply that in a symmetric setting the fall in demand for imports is compensated by the rise in demand for domestically produced goods, implying a negligible net effect on both home and foreign GDP. The impulse responses of terms of trade for both home and foreign countries as well as the global trade to GDP ratio show that although the net effect on GDP is negligible, the movements in terms of trade indicate a substantial decline in global trade, since in the case with trade finance constraints on trade the effect on both home and foreign terms of trade is lower, signaling the rise in competitiveness of domestically produced goods and fall in competitiveness of imports in both the home and foreign markets.

There are at least three interesting implications captured in these results. Firstly, note that although GDP is not significantly affected by trade finance in this case, the model with trade finance constraints does imply a larger fall in global trade, and hence points towards lower welfare for both domestic and foreign agents.³³ Secondly, this analysis shows that the model with trade finance constraints has the potential to explain phenomena like the Great Trade Collapse which characterized the great recession and the subsequent recovery³⁴, at least qualitatively, since the model with trade finance constraints leads to a much sharper fall in trade to GDP ratio compared to the model without trade finance constraints. Although monetary policy may not have been the primary cause of the increase in financing costs (and may have in fact mitigated their rise), financial intermediation, and in particular trade finance did take a big hit in the aftermath of the great recession for many different reasons including increase in uncertainty. Although this paper models financing costs solely as captured by changes in the risk free interest rate, changes in trade finance premia for other reasons are likely to generate the same effects. Thirdly, these pictures emphasize the difference and provide a comparison between the real exchange rate and terms of trade and measures of competitiveness. The real exchange rate (RER) in its many forms is typically used as a measure of competitiveness.³⁵ However, when the law of one price does not hold—as is the case in this model—competitiveness in the home and foreign markets become de-linked from one another and a single measure like the RER becomes insufficient to quantify competitiveness movements. Terms of trade, separately defined for the two countries to account for the disparity in prices, are the right quantities to examine in order to make inferences regarding competitiveness. This also allows for the possibility of simultaneous increase and/or decrease

³³The model is analytically intractable and the simulation results are based on a first-order approximation and a full quantitative characterization of the welfare is beyond the scope of the paper.

³⁴See for instance [Bems et al. \(2010\)](#)

³⁵See for instance [Chinn \(2006\)](#) and [Patel et al. \(2014\)](#).

in competitiveness in the two countries, something that an RER measure by construction cannot accommodate.

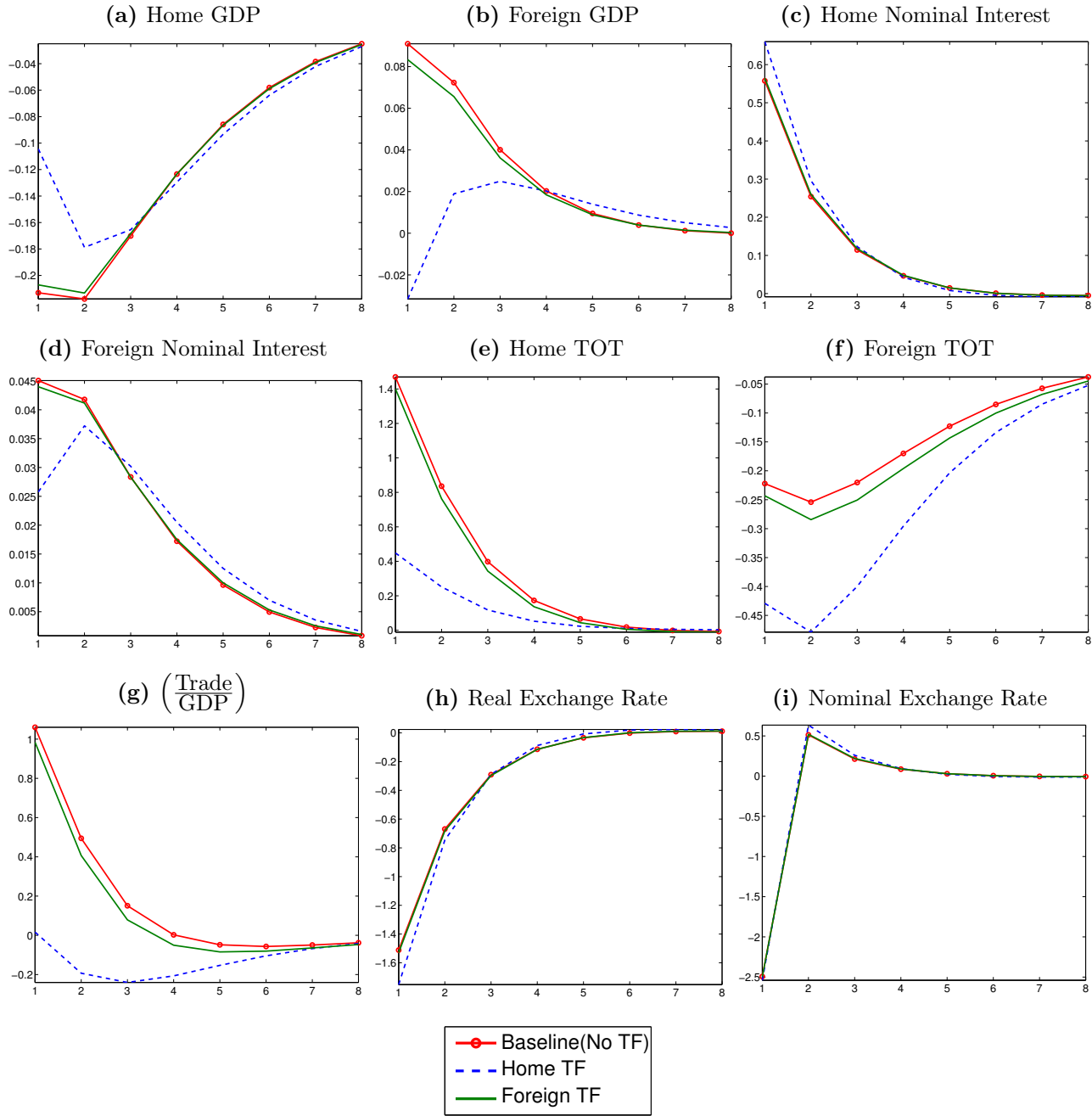
Figures A.1 and A.2 in the appendix show impulse responses to the same endogenous variables and the same shock as above but for the case in which both home and foreign import prices have lower passthrough ($\theta^{hf} = \theta^{fh} = 0.7$). In this case the aggregate demand effect dominates the expenditure switching effect and foreign GDP falls in response to a home monetary contraction. With regard to trade finance constraints, however, the message from this picture is the same as above, i.e with symmetric passthrough trade finance constraints imply a large drop in international trade (and terms of trade) but have a minimal net effect on both home and foreign GDP. The results are similar if trade is assumed to be financed by borrowing at the foreign risk free rate instead of home, although the magnitude of the effect is less.

The main conclusion that emerges from the analysis so far is that when the external sectors of the two countries are symmetric (with regard to their passthrough as well as external finance dependence), the presence of trade finance constraints affects the response of trade and terms of trade variables but has minimal impact on the GDP of two countries. The remainder of this section will show that if the external sectors of the two countries are asymmetric, then trade finance constraints alter not just the response of trade variables, but also the responses of home and foreign GDP to various shocks.

Figure 5.3 shows how the domestic and spillover effects of contractionary monetary policy at home are altered in the presence of trade finance requirements in the case in which home import prices are more flexible than foreign import prices. As a starting point, the dotted line (without trade finance constraints) shows that this parameter specification implies that the expenditure switching effect dominates the aggregate demand effect and the net effect of the shock is to cause an increase in foreign output accompanied by a fall in domestic output.³⁶ Comparing the impulse responses with and without trade finance constraints also serves to show that trade finance constraints tend to generate a positive effect on home GDP and a negative effect on foreign GDP. This is due to the fact that trade finance constraints coupled with a higher interest rates imply that imports become more expensive. Since home import prices are more flexible, this effect is felt more in the form of a shift towards home-produced goods by home consumers, whereas the low passthrough to foreign import prices that the consumers end up paying implies that the corresponding shift in the foreign country is minimal. Together these two effects lead to a lower fall in the demand for goods produced at home compared to the case in which trade is not dependent on external finance. The remaining plots in figure 5.3 illustrate how the transmission mechanism is altered in the

³⁶i.e, with this parameters specification monetary expansions are “beggar thy neighbor”

Figure 5.3 – Home Monetary Contraction: $\theta^{fh} = 0.1, \theta^{hf} = 0.7$



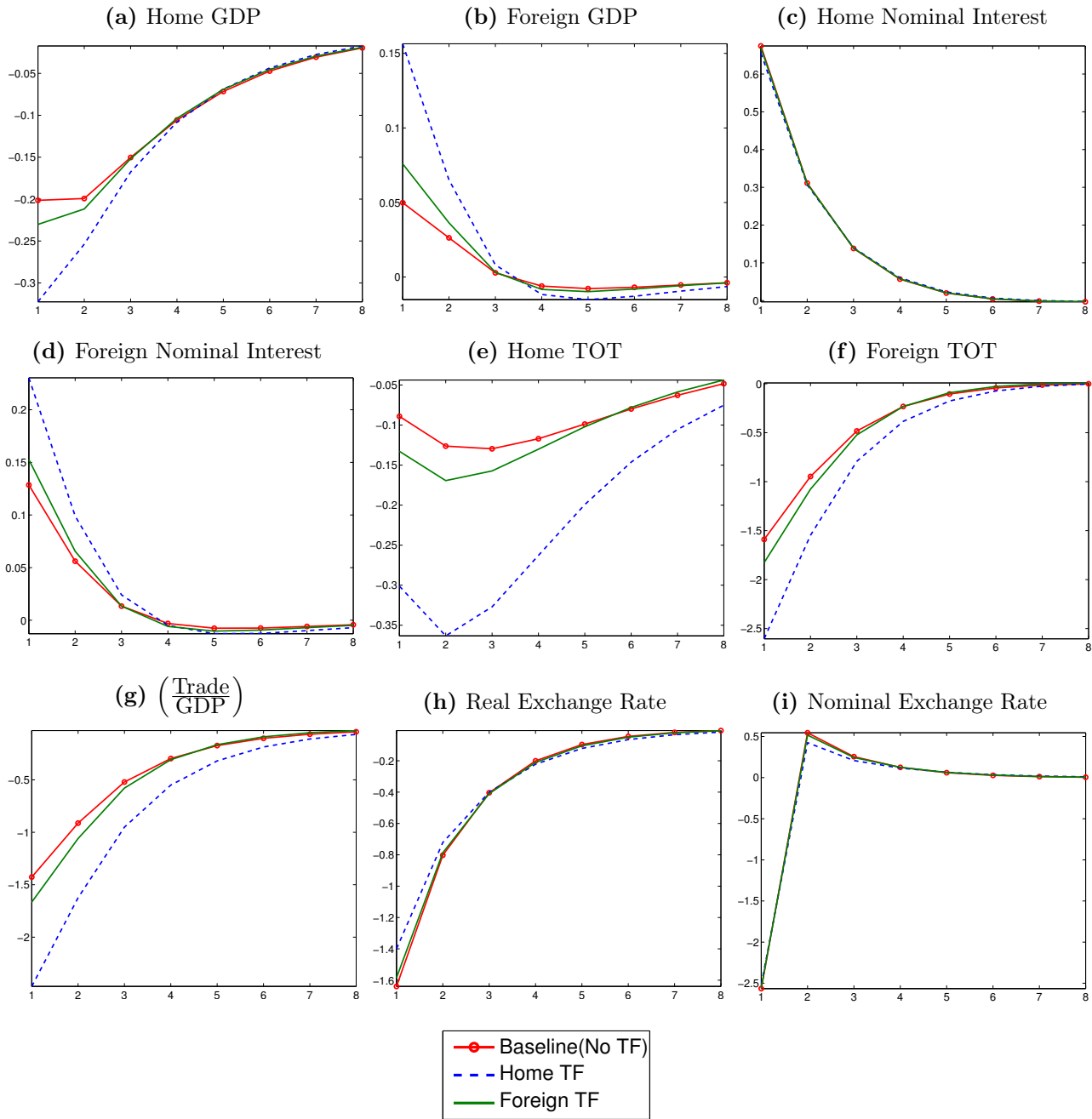
Notes: The impulse responses are computed through simulations using the values in table 3. The horizontal axis measures time in quarters. The vertical axis units are deviations from the unshocked path. Inflation and nominal interest rate are given in annualized percentage points. The other variables are in percentages.

presence of trade finance constraints. As argued above, the key relative price governing the allocation of expenditure between domestically produced goods and imports in this model is the terms of trade, which is defined as the ratio of the price of domestically produced goods to the price of imports. As seen in figure 5.3 the home terms of trade increases by less in the presence of trade finance constraints. This is due to the interest rate component which enters the denominator of terms of trade (via the import price) and tends to reduce the expenditure switching towards foreign produced goods. Foreign terms of trade, which show lower impact because of high price stickiness in foreign imports, exhibit the same pattern qualitatively. In standard open economy models, the real exchange rate is the quantity that determines the relative expenditure shares across home and imported goods and serves as a measure of competitiveness. However, as the impulse responses of the real exchange rate in figure 5.3 show, this is not the case in the present model. With trade finance, the real exchange rate appreciates more, which in the absence of the interest rate channel would imply a larger spillover effect.

Figure 5.4 presents the other case of asymmetric passthrough in which foreign import prices are highly flexible while domestic import prices are sticky. In this case the trade finance constraints generate a negative impact on home GDP and a positive impact on foreign GDP. The intuition is the same as above. Once again the higher interest rates translate into higher import prices as before, but now the impact on foreign import prices is much higher due to greater price flexibility in that sector. As a result, demand for home exports decline to a greater extent leading to a greater fall in home GDP and a higher rise in foreign GDP. Figure 5.4 also shows the differences in transmission mechanism across the different models as manifested in the terms of trade, which experience much larger movements in the presence of trade finance constraints in this case.

As emphasized above, import price flexibility (or passthrough) is not the only dimension along which the external sectors of the two countries can differ. So far it was assumed that within each model there is only one interest rate (i.e the risk free rate of one of the two countries) that governs external finance cost for all trade firms. A priori there is no reason to believe that this would necessarily be the case. Because of institutional constraints or other frictions, trade firms may be constrained to borrow only in the risk free rate of a particular country. As two extreme cases, we may have a scenario in which all bilateral trade finance is governed by either the exporter's risk free interest rate or the importer's risk free rate. In comparison to figure 5.1, figure 5.2 shows that if this is the case, then even if passthrough is symmetric in both countries, trade finance constraints can alter the response of GDP to monetary shocks. Consider for instance the impulse responses of home and foreign GDP in figure 5.2. The baseline case (without trade finance constraints) is represented by

Figure 5.4 – Home Monetary Contraction: $\theta^{fh} = 0.7, \theta^{hf} = 0.1$



Notes: The impulse responses are computed through simulations using the values in table 3. 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.

the dotted line. If trade finance is governed by the exporting country’s monetary policy (blue/dashed lines), then the figure shows that trade finance constraints generate a negative impact on home GDP and a positive impact on foreign GDP. The intuition is as follows: as a result of the home monetary shock, home interest rate rises significantly more than foreign interest rate.³⁷ This affects trade flows from home to foreign country more than from foreign to home country, since the latter set of trade flows are dependent on the foreign interest rates. As a result, the demand for home goods from abroad falls sharply, with little countervailing increase coming from domestic demand since foreign interest rates rise only moderately. The net effect is a sharper fall in home GDP and a reduced spillover effect on foreign GDP. The scenario reverses itself when trade finance is governed by the importing country’s nominal interest rate (green/solid line). Now the trade finance constraints generate a positive impact on home GDP and a negative effect on foreign GDP. More generally, trade finance in either direction could be governed by a combination of home and foreign interest rates. This possibility will also be considered in the estimation section.

There is potentially a third source of asymmetry vis-à-vis the the external sectors of the two countries as they could differ in their external finance dependence parameters themselves (i.e $\delta^{hf} \neq \delta^{fh}$). The mechanics in this scenario will be much like the ones discussed above for the exporter vs importer trade finance scenarios.

Table 4 summarizes the impact of trade finance constraints on the transmission of home monetary contraction to home and foreign GDP. When home import prices are more flexible than foreign import prices, trade finance constraints tend to increase home GDP at the expense of foreign GDP. The opposite happens when foreign import prices are more flexible than home import prices.

Labor hiring costs: A comparison with the closed economy cost channel

External finance dependence of goods-producing firms (in the form of labor financing) is another channel through which monetary policy generates a cost-push effect in this model.³⁸ Figure 5.5 displays the impulse responses to a contractionary monetary policy shock at home in which both home and foreign import passthrough is high ($\theta^{hf} = \theta^{fh} = 0.1$). The top row shows that the effect on GDP is minimal, much like the case with symmetric passthrough and trade finance constraints. However, unlike the latter, in this case the difference in the response of terms of trade and trade to GDP ratios across the two models is also minimal,

³⁷Which also rises in this case, but may actually fall for different calibration of parameters as seen in figure A.2 .

³⁸In fact this is the only channel through which cost side effects of monetary policy are modeled in closed economy settings-see for instance [Ravenna and Walsh \(2006\)](#)

Table 4 – Summary of Transmission of Monetary Policy with Trade Finance Constraints and Asymmetric Passthrough

θ^{fh}	θ^{hf}	Home GDP	Foreign GDP
Symmetric			
High	High	Negligible	Negligible
Low	Low	Negligible	Negligible
Asymmetric Passthrough			
low	high	↑	↓
high	low	↓	↑
Asymmetric Interest rate dependence for trade finance			
Exporter interest rate trade finance		↓	↑
Importer interest rate trade finance		↑	↓

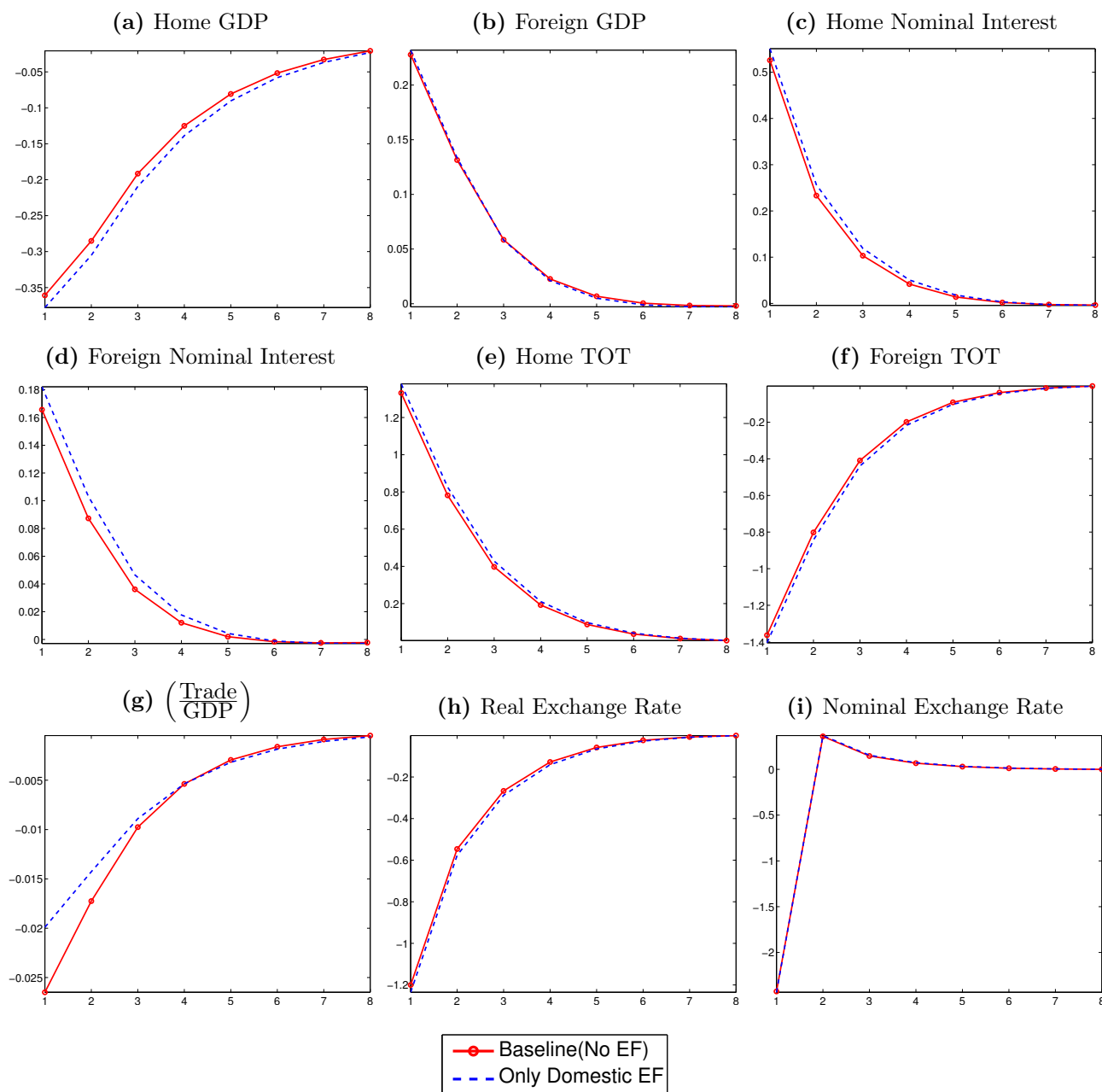
indicating that there is little effect of these constraints on international trade as well. This confirms the results obtained in closed economy settings by Gilchrist (2002) and [Kaufmann and Scharler \(2009\)](#), that the cost side effects of monetary policy-as captured by labor financing constraints-have little quantitative impact over and above the aggregate demand effects of monetary policy.

Figure 5.6 further shows that the response of GDP to a monetary contraction continues to be minimal even under asymmetric passthrough. The results are similar to the ones reported above and the main conclusion that emerges from this exercise is that labor financing constraints, which is the primary means through which cost side effects of monetary policy have been introduced in the literature so far, are not quantitatively important.

Effects of External Finance Constraints on Propagation of Non-Monetary Shocks

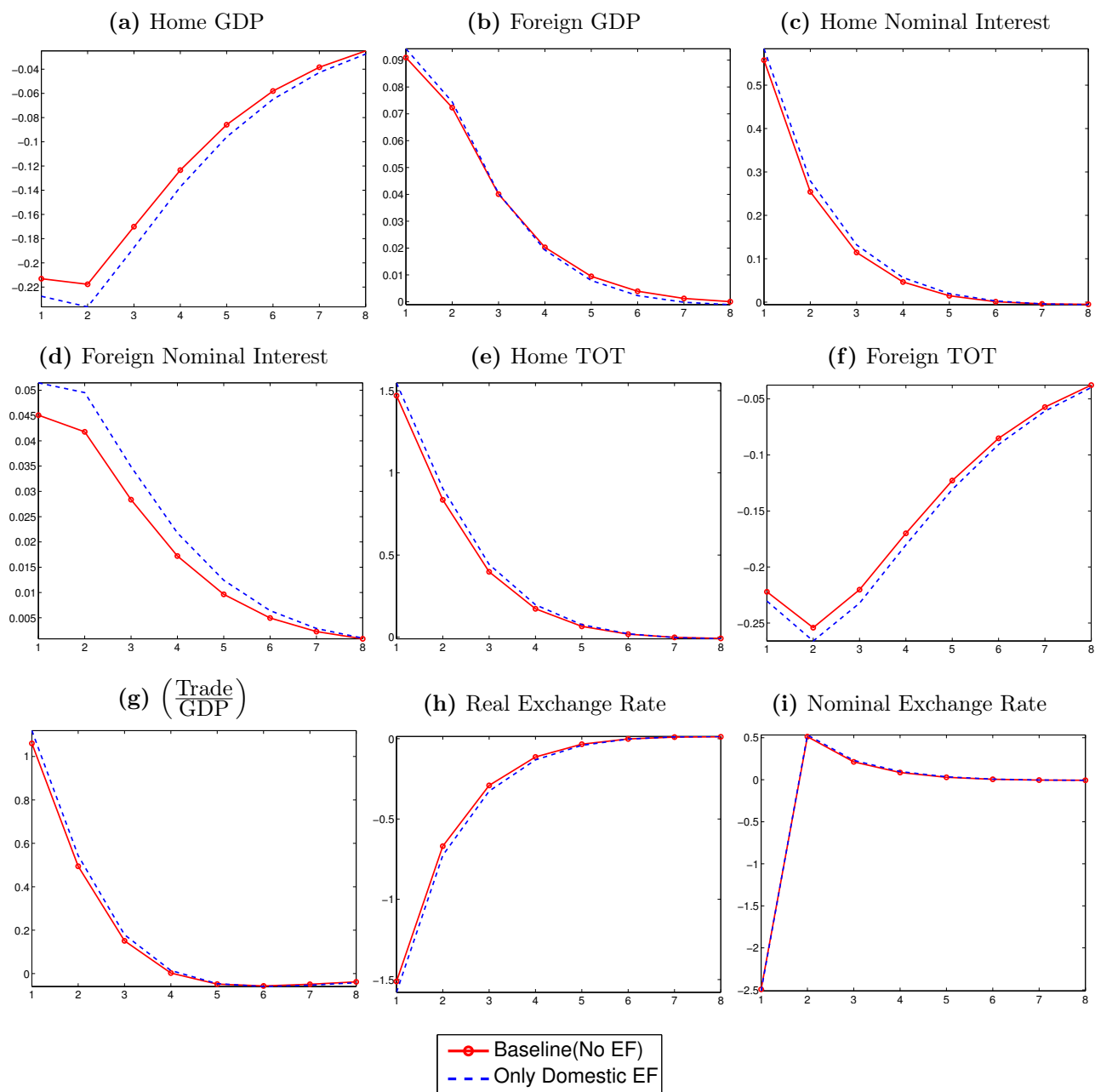
The main theoretical contribution of this paper is the incorporation of cost side effects of interest rates through trade and labor finance constraints. While the impact of these features shows up most clearly in the case of propagation of monetary policy shocks, they also affect the propagation mechanism of all other shocks in the economy via their effects on

Figure 5.5 – Home Monetary Contraction with labor cost: $\theta^{fh} = \theta^{hf} = 0.1$



Notes: The impulse responses are computed through simulations using the values in table 3. 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.

Figure 5.6 – Home Monetary Contraction with labor cost: $\theta^{fh} = 0.1, \theta^{hf} = 0.7$



Notes: The impulse responses are computed through simulations using the values in table 3. 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.

global interest rates through the endogenous component of monetary policy represented by the interest rate rule. For instance, following a positive aggregate demand shock the central bank is likely to respond by raising interest rates. In the model with financial constraints, this change would trigger cost side effects that are absent in the standard model and that can significantly alter the transmission mechanism of the original demand shock in both the home and the foreign economy. This Appendix A illustrates some such effects for two non-monetary shocks in the model—a supply shock (rise in home productivity) and a demand shock (rise in home government spending).

6 Estimation Set Up

The different models in this paper are estimated using Bayesian techniques. While in principle the model can be estimated using frequentist likelihood-based methods, two aspects of the nature of the problem at hand make the Bayesian framework more suited for the purpose of this paper. Firstly, the Bayesian framework allows for explicit incorporation of information from outside the model in the form of prior distributions. Likelihoods in highly non-linear (in terms of parameters) models like this are likely to be multi-modal and not well behaved in certain regions of the parameter space. Hence even in a frequentist setting the researcher has to guide the estimation routine by providing appropriate set of starting values. The Bayesian framework makes this more explicit in the form of prior distributions. Moreover, the model is not stable for all values in the parameter space. For instance, the coefficient on inflation in the Taylor rule has to be high enough (typically greater than one) for the model to have a unique solution with a non-explosive path for inflation.³⁹ Priors can be used to ensure that the unstable regions of the parameter space are assigned low or zero probability. Secondly, the Bayesian framework is much more amenable to post-estimation analysis including model selection and comparison (especially for non-nested models). Since a major aim in the empirical part of the paper is to document evidence for or against models incorporating trade finance, model comparisons will be used extensively, making the Bayesian framework more appealing.

Within the Bayesian estimation setting, the estimation is based on a full information approach which considers the likelihood of the data for each model in the presence of multiple

³⁹See [Blanchard and Kahn \(1980\)](#) for conditions under which linearized rational expectations models of the form considered here have unique and stable solutions.

shocks that have been identified in the prior DSGE literature as important drivers of business cycles. Since impulse responses to shocks are a useful and intuitive way of summarizing the properties of DSGE models, a common estimation routine in the literature involves impulse response matching—where parameters of the model are chosen to minimize the distance between impulse responses to a shock in the model and impulse responses obtained from the data using an identified empirical model (like a structural vector autoregression).⁴⁰ Since the influence of trade finance is most noticeable in the case of monetary policy shocks, impulse response matching vis-a-vis monetary policy shocks seems to be a natural candidate for estimation. However, as has been shown in the prior DSGE literature, monetary policy shocks account for only a small fraction of fluctuations in advanced economies, and restricting attention to them would come at the cost of ignoring the insights that can be gained from looking at a broad array of shocks that account for majority of business cycle fluctuations. Moreover, identifying monetary policy shocks in the data has been the subject of much contentious debate and no consensus has emerged in the literature.⁴¹ Paradoxical results across sample periods, as documented in [Ilzetzi and Jin \(2013\)](#) and [Crowe and Barakchian \(2010\)](#) have further questioned common identification schemes for monetary policy shocks, and [Fernández-Villaverde et al. \(2005\)](#) too have cautioned against the VAR-based impulse response matching approach. Appendix D provides an overview of the Bayesian approach and model selection criterion used in the paper.⁴²

Data

The model is matched to the data by treating the US and the Eurozone as the two countries comprising the world economy. The sample period is 1983Q1-2007Q4. The period from 2007 onwards has been characterized by abnormally low interest rates with US interest rates stuck at zero and the European interest rates exhibiting a wide divergence across countries. Since the focus of the paper is to capture variations in cost of external finance as captured by interest rates, the period since the financial crisis is not suited for the study for both the reasons mentioned above.

⁴⁰See for instance [Christiano et al. \(2005\)](#), [Miyamoto and Nguyen \(2014\)](#) and [Ravn et al. \(2010\)](#)

⁴¹In broadly the same sample period, while [Christiano et al. \(2005\)](#) find a moderate and persistent fall in GDP in response to a monetary contraction while [Romer and Romer \(2004\)](#) find a much sharper fall (more than twice compared to [Christiano et al. \(2005\)](#)). Using an identification scheme based on sign restrictions, [Uhlig \(2005\)](#) on the other hand finds a positive response of GDP in response to a monetary contraction.

⁴²For a detailed discussion of Bayesian Estimation in the context of models like the the present one see [Schorfheide \(2011\)](#).

Table 5 lists the variables used as observables in the estimation (A more detailed description along with data sources can be found in appendix H). These comprise short-term nominal interest rates, the euro-dollar nominal exchange rate, GDP growth rates and various inflation rates for the two countries, as well as the change in bilateral trade to GDP ratio. Compared to previous studies like Lubik and Schorfheide (2006) that have used only one measure of prices (namely the CPI inflation) I use both CPI and GDP deflator based inflation as well as trade data (and an import price index for the US in some specifications). This is done in order to make the likelihood of the model more informative regarding the new features and parameters introduced in the model. The US data is taken from the Bureau of Economic Analysis and the European data is taken from the European Central Bank’s Area Wide Model (AWM) database. Bilateral Trade data comes from the IMF’s Direction of Trade Statistics (Database). The DOTS covers only merchandise trade which in the absence of more comprehensive data will be used as a proxy for aggregate trade.⁴³ Prior to estimation, all the data is seasonally adjusted and demeaned.

Shocks

All estimated models allow for a minimum of 10 shocks. These include government spending shocks, idiosyncratic (country-specific) productivity shocks, labor supply shocks and monetary policy shocks for each country, as well as a global productivity shock and a shock to the nominal exchange rate depreciation rate. Moreover, since import and export prices are particularly vulnerable to miscalculation,⁴⁴ I explicitly introduce measurement errors in this variable whenever it is included in the estimation exercise. Another reason to introduce measurement error in this equation is evident from 3.29, which shows that there is a linear relationship between three observables and hence stochastic singularity would arise in the absence of such a measurement error.

⁴³Since DOTS does not explicitly have the Eurozone imports from the US, I take the difference between European Union imports and imports by Britain.

⁴⁴see for instance Nakamura and Steinsson (2009)

Table 5 – 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
$\pi^{US,IMP}$	Import price inflation, US
Exchange Rate	
$\% \Delta E$	Nominal Depreciation rate of UD dollar against EURO
Output	
ΔY^{US}	GDP growth Rate, US
ΔY^{EU}	GDP growth Rate, EU
Trade	
$\Delta \left(\frac{Trade}{GDP} \right)$	Change in Trade/GDP ratio
$\Delta \left(\frac{Import}{GDP} \right)$	Change in Imports/GDP ratio

Priors

The first four columns of table 6 list the priors used in the estimation prices. Most of the priors are based on priors and estimates from [Lubik and Schorfheide \(2006\)](#), [Smets and Wouters \(2007\)](#) and [Smets and Wouters \(2003\)](#). There are two parameters that quantify trade finance dependence which are new in the paper (δ^{hf} and δ^{fh}). Regarding δ^{hf} and δ^{fh} , no off-the-shelf parameter estimates are available as reliable benchmarks. Relying on the observations from calibration results a value of 2 is used as the mean for the prior. A fairly high standard deviation is allowed in the prior in order to reflect parameter uncertainty. Regarding 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.

7 Estimation Results

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 borrowing at the US interest rate. This is the model which has the highest Bayes factor, as will be discussed later.

It is pertinent to note that the posterior estimates of the price stickiness parameters imply that the data supports a model in which there is asymmetry in the passthrough into import prices across the two countries. While the passthrough into EU import prices is quite low ($\theta^{\text{EU Import}}$ has a posterior mean of 0.87), the corresponding value for the US is fairly high (posterior mean of $\theta^{\text{US Import}}$ is 0.38). The obvious candidate behind this discrepancy seems to be the US import price index. Since import prices are known to be highly volatile, and since the estimation uses import prices for only the US, it is likely to lead to high passthrough estimates (low price stickiness parameters). This, however is not the case, since the passthrough estimates do not change much even if the US import price inflation is removed from the list of observables used in the estimation, which is the case in the reported results.⁴⁵ These results are in line with estimates from [Lubik and Schorfheide](#)

⁴⁵Even when it is included, the estimation procedure explicitly allows for measurement error in this variable in order to account for the extremely high volatility of this variable compared to other prices used in the

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

Parameter	Description	Prior			Posterior		
		Distribution	Mean	Stdev	Mean	90% C.I	
θ^{US}	Calvo Domestic	beta	0.5	0.05	0.837	0.8	0.874
θ^{US} Import	Calvo Import	beta	0.5	0.1	0.377	0.229	0.518
θ^{EU} Import	Calvo Import	beta	0.5	0.1	0.872	0.726	0.986
θ^{EU}	Calvo Domestic	beta	0.5	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	Intra Temporal 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}	US TFP Persistence	beta	0.8	0.1	0.996	0.992	0.999
ρ_R^{US}	US Interest rate Smoothing	beta	0.5	0.2	0.821	0.789	0.856
ρ_G^{US}	US 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	gam	2	0.75	2.27	0.991	3.423
$\delta^{US \rightarrow EU}$	Trade Finance Parameter: US	gam	2	0.75	1.837	0.735	2.909
ρ_N^{US}	US 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 2 chains) after burn in with the posterior mode used as the starting value for each parameter

Table 7 – Summary of Priors and Posterior distributions of Standard Deviations of shocks

Shock	Prior Distribution	Posterior				
		Mean	Stdev	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. h denotes the home country (US) and f denotes the foreign country (EU)

(2006) who also find evidence in favor of this asymmetry. Table 8 shows a comparison of the posterior means for the Calvo parameters from table 6. In their case this difference may also be driven by the choice of their prior distribution, which is asymmetric and implies higher price flexibility in the US compared to EU for both domestic and import prices.⁴⁶ This paper on the other hand does not impose this asymmetry ex ante.

Table 9 reports the log marginal density for various specifications of the model that are estimated, along with the Bayes factor for each model in comparison to the model without estimation.

⁴⁶They rely on [Bils and Klenow \(2004\)](#) and [Angeloni et al. \(2006\)](#) to impose a high prior on Europe and low prior on the US.

Table 8 – Comparison of Calvo Parameters with [Lubik and Schorfheide \(2006\)](#)

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

Table 9 – 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	US interest rate trade finance	-1227.37	5825
4	EU interest rate trade finance	-1236.15	0.9
5	Importer Interest rate trade finance	-1227.42	5541
6	Exporter interest rate trade finance	-1232.34	40

Notes: The second model “trade finance: both Interest rates” allows for trade finance to be dependent on both home and foreign interest rates

trade finance. Assuming the prior 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 (i.e lower absolute values) indicating higher posterior odds for the corresponding model.⁴⁷ The last column report 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 one indicate that the respective model is more preferred by the data than the baseline model. According to [Jeffreys \(1998\)](#), any Bayes factor greater than 30 is “very strong ” and a Bayes factor greater than 20 is “decisive” evidence.

As can be seen from the first row, the models with trade financing with US interest rates and importer interest rates carry the highest posterior probability and Bayes factors. The first of these is not surprising, given the central role that US 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.⁴⁸ The higher posterior marginal data density of the model with importer interest rate trade finance is interesting. Although the majority of the empirical literature in trade finance has documented the link between exporter monetary policy and volume of exports, theoretical justifications given for these apply equally to the link between imports and interest rates as well. The question of which channel (or both) is

⁴⁷Note that this comparison is valid as long as the prior is proper, which is the case throughout this paper.

⁴⁸For evidence regarding the latter, see [Goldberg and Tille \(2008\)](#).

more important is an empirical question that calls for more research and this paper provides indicative evidence that the link between imports and external finance conditions in importing countries could be an important aspect affecting business cycle fluctuations. In the data, the trade finance channel seems to be governed by the interaction of US interest rates with US imports. Since European imports play a limited role due to their low price flexibility, the models with US interest rate and importer interest rate financing both seem to be consistent and the data is not clearly able to distinguish between the two.⁴⁹

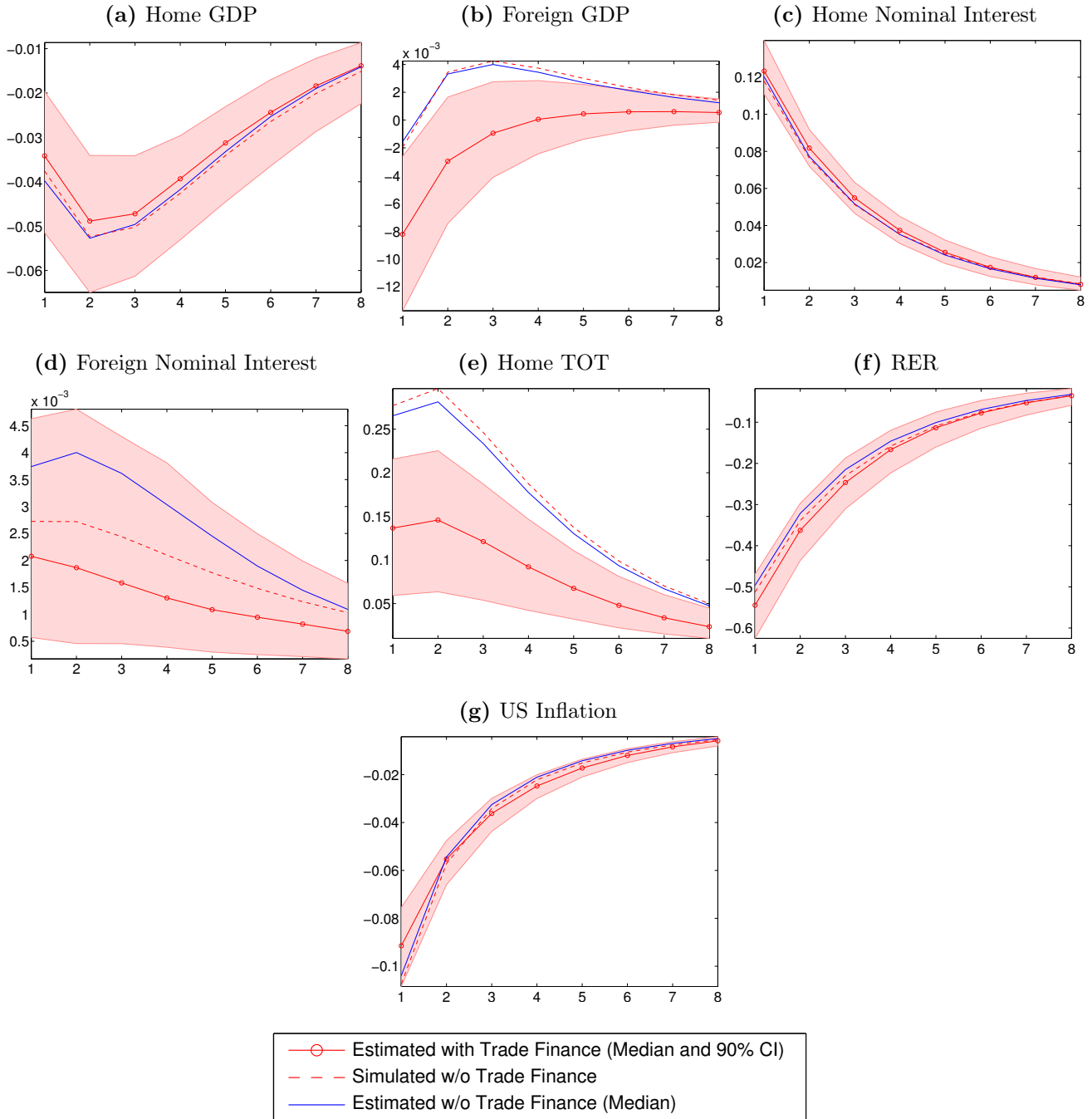
Comparison of Shock Propagation Mechanism Across Estimated Versions of the Model

This section illustrates the differences in propagation mechanisms using estimated impulse responses for two shocks. Figure 7.1 shows the impulse response of a one standard deviation US monetary contraction (median and 90 percent confidence bands) using the estimated model with trade finance constraints and US 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 (labelled “Estimated w/o trade finance (Median)”) corresponds to the estimated model without trade finance constraints and the second (labelled “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 alternative ways of comparing the results with the estimated model with trade finance. Qualitatively, the results in figure 7.1 are broadly in line with the simulation results. Quantitatively, the figure shows that while the models generate similar predictions for the response of domestic GDP, they differ appreciably in the response of foreign GDP and terms of trade. This is also true in figure 7.2 which compares the estimated impulse responses to a monetary contraction with the model with importer trade finance taken as the benchmark.

Figures G.1 and G.2 in appendix G display a similar exercise with two non-monetary shocks—a one standard deviation labor supply shock and a one standard deviation productivity

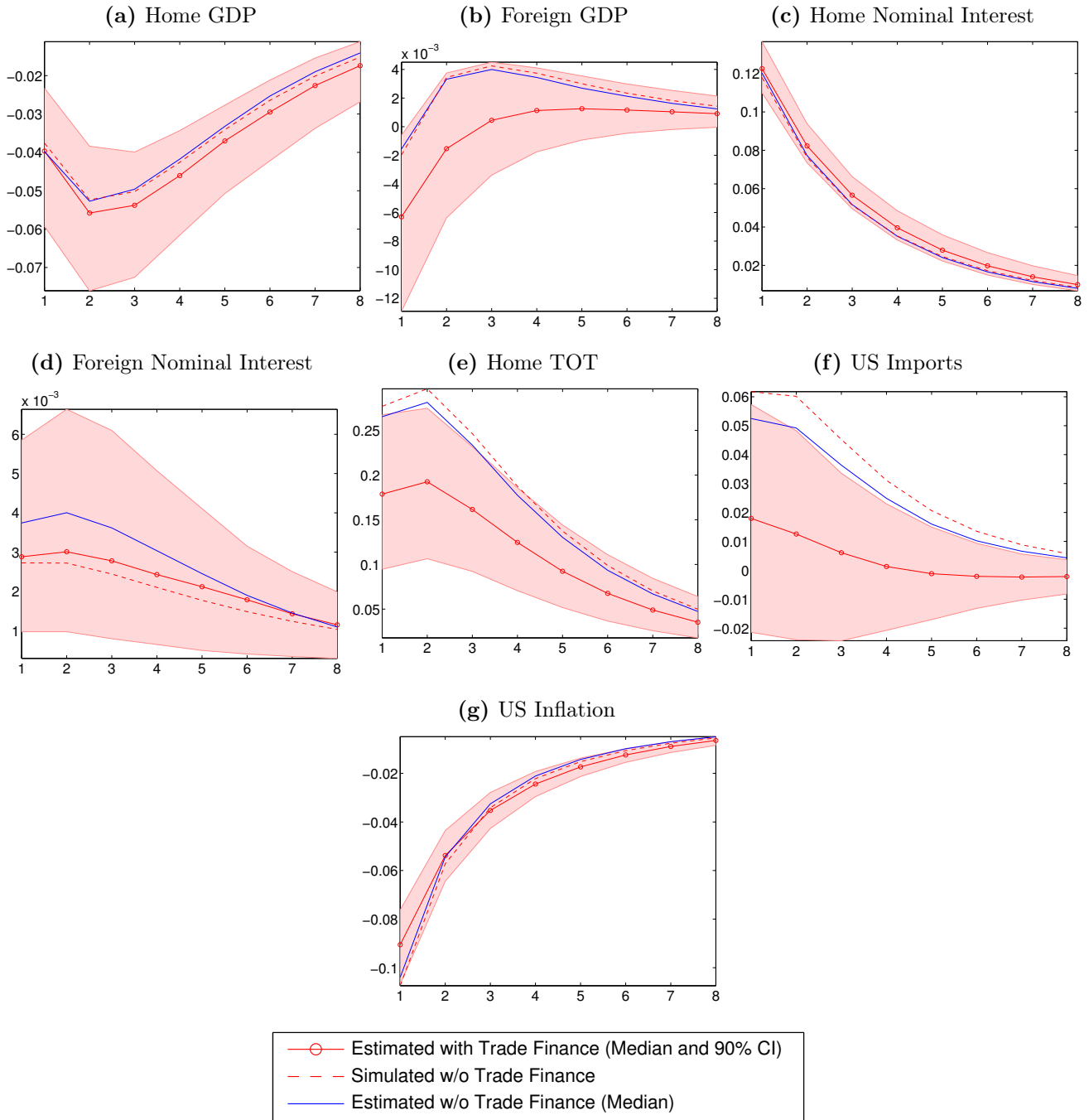
⁴⁹The parameter estimates are also quite similar across the two models. Table 10 in the appendix summarizes the parameter estimates for the latter model.

Figure 7.1 – US Monetary Contraction



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

Figure 7.2 – US Monetary Contraction



Note: Baseline model (dotted line) assumes importer country trade finance.

shock respectively. Once again, the results are qualitatively in agreement with the simulation results. The productivity shock, which has a high persistence (the autoregressive coefficient being 0.99) provides an opportunity to illustrate that since in line with evidence from the empirical literature trade finance is modeled in a way such that it has minimal impact at low frequencies, it is unlikely to make much difference in terms of the response of variables to persistent shocks, as is found to be the case in figure [G.2](#).

These results convey that trade finance constraints have a larger impact in altering the spillover effects of domestic shocks as opposed to the domestic effects themselves. One implication of this is that, for a large open economy like the US 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. The intuitive underpinning for this comes from the fact that trade finance exerts its influence on shock propagation by affecting terms of trade which translate into changes in trade volumes. As far as the domestic economy is concerned, it is therefore just an additional channel through which the main effects are likely to come from the domestic impact of shocks in variables only weakly related to international trade. 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 constraints. As a result, the incorporation of trade finance constraints matters more for spillover effects of shocks as opposed to domestic effects. Section [F](#) in the appendix considers some robustness which serve to show that the results reported in this section are fairly robust to alternate priors and model characteristics.

8 Implications for Monetary Policy

Spillover effects of monetary policy and the need and scope for monetary policy coordination across central banks has received renewed interest following the financial crisis which compelled many central banks to undertake extraordinary monetary policy actions. [Rajan \(2014\)](#) emphasized the need for reconsidering a possible role for monetary policy coordination and for countries-especially the US-to take into account the effects of their monetary policy actions on the rest of the world. This analysis lends support to the arguments made in the

speech on several counts. Insofar as trade finance is an important channel through which monetary policy affects domestic and foreign economies, this paper highlights the conditions under which spillover effects of monetary policy can be fairly large and can differ both qualitatively and quantitatively from the predictions of standard models. Moreover, it also shows that trade finance alters the spillover effects of domestic shocks in significant ways while affecting the domestic economy only mildly. This implies that although it might be beneficial to re-evaluate the merits of monetary policy coordination in light of these results, it might not necessarily be in the best interest of the central country to take initiatives to do so, given their domestic mandates.⁵⁰

Evidence regarding the importance of US interest rates as the primary determinant of trade finance conditions uncovered here is in line with the central role that US monetary policy is acknowledged to play in the global economy.⁵¹ Since the US dollar is the primary vehicle currency for international trade (Goldberg and Tille 2008), US interest rates are likely to be the primary determinants of external finance conditions in international trade, a consequence of what has been termed the “exorbitant privilege”.⁵² Since this is likely to be the case more generally across countries and especially emerging markets and developing economies, a new channel through which US monetary policy can affect countries is uncovered in this analysis, above and beyond traditional trade and financial linkages. For instance, even if there are two economies that trade with each other but have no direct trade or financial linkages with the US, US monetary policy can affect these economies by affecting the external finance conditions that trade firms are subject to.⁵³

Because interest rates affect financing costs governing international trade, competitive devaluations or “currency wars” may not always be a zero sum game and may actually end up increasing welfare even in the absence of distortions associated with monopoly power on the part of firms.

⁵⁰Fischer (2014) for instance emphasizes the domestic objectives of the Federal Reserve, arguing that it is not the global central bank.

⁵¹See for instance Rey (2013) and Bruno and Shin (2013) for the critical role played by US monetary policy in driving the global economic cycle.

⁵²See for McCauley (2015) for a critical assessment of the exorbitant privilege of the US.

⁵³See McCauley et al. (2015) for a description of offshore dollar credit including its determinants and evolution since the great recession.

9 Conclusion

This paper assesses how international trade finance affects business cycle fluctuations in open economies by modeling the link between trade finance and the cost channel of monetary policy in a two-country New Keynesian DSGE model. Unlike the domestic component of the cost channel of monetary policy, which has been studied extensively in the literature, this 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 with respect to their sensitivity to trade finance conditions, trade finance constraints lead to sharp movements in terms of trade and trade volumes, but do not significantly alter the response of GDP to shocks in either country. But if external sectors are asymmetric, trade finance constraints significantly alter the response of GDP to both monetary and non-monetary shocks. Various sources of this asymmetry (including differences in import price flexibility) are identified and their implications are explored.

Bayesian techniques are used to estimate a two-country DSGE model with trade finance using data from the US and the Eurozone (EZ), two regions which share one of the largest bilateral trade relationships in the world. Based on formal model comparison exercises, models that appropriately incorporate trade finance constraints are found to provide a better characterization of the data and trade finance is established to be quantitatively important even after accounting for parameter uncertainty. Moreover, trade finance is found to have a larger impact on spillover effects of shocks rather than the effects on the country of origin. The intuition for this is as follows: Because of home bias in consumption, the domestic sector in a country is typically larger than the external sector. When a shock originates in the domestic sector, its primary impact is through the direct impact that it has on the domestic sector. For instance, in the case of a monetary contraction, the primary impact comes from a rise in the risk free rate, which alters the consumption-saving decision of households and leads to a fall in aggregate demand and prices. If the economy is open, there is an additional effect of the shock which comes from the external sector (in the case of a monetary contraction, this would be a fall in demand due to an appreciation of the exchange rate). However, since the external sector is small, the second effect is small as far as the domestic economy is concerned. This is no longer true for the spillover effects of the shock to other countries. These spillover effects are transmitted exclusively through the external sectors of the two countries, so if trade finance can influence the dynamics of these external sectors, it can make large alterations to the spillover effects. This makes the incorporation of trade finance constraints especially

important for understanding business cycles in small open economies and countries that face a sizable fraction of their fluctuations due to shocks originating beyond their borders. On the other hand, omission of trade finance in modeling a large open economy like the US may indeed be innocuous.

The parameter estimates across models provide compelling evidence for asymmetry in import price flexibility across these two countries. In particular, US import prices are found to be more flexible than their European counterparts. In line with the theoretical results discussed in the paper, this distinction implies that trade finance matters not only for trade volumes and terms of trade, but also for variables like GDP and inflation. This is the first paper to consider the implications for heterogeneity in import price flexibility across countries and estimate the relevant parameters. While the estimates are somewhat in agreement with [Lubik and Schorfheide \(2006\)](#), who also estimate analogous parameters, they seem to be at odds with the extensive literature which has found passthrough (in particular with regards to the nominal exchange rate) into US import prices to be low, pointing to a very low import price flexibility for the US.⁵⁴ Although a thorough exploration of this apparent discrepancy requires detailed examination of micro data and is beyond the scope of this paper, two possible explanations can be conjectured. Firstly, while the trade literature for the most part has focussed exclusively on nominal exchange rate passthrough, the asymmetry revealed here is with regard to passthrough 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 focussed 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 markets and intermediaries involved would be an important part of interpreting these findings.

Models incorporating the financial accelerator have become prominent in the DSGE literature, especially since the financial crisis. In order to isolate the role of trade finance in the simplest possible setting, this paper abstracted from the interaction between firm value and external finance premia. Endogenizing the external finance premium, in particular its variation across time while maintaining the international vs intra-national trade distinction would be an extension worth pursuing in future research.

Lastly, the approach in this paper is primarily positive and is focused on analyzing the role of trade finance constraints in affecting the propagation mechanism of shocks. Given the strong evidence in favor of models incorporating trade finance, normative aspects of trade finance also seem worthy of consideration. Most important amongst these is likely to be a characterization of optimal monetary policy in models incorporating trade finance constraints.

⁵⁴See for instance [Gopinath et al. \(2010\)](#)

Although [Ravenna and Walsh \(2006\)](#) characterize the optimal monetary policy problem in the presence of the cost channel, they do so in a closed economy setting. As emphasized above, the more important cost side effects are likely to come from international trade finance constraints and their incorporation into an optimal monetary policy problem is likely to be a fruitful avenue for future research, especially for economies that face a larger fraction of their fluctuations from foreign shocks.

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Appendix

A Simulated Impulse Responses

A.1 Monetary Shocks

See figures [A.1-A.4](#).

A.2 Non-Monetary Shocks

Government Spending Shock

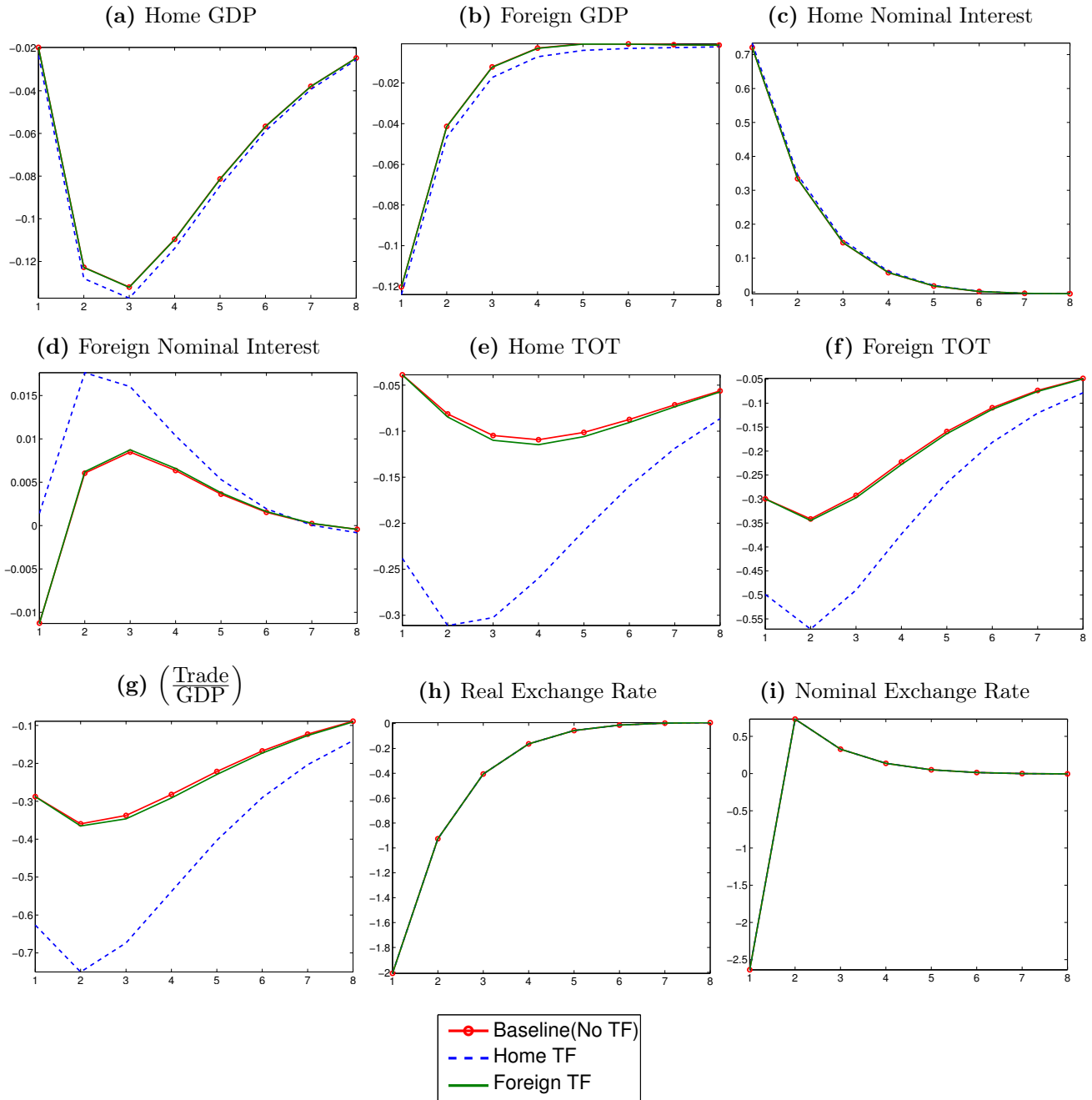
Figure [A.5](#) shows the impulse response to a home government spending shock in the symmetric case for three models that differ in their trade finance setup as indicated, and under three different scenarios of import price flexibility as described above. The results are in line with those reported in table [4](#).

Productivity Shocks

Positive productivity shocks present the opposite scenario to the one operational in the case of monetary contractions and positive aggregate demand shocks since with the interest rule modeled in the paper they typically lead to a fall in interest rates following a positive shock. Figures [A.6](#) through [A.11](#) illustrate the impulse responses of different variables in the model to a positive home productivity shock under different model assumptions as before.

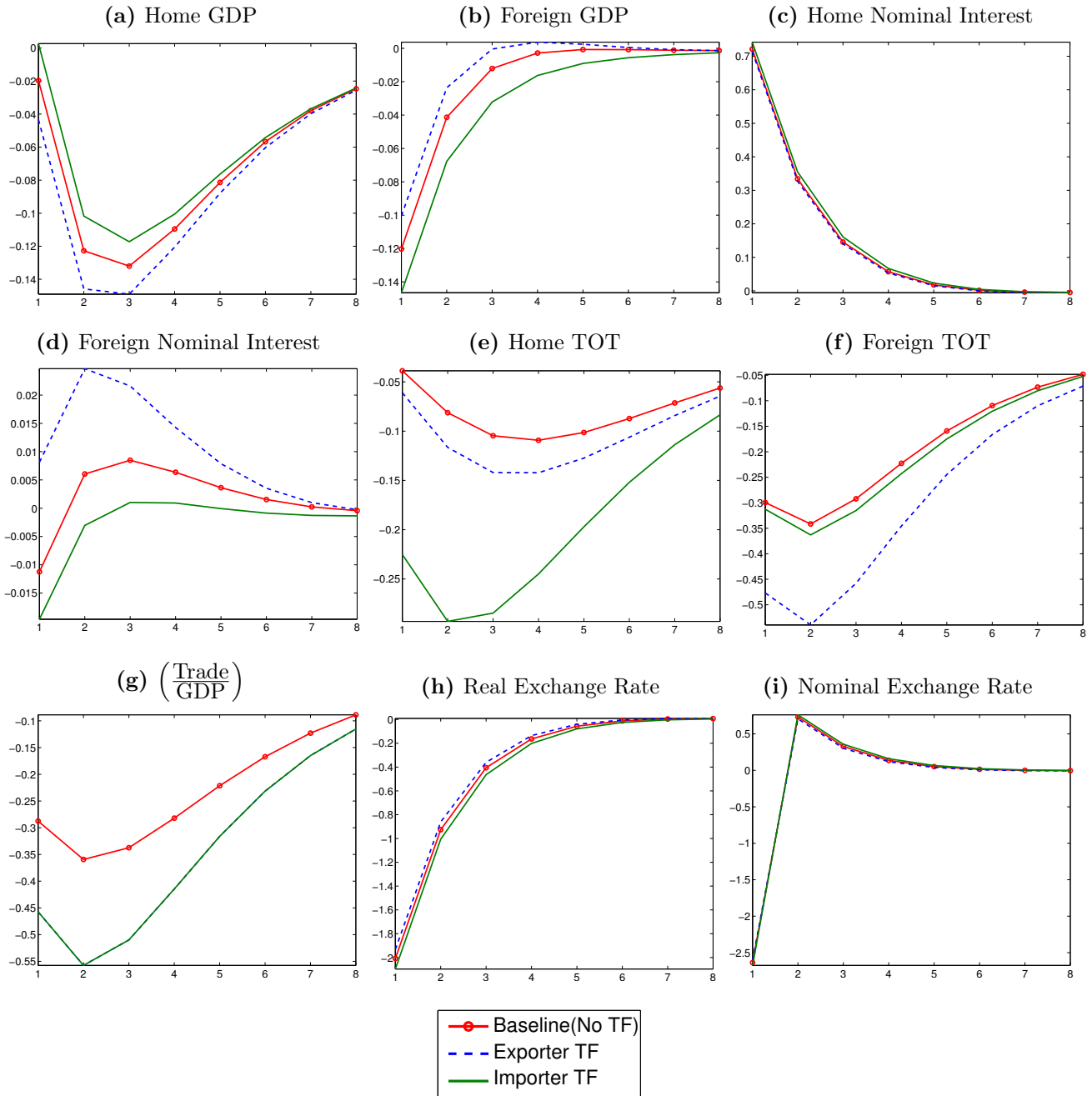
The results are in line with those reported above (and summarized in table [4](#)), but operational in reverse, so that when home import prices are more flexible than their foreign counterpart, trade finance constraints end up increasing the demand for foreign goods compared to the model without trade finance constraints. (see figure [A.6](#)).

Figure A.1 – Home Monetary Contraction: $\theta^{fh} = 0.7, \theta^{hf} = 0.7$



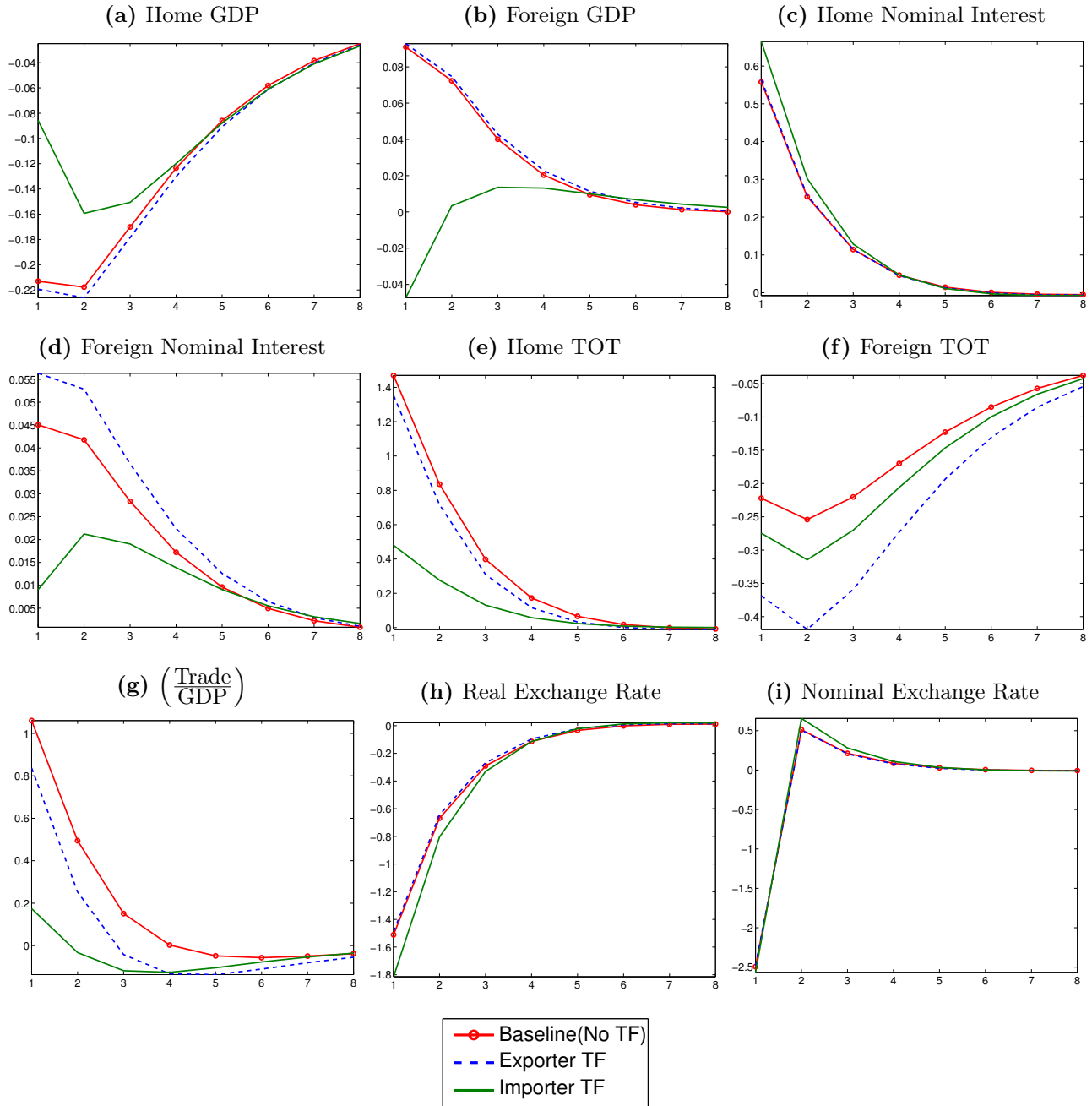
Notes: The impulse responses are computed through simulations using the values in table 3. The horizontal axis measures time in quarters. The vertical axis units are deviations from the unshocked path. Inflation and nominal interest rate are given in annualized percentage points. The other variables are in percentages.

Figure A.2 – Home Monetary Contraction: $\theta^{fh} = 0.7, \theta^{hf} = 0.7$



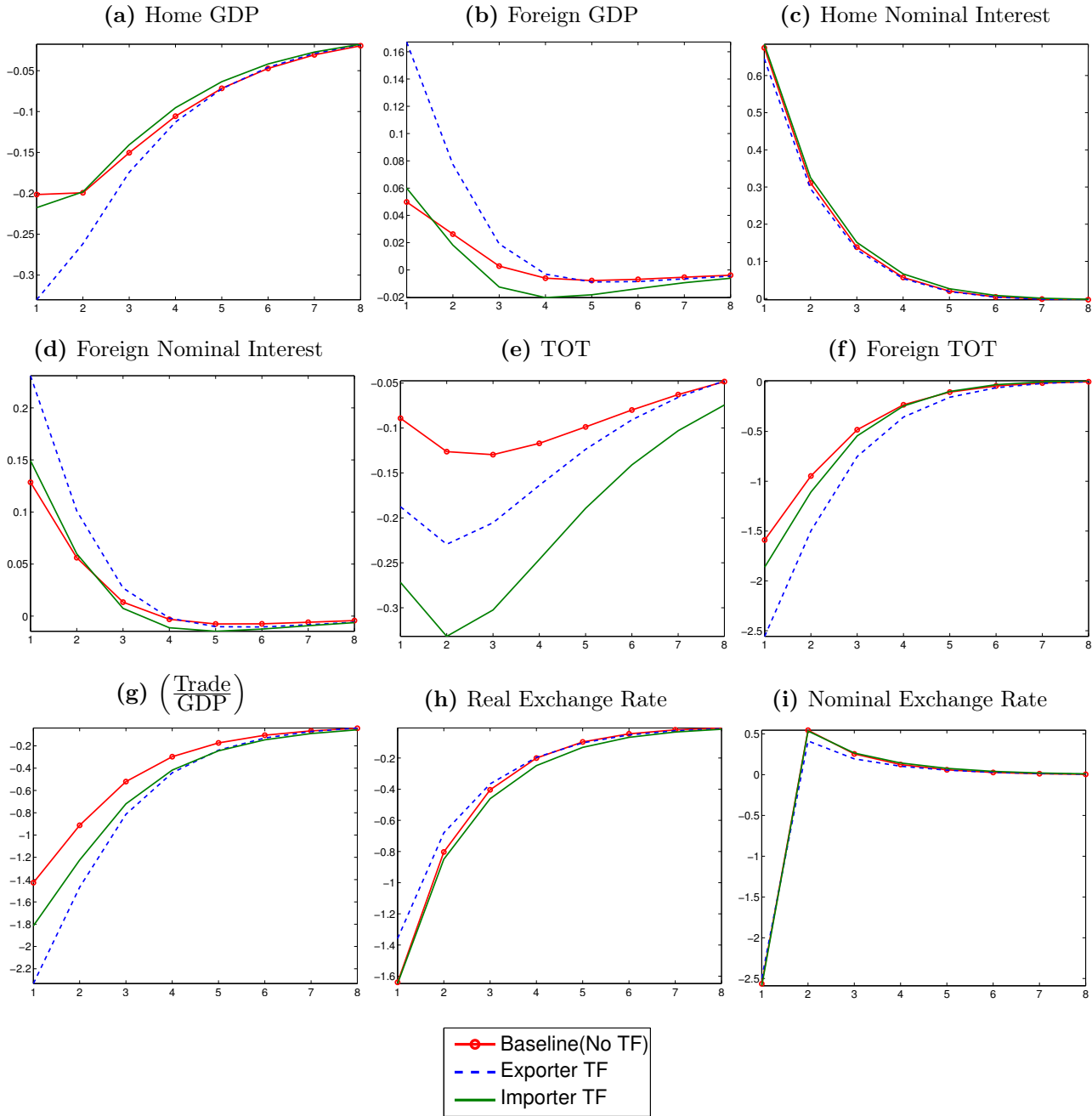
Notes: The impulse responses are computed through simulations using the values in table 3. The horizontal axis measures time in quarters. The vertical axis units are deviations from the unshocked path. Inflation and nominal interest rate are given in annualized percentage points. The other variables are in percentages.

Figure A.3 – Home Monetary Contraction: $\theta^{fh} = 0.1, \theta^{hf} = 0.7$



Notes: The impulse responses are computed through simulations using the values in table 3. 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.

Figure A.4 – Home Monetary Contraction: $\theta^{hh} = 0.7, \theta^{hf} = 0.1$



Notes: The impulse responses are computed through simulations using the values in table 3. 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.

Figure A.5 – Home Government Spending Shock

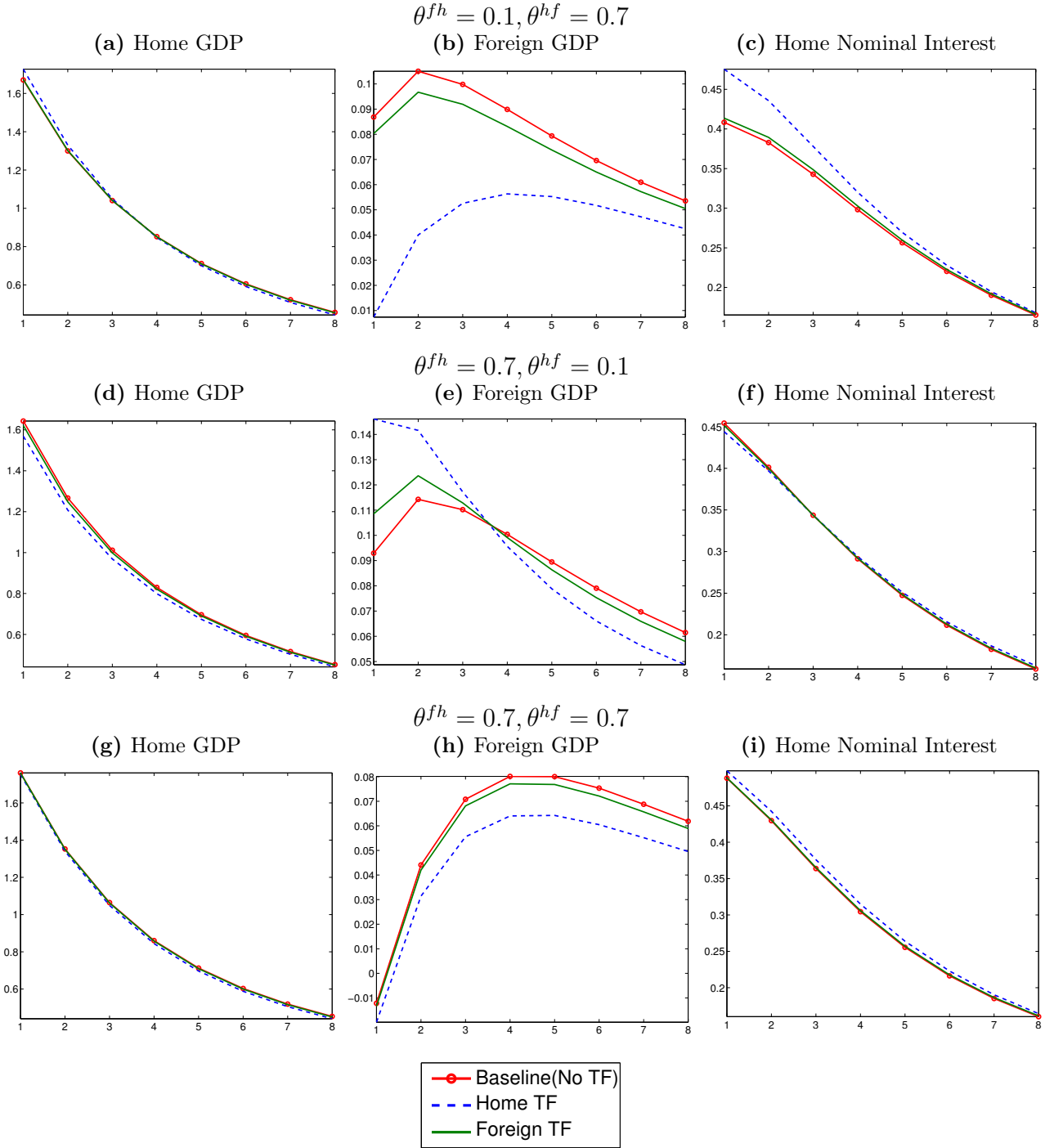
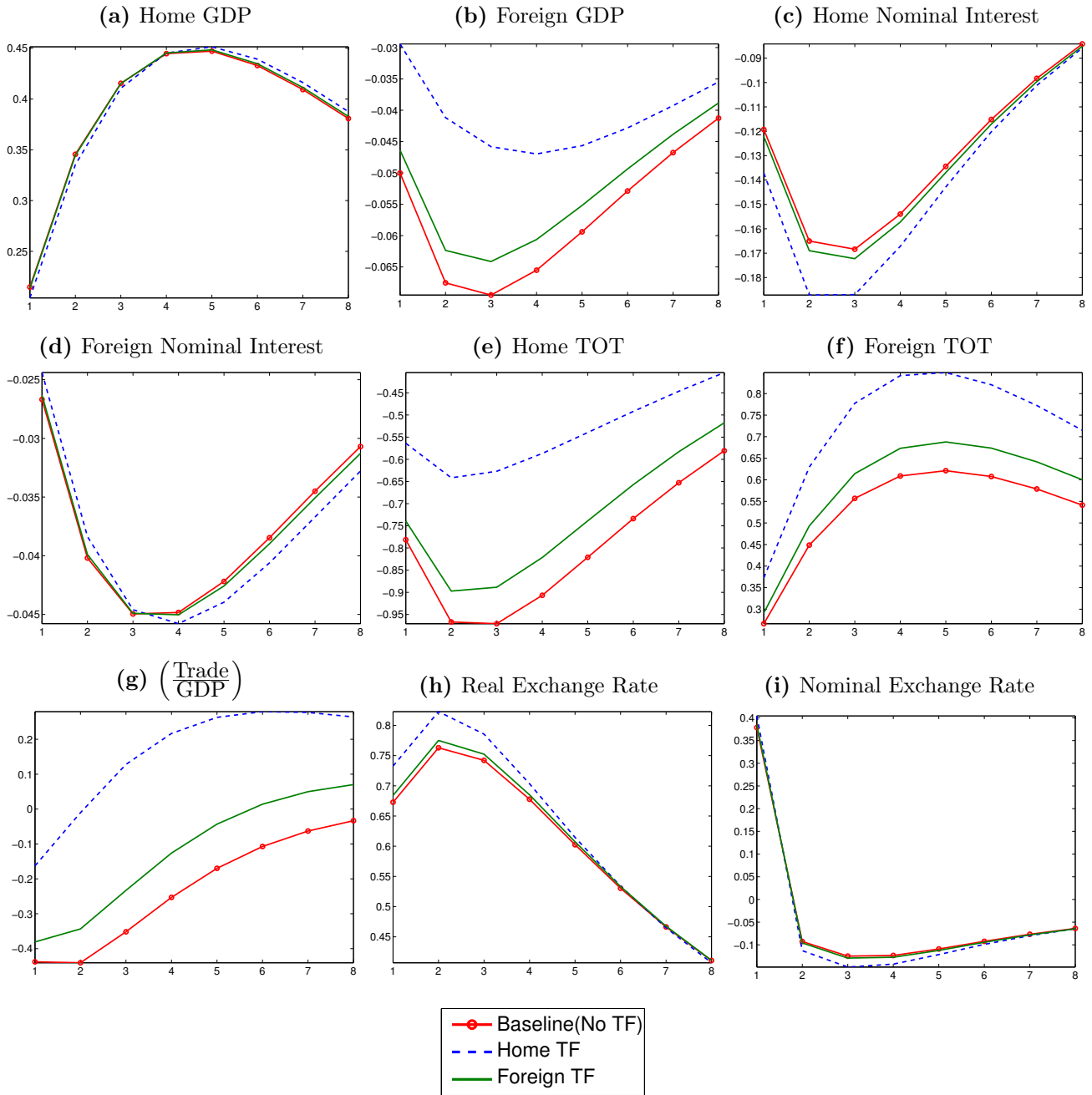
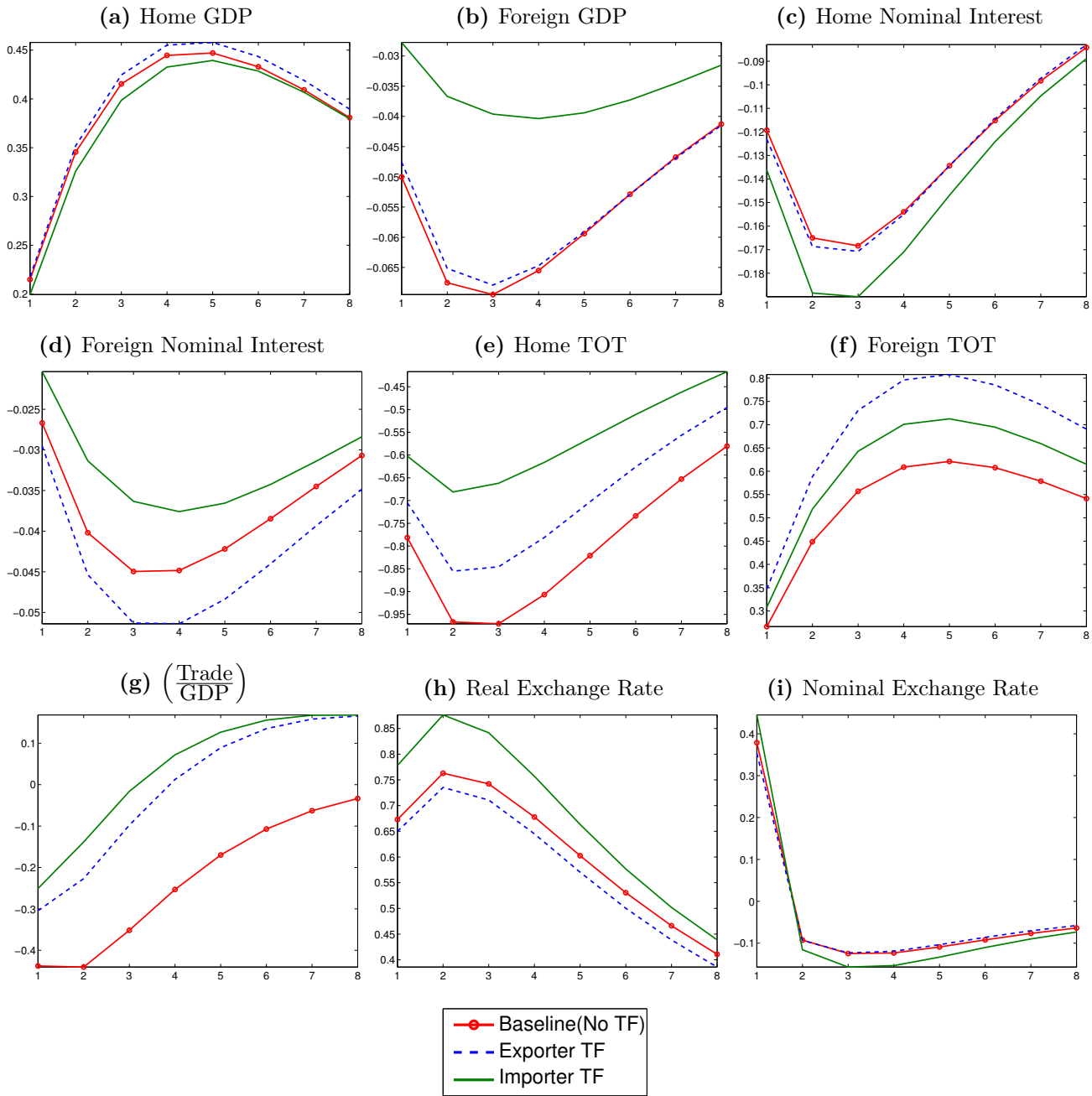


Figure A.6 – Home Productivity Shock: $\theta^{fh} = 0.1, \theta^{hf} = 0.7$



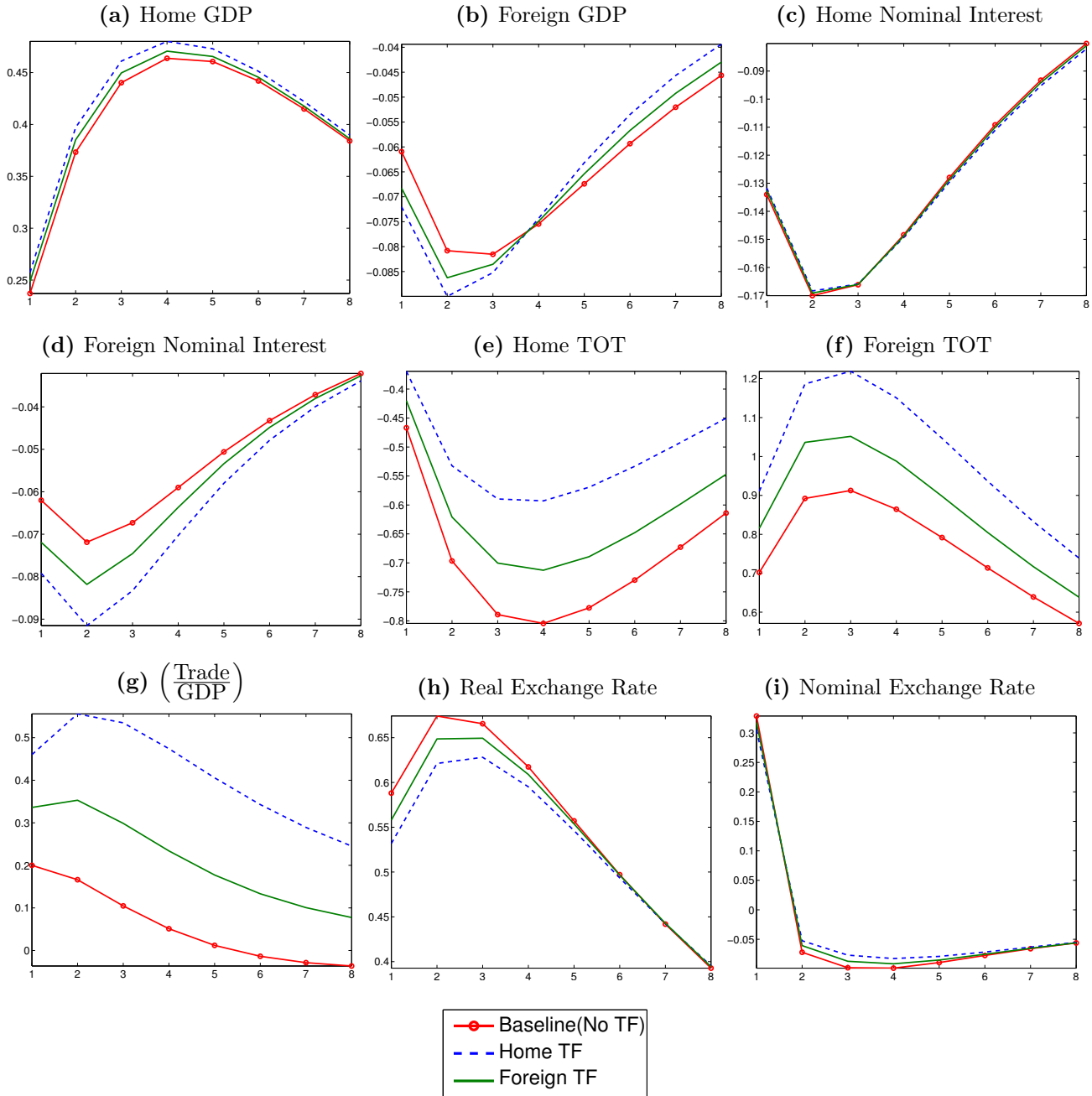
Notes: The impulse responses are computed through simulations using the values in table 3. The horizontal axis measures time in quarters. The vertical axis units are deviations from the unshocked path. Inflation and nominal interest rate are given in annualized percentage points. The other variables are in percentages.

Figure A.7 – Home Productivity Shock: $\theta^{fh} = 0.1, \theta^{hf} = 0.7$



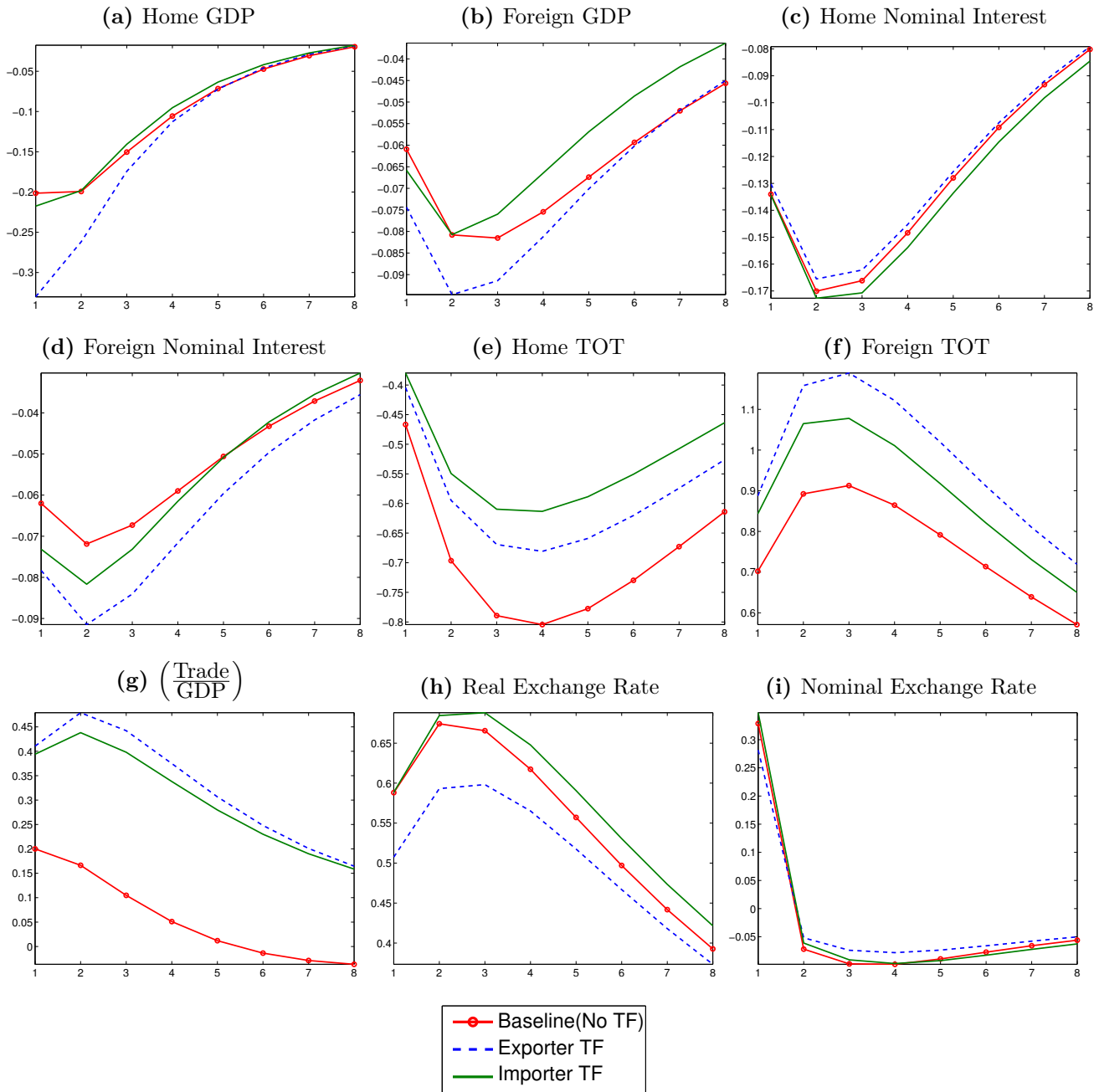
Notes: The impulse responses are computed through simulations using the values in table 3. The horizontal axis measures time in quarters. The vertical axis units are deviations from the unshocked path. Inflation and nominal interest rate are given in annualized percentage points. The other variables are in percentages.

Figure A.8 – Home Productivity Shock: $\theta^{fh} = 0.7, \theta^{hf} = 0.1$



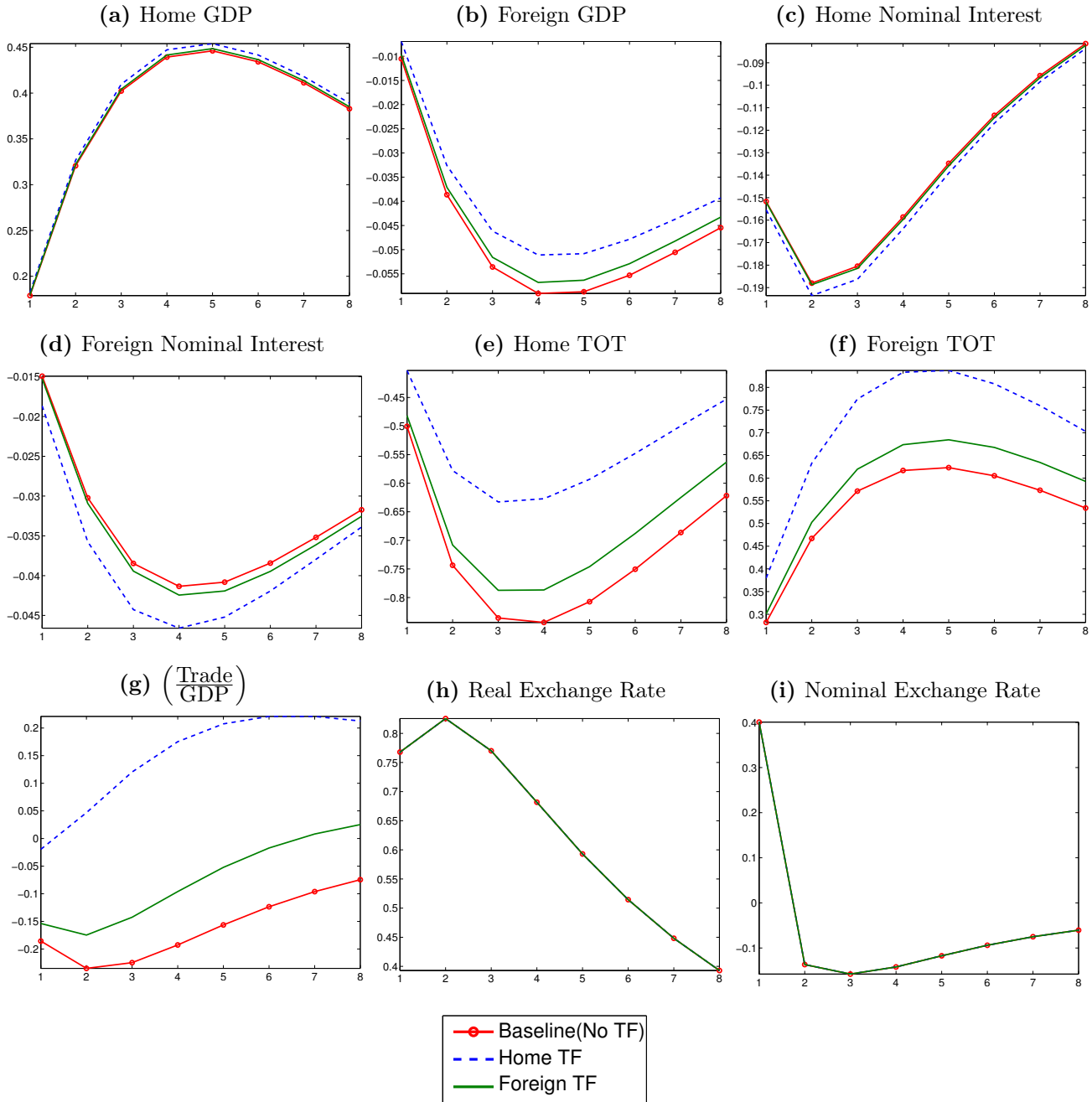
Notes: The impulse responses are computed through simulations using the values in table 3. The horizontal axis measures time in quarters. The vertical axis units are deviations from the unshocked path. Inflation and nominal interest rate are given in annualized percentage points. The other variables are in percentages.

Figure A.9 – Home Productivity Shock: $\theta^{fh} = 0.7, \theta^{hf} = 0.1$



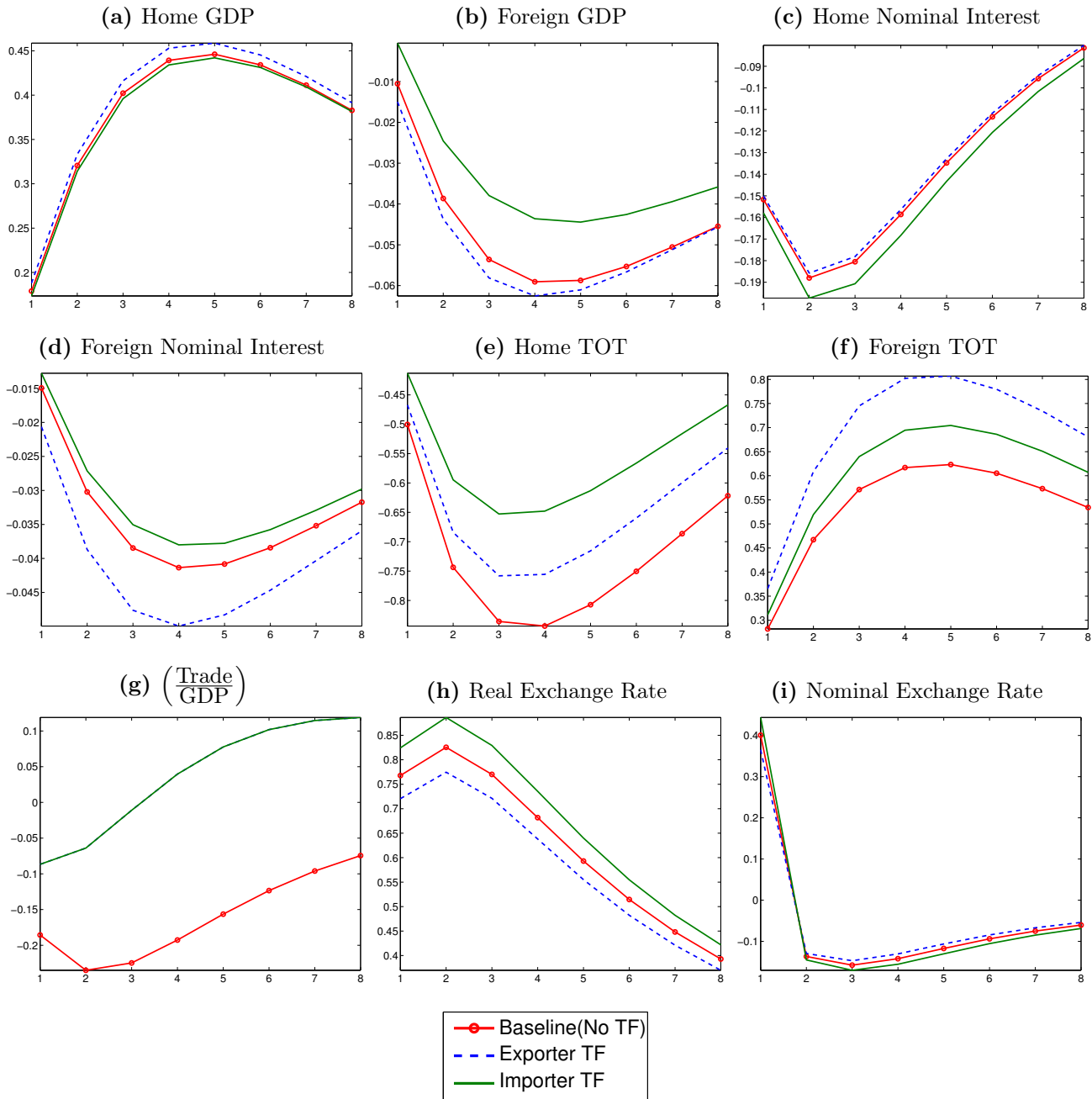
Notes: The impulse responses are computed through simulations using the values in table 3. The horizontal axis measures time in quarters. The vertical axis units are deviations from the unshocked path. Inflation and nominal interest rate are given in annualized percentage points. The other variables are in percentages.

Figure A.10 – Home Productivity Shock: $\theta^{fh} = 0.7, \theta^{hf} = 0.7$



Notes: The impulse responses are computed through simulations using the values in table 3. 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.

Figure A.11 – Home Productivity Shock: $\theta^{fh} = 0.7, \theta^{hf} = 0.7$



Notes: The impulse responses are computed through simulations using the values in table 3. 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.

B Application: Expansionary Monetary Contractions

Expansionary monetary contractions (or equivalently contractionary devaluations) are phenomena that standard macro models are unable to account for, especially for advanced economies. Although, liability dollarization can explain this puzzle for developing economies (see for instance (Cook, 2004)), these explanations cannot explain the evidence in favor of expansionary monetary contractions in the US based on certain identified vector autoregressions like those in Uhlig (2005). The trade finance mechanism proposed in this paper can in principle account for this result if the external finance dependence is relatively high. Figure B.1 displays the impulse responses to a home monetary contraction with asymmetric passthrough ($\theta^{hf} = 0.9, \theta^{fh} = 0.1$) and varying degrees of external finance dependence when the elasticity of substitution is 2. It shows that in this case when δ is high enough, home output actually expands following a monetary contraction. The reason is that although the exchange rate appreciates, because of the heavy reliance of imports on external finance import prices increase to such an extent that demand for home output ends up increasing, even though aggregate demand by home agent falls.

C Model With Sticky Wages

Household Problem is to maximize utility given by:

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

Subject to the per period budget constraint given by:

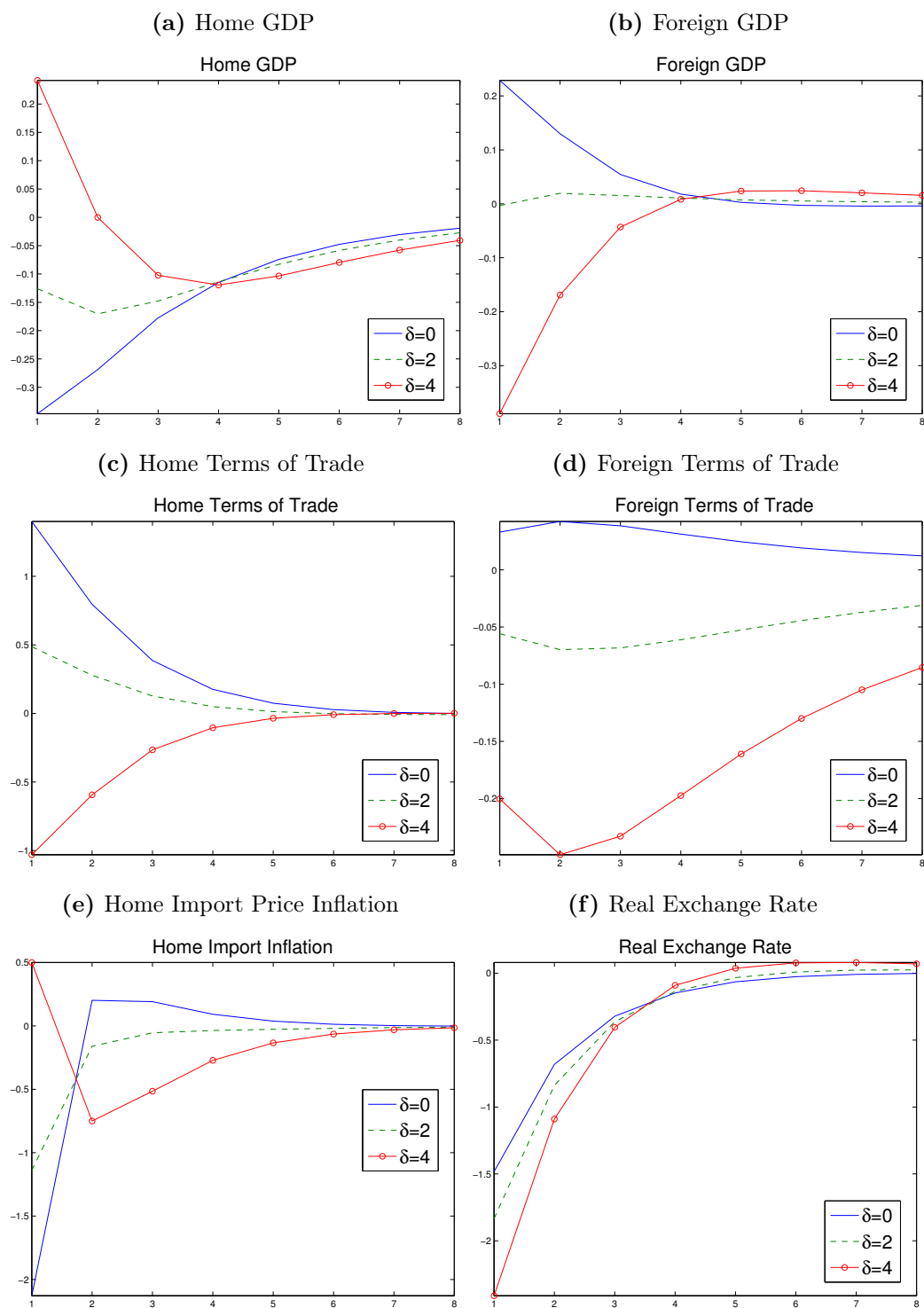
$$P_t^{cpi} C_t + \int_s \mu_{t,t+1}(s) D_{t+1}(s) \leq W_t N_t + D_t + T_t \quad (\text{C.2})$$

and the labor demand schedule given by:

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

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

Figure B.1 – Expansionary Monetary Contractions



Notes: $\theta^{hf} = 0.9, \theta^{fh} = 0.1, \eta = 2$. Remaining parameters are calibrated to values in table 3. 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.

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

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

Which linearizes to:

$$\hat{w}_t^* = (\beta\theta_w)E_t(\hat{w}_{t+1}^*) + (1 - \beta\theta_w)\left(\hat{U}_N(t) - \hat{U}_c(t) + \hat{p}_c(t)\right) \quad (\text{C.5})$$

The aggregate wage evolves according to the following equation:

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

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

$$\hat{w}_t = \frac{\beta\theta_w}{1 + \beta\theta_w^2}E_t\hat{w}_{t+1} + \frac{\theta_w}{1 + \beta\theta_w^2}\hat{w}_{t-1} + \frac{(1 - \beta\theta_w)(1 - \theta_w)}{1 + \beta\theta_w^2}(\hat{U}_N(t) - \hat{U}_c(t) + \hat{p}_c(t)) \quad (\text{C.7})$$

D 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:

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

Draws from the posterior distribution are generated by applying the Gibbs Sampler using standard Markov Chain Monte Carlo (MCMC) techniques.⁵⁵

⁵⁵See [Koop et al. \(2007\)](#) for an overview of MCMC techniques.

Model Selection

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

$$\mathbb{P}(\mathbb{Y}|\mathbb{M}) = \int_{\theta_{\mathbb{M}}} \mathbb{P}(\mathbb{Y}|\mathbb{M}, \theta_{\mathbb{M}})\mathbb{P}(\mathbb{M}, \theta_{\mathbb{M}}) \quad (\text{D.2})$$

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.

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

One advantage of the Bayesian framework is that the models do not have to be nested.⁵⁶ 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.

⁵⁶Note 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

E Parameter Estimates for Model With Importer Interest Rate Trade Finance

Table 10 – Summary of Prior and Posterior Prior and Posterior Distribution of Estimated Parameters

Parameter	Description	Prior			Posterior		
		Distribution	Mean	Stdev	Mean	90% C.I	
θ^{US}	Calvo Domestic	beta	0.7	0.05	0.8507	0.815	0.8876
θ^{US} Import	Calvo Import	beta	0.5	0.15	0.3525	0.2044	0.5103
θ^{EU} Import	Calvo Import	beta	0.5	0.15	0.8029	0.6366	0.9809
θ^{EU}	Calvo Domestic	beta	0.7	0.05	0.7494	0.6947	0.8073
σ_c	Intertemporal Elasticity	gamma	1	0.5	4.4685	3.288	5.6461
σ_L	Labor supply Elasticity	gamma	2	0.5	1.6053	1.0014	2.205
h	Habit Parameter	beta	0.5	0.1	0.5452	0.3916	0.704
η	Intra Temporal Elasticity	gamma	1	0.25	0.4044	0.2543	0.5505
ϕ_π^{US}	Taylor Rule Parameter	gamma	1.5	0.25	1.8714	1.5407	2.1731
ϕ_y^{US}	Taylor Rule Parameter	gamma	0.5	0.25	0.4654	0.2106	0.7025
ϕ_e^{US}	Taylor Rule Parameter	gamma	0.1	0.05	0.0312	0.0099	0.0509
ϕ_π^{EU}	Taylor Rule Parameter	gamma	1.5	0.25	1.8547	1.5163	2.1842
ϕ_y^{EU}	Taylor Rule Parameter	gamma	0.5	0.25	0.5387	0.2365	0.8255
ϕ_e^{EU}	Taylor Rule Parameter	gamma	0.1	0.05	0.0271	0.0077	0.0448
ρ_A^{US}	US TFP Persistence	beta	0.8	0.1	0.7892	0.7149	0.8681
ρ_R^{US}	US Interest rate Smoothing	beta	0.5	0.2	0.8247	0.794	0.8553
ρ_G^{US}	US Government spending Persistence	beta	0.8	0.1	0.9655	0.9463	0.9848
ρ_A^{EU}	EU TFP Persistence	beta	0.6	0.2	0.5841	0.2818	0.9445
ρ_R^{EU}	EU Interest rate Smoothing	beta	0.5	0.2	0.8633	0.8372	0.8891
ρ_G^{EU}	EU Government spending Persistence	beta	0.8	0.1	0.9275	0.8869	0.9699
ρ_Z	Global Productivity Persistence	beta	0.66	0.15	0.4494	0.2541	0.644
$\delta^{EU \rightarrow US}$	Trade Finance Parameter: US	gamma	2	0.75	2.1414	0.9446	3.2773
$\delta^{US \rightarrow EU}$	Trade Finance Parameter: US	gamma	2	0.75	2.1258	0.8294	3.341
ρ_N^{US}	US Labor Supply Shock persistence	beta	0.85	0.1	0.9989	0.9989	0.9989
ρ_N^{EU}	EU Labor Supply Shock persistence	beta	0.85	0.1	0.8859	0.8352	0.9416

Notes: The results are based on 200,000 MCMC draws (split across 2 chains) after burn in with the posterior mode used as the starting value for each parameter

Table 11 – 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

Notes: 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.

F 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 11 reports posterior means of these parameters under different variations of the model. For each of the cases reported in table 11, 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 to 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 intra-temporal 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.⁵⁷ 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.⁵⁸ As is evident from the results reported in the table, the estimates of

⁵⁷A more thorough approach would be to allow for dynamic elasticities as discussed in Drozd et al. (2014) and Crucini and Davis (2013). However, this approach is not undertaken since the main message of the paper is robust to the value of the elasticity used.

⁵⁸See for instance Christiano et al. (2005), Barth III and Ramey (2002) and Ravina (2007)

the main parameters of interest are robust to all these departures from the baseline version of the model.

G Estimated Impulse Responses for non-monetary Shocks

Figure G.1 – US Labor Supply Shock

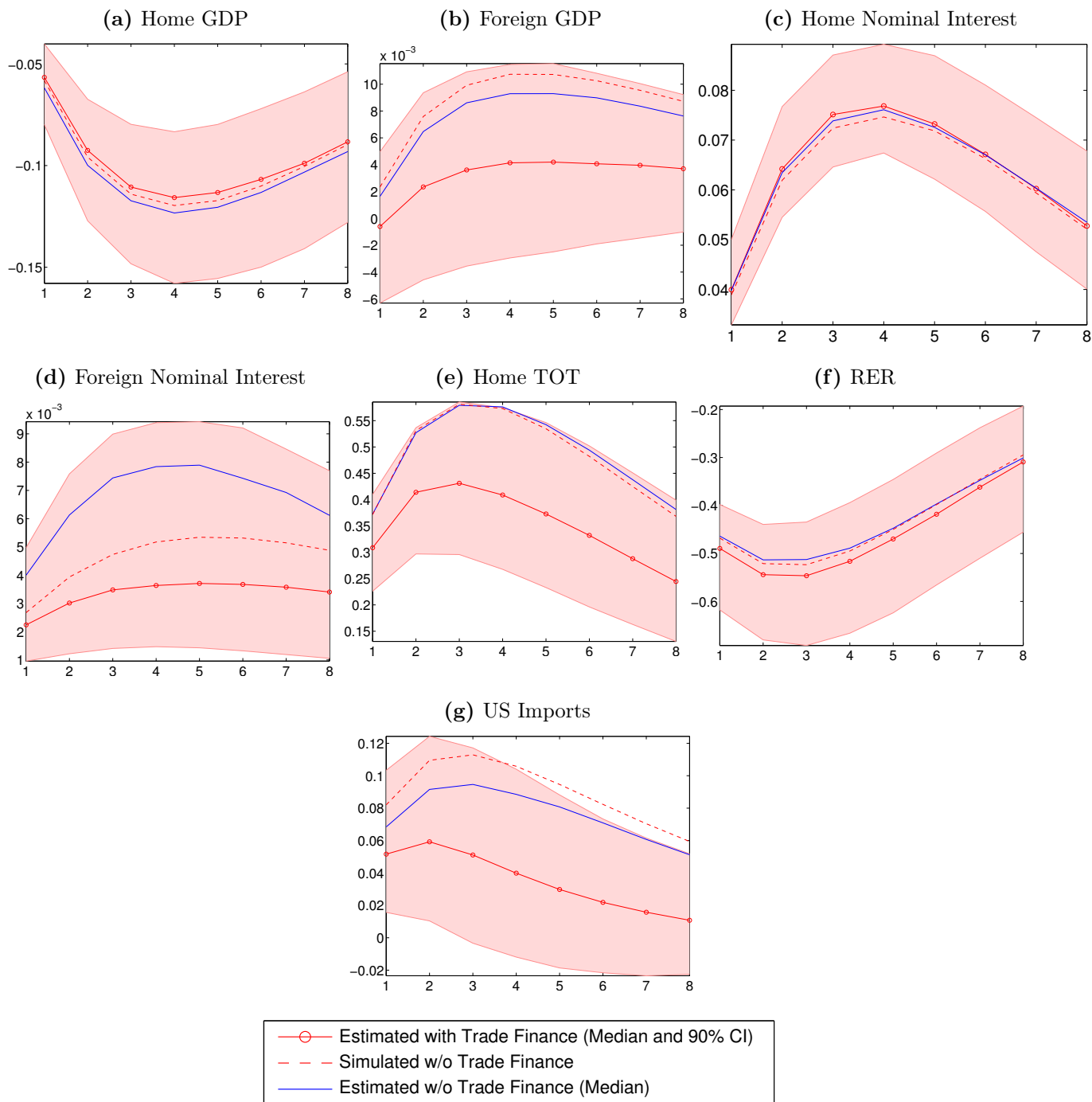
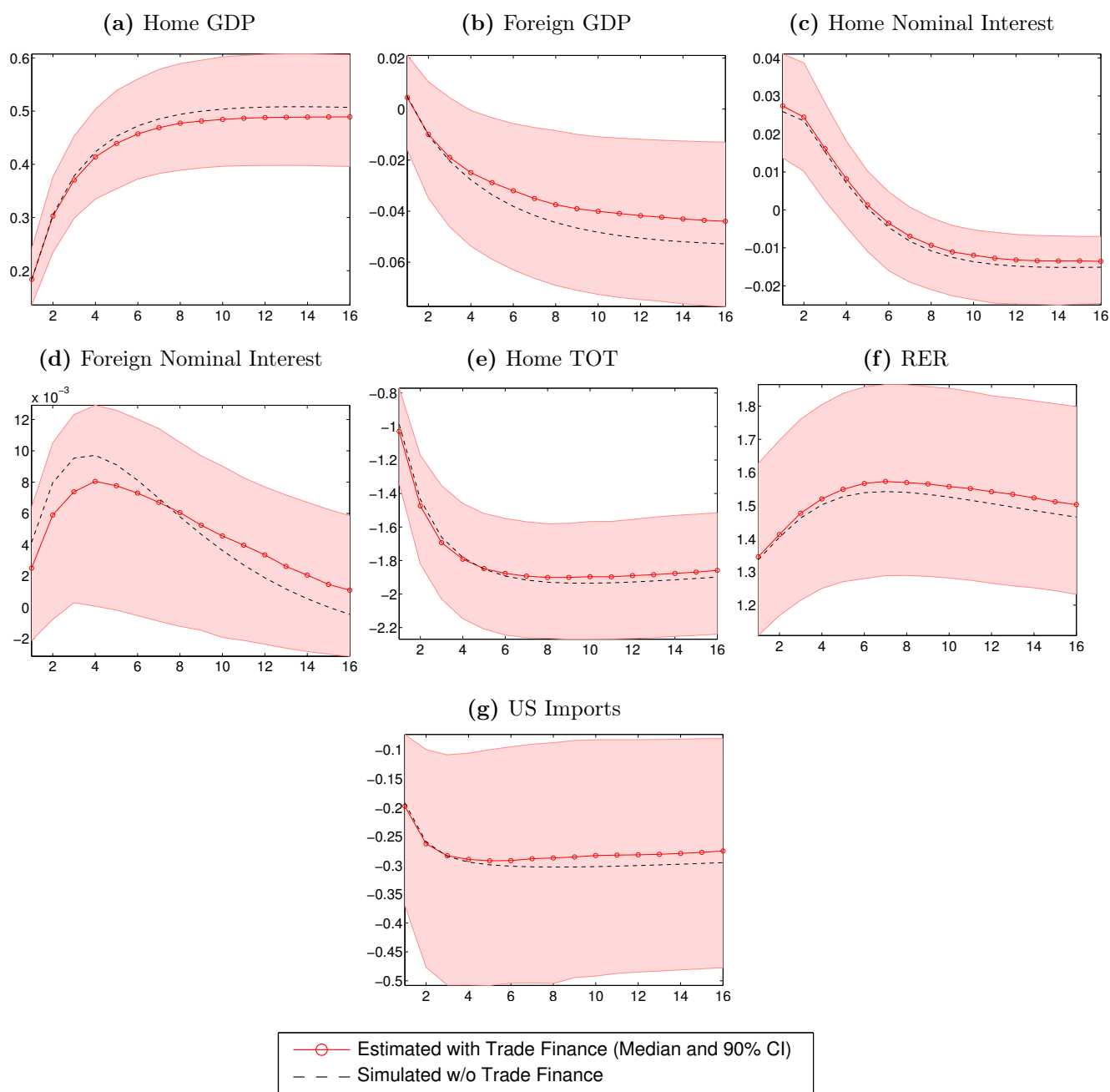


Figure G.2 – US Productivity Shock



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

Table 12 – Correlations Between Observables Used in Estimation

	ΔY^{US}	i^{US}	$\pi^{CPI,US}$	$\pi^{GDP,US}$	$\pi^{IM,US}$	ΔY^{EU}	i^{EU}	$\pi^{CPI,EU}$	$\pi^{GDP,EU}$	ΔE
ΔY^{US}	1									
i^{US}	0.142	1								
$\pi^{CPI,US}$	-0.042	0.311	1							
$\pi^{GDP,US}$	-0.015	0.368	0.627	1						
$\pi^{IM,US}$	-0.098	-0.199	0.606	0.155	1					
ΔY^{EU}	0.126	0.236	0.039	0.047	0.048	1				
i^{EU}	0.088	0.698	0.323	0.384	-0.16	-0.063	1			
$\pi^{CPI,EU}$	0.157	0.498	0.459	0.552	0.025	-0.124	0.649	1		
$\pi^{GDP,EU}$	-0.056	0.287	0.499	0.732	0.124	0.113	0.185	0.416	1	
ΔE	-0.156	-0.107	0.011	-0.195	0.409	-0.009	-0.067	-0.242	-0.243	1

H Data:

H.1 Correlations and Plots

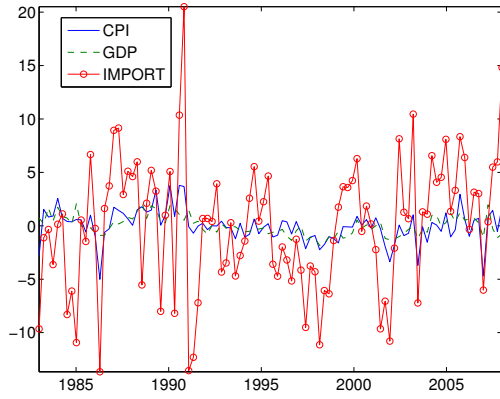
This appendix provides the details and sources for the data used in the empirical part of the paper. Unless otherwise mentioned, the data is at quarterly frequency from 1983Q1-2007Q4. It is seasonally adjusted and demeaned before estimation.

US Data

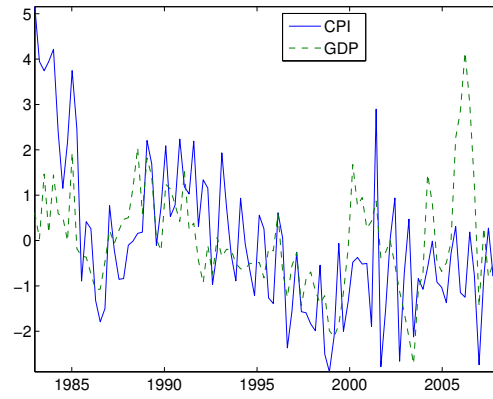
- R^{US} : Effective Federal funds Rate, nominal, annualized, percentage
- ΔY^{US} : Quarter to quarter growth rate of GDP per capita computed as follows:

Figure H.1 – Time series Plots of Data Used in Estimation

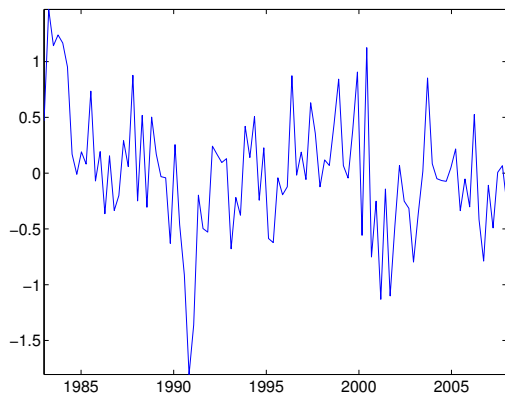
(a) US Inflation Rates



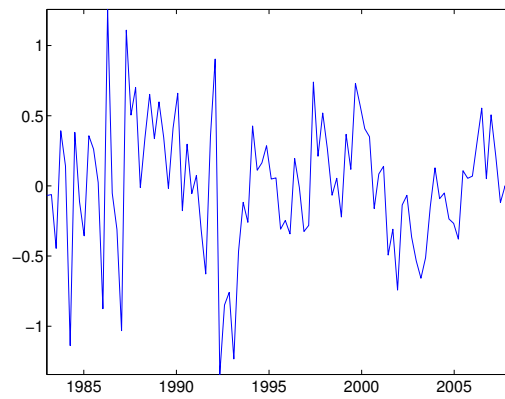
(b) EU Inflation Rates



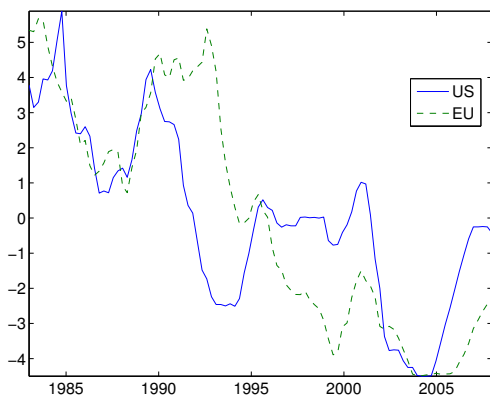
(c) US GDP Growth Rate



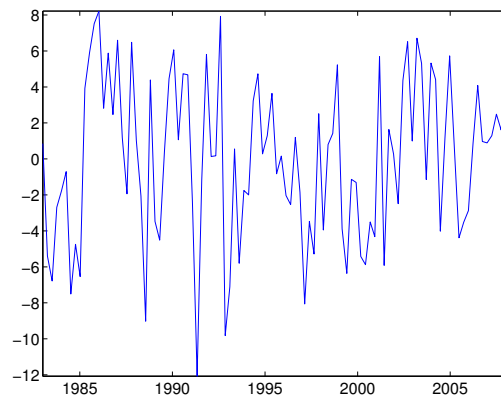
(d) EU GDP Growth Rate



(e) Nominal Interest Rates



(f) Nominal Depreciation



Notes: This figure plots the 10 time series used in the estimation. All data is at quarterly frequency from 2003Q1-2007Q4 and is seasonally adjusted and demeaned.

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

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

- CPI inflation:

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

- GDP Deflator Inflation:

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

- Import Price Inflation

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

Data Sources: The data for the US block is taken from the Bureau of Economic Analysis (BEA) National Income and Product Accounts (NIPA). The data on population is taken from [Ramey \(2011\)](#)'s publicly available dataset.

EU data

- R^{EU} : Effective Federal funds Rate, nominal, annualized, percentage

- ΔY^{EU} : Quarter to quarter growth rate of GDP per capita computed as follows:

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

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

- CPI inflation:

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

- GDP Deflator Inflation:

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

- Nominal Exchange rate Depreciation:

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

Data Sources: The data for the EU block is 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 US and European Union at quarterly frequency is taken from the 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.

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

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

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