Capital Flows and Exchange Rates:
A Quantitative Assessment of the Dilemma Hypothesis*

Ambrogio Cesa-Bianchi† Andrea Ferrero‡ Shangshang Li§

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Abstract

In response to an unanticipated monetary policy tightening in the US, real GDP and exports of a typical small open economy fall, despite the depreciation of the local currency. The reason is that the financial channel of the transmission of monetary policy shocks across countries dominates over the traditional expenditure-switching effect. The dominant role of the reserve currency in trade and global financial transactions can account for the evidence in an otherwise standard two-country open economy model with nominal and real rigidities. Yet, even in the presence of a global financial cycle, the exchange rate regime matters. In particular, a peg substantially increases macroeconomic volatility. Conversely, the introduction of an additional policy instrument to manage capital flows dampens economic fluctuations. A tax on domestic credit achieves nearly equivalent results. Tax instruments can insulate the effects of foreign monetary policy shocks on real economic activity in a fixed exchange rate regime, but not on inflation.

Keywords: Exchange rates flexibility, Currency invoicing, Dilemma, Expenditure Switching, Foreign exchange liabilities, Global financial cycle, Trilemma.
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†Bank of England, CEPR, and CfM. Email: ambrogio.cesa-bianchi@bankofengland.co.uk.
‡University of Oxford, CEPR and CfM. Email: andrea.ferrero@economics.ox.ac.uk.
§University of Liverpool and University of Oxford. Email: shangshang.li@economics.ox.ac.uk.

1 Introduction

As central banks around the world started their tightening cycle following the recovery from the Covid crisis, issues related to exchange rate volatility and capital flows became once again front and center in the debate on the cross-country transmission of monetary policy.

The reference framework for this discussion often relies on the notion of 'Trilemma.' The Trilemma is a cornerstone proposition in international macroeconomics according to which a country can only attain two of the following three policy objectives: independent monetary policy, a fixed exchange rate, and free capital mobility.

Rey (2013) challenged this traditional view. Her critique contains two key points. The first is an empirical observation. Following a monetary policy shock in the US, asset prices and capital flows move together across countries, giving rise to a 'Global Financial Cycle' (GFC). Subsequent work (e.g. Miranda-Agrippino and Rey, 2020, di Giovanni et al., 2022) has confirmed and extended these findings. The second point focuses on the policy implications. Since the GFC holds regardless of the exchange rate regime, the key policy choice is not a Trilemma, but a 'Dilemma' between retaining monetary policy independence and free international capital mobility. A central bank can pursue inflation stability only if additional instruments, such as capital flows management and/or macroprudential tools, are available.

In this paper, we offer a quantitative evaluation of the Dilemma hypothesis. Our analysis proceeds in three steps. First, we show empirically that indeed a flexible exchange rate regime is not enough to insulate countries from the consequences of the GFC. In response to a contractionary monetary policy shock in the US, the nominal exchange rate of countries with a flexible exchange rate depreciates. Yet, exports and real GDP fall. The expenditure-switching channel (Engel, 2003) does not offset the negative consequences of lower global aggregate demand.

Second, we develop a two-country open economy model with real, nominal, and financial frictions that matches our empirical evidence. In the model, the GFC arises because of the cross-country links in the financial sector and the existence of a global reserve currency in trade and financial transactions. We estimate the model by matching its impulse responses to a foreign monetary policy shock to those of the VAR. Several counterfactual experiments highlight the crucial interplay between financial frictions and trade pricing frictions. The former are necessary for the amplification of the shock. The latter allow the model to replicate the empirical response of exports and inflation.

Third, endowed with the estimated model, we perform a number of policy experiments. In the model, GFC notwithstanding, abandoning a flexible exchange rate regime in favor of a peg increases macroeconomic volatility because of the negative effects of higher interest rates on domestic demand. Conversely, the introduction of countercyclical tax instruments that respond to credit growth reduces macroeconomic volatility. Our experiments show that a capital flows management tool (a tax on borrowing in foreign currency) or a financial stability tool (a tax on domestic credit) have nearly equivalent effects. The adoption of one of these instruments in a country with a fixed exchange rate regime can approximately generate the same response of domestic output to a foreign monetary policy contraction as with flexible exchange rates. However, inflation volatility remains higher. Therefore, the tradeoff between inflation and output stabilization is worse under a peg than under a flexible exchange rate regime.

The early empirical literature on the GFC has largely emphasized the response of financial variables to US monetary policy shocks. More recently, a number of contributions, such as Dedola et al. (2017), Han and Wei (2018), Degasperi et al. (2020), Flaccadoro and Nispi Landi (2022), and De Leo et al. (2023), have extended the focus on to macro variables.[1] While we share the interest of these papers in the joint dynamics of financial and macroeconomic variables, our empirical analysis relies solely on a sample of countries with a flexible exchange arrangement. Under the Trilemma paradigm, exchange rate flexibility should insulate countries from external shocks, including those driving the GFC. The fact that we observe the typical elements of the transmission of a US monetary policy shock even when we exclusively focus on countries with flexible exchange rates strikes a key point in favor of the GFC.

Our model is closely related to Dedola and Lombardo (2012), Aoki et al. (2020), and, especially, Akinci and Queralto (2019). The common element in those papers, as well as in ours, is the presence of a moral hazard friction between households and banks, as in Gertler and Karadi (2011). In open economy, the distinguishing feature is that the friction depends on the currency composition of the private sector's balance sheet, which gives rise to an endogenous wedge in the uncovered interest rate parity (UIP) condition (Gabaix and Maggiori, 2015).[2] An international interbank market links domestic and foreign financial intermediaries, thus amplifying the transmission of foreign monetary policy shocks. On the trade side, two pricing frictions determine the propagation of exchange rate movements on to exports and inflation. In line with the recent evidence on the 'Dominant Currency Paradigm' (Gopinath et al., 2020), domestic firms price their exports in the reserve currency,

[1]The empirical literature on the GFC, in turn, builds on an broader literature on the international transmission of monetary policy (see, for example, Kim, 2001; Faust and Rogers, 2003; Canova, 2005; and Ilzetzki and Jin, 2021).

[2]Itskhoki and Mukhin (2021) show that shocks to the UIP condition can rationalize several outstanding exchange rate puzzles.

allowing the model to match the decline of exports despite the depreciation of the domestic currency. The depreciation of the exchange rate has also a limited effect on domestic inflation because of imperfect pass-through (Monacelli, 2005). Overall, our framework thus features a dominant currency both in trade and finance, as in Gopinath and Stein (2018).

In our estimated model, as in Akinci and Queralto (2019), the volatility of output and inflation increases under a peg, while taxes on either foreign borrowing or domestic credit reduce macroeconomic volatility.[3] This result is consistent with Farhi and Werning (2016), who find that this kind of taxes are generally desirable because of the interaction between nominal rigidities and imperfections in financial markets. In a small open economy with nominal rigidities and incomplete international financial markets, Farhi and Werning (2012) show that, under a peg, capital controls can restore domestic monetary policy independence, especially in response to risk-premium shocks.[4] In our setting, under a peg, we can design a countercyclical tax, either on foreign liabilities or domestic credit, that replicates the same response of output as under flexible exchange rates. The tax alleviates the negative consequences of the peg on real activity by reducing financial frictions. Nonetheless, inflation falls significantly more than with a flexible exchange rate because in a fixed exchange rate regime the domestic central bank must track the higher foreign nominal interest rate, thus lowering domestic demand.

Our paper is also closely related to the IMF Integrated Policy Framework. Basu et al. (2020) develop a three-period model with trade and financial frictions similar to those present in our setup. Adrian et al. (2020) add several quantitative features, including extending the model to an infinite horizon and allowing for behavioral features (a fraction of agents with adaptive expectations, and discounting in both aggregate demand and supply). Our estimation exercise complements this work and provides a solid empirical grounding to the literature on the GFC.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 reports estimation results for critical parameters of the model. Section 4 focuses on the model properties. Section 5 reports the quantitative analysis. Section 6 concludes. The appendix contains additional empirical results and details of the model.

[3] Rebucci and Ma (2020) survey the literature on the use of macroprudential instruments, and in particular capital controls, to address the inefficiencies arising from pecuniary externalities, which our model abstracts from.

[4] Schmitt-Grohé and Uribe (2016) reach a similar result in a model with downward wage rigidities.

2 Revisiting the GFC Evidence

In this section, we estimate a panel VAR (PVAR) on a sample of countries with a flexible exchange rate. The data cover 15 countries (Australia, Canada, Chile, Germany, Japan, Korea, Mexico, New Zealand, Norway, Singapore, South Africa, Sweden, Switzerland, Thailand and the United Kingdom) during the period 1997M1–2019M12. In this group of countries, the cross-sectional average of the classification of exchange rates by Ilzetzki et al. (2019) during the 1999–2019 period is 11.7, with a minimum value of 9.6 for Canada (higher values correspond to a more flexible exchange rate regime).[5]

The empirical VAR specification for each country i is

$$x_{it} = a_i + b_i t + \sum_{\ell=1}^{L} F_{i\ell} x_{it-\ell} + u_{it}, \tag{1}$$

where x_{it} is the vector of endogenous variables at time t, a_i is a vector of constants, t is a deterministic time trend, each $F_{i\ell}$ is a matrix of coefficients, and u_{it} is a vector of reduced form residuals with variance-covariance matrix Σ_{iu}. The vector x_{it} includes three US-specific variables and six country-specific variables. The US-specific variables are the monetary policy shock (ϵ_t^m), the excess bond premium (EBP_t^{US}) from Gilchrist and Zakrajsek (2012) and the log of real GDP (Y_t^{US}). The country-specific variables are the log of real GDP (Y_{it}), the CPI level (P_{it}), the log of exports in real terms (X_{it}), the level of the nominal policy interest rate (i_{it}), the log of the nominal exchange rate (e_{it}), and the level of a measure of credit spreads (CS_{it}).[6]

To identify a US monetary policy shock, we employ the high-frequency monetary policy surprises constructed by Jarocinski and Karadi (2020) as an 'internal instrument' (Plagborg-Møller and Wolf, 2021).[7] Specifically, we include the series of monetary surprises as the first element of the vector of endogenous variables

$$x_{it} = \left[\begin{array}{ccccccccc} \epsilon_t^m & EBP_t^{US} & Y_t^{US} & Y_{it} & P_{it} & X_{it} & e_{it} & i_{it} & CS_{it} \end{array} \right].$$

The introduction of the excess bond premium in the vector of endogenous variables is important for two reasons. First, given the small scale of our empirical model, this variable

[5] For robustness, we also consider a larger panel of 24 countries, for which the average value of the exchange rate classification is 10.9, with a minimum value of 7.5 for India. See Appendix A for details.

[6] Following Miranda-Agrippino and Rey (2020), we interpolate macroeconomic quantities (real GDP and exports) at monthly level. Appendix A provides additional details on the definition and sources of the data.

[7] We downloaded the updated series of surprises from Marek Jarocinski's website (`https://marekjarocinski.github.io/`).

helps with the correct specification because of its strong predictive power for real economic activity, thus expanding the VAR information set (Caldara and Herbst, 2019). Second, the EBP can provide useful information about the quantitative strength of financial frictions in the transmission of monetary policy shocks (Gertler and Karadi, 2015).

We obtain impulse responses from a Cholesky factorization of the reduced-form variance-covariance matrix of the VAR residuals. We estimate the VAR using the mean group estimator of Pesaran and Smith (1995) and Pesaran et al. (1996), as pooled estimators are not consistent in dynamic panel data with heterogeneous (i.e. across countries) slope coefficients. The Hannan–Quinn information criterion suggest 4 lags for the majority of countries (12 out of 15). We thus set $L = 3$ but the Appendix shows that the results are robust to using different lag information criteria.[8]

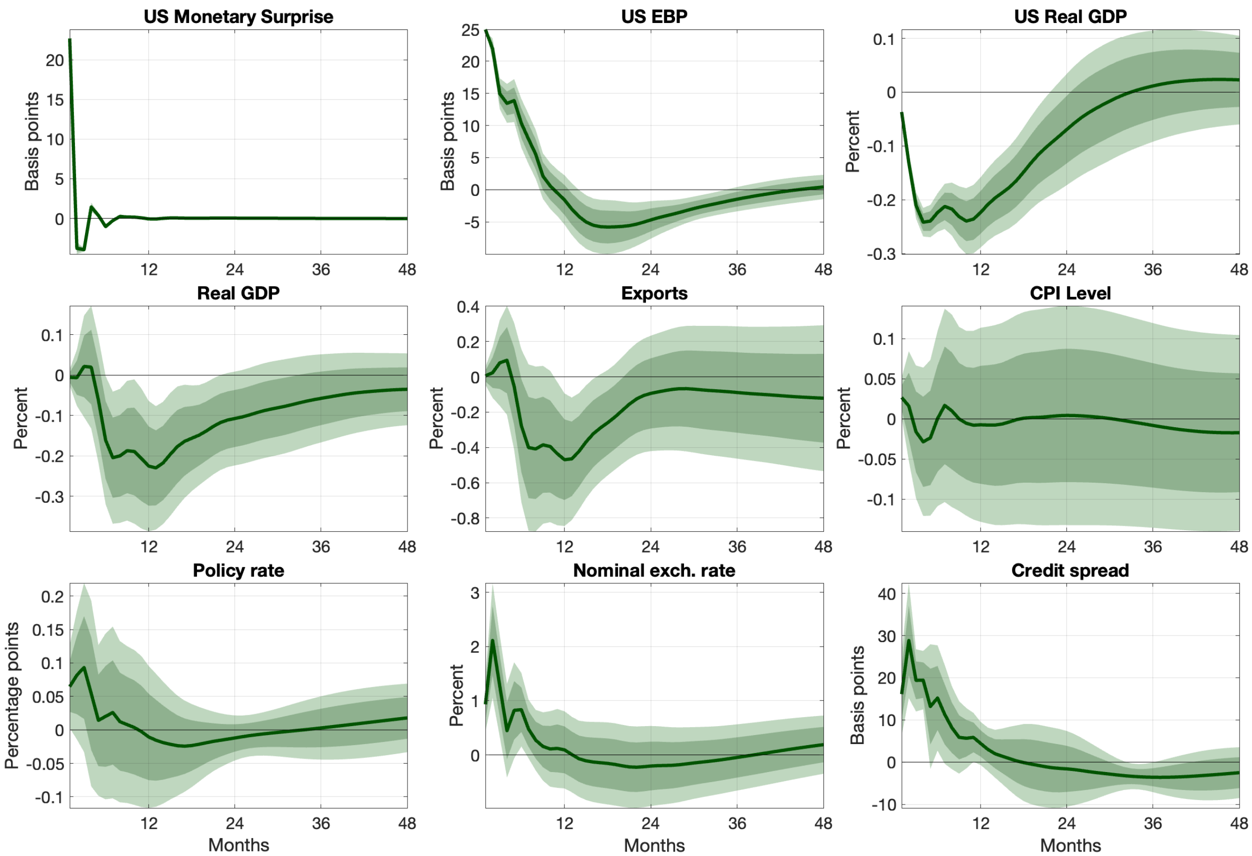
2.1 PVAR Baseline Estimation Results

Figure 1 reports the impulse responses of the EBP and real GDP in the US, and of macroeconomic and financial variables in a typical small open economy to an identified US monetary policy tightening. We pick the size of the shock to generate a 25 basis points increase in the EBP, which roughly corresponds to a two-standard-deviation shock or, equivalently, to a 40 basis points increase in the 1-year rate in Gertler and Karadi (2015). The dark and light shaded areas represent the 68% and 90% confidence intervals computed scaling the variance of the country responses across countries as suggested by (Pesaran et al., 1996), which provides a consistent estimate of the true cross-sectional mean impulse response.

The tightening of monetary policy in the US leads to an increase of the EBP and a persistent and hump-shaped decline of US real GDP, as in the closed economy analysis of Gertler and Karadi (2015) and Caldara and Herbst (2019). The remaining impulse responses show the average response of macroeconomic and financial variables in our sample of countries with flexible exchange rates. As expected, the monetary policy tightening in the US causes a depreciation of the local currency. A persistent contraction of credit conditions in the typical small open economy is a first indication of the GFC since domestic financial variables closely co-move with those in the US. The persistent fall of real GDP and exports is also in line with the idea of a GFC, in the sense that the financial channel of the transmission mechanism dominates over the expenditure-switching effect. In a Mundellian framework, the depreciation of the nominal exchange rate should boost exports and possibly insulate the

[8] The panel is unbalanced due to the data being available only starting after 1997M1 for some countries. Nevertheless, we estimate the same empirical model for all countries to avoid introducing differences in country responses due to alternative specifications.

Figure 1: Impulse responses to a US monetary policy tightening.



NOTE: Impulse responses to a contractionary monetary policy shock in the US. The solid line is the mean group estimate. The light and dark shaded areas are the 68% and 90% confidence intervals, respectively. The nominal interest rate and credit spreads are in annualized terms. The shock is normalized to generate a 25 basis points increase in the EBP.

small open economy from the foreign monetary policy shock. While this mechanism may be in place, the data highlight the importance of the transmission through financial variables. In particular, the negative effect of the monetary policy tightening on US real GDP explains the fall of exports in the small open economy because of lower foreign demand. Finally, despite the non-significant response of inflation, the nominal interest rate initially marginally increases, possibly suggesting some mild degree of exchange rate targeting by the monetary policy authority. After a few months, the policy rate falls and eventually becomes negative, even though the impulse response is only marginally statistically significant.[9]

[9]The non-significant response of inflation among countries with flexible exchange rates is in line with the evidence in Flaccadoro and Nispi Landi (2022). Degasperi et al. (2020) find a statistically significant negative response of inflation, which rationalizes the monetary policy accommodation. The combination of near-zero or mildly negative policy rates and increasing spreads is consistent with the recent evidence in De Leo et al. (2023) that documents the rise in risk premia for emerging markets.

Our results are robust to a number of robustness exercises, which we report in Appendix A. Specifically, we show that our results are similar if we consider alternative specifications where we use data for a larger set of small open economies; set the number of lags according to different lag length criteria; drop the deterministic trend; consider a longer sample period starting in 1985; use measure of short-term market interest rates instead of policy rates; include additional variables (e.g. US CPI, the price of oil, or equity prices in the small open economies).

In summary, the results from our PVAR are consistent with the GFC hypothesis. In response to a contractionary monetary policy in the US, the nominal exchange rate of a typical small open economy that adopts a flexible exchange rate regime depreciates while credit spreads increase. The tightening of domestic financial conditions leads to a fall in real GDP and exports, despite the exchange rate depreciation. The central bank in the small open economy eases monetary policy over time to stabilize output and inflation. The next section develops and estimates a two-country DSGE model with financial frictions to account for the evidence from the PVAR.

3 A Model of the Global Financial Cycle

The model that we use is closely related to Akinci and Queralto (2019). The world consists of two countries, Home (of size n) and Foreign (of size $1-n$). Households in each country consume Home and Foreign goods, supply labor, and can save via deposits in financial intermediaries (banks). Foreign banks operate both domestically and internationally, whereas Home banks only operate domestically. On the supply side, capital producers transform the final consumption good (a combination of diversified varieties) into investment goods subject to an adjustment cost function. Intermediate goods firms combine labor and capital to produce differentiated varieties. Retailers bring these products to consumers, and set prices on a staggered basis. In each country, a central bank sets monetary policy. In what follows, we describe the model from the perspective of the Home country. Where necessary, an asterisk denotes Foreign variables.

3.1 Households

In the Home country, the representative household consists of a continuum of members $i \in (0, n)$ who supply differentiated labor inputs $\ell_t(i)$. A representative union combines labor inputs into a homogeneous aggregate

$$\ell_t \equiv \left[\left(\frac{1}{n}\right)^{\frac{1}{\nu}} \int_0^n \ell_t(i)^{\frac{\nu-1}{\nu}} di\right]^{\frac{\nu}{\nu-1}}, \tag{2}$$

where $\nu > 1$ is the elasticity of substitution among labor inputs. The demand for the i^{th} labor variety is

$$\ell_t(i) = \frac{1}{n}\left[\frac{W_t(i)}{W_t}\right]^{-\nu} \ell_t, \tag{3}$$

where $W_t(i)$ is the nominal wage specific to type$-i$ labor input and the aggregate wage index is

$$W_t = \left[\frac{1}{n}\int_0^n W_t(i)^{1-\nu} di\right]^{\frac{1}{1-\nu}}. \tag{4}$$

The representative household takes labor demand (3) as given, and sets wages on a staggered basis, where $\xi_w \in (0,1)$ is the probability of keeping the wage fixed.

Because of perfect risk sharing among its members, the household chooses consumption c_t and savings in nominal deposits D_t on behalf of all its members to maximize

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left[\ln(c_{t+j} - h\bar{c}_{t+j-1}) - \frac{\chi}{1+\zeta}\int_0^n \ell_{t+j}(i)^{1+\zeta} di\right], \tag{5}$$

where $\bar{c}_{t-1}$ is a reference consumption level that the household takes as given, $h \in (0,1)$ is the habits parameter, $\zeta > 0$ is the inverse Frisch elasticity of labor supply, and $\chi > 0$ is a parameter that pins down the steady state level of hours worked. The budget constraint at time t is

$$P_t c_t + D_t = \int_0^n W_t(i)\ell_t(i) di + R_{t-1}D_{t-1} + T_t, \tag{6}$$

where P_t is the consumer price index (CPI), R_t is the nominal gross nominal interest rate on deposits, and T_t are profits from ownership of banks and firms net of lump-sum taxes.

The overall consumption bundle is a CES aggregator defined over goods produced in the Home and Foreign country

$$c_t \equiv \left[a^{\frac{1}{\epsilon}} c_{Ht}^{\frac{\epsilon-1}{\epsilon}} + (1-a)^{\frac{1}{\epsilon}} c_{Ft}^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}}, \tag{7}$$

where $\epsilon > 0$ is the elasticity of substitution between Home and Foreign goods, and $a \in (n,1)$ is the degree of home bias. Expenditure minimization implies that the consumer price index is

$$P_t = \left[aP_{Ht}^{1-\epsilon} + (1-a)P_{Ft}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}, \tag{8}$$

where P_{Ht} and P_{Ft} are the Home currency prices of goods produced in the Home and Foreign country, respectively. In turn, the consumption bundle for Home-produced goods consists of a continuum of varieties whose measure corresponds to the country size

$$c_{Ht} = \left[\left(\frac{1}{n}\right)^{\frac{1}{\varrho}} \int_0^n c_t(h)^{\frac{\varrho-1}{\varrho}} dh\right]^{\frac{\varrho}{\varrho-1}} \tag{9}$$

where $\varrho > 0$ is the elasticity of substitution among varieties. The implied price index for the Home goods bundle is

$$P_{Ht} = \left[\frac{1}{n}\int_0^n P_t(h)^{1-\varrho} dh\right]^{\frac{1}{1-\varrho}}. \tag{10}$$

Similarly, the consumption bundle for Foreign-produced goods is

$$c_{Ft} = \left[\left(\frac{1}{1-n}\right)^{\frac{1}{\varrho}} \int_n^1 c_t(f)^{\frac{\varrho-1}{\varrho}} df\right]^{\frac{\varrho}{\varrho-1}}, \tag{11}$$

and the corresponding price index is

$$P_{Ft} = \left[\frac{1}{1-n}\int_n^1 P_t(f)^{1-\varrho} df\right]^{\frac{1}{1-\varrho}}. \tag{12}$$

The structure for the Foreign country is symmetric (adjusting for country size), except that the degree of home bias may be different.

3.2 Financial Intermediation

We assume an asymmetric international financial structure. Foreign banks operate both domestically and internationally, whereas Home banks only operate domestically.[10] As a consequence of this asymmetric financial structure, we interpret the Home country as the typical small open economy and the Foreign country as a financial hegemon (e.g. the US).

[10] Our international financial structure is slightly different from Akinci and Queralto (2019), who do not model banking frictions in the Foreign country. This different assumption has some consequences on the degree of amplification of financial frictions, as we discuss below.

3.2.1 Foreign Banks

Foreign banks fund their operations with domestic deposits and net worth, which in real terms we denote with n_t^*. Their assets consists of loans to both Foreign firms and Home banks, whose market value in real terms are $q_t^* z_t^*$ and $b_t^* \equiv B_t^*/P_t^*$, respectively.[11] International interbank borrowing and lending takes place in Foreign currency. The balance sheet of Foreign banks in real terms at the end of time t is

$$q_t^* z_t^* + b_t^* = d_t^* + n_t^*, \tag{13}$$

where $d_t^* \equiv D_t^*/P_t^*$. Net worth is the difference between the gross return on assets and liabilities

$$n_t^* = r_{kt}^* q_{t-1}^* z_{t-1}^* + \frac{R_{bt-1}^*}{\Pi_t^*} b_{t-1}^* - \frac{R_{t-1}^*}{\Pi_t^*} d_{t-1}^*, \tag{14}$$

where r_{Kt}^* is the real return on capital, R_{Bt}^* is the gross nominal interest rate on loans to Home banks, and $\Pi_t^* \equiv P_t^*/P_{t-1}^*$ is the gross inflation rate.

As in Gertler and Karadi (2011), we assume that in each period banks continue their operations with probability ω. With the complementary probability, banks exit the industry, turn their net worth to households, and are replaced by an equal mass of new banks that start operating with a small transfer from households. The objective function of banks is the expected value of terminal wealth, which we can write in recursive form as

$$V(n_t^*) = \mathbb{E}_t \left\{ \mathcal{M}_{t,t+1}^* [(1-\omega) n_{t+1}^* + \omega V(n_{t+1}^*)] \right\}, \tag{15}$$

where $\mathcal{M}_{t,t+1}^*$ is the stochastic discount factor of the Foreign representative household for real payoffs.

In principle, bankers can divert a fraction $\theta^* \in (0,1)$ of their assets, in which case the bank gets liquidated. Without any constraint, banks would seek to expand their balance sheet indefinitely and maximize the benefit of diversion. Thus, the incentive compatibility constraint for banks must be such that the value of the bank is greater than the private benefit of diversion to the banker

$$V(n_t^*) \geq \theta^* \left(q_t^* z_t^* + b_t^* \right), \tag{16}$$

where $\theta^* > 0$.

The problem of a banker consists of maximizing (15) subject to the balance sheet con-

[11] Formally, firms issue financial securities in exchange for the loans obtained from the bank.

straint (13), the evolution of net worth (14) and the incentive compatibility constraint (16). In an equilibrium in which the incentive compatibility constraint binds, the solution to the bankers' problem implies

$$\lambda_t^* = \frac{\mu_{dt}^*}{\theta^* - \mu_{kt}^*}, \tag{17}$$

where $\lambda_t^* \equiv (q_t^* z_t^* + b_t^*)/n_t^*$ is the leverage ratio.[12] The numerator of (17) is the discounted expected real return on deposits

$$\mu_{dt}^* = \mathbb{E}_t \left(\mathcal{M}_{t,t+1}^* \Omega_{t,t+1}^* \frac{R_t^*}{\Pi_{t+1}^*} \right),$$

where $\Omega_{t,t+1}^* \equiv 1 - \omega + \omega \kappa_{t+1}^*$ is an additional discount rate that banks apply to future returns due to the probability of exiting, and $\kappa_t^* \equiv V(n_t^*)/n_t^* = \theta^* \lambda_t^*$ is the franchise value of the bank per unit of net worth. The denominator of (17) is instead the discounted expected excess return of capital over deposits

$$\mu_{kt}^* = \mathbb{E}_t \left[\mathcal{M}_{t,t+1}^* \Omega_{t,t+1}^* \left(r_{kt+1}^* - \frac{R_t^*}{\Pi_{t+1}^*} \right) \right].$$

As Gertler and Karadi (2011) stress, in the absence of financial frictions, μ_{kt} would be zero. In order to satisfy the incentive compatibility constraint (16), banks need to earn an excess return in expectation.

3.2.2 Home Banks

Home banks raise deposits from domestic households, borrow from Foreign banks, and use their net worth to lend to Home firms in domestic currency. Their balance sheet in real terms is

$$q_t z_t = d_t + s_t b_t^* + n_t, \tag{18}$$

where $s_t \equiv \mathcal{E}_t P_t^*/P_t$ is the real exchange rate and $\mathcal{E}_t$ is the nominal exchange rate from the perspective of the Home country (units of Home currency to buy one unit of Foreign currency). Their net worth evolves according to

$$n_t = r_{kt} q_{t-1} z_{t-1} - \frac{R_{t-1}}{\Pi_t} d_{t-1} - \frac{R_{bt-1}^*}{\Pi_t^*} s_t b_{t-1}^*. \tag{19}$$

The presence of liabilities denominated in Foreign currency creates a balance sheet mismatch. For example, a depreciation of the Home currency for a given value of assets implies a

[12] Appendix B reports the details of the derivations.

reduction of the banks' net worth.[13]

Home banks are subject to a similar moral hazard problem as Foreign banks. The key difference is that, as in Akinci and Queralto (2019), we assume that the fraction of assets that Home banks can divert is an increasing function of the share of foreign currency liabilities

$$V(n_t) \geq \Theta(x_t) q_t z_t, \tag{20}$$

where

$$\Theta(x_t) \equiv \theta \left(1 + \frac{\gamma}{2} x_t^2\right), \tag{21}$$

and $x_t \equiv s_t b_t^* / (q_t z_t)$, with θ and $\gamma > 0$. The parameter θ governs the tightness of the financial friction, while γ determines the extent to which the financial friction varies with the share of foreign currency liabilities.

The problem of Home banks consists of maximizing

$$V(n_t) = \mathbb{E}_t \left\{ \mathcal{M}_{t,t+1} [(1-\omega) n_{t+1} + \omega V(n_{t+1})] \right\}, \tag{22}$$

subject to (18), (19) and (20). Similarly to Foreign banks, we can write the solution to this problem as

$$\lambda_t = \frac{\mu_{dt}}{\Theta(x_t) - (\mu_{kt} + \mu_{bt} x_t)}, \tag{23}$$

where $\lambda_t \equiv q_t z_t / n_t$ is the leverage ratio for Home banks. The definitions of the expected discounted real return on deposits μ_{Dt} and of the expected discounted excess return of capital over deposits μ_{Kt} correspond to their counterparts in the Foreign country

$$\mu_{dt} = \mathbb{E}_t \left(\mathcal{M}_{t,t+1} \Omega_{t,t+1} \frac{R_t}{\Pi_{t+1}} \right), \tag{24}$$

$$\mu_{kt} = \mathbb{E}_t \left[\mathcal{M}_{t,t+1} \Omega_{t,t+1} \left(r_{kt+1} - \frac{R_t}{\Pi_{t+1}} \right) \right], \tag{25}$$

where $\Omega_{t,t+1} \equiv 1 - \omega + \omega \kappa_{t+1}$ is the additional discount factor and $\kappa_t \equiv V(n_t)/n_t = \Theta(x_t)\lambda_t$ is the franchise value of Home banks. Home banks also arbitrage between domestic deposits and funds raised in foreign currency from the international interbank market. Financial frictions limit this arbitrage activity that banks perform and create an endogenous wedge in the uncovered interest rate parity condition, in line with a large body of empirical evidence

[13] In practice, financial intermediaries typically hedge the currency exposure on their balance sheet. In this sense, the balance sheet mismatch in the model better captures the overall exposure of the private sector in the small open economy.

since Fama (1984)

$$\mu_{bt} = \mathbb{E}_t \left[\mathcal{M}_{t,t+1} \Omega_{t,t+1} \left(\frac{R_t}{\Pi_{t+1}} - \frac{R^*_{bt}}{\Pi^*_{t+1}} \frac{s_{t+1}}{s_t} \right) \right]. \tag{26}$$

Given the functional form assumed for $\Theta(\cdot)$, we can solve for optimal proportion of foreign currency debt

$$x_t = \frac{1}{\mu_t} \left(\sqrt{1 + \frac{2\mu_t^2}{\gamma}} - 1 \right), \tag{27}$$

where $\mu_t \equiv \mu_{bt}/\mu_{kt}$. Since interbank borrowing corresponds to the net external position, equation (27) in steady state pins down net foreign liabilities.

3.3 Firms

Four types of firms operate in the Home country: capital producers, importers, intermediate goods producers and final goods producers. This rich production structure allows us to introduce a number of key pricing frictions in the model.

As in Akinci and Queralto (2019), final goods producers in both countries set prices on a staggered basis (Calvo, 1983). In the Home country, these firms price their products in the currency of the market of destination. In a two-country setting, this assumption is consistent with the evidence on "dominant currency pricing" emphasized by Gopinath et al. (2020).

The presence of importers in the Home country distinguishes our framework from Akinci and Queralto (2019). Following Monacelli (2005), we assume that the law of one price for imported goods holds at the dock but importers adjust their price in domestic currency infrequently. This friction introduces imperfect exchange rate pass-through to the Home economy and is a key ingredient for matching the empirical response of inflation to a Foreign monetary policy shocks in the model, as we later demonstrate.

Production in the Foreign country is symmetric except that we abstract from importers since Home final goods producers price their exports in Foreign currency.

3.3.1 Capital Producers

Capital producers transform final goods into capital goods. On top of the cost of acquiring one unit of final good, capital producers pay an adjustment cost, which we assume to be quadratic in the growth rate of investment. The problem of capital producers in the Home country is to maximize

$$\mathbb{E}_t \sum_{j=0}^{\infty} \mathcal{M}_{t,t+j} \left[q_{t+j} - 1 - \frac{\varphi_i}{2} \left(\frac{i_{t+j}}{i_{t+j-1}} - 1 \right)^2 \right] i_{t+j}, \tag{28}$$

where $\varphi_i > 0$.

3.3.2 Intermediate Goods Producers

Competitive intermediate goods producers have access to a Cobb-Douglas technology in capital and labor

$$y_t = A_t k_{t-1}^{\alpha} \ell_t^{1-\alpha}, \tag{29}$$

where $\alpha \in (0, 1)$ is the capital share. At the end of each period, firms issue securities to acquire capital for production in the subsequent period. After production takes place in a period, firms sell the undepreciated capital on the open market. Therefore, their balance sheet at time t is

$$q_t z_t = q_t k_t, \tag{30}$$

and their profits are

$$\mathcal{P}_t = p_{mt} y_t - w_t \ell_t - r_{kt} q_{t-1} z_{t-1} + (1 - \delta) q_t k_{t-1}, \tag{31}$$

where p_{mt} is the relative price of intermediate goods and $w_t \equiv W_t / P_t$ is the real wage. The first order condition for labor is standard

$$w_t = (1 - \alpha) p_{mt} A_t k_{t-1}^{\alpha} \ell_t^{-\alpha}. \tag{32}$$

Plugging this expression back into the profits of intermediate goods producers, we obtain

$$\mathcal{P}_t = \alpha p_{mt} y_t - r_{kt} q_{t-1} k_{t-1} + (1 - \delta) q_t k_{t-1}. \tag{33}$$

Since intermediate goods producers are perfectly competitive, zero profits implies

$$r_{kt} = \frac{\alpha p_{mt} A_t k_{t-1}^{\alpha-1} \ell_t^{1-\alpha} + (1 - \delta) q_t}{q_{t-1}}. \tag{34}$$

3.3.3 Final Goods Producers

Final goods producers operate in monopolistic competition and set prices on a staggered basis (Calvo, 1983). In each period, the probability that the price remains unchanged is $\xi_p \in (0, 1)$.

In the Home country, final goods producers set prices in the currency of the destination market (i.e., local currency pricing, or LCP). This assumption captures the idea that the Foreign country currency is "dominant" in goods markets, as we have also assumed for financial markets.

The problem for Home producers consists of choosing $\widetilde{P}_t(h)$ and $\widetilde{P}_t^*(h)$ to maximize

$$\mathbb{E}_t \sum_{j=0}^{\infty} \xi_p^j \mathcal{M}_{t,t+j} \left\{ \left[\frac{\widetilde{P}_t(h)}{P_{t+j}} - p_{mt+j} \right] y_{t,t+j}(h) + \left[\frac{\mathcal{E}_{t+j} \widetilde{P}_t^*(h)}{P_{t+j}} - p_{mt+j} \right] y_{t,t+j}^*(h) \right\}, \qquad (35)$$

where

$$y_{t,t+j}(h) = \left[\frac{\widetilde{P}_t(h)}{P_{Ht+j}} \right]^{-\varrho} y_{Ht+j} \qquad \text{and} \qquad y_{t,t+j}^*(h) = \left[\frac{\widetilde{P}_t^*(h)}{P_{Ht+j}^*} \right]^{-\varrho} y_{Ht+j}^*$$

and the demand for Home goods by Home and Foreign households, respectively, are

$$y_{Ht} = a \left(\frac{P_{Ht}}{P_t} \right)^{-\epsilon} \left[c_t + i_t + \frac{\varphi_i}{2} \left(\frac{i_t}{i_{t-1}} - 1 \right)^2 i_t \right],$$

and

$$y_{Ht}^* = a^* \left(\frac{P_{Ht}^*}{P_t^*} \right)^{-\epsilon} \left[c_t^* + i_t^* + \frac{\varphi_i}{2} \left(\frac{i_t^*}{i_{t-1}^*} - 1 \right)^2 i_t^* \right].$$

The first-order conditions for $\widetilde{P}_t(h)$ and $\widetilde{P}_t^*(h)$ are standard and, together with the price indexes, determine two Phillips curves.

The problem for final goods producers in the Foreign country is similar, except that those firms price in their domestic currency independently of the market of destination. As a consequence, the solution of their problem gives rise only to one Phillips curve.

3.3.4 Importers

The law of one price for imported goods holds at the dock, that is, $P_t^{im}(f) = \mathcal{E}_t P_t^*(f)$. However, in the Home country, the retailers that distribute imported goods each period change their prices with probability $\xi_{im} \in (0, 1)$. Their problem is to choose the price $\widetilde{P}_t(f)$

to maximize

$$\mathbb{E}_t \sum_{j=0}^{\infty} \xi_{im}^j \mathcal{M}_{t,t+j} \left[\frac{\widetilde{P}_t(f)}{P_{t+j}} - \frac{P_{t+j}^{im}(f)}{P_{t+j}} \right] y_{t,t+j}(f), \tag{36}$$

where

$$y_{t,t+j}(f) = \left[\frac{\widetilde{P}_t(f)}{P_{Ft+j}} \right]^{-\varrho} y_{Ft+j},$$

and

$$y_{Ft} = (1-a) \left(\frac{P_{Ft}}{P_t} \right)^{-\epsilon} \left[c_t + i_t + \frac{\varphi_i}{2} \left(\frac{i_t}{i_{t-1}} - 1 \right)^2 i_t \right].$$

The first-order condition for this problem is a Phillips curve that links the inflation rate of imported goods in domestic currency to the law of one price gap, that is, the difference between the price of imports in Foreign currency converted in domestic currency using the nominal exchange rate and the price of imports in domestic currency (Monacelli, 2005).

3.4 Monetary Policy

The baseline monetary policy configuration for the Home country assumes that the central bank sets the nominal interest rate according to a standard feedback rule (Taylor, 1993) with inertia

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R} \right)^{\rho_R} \left[\Pi_t^{\phi_\pi} \left(\frac{y_t}{y_{t-1}} \right)^{\phi_y} \right]^{1-\rho_R},$$

where $\rho_R \in (0,1)$ is the inertia parameter, $\phi_\pi > 1$ and $\phi_y > 0$ are the feedback coefficients on inflation and output, respectively, and $R = 1/\beta$ is the steady state nominal interest rate consistent with zero inflation (assumed to be the target for the central bank).

The monetary policy rule in the Foreign country is identical, except that we add a monetary policy innovation $\varepsilon_{Rt}^* \sim \mathcal{N}(0, \sigma_{R^*}^2)$, which is the focus of our empirical analysis.

3.5 Equilibrium

The labor and capital markets clear nationally within each country. From the perspective of the Home country, net foreign liabilities correspond to the amount of interbank borrowing. Their evolution, in real units of Foreign currency, is

$$b_t^* = \frac{R_{bt-1}^* b_{t-1}^*}{\Pi_t^*} + p_{Ft}^* y_{Ft} - \left(\frac{1-n}{n} \right) p_{Ht}^* y_{Ht}^*$$

Accordingly, the Home current account balance in real units of domestic currency is

$$ca_t \equiv -s_t(b_t^* - b_{t-1}^*).$$

4 Estimation and Counterfactuals

The quantitative assessment of the model relies on a mix of calibrated and estimated parameters. We calibrate all the parameters for the Foreign country, except those of the monetary policy rule, and some of the parameters of the Home country.

Table 1 reports the calibrated parameters. The values for the Foreign country are consistent with the estimated values for the US economy in Smets and Wouters (2007), and whenever possible we maintain symmetry across countries. The relative size of the Home country is equal to 0.1, which corresponds to the average size of the countries in our sample relative to the US. Given the calibrated individual discount factors, the steady state real interest rate in annualized terms is 1% in the Home country and 3% in the Foreign country. The home bias parameter implies that the export share of GDP for the Home country is about 10%, in line with the data for exports towards the US of major emerging markets in Asia and Latin America (Akinci and Queralto, 2019). The choice of parameters for the US banks gives a steady state leverage ratio of 5 and a credit spread of 150 basis points annualized, which are standard values in literature (see, e.g., Gertler and Karadi, 2011).

We estimate the remaining parameters by minimizing the distance between the model-implied impulse responses to a US monetary policy shock and the impulse responses of the PVAR presented in section 2 for the typical small open economy. To better align the model with the data, we make two transformation of the VAR impulse responses: (i) we compute the response of CPI inflation and the exchange rate depreciation by taking first differences of the log-level responses; and (ii) we convert the impulse responses to quarterly frequency by taking quarterly averages of the monthly responses.

Formally, the estimator $\hat{\eta}$ solves

$$\min_{\eta} \left\{ \left[\widehat{\Psi} - \Psi(\eta) \right]' \widehat{W}^{-1} \left[\widehat{\Psi} - \Psi(\eta) \right] \right\},$$

where η is the vector of parameters to be estimated, $\widehat{\Psi}$ is the vector of impulse responses from the PVAR, $\Psi(\gamma)$ is the vector containing of impulse responses from the DSGE model and $\widehat{W}$ is a diagonal matrix collecting the estimated variances of each impulse response from the PVAR (i.e., the width of the error bands).

Table 1: Calibrated parameters

Parameter		**Home**	**Foreign**
n	Relative size of country H	0.1	0.9
β	Individual discount factor	0.9926	0.9975
h	Habits in consumption	–	0.71
σ	Relative risk aversion	–	1.38
χ	Relative weight on disutility of labor	24	52
ζ	Inverse Frisch elasticity	1	1
ϱ	Elasticity of substitution among goods varieties	6	6
a	Home bias in consumption	0.91	0.99
ϵ	Elasticity of substitution between H and F goods	1.5	1.5
ν	Elasticity of substitution among labor varieties	6	6
ξ_w	Wage rigidity	0.66	0.66
ξ_p	Price rigidity	–	0.66
α	Capital share	0.33	0.33
δ	Depreciation rate	0.025	0.025
φ_i	Investment adjustment cost	–	5.74
ω	Bank survival rate	0.97	0.97
θ	proportion of divertible funds	–	0.51
ξ_b	bank transfer rate	–	0.002

NOTE: The missing parameters for the Home country are estimated.

As in Christiano et al. (2011), we follow a Bayesian approach to estimate the parameters of the model with impulse response matching. Table 2 reports the list of estimated parameters (first column), their prior distributions (second to fourth columns), and their posteriors (fifth to eight column). We specify a prior directly on the steady state value of the leverage ratio of Home banks (λ) and on the steady state share of foreign currency debt (x). The data are particularly informative for the latter. At the posterior mode, the estimated values for these two variables imply a fraction of divertible funds θ equal to 0.511 (very close to the assumed value for θ^*), a degree of Home bias for bank funding γ equal to 2.077, and a bank transfer rate ξ_b equal to 0.0009, which is about half of the assumed value for Foreign banks.

The estimates of the other parameters are reasonably standard and the data are generally informative about their values.[14] The degree of price stickiness is fairly high, but very much comparable to recent estimates that include data after the financial crisis (Del Negro et al., 2015). Conversely, the degree of import price stickiness is significantly lower, implying an

[14] Appendix A reports a systematic comparison of prior and posterior distributions.

Table 2: Estimated parameters

Parameter	Prior			Posterior			
	Distribution	Mean	SD	Mode	Median	5%	95%
h	Beta	0.650	0.1	0.648	0.654	0.497	0.809
σ	Normal	1	0.375	0.703	0.839	0.517	1.258
λ	Normal	5	1	4.977	5.014	3.523	6.663
x	Normal	0.300	1	0.154	0.136	0.035	0.235
φ_i	Normal	2.850	1.5	0.587	0.799	0.182	1.862
ξ_p	Beta	0.660	0.1	0.914	0.882	0.786	0.962
ξ_{im}	Beta	0.660	0.1	0.702	0.688	0.525	0.841
ρ_R	Normal	0.750	0.1	0.666	0.689	0.543	0.839
ϕ_π	Normal	1.500	0.25	1.616	1.637	1.266	2.022
ϕ_y	Normal	0.125	0.05	0.155	0.147	0.065	0.231
ρ_R^*	Normal	0.750	0.1	0.731	0.702	0.564	0.819
ϕ_π^*	Normal	1.500	0.25	1.615	1.641	1.275	1.999
ϕ_y^*	Normal	0.125	0.05	0.126	0.126	0.129	0.208

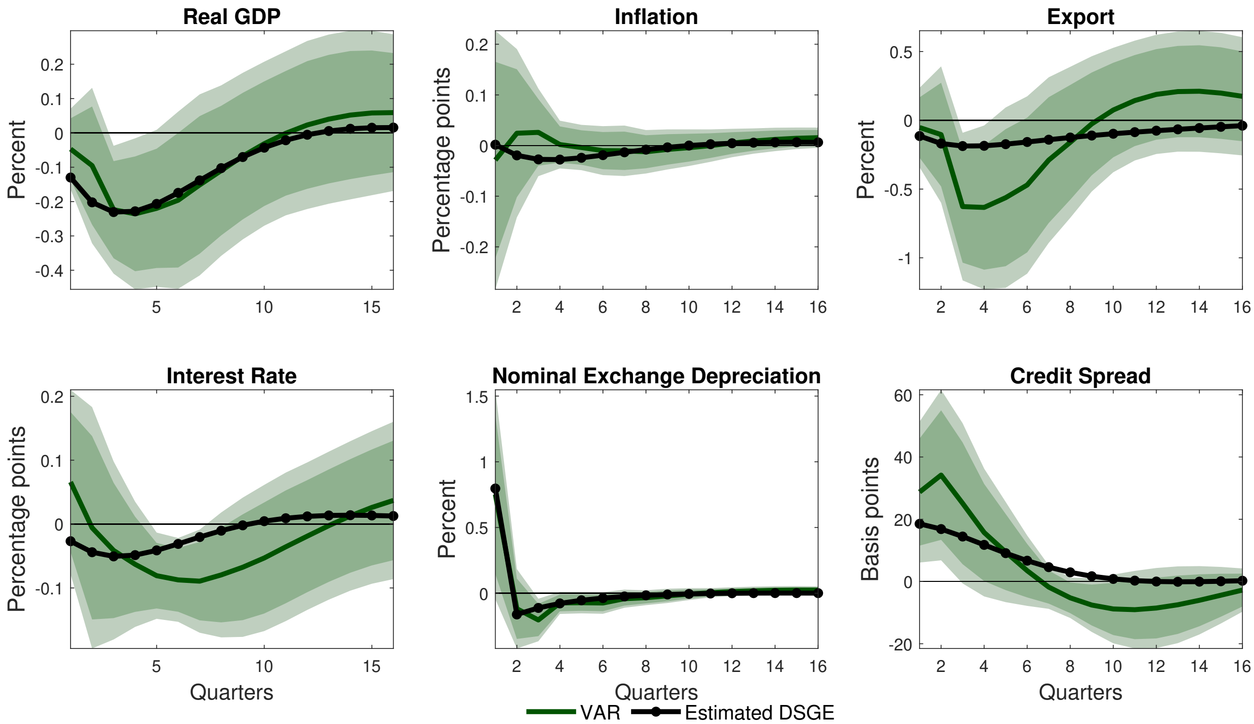
NOTE:

average contract duration between three and four quarters. The coefficients on inflation and output growth in the interest rate rule are very close across countries. Interest rate inertia is slightly higher in the Foreign country than in the Home country.

Figure 2 replicates the mean group estimate of the impulse responses for the typical small open economy to a contractionary US monetary policy shocks (solid green line) presented in Figure 1, as well as the 68% (dark shaded areas) and the 90% (lighter shaded areas) confidence bands. The solid black lines with markers in the figure correspond to the impulse responses to a Foreign monetary policy shock of the same variables in the model at the posterior mode. The model fits well the response of real GDP, inflation, the depreciation of the nominal exchange rate and credit spreads. Although quantitatively not as impressive, the response of exports and the nominal interest rate are also qualitatively in line with the data and lie at least within the 10-90 confidence bands throughout the simulation horizon.

The model, therefore, is able to replicate the dominant role of the financial channel in propagating Foreign monetary policy shocks to the domestic economy that we have highlighted in section 2. The next section investigates the key ingredients of transmission mechanism by way of two counterfactuals.

Figure 2: Impulse response matching.



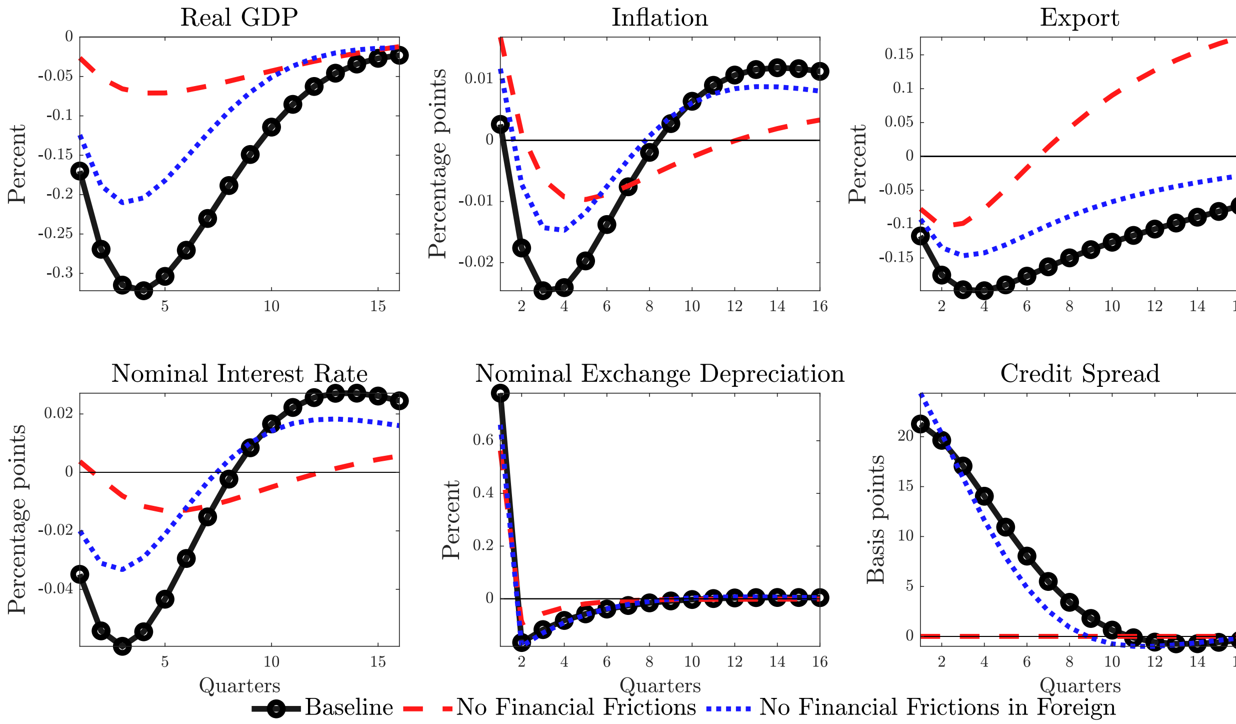
Note: The figure displays the impulse responses of real GDP, CPI inflation, exports, interest rate, nominal exchange rate depreciation and credit spreads in a typical small open economy to a US contractionary monetary policy shock, comparing the VAR (solid green lines) and the DSGE model (solid black lines with markers). The light and dark grey shaded areas are the PVAR 68% and 90% confidence intervals from the VAR, respectively. Inflation, the nominal interest rate and spreads are in annualized terms.

4.1 The Role of Financial and Trade Frictions

In the first counterfactual exercise, we shut down financial frictions in both countries. The difference with the baseline model is that households now invest directly in physical capital and in nominal bonds. Bonds denominated in Foreign currency are internationally traded, whereas bond denominated in Home currency only circulate domestically and are in zero net supply. These assumptions preserve the dominance of the Foreign currency (in practice the US dollar) in international financial markets even in the absence of global banks. In order to ensure stationarity of the net foreign asset position, we introduce a small portfolio-adjustment cost for trading bonds (Schmitt-Grohé and Uribe, 2003). The resulting model is thus a standard two-country open economy framework with incomplete international financial markets, similar to Baxter and Crucini (1995) and Kollmann (1996).

Figure 3 highlights the amplification effect of financial frictions on macroeconomic and financial outcomes. The dashed red line in the figure reports the response to a foreign monetary policy shocks without financial frictions, while the solid black line is the estimated

Figure 3: No financial frictions.



Note: The figure displays the impulse responses of real GDP, CPI inflation, exports, interest rate, nominal exchange rate depreciation and credit spreads in the Home country to a contractionary monetary policy shock in the Foreign country with (solid black line) and without (dashed red line) financial frictions. Inflation, the nominal interest rate and spreads are in annualized terms.

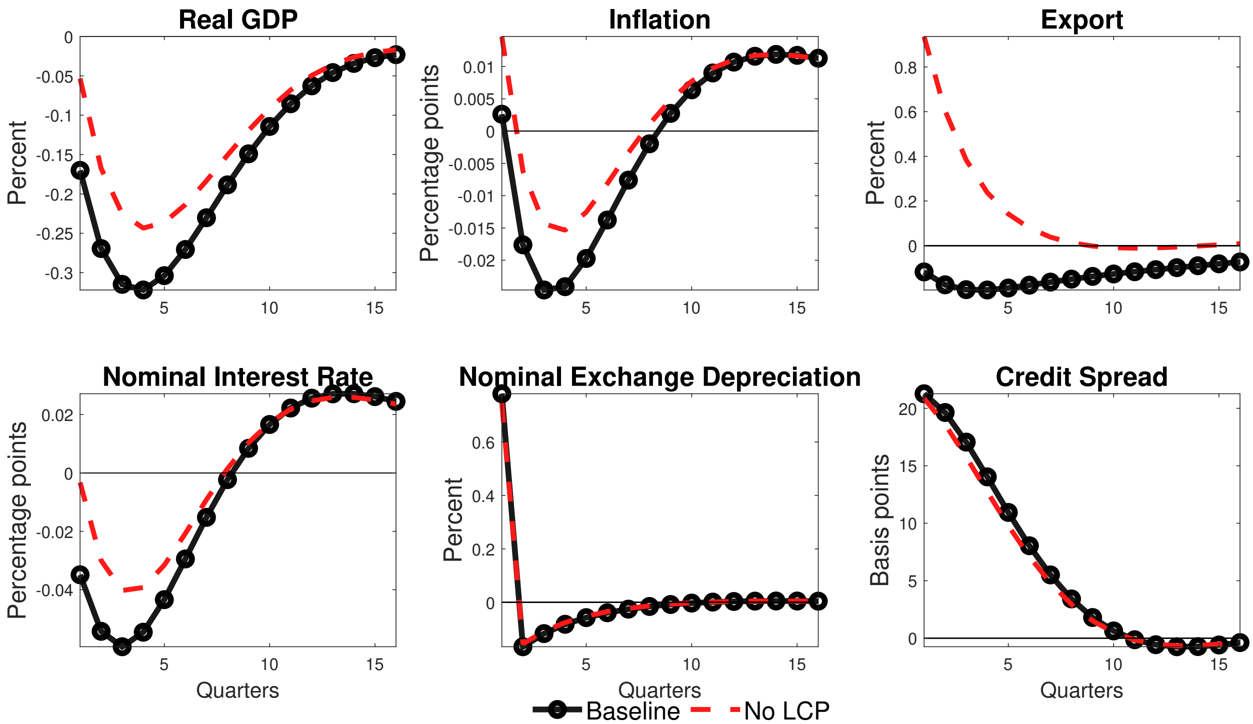
response from the baseline model. In the counterfactual, output drops by about 0.05% at the trough, compared to 0.3% with financial frictions.

At the same time, without financial frictions, the absence of an endogenous UIP wedge slightly reduces the depreciation of the Home currency. The first effect (smaller recession) quantitatively dominates over the second (smaller depreciation), implying somewhat higher inflation than in the baseline. As a consequence, the central bank keeps the nominal interest rate roughly unchanged to balance the tradeoff between output and inflation.

Financial frictions also significantly amplify the response of exports. In the frictionless model, the response is much less persistent than in the baseline case and turns positive after about eight quarters. The reason is that, in the absence of financial frictions, foreign demand drops less than in the baseline, which allows exports to recover more quickly.

The key element of the model that explains the sign of the response of exports is, however, currency pricing. Under our baseline assumption of LCP in the Home country aimed at mimicking the dominance of the US dollar in goods price invoicing, exports fall following a monetary policy contraction in the Foreign country.

Figure 4: No LCP in the Home country.



NOTE: The figure displays the impulse responses of real GDP, CPI inflation, exports, interest rate, nominal exchange rate depreciation and credit spreads in the Home country to a contractionary monetary policy shock in the Foreign country with (solid black line) and without (dashed red line) financial frictions under PCP. Inflation, the nominal interest rate and spreads are in annualized terms.

In general, the response of exports is the result of two channels. On the one hand, the depreciation of the Home currency makes domestic goods more competitive and increases the demand for exports (expenditure-switching channel). On the other hand, the fall of Foreign demand reduces demand for Home exports (global-demand channel). Under LCP, exports are insensitive to the nominal exchange rate depreciation. Conversely, financial frictions make the global demand channel even stronger by amplifying the drop of Foreign output.

Figure 4 illustrates the importance of the LCP assumption. The figure compares the baseline (solid black line) with the impulse response functions under PCP (red dashed lines). In the counterfactual experiment, exports increase and return to steady state after about eight quarters. The positive effect of the depreciation on exports limits the decline of real GDP.[15] Furthermore, inflation is positive, at least on impact. As in the case without financial frictions, the response of the domestic interest rate on impact is muted to balance the two central bank mandates.

[15] In the absence of financial frictions (not shown), the positive response of exports pushes real GDP in positive territory, at least temporarily.

Overall, the two counterfactual exercises in this section clarify that the combination of financial and trade frictions is indeed crucial in accounting for the key empirical features of the GFC.

4.2 The Response of Inflation

From the perspective of monetary policy stabilization, the response of domestic inflation in a small open economy following a foreign monetary policy shock is an important dimension of the GFC and the dilemma debate. As Rey (2013) emphasizes, if a country with a flexible exchange rate regime does not manage to stabilize domestic inflation in the face of foreign shocks, the benefits of floating its currency may indeed prove elusive.

Our evidence suggests that the response of inflation to a contractionary foreign monetary policy shock is small and not significant. This result is consistent with the findings in Passari and Rey (2016) for the UK, in Rey (2016) for Sweden, and in Flaccadoro and Nispi Landi (2022) for their overall sample.[16]

Figure 5 shows that imperfect pass-through plays a key role in aligning the model with the evidence for the response of inflation, above and beyond the contribution of financial frictions discussed in the previous section. The dashed red line in the figure reports the response to a foreign monetary policy shocks when the law of one price holds at the consumer level. In this variant of the model, importers are perfectly competitive firms that deliver foreign goods to final consumers without pricing frictions ($\xi_{im} = 0$). The solid black line is the estimated response from the baseline model.

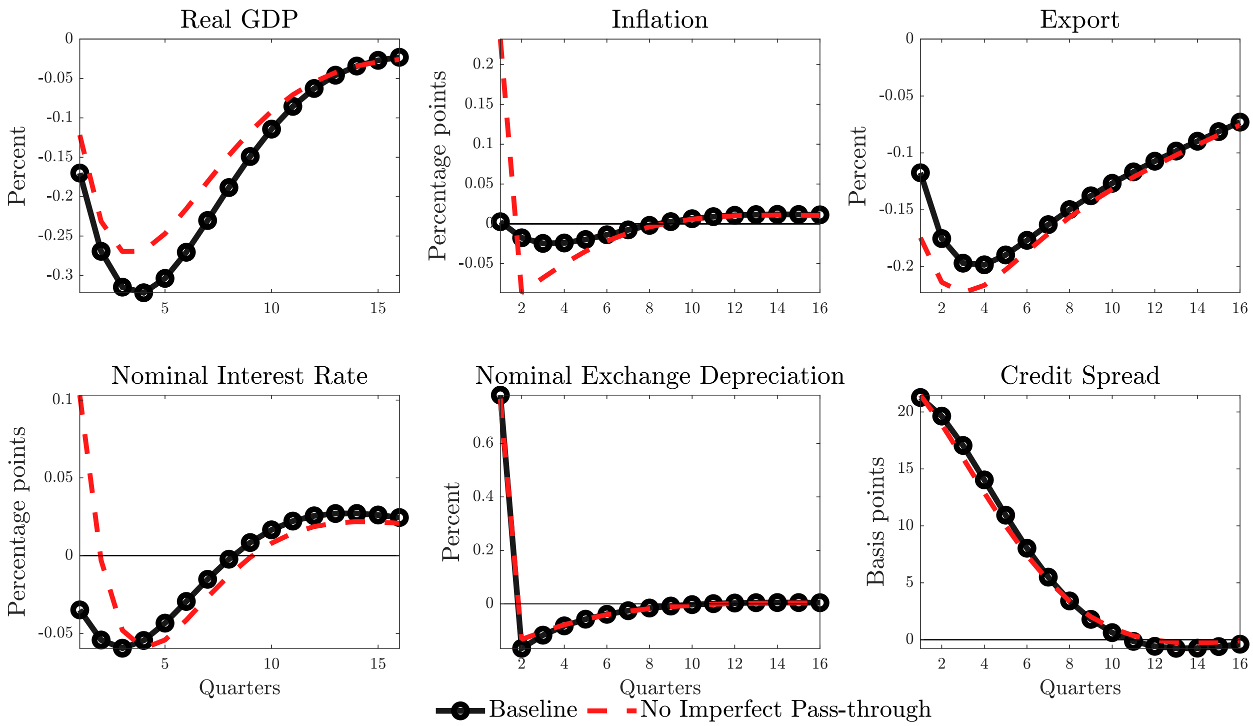
The figure shows that the same depreciation of the nominal interest rate makes inflation jump in positive territory.

Without pricing frictions on importers, the exchange rate pass-through coefficient on impact is approximately 0.25, compared to essentially zero in the baseline. The inflation increase forces the central bank to raise the nominal interest rate, instead of providing accommodation as in the baseline formulation of the model and in the data. When the law of one price holds, the foreign monetary policy shock creates a tradeoff between inflation and output stabilization which is not present with imperfect pass-through.

Importantly, the response of the other variables does not display significant changes compared to the baseline, highlighting the complementarity of imperfect pass-through and

[16] In Rey (2016), the median response of inflation for Canada, the UK and New Zealand is positive but generally not significant. The response of inflation for floaters is negative and significant in Miranda-Agrippino and Rey (2020) and Degasperi et al. (2020), reinforcing the narrative that a flexible exchange rate regime provides little insulation against foreign monetary policy shocks.

Figure 5: No imperfect pass-through.



NOTE: The figure displays the impulse responses of real GDP, CPI inflation, exports, interest rate, nominal exchange rate depreciation and credit spreads in the Home country to a contractionary monetary policy shock in the Foreign country with (solid black line) and without (dashed red line) price rigidities for importers. Inflation, the nominal interest rate and spreads are in annualized terms.

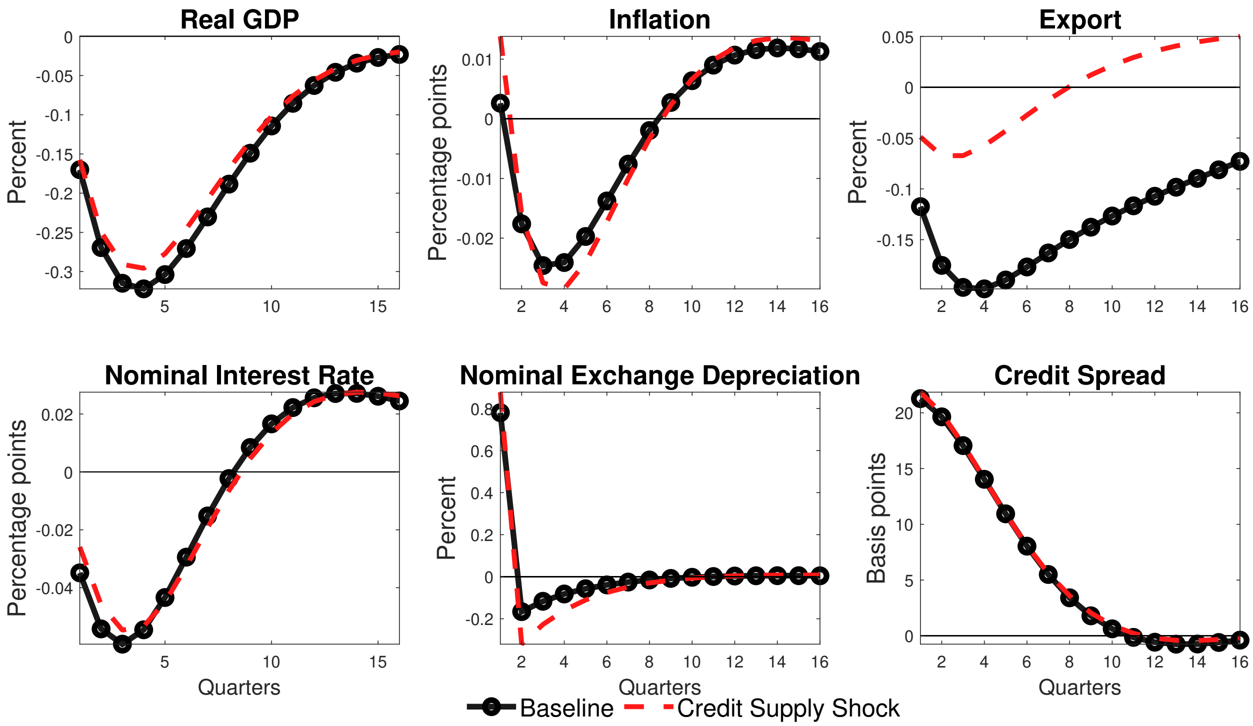
financial frictions in determining the response of macroeconomic and financial variables to foreign monetary policy shocks.

4.3 International Credit Supply Shocks

This section compares the responses of macroeconomic and financial variables in the Home country to the monetary policy shock considered so far with the responses to a contractionary credit supply shock for Foreign banks. For this experiment, we modify the baseline model by allowing the tightness of the financial constraint for Foreign banks to be time-varying. In particular, we assume that $\hat{\theta}_t^* \equiv \ln(\theta_t^*/\theta^*)$ follows a stationary process with persistence $\rho_{\theta^*} = 0.731$, which corresponds to the posterior mode of the inertia parameter in the monetary policy rule for country F. The size of the credit supply shock is such that credit spreads in the Home economy increase by 23 basis points on impact, as in the case of the monetary policy shock.

Figure 6 shows that the response of the Home country macroeconomic and financial

Figure 6: A credit supply shock.



NOTE: The figure displays the impulse responses of real GDP, CPI inflation, exports, interest rate, nominal exchange rate depreciation and credit spreads in the Home country to a contractionary monetary policy shock in the Foreign country (solid black line) and to a negative shock to the US credit supply (dashed red line). The size of the credit supply shock is such that, under both shocks, credit spreads in the Home economy increase by 23 basis points on impact. Inflation, the nominal interest rate and spreads are in annualized terms.

variables is qualitatively and quantitatively very similar under monetary policy and credit supply shocks. Like a contractionary monetary policy shock, the negative credit supply shock in the Foreign country causes spreads to increase. Global banks tighten lending conditions in the international interbank market, giving rise to a similar transmission to macroeconomic and financial variables in the Home country.

Interestingly, the close correspondence between the response to monetary policy and credit supply shocks is consistent with the VAR evidence in Cesa-Bianchi et al. (2018). Their work demonstrates how shocks to the leverage of US broker-dealers are a complementary driver of the GFC, even when controlling for monetary policy and global demand shocks.

5 Policy Analysis

In this section, we study two questions. First, we revisit the benefits of flexible exchange rates in our estimated model. Second, we analyze the extent to which the introduction of additional policy instruments (a tax on either foreign borrowing or domestic credit) affects the volatility of macroeconomic and financial variables induced by foreign monetary policy shocks.[17]

5.1 The Benefits of a Flexible Exchange Rate

The model developed in section 3 can match the empirical evidence that the financial channel dominates over the trade channel in the international transmission of monetary policy shocks. An interest rate increase in the Foreign country determines a tightening of domestic financial conditions. In spite of the depreciation of the domestic currency, exports decline and so does GDP. Thus, the flexible exchange rate regime does not appear to be providing any substantial insulation to the domestic economy. In fact, the depreciation of the exchange rate increases the cost of foreign funds for domestic financial intermediaries and thus contributes to exacerbate the negative impact of the shock.

Figure 7 shows that a flexible exchange rate nevertheless limits macroeconomic volatility compared to a manage float or a peg. The interest rate rule becomes

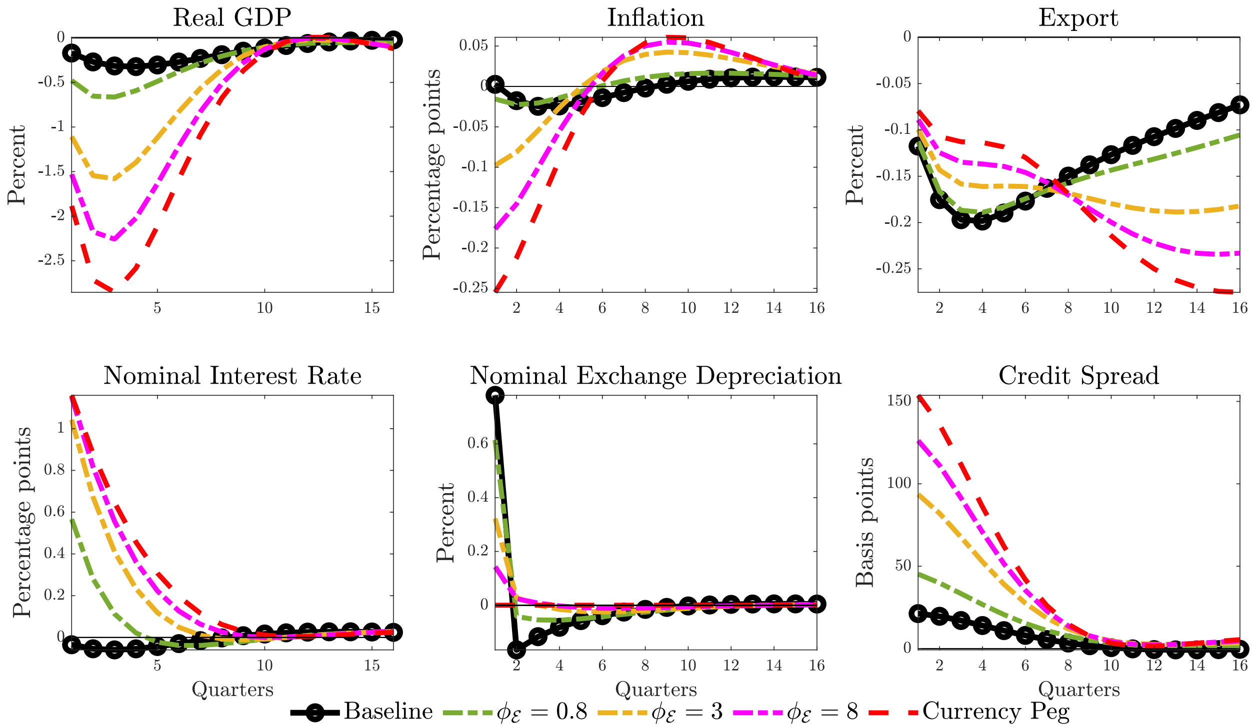
$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[\Pi_t^{\phi_\pi} \left(\frac{y_t}{y_{t-1}}\right)^{\phi_y} \left(\frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}\right)^{\phi_{\mathcal{E}}}\right]^{1-\rho_R},$$

with $\phi_{\mathcal{E}} \geq 0$.

In the extreme case when the nominal exchange rate is fixed (the limit for $\phi_{\mathcal{E}} \to \infty$, represented by the dashed red line in Figure 7), the central bank of the Home country must increase the nominal interest rate to track the monetary policy tightening abroad. Interestingly, in the model, the domestic nominal interest rate increases slightly more than one to one with the Foreign rate because of the endogenous wedge in the UIP condition. As a result, domestic financial conditions significantly worsen, with spreads increasing by a factor of six compared to the baseline. Real GDP falls more than 2.5 percentage points, compared to less the 0.5 percentage points under flexible exchange rates. The Home country also experiences a decline of inflation and a much more persistent fall in exports compared with the baseline. As the Home central bank lowers the weight on the depreciation of the

[17] Fanelli and Straub (2021) study optimal foreign exchange interventions in model with financial frictions similar to Gabaix and Maggiori (2015) and a pecuniary externality with domestic distributional effects.

Figure 7: Managed nominal exchange rate.



NOTE: The figure displays the impulse responses of real GDP, CPI inflation, exports, interest rate, nominal exchange rate depreciation and credit spreads in the Home country to a contractionary monetary policy shock in the Foreign country under a flexible exchange rate regime (solid black line) and under a peg (dashed red line). The dashed-dotted green, yellow and magenta lines correspond to a manage float regime, in which the central bank of the Home country responds to the depreciation of the nominal exchange rate with increasingly higher coefficients ($\phi_{\mathcal{E}} = 0.8$, 3, and 8, respectively). Inflation, the nominal interest rate and spreads are in annualized terms.

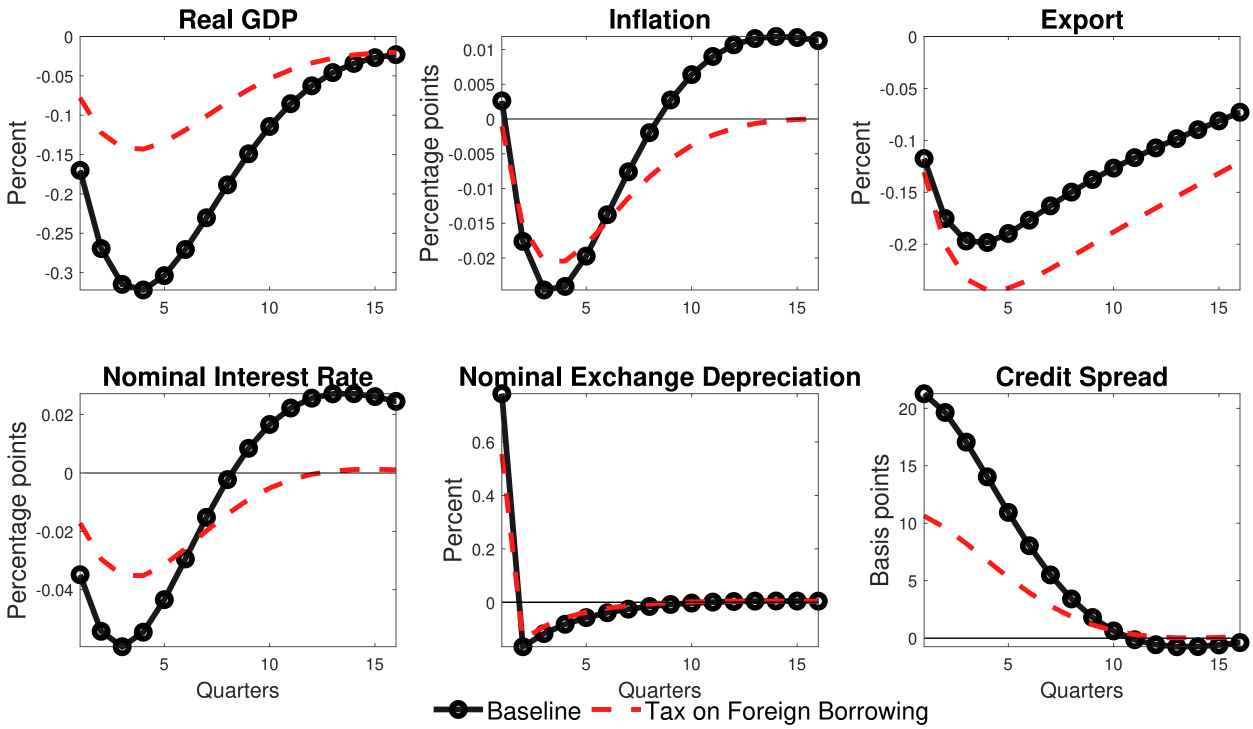
nominal exchange rate (dashed-dotted magenta, yellow and green lines), the response of macroeconomic and financial variables become progressively closer to the flexible exchange rate case ($\phi_{\mathcal{E}} = 0$, represented by the solid black line).

Overall, the results in the model are consistent with the empirical evidence in Obstfeld et al. (2019). While a flexible exchange rate regime does not fully insulate a country from foreign monetary policy shocks, the transmission is not independent of the exchange rate regime, and a peg increases the volatility of both macroeconomic and financial variables.

5.2 A Tax on Foreign Borrowing

In addition to questioning the consensus on the advantages of flexible exchange rates, the recent literature on the GFC has also brought to the fore a discussion on the merits of a number of other policy instruments. In particular, Rey (2013) explicitly mentions the idea of

Figure 8: A tax on foreign borrowing.



NOTE: The figure displays the impulse responses of real GDP, CPI inflation, exports, interest rate, nominal exchange rate depreciation and credit spreads in the Home country to a contractionary monetary policy shock in the Foreign country with (dashed red line) and without (solid black line) a tax on foreign borrowing. Inflation, the nominal interest rate and spreads are in annualized terms.

actively managing the capital account as a way to curb excessive macroeconomic volatility due to global financial shocks.

In our setting, we can allow the government to actively manage the capital account by introducing a countercyclical tax on borrowing in foreign currency, denoted by τ_t^b. We model the tax as an additional cost (subsidy) that banks pay (receive) at maturity. The net worth of financial intermediaries in the Home country thus becomes

$$n_t = r_{kt} q_{t-1} z_{t-1} - \frac{R_{t-1} d_{t-1}}{\Pi_t} - (1 + \tau_t^b) \frac{R_{bt-1}^*}{\Pi_t^*} s_t b_{t-1}^*, \tag{37}$$

while their balance sheet remains unchanged.

We assume that the government in country H sets the tax in response to deviations of the value of credit from its steady state value

$$\tau_t^b = \phi_b \ln \left(\frac{q_t z_t}{q z} \right), \tag{38}$$

where $\phi_b > 0$.[18] With this formulation, the additional policy instrument directly targets the inefficiencies associated with fluctuations in the value of credit (Borio and Lowe, 2002). The proceedings of the tax are rebated lump-sum to households. The countercyclical nature of the tax reduces the UIP wedge, which now is

$$\mu_{bt} = \mathbb{E}_t \left\{ \mathcal{M}_{t,t+1}\Omega_{t,t+1} \left[\frac{R_{t+1}}{\Pi_{t+1}} - (1+\tau^b_{t+1}) \frac{R^*_{bt}}{\Pi^*_{t+1}} \frac{s_{t+1}}{s_t} \right] \right\}. \tag{39}$$

Figure 8 displays the effects of introducing the countercyclical tax on foreign borrowing by Home banks. The results clearly show that the policy is very effective in reducing the volatility of real GDP in response to the monetary tightening abroad. The main channel is the reduction of credit spreads, which roughly fall by a half relative to the baseline. Given the contractionary monetary policy shock in country F, the active management of the capital account actually requires the government to subsidize Foreign borrowing by reducing its cost. The subsidy narrows the UIP wedge, which in turn limits the leverage ratio of financial intermediaries (23) and reduces the cost of funding in foreign currency.

A side effect of a smaller UIP wedge is that the real exchange rate depreciates less than in the baseline case, which has a negative effect on exports. Nevertheless, the expansionary effect on domestic GDP associated with the easier financial conditions more than compensates the negative contribution of exports. The response of inflation and the nominal interest rate is quantitatively similar to the baseline case, albeit somewhat more persistent.

5.3 A Tax on Domestic Credit: A Near-Equivalence Result

Equation (37) highlights that a countercyclical tax on foreign borrowing stabilizes the net worth of Home banks. An instrument that has the potential to achieve a similar effect is a countercyclical tax on domestic credit, which we denote by τ^k_t. This tax reduces the effective return on loans that accrues to Home banks so that their balance sheet becomes

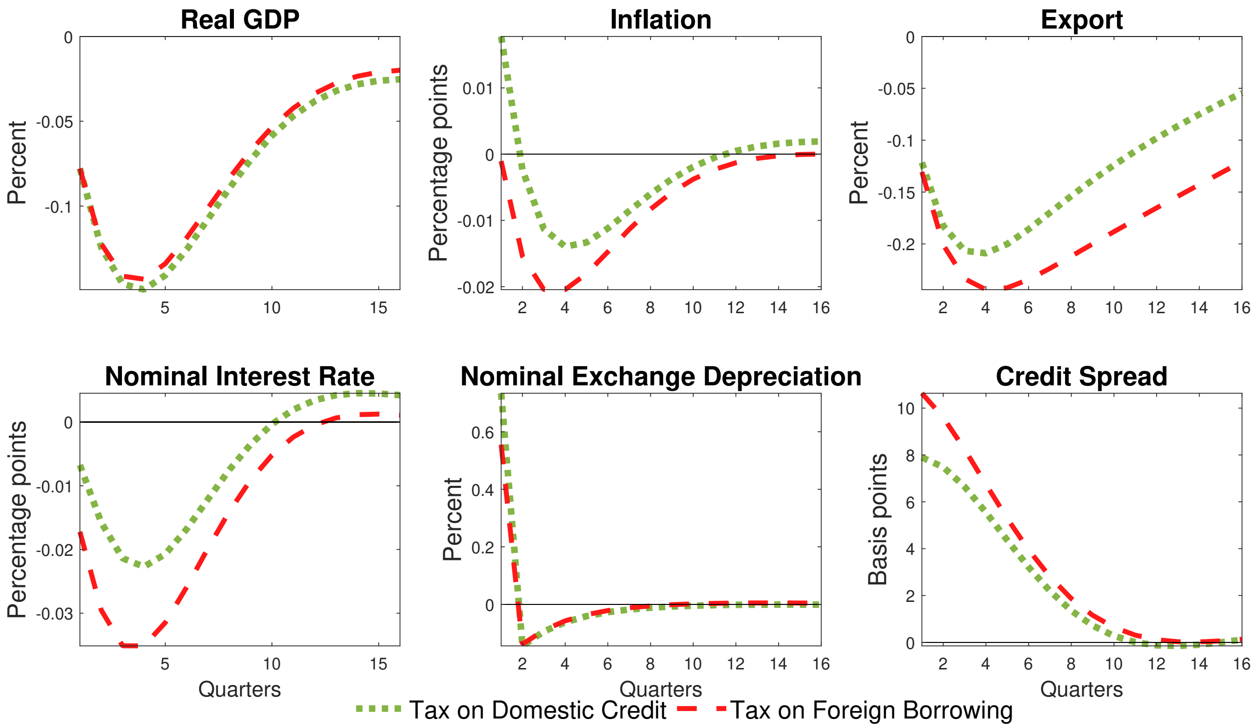
$$n_t = (1-\tau^k_t) r_{kt} q_{t-1} z_{t-1} - \frac{R_{t-1} d_{t-1}}{\Pi_t} - \frac{R^*_{bt-1}}{\Pi^*_t} s_t b^*_{t-1}. \tag{40}$$

As in the case of a tax on foreign borrowing, we assume that the government sets the tax in response to deviations of the value of credit from steady state (like in rule 38) and rebates the revenues lump-sum to households.[19] The tax on domestic credit directly affects

[18] For the exercise reported in Figure 8, we set ϕ_b so that the impact of the Foreign monetary policy shock on domestic spreads is halved.

[19] We calibrate the feedback coefficient so that the impact response on real GDP is the same as in the case of a tax on foreign borrowing.

Figure 9: Tax on foreign borrowing versus tax on domestic credit.



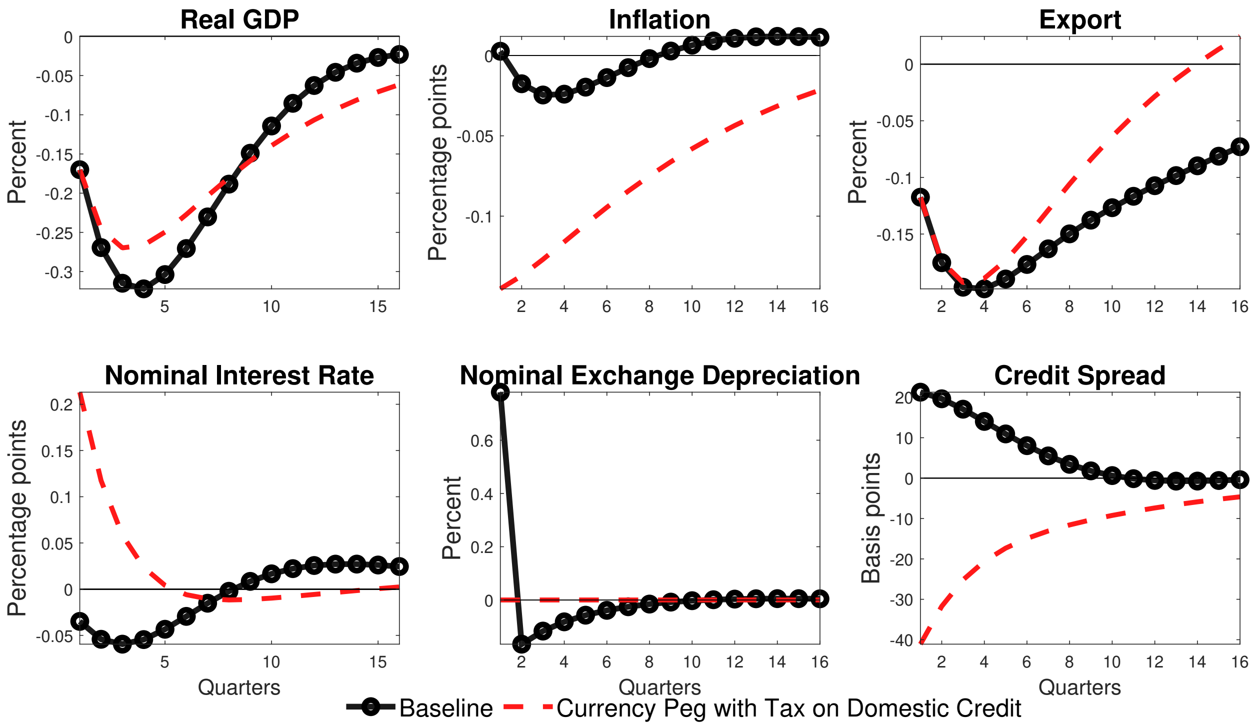
NOTE: The figure displays the impulse responses of real GDP, CPI inflation, exports, interest rate, nominal exchange rate depreciation and credit spreads in the Home country to a contractionary monetary policy shock in the Foreign country with a tax on foreign borrowing (dashed red line) and with a tax on domestic credit (dotted green line). Inflation, the nominal interest rate and spreads are in annualized terms.

the credit spread

$$\mu_{kt} = \mathbb{E}_t \left\{ \mathcal{M}_{t,t+1} \Omega_{t,t+1} \left[(1 - \tau^k_{t+1}) r_{kt+1} - \frac{R_t}{\Pi_{t+1}} \right] \right\}. \tag{41}$$

Figure 9 compares the effects of the tax on domestic credit (dotted green line) with those of the tax on foreign borrowing (dashed red line) discussed in the previous section. The effect on real GDP is almost identical, not only on impact (which happens by construction) but also over time. The tax on domestic credit reduces credit spreads even more than the tax on foreign borrowing. Conversely, the impact on the UIP wedge is smaller. Therefore, the domestic currency depreciates more in real terms and exports fall less, almost in line with the baseline without taxes. The combination of these two effects results in inflation actually rising above target, which requires relatively higher nominal interest rate. The differences in the response of inflation and the nominal interest rate remain nevertheless rather small. Overall, the two taxes have nearly equivalent consequences on macroeconomic volatility and can contribute to stabilize the domestic economy in the face of foreign monetary policy

Figure 10: A tax on domestic credit with a fixed exchange rate.



NOTE: The figure displays the impulse responses of real GDP, CPI inflation, exports, interest rate, nominal exchange rate depreciation and credit spreads in the Home country to a contractionary monetary policy shock in the Foreign country with a tax on domestic credit under a fixed exchange rate regime (dashed red line) and with no taxes under a flexible exchange rate regime (solid black line). Inflation, the nominal interest rate and spreads are in annualized terms.

shocks.

5.4 A Tax on Domestic Credit with a Peg

The last policy experiment asks if a tax on domestic credit under a peg can approximate the macroeconomic outcomes under flexible exchange rates. We set the feedback coefficient on credit so that the impact effect on real GDP is the same in the two cases.

Figure 10 shows that the introduction of a tax on domestic credit reduces the volatility of real GDP under a peg for the first eight quarters. Exports are very close to the case of flexible exchange rates in the first year and then recover faster. The tax (indeed a subsidy in this case) substantially compresses domestic spreads (-40 basis points relative to steady state) and reduces the inefficiencies associated with financial frictions. Yet, as under a peg in the absence of the tax, the Home nominal interest rate continues to follow the Foreign one, which reduces aggregate demand and keeps inflation well below target. As a consequence, even in the presence of an additional instrument, inflation volatility remains higher under a peg than under flexible exchange rates.

6 Conclusions

Monetary policy shocks originating in large financial centers give rise to a Global Financial Cycle worldwide. Real GDP and inflation co-move across countries despite a fully flexible exchange rate regime. The expenditure-switching channel is not strong enough to fully offset the headwinds implied by higher spreads. Key to this transmission are the role of global banks in propagating the initial shock and the currency denomination of exports in the receiving country. Imperfect pass-through is crucial in accounting for the muted response of domestic inflation to the depreciation of the exchange rate.

While a flexible exchange rate regime does not insulate countries from foreign financial shocks, a fixed exchange rate increases domestic macroeconomic volatility. Capital flows management tools, in the form of a countercyclical tax on foreign borrowing, represent one policy instrument that can mitigate the transmission of foreign financial shocks. A tax on domestic credit has nearly-equivalent effects. With fixed exchange rates, either instrument can approximate the response of economic activity under flexible exchange rates. However, because the domestic nominal interest rate must still track the foreign interest rate, the combination of fixed exchange rates and a countercyclical tax on credit or foreign borrowing exerts disinflationary pressures that are largely absent under a flexible exchange rate regime.

As the world remains as financially interconnected as ever, the results in this paper are informative for the current monetary policy tightening cycle taking place in advanced economies as well as, more generally, for the design of appropriate policy frameworks that address the international transmission of financial shocks.

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Appendix

A Data and Empirics

A.1 Data Sources

The larger sample includes 24 countries: Argentina, Australia, Brazil, Canada, Chile, Colombia, Germany, India, Indonesia, Israel, Japan, Korea, Mexico, New Zealand, Norway, Philippines, Poland, Russia, Singapore, South Africa, Sweden, Switzerland, Thailand, United Kingdom. The choice of countries, in this case, depends on data availability:

1. **Exchange rate regime**: Countries need to have a relatively flexible exchange rates (floats and managed floats).

2. **Sample period**: Countries need to have a long enough sample period over which the exchange rate regime is classified as flexible.

3. **Size**: We ignore very small countries.

Data sources:

- **GDP** (real index): OECD, IMF IFS, Bloomberg. The quarterly level data are interpolated using a shape-preserving piecewise cubic interpolation (MatLab command: `y1 = interp1(t0,y0,t1,'pchip')`.

- **Consumer prices** (CPI): OECD, IMF IFS, Bloomberg.

- **Nominal interest rates (policy rates)**: OECD, National Central Banks.

- **Nominal exchange rate** (units of local currency per US dollar, so that an increase corresponds to a depreciation of the local currency): Datastream.

- **Exports** (exports of goods and services, by expenditure in constant prices): OECD. The quarterly level data are interpolated using a shape-preserving piecewise cubic interpolation (MatLab command: `y1 = interp1(t0,y0,t1,'pchip')`.

- **Credit spreads** (average of the option-adjusted spreads across non-financial firms in a country): ICE Bank of America Merrill Lynch Global Index.

A.2 Panel VAR

Figure A.1 reports the impulse responses obtained when we estimate our VAR on the larger sample of 24 small open economies, as outlined in Appendix A. The results are very similar to our baseline.

Figure A.2 and A.3 report the impulse responses obtained when we estimate our VAR with 4 lags (as suggested by the Hannan–Quinn criterion) and without a deterministic trend. The results are very similar to our baseline, with slightly more persistent effects in the specification with no trend.

Figure A.4 reports the impulse responses obtained when we estimate our VAR on a sample starting in 1985 (instead of 1997). As credit spreads are only available from 1997, in this specification with drop credit spreads from the vector of endogenous variables. The results are very similar to our baseline.

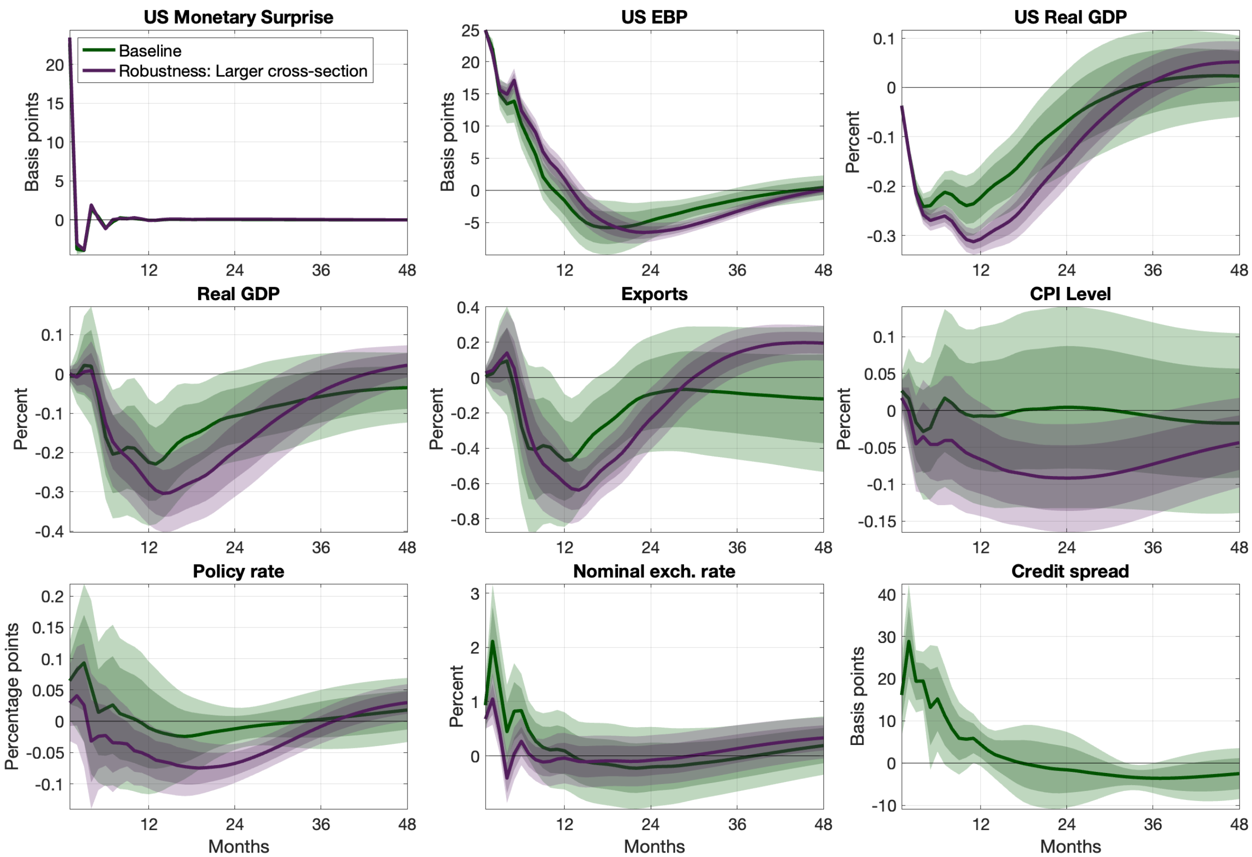
Figure A.5 reports the impulse responses obtained when we estimate our VAR with a measure of short-term market interest rates instead of policy interest rates, to address concerns that our results may be affected by the little variability of policy rates over the zero lowe bound period. The results are very similar to our baseline.

Figure A.6 reports the impulse responses obtained when we estimate our VAR on an extended vector of endogenous variables that includes US CPI. In line with the evidence in Jarocinski and Karadi (2020) we find that a contractionary US monetary policy shock reduces US consumer prices. The responses of the small open economy are not affected by the introduction of US CPI in the vector of endogenous variables.

Figure A.7 reports the impulse responses obtained when we estimate our VAR on an extended vector of endogenous variables that includes an equity price index for the small open economy. We find that a contractionary US monetary policy shock reduces equity prices in the small open economy, and that the responses of other variables are not affected.

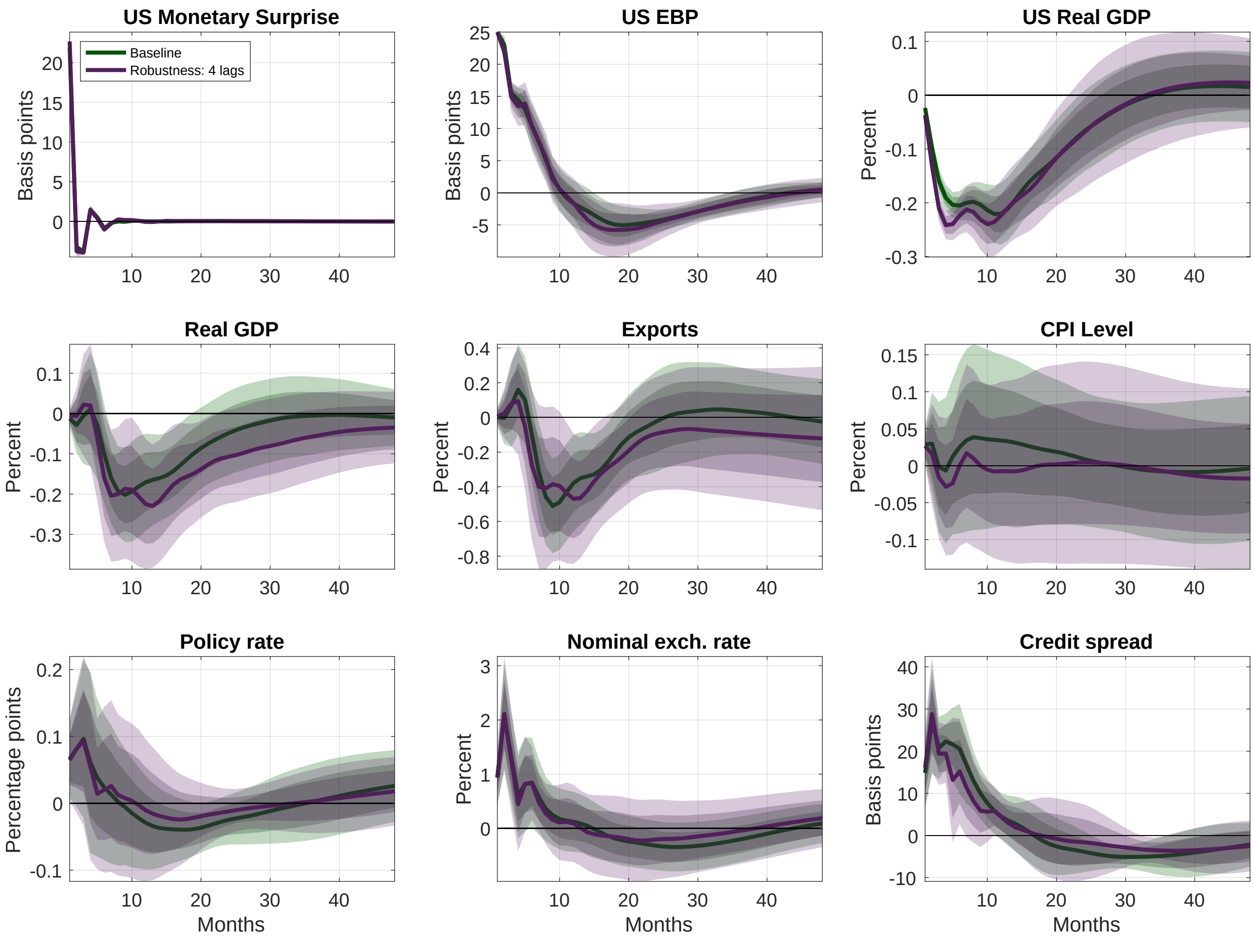
Figure A.8 reports the impulse responses obtained when we estimate our VAR on an extended vector of endogenous variables that includes oil prices. We find that a contractionary US monetary policy shock reduces oil prices, and that the responses of other variables are not affected.

Figure A.1: Robustness: Larger Sample of Countries



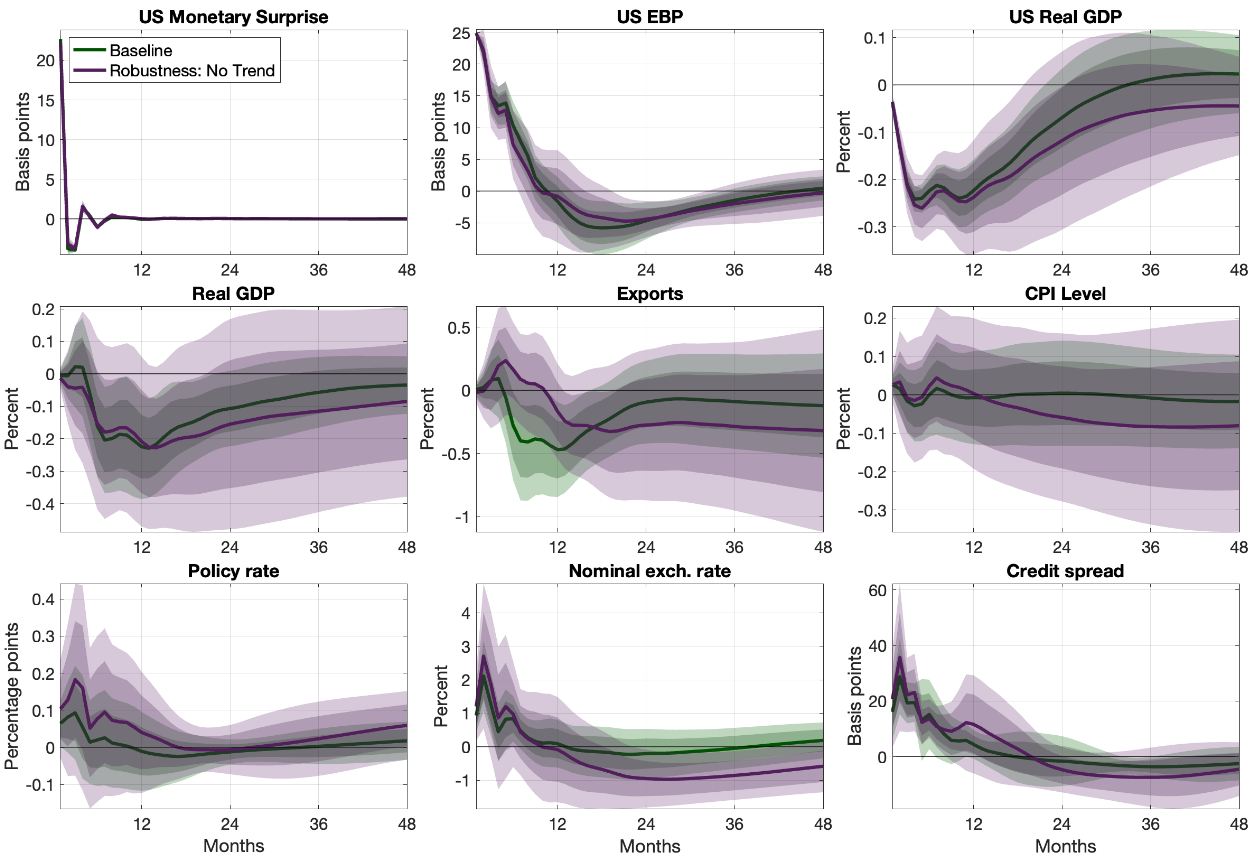
Note: The figure displays the impulse responses of the EBP and real GDP in the US, and of real GDP, CPI, exports, interest rate, nominal exchange rate, and credit spreads in a typical small open economy with a flexible exchange rate regime to a contractionary monetary policy shock in the US. The solid green line and shaded areas report the mean group estimate in our baseline. The solid purple line and shaded areas report the mean group estimate in our robustness exercise. The nominal interest rate and spreads are in annualized terms. The shock is normalized to generate a 25 basis points increase in the EBP.

Figure A.2: Robustness: 4 lags



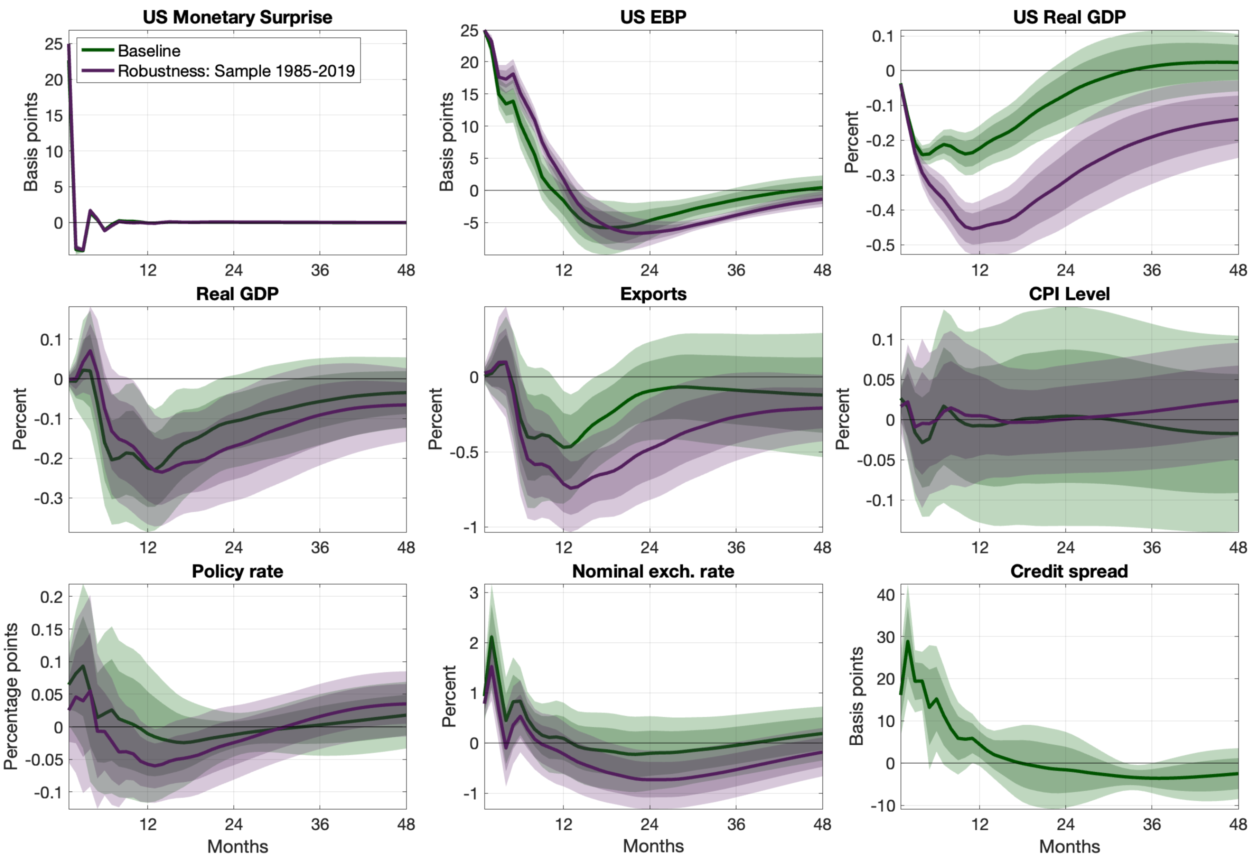
NOTE: The figure displays the impulse responses of the EBP and real GDP in the US, and of real GDP, CPI, exports, interest rate, nominal exchange rate, and credit spreads in a typical small open economy with a flexible exchange rate regime to a contractionary monetary policy shock in the US. The solid green line and shaded areas report the mean group estimate in our baseline. The solid purple line and shaded areas report the mean group estimate in our robustness exercise. The nominal interest rate and spreads are in annualized terms. The shock is normalized to generate a 25 basis points increase in the EBP.

Figure A.3: Robustness: No Trend



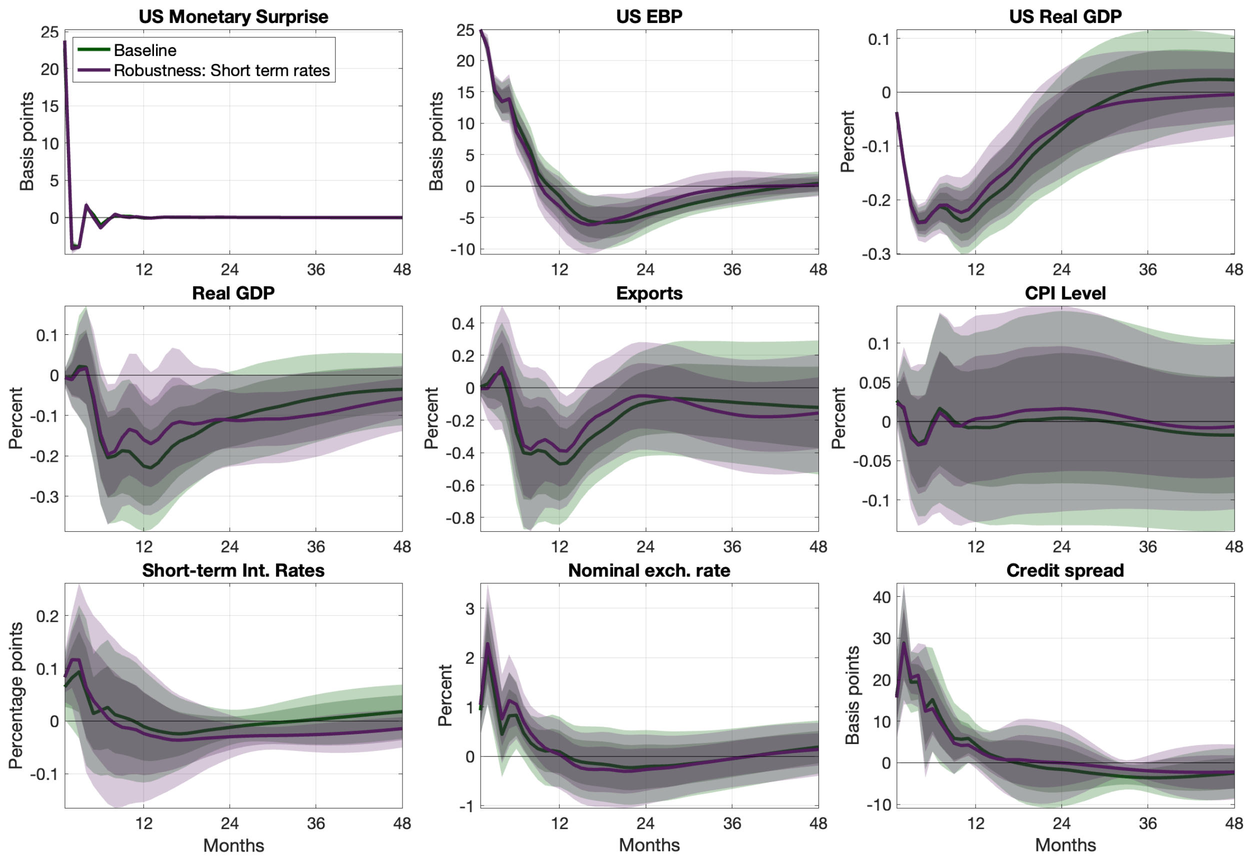
NOTE: The figure displays the impulse responses of the EBP and real GDP in the US, and of real GDP, CPI, exports, interest rate, nominal exchange rate, and credit spreads in a typical small open economy with a flexible exchange rate regime to a contractionary monetary policy shock in the US. The solid green line and shaded areas report the mean group estimate in our baseline. The solid purple line and shaded areas report the mean group estimate in our robustness exercise. The nominal interest rate and spreads are in annualized terms. The shock is normalized to generate a 25 basis points increase in the EBP.

Figure A.4: Robustness: Sample 1985 to 2019



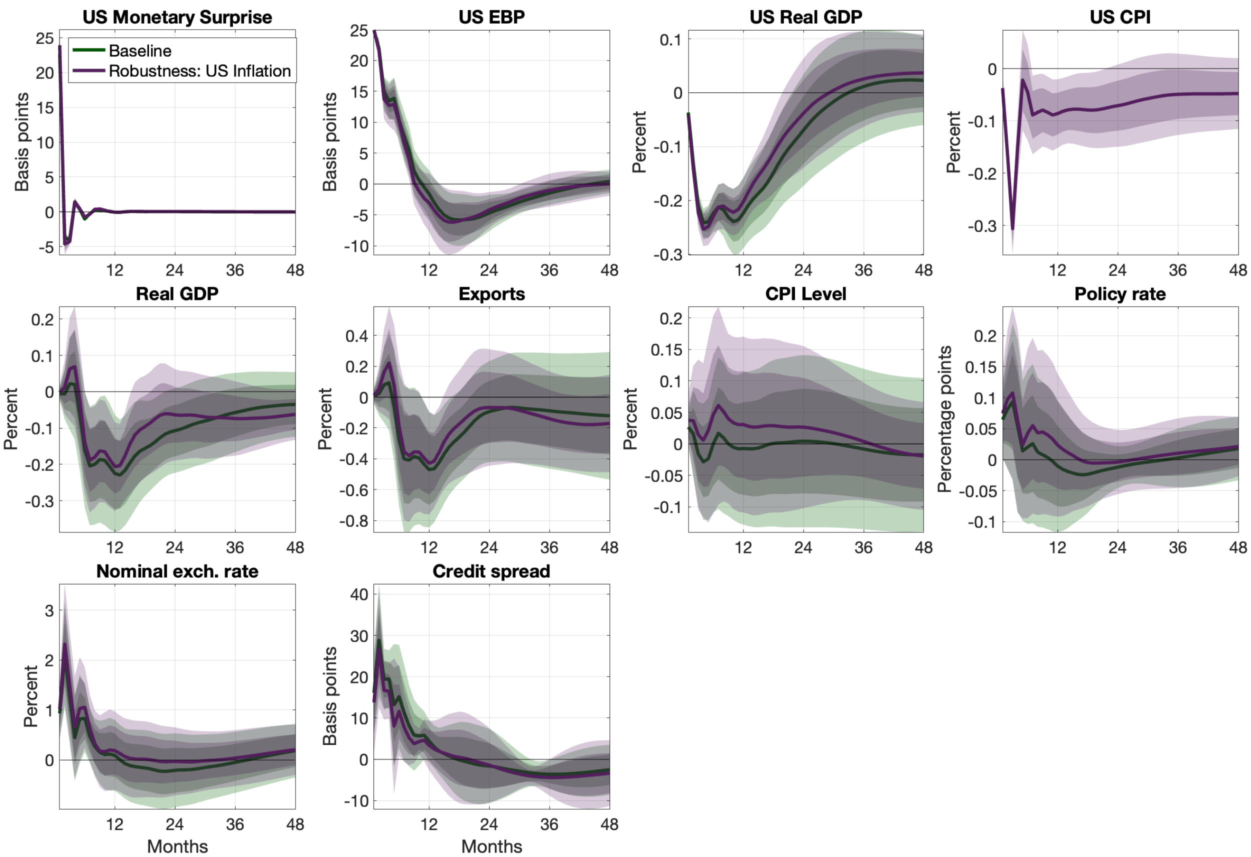
Note: The figure displays the impulse responses of the EBP and real GDP in the US, and of real GDP, CPI, exports, interest rate, nominal exchange rate, and credit spreads in a typical small open economy with a flexible exchange rate regime to a contractionary monetary policy shock in the US. The solid green line and shaded areas report the mean group estimate in our baseline. The solid purple line and shaded areas report the mean group estimate in our robustness exercise. The nominal interest rate and spreads are in annualized terms. The shock is normalized to generate a 25 basis points increase in the EBP.

Figure A.5: Robustness: Short-term Market Interest Rates



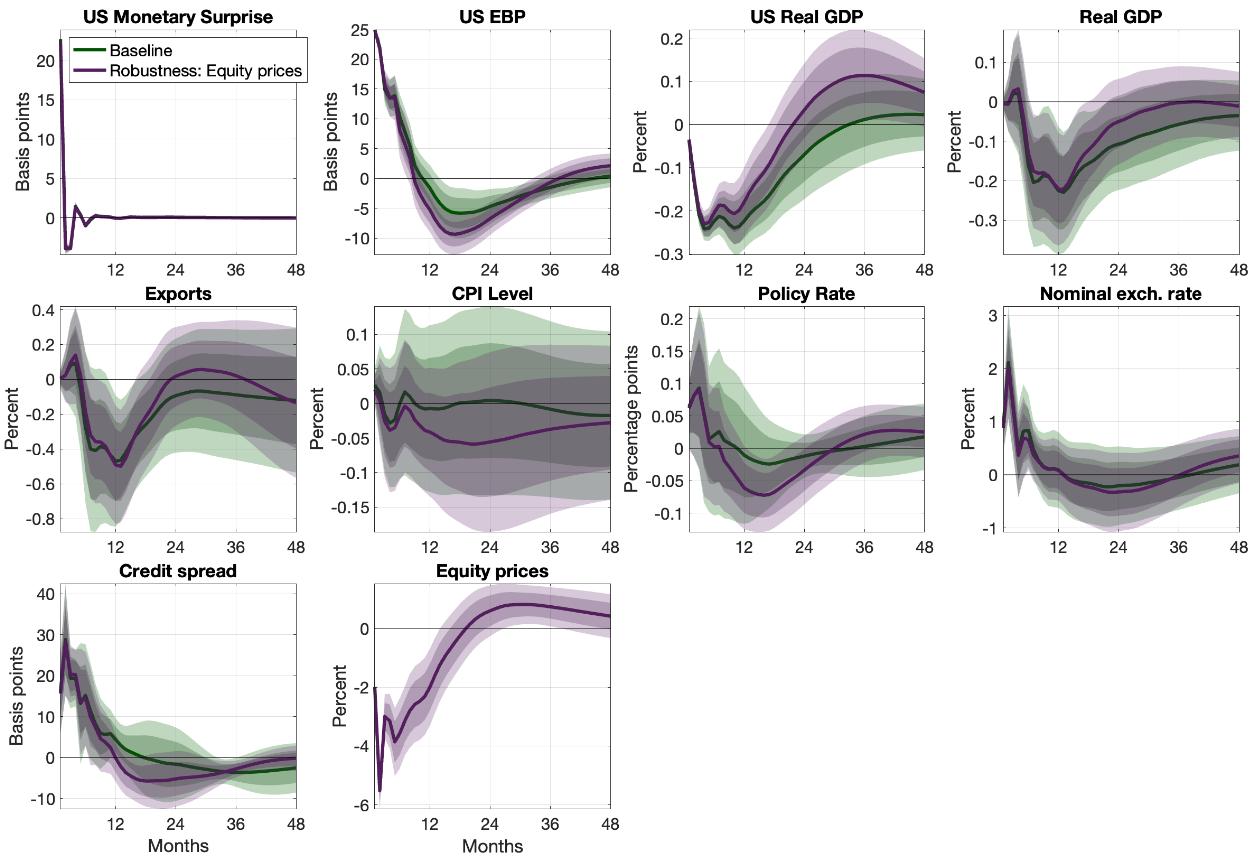
Note: The figure displays the impulse responses of the EBP and real GDP in the US, and of real GDP, CPI, exports, interest rate, nominal exchange rate, and credit spreads in a typical small open economy with a flexible exchange rate regime to a contractionary monetary policy shock in the US. The solid green line and shaded areas report the mean group estimate in our baseline. The solid purple line and shaded areas report the mean group estimate in our robustness exercise. The nominal interest rate and spreads are in annualized terms. The shock is normalized to generate a 25 basis points increase in the EBP.

Figure A.6: Robustness: Adding US CPI



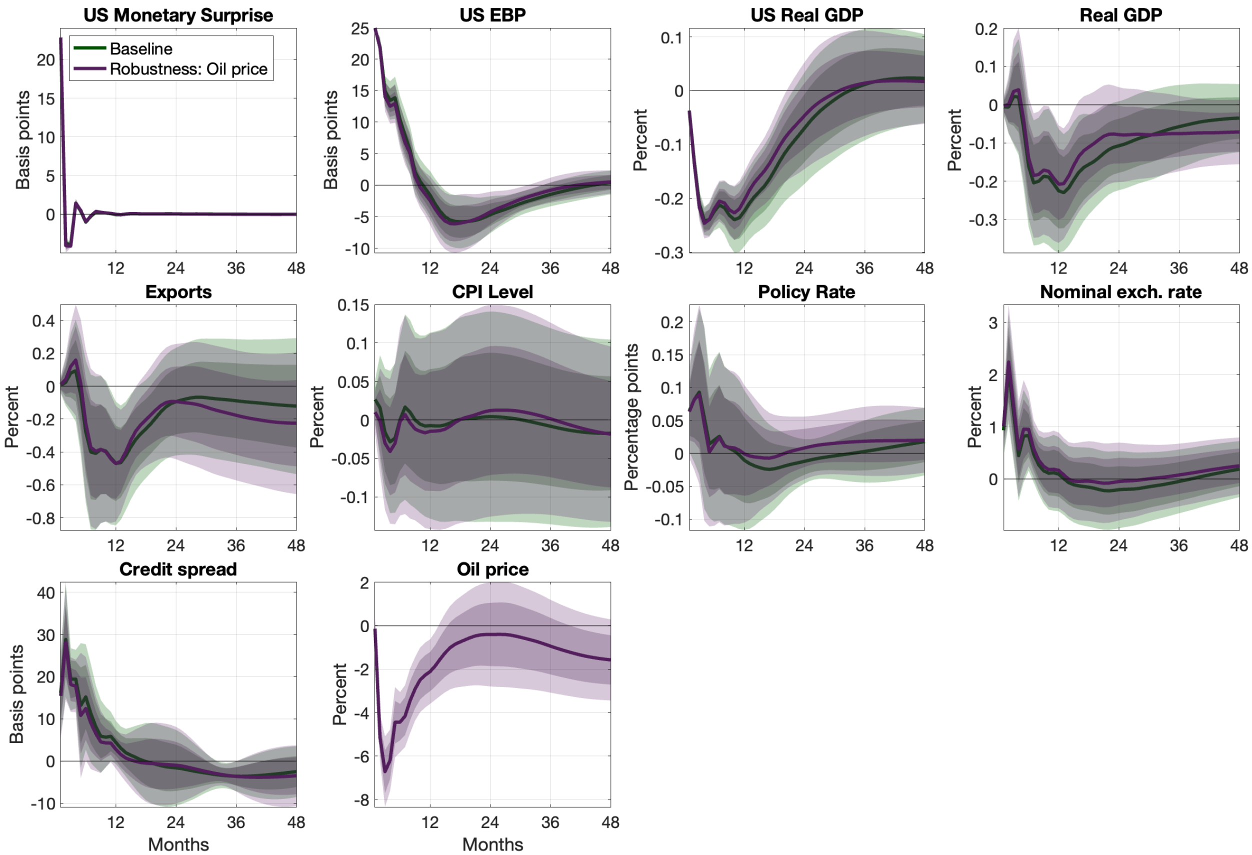
NOTE: The figure displays the impulse responses of the EBP and real GDP in the US, and of real GDP, CPI, exports, interest rate, nominal exchange rate, and credit spreads in a typical small open economy with a flexible exchange rate regime to a contractionary monetary policy shock in the US. The solid green line and shaded areas report the mean group estimate in our baseline. The solid purple line and shaded areas report the mean group estimate in our robustness exercise. The nominal interest rate and spreads are in annualized terms. The shock is normalized to generate a 25 basis points increase in the EBP.

Figure A.7: Robustness: Controlling for Equity Prices



NOTE: The figure displays the impulse responses of the EBP and real GDP in the US, and of real GDP, CPI, exports, interest rate, nominal exchange rate, and credit spreads in a typical small open economy with a flexible exchange rate regime to a contractionary monetary policy shock in the US. The solid green line and shaded areas report the mean group estimate in our baseline. The solid purple line and shaded areas report the mean group estimate in our robustness exercise. The nominal interest rate and spreads are in annualized terms. The shock is normalized to generate a 25 basis points increase in the EBP.

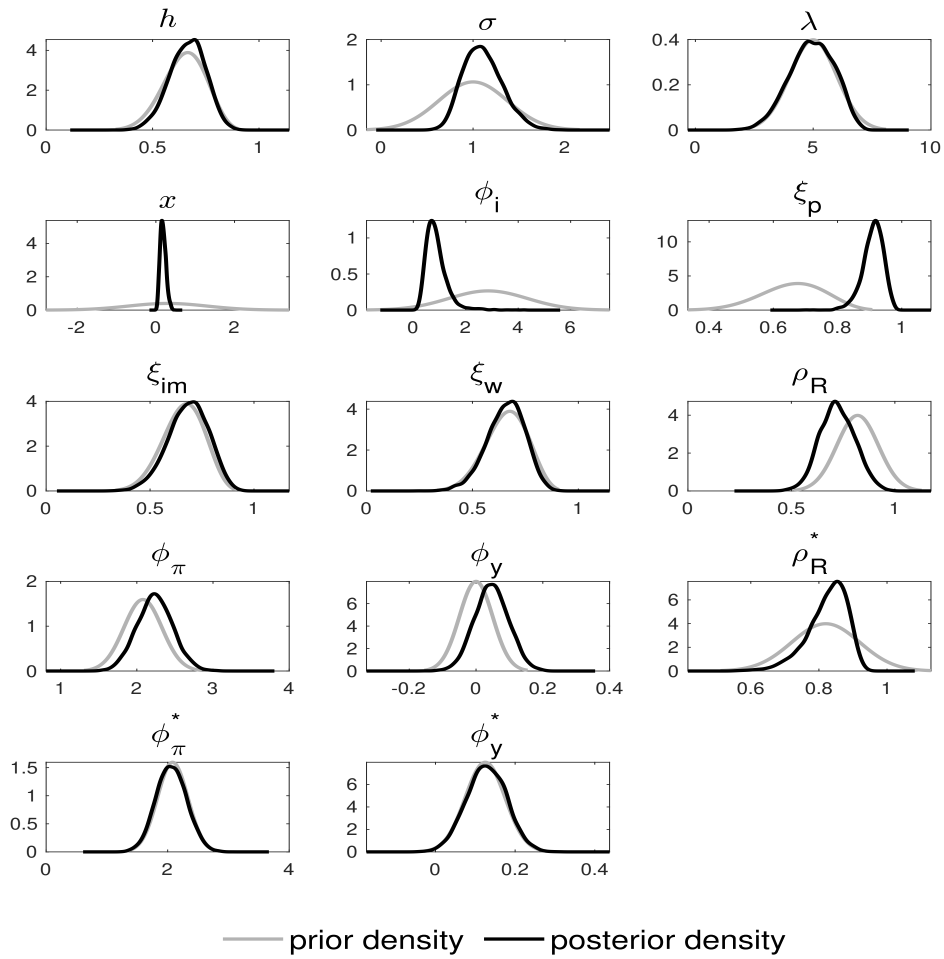
Figure A.8: Robustness: Controlling for Oil Prices



Note: The figure displays the impulse responses of the EBP and real GDP in the US, and of real GDP, CPI, exports, interest rate, nominal exchange rate, and credit spreads in a typical small open economy with a flexible exchange rate regime to a contractionary monetary policy shock in the US. The solid green line and shaded areas report the mean group estimate in our baseline. The solid purple line and shaded areas report the mean group estimate in our robustness exercise. The nominal interest rate and spreads are in annualized terms. The shock is normalized to generate a 25 basis points increase in the EBP.

A.3 Prior and Posterior Densities

Figure A.9: Prior and posterior densities for impulse response matching exercise



NOTE: The figure displays the prior (light grey) and posterior (black) densities for the impulse response matching exercise for the habit parameter (h), the coefficient of relative risk aversion (σ), the leverage ratio (λ), the ratio of foreign-currency liabilities (x), the investment adjustment cost parameter (φ_i), the domestic price stickiness parameter (ξ_p), th import price stickiness parameter (ξ_{im}), the wage stickiness parameter (ξ_w), and the parameters in the monetary policy rules of both countries (ρ_R, ϕ_π, ϕ_y, and their Foreign counterparts).

Figure A.9 reports the prior and posterior densities of the estimation exercise.

B Model Derivations

In this section, we report the first-order conditions for households, financial intermediaries, and firms, and characterize the steady state of the model.

B.1 Households

The first-order conditions for the Home household are

$$\Lambda_t = \frac{1}{c_t - h\bar{c}_{t-1}} \tag{A1}$$

$$\Lambda_t = \beta \mathbb{E}_t \left(\Lambda_{t+1} \frac{R_t}{\Pi_{t+1}} \right). \tag{A2}$$

The optimal wage-setting condition is

$$\widetilde{w}_t^{1+\nu\zeta} = \frac{\chi\nu}{\nu - 1} \frac{F_{1t}^W}{F_{2t}^W} \tag{A3}$$

where $\widetilde{w}_t$ is the optimal real wage, and

$$F_{1t}^W = \ell_t^{1+\zeta} w_t^{\nu\zeta} + \beta\xi_w \mathbb{E}_t \left[\left(\frac{w_{t+1}}{w_t} \right)^{\nu} \Pi_{t+1}^{\nu(1+\zeta)} F_{1t+1}^W \right] \tag{A4}$$

$$F_{2t}^W = \Lambda_t \ell_t + \beta\xi_w \mathbb{E}_t \left[\left(\frac{w_{t+1}}{w_t} \right)^{\nu} \Pi_{t+1}^{\nu-1} F_{2t+1}^W \right]. \tag{A5}$$

The aggregate nominal wage level evolves according to

$$W_t = [(1 - \xi_w)\widetilde{W}_t^{1-\nu} + \xi_w W_{t-1}^{1-\nu}]^{\frac{1}{1-\nu}}, \tag{A6}$$

which we can rewrite in real terms as

$$w_t = \left[(1 - \xi_w)\widetilde{w}_t^{1-\nu} + \xi_w \left(\frac{w_{t-1}}{\Pi_t} \right)^{1-\nu} \right]^{\frac{1}{1-\nu}}. \tag{A7}$$

The first-order conditions for the Foreign representative household are symmetric.

B.2 Financial Intermediation

We define the leverage ratio of a typical bank in the Foreign country as $\lambda_t^* = (q_t^* z_t^* + b_t^*)/n_t^*$, where $b_t^* = B_t^*/P_t^*$ is the amount of lending to Home banks in real terms. The bank chooses an optimal leverage ratio to maximize the expected value of terminal wealth $V(n_t^*)$, subject to the balance sheet constraint and the incentive compatibility constraint. The fact that the bank can arbitrage between lending to firms and lending to Foreign banks implies the first order condition

$$\mathbb{E}_t(\mathcal{M}^*_{t,t+1}\Omega^*_{t,t+1}r^*_{kt+1}) = \mathbb{E}_t\left(\mathcal{M}^*_{t,t+1}\Omega^*_{t,t+1}\frac{R^*_{bt}}{\Pi^*_{t+1}}\right), \tag{A8}$$

where

$$\Omega^*_{t,t+1} = \mathbb{E}_t(1-\omega+\omega\kappa^*_{t+1}) \tag{A9}$$

and

$$\kappa^*_t = \frac{V(n^*_t)}{n^*_t}. \tag{A10}$$

In an equilibrium in which the incentive compatibility constraint binds, we have

$$\kappa^*_t = \theta^*\lambda^*_t, \tag{A11}$$

which implies

$$\lambda^*_t = \frac{\mu^*_{1t}}{\theta^* - \mu^*_{0t}} \tag{A12}$$

where

$$\mu^*_{kt} = \mathbb{E}_t\left[\mathcal{M}^*_{t,t+1}\Omega^*_{t,t+1}\left(r^*_{kt+1} - \frac{R^*_t}{\Pi^*_{t+1}}\right)\right] \tag{A13}$$

and

$$\mu^*_{dt} = \mathbb{E}_t\left(\mathcal{M}^*_{t,t+1}\Omega^*_{t,t+1}\frac{R^*_t}{\Pi^*_{t+1}}\right). \tag{A14}$$

The aggregate balance sheet of the banking sector is

$$q^*_t z^*_t + b^*_t = d^*_t + n^*_t. \tag{A15}$$

The aggregate banking sector net worth evolves such that

$$n^*_t = (\omega+\xi^*_b)\left(r^*_{kt}q^*_{t-1}z^*_{t-1} + \frac{R^*_{bt-1}b^*_{t-1}}{\Pi^*_t}\right) - \omega\frac{R^*_{t-1}d^*_{t-1}}{\Pi^*_t} \tag{A16}$$

where ξ^*_b is the proportion of total assets that the household transfers to new bankers.

The optimality conditions for Home banks are similar. The leverage ratio is $\lambda_t = q_t z_t/n_t$ and is determined by

$$\kappa_t = \underbrace{\theta\left(1+\frac{\gamma}{2}x_t^2\right)}_{\equiv\Theta(x_t)}\lambda_t, \tag{A17}$$

where $x_t = s_t b^*_t/(q_t z_t)$, which implies

$$\lambda_t = \frac{\mu_{dt}}{\Theta(x_t) - (\mu_{kt} + \mu_{bt}x_t)} \tag{A18}$$

where

$$\mu_{bt} = \mathbb{E}_t \left[\mathcal{M}_{t,t+1} \Omega_{t,t+1} \left(\frac{R_t}{\Pi_{t+1}} - \frac{R^*_{bt}}{\Pi^*_{t+1}} \frac{s_{t+1}}{s_t} \right) \right] \tag{A19}$$

$$\mu_{kt} = \mathbb{E}_t \left[\mathcal{M}_{t,t+1} \Omega_{t,t+1} \left(r_{kt+1} - \frac{R_t}{\Pi_{t+1}} \right) \right] \tag{A20}$$

$$\mu_{dt} = \mathbb{E}_t \left(\mathcal{M}_{t,t+1} \Omega_{t,t+1} \frac{R_t}{\Pi_{t+1}} \right) \tag{A21}$$

$$\Omega_{t,t+1} = \mathbb{E}_t (1 - \omega + \omega \kappa_{t+1}) \tag{A22}$$

$$\kappa_t = \frac{V(n_t)}{n_t}. \tag{A23}$$

The optimal proportion of foreign currency debt is given by

$$x_t = \frac{\sqrt{1 + \frac{2\mu_t^2}{\gamma}} - 1}{\mu_t}, \tag{A24}$$

where $\mu_t = \mu_{bt}/\mu_{kt}$.

The aggregate balance sheet is

$$q_t z_t = d_t + s_t b^*_t + n_t, \tag{A25}$$

while net worth evolves according to

$$n_t = (\omega + \xi_b) r_{kt} q_{t-1} z_{t-1} - \omega \left(\frac{R_{t-1} d_{t-1}}{\Pi_t} + \frac{s_t R^*_{bt-1} b^*_{t-1}}{\Pi^*_t} \right). \tag{A26}$$

B.3 Intermediate Goods Producers

The balance sheet of intermediate goods producer in the Home country is

$$q_t z_t = q_t k_t. \tag{A27}$$

Profit maximization yields the first-order conditions with respect to ℓ_t and k_{t-1}, which are

$$w_t = (1 - \alpha) p_{mt} k^{\alpha}_{t-1} \ell^{-\alpha}_t \tag{A28}$$

and

$$r_{kt} = \frac{\alpha p_{mt} k^{\alpha-1}_{t-1} \ell^{1-\alpha}_t + (1 - \delta) q_t}{q_{t-1}}. \tag{A29}$$

The zero-profit condition implies that the price for intermediate goods is

$$p_{mt} = \frac{[r_{kt} q_{t-1} - (1 - \delta) q_t]^{\alpha} w^{1-\alpha}_t}{A_t \alpha^{\alpha} (1 - \alpha)^{1-\alpha}}, \tag{A30}$$

where $a_t \equiv \ln(A_t/A)$ follows an exogenous first-order autoregressive process

$$a_t = \rho_a a_{t-1} + e_{at}, \tag{A31}$$

with $\rho_a \in [0,1]$ and $e_{at} \sim \mathcal{N}(0, \sigma_a^2)$. The problem for Foreign intermediate goods producers and the resulting first-order conditions are symmetric.

B.4 Capital Producers

The first-order condition for capital producers in the Home country is

$$q_t = 1 + \frac{\varphi_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 + \varphi_i\left(\frac{i_t}{i_{t-1}} - 1\right)\frac{i_t}{i_{t-1}} - \varphi_i \mathbb{E}_t\left[\mathcal{M}_{t,t+1}\left(\frac{i_{t+1}}{i_t} - 1\right)\frac{i_{t+1}^2}{i_t^2}\right], \tag{A32}$$

and the capital accumulatation equation is

$$k_t = i_t + (1-\delta)k_{t-1}. \tag{A33}$$

The problem for capital producers in the Foreign country yields similar first-order conditions.

B.5 Final Goods Producers

Home final goods producers that serve the domestic market and can reset their price at time t choose

$$\frac{\widetilde{P}_t(h)}{P_{Ht}} = \frac{\varrho}{\varrho - 1}\frac{\mathcal{H}_{1t}}{\mathcal{H}_{2t}} \tag{A34}$$

where

$$\mathcal{H}_{1t} = \Lambda_t p_{mt} y_{Ht} + \beta\xi_H \mathbb{E}_t(\Pi_{Ht+1}^{\varrho}\mathcal{H}_{1t+1}) \tag{A35}$$

$$\mathcal{H}_{2t} = \Lambda_t p_{Ht} y_{Ht} + \beta\xi_H \mathbb{E}_t(\Pi_{Ht+1}^{\varrho-1}\mathcal{H}_{2t+1}), \tag{A36}$$

with $p_{Ht} \equiv P_{Ht}/P_t$ and

$$y_{Ht} = a p_{Ht}^{-\epsilon}\left[c_t + i_t + \frac{\varphi_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 i_t\right].$$

The link between the optimal reset price and inflation is

$$\xi_H \Pi_{Ht}^{\varrho-1} + (1-\xi_H)\left[\frac{\widetilde{P}_t(h)}{P_{Ht}}\right]^{1-\varrho} = 1. \tag{A37}$$

A similar set of conditions applies to all Foreign final goods producers.

Home final goods producers that serve the Foreign market and can reset their price at time t

choose

$$\frac{S_t \widetilde{P}_t^*(h)}{P_{Ht}^*} = \frac{\varrho}{\varrho - 1} \frac{\mathcal{F}_{1t}}{\mathcal{F}_{2t}}, \tag{A38}$$

where

$$\mathcal{F}_{1t} = \left(\frac{1-n}{n}\right) \Lambda_t p_{mt} y_{Ht}^* + \beta \xi_H \mathbb{E}_t[(\Pi_{Ht+1}^*)^{\varrho} \mathcal{F}_{1t+1}] \tag{A39}$$

$$\mathcal{F}_{2t} = \left(\frac{1-n}{n}\right) \Lambda_t p_{Ht}^* y_{Ht}^* + \beta \xi_H \mathbb{E}_t \left[\frac{S_{t+1}}{S_t} (\Pi_{Ht+1}^*)^{\varrho - 1} \mathcal{F}_{2t+1}\right], \tag{A40}$$

with

$$y_{Ht}^* = a^* (p_{Ht}^*)^{-\epsilon} \left[c_t^* + i_t^* + \frac{\varphi_i}{2} \left(\frac{i_t^*}{i_{t-1}^*} - 1\right)^2 i_t^*\right].$$

In this case, the link between the optimal reset price and inflation is

$$\xi_H (\Pi_{Ht}^*)^{\varrho - 1} + (1 - \xi_H) \left[\frac{\widetilde{P}_t^*(h)}{P_{Ht}^*}\right]^{1-\varrho} = 1. \tag{A41}$$

B.5.1 Importers

Importers who adjust their price at time t set

$$\frac{\widetilde{P}_t(f)}{P_{Ft}} = \frac{\varrho}{\varrho - 1} \frac{\mathcal{I}_{1t}}{\mathcal{I}_{2t}}, \tag{A42}$$

where

$$\mathcal{I}_{1t} = \left(\frac{1-n}{n}\right) \Lambda_t p_t^{im} y_{Ft} + \beta \xi \mathbb{E}_t (\Pi_{Ft+1}^{\varrho} \mathcal{I}_{1t+1}) \tag{A43}$$

$$\mathcal{I}_{2Ft} = \left(\frac{1-n}{n}\right) \Lambda_t p_{Ft} y_{Ft} + \beta \xi \mathbb{E}_t (\Pi_{Ft+1}^{\varrho - 1} \mathcal{I}_{2t+1}), \tag{A44}$$

with

$$y_{Ft} = (1-a) p_{Ft}^{-\epsilon} \left[c_t + i_t + \frac{\varphi_i}{2} \left(\frac{i_t}{i_{t-1}} - 1\right)^2 i_t\right].$$

The link between the optimal reset price of Foreign goods and inflation is

$$\xi_F \Pi_{Ft}^{\varrho - 1} + (1 - \xi_F) \left[\frac{\widetilde{P}_t(f)}{P_{Ft}}\right]^{1-\varrho} = 1. \tag{A45}$$

B.6 Relative Prices and Inflation

From the definition of the CPI index (8), we can link the relative price of Home goods p_{Ht} to the terms of trade according to

$$p_{Ht}^{\epsilon-1} = a + (1-a)\mathcal{T}_t^{1-\epsilon}, \tag{A46}$$

where $\mathcal{T}_t = P_{Ft}/P_{Ht}$.

Similarly, for the relative price of Foreign goods, we have

$$(p_{Ft}^*)^{\epsilon-1} = a^* \left(\frac{\psi_t}{\psi_t^* \mathcal{T}_t}\right)^{1-\epsilon} + (1-a^*), \tag{A47}$$

where $\psi_t = \mathcal{E}_t P_{Ht}^*/P_{Ht}$ and $\psi_t^* = \mathcal{E}_t P_{Ft}^*/P_{Ft}$ are the law-of-one-price gaps for Home and Foreign goods, respectively (the measure of price pass-through for tradable goods).

The link between the relative prices of the two goods in the Home country is

$$a p_{Ht}^{1-\epsilon} + (1-a) p_{Ft}^{1-\epsilon} = 1, \tag{A48}$$

while the link between CPI inflation and domestic inflation is

$$\frac{\Pi_{Ht}}{\Pi_t} = \frac{p_{Ht}}{p_{Ht-1}}. \tag{A49}$$

The last two equations have identical counterparts for the Foreign country.

Finally, the link between the terms of trade $\mathcal{T}_t$ and the real exchange rate is

$$S_t^{1-\epsilon} = \frac{a^* \psi_t^{1-\epsilon} + (1-a^*)(\psi_t^* \mathcal{T}_t)^{1-\epsilon}}{a + (1-a)\mathcal{T}_t^{1-\epsilon}}. \tag{A50}$$

B.7 Monetary Policy

The central bank in the Home country follows the interest rate rule

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[\Pi_t^{\phi_\pi} \left(\frac{y_t}{y_{t-1}}\right)^{\phi_y} \left(\frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}\right)^{\phi_\mathcal{E}}\right]^{1-\rho_R}. \tag{A51}$$

In the baseline analysis, we set $\phi_\mathcal{E} = 0$, which instead we allow to be positive in some of the counterfactual experiments.

The interest rate rule in the Foreign country is

$$\frac{R_t^*}{R^*} = \left(\frac{R_{t-1}^*}{R^*}\right)^{\rho_R} \left[(\Pi_t^*)^{\phi_\pi} \left(\frac{y_t^*}{y_{t-1}^*}\right)^{\phi_y}\right]^{1-\rho_R} e^{\epsilon_{Rt}^*}, \tag{A52}$$

where $\epsilon^*_{Rt} \sim \mathcal{N}(0, \sigma^2_{R^*})$ is a monetary policy shock.

B.8 Market Clearing

In the Home country, the market clearing condition for intermediate goods requires

$$y_t = \Delta_{Ht} y_{Ht} + \left(\frac{1-n}{n}\right) \Delta^*_{Ht} y^*_{Ht}, \tag{A53}$$

where Δ_{Ht} and Δ^*_{Ht} are indexes of price dispersion defined as

$$\Delta_{Ht} \equiv \int_0^n \left[\frac{\widetilde{P}_t(h)}{P_{Ht}}\right]^{-\varrho} dh \qquad \Delta^*_{Ht} \equiv \int_n^1 \left[\frac{\widetilde{P}^*_t(h)}{P^*_{Ht}}\right]^{-\varrho} dh.$$

From the expression of the domestic price index, we can derive the law of motion of the two price dispersion variables as

$$\Delta_{Ht} = \xi_H \Pi^{\varrho}_{Ht} \Delta_{Ht-1} + (1-\xi_H) \left[\frac{\widetilde{P}_t(h)}{P_{Ht}}\right]^{-\varrho}$$

and

$$\Delta^*_{Ht} = \xi_H (\Pi^*_{Ht})^{\varrho} \Delta^*_{Ht-1} + (1-\xi_H) \left[\frac{\widetilde{P}^*_t(h)}{P^*_{Ht}}\right]^{-\varrho}.$$

The market clearing condition for the Foreign country is

$$y^*_t = \Delta^*_{Ft} \left(y^*_{Ft} + \frac{n}{1-n} y_{Ft}\right)$$

where

$$\Delta^*_{Ft} = \int_n^1 \left[\frac{\widetilde{P}^*_t(f)}{P^*_{Ft}}\right]^{-\varrho} df,$$

and the index of price dispersion evolves according to

$$\Delta^*_{Ft} = \xi^*_F (\Pi^*_{Ft})^{\varrho} \Delta^*_{Ft-1} + (1-\xi^*_F) \left[\frac{\widetilde{P}^*_t(f)}{P^*_{Ft}}\right]^{-\varrho}.$$

Lastly, the law of motion of net foreign debt for the Home country is

$$b^*_t = \frac{R^*_{bt-1} b^*_{t-1}}{\Pi^*_t} + p^*_{Ft} y_{Ft} - \left(\frac{1-n}{n}\right) p^*_{Ht} y^*_{Ht}. \tag{A54}$$

C Steady State

We approximate the model around a non-stochastic steady state with zero inflation in both countries and relative prices normalized to one. As a consequence, also steady state price dispersion is equal to one.

In each country, the steady state real interest rate is equal to the inverse of the individual discount factor. We choose χ so that steady state hours ℓ are equal to one-third. Zero steady state investment adjustment costs imply that the relative price of capital q is equal to one. Moreover, since in steady state all firms can adjust their price, the relative price of intermediate goods is equal to the inverse of the steady state markup ($p_m = (\varrho - 1)/\varrho$). Given this value, the first order conditions for intermediate goods producers pin down w, r_k and k. In turn, from the production function, we obtain y, and from the law of motion of capital we can derive i.

In equilibrium, the quantity of securities that banks hold z corresponds to the capital stock k. Given the leverage ratio λ and the ratio of foreign currency liabilities x, banks' net worth of banks is $n = k/\lambda$ and the stock of foreign liabilities is $b^* = xk$.[20] The aggregate balance sheet of banks residually determines deposits ($d = (1 - 1/\lambda - x)k$). With these expressions, we can derive $V(n)$ and κ, which, together with the returns on deposits and capital, pin down μ_d, μ_k, and μ_b.

Finally, the demand equations and the market clearing conditions determine the quantities c_h, c_h^*, c_f, c_f^*, y_h, y_h^*, y_f, y_f^*, c and c^*.

[20] Our choice to directly estimating λ and x corresponds to choosing values for the parameters γ and θ consistent with the moral hazard constraint at equality and the first order condition for the optimal portfolio choice.