Balance Sheets, Exchange Rates, and International Monetary Spillovers*

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Abstract

We use a two-country New-Keynesian model with balance-sheet constraints on banks to investigate the extent of international spillovers of U.S. monetary policy. Home banks borrow from domestic households in domestic currency, as well as from residents of the foreign economy (the U.S.) in dollars. We assume agency frictions are more severe for foreign debt than for domestic deposits. As a consequence, a deterioration in domestic banks' balance sheets induces a rise in the home currency's risk premium and an exchange rate depreciation. We use the model to investigate how domestic monetary transmission and international monetary spillovers are affected by the extent of banks' liability dollarization, and whether the latter makes it desirable for domestic policy to target the nominal exchange rate.

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1 Introduction

With U.S. monetary policy normalization well underway, an important question facing monetary policymakers across the globe is to what extent rising U.S. interest rates can have adverse spillovers to their own economies, and what are the tradeoffs they face in this environment. A common view, particularly among emerging market economies, recommends gearing policy toward preventing capital outflows and mitigating currency depreciation. A frequent argument underlying this view is the presence of currency mismatches in balance sheets, which render the latter undesirably vulnerable to movements in the nominal exchange rate.[1]

Our goal in this paper is to investigate how balance sheet dollarization of the domestic private sector may affect the degree of spillovers from U.S. monetary policy, and to lay out its consequences for the tradeoffs faced by domestic monetary policymakers. In particular, we investigate whether balance sheet dollarization provides grounds for an interest rate policy that attempts to stabilize the nominal exchange rate, as argued by the common view described above. To this end, we develop a two-country New Keynesian model, consisting of a "home" economy (e.g. an emerging market economy) and the U.S., and augment it with financial frictions in the banking sector of the home economy. We then allow for dollar-denominated liabilities in home banks' balance sheets, by assuming that domestic banks can borrow from U.S. households (in dollars) as well as from domestic households (in domestic currency). In each case, banks' borrowing is subject to agency frictions, modelled as in Gertler and Kiyotaki (2010). Because banks' assets consist of home productive capital (denominated in home currency), the presence of dollar liabilities creates a currency mismatch whereby a home currency depreciation worsens domestic balance sheets.

An important assumption within our setting is that the agency frictions affect foreign borrowing more severely than domestic borrowing. Here we attempt to capture the realistic notion that it is harder for foreign creditors to monitor home-economy borrowers and enforce contracts with them than it is for domestic creditors. We begin by illustrating the role of this assumption by means of a very simple model designed to isolate the role of balance sheet constraints. We show how a domestic balance sheet deterioration induces a deviation from uncovered interest parity (a rise in the domestic "currency risk premium") and an exchange rate depreciation.

[1] Calvo and Reinhart (2002) and Hausmann, Panizza and Stein (2001), for example, appeal to currency mismatches in balance sheets, and the consequent sensitivity of the latter to exchange rate variations, as an explanation for the observed "fear of floating" among emerging economies.

We then embed this mechanism within a larger-scale New Keynesian model with empirically realistic features. We use the model to investigate the quantitative role of balance sheet conditions in exchange rate determination, as well as how the transmission of domestic monetary policy is affected by the extent of liability dollarization. We then move on to quantify how the latter may influence the size of the spillovers from U.S. monetary tightening. Finally, we examine the desirability of following a standard inflation-targeting Taylor rule versus a policy rule aimed at nominal exchange rate stabilization.

The key findings that emerge from our analysis are as follows. First, the degree of liability dollarization significantly affects the transmission of domestic monetary policy, particularly regarding the behavior of the real and nominal exchange rate. In particular, because a domestic interest rate hike hurts balance sheets, it induces a rise in the currency risk premium, which partially counteracts the standard effect through the uncovered interest parity condition (UIP henceforth) leading to an exchange rate appreciation. This effect turns more powerful as the degree of liability dollarization rises, because balance sheets turn more sensitive to a depreciation—thus exacerbating the adverse feedback between the state of balance sheets and the exchange rate. When dollarization is very high, a monetary tightening actually leads the currency to *depreciate* in the short run, due to a sharp rise in the currency risk premium.

Second, we find that dollarization significantly enhances the spillovers from a U.S. tightening to the home economy. The reason is the downward pressure on the currency exerted by a U.S. policy rate hike. The depreciation initiates losses in domestic balance sheets when dollarization is high, setting off the adverse feedback loop between exchange rates and balance sheets.

We next examine the spillovers from U.S. monetary policy under an alternative policy regime in which the domestic monetary authority systematically rises the policy rate as the nominal exchange rate depreciates. Our key finding is that the appeal of such a policy actually *diminishes* as the degree of liability dollarization rises, rather than increasing as suggested by the conventional view. The reason is the significant adverse effect on the currency risk premium exerted by a domestic tightening. In the case of a very high rate of dollarization, the alternative policy regime (the one that targets the nominal exchange rate) induces an enormous output drop following a U.S. tightening, and does not even succeed in containing the short-run exchange rate depreciation.

Compared to standard New Keynesian models like Gali and Monacelli (2005), in which a UIP condition always holds, our model features significant deviations from uncovered interest parity, which are related to the state of domestic balance sheets (and therefore linked to domestic credit spreads). In the empirical section of the paper, we provide a test this feature of the model. We do so by augmenting Fama regressions (Fama (1984)) with measures of domestic credit spreads, which proxying for the domestic external finance premium. Here we find significant support for the basic model prediction linking the currency risk premium with domestic credit spreads.

Our paper is related to several strands in the literature. We build our model on the New-Keynesian open economy macroeconomics presented in Gali and Monacelli (2005) and Erceg et al. (2007). The model is augmented to include financial frictions in the banking sector as in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) and balance sheet channel of exchange rate changes as in Céspedes et al. (2004) (see, also, Gertler et al. (2007), Aghion et al. (2001), Aghion et al. (2004), Krugman (1999)). The latter feature of the model is consistent with recent micro evidence presented in Kalemli-Ozcan et al. (2016) and Niepmann and Schmidt-Eisenlohr (2017) that document adverse effects of currency depreciations on real and financial variables in the presence of foreign-denominated debt.[2] Our paper is also related to recent work by Aoki, Benigno and Kiyotaki (2016), Bocola and Lorenzoni (2017) and Gabaix and Maggiori (2015). Unlike these papers, our focus is to develop a large scale two-country New Keynesian model that does not stray too far from the standard quantitative DSGE models used in policy analysis, and that is tractable enough to accommodate the features that are present in that literature.

The paper is organized as follows. We begin by describing, in Section 2, a very simple model aimed at isolating the role of domestic balance sheets on deviations from uncovered interest parity—the key novel element in our setting relative to Gali and Monacelli (2005) or Erceg et al. (2007). Section 3 describes the full model. Section 4 shows our quantitative experiments. Section 5 contains the empirical analysis. Section 6 concludes.

2 Simple Model

We begin with a very simple, stripped-down version of the model which allows us to isolate the role of the state of balance sheets on the currency risk premium and the exchange rate. The model consists of a foreign economy (the U.S.) and a domestic economy populated by households, firms, and bankers. There are two nondurable consumption goods (one

[2]Currency mismatches are still a concern for emerging market economies. See, for example, Goldstein and Turner (2004), Chui, Kuruc and Turner (2016).

produced at home and the other produced abroad) as well a durable capital good. Home bankers borrow from domestic households and from U.S. households to fund the acquisition of physical capital. An agency friction potentially limits bankers' ability to borrow (from both domestic and foreign creditors). Aside from the agency friction, the model features no other real or nominal imperfections. For simplicity, throughout we assume there are no financial frictions in the foreign economy.

2.1 Banks

We assume each banker i lives for two periods, and operates on behalf of the representative household.[3] At the beginning of the period, the banker receives an equity transfer from the household. The banker then uses this equity endowment ξ_{it} (an exogenous variable) as well as borrowed funds from domestic households (D_{it}) and foreign households (D^*_{it}, in real dollars) to finance capital purchases S_{it}:

$$q_t S_{it} = D_{it} + \mathcal{Q}_t D^*_{it} + \xi_{it}$$

where q_t is price of capital and $\mathcal{Q}_t$ denotes the real exchange rate (the real price of foreign currency). S_{it} is claims on domestic firms, which are perfectly state-contingent on the underlying return (given that there are no frictions in the relationship between banks and nonfinancial firms). Thus, the banker can be thought of as a holder of equity of domestic firms.

In $t + 1$, the bank receives net payment

$$\underbrace{\frac{r_{Kt+1} + q_{t+1}}{q_t}}_{\equiv R_{Kt+1}} q_t S_{it} - R_{t+1} D_{it} - R^*_{t+1} \mathcal{Q}_{t+1} D^*_{it}$$

which he or she transfers to the household and then exits. Here r_{Kt+1} is the dividend payout and R_{t+1}, R^*_{t+1} are the (noncontingent) interest rates on domestic and foreign funds, respectively.

The agency friction takes the form of a simple limited enforcement problem. In particular, after borrowing funds, the banker may default on creditors and divert the amount

$$\theta\Big(D_{it} + (1 + \gamma)\mathcal{Q}_t D^*_{it} + \xi_{it}\Big)$$

[3] In the larger-scale model presented later, we allow for long-lived bankers.

for personal gain, where $0 < \theta < 1$ and $\gamma > 0$. The latter assumption, $\gamma > 0$, implies that foreign loans are more easily divertable than domestic loans. We believe this is a natural assumption: It captures the notion that it is harder for foreign creditors to monitor borrowers and enforce contracts than it is for domestic creditors. Upon default, creditors liquidate the bank and recover the remaining amount. For creditors to be willing to supply funds in the first place, the banker's choices need to satisfy an incentive constraint requiring his or her continuation value to be higher than the value of defaulting and diverting funds.

Let

$$\begin{aligned}
\mu_t &\equiv \beta \mathbb{E}_t \left(R_{Kt+1} - R_{t+1} \right) \\
\varrho_t &\equiv \beta \mathbb{E}_t \left(R_{Kt+1} - \frac{R^*_{t+1} \mathcal{Q}_{t+1}}{\mathcal{Q}_t} \right) \\
x_{it} &\equiv \frac{\mathcal{Q}_t D^*_{it}}{q_t S_{it}}
\end{aligned}$$

The variable μ_t denotes expected excess returns with respect to the domestic rate R_{t+1}, while ϱ_t is expected excess returns relative to the foreign borrowing rate. The variable x_{it} is the foreign funding ratio—the ratio of the bank's foreign liabilities (expressed in real domestic currency) to total assets. Each banker solves the following problem:

$$\max_{S_{it}, x_{it}} \quad \Big[x_{it} \varrho_t + (1 - x_{it}) \mu_t \Big] q_t S_{it} + \xi_{it}$$

subject to

$$\Big[x_{it} \varrho_t + (1 - x_{it}) \mu_t \Big] q_t S_{it} + \xi_{it} \geq \theta \left(1 + \gamma x_{it} \right) q_t S_{it} \quad \text{(IC)}$$

The incentive constraint (IC) above requires that the banker's continuation value be higher than the value of defaulting.

Given a binding IC, the banker's first order conditions imply the optimal liability portfolio condition

$$(1 + \gamma) \mu_t = \varrho_t$$

The intuition is straightforward. Consider a marginal increase in the bank's foreign borrowing, financed by a decrease of the amount of borrowing from the domestic market. The benefit of this operation is ϱ_t, the excess return on foreign borrowing. The cost is $(1+\gamma)\mu_t$—

the excess return on domestic borrowing, μ_t, plus the loss due to a tighter IC, $\gamma\mu_t$ (recall that an extra unit of foreign borrowing tightens the constraint by γ marginally). If the bank's portfolio is optimal in the first place, the benefit of the operation must equal its cost.

The wedge in the UIP condition (or "foreign exchange risk premium") is then given by:

$$\begin{aligned}\mu_t^* &\equiv \beta\mathbb{E}_t\left(R_{t+1} - \frac{R_{t+1}^*\mathcal{Q}_{t+1}}{\mathcal{Q}_t}\right) \\ &= \varrho_t - \mu_t \\ &= \gamma\mu_t\end{aligned}$$

Thus the foreign exchange risk premium is proportional to the domestic excess return μ_t, with the constant of proportionality given by the parameter γ.

Throughout we assume that the primitive parameters are such that the IC always binds in a neighborhood of the steady state:

$$(1 + \gamma x_{it})\, q_t S_{it} = \frac{\xi_{it}}{\theta - \mu_t}$$

2.2 Households and export demand

The representative consumer maximizes

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_{Dt}, M_{Ct})$$

subject to

$$C_{Dt} + \mathcal{Q}_t M_{Ct} + D_t \leq W_t\overline{L} + R_t D_{t-1} + \pi_t$$

C_{Dt} is domestic-good consumption, M_{Ct} is imports, D_t is bank deposits, and π_t is net transfers from bankers. Assuming preferences take the form $U(C_D, M_C) = C_D + \chi_m \log(M_C)$, we get the following first-order conditions:

$$\begin{aligned}R &= \beta^{-1} \\ M_{Ct} &= \chi_m \mathcal{Q}_t^{-1}\end{aligned}$$

Given symmetric preferences in the foreign country, export demand from the foreign country is analogous to import demand: $M^*_{Ct} = \chi_x \mathcal{Q}_t$. We assume inelastic labor supply and linear utility in C_D for simplicity, as these features are not essential (qualitatively) to the transmission from balance sheets to exchange rates. On the other hand, it is important to allow for a qualitatively realistic response of net exports to the real exchange rate, justifying the assumption of curvature in the preferences for imports and exports.

2.3 Equilibrium conditions

We assume that physical capital is in fixed aggregate supply $\overline{K}$. Capital market clearing is then given by $\int S_{it} di = \overline{K}$. We assume banks' transfer is $\xi_{it} = \xi_t q_t \overline{K}$, where ξ_t follows an exogenous process with mean $\xi \in (0,1)$. Aggregating banks' incentive constraint and assuming symmetry, we get $1 + \gamma x_t = \frac{1}{\theta - \mu_t} \xi_t$.

Aggregating domestic budget constraints (where $R^* = \beta^{*-1} < R$),

$$\mathcal{Q}_t \left(R^* D^*_{t-1} - D^*_t \right) = NX_t$$
$$NX_t = \chi_x \mathcal{Q}_t - \chi_m$$

where NX_t is net exports expressed in terms of the home good ($NX_t \equiv M^*_{Ct} - \mathcal{Q}_t M_{Ct}$).

We assume firms are perfectly competitive and operate a Cobb-Douglas technology $Y_t = K_t^\alpha L_t^{1-\alpha}$. Given the aggregate supplies of labor and capital $\overline{K}$ and $\overline{L}$, the dividend payout is then given by $\overline{r}_K = \alpha (\overline{K}/\overline{L})^{\alpha - 1}$.

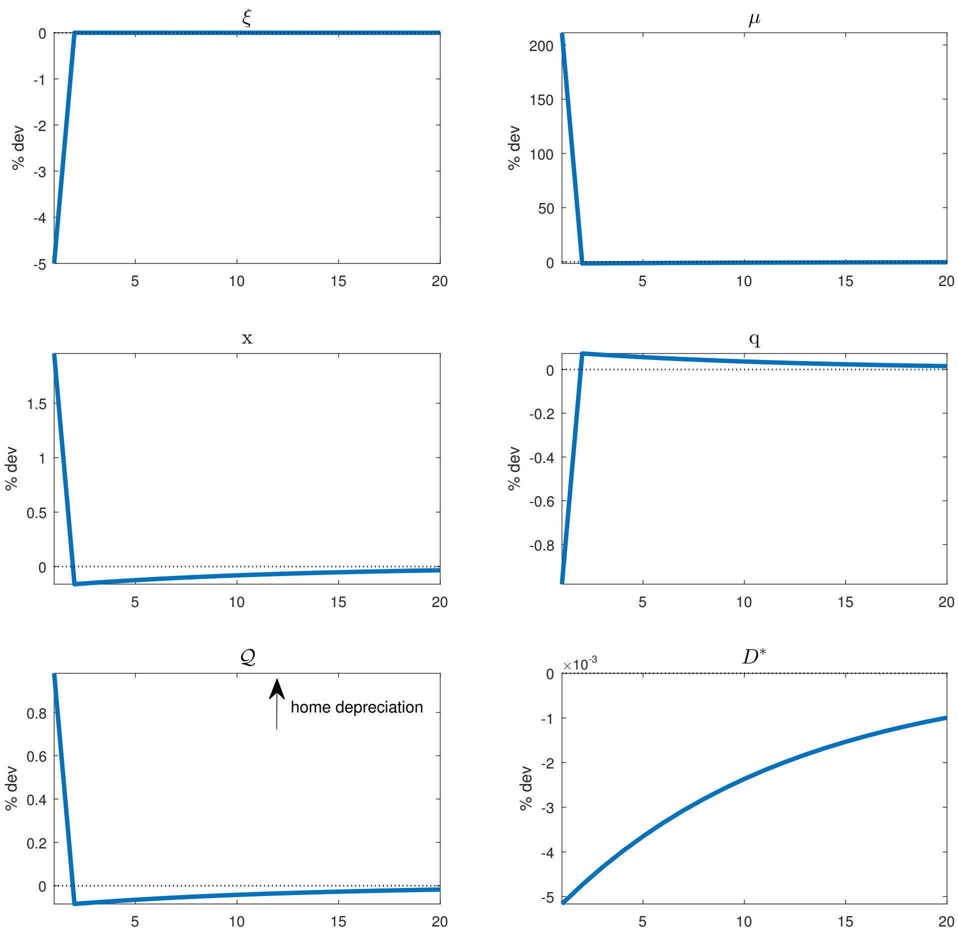
The full set of equilibrium conditions characterizing the home economy consists of 5 equations determining $x_t, \mu_t, \mathcal{Q}_t, q_t$ and D^*_t:[4]

$$1 + \gamma x_t = \frac{1}{\theta - \mu_t} \xi_t \qquad \text{(1. IC)}$$
$$x_t = \frac{\mathcal{Q}_t D^*_t}{q_t \overline{K}} \qquad \text{(2. Foreign funding ratio)}$$
$$q_t = \beta \frac{\mathbb{E}_t(\overline{r}_K + q_{t+1})}{1 + \mu_t} \qquad \text{(3. Price of capital)}$$
$$\mathcal{Q}_t = \frac{\frac{\beta}{\beta^*} \mathbb{E}_t(\mathcal{Q}_{t+1})}{1 - \gamma \mu_t} \qquad \text{(4. RER)}$$
$$D^*_t = \frac{\chi_m}{\mathcal{Q}_t} - \chi_x + R^* D^*_{t-1} \qquad \text{(5. BOP)}$$

[4]Appendix A contains the model's steady state and log-linearized equilibrium conditions.

2.4 Effect of net worth shock

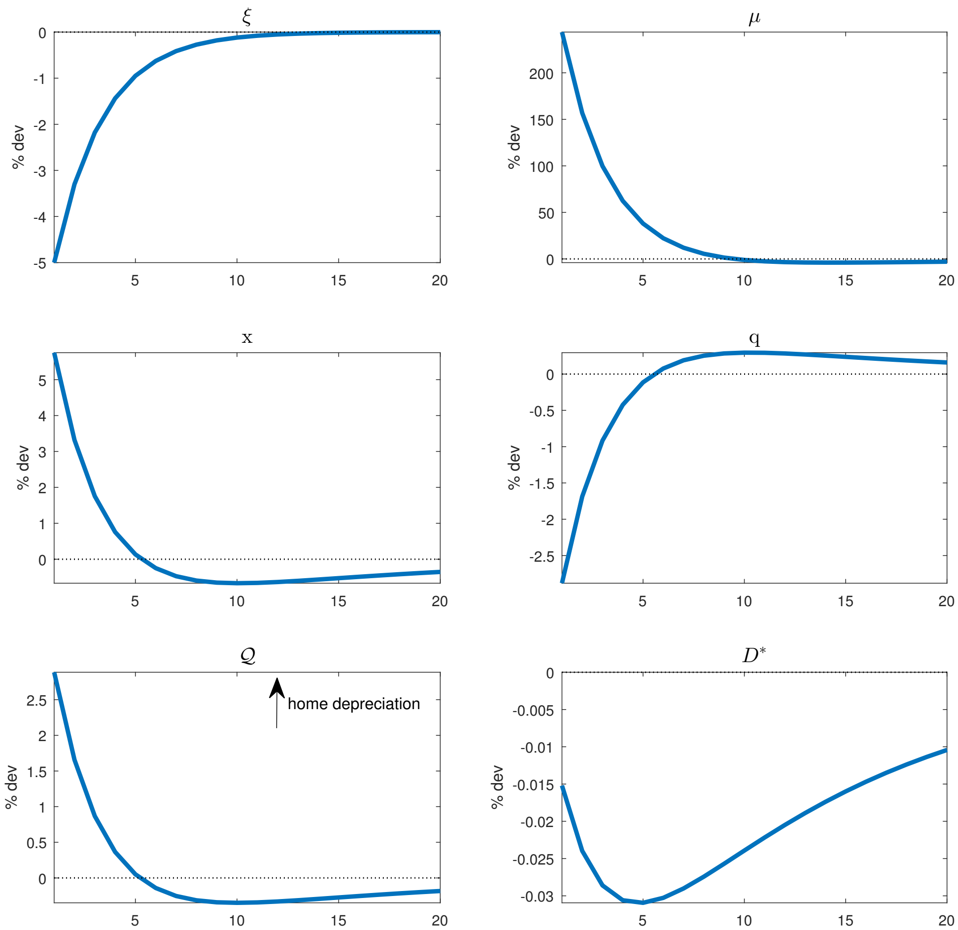
Figure 1: *iid* ξ shock in the simple model



$(\beta = 0.9925, \beta^* = 0.9975, \gamma = 1, \theta = 0.2, \xi = 0.25, \chi_m = \chi_x = .25)$

What are the consequences of a drop in aggregate bank net worth? Figure 1 shows the impulse responses to a negative innovation of five percent to ξ_t, assuming that the latter follows an *iid* process. We set the parameters to the values indicated below Figure 1, but emphasize that the basic qualitative patterns hold quite generally. On impact ($t = 1$), lower net worth forces the excess return μ_t to rise, via equation (1) (the incentive constraint). Through the optimal loan portfolio condition, the currency risk premium also rises, and the real exchange rate appreciates (through equation (4)). The home depreciation boosts net exports, leading D_t^* to fall through the balance of payments (BOP) equation (5). On impact, the foreign funding ratio x_t rises despite the fall in D_t^*, as $\mathcal{Q}$ rises and q falls—both pushing

Figure 2: Persistent ξ shock in the simple model



up x_t as seen in equation (2). To understand the dynamics for $t > 1$, note that at $t = 1$ the economy now starts with a depressed D^*_{t-1} (the only state variable other than ξ_t) which, from the BOP, is associated with either a depressed D^*_t, or a low $\mathcal{Q}_t$, or both. In either case, the foreign funding ratio x_t must fall, which exerts modest downward pressure on μ_t through the IC—as lower holdings of foreign debt improve the agency friction. With lower current and future μ_t, the price of capital q_t rises and the real exchange rate appreciates somewhat ($\mathcal{Q}_t$ falls). The appreciation then slowly erodes the net foreign asset position by reducing net exports, thus bringing up D^*_t.

A similar holds in the more realistic case in which net worth falls persistently, shown in Figure 2 (with first-order autoregressive parameter set to 0.66, a value associated with a moderately persistent shock). The key difference is that now the initial depreciation lasts longer than just one period, with $\mathcal{Q}_t$ remaining below zero for about five quarters. The drop below zero of $\mathcal{Q}_t$ after the initial rise as well as its convergence back to steady state now occur in a delayed and more gradual manner.

3 Full Model

The core model is a two-country extension of an open-economy New Keynesian model (for example, Gali and Monacelli (2005) and Erceg et al. (2007)) augmented with financing frictions as in Gertler and Kiyotaki (2010) or Gertler and Karadi (2011). Compared to the simple model in the previous section, we now allow banks to be long-lived. This introduces endogenous persistence in their net worth and, more importantly, allows it to be affected by movements in the exchange value of domestic currency (to the extent that part of banks' liabilities are in foreign currency). In addition, we augment the model with a standard set of nominal and real rigidities—including nominal price and wage stickiness, habit persistence in consumption, and adjustment costs in investment and in imports. These features help enhance the model's empirical realism.

3.1 Banks

We begin by describing the banker's problem in the full model. We first describe the evolution of banks' net worth, and then outline their optimization problem.

3.1.1 Balance sheet and net worth evolution

Banks' positive survival probability, $\sigma_b > 0$, leads net worth to evolve endogenously, in contrast to the simple model described above. Exiting bankers are replaced by new entrants, which receive a small endowment in the form of fraction ξ_b of the value of the capital stock. The balance sheet identity is

$$\underbrace{q_t S_{it}}_{\substack{\text{claims on}\\ \text{domestic firms}}} \equiv \underbrace{D_{it}}_{\substack{\text{domestic}\\ \text{deposits}}} + \underbrace{\mathcal{Q}_t D_{it}^*}_{\substack{\text{(real) dollar}\\ \text{deposits}}} + \underbrace{N_{it}}_{\substack{\text{net}\\ \text{worth}}}$$

The banker's budget constraint, expressed in (real) domestic currency, is

$$q_t S_{it} + R_t D_{it-1} + R_t^* \mathcal{Q}_t D_{it-1}^* \leq R_{kt} q_{t-1} S_{it-1} + D_{it} + \mathcal{Q}_t D_{it}^*$$

The left-hand side is bank i's uses of funds, including lending to non-financial firms ($q_t S_{it}$) plus deposit repayments (both domestic, $R_t D_{it-1}$, and foreign, $R_t^* \mathcal{Q}_t D_{it-1}^*$). The right-hand side is the source of funds, including returns from past loans (the first term) plus deposits issued (to domestic residents and to foreigners, second and third term respectively).

Combining the two equations above yields the evolution of net worth:

$$N_{it} = (R_{kt} - R_t) q_{t-1} S_{it-1} + \left(R_t - R_t^* \frac{\mathcal{Q}_t}{\mathcal{Q}_{t-1}} \right) \mathcal{Q}_{t-1} D_{it-1}^* + R_t N_{it-1} \tag{1}$$

3.1.2 Optimization problem

The banker's objective is

$$\begin{aligned} V_{it} = \max_{S_{it}, D_{it}, D_{it}^*} \ (1-\sigma_b) \mathbb{E}_t \Big[\Lambda_{t,t+1} \big(R_{kt+1} q_t S_{it} - R_{t+1} D_{it} - R_{t+1}^* \mathcal{Q}_{t+1} D_{it}^* \big) \Big] \\ + \sigma_b \mathbb{E}_t \Big(\Lambda_{t,t+1} V_{it+1} \Big) \end{aligned}$$

subject to

$$\begin{aligned} q_t S_{it} &= D_{it} + \mathcal{Q}_t D_{it}^* + N_{it} \\ N_{it+1} &= (R_{kt+1} - R_{t+1}) q_t S_{it} + \left(R_{t+1} - R_{t+1}^* \frac{\mathcal{Q}_{t+1}}{\mathcal{Q}_t} \right) \mathcal{Q}_t D_{it}^* + R_{t+1} N_{it} \\ V_t &\geq \theta \left(1 + \frac{\gamma}{2} x_t^2 \right) q_t S_{it} \quad \text{(IC)} \end{aligned}$$

where $x_{it} = \mathcal{Q}_t D_{it}^* / q_t S_{it}$ and $\Lambda_{t,t+1}$ is household's real stochastic discount factor between t and $t+1$. Compared to the simple model, here we assume that the default payoff is quadratic in the foreign funding ratio (rather than linear). This turns out to have some desirable properties, without affecting the qualitative insights obtained from the simpler linear case. In particular, the quadratic formulation implies an interior solution for each bank's foreign funding ratio.

3.2 Employment agencies

As in Erceg, Henderson and Levin (2000), there is a continuum of households indexed by $i \in [0,1]$, each of which is a monopolistic supplier of specialized labor $L_{i,t}$. A large number of competitive "employment agencies" combine specialized labor into a homogeneous labor input used by intermediate goods producers, according to

$$L_t = \left[\int_0^1 L_{i,t}^{\frac{1}{1+\theta_w}} di \right]^{1+\theta_w}$$

From employment agencies' cost minimization, demand for labor variety i is

$$L_{i,t} = \left(\frac{W_{i,t}}{W_t} \right)^{-\frac{1+\theta_w}{\theta_w}} L_t$$

where $W_{i,t}$ is the nominal wage received by supplier of labor of type i and the wage paid by goods producers is

$$W_t = \left[\int_0^1 W_{i,t}^{-\frac{1}{\theta_w}} dj \right]^{-\theta_w} \tag{2}$$

3.3 Domestic households and wage setting

Household i seeks to maximize

$$\mathbb{E}_0 \sum_{j=0}^{\infty} \beta^j \left(\frac{\sigma}{\sigma - 1} \left(C_{t+j} - hC_{t+j-1} \right)^{\frac{\sigma-1}{\sigma}} - \frac{\chi_0}{1+\chi} L_{i,t+j}^{1+\chi} \right)$$

subject to

$$P_{Ct} C_t + P_{Ct} D_t \leq W_{i,t} L_{i,t} + P_{Ct} R_t D_{t-1} + \mathcal{W}_{it} + \Pi_t$$

$$C_t = \left[(1-\omega)^{\frac{\rho}{1+\rho}} C_{Dt}^{\frac{1}{1+\rho}} + \omega^{\frac{\rho}{1+\rho}} \left(\varphi_{Ct} M_{Ct} \right)^{\frac{1}{1+\rho}} \right]^{1+\rho}$$

$$P_{Ct} = \left[(1-\omega) P_{Dt}^{-\frac{1}{\rho}} + \omega P_{Mt}^{-\frac{1}{\rho}} \right]^{-\rho}$$

Above, C_t denotes the consumption basket, a CES aggregate of domestically-produced goods, C_{Dt}, and imports, M_{Ct}; D_t is deposits in domestic banks, which pay real (i.e. in terms of the domestic basket) interest rate R_t; $\mathcal{W}_{it}$ is the net cash flow from household i's portfolio of state-contingent securities (used to ensure that all workers in the household consume the same amount C_t, despite earning different wage income); and Π_t is total bank and firm profits distributed to the household. The variables P_{Dt} and P_{Mt} denote, respectively, the price of the domestically-produced good and the price of the imported good, and P_{Ct} is the price of the home basket (i.e. the CPI). We assume producer currency pricing (PCP): $P_{Mt} = e_t P^*_{Dt}$, where e_t is the nominal exchange rate (i.e. the price of a dollar in terms of home currency). The parameter h, satisfying $0 < h < 1$, governs the extent of consumption habits.

Following Erceg, Guerrieri and Gust (2006) we assume costs of adjusting consumption imports, which take the following form:

$$\varphi_{Ct} = 1 - \frac{\varphi_M}{2}\left(\frac{M_{Ct}/C_{Dt}}{M_{Ct-1}/C_{Dt-1}} - 1\right)^2$$

This formulation of adjustment costs implies that it is costly to change the proportion of domestic and foreign goods in the aggregate consumption basket. As such, it dampens the short-run to response of the import share to movements in the relative price of imports, but allows the level of imports to respond quickly to changes in overall consumption C_t.[5]

As in Erceg et al. (2000), fraction ξ_w of households cannot set the wage but instead follows the indexation rule

$$W_{i,t} = W_{i,t-1}\pi^{\iota_w}_{wt-1}, \;\; \pi_{wt} \equiv \frac{W_t}{W_{t-1}}$$

The remaining fraction of households solves

$$\max_{W_t^o} \;\; \mathbb{E}_t\left\{ \sum_{j=0}^{\infty} (\xi_w \beta)^j \Big[- \frac{\chi_0}{1+\chi} L^{1+\chi}_{i,t+j} + \frac{U_{C,t+j}}{P_{Ct+j}} L_{i,t+j} W_t^o \prod_{k=1}^{j} \pi^{\iota_w}_{wt+k-1} \Big] \right\}$$

subject to the labor demand function (2).

3.4 Foreign (U.S.) households

U.S. household's problem is analogous to that of domestic households:

$$\max \;\; \mathbb{E}_0 \sum_{j=0}^{\infty} \beta^{*j} \left(\frac{\sigma}{\sigma-1} \left(C^*_{t+j} - hC^*_{t+j-1} \right)^{\frac{\sigma-1}{\sigma}} - \frac{{\chi_0}^*}{1+\chi} {L^*_{i,t+j}}^{1+\chi} \right)$$

[5]As emphasized by Erceg et al. (2005), adjustment costs as modeled above permit the model to match the evidence described in Hooper et al. (2000) and in Mc Daniel and Balistreri (2003) that the short-run trade price elasticity is smaller than the long-run elasticity.

subject to

$$P^*_{Ct}C^*_t + B^*_t + P^*_{Ct}D^*_t \leq W^*_{i,t}L^*_{i,t} + R^{n*}_t B^*_t + P^*_{Ct}\tilde{R}^*_t D^*_{t-1} + \Pi^*_t + \mathcal{W}^*_{it}$$

where D^*_t is short-term deposits in home banks by U.S. households, B^*_t is short-term nominal bonds (in zero net supply), $\tilde{R}^*_t$ is the real return received from deposits in banks of the home economy (in real dollars), and R^{n*}_t is the Fed funds rate. We allow for the possibility of a tax τ on home banks' foreign borrowing: $R^*_t = (1+\tau)\tilde{R}^*_t$. As explained below, we use this tax as a device to vary the steady-state amount of borrowing from the U.S. by home banks. U.S. households also face nominal wage rigidities and costs of adjusting imports, in a manner analogous to the description in the preceding section.

3.5 Firms and price setting

A continuum of mass unity of retail firms produce final output using intermediate goods as inputs. Final output Y_t is a CES composite of retailers' output:

$$Y_t = \left(\int_0^1 Y_{i,t}^{\frac{1}{1+\theta_p}} di\right)^{1+\theta_p}$$

where $Y_{i,t}$ is output by retailer $i \in [0,1]$. Let the price set by home retailer i be $P_{Di,t}$. The price level of final home output is $P_{Dt} = \left[\int_0^1 P_{Di,t}^{-\frac{1}{\theta_p}} di\right]^{-\theta_p}$. Cost minimization by users of final output yields the following demand function for firm i's output:

$$Y_{i,t} = \left(\frac{P_{Di,t}}{P_{Dt}}\right)^{-\frac{1+\theta_p}{\theta_p}} Y_t$$

Each firm can reset its price with probability $1-\xi_p$. Firms not resetting their price follow the indexation rule

$$P_{Di,t} = P_{Di,t-1}\pi_{t-1}^{\iota_p}, \quad \pi_t \equiv P_{Dt}/P_{Dt-1}$$

where π_t is home-good inflation. The problem facing a firm resetting its price in period

t is thus

$$\max_{P^o_{Dt}} \ \mathbb{E}_t \sum_{j=0}^{\infty} \Lambda_{t,t+j} \xi_p^j \left(P^o_{Dt} \prod_{k=1}^{j} \pi_{t+k-1}^{\iota_p} - MC_{t+j} \right) Y_{i,t+j}$$

The production function of each intermediate goods firm i is given by $Y_{i,t} = K_{i,t}^{\alpha} L_{i,t}^{1-\alpha}$.

3.6 Capital producers

Capital producers produce new capital goods subject to costs of adjusting the level of investment I_t given by

$$\phi_{It} = \frac{\psi_I}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 I_t$$

(in units of the home good). The objective of the representative capital producer is to choose a state-contingent sequence $\{I_{t+j}\}_{j=0}^{\infty}$ to maximize the expected discounted value of profits:

$$\mathbb{E}_t \left\{ \sum_{j=0}^{\infty} \Lambda_{t,t+j} \left[q_{t+j} I_{t+j} - \frac{P_{Dt+j}}{P_{Ct+j}} \phi_{It+j} \right] \right\}$$

where q_t denotes the real price of capital goods (in terms of the home basket). As in the case of consumption goods, investment goods are a composite of domestic (I_{Dt}) and imported (M_{It}) goods, also subject to costs of adjusting the imported-domestic good mix:

$$I_t = \left[(1-\omega)^{\frac{\rho}{1+\rho}} I_{Dt}^{\frac{1}{1+\rho}} + \omega^{\frac{\rho}{1+\rho}} \left(\varphi_{It} M_{It} \right)^{\frac{1}{1+\rho}} \right]^{1+\rho}$$

with

$$\varphi_{It} = 1 - \frac{\varphi_M}{2} \left(\frac{M_{It}/I_{Dt}}{M_{It-1}/I_{Dt-1}} - 1 \right)^2$$

Optimality with respect to the investment aggregate I_t gives rise to an investment-q

relation:

$$q_t = 1 + p_{Dt}\phi\left(\frac{I_t}{I_{t-1}} - 1\right)\frac{I_t}{I_{t-1}} + p_{Dt}\frac{\phi_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 - \mathbb{E}_t\left\{\Lambda_{t,t+1}p_{Dt+1}\phi\left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right\}$$

where $p_{Dt} \equiv P_{Dt}/P_{Ct}$.

3.7 Domestic market clearing, BOP, and monetary policy rule

The market clearing condition for the home good is as follows:

$$Y_t = C_{Dt} + I_{Dt} + \frac{\xi_f}{\xi_h}\left(M^*_{Ct} + M^*_{It}\right) + \phi_{It}$$

where $\frac{\xi_f}{\xi_h}$ is the relative population size of the foreign economy (note that all variables are expressed in per capita terms). The balance of payments, obtained by aggregating the budget constraints of agents in the home economy, is given by

$$\mathcal{Q}_t\left(D^*_t - R^*_t D^*_{t-1}\right) = C_t + I_t + p_{Dt}\phi_{It} - p_{Dt}Y_t$$

As a baseline case, we assume that monetary policy in the home country follows an inertial Taylor rule:

$$R^n_t = \left(R^n_{t-1}\right)^{\gamma_r}\left(\overline{R}\pi_t^{\gamma_\pi}\right)^{1-\gamma_r}\varepsilon^r_t \tag{3}$$

where $\pi_t \equiv P_{Dt}/P_{Dt-1}$ is domestic inflation. Later we consider an alternative policy rule which allows for an exchange rate stabilization motive. Monetary policy in the U.S. is conducted according to an inertial Taylor rule as specified by Justiniano et al. (2010) which, in addition to inflation, includes the output gap (both in levels and in growth rates) as an argument.

This completes the description of the model.

4 Model Analysis

4.1 Calibration

Table 1: Calibration

Parameter	**Symbol**	**Value**
Home discount factor	β	0.9925
U.S. discount factor	β^*	0.9975
IES	σ	1
Habit parameter	h	0.78
Inverse Frisch elasticity of labor supply	χ	3.79
Trade price elasticity	$\frac{1+\rho}{\rho}$	1.5
Trade openness	ω	0.2
Relative home size	ξ_h/ξ_f	0.2
Trade adjustment cost parameter	φ_M	10
Capital share	α	0.33
Capital depreciation	δ	0.025
Prob. of keeping price fixed	ξ_p	0.84
Price indexation	ξ_p	0.24
Price markup	θ_p	0.2
Prob. of keeping wage fixed	ξ_p	0.70
Wage indexation	ξ_p	0.15
Wage markup	θ_p	0.2
Investment adjustment cost	Ψ_I	2.85
Home Taylor rule	γ_r	0.82
	γ_π	1.50
US Taylor rule	γ_r^*	0.82
	γ_π^*	2.09
	γ_x^*	0.07
	γ_{dx}^*	0.24
Bank survival rate	σ_b	0.969
Bank fraction divertable	θ	0.57
Bank transfer rate	ξ_b	0.02
Home bias in bank funding	γ	6

Table 1 reports parameter values. We calibrate the U.S. discount factor, β^*, to 0.9975, implying a steady-state real interest rate of 1% per year. This choice follows several recent studies (e.g. Reifschneider (2016)) and is motivated by estimates indicating a decline in the U.S. natural rate (see, for example, Holston, Laubach and Williams (2017)). To calibrate the home discount factor, we rely on estimates of Mexico's long-run natural rate from Carrillo et al. (2017) of about 3 percent, and accordingly calibrate β to 0.9925.[6]

The intertemporal elasticity of substitution (σ), capital share (α) and capital depreciation rate (δ) are calibrated to the conventional values of 1, 0.33, and 0.025, respectively. We also calibrate the steady-state wage and price markup to 20 percent, a conventional value. For the remaining parameters governing features of the domestic economy, we rely on estimates from Justiniano et al. (2010). These parameters include the degree of consumption habits (h), the inverse Frisch elasticity of labor supply (χ), the parameters governing price and wage rigidities ($\theta_p, \xi_p, \theta_w$, and ξ_w), and the investment adjustment cost parameter (Ψ_I). The values for these parameters are listed in the top part of Table 1. We also rely on Justiniano et al. (2010) to calibrate the parameters for the U.S. Taylor rule (γ_r^*, γ_π^*, γ_x^* and γ_{dx}^*, where the latter two parameters govern the response to the output gap and to output gap growth, respectively). Turning to the baseline home policy rule, we set γ_π to the conventional value of 1.5. Aside from the policy rule and the discount factor, all other parameters are set symmetrically across the two countries.

Turning to parameters governing international trade, we follow Erceg et al. (2007) (who rely on estimates by Hooper et al. (2000)) and set the trade price elasticity $\frac{1+\rho}{\rho}$ to 1.5. We set $\omega = 0.20$, which implies a steady-state exports-to-gdp ratio of 28 percent—a value in the neighborhood of that observed for emerging economies like Mexico or Turkey. We set the population size of the home economy to one fifth that of the U.S. The trade adjustment cost parameter φ_M is set to 10, as in Erceg et al. (2006) or Erceg et al. (2005). This value implies a price elasticity of slightly below unity after four quarters, consistent with the evidence that the short-run elasticity is lower than the long-run one.

Turning to the parameters governing the financial friction, we set the survival rate σ_b to 0.969, implying an expected horizon of 8 years. To remaining three parameters are set to hit three targets: a steady-state credit spread of 150 basis points annually, a leverage ratio of 5, and a ratio of foreign-currency debt to total debt of 30 percent (conditional on the tax on

[6] Magud and Tsounta (2012) also estimate the natural rate for several Latin American countries using various methodologies. Averaging across methodologies yields a range of values between 2 and 5 percent across countries, with a cross-country average of about 3 percent.

foreign borrowing, τ, being set to zero). The target for the credit spread reflects the average value of BBB corporate bond spreads in emerging economies. The target leverage ratio is a rough average of leverage across different sectors. Leverage ratios in the banking sector are typically greater than five,[7] but the corporate sector features a much lower ratio of assets to equity (between two and three in emerging markets[8]). Our target of five reflects a rough compromise between these two values. Finally, evidence in Goldstein and Turner (2004) and Chui, Kuruc and Turner (2016) on ratios of foreign-currency debt to total debt in emerging markets suggests an upper bound for this ratio of about 30 percent, justifying our target when $\tau = 0$. These targets imply $\theta = 57, \xi_b = 0.02$, and $\gamma = 6$.

One of our goals in the analysis below is to illustrate how the dynamics following various shocks differ depending on the amount of foreign-currency debt present in the economy when the shock hits. To this end, we consider three different values for τ: a high value (of 160 basis points annually) which induces a steady-state foreign debt ratio of 5 percent, a value in the lowest range across emerging economies; an intermediate value (50 basis points) which implies a foreign debt ratio of 18 percent, a moderate value in light of the evidence; and finally a very low value of τ just 20 basis points, leading to a high value for the foreign debt ratio (25 percent).

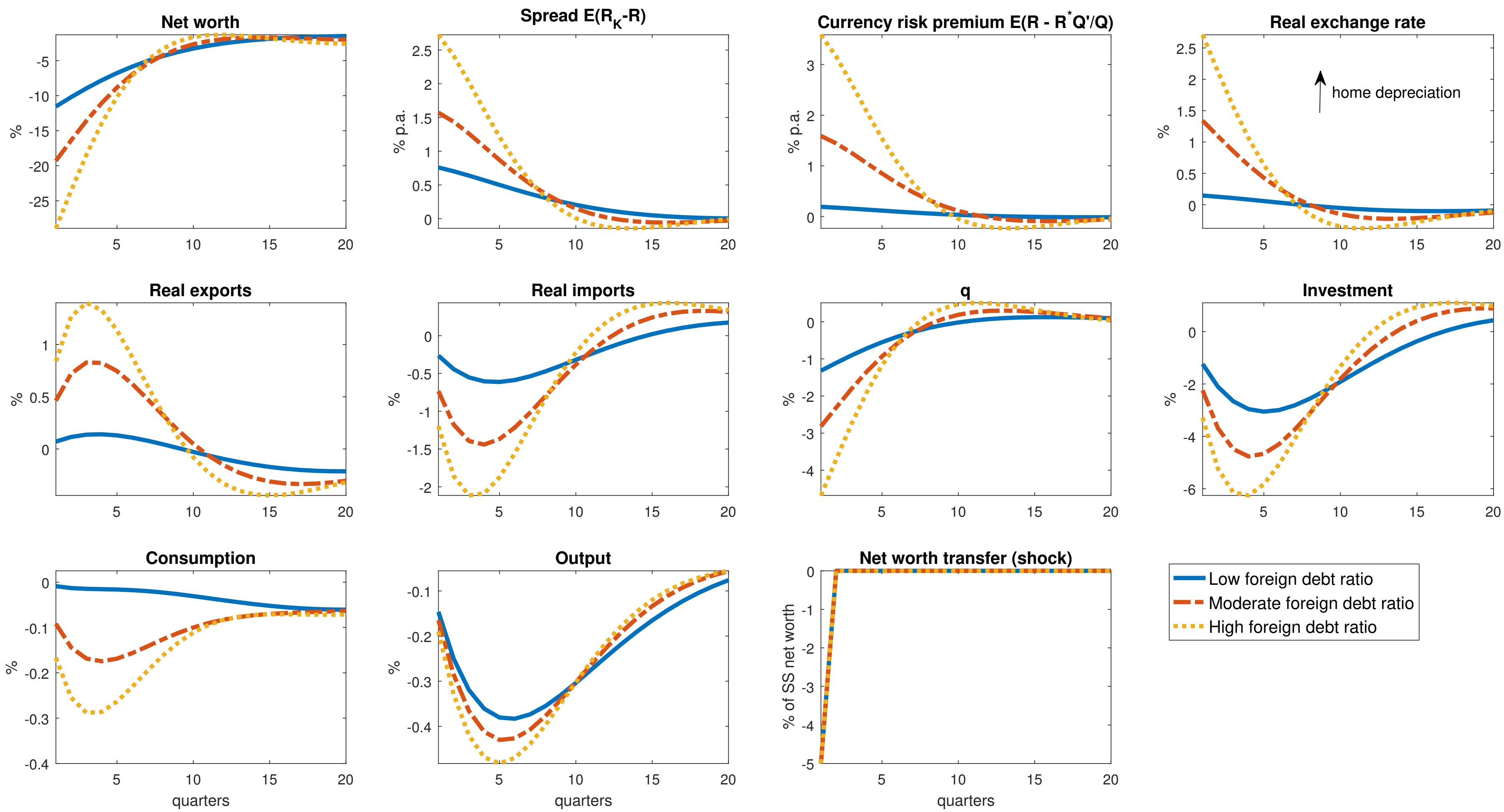
4.2 Drop in aggregate net worth

We begin by illustrating the effects of a drop in aggregate bank net worth in the full model, an exercise analogous to that performed earlier in the context of the simple model. Specifically, we document the effects of a one-time transfer of wealth from bankers to households (think of a tax levied on banks' equity, the proceeds of which are distributed lump-sum back to households). The transfer is sized to 5 percent of steady-state net worth. The effects of the drop in net worth are shown in Figure 3.

[7] For example, bank assets to capital averaged around 10 for Mexico in recent years. Source: IMF Global Financial Stability Report.

[8] See e.g. IMF Global Financial Stability Report October 2015, Chapter 3.

Figure 3: One-time drop in aggregate bank net worth



Note: The Figure shows the effects of one-time net worth transfer from bankers to households (sized at 5 percent of steady-state net worth) when the foreign debt ratio in the economy is low (blue solid line), moderate (red dashed line), and high (yellow dotted line). All variables shown relative to steady state.

Starting with the case in which the foreign debt ratio is low (blue solid line), note that the dynamic responses of the credit spread $\mathbb{E}(R_K - R)$, the currency risk premium $\mathbb{E}(R - R^*\mathcal{Q}'/\mathcal{Q})$, the price of capital q and the real exchange rate $\mathcal{Q}$ resemble the responses highlighted by the simple model described earlier. For example, zooming in the real exchange rate response reveals that this variable rises (i.e., the home real exchange rate depreciates) by about 15 basis points on impact, and remains elevated for about eight quarters before turning negative and gradually converging back to zero from below. This dynamic pattern resembles the one obtained from the much simpler model from Section 2. There are, however, some notable differences with respect to the simple model. Note, first, that now the drop in net worth is persistent, even though the transfer shock is transient. This reflects the fact that bankers are long-lived. Second, note that the net worth drops by over 10 percent on impact, i.e. twice the size of the transfer. This is the result of the financial accelerator effect working through a general-equilibrium decline in the asset price q: lower aggregate net worth lowers investment and q, and the lower asset price works to diminish net worth further. Notably, in contrast to the simple model, now the drop in net worth now has adverse consequences for the real economy: aggregate investment falls by about 3 percent, leading output to fall despite a modest rise in exports.

The exchange rate depreciation in the experiment just described is, however, quantitatively small, as the currency risk premium rises only modestly (about 20 basis points). As the ratio of foreign debt rises, however, the self-reinforcing feedback between a depreciating currency and declining net worth becomes stronger: from equation (1), note that a realized depreciation (high $\mathcal{Q}_t/\mathcal{Q}_{t-1}$) lowers N_{it}, with the magnitude of this effect larger the greater the amount of foreign debt.[9] Thus, the adverse feedback loop between net worth and currency movements becomes more powerful when banks' balance sheets feature larger shares of foreign-currency debt, as made clear by comparing the red dashed (moderate foreign debt ratio) and the yellow dotted line (high foreign debt ratio) to the blue line. In the high foreign debt case, net worth falls by over 25 percent on impact, more than five times the size of the transfer shock. The currency risk premium skyrockets, and the real exchange rate depreciates about 2.5 percent. Because the domestic spread $\mathbb{E}(R_K - R)$ also rises much more than with low foreign debt, the fall in investment is much more severe—about twice as large—which pushes output down to a greater degree. At the same time, the larger depreciation implies a larger rise in exports, which provides some offset in the response of output. Still output

[9]The elasticity of net worth to a real depreciation is given by $\frac{\sigma^b}{\beta^*}\frac{\mathcal{Q}D^*}{N}$ (where letters without subscripts indicate steady-state values), and hence rises as the ratio of foreign debt to net worth increases.

drops by about ten basis points more in the high foreign debt case, relative to the case with low foreign debt.

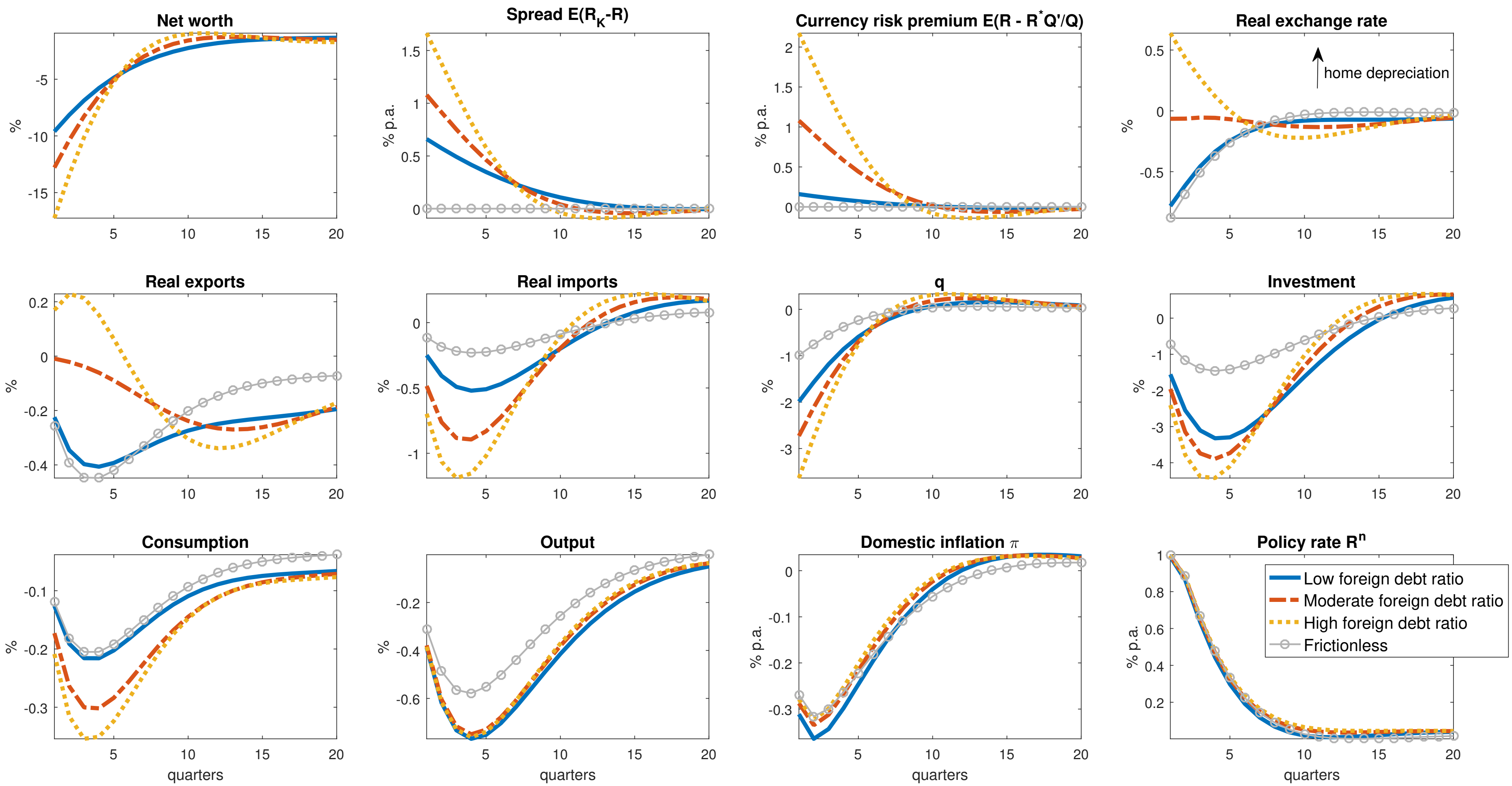
4.3 Domestic monetary transmission

We next explore the consequences of a monetary policy tightening in the domestic economy, and how they differ depending on the degree of the extent of dollar borrowing in banks' balance sheets. The corresponding dynamic responses are shown in Figure 4. The shock to ε_t^4 is sized to induce a 1 percent rise in the policy rate R^n. For comparison, we include the responses in an economy without financial frictions (shown by the gray circled line). In the frictionless case, the monetary shock induces familiar dynamics: output and investment decline in a hump-shaped manner, consistent with the empirical evidence, and the magnitudes of their decline roughly match the evidence as well (e.g. Christiano, Eichenbaum and Evans (2005)). Inflation drops, and the currency appreciates by about 1 percent. Exports fall due to the stronger currency, while imports also decline due to the demand contraction at home.

Turning to the low foreign debt case (blue solid line), now the financial accelerator effect kicks in. The economy suffers larger declines in output and investment, amid falling net worth and rising credit spreads. Interestingly, the domestic currency now appreciates a little less in the short run compared to the frictionless economy. The reason, of course, is the rise in the currency risk premium, resulting from the drop in bank net worth. Still, the effect of the latter on the exchange rate is relatively small: the real exchange rate now appreciates by 80 basis points on impact, compared to 90 basis points in the frictionless case.

The adverse effect on the currency risk premium induced by a domestic monetary tightening becomes much larger in the moderate (red dashed) and high (yellow dotted) dollarization economies. In the latter cases the the rise in the currency risk premium is enormous, more than 200 basis points annually. As a consequence, the real exchange rate now *depreciates* on impact, and remain depreciated in the short run (for about 4 quarters). Thus, and in sharp contrast to standard monetary models (e.g. Gali and Monacelli (2005)), a hike in the policy rate leads to a weaker currency in the short run. On the other hand, the magnitude of the output response is about the same regardless of the degree of foreign indebtedness: while investment falls more due to the higher increase in the credit spread, exports also rise by more due to the smaller appreciation (and eventually depreciation), leaving the output response roughly unchanged.

Figure 4: Domestic monetary tightening



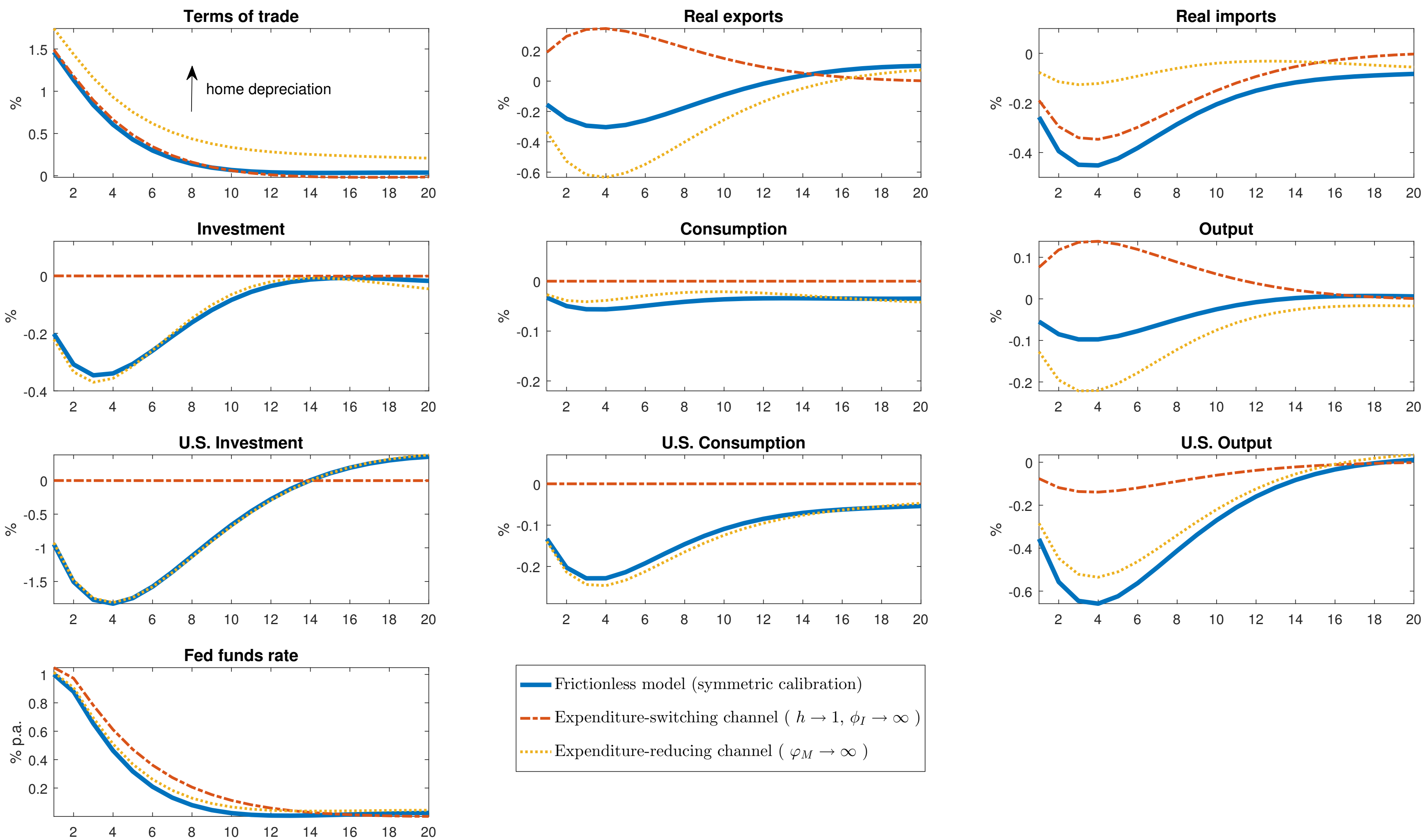
Note: The Figure shows the effects of a domestic monetary tightening in a frictionless economy (grey circled line), and in the economies with low, moderate, and high foreign debt (blue solid, red dashed, and yellow dotted lines respectively. All variables shown relative to steady state.

4.4 Spillovers from U.S. tightening

We begin by reviewing the spillovers from a tightening of U.S. monetary policy in a setting with frictionless financial markets, shown in Figure 5. For this exercise we assume a symmetric calibration of the two countries (i.e. similar country size, discount factor, and Taylor rule) although the main insights carry over to the asymmetric case. the effects of U.S. tightening on the home economy reflect two distinct channels often emphasized in the literature: an "expenditure-switching" effect due to the induced depreciation of the home terms of trade which leads consumers and firms away from U.S. goods and into home goods, and an "expenditure-reducing" effect arising from the overall demand contraction due to higher real rates. We capture the expenditure-switching effect by setting $h \to 1$ and $\phi_I \to \infty$, implying that consumers and firms (both at home and abroad) keep aggregate consumption and investment constant. The resulting output movements reflect solely the switching from U.S. into home goods, and thus lead home output to rise by around 10 basis points and U.S. output to fall by the same amount. By contrast, the expenditure-reducing channel (captured by setting φ_M very high, which implies that agents do not alter the share of imports in total consumption or investment despite the relative price change) implies a reduction in home output of around 20 basis points. The net effect (the blue line) reflects the combination of these two forces: home output still declines as the expenditure-reducing channel is somewhat more powerful, but the drop is quantitatively modest.

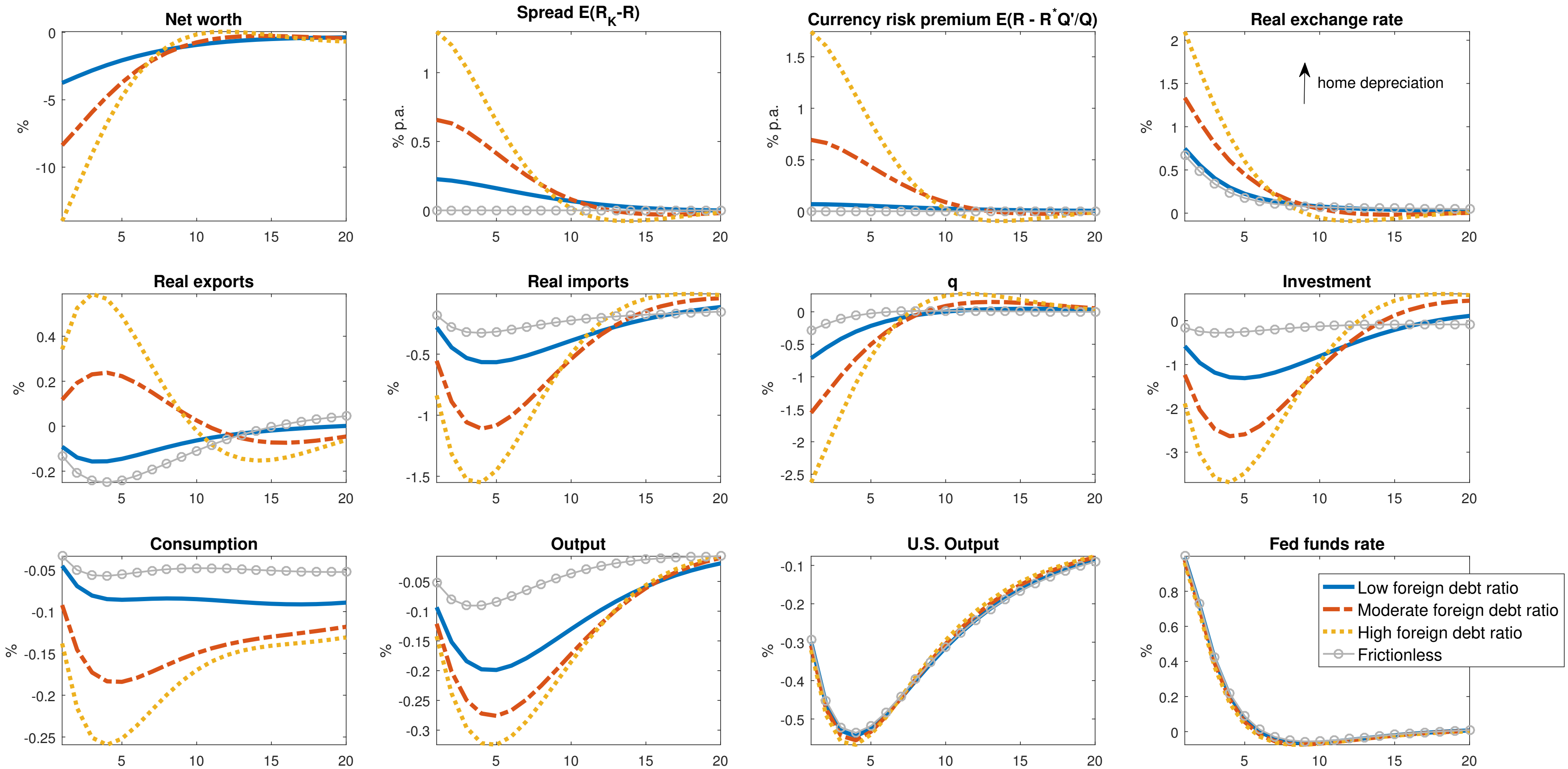
We now examine spillovers under our baseline model with financial frictions, shown in Figure 6. When the amount of foreign-currency debt is low (blue solid line), the drop in q now initiates a decline in banks' net worth, leading credit spreads to rise modestly. As a consequence, investment now falls significantly more than in the frictionless economy. The lower bank net worth also induces a small rise in the currency risk premium, and the nominal and real exchange rate depreciate by somewhat more as a consequence. This leads exports to fall a little less, and imports a little more, compared to the frictionless case. Still, the larger drag from investment on real activity dominates, and leads output to fall noticeably more than in the frictionless economy.

Figure 5: U.S. monetary tightening, frictionless economy



Note: The blue solid line shows the effects of a U.S. monetary tightening in an economy without financial frictions and with the parameters calibrated symmetrically (blue solid line). The red dashed line sets the habit parameter h very close to 1 and the investment adjustment cost parameter ϕ_I to a very high value. The yellow dash-dotted line sets the trade adjustment cost parameter to a very high value (and h and ϕ_I back to their baseline values). All variables shown relative to steady state.

Figure 6: U.S. monetary tightening, economy with frictions



Note: The Figure shows the effects of a U.S. monetary tightening in the economies with low, moderate, and high foreign debt (blue solid, red dashed, and yellow dotted respectively). THe grey circled line reports the effects in a frictionless economy. All variables shown relative to steady state.

The spillovers from U.S. monetary tightening are significantly larger with high foreign debt economy (yellow dotted line). The self-reinforcing feedback between currency movements and net worth is now much stronger, magnifying the response of financial variables: spread and currency risk premium rise by more, net worth and q fall more steeply, and the real exchange rate depreciates by more. The end result is a 15 percent drop in net worth, three times that in the low foreign debt economy, and a depreciation of the real exchange rate of 2 percent, almost four times as much as the low-dollarization case. The decline in investment is much larger as well—more than 3 percent, and even larger than the decline in U.S. investment (not shown). As a result, home output drops more than 0.30 percent—three times as much as in the frictionless economy. The drop in home output is more than half the U.S. decline, and is more persistent. Thus, a high amount of dollar liabilities in domestic balance sheets works to significantly enhance the spillover effects of U.S. monetary tightening.

4.5 Domestic monetary regimes

We next turn to the question of whether a high degree of banks' liability dollarization provides grounds for a domestic monetary policy which attempts to stabilize (to some extent) the nominal exchange rate (NER henceforth). We are interested in this question because balance-sheet mismatches are often highlighted as the primary reason why policymakers in many emerging markets favor managing the exchange rate (e.g. Reinhart (2000)). To this end, we assume that domestic monetary policy is described by an interest rate rule that includes NER:

$$\begin{aligned} R_t^n &= \left(R_{t-1}^n\right)^{\gamma_r} \left(R_t^{nT}\right)^{1-\gamma_r} \varepsilon_t^r \\ R_t^{nT} &= \frac{1}{\beta} \pi_t^{\frac{1-\gamma_e}{\gamma_e}} \left(\frac{e_t}{e}\right)^{\frac{\gamma_e}{1-\gamma_e}} \end{aligned}$$

where $\gamma_e \in [0, 1]$, i.e., the central bank in the domestic economy is assumed to respond to the NER in addition to domestic inflation, and higher values of γ_e represent cases in which the exchange rate stabilization motive of the central bank is more important.[10] This specification nests the two polar cases of strict inflation targeting and exchange rate peg, and allows parametrization of hybrid regimes of managed exchange rates.

[10]We take this formulation from Gali and Monacelli (2016).

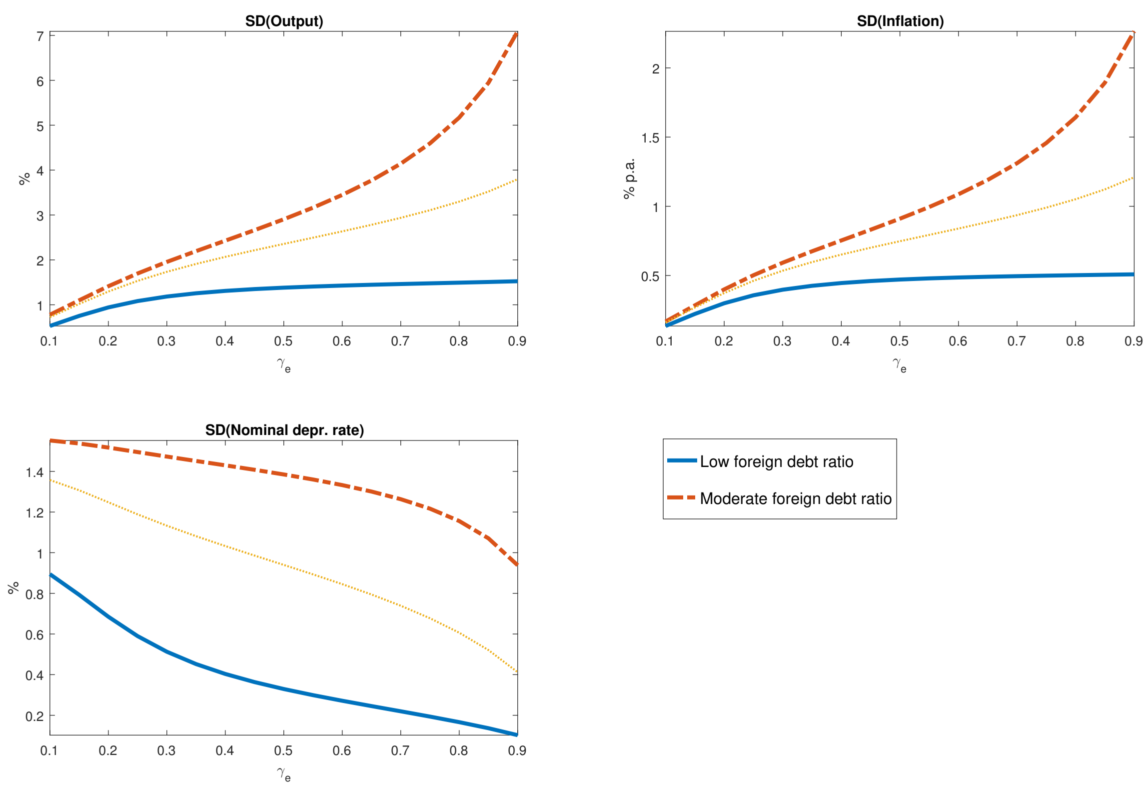
Figure 7 displays standard deviations of output, inflation and nominal exchange rate depreciation in an economy with low foreign debt ratio (blue solid line) and with medium foreign debt ratio (red dashed line) for different values of γ_e. The economy with low foreign debt ratio has the lowest output and inflation volatility for the smallest value of γ_e, which in turn entail highest exchange rate volatility (as in Gali and Monacelli (2005)). The same result holds in an economy with high dollar debt, but with one important difference: As the coefficient on the NER increases in the Taylor rule, the implied volatility of output and inflation volatility increases exponentially while the benefit of this rule in terms of lower volatility in exchange rate depreciation gets much smaller (as the curve flattens out with higher levels of foreign debt). This finding already suggests that conditional on U.S. monetary policy shocks, the desirability of gearing domestic monetary policy toward stabilizing the NER may actually *diminish* with the level of dollar-denominated debt in balance sheets.

Figure 8 shows the effects of U.S. monetary tightening under different policy regimes in economies with low, medium and high foreign debt ratios (shown in the upper, medium and lower rows, respectively). The solid blue lines in Figure 8 displays the outcomes following a U.S. tightening with a relatively small weight in NER ($\gamma_e = 0.05$) and the dashed-red lines shows then with high weight on NER stabilization ($\gamma_e = 0.40$). The rule that gives a higher weight to NER is successful in moderating the depreciation in the economy with low foreign debt: the home currency depreciates about 140 basis points on impact under the rule with $\gamma_e = 0.05$, compared to 60 basis points under the rule with $\gamma_e = 0.40$. The smaller exchange rate movement, however, comes at the cost of a much larger output contraction, of almost 35 basis points. This result accords with the findings by Gali and Monacelli (2005), who show that policy rules that entail lower output gap volatility (and thus higher welfare) also entail higher exchange rate volatility.

How does the degree of foreign indebtedness affect the consequences of following rule with a higher weight on NER? Consider first the economy with moderate foreign debt ratio, shown in the middle row of Figure 8. The NER-targeting rule still helps moderate the movement in the exchange rate: the NER depreciates 200 basis points, somewhat more than in the economy with low foreign debt ratio, but still less than under the baseline rule with a small weight on NER. The drop in output, however, is now much larger–almost four time as large as under the baseline rule. Thus, the output cost of stabilizing the NER is much higher than in the economy with low foreign debt ratio. This is a consequence of two forces: first, because now domestic monetary tightening raises the currency risk premium, the policy rate needs to raise by more, *ceteris paribus*, to achieve a given appreciation. Second, higher foreign debt implies a larger exchange-rate depreciation due to a U.S. rate hike of a given size.

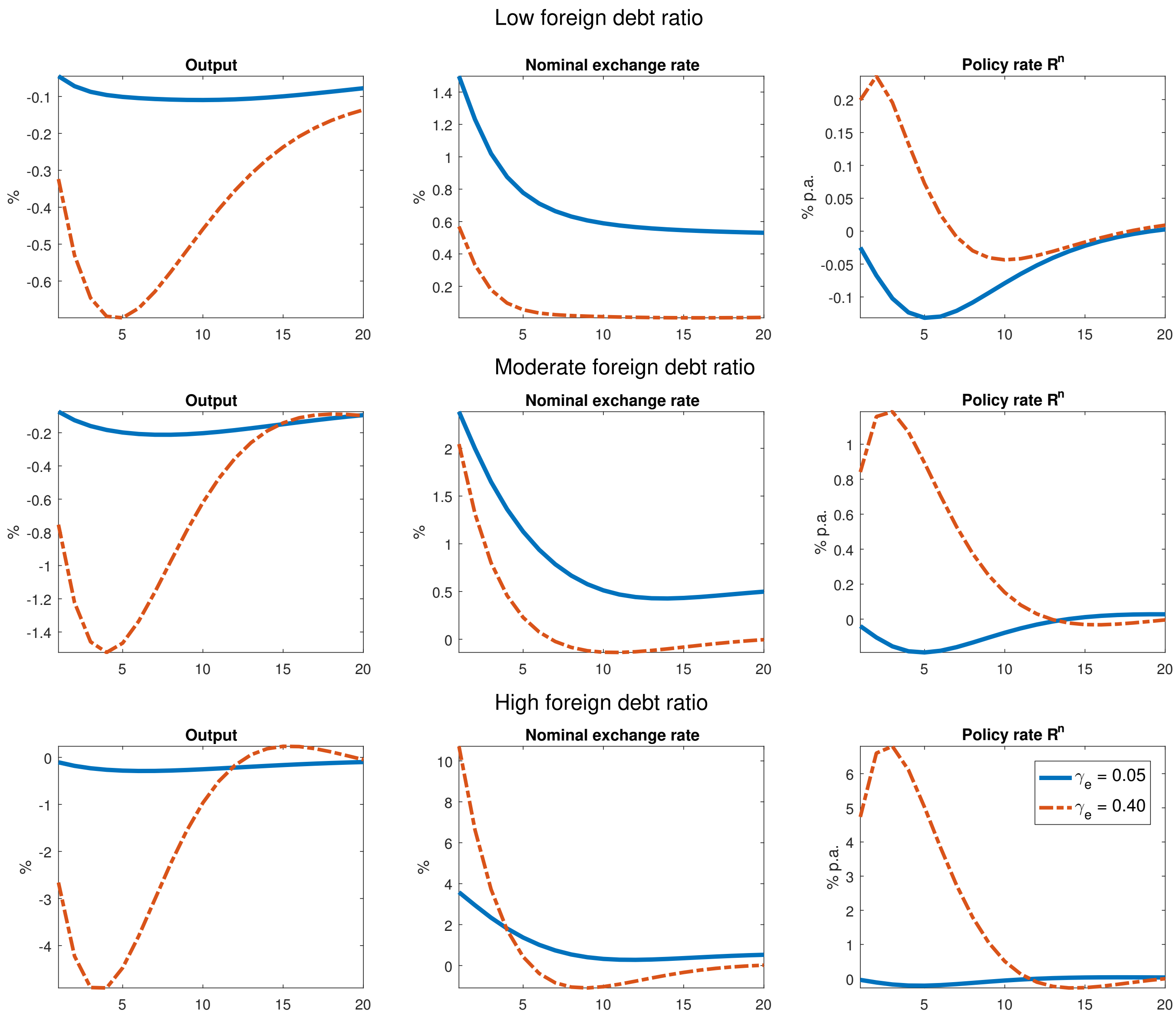
These basic forces play out in a much more dramatic way in the economy with high foreign debt ratio, shown in the bottom row. Because raising the domestic policy rate now induces a currency *depreciation* in the short run (due to an enormous upward movement in the currency risk premium), attempting to defend the currency turns out to be disastrous in this case. The monetary authority raises rates sharply, inducing an enormous output decline; and it still does not succeed in halting the depreciation, with the currency falling by almost ten percent in the short run, more than twice as much as under the baseline rule with a smaller weight to NER.

Figure 7: Standard deviations and different monetary regimes



Note: The Figure shows the standard deviations of output, inflation, and the nominal depreciation rate for different values of γ_e in the economies with low foreign debt (blue solid) and with moderate foreign debt (red dashed).

Figure 8: U.S. monetary tightening, different monetary regimes



Note: The Figure shows the effects of U.S. monetary tightening under different policy regimes: γ_e captures a regime characterized mostly by domestic inflation targeting, while γ_e captures a regime with significant exchange-rate stabilization motives. The top, middle, and bottom rows refer to the economies with low, moderate, and high foreign debt respectively.

Taken together, the findings above cast doubt on the conventional argument that liability dollarization provides grounds for a rule that includes exchange rate: even when the degree of dollarization is low, the rule stabilizes the NER by less at the cost of a larger decline in output. In the more extreme case of high dollarization, the rule implies an enormous output drop, and actually fails at moderating the short-run depreciation.

5 Empirics: Credit Spreads and Exchange Rates

Standard open economy macroeconomic models with either complete or incomplete international financial markets, such as Gali and Monacelli (2005), assume the uncovered interest parity (UIP) condition holds. This means that expected exchange rate depreciation in one country has to be equal to the difference between its short term interest rate on its deposits and the corresponding interest rate that a typical investor would earn if he invested in short term deposits in the other country; i.e, there are no ex ante excess returns from holding deposits in one country relative to another.[11] However, the failure of the UIP condition in the data is a long-standing and well documented puzzle in international finance (see, for example, the seminal contribution of Fama (1984) and the excellent survey paper by Engel (2014)).

The UIP wedge or the so-called foreign exchange rate risk premium in our model arises endogenously due to balance sheet constraints faced by banks, and it is strongly linked to credit spreads in the economy. To provide evidence that there is empirical connection between the UIP spreads and credit spreads, we run the following regression both using the model simulated data and actual data:

$$\underbrace{e_t - e_{t+1} + (i_t - i_t^*)}_{log(\mu_t^*)} = a + b\,(i_t - i_t^*) + c\,CS_t + d\,VIX_t + u_{t+1} \tag{4}$$

where the dependent variable is the empirical counterpart of the logarithm of excess currency risk premium, μ^*. The variable i_t is the home one period nominal interest for deposits that pay off in period $t+1$ and i_t^* is the corresponding US interest rates. We denote nominal exchange as e_t, the log of the foreign exchange rate, expressed as home currency price of the US dollar (increase means a depreciation of home currency). The variable, CS_t, stands for

[11]Note that open economy macroeconomic models with incomplete financial market models assume an ad-hoc foreign exchange risk premium solely for the purpose of rendering stationarity which does not play significant role in the determination of exchange rates.

corporate credit spreads and VIX_t is included in the regression as a proxy for global risk which is shown to be important driver of global asset prices (see, for example, Rey (2015)).

Table 2 presents our estimation results for the 1995-2017 period using quarterly data.[12] As a reference, the same table also shows the results from the model simulated data. As shown in the second column of Table 2, the empirical regression predicts that there is very tight and significant relationship between the UIP wedge and the credit spreads, as in the model, even after controlling for several factors such as interest rate differential and a measure of global risk.[13] These results are also broadly consistent with the empirical findings documented in Corte et al. (2015) and Hofmann et al. (2016).

Table 2: Foreign Currency Risk Premium and Credit Spreads

Explanatory Variables	**Data**	**Model**
Interest diff., $(i_t - i_t^*)$	1.16^{***}	0.13
	(0.23)	
Credit Spreads, CS_t	2.15^{***}	0.54
	(0.80)	
Global Risk, VIX_t	0.31^{***}	–
	(0.01)	
Country Fixed Effect	Yes	
Time Fixed Effect	Yes	
Method	Pooled OLS	
R^2	0.60	
# of Observations	410	

Notes: Countries included in the pooled OLS regression are Korea, Brazil, Mexico, Chile, Indonesia, Colombia,Thailand and Turkey. This table presents estimates of a, b and c from the regression $e_t - e_{t+1} + (i_t - i_t^*) = a + b\,(i_t - i_t^*) + c\,CS_t + dVIX_t + u_{t+1}$. The standard errors for the panel estimations are computed according to the Driscoll and Kraay (1998) method that is robust to heteroskedasticity, serial correlation and contemporaneous correlation across equations.

[12]It is unbalanced panel data regression.

[13]The results do not change if we include the lagged dependent variable and lagged credit spreads in the regressions.

6 Conclusion

We have developed a medium-scale quantitative New Keynesian model representing the U.S. economy and an emerging market economy. The latter is subject to financial frictions and dollar-denominated debt in banks' balance sheets, which gives rise to a self-reinforcing feedback loop between the currency risk premium, the exchange rate and financial conditions. We investigated the consequences of this mechanism for spillovers from U.S. monetary policy shocks and the desirability of mitigating exchange rate depreciations using domestic monetary policy.

We showed that our model economy, which is reasonably calibrated to capture the U.S. economy and an emerging market economy, predicts that the expenditure-switching and expenditure-reducing channels broadly cancel each other, and that U.S. monetary spillovers are larger for economies with larger dollar denominated liabilities (i.e. financial spillovers determine the overall size of spillovers).

Regarding the desirability of mitigating exchange rate fluctuations, our results call into question the common view that large foreign-currency indebtedness renders exchange rate-targeting rules desirable. We find that domestic monetary policy aiming at stabilizing exchange rate depreciations might end up being destabilizing at an additional cost in terms of larger output and inflation volatility.

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A Details on simple model

A.1 Steady state

The deterministic steady state can be solved in closed form:

$$\mu = \left(1 - \frac{\beta}{\beta^*}\right)\frac{1}{\gamma}$$
$$x = \left(\frac{\xi}{\theta - \mu} - 1\right)\frac{1}{\gamma}$$
$$q = \frac{\frac{\beta}{1+\mu}}{1 - \frac{\beta}{1+\mu}}\overline{r}_K$$
$$Q = \frac{(\beta^{*-1} - 1)xq\overline{K} + \chi_m}{\chi_x}$$

Note that $x > 0$ requires the parameters to satisfy $\xi > \theta - \left(1 - \frac{\beta}{\beta^*}\right)\frac{1}{\gamma}$.

A.2 Loglinearized equilibrium conditions

Letting $\hat{y}_t \equiv \log\left(\frac{y_t}{y}\right)$ for any variable y_t, the loglinearized equilibrium conditions are

$$\frac{\gamma x}{1+\gamma x}\hat{x}_t = \frac{\mu}{\theta - \mu}\hat{\mu}_t + \hat{\xi}_t \quad (5)$$
$$\hat{x}_t = \hat{\mathcal{Q}}_t + \hat{D}^*_t - \hat{q}_t \quad (6)$$
$$\hat{\mathcal{Q}}_t = \frac{\beta^* - \beta}{\beta}\hat{\mu}_t + \mathbb{E}_t(\hat{\mathcal{Q}}_{t+1}) \quad (7)$$
$$\hat{q}_t = -\frac{\mu}{1+\mu}\hat{\mu}_t + \frac{\beta}{1+\mu}\mathbb{E}_t\left(\hat{q}_{t+1}\right) \quad (8)$$
$$\hat{D}^*_t = -\kappa(\beta^{*-1} - 1)\hat{\mathcal{Q}}_t + \beta^{*-1}\hat{D}^*_{t-1} \quad (9)$$

with $\kappa \equiv \frac{\chi_m}{\chi_x Q - \chi_m} > 0$.

B Data

This section review the data sources used in analysis of section 5. More specifically, below is information on the exchange rates, interest rates and corporate spread data used in the empirical analysis. Countries are included in the data set when the currencies have a flexible currency regime (or, fluctuations in exchange rate is contained in a band that is wider than plus and minus 2 percent according to the definition given in Ilzetzki et al. (2017). The start data of the data is different for each country. Data ends in November 2017. For Fama regressions, data sets are constructed using the last trading day of the month (quarter) for if the regression is monthly (quarter).

Exchange Rates

Exchange rates are end of day spot rates from Bloomberg and are measured in units of foreign country / USD. For example, the US-UK exchange rate is measured in pounds per dollar (pounds/dollar).

Interest Rates

Interest rates are 1M deposit rates and follow conventions from Exchange Rates, Interest Rates, and the Risk Premium paper by Engel (2016). For the US, Euro area, Australia, Canada, Japan, Norway, UK, South Africa and New Zealand, data are the average of offer and bid rate of 1M annual Eurorates. This data comes from DataStream. For Turkey, Brazil, Indonesia, Singapore, interest rates are the average of offer and bid rates of 1Month Deposit rates. For Chile, Colombia, Thailand, Korea and Mexico, Uruguay and the Philippines data are 1 Month deposit rates from Haver. We also used 3M deposit rates in the regressions and the results do stay the same.

Corporate Spread Data

- BBB corporate spread data: Canada, Euro area, Japan, UK, Brazil, Korea, Mexico
- EMBI: Chile, Indonesia, Thailand, Uruguay
- Gilchrist and Mojon credit spread data: Spain, Italy, Germany and France.
- EMBI+: Colombia, Philippines, South Africa, Turkey (J.P. Morgan EMBI+ data are retrieved from Bloomberg).