Exchange Rate Dynamics and Monetary Spillovers with Imperfect Financial Markets*

Ozge Akinci[†]
Federal Reserve Bank of New York

Albert Queralto[‡]
Federal Reserve Board

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Abstract

Why do shifts in U.S. monetary policy trigger large cross-border spillovers, especially on emerging markets (EMs)? We propose a model featuring imperfections in domestic and international financial markets that generates strong effects of U.S. monetary policy on EM asset prices, financial conditions, currency values, and economic activity. Financial imperfections prevent arbitrage both between local EM lending and borrowing rates, and between local-currency and dollar borrowing rates: both the local lending spread and the premium on the local currency, which are typically positive, vary inversely with EM borrowers' financial health. A novel adverse feedback effect between financial health and external conditions complements and amplifies the domestic-based "financial accelerator," accounting for large spillovers of U.S. monetary policy. Our model's implications for the effects of U.S. monetary shocks on EM GDP, as well as the model-predicted link between violations of uncovered interest parity and EM lending spreads, are consistent with the data.

Keywords: Financial Frictions; U.S. Monetary Policy Spillovers; Currency Premium; Uncovered Interest Rate Parity Condition.
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[†]Federal Reserve Bank of New York, 33 Liberty Street, New York, NY 10045, USA. Email: ozge.akinci@ny.frb.org.
[‡]Federal Reserve Board, 20th St&Cons. Ave NW, Washington, DC, 20551, USA. Email: albert.queralto@frb.gov.

1 Introduction

The effects on foreign economies of monetary policy shifts in the United States, often referred to as monetary "spillovers," are the subject of increasing attention. The financial media regularly publishes stories highlighting potent global reverberations from Federal Reserve decisions, and foreign policymakers often express concern about the impact of U.S. monetary policy on their own economies.[1] A recent, fast-growing empirical literature aims to quantify the effects of U.S. monetary shocks on foreign countries' financial and economic developments; a common finding in this literature is that these spillovers can be substantial, particularly on emerging market economies (EMs).[2]

One prominent theme within the aforementioned literature, forcefully put forward by Miranda-Agrippino and Rey (2020), is that these spillovers occur largely through financial channels. Monetary policy shifts in the United States, it is argued, exert powerful effects on financial conditions throughout the globe. When the Federal Reserve tightens policy, global asset prices decline, foreign currencies depreciate sharply against the dollar, and financial conditions tighten in foreign economies. These developments occur in reverse when the Fed eases policy. In a detailed, microeconomic-level analysis of Turkish data, Giovanni, Kalemli-Ozcan, Ulu and Baskaya (2017) provide evidence on how these global effects may feed into credit market conditions in EMs, ultimately affecting the cost of credit facing local nonfinancial borrowers in these countries. Furthermore, these authors document systematic, time-varying violations of uncovered interest parity (UIP): the premium on the cost of credit in local currency relative to the cost of dollar credit, which is typically positive, tends to be larger when overall financial conditions are relatively tight.

In this paper, we propose a two-country model that can account for powerful spillovers of U.S. monetary policy on EMs. Within our theory, imperfections in financial markets—both domestic and international—play a key role. We show that the model can generate strong effects of U.S. monetary policy shocks on (i) the prices of assets in EMs; (ii) the tightness in EM financial conditions, as measured by the credit spread facing local nonfinancial borrowers; (iii) large movements in the local currency relative to the dollar, driven in part by an endogenous deviation from UIP that widens when the Fed tightens; and (iv) considerable

[1] As an example, in 2018 Urjit Patel, then-Governor of the Reserve Bank of India, urged the Fed to slow its plans to shrink its balance sheet, arguing that it would contribute to turmoil in emerging markets (Patel 2018). See Bernanke (2017) for a first-hand account describing other examples.

[2] Examples include Rey (2015), Bruno and Shin (2015), Dedola et al. (2017), Iacoviello and Navarro (2018), Bräuning and Ivashina (2019), and Miranda-Agrippino and Rey (2020).

effects on EM GDP. Our model can thus capture the salient facts uncovered by the papers referenced above, including the response of non-U.S. asset prices and credit conditions to U.S. monetary shocks and the pattern of time variation in UIP violations. In addition, our framework is able to capture the implications for real economic activity of these financial developments triggered by U.S. monetary shocks.

Our starting point is an EM borrower that seeks financing for the acquisition of a local productive asset. We will treat the EM as the home economy, and henceforth refer to the EM as "home" and to the U.S. as "foreign." The EM borrower has limited internal resources, and therefore requires external financing. The borrower can raise additional funding both from a domestic capital market—in which local households supply funds denominated in the local currency—and in an international market—in which U.S. households supply dollar funds. Both forms of external financing are subject to agency frictions. In addition, these frictions are more severe for funds of foreign origin, making the local asset less valuable as collateral against dollar loans than against domestic-currency loans. Effectively, the two types of funding are imperfect substitutes.

This imperfect substitutability implies a failure of UIP. We show that in the setting described above, the EM borrower adjusts its liability portfolio up to the point in which the difference between the local-currency interest rate and the dollar cost of credit (inclusive of expected dollar appreciation), henceforth the "currency premium," is proportional to the expected yield on the local asset in excess of the local safe rate (i.e., the domestic lending spread). Given agency frictions, the domestic lending spread is typically positive, and therefore the currency premium is positive also; in addition, in general equilibrium an economywide worsening of EM borrowers' balance sheets (i.e., a decrease in their available internal resources) raises the agency costs of external financing, and is therefore associated with both a higher domestic lending spread and a wider currency premium. Overall, we show that in this economy a weakening of EM borrowers' balance sheets triggers higher local credit spreads and lower local asset prices, a widening of the UIP violation and a depreciation of the local currency against the dollar, and an outflow of dollar funding.

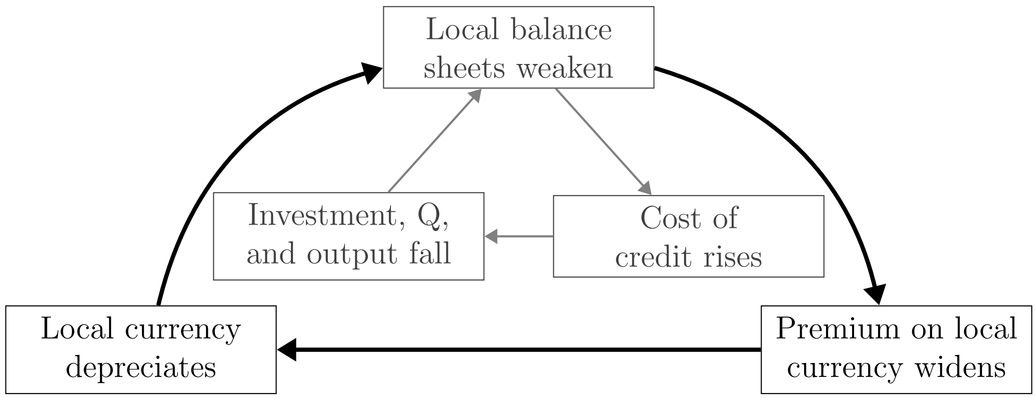
We embed the financial imperfection just described within a conventional, New Keynesian production economy, and use the framework to study the spillover effects of U.S. monetary policy shocks on the EM. Absent financing frictions, the model implies modest spillovers. The reason is simple: a monetary action in the U.S. induces both expenditure-switching and expenditure-reducing effects, which have opposite effects on economic activity in the EM. Consider an increase in the U.S. nominal interest rate. Given nominal rigidities, the U.S.

real interest rate rises, and the EM's currency depreciates against the dollar (and is expected to appreciate), via the conventional UIP condition. The expected future appreciation also leads to some increase in the EM's real interest rate (via lower expected inflation of imported goods). Higher real interest rates reduce desired expenditure by households and firms in both countries, and thus demand for EM goods falls—this is the expenditure-reducing effect. But the increase in the relative price of U.S. goods associated with the stronger dollar makes EM-produced goods relatively more attractive, and leads households and firms in both countries to partly switch demand into these goods and away from U.S.-produced goods—the expenditure-switching effect.

The picture changes considerably once we allow for imperfect financial markets. Now, in addition to the effects outlined previously, a tightening of U.S. monetary policy also triggers losses in EM borrowers' balance sheets. This occurs through two main channels: given the presence of some dollar-denominated debt on the balance sheet of these borrowers, and because the assets held by these borrowers are denominated in the local currency, the depreciation of the local currency against the dollar that occurs in the wake of the U.S. tightening raises the real burden of the dollar-denominated debt, thus reducing borrowers' net worth. In addition, the rise in the EM real interest rate lowers the value of domestic assets (via heavier discounting of future payoffs), which also damages balance sheets. Weaker local balance sheets then initiate powerful feedback effects, which we illustrate in Figure 1. Consider first the inner set of arrows. Weaker local balance sheets lead to higher agency costs of external finance. The local lending spread increases as a result, making credit more expensive for local borrowers and triggering declines in investment and in the local price of capital (i.e., Tobin's Q), and ultimately slowing local economic activity. These developments then feed back into borrowers' financial positions, further weakening them. These feedback effects operating through domestic conditions are well-known—they constitute the standard "financial accelerator" effect pioneered by Bernanke, Gertler and Gilchrist (1999).

Our model adds a second set of feedback effects, based on the interaction between balance sheets and external conditions, that complements and amplifies the domestic-based financial accelerator. These feedback effects are summarized by the outer arrows in Figure 1. In equilibrium, a weakening of local balance sheets widens the deviation from UIP, for reasons explained earlier: the currency premium required by borrowers' optimal liability portfolio increases along with the domestic lending spread. The higher currency premium is accommodated via a depreciation of the local currency against the dollar. The state of borrowers' balance sheets thus exerts its own, *independent* effect on exchange rate dynamics—over-and-

Figure 1. External Feedback Effects and the Financial Accelerator



above the interest differential channel present in models in which conventional UIP holds. Because local balance sheets are partly mismatched, a weaker local currency then feeds back into balance sheet health, further weakening it, and once again initiating both rounds of feedback. Not surprisingly, the end result is sharply amplified declines in local investment, asset prices, and exchange rates, and ultimately GDP (through a large contraction in investment demand). Given the strength of the feedback mechanisms depicted in the figure, the amount of amplification is considerable despite a relatively modest degree of balance sheet mismatch (for the typical borrower, the majority of debt is still denominated in local currency, consistent with the available data from EMs).

The above effects play out even more dramatically when we adopt the Dominant Currency Paradigm (DCP, Gopinath, Boz, Casas, Diez, Gourinchas and Plagborg-Møller 2018) instead of the conventional producer currency pricing. Under DCP, exporting firms in both the EM and the United States set prices in dollars, and therefore the EM depreciation resulting from the U.S. rate hike (which is amplified considerably with financing frictions present) does little to boost EM's exports. As a consequence, the model's predicted drop in EM GDP following a U.S. rate hike is even larger, and in fact approaches the drop in the U.S. itself, consistent with the empirical evidence. This result thus underscores how the funding *and* trade invoicing dimensions of the dollar's dominance work together to imply powerful effects of U.S. monetary policy on other countries.[3]

We use our model to revisit the long-standing question on the desirability of monetary regimes that aim to curb exchange rate volatility. Our framework is a natural one to address

[3]Gopinath and Stein (2018) develop a model in which these two forms of dominance complement each other, providing a unified explanation of the dollar's prominent international role.

this question: as we have argued throughout, exchange rate fluctuations contribute in a potentially undesirable way to the adverse feedback effects illustrated in Figure 1. As it turns out, however, we find that attempting to damp exchange rate fluctuations using monetary policy is counterproductive. The reason is that the currency premium *also* rises endogenously when the EM central bank tightens policy, as the latter lowers domestic asset prices and thus hurts the net worth of local borrowers. As a consequence, a domestic rate hike of a given size has a smaller effect on the exchange rate (and a larger one on output) compared to an economy without financing frictions. For this reason, the presence of financing frictions actually *weakens* the case for regimes with managed exchange rates: the latter entail larger costs in terms of domestic instability, and smaller gains in terms of exchange rate stability, than in frictionless economies. Our analysis also reveals a potential pitfall of managed exchange rate regimes that may be under-appreciated: the model predicts that these regimes actually encourage EM borrowers to finance a larger fraction of their portfolios using dollar debt, as they effectively make dollar debt issuance less risky.[4]

Although our model's predictions are consistent with much of the empirical literature on monetary spillovers we referenced above, we present additional empirical evidence that tests two key model predictions. First, we compare our model's predicted response of EM GDP to a U.S. monetary policy shock with its empirical counterpart based on a vector autoregression (VAR). Here we rely on the VAR model in Christiano, Trabandt and Walentin (2010), which has been widely used to assess the effects of U.S. monetary shocks on the U.S. economy, and simply augment the empirical model developed by these authors to include EM data. Second, we test the key model implication that the local currency premium is tied to the local premium on external finance. We do so by running exchange rate regressions similar to those in Galí (forthcoming) for several EMs, in which we include proxies for the external finance premium as well as interest rate differentials. On both counts, we find that our model's implications are consistent with the data.

Related Literature. Our paper builds on a large literature focused on developing open-economy New Keynesian macroeconomic models—for example, Corsetti and Pesenti (2001), Gali and Monacelli (2005), Erceg, Gust and Lopez-Salido (2007), Farhi and Werning (2014), and Corsetti, Dedola and Leduc (2018). This literature is based on the seminal work by Obstfeld and Rogoff (1995) which studied the effects of monetary and fiscal policies in open

[4] Diamond, Hu and Rajan (2018) argue informally that fear of floating can induce moral hazard if corporations are confident that the central bank will moderate currency volatility. Our analysis endogenizes EM borrowers' liability portfolio choice, showing formally how such an outcome can arise.

economies. The models in this literature generally feature frictionless domestic and international financial markets,[5] while we depart by introducing financial market frictions following Gertler and Kiyotaki (2010).[6]

This paper also relates to a lengthy literature that developed in response to the EM crises of the 1990s, which in several cases highlighted the balance-sheet channel of exchange rate fluctuations. Well-known examples include Krugman (1999), Céspedes, Chang and Velasco (2004), and Gertler et al. (2007).[7] Our model also features balance-sheet effects of exchange rates, but is otherwise quite different from the models in this literature. In our model financial imperfections are microfounded via an explicitly agency problem, with the share of assets financed by each type of debt determined endogenously as the solution of an optimal portfolio problem. This setup leads to the interaction between domestic and external feedback effects illustrated in Figure 1—a finding which, we believe, is novel. Also different from the existing literature, our paper focuses on quantifying the cross-border effects of U.S. monetary policy.

Our model shares with the well-known theory developed by Gabaix and Maggiori (2015) a key role of financial market imperfections in driving exchange rate dynamics. There are, however, several notable differences between our model and theirs. Unlike Gabaix and Maggiori (2015), we focus on borrowers in EMs seeking funding in different currencies to fund a local productive asset; imperfect arbitrage arises because enforcement frictions have greater severity for funds of foreign origin. This leads to the distinct prediction that the currency premium is tied to the local lending spread, which we find has strong support in the data, and which underpins the strong amplification effects we have emphasized throughout.

The focus of our paper is closely related to Gourinchas (2018): both papers focus on quantifying the different channels of spillovers from U.S. monetary shocks, and on the desirability of flexible exchange rate regimes in the face of adverse financial spillovers. The details of both modeling frameworks are quite different however, with ours devoting considerable attention to endogenizing both the EM's local lending spread and the currency premium. Aoki, Benigno and Kiyotaki (2016) develop a small open economy model with financing frictions to study monetary and financial policies in EMs, which shares several similiarities with our model. Our work differs both in terms of focus—we study spillovers from U.S. monetary policy within an asymmetric two-country model—and in terms of modeling

[5]In particular, these models generally feature either no deviations or *exogenous* deviations from UIP.

[6]See also Bernanke, Gertler and Gilchrist (1999), Gertler and Karadi (2011), Gertler, Kiyotaki and Queralto (2012), Gourinchas et al. (2016), and Akinci and Queralto (2017) for related frameworks.

[7]Other prominent papers are Aghion et al. (2001), Aghion et al. (2004) and Braggion et al. (2009).

features—for example, we highlight the importance of allowing for dollar invoicing of international trade in EMs.[8] In addition, our paper emphasizes the critical role of endogenous deviations from UIP in shaping dynamics; we study this issue within a simplified setting that allows analytical insight, and also provide empirical evidence supporting the model-implied UIP deviations. These considerations also differentiate our work from other related papers, including Banerjee et al. (2015), who focus only on domestic financial frictions in accounting for cross-border spillovers, and Fornaro (2015) and Devereux, Young and Yu (2015), who focus on capital controls and exchange rate policy during sudden stops in the context of a small open economy framework with an occasionally binding collateral constraint.[9]

Outline. The article is organized as follows. Section 2 presents a simplified model that illustrates the main mechanism and motivates the larger-scale framework. Section 3 describes our baseline New Keynesian model used to analyze monetary spillovers. Section 4 describes our main experiments exploring the effects of monetary shocks. Section 5 contains our analysis of exchange rate policy. Section 6 compares our model's predictions with VAR-based empirical estimates of monetary spillovers, and also provides novel empirical evidence supporting the UIP deviation's tight link with credit market frictions in EMs. Section 7 concludes. Appendices A-C include supplementary material.

2 A Basic Model with Imperfect Financial Markets

We begin with a simple, stripped-down model which permits isolating the role of financial market imperfections in exchange rate dynamics. This basic model simplifies the demand and production side of the model with the goal of clearly illustrating the link between the UIP failure and the state of borrowers' balance sheets. The main intuition will carry over to the more realistic setting presented later.

Time is discrete and runs to infinity: $t = 0, 1, 2, ...$ There are two countries, an EM (home) and the United States (foreign), each populated by a continuum of households of measure unity. There are two distinct types of nondurable consumption goods, one produced

[8]Also different from Aoki et al. (2016), our framework includes numerous features that have been found to be critical for an empirically realistic account of the effects of monetary and other shocks (e.g. Christiano et al. 2005), and which are commonly included in open economy models used for studying the effects of monetary and fiscal policies (see, for example, Erceg et al. 2006 or Blanchard et al. 2016).

[9]The IMF's integrated policy framework, released after our paper, consists of two small open economy models (Adrian et al. 2020 and Basu et al. 2020) that have some similarities with the model proposed in our research. Differently from these papers, our framework is a two-country quantitative model with a focus on the role of endogenous UIP deviations in the spillovers from U.S. monetary policy.

at home and the other produced abroad, and a durable productive good, "capital." Our focus is on imperfections in the financing of the capital good in the EM. Accordingly, the discussion that follows focuses on describing the home economy.

At home, a set of financial intermediaries ("banks," for short) borrow funds both from domestic households and from U.S. households. These funds are used to finance the acquisition of the capital good. We assume that each type of financing is denominated in the source country's currency. Due to a limited enforcement friction, the bank may face limits in its ability to borrow. Further, the friction affects the two types of borrowing (domestic and foreign) asymmetrically: enforcement problems are more severe for funds of foreign origin. This asymmetry is at the core of the failure of UIP, as we will show.

Next, we describe the optimization problems of banks and households, as well as the resulting equilibrium conditions.

2.1 Bankers

A continuum of bankers, each a member of a household residing in the home country, operate financial intermediaries. Each banker i lives for two periods.[10] In their first period t, the banker receives an exogenous wealth endowment N_{it} from their respective family. The banker then uses these internal funds, combined with funds borrowed from domestic households, D_{it}, and from foreign households in an international credit market, D^*_{it}, to finance purchases of physical capital, K_{it}. Because any banker i is just one in a continuum, the domestic deposits are supplied with probability one by a household different than the one banker i is a member of. The market price of a unit of capital is denoted by Q_t, and the price of a unit of the foreign good is S_t^{-1} (both expressed in terms of the domestic good). We refer to S_t as the real exchange rate.[11] Note that unlike in much of the literature, here a depreciation of the home currency is captured by a *decrease* in S_t. Given these considerations, banker i's budget constraint is the following: $Q_t K_{it} \leq D_{it} + S_t^{-1} D^*_{it} + N_{it}$.

In period $t + 1$, the banker receives dividends generated by his or her physical capital holdings, repays both domestic and foreign creditors, and exits. Upon exit, the banker transfers the profits from his or her activity back to the household. A new banker then takes

[10] The assumption that banks live for only two periods is helpful to make the model transparent, but is not essential. In the quantitative model bankers have infinite horizons.

[11] In the basic model we normalize the price of the domestic good in each country to unity, so that S_t is the only relative price of consumption goods, and there is no meaningful distinction between the terms of trade and the real exchange rate. By contrast, this distinction will be relevant in the quantitative model, in which prices of domestically-produced goods also fluctuate.

over managing the intermediary. Let Z_{t+1} be the dividend generated by the banker's capital holdings, R_{t+1} the (non-contingent) gross real interest rate on domestic deposits, and R^*_{t+1} the real interest rate on foreign deposits. The exiting banker's profits, denoted by Π_{it+1}, are then given by: $\Pi_{it+1} = [Z_{t+1} + Q_{t+1}]K_{it} - R_{t+1}D_{it} - R^*_{t+1}S^{-1}_{t+1}D^*_{it}$. The banker's objective is to maximize the expected value of the profits that will be returned to the household: $\beta\mathbb{E}_t(\Pi_{it+1})$, where $\beta \in (0, 1)$ is the household's discount factor.[12]

The limited enforcement problem takes the following form. After borrowing funds, the banker may decide to divert a fraction of funds for personal gain, rather than honoring obligations with creditors. If the banker defaults, its intermediary goes into bankruptcy, and the banker obtains the following payoff: $\theta\left[D_{it} + (1 + \gamma)S^{-1}_t D^*_{it} + \xi_{it}\right]$, where $0 < \theta < 1$, $\gamma > 0$. Thus, the banker loses some funds in the event of a default ($\theta < 1$), which are seized by the bank's creditors in bankruptcy proceedings. In addition, funds of foreign origin are harder for creditors to recover than domestic funds ($\gamma > 0$): the parameter γ thus indexes the degree to which credit contracts with foreign households are harder to enforce than are contracts with domestic households.[13]

The assumption that $\gamma > 0$ captures the notion that the legal and institutional environment in EMs, as well as the nature of the EM capital which serves as collateral, effectively make it harder for foreign creditors to recover assets from a defaulting borrower, compared with domestic depositors. We elaborate on this assumption in Section 2.4.

Banker i's optimization problem then consists in choosing K_{it}, D_{it}, and D^*_{it} to maximize $\beta\mathbb{E}_t(\Pi_{it+1})$, subject to the budget constraint and to the incentive constraint

$$\beta\mathbb{E}_t(\Pi_{it+1}) \geq \theta\left[D_{it} + (1 + \gamma)S^{-1}_t D^*_{it} + N_{it}\right], \tag{1}$$

which requires the banker's continuation value to be no smaller than the value of diverting funds. If (1) were not satisfied, no creditor would be willing to lend to the banker, in recognition of the latter's incentive to default. This form of constraint, first introduced by Gertler and Kiyotaki (2010), has been widely used in recent literature as a way to endogenize

[12]Below, we assume that households' utility is linear in domestic consumption. In anticipation of that assumption, we omit here the marginal utility of consumption in the expression for the banker's objective.

[13]For example, assume that $N_{it} = 0$ and that banker i finances his or her assets solely with domestic loans ($D^*_{it} = 0$). Given the budget constraint at equality, in the event of a default the bank's creditors are able to seize $(1 - \theta)Q_tK_{it}$, so that the banker's payoff is θQ_tK_{it}. If instead the banker finances capital with foreign funds only ($D_{it} = 0$), the bank's creditors instead can seize $[1 - \theta(1 + \gamma)]\,Q_tK_{it} < (1 - \theta)Q_tK_{it}$, and the banker's payoff is $\theta(1 + \gamma)Q_tK_{it}$. We assume $\theta(1 + \gamma) < 1$, ensuring that foreign creditors can always recover a positive amount.

financial market frictions. The key difference in our setup is to allow for a different degree of frictions affecting funds of different origin.

The banker's problem simplifies considerably when expressed in terms of excess returns. To that end, let $\mu_t \equiv \beta \mathbb{E}_t \left(\frac{Z_{t+1}+Q_{t+1}}{Q_t} - R_{t+1} \right)$ and $\mu_t^* \equiv \beta \mathbb{E}_t \left(\frac{Z_{t+1}+Q_{t+1}}{Q_t} - R_{t+1}^* \frac{S_t}{S_{t+1}} \right)$. The variable μ_t is the (discounted) expected return on capital, given by $\frac{Z_{t+1}+Q_{t+1}}{Q_t}$, in excess of the domestic deposit rate R_{t+1}. The variable μ_t^* is the same excess return relative to the foreign deposit rate R_{t+1}^*, with the latter adjusted for expected variation in the real exchange rate. Let also x_{it} denote the ratio of the value of banker i's foreign liabilities to total assets: $x_{it} \equiv \frac{S_t^{-1} D_{it}^*}{Q_t K_{it}}$. With these definitions, and using the budget constraint at equality, it is straightforward to show that the banker's discounted profit can be expressed as follows: $\beta \mathbb{E}_t (\Pi_{it+1}) = [(1-x_{it})\mu_t + x_{it}\mu_t^*] Q_t K_{it} + \beta R_{t+1} N_{it}$.

The banker's constrained optimization problem is therefore:

$$\max_{K_{it}, x_{it}} \; [(1-x_{it})\mu_t + x_{it}\mu_t^*] Q_t K_{it} + \beta R_{t+1} N_{it} \tag{2}$$

subject to

$$[(1-x_{it})\mu_t + x_{it}\mu_t^*] Q_t K_{it} + \beta R_{t+1} N_{it} \geq \theta(1+\gamma x_{it}) Q_t K_{it} \tag{3}$$

where in the right-hand side of the incentive constraint (3) we have used the budget constraint and the definition of x_{it}.

In the remainder of the analysis, we will restrict attention to parameter configurations such that (3) always binds. In that case, forming the Lagrangian associated with (2)-(3) and taking first-order conditions yields the following optimal portfolio condition (see Appendix A.1 for details):

$$\mu_t^* = (1+\gamma)\mu_t. \tag{4}$$

The intuition for (4) is the following. Assume the banker increases foreign borrowing marginally, and decreases domestic borrowing such that he or she can finance the same amount of assets. The banker thus raises x_{it} marginally while keeping $Q_t K_{it}$ constant. The benefit of this operation is μ_t^*, the excess return on foreign borrowing. The cost is $(1+\gamma)\mu_t$: the foregone excess return on domestic borrowing, μ_t, plus the loss due to the tightening of (3), $\gamma\mu_t$ (since foreign borrowing tightens the incentive constraint by γ marginally). If the banker's liability portfolio is optimal in the first place, the benefit of the operation must equal its cost.

It immediately follows from (4) that the UIP condition is violated. The (discounted) premium on the domestic-currency yield, $\beta\mathbb{E}_t\left(R_{t+1} - R^*_{t+1}S_t/S_{t+1}\right)$, satisfies

$$\begin{aligned}\beta\mathbb{E}_t\left(R_{t+1} - R^*_{t+1}S_t/S_{t+1}\right) &= \mu^*_t - \mu_t \\ &= \gamma\mu_t > 0,\end{aligned} \tag{5}$$

where the second equality uses (4). Thus, home's currency premium is proportional to the domestic excess return μ_t (which is positive as long as (3) binds), with the constant of proportionality given by the parameter γ.

By making use of (4), the constraint (3) at equality can be re-written as

$$\left(1 + \gamma x_{it}\right) Q_t K_{it} = \frac{\beta R_{t+1}}{\theta - \mu_t} N_{it}, \tag{6}$$

Equation (6) indicates that the value of banker i's assets, $Q_t K_{it}$, "augmented" by factor $(1 + \gamma x_{it})$ (since a larger ratio of foreign funding implies a tighter incentive constraint) is constrained by a multiple of the banker's net worth N_{it} (with the multiple given by non-banker-specific variables).

2.2 Households

The representative household in the home economy consumes the domestically-produced good, denoted C_{Dt}, and the imported foreign good, denoted M_{Ct}, and saves via deposits D_t in domestic banks. The household seeks to solve

$$\max_{\substack{\{C_{Dt+k}, M_{Ct+k}, \ldots \\ D_{t+k}\}_{k=0}^{\infty}}} \mathbb{E}_t \left\{ \sum_{k=0}^{\infty} \beta^k \left[C_{Dt+k} + \chi_m \log(M_{Ct+k}) \right] \right\} \tag{7}$$

subject to

$$C_{Dt} + S_t^{-1} M_{Ct} + D_t \leq R_t D_{t-1} + \Pi_t - N_t \tag{8}$$

for all t, where Π_t are profits received from exiting bankers, and N_t are funds transferred to entering bankers. By assuming linear utility in domestic-good consumption, we abstract from consumption dynamics that are not at the heart of the key mechanism operating through financing frictions. At the same time, it is convenient to preserve curvature in the utility derived from the foreign good, for otherwise imports and exports (and therefore the EM's external goods balance) would be inelastic to the exchange rate. These simplifying assumptions are relaxed in the full model below, in which consumers' preferences over goods take a standard CES form.

The household's first-order conditions are

$$R_{t+1} = \beta^{-1}, \tag{9}$$

$$M_{Ct} = \chi_m S_t, \tag{10}$$

together with a transversality condition: $\lim_{k\to\infty} \mathbb{E}_t(\beta^k D_{t+i}) = 0$.

U.S. households' preferences are exactly analogous to (7), with their discount factor denoted β^*, the preference parameter over the EM-produced good denoted χ_m^*, and their imports of the latter denoted M_{Ct}^*. We assume $\beta^* > \beta$, implying that EM households are more impatient than U.S. households. U.S. households can save in a one-period dollar-denominated bond in zero net supply, with gross yield R_{t+1}^*. They can also save by supplying dollar funds D_t^* to EM banks, which must therefore also yield R_{t+1}^*.[14] Because it is analogous to (7)-(8), we omit presenting U.S. households' optimization problem explicitly, and instead directly refer to the resulting optimality conditions:

$$R_{t+1}^* = \beta^{*-1}, \tag{11}$$

$$M_{Ct}^* = \chi_m^* S_t^{-1}, \tag{12}$$

$$\lim_{k\to\infty} \mathbb{E}_t(\beta^{*k} D_{t+k}^*) = 0. \tag{13}$$

2.3 Equilibrium

We assume that EM capital is in fixed supply, given by $\overline{K}$, and also assume the marginal product of capital is constant at Z. For the capital market to clear the financial intermediation sector as a whole needs to hold the supply of capital: $\int K_{it}di = \overline{K}$. Similarly, domestic credit market clearing requires that the funds supplied by the representative EM household equal the funds demanded by the EM banking sector: $\int D_{it}di = D_t$. A similar condition must hold for the dollar credit market, requiring the funds supplied by U.S. households to equal the funds demanded by EM banks: $\int D_{it}^*di = D_t^*$. Finally, the aggregate supply of the

[14]We assume for simplicity no financial intermediation frictions in the U.S., so that U.S. households can also save by directly holding the U.S. capital stock. This feature is irrelevant for our analysis, which focuses on the EM, and we omit further reference to it.

EM good, $Z\overline{K}$, must equal demand: $C_{Dt} + M^*_{Ct} = Z\overline{K}$.

In the remainder of the analysis, our focus is on tracing the impact of a decline in EM banks' aggregate net worth on the magnitude of the UIP violation, the exchange rate, and the market price of capital, as well as on the EM's external balance. To that end, we begin by aggregating EM households' and bankers' budget constraints, and combining them with the market-clearing conditions mentioned previously. The resulting balance-of-payments condition is the following (see Appendix A.2 for a derivation):

$$D^*_t - \beta^{*-1} D^*_{t-1} = \chi_m S_t - \chi^*_m. \tag{14}$$

Equation (14) states that the net accumulation of foreign liabilities (the left-hand side), measured in dollars, must equal the negative of the dollar value of net exports, $NX_t \equiv S_t M^*_{Ct} - M_{Ct} = \chi^*_m - \chi_m S_t$, where we have used the demand equations (10) and (12). Note that in financial autarky ($D^*_t = 0\ \forall t$) the exchange rate would be determined solely by the preference parameters over goods of different origin, $S_t = \chi^*_m/\chi_m$, with a greater relative preference for the home good associated with a higher relative price of the latter.

The second key equilibrium relationship links the exchange rate with the premium μ_t. From (5) after imposing (9) and (11),

$$1 - \frac{\beta}{\beta^*}\mathbb{E}_t\left\{\left(\frac{S_{t+1}}{S_t}\right)^{-1}\right\} = \gamma\mu_t, \tag{15}$$

through which the premium μ_t and the home currency's expected appreciation are positively related. Intuitively, a larger μ_t is associated with a larger UIP violation (with a greater premium on the local rate over the expected dollar rate), generated via a larger expected home appreciation given the constancy of local and foreign yields.

The next condition is the definition of the excess return μ_t, linking the latter inversely to the domestic price of capital Q_t:

$$\mu_t = \beta\mathbb{E}_t\left(\frac{Z + Q_{t+1}}{Q_t}\right) - 1. \tag{16}$$

The final condition is the incentive constraint (6). We suppose that the aggregate net worth endowment, $N_t = \int N_{it}di$, is given by the following: $N_t = Q_t\overline{K}\eta_t$, where η_t is an exogenous variable satisfying $0 < \eta_t < 1$ with steady-state value $\eta \in (\theta, 1)$. We will consider the dynamic effects of a temporary fall in η_t below η. Note that the EM's aggregate financing needs are $Q_t\overline{K}$. The assumption that $\eta_t < 1$ thus has the effect of creating a need for external financing, as bankers' inside resources are not sufficient to finance the aggregate capital stock. The experiment of studying a decline in η_t then traces out the dynamic effects of making the need for external finance temporarily more acute. This analysis is helpful because it helps illustrate the role of agency frictions associated with external finance.[15] We consider a symmetric equilibrium in which all bankers choose the same ratio x_{it} (note that given that (4) holds, bankers are indifferent as to their choice of x_{it}). Given these considerations, the aggregate version of (6) can be written

$$1 + \gamma x_t = \frac{1}{\theta - \mu_t}\eta_t \tag{17}$$

with $x_t = S_t^{-1} D_t^* / Q_t \overline{K}$.

Equations (14), (15), (16), and (17) determine the evolution of variables D_t^*, S_t, Q_t, and μ_t, given a process for exogenous variable η_t. The steady-state of the system can be solved in closed form, as shown in Appendix A.3. We next characterize the dynamic effects of a one-time unexpected decline in η_t, which persists with first-order autoregressive parameter ρ. To that end, we assume that $\beta^* = 1$ and that $(1 - \beta)$ is of second order. It is straightforward to show numerically that the results we emphasize below generalize to much wider ranges of values of the discount factors, but these assumptions provide a very useful case in which the (first-order) dynamics can be characterized analytically. We also normalize the steady-state value of the capital stock, $Q\overline{K}$, to unity.

Under these assumptions, a first-order approximation of (14) yields

$$\hat{d}_t^* = \Phi \hat{s}_t + \hat{d}_{t-1}^*, \tag{18}$$

where $\hat{d}_t \equiv \log(D_t/D)$, $\hat{s}_t \equiv \log(S_t/S)$, and $\Phi \equiv \chi_m / x$, with variables without subscript denoting their steady-state value. A first-order approximation of (15) and (16) yields, respectively,

$$\hat{s}_t = -\gamma \hat{\mu}_t + \mathbb{E}_t(\hat{s}_{t+1}), \tag{19}$$

$$\hat{q}_t = -\hat{\mu}_t + \mathbb{E}_t(\hat{q}_{t+1}), \tag{20}$$

[15]Note that absent agency frictions, the value of η_t would have no aggregate implications (as bankers would freely borrow to make up for any shortfall in internal funds), and perfect arbitrage would follow: $\mathbb{E}_t(R_{K,t+1}) = R_{t+1} = R_{t+1}^* \mathbb{E}_t(S_t/S_{t+1})$.

where $\hat{q}_t \equiv \log(Q_t/Q)$ and $\hat{\mu}_t \equiv \mu_t - \mu$. Thus, $\hat{s}_t = -\gamma \mathbb{E}_t\left(\sum_{i=0}^{\infty} \hat{\mu}_t\right)$ and $\hat{q}_t = -\mathbb{E}_t\left(\sum_{i=0}^{\infty} \hat{\mu}_t\right)$, implying $\hat{s}_t = \gamma \hat{q}_t$: movements in the real exchange rate are proportional to movements in the market price of capital, with constant of proportionality given by parameter γ.

Finally, a first-order approximation of (17) yields

$$\hat{\mu}_t = -\theta \hat{\eta}_t + \varepsilon \hat{x}_t, \tag{21}$$

where $\hat{\eta}_t \equiv \log(\eta/\eta)$, $\hat{x}_t = \hat{d}_t^* - \hat{s}_t - \hat{q}_t$, and $\varepsilon \equiv \frac{\theta(\eta-\theta)}{\eta} > 0$. The parameter composite ε governs the semi-elasticity of the premium μ_t to the foreign funding ratio, and satisfies $0 < \varepsilon < 1/4$ (given $0 < \theta < \eta < 1$).

Assuming that ε is of second order yields a case that is particularly simple to solve. In that case, to a first order we have $\hat{\mu}_t = -\theta \hat{\eta}_t$. Thus $\hat{s}_t = \frac{\gamma\theta}{1-\rho}\hat{\eta}_t$ and $\hat{q}_t = \frac{\theta}{1-\rho}\hat{\eta}_t$, and from (18) $\hat{d}_t^* = \frac{\Phi\gamma\theta}{1-\rho}\hat{\eta}_t + \hat{d}_{t-1}^*$. A decline in $\hat{\eta}_t$ leads to an exchange rate depreciation and a drop in the market price of capital. The currency depreciation triggers a (permanent) decline in the EM's foreign liability position $\hat{d}_t^*$ (i.e. an improvement in net foreign assets), resulting from the rise in net exports NX_t associated with the depreciated EM currency.

Consider next the case when ε is not of second order. Using $\hat{x}_t = \hat{d}_t^* - \hat{s}_t - \hat{q}_t$ and $\hat{s}_t = \gamma \hat{q}_t$ in (21) and substituting the resulting expression for $\hat{\mu}_t$ in (19) yields

$$[1 - \varepsilon(\gamma+1)]\, \hat{s}_t = \theta\gamma\hat{\eta}_t - \gamma\varepsilon\hat{d}_t^* + \mathbb{E}_t(\hat{s}_{t+1}), \tag{22}$$

where $\varepsilon(\gamma+1) \in (0,1)$. Equations (18) and (22) form a dynamic system in the variables $\hat{d}_t^*$ and $\hat{s}_t$, which can be solved using the method of undetermined coefficients. The solution is particularly tractable in the special case $\Phi = 1$ (in turn requiring $\chi_m = x$) and we focus on that case here (Appendix A.4 shows the solution for any Φ). We conjecture a solution of the form:

$$\hat{s}_t = \psi_\eta \hat{\eta}_t - \psi_d \hat{d}_{t-1}^*, \tag{23}$$

$$\hat{d}_t^* = \psi_\eta \hat{\eta}_t + (1-\psi_d)\hat{d}_{t-1}^*. \tag{24}$$

Imposing the conjectured relations in (18) and (22) allows solving for the undetermined coefficients, which yields the expressions $\psi_d = \frac{1}{2}\left\{\varepsilon^{\frac{1}{2}}\left[\varepsilon^{\frac{1}{2}} + (\varepsilon + 4\gamma)^{\frac{1}{2}}\right]\right\} > 0$ and $\psi_\eta = \frac{\gamma\theta}{1-\rho+\psi_d-\varepsilon}$.[16]

[16] The solution takes the form of a quadratic equation for ψ_d, with one positive and one negative root. The negative root implies $1 - \psi_d > 1$, which can be ruled out because it leads to explosive dynamics (as made clear by (24)), violating the transversality condition (13).

As long as γ is not too large, we will have $\psi_d < 1$ (it is sufficient that $\gamma < 3$) and we also have $\psi_d - \varepsilon > 0$. Thus, as before, a decline in bankers' net worth triggers an exchange rate depreciation, though the magnitude of the effect is smaller than in the previous case ($\psi_\eta < \frac{\gamma\theta}{1-\rho}$). Different from the previous case, the equilibrium now features a direct negative effect of the EM's (pre-determined) liability position $\hat{d}^*_{t-1}$ on the value of the exchange rate, with above-steady-state foreign liabilities associated with a below-steady-state exchange rate. Also different from the previous case, now $\hat{d}^*_t$ is strictly stationary, with autoregressive coefficient $(1-\psi_d) \in (0,1)$. For intuition on these observations, assume $\hat{\eta}_t = 0\ \forall t$ and consider an economy starting out with above-steady-state dollar debt, $\hat{d}^*_0 > 0$. If the exchange rate were at its steady-state value in period 1, EM borrowers would need to hold above-steady-state foreign debt in that period (see (18)), $\hat{d}^*_1 = \hat{d}^*_0 > 0$. But $\hat{d}^*_1 > 0$ puts upward pressure on the premium μ_1 (given the greater enforcement frictions associated with foreign debt) and is therefore associated with a wider UIP violation and a depreciated currency, $\hat{s}_1 < 0$. The lower exchange rate then improves the EM's net exports, which in turn pushes net foreign liabilities back toward steady state, $\hat{d}^*_1 = (1-\psi_d)\hat{d}^*_0 < \hat{d}^*_0$.

The finding that the stock of foreign debt exerts a negative effect on the value of the currency is reminiscent of a similar result in Blanchard et al. (2005), obtained in a setting with imperfect substitutability across assets and home bias in asset preferences. More generally, our model effectively features a form of imperfect substitutability between local-currency and dollar debt—given the different degree of enforcement frictions affecting debt in different currencies—which ties into an earlier literature that goes back to Kouri (1976) focusing on the role of imperfect asset substitutability in exchange rate determination.

2.4 Discussion

We briefly discuss here the assumptions underlying the violation of UIP implied by our model.

First, financial contracts are less enforceable across than within borders. This assumption captures features of the institutional environment in EMs that make it harder for foreign creditors to recover assets from a defaulting borrower, compared with domestic depositors. For example, domestic depositors are able to benefit from deposit insurance protections unavailable to foreign lenders, and bankruptcy law is likely biased toward domestic lenders (Hermalin and Rose 1999). More generally, differences in the legal systems between EMs and advanced countries may create difficulties in contract enforcement (Rajan and Zingales

1998). Foreign creditors may also face greater informational disadvantages.[17] While our model captures these considerations by means of the assumption that $\gamma > 0$, deeper micro-foundations are possible inducing similar implications for the failure of UIP.[18]

Second, there is market segmentation: EM banks are the only agents who can borrow from U.S. households. We interpret banks as "specialists" with the expertise necessary for large FX transactions. We highlight, however, that the main results survive under a weaker form of market segmentation, whereby EM households can also borrow in the FX market but face a convex cost of doing so (capturing the notion that there is a limited supply of households sophisticated enough to perform FX transactions).[19]

Third, we assume that creditors in each country lend exclusively in their own currency. This assumption is realistic in light of the evidence in Maggiori et al. (2020) of a very strong home-currency bias on the part of investors.

Fourth, banks in our model are the agents holding the economy's productive asset, and so may be interpreted as an agglomeration of banks and the non-financial firms they lend to. In the spirit of this interpretation we see the currency mismatch present in the model as capturing both an explicit mismatch on the part of banks, as well as an implicit one whereby banks' debtor firms are mismatched and may default on their obligations (making banks effectively exposed to exchange rate risk). Recent literature follows a similar approach (Gopinath and Stein 2018, Bocola and Lorenzoni 2017).

3 A Medium-Scale New Keynesian Model

This section describes our baseline quantitative model. We build on existing multi-country New Keynesian models (as in Gali and Monacelli 2005 or Erceg et al. 2007, for example). The critical departure from this literature is that we allow for imperfect financial markets: as in the basic model, a financial imperfection leads to endogenous fluctuations in the domestic borrowing spread and in the UIP deviation. Different from the simple model, banks have infinite horizons, which makes the evolution of net worth fully endogenous (including to both domestic returns and, to the extent that banks issue debt in dollars,

[17] Caballero and Simsek (2016) make an assumption in this spirit to motivate "fickleness" of foreign investors during distress episodes.

[18] In Gopinath and Stein (2018), for example, banks have more difficulty in creating dollar-denominated collateral than domestic-currency collateral because the bank's underlying assets pay off in domestic currency.

[19] Gertler and Karadi (2013) appeal to a similar notion applied to holdings of long-term U.S. government bonds, within the context of a model of the Federal Reserve's large-scale asset purchases.

to currency movements). We also include a standard set of nominal and real rigidities: nominal price and wage stickiness, habit persistence in consumption, and adjustment costs in investment and in trade flows. We include these features because they are necessary for a realistic account of the effects of monetary policy (Christiano et al. 2005).

3.1 Bankers

The representative household has two types of members: workers and bankers, with measures $1-f$ and f respectively. There is random turnover between bankers and workers: bankers alive in period t survive into $t+1$ with exogenous probability $\sigma_b > 0$, and become workers with complementary probability. Workers become bankers with probability $(1-\sigma_b)\frac{f}{1-f}$, so there is a measure $(1-\sigma_b)f$ of new bankers each period, exactly offsetting the number that exit. Entrant bankers receive a small endowment in the form of fraction $\frac{\xi_b}{f}$ of the value of the capital stock.

Banker i's balance sheet identity is

$$Q_t A_{it} = D_{it} + S_t^{-1} D_{it}^* + N_{it}, \tag{25}$$

where A_{it} is the banker's claims on domestic non-financial firms, which have price Q_t. A continuing banker's budget constraint, expressed in (real) domestic currency, is

$$Q_t A_{it} + R_t D_{it-1} + R_t^* S_t^{-1} D_{it-1}^* \leq R_{Kt} Q_{t-1} A_{it-1} + D_{it} + S_t^{-1} D_{it}^*. \tag{26}$$

The left-hand side of (26) is banker i's uses of funds, consisting of loans to non-financial firms ($Q_t A_{it}$) plus deposit repayments (both domestic, $R_t D_{it-1}$, and foreign, $R_t^* S_t^{-1} D_{it-1}^*$). 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 foreign households: second and third term, respectively). Given frictionless contracting between banks and domestic non-financial firms, the return R_{Kt} satisfies

$$R_{Kt} = \frac{Z_t + (1-\delta)Q_t}{Q_{t-1}}, \tag{27}$$

where Z_t is the (real) capital rental rate and δ is capital's depreciation rate.

Combining (25) and (26) yields the evolution of banker i's net worth, conditional on his or her survival into $t+1$:

$$N_{it+1} = (R_{Kt+1} - R_{t+1})Q_t A_{it} + \left(R_{t+1} - R^*_{t+1} S_t/S_{t+1}\right) S_t^{-1} D^*_{it} + R_{t+1} N_{it}. \tag{28}$$

Banker i's objective is

$$V_{it} = \max_{A_{it}, D^*_{it}} \; (1-\sigma_b)\mathbb{E}_t\left(\Lambda_{t,t+1} N_{it+1}\right) + \sigma_b \mathbb{E}_t\left(\Lambda_{t,t+1} V_{it+1}\right) \tag{29}$$

subject to (28) and

$$(1-\sigma_b)\mathbb{E}_t\left(\Lambda_{t,t+1} N_{it+1}\right) + \sigma_b \mathbb{E}_t\left(\Lambda_{t,t+1} V_{it+1}\right) \geq \Theta(x_{it}) Q_t A_{it}, \tag{30}$$

where $x_{it} \equiv S_t^{-1} D^*_{it}/Q_t A_{it}$ and $\Lambda_{t,t+1}$ is the domestic household's real stochastic discount factor between t and $t+1$. Equation (30) is the incentive constraint, which now incorporates the fact that bankers are infinite-lived. Unlike in the simple model of Section 2, we assume $\Theta(x_t)$ is quadratic rather than linear: $\Theta(x_t) = \theta\left(1 + \frac{\gamma}{2} x_{it}^2\right)$. This formulation has the advantage of inducing an interior solution for banks' portfolio choice x_{it}, without affecting the key qualitative insights obtained from the simpler linear case. This feature will prove useful later when we analyze banks' portfolio choice as a function of the monetary regime in place.

We next highlight the key features of the banker's problem, and defer detailed derivations to Appendix (B.1). All bankers choose the same ratio of dollar debt to assets: $x_{it} = x_t \; \forall i$. The associated first order condition is

$$\varrho_t = \left(\frac{\Theta(x_t)}{\Theta'(x_t)} - x_t\right)^{-1} \mu_t, \tag{31}$$

where ϱ_t and μ_t are given, respectively, by

$$\varrho_t = \mathbb{E}_t\left[\Lambda_{t,t+1}\Omega_{t+1}\left(R_{t+1} - R^*_{t+1} S_t/S_{t+1}\right)\right] \tag{32}$$

and

$$\mu_t = \mathbb{E}_t\left[\Lambda_{t,t+1}\Omega_{t+1}(R_{Kt+1} - R_{t+1})\right], \tag{33}$$

with

$$\Omega_t = 1 - \sigma_b + \sigma_b\left[\nu_t + \left(\mu_t + \mu^*_t x_t\right)\phi_t\right], \tag{34}$$

$$\nu_t = \mathbb{E}_t \left(\Lambda_{t,t+1} \Omega_{t+1} \right) R_{t+1}. \tag{35}$$

The leverage ratio $\phi_{it} = Q_t A_{it}/N_{it}$ is also common across bankers and satisfies

$$\phi_t = \frac{\nu_t}{\Theta(x_t) - (\mu_t + \mu_t^* x_t)}. \tag{36}$$

Different from the basic model described previously, bankers now discount future returns using an "augmented" discount factor $\Lambda_{t+1}\Omega_{t+1}$, which accounts for next period's marginal value of funds internal to the bank (given by the variable Ω_{t+1}). Equation (31) is the counterpart of (5). Given curvature in $\Theta(x_t)$, now ϱ_t and μ_t are not linked simply by a constant, but rather their relationship also depends on x_t, as banks adjust the latter to equalize the marginal benefit of foreign funds with their marginal cost.

From equation (36), the leverage ratio ϕ_t is increasing in ν_t, the saving to the bank in deposit costs from an extra unit of net worth, and in $\mu_t + \varrho_t x_t$, the discounted total excess return on the bank's assets; and decreasing in the fraction of funds banks are able to divert, $\Theta(x_t)$.

Given that banks' leverage ratio ϕ_t and foreign funding ratio x_t do not depend on bank-specific factors, aggregating across banks yields the following relationships between the EM's aggregate assets and foreign debt ($A_t = \int_0^f A_{it} di$ and $D_t^* = \int_0^f D_{it}^* di$ respectively) and aggregate net worth $N_t = \int_0^f N_{it} di$:

$$Q_t A_t = \phi_t N_t, \tag{37}$$

$$S_t^{-1} D_t^* = x_t \phi_t N_t. \tag{38}$$

If bank i is a new entrant, its net worth is given by $N_{it} = \frac{\xi_b}{f} Q_{t-1} A_{t-1}$. Using this condition and (28), aggregating N_{it} across all banks (continuing ones and new entrants) yields the evolution of aggregate net worth:

$$N_t = \sigma_b \left[(R_{Kt} - R_t) Q_{t-1} A_{t-1} + \left(R_t - R_t^* S_{t-1}/S_t \right) S_{t-1}^{-1} D_{t-1}^* + R_t N_{t-1} \right] + (1 - \sigma_b) \xi_b Q_{t-1} A_{t-1}. \tag{39}$$

3.2 Households

Following Erceg, Henderson and Levin (2000), there is a continuum of households indexed by $i \in [0, 1]$, each a monopolistic supplier of specialized labor L_{it}. A large number of competitive "employment agencies" combine specialized labor into a homogeneous labor input L_t (in turn supplied to retail firms), according to $L_t = \left(\int_0^1 L_{it}^{\frac{1}{1+\theta_w}} di\right)^{1+\theta_w}$. From employment agencies' cost minimization, demand for labor variety i is

$$L_{it} = \left(\frac{W_{it}}{W_t}\right)^{-\frac{1+\theta_w}{\theta_w}} L_t, \tag{40}$$

where W_{it} is the nominal wage received by supplier of labor of type i, and the wage paid by goods producers is $W_t = \left(\int_0^1 W_{it}^{-\frac{1}{\theta_w}} dj\right)^{-\theta_w}$.

Household i seeks to solve

$$\max_{\substack{\{C_{Dt+j}, M_{Ct+j}, C_{t+j}, \\ D_{t+j}, W_{it+j}, L_{it+j}\}_{j=0}^{\infty}}} \mathbb{E}_t \left\{ \sum_{j=0}^{\infty} \beta^j \left[\log(C_{t+j} - hC_{t+j-1}) - \frac{\chi_0}{1+\chi} L_{it+j}^{1+\chi} \right] \right\} \tag{41}$$

subject to (40) and to a sequence of budget constraints

$$P_t C_t + P_t D_t + B_t \leq W_{it} L_{it} + P_t R_t D_{t-1} + R_t^n B_{t-1} + \mathcal{W}_{it} + \Pi_t \tag{42}$$

for all t, where C_t and P_t are given, respectively, by

$$C_t = \left[(1-\omega)^{\frac{\rho}{1+\rho}} C_{Dt}^{\frac{1}{1+\rho}} + \omega^{\frac{\rho}{1+\rho}} (\varphi_{Ct} M_{Ct})^{\frac{1}{1+\rho}} \right]^{1+\rho} \tag{43}$$

and

$$P_t = \left[(1-\omega) P_{Dt}^{-\frac{1}{\rho}} + \omega P_{Mt}^{-\frac{1}{\rho}} \right]^{-\rho}. \tag{44}$$

The variable C_t denotes the domestic consumption basket, a CES aggregate of a domestically-produced composite good, C_{Dt}, and an imported composite good, M_{Ct}; D_t is deposits in domestic banks, which pay real (i.e. in terms of the domestic basket) gross interest rate R_t; B_t is holdings of a nominal one-period riskless bond (offered in zero net supply), which pays interest R_t^n (set by the domestic monetary authority) between $t-1$ and t; $\mathcal{W}_{it}$ is the net cash flow from household i's portfolio of state-contingent securities (which ensure that all households consume the same amount C_t, despite earning different wages); and Π_t is bank and firm profits distributed to the household.

The variables P_{Dt} and P_{Mt} denote, respectively, the price of the domestically-produced composite good and of the imported good, and P_t denotes the price of the home consumption basket (i.e. the CPI). In our baseline case, we assume that exporters in each country practice producer currency pricing (PCP):

$$P_{Mt} = e_t^{-1} P_{Dt}^* \tag{45}$$

and

$$P_{Mt}^* = e_t P_{Dt}, \tag{46}$$

where e_t is the nominal exchange rate (i.e. the price in dollars of a unit of the home currency), P_{Dt}^* is the price of the foreign composite good (in dollars), and P_{Mt}^* is the price of the domestic composite good abroad (throughout, we use * to refer to the foreign economy). The real exchange rate is thus $S_t = e_t P_t / P_t^*$.

The variable φ_{Ct} in (43) is given by $\varphi_{Ct} = 1 - \frac{\varphi_M}{2}\left(\frac{M_{Ct}/C_{Dt}}{M_{Ct-1}/C_{Dt-1}} - 1\right)^2$, and captures costs of changing the ratio of imports to domestically-produced goods. As such, it works to dampen the short-run response of the import share to movements in the relative price of imports consistent with the evidence.[20] This formulation is used frequently in the literature—for example, in Erceg et al. (2006), Blanchard et al. (2016), and Eichenbaum et al. (2020).

Finally, the household's problem (41) is also subject to a constraint on wage adjustment, whereby the wage can only be set optimally with probability $1 - \xi_w$, and otherwise must follow the indexation rule $W_{it} = W_{it-1}\pi_{wt-1}^{\iota_w}$, where $\pi_{wt} = W_t / W_{t-1}$ is the wage inflation rate.

As in the basic model, the problem facing U.S. households is analogous to (41), with the exception that they can also hold supply dollar funds D_t^* to EM bankers, at interest rate R_t^*. We continue to assume no financial frictions in the U.S. economy, so that U.S. households can directly hold claims on U.S. firms. Aside from the absence of financial frictions, the U.S. economy mirrors the features of the home country, and we therefore omit any reference to it in the main text (Appendix B.2 contains the corresponding equilibrium conditions).

[20] See, for example, Hooper et al. (2000) and Mc Daniel and Balistreri (2003).

3.3 Firms

There is a continuum of mass unity of retail firms that are subject to pricing frictions. Final output Y_t is a CES composite of retailers' output: $Y_t = \left(\int_0^1 Y_{jt}^{\frac{1}{1+\theta_p}} dj\right)^{1+\theta_p}$, where Y_{jt} is output by retailer $j \in [0,1]$. Let the price set by retailer j be P_{Djt}. The price level of domestic final output is $P_{Dt} = \left(\int_0^1 P_{Djt}^{-\frac{1}{\theta_p}} dj\right)^{-\theta_p}$. Cost minimization by users of final output yields the following demand function for firm j's output: $Y_{jt} = \left(\frac{P_{Djt}}{P_{Dt}}\right)^{-\frac{1+\theta_p}{\theta_p}} Y_t$.

Retailer i uses capital K_{jt} and labor L_{jt} as inputs to produce output Y_{jt}, by means of the production function

$$Y_{jt} = K_{jt}^{\alpha} L_{jt}^{1-\alpha}. \tag{47}$$

The (real) labor and capital rental rates are W_t/P_t and Z_t respectively. Firm j can reset its price with probability $1-\xi_p$, and otherwise must follow the indexation rule $P_{Djt} = P_{Djt-1}\pi_{t-1}^{\iota_p}$, where $\pi_t = P_{Dt}/P_{Dt-1}$ is inflation of domestically-produced goods.

3.4 Capital Producers

The domestic representative capital good producer uses domestic output to produce capital goods, subject to costs of adjusting the level of investment I_t given by $\phi_{It} = \frac{\psi_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 I_t$ and expressed in units of the home good. The representative capital producer solves

$$\max_{\{I_{t+j}\}_{j=0}^{\infty}} \quad \mathbb{E}_t \left\{ \sum_{j=0}^{\infty} \Lambda_{t,t+j} \left[Q_{t+j} I_{t+j} - \frac{P_{Dt+j}}{P_{t+j}} \phi_{It+j} \right] \right\} \tag{48}$$

where Q_t denotes the real (i.e. in units of the home consumption basket) price of the capital good. Similar to consumption, 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:

$$I_t = \left[(1-\omega)^{\frac{\rho}{1+\rho}} I_{Dt}^{\frac{1}{1+\rho}} + \omega^{\frac{\rho}{1+\rho}} \left(\varphi_{It} M_{It}\right)^{\frac{1}{1+\rho}} \right]^{1+\rho}, \tag{49}$$

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–Tobin's

Q relation:

$$Q_t = 1 + \frac{P_{Dt}}{P_t}\left[\psi_I\left(\frac{I_t}{I_{t-1}}-1\right)\frac{I_t}{I_{t-1}} + \frac{\psi_I}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2\right] - \mathbb{E}_t\left\{\Lambda_{t,t+1}\frac{P_{Dt+1}}{P_{t+1}}\psi_I\left(\frac{I_{t+1}}{I_t}-1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right\} \tag{50}$$

3.5 Market Clearing, Balance of Payments, and Monetary Policy

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

$$Y_t = C_{Dt} + I_{Dt} + \phi_{It} + \frac{\xi^*}{\xi}\Big(M^*_{Ct} + M^*_{It}\Big), \tag{51}$$

where ξ^* and ξ, are, respectively, the population sizes of the foreign and home economies (note that all variables are expressed in per-capita terms). Home output is either used domestically (for consumption or investment) or exported. Capital and labor market clearing require $K_t = \int_0^1 K_{jt}dj$ and $L_t = \int_0^1 L_{jt}dj$, respectively. The aggregate capital stock evolves according to $K_{t+1} = (1-\delta)K_t + I_t$. In turn, market clearing for claims on EM physical capital (held by EM banks) requires $A_t = (1-\delta)K_t + I_t$.

The balance of payments, obtained by aggregating the budget constraints of agents in the home economy, is given by

$$D^*_t - R^*_t D^*_{t-1} = S_t\left[\frac{P_{Mt}}{P_t}(M_{Ct} + M_{It}) - \frac{P_{Dt}}{P_t}\frac{\xi^*}{\xi}(M^*_{Ct} + M^*_{It})\right]. \tag{52}$$

Similar to (14), (52) states that the EM's net accumulation of foreign liabilities, expressed in (real) dollars, equals the negative of the value of net exports.

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

$$R^n_{t+1} = \Big(R^n_t\Big)^{\gamma_r}\Big(\beta^{-1}\pi_t^{\gamma_\pi}\Big)^{1-\gamma_r}\varepsilon^r_t, \tag{53}$$

where ε^r_t is an exogenous shock. Later we consider an alternative policy rule which allows for an exchange rate stabilization motive. Finally, monetary policy in the United States is conducted according to an inertial Taylor rule which, in addition to inflation, includes the output gap as an argument and is buffeted by exogenous shocks ε^{r*}_t, in a manner analogous to (53). The U.S. monetary shock is assumed to follow the process $\varepsilon^{r*}_t = \rho_r\varepsilon^{r*}_{t-1} + u_t$, where

$u_t \sim \mathcal{N}(0, \sigma_u^2)$.

Appendix B.2 contains a complete description of the model's equilibrium conditions.

3.6 Parameter Values

We calibrate the foreign economy to the United States, and take the home economy to represent an EM, such as Mexico, with trade and financial linkages to the United States. An alternative possibility is to think of the home economy as a bloc of emerging economies, such as the Asian or the Latin American EMs.[21] The calibration is asymmetric: the U.S. is much larger in size, and EM households are assumed to be relatively impatient, which introduces a motive for the latter to borrow from U.S. households. The relative impatience feature can be seen as capturing more-structural differences between EMs and advanced economies, such as faster prospective trend growth in EMs.

Table 1 reports parameter values. We calibrate the U.S. discount factor, β^*, to 0.9950, implying a steady-state real interest rate of 2% 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.[22] The size of the home economy relative to the United States is $\xi/\xi^* = 1/3$.

The capital share (α) and capital depreciation rate (δ) are calibrated to the conventional values of 0.33 and 0.025, respectively. We calibrate the steady-state wage and price markups, θ_p and θ_w, to 20 percent in each case, a conventional value. For the remaining parameters governing household and firm behavior, 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 (ξ_p, ι_p, ξ_w, and ι_w), and the investment adjustment cost parameter (Ψ_I). These parameters are set symmetrically across the two economies, and their values are fairly conventional. They are listed in the top part of Table 1.

The Taylor rule both at home and in the U.S. features inertia with a coefficient of 0.82 (an estimate also taken from Justiniano et al. 2010). In our baseline experiments we set the home

[21]The approach of grouping countries into blocs is often used in larger-scale models for policy analysis, e.g. Erceg et al. (2006).

[22]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.

Taylor rule coefficient γ_π to the standard value of 1.5, capturing a rule focused on stabilizing domestic inflation. We use the domestic monetary shock ε_t^r in Section 5 to illustrate the effects of domestic monetary policy, and otherwise set its volatility to zero. Turning to the U.S. Taylor rule, we set the coefficients γ_π^* and γ_x^* to 1.5 and 0.125 respectively, conventional values used in the literature (e.g. Taylor 1993). To calibrate the standard deviation and persistence of U.S. monetary shocks, we use the calibrated U.S. Taylor rule, together with observations on the Fed funds rate, core inflation, and the output gap (proxied by -2 times the deviation of the unemployment rate from the natural rate, with the latter set to 4.8 as in Reifschneider 2016) for the period 1980-present, to extract a series for the empirical counterpart of ε_t^{r*}, to which we fit an AR(1) process. The resulting values are $\rho_r = 0.25$ and $\sigma_u = 0.20/100$.[23]

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 $(1+\rho)/\rho$ to 1.5. We impose the restriction that $\omega^* = \omega\xi/\xi^*$, as frequently done in the literature (e.g. Blanchard et al. 2016). We set $\omega = 0.20$, implying that 20 percent of the home economy's output is exported in steady state. This value is somewhat lower than the ratio of Mexico's exports to the United States as a fraction of GDP (which equaled 0.28 in 2017) but higher than in other EMs (for example, aggregating across the major EMs in Asia and Latin America leads to a ratio of around 0.10 for 2017).[24] The trade adjustment cost parameter φ_M is set to 10, as in Erceg et al. (2005) and Erceg et al. (2006). 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.

Regarding the parameters governing financial market frictions, we set the survival rate σ_b to 0.95, implying an expected horizon of 6 years. This value is around the mid-point of values found in related work using variants of this framework.[25] The remaining three parameters are set to hit three steady-state targets: a credit spread of 200 basis points annually, a leverage ratio of 5, and a ratio of foreign-currency debt to domestic debt (D^*/SD) of 30 percent. The target for the credit spread reflects the average value of 5-year BBB corporate bond spreads

[23] If we instead estimate a rule for the Fed funds rate with core inflation and unemployment as arguments (rather than calibrating the coefficients on these variables ex-ante), the resulting residual has a similar standard deviation, but lower persistence.

[24] These statistics refer only to merchandise trade, so do not include services. Source: IMF Direction of Trade statistics.

[25] For example, Gertler et al. (2020) calibrate a survival rate of 0.93 and Gertler et al. (2019) of 0.935, while earlier work (Gertler and Kiyotaki 2010, Gertler and Karadi 2011, Gertler et al. 2012) had values closer to 0.97.

in major emerging market economies (including both Asian and Latin American EMs) over the period 1999-2017 (excluding the global financial crisis period). The target leverage ratio is a rough average of leverage across different sectors. Leverage ratios in the banking sector are typically greater than five,[26] but the corporate sector features a much lower ratio of assets to equity (between two and three in emerging markets).[27] Our target of five reflects a compromise between these two values. Finally, evidence in Hahm et al. (2013) on ratios of foreign-currency deposits to domestic deposits in EMs suggests an average of about 30 percent. This value is also consistent with evidence presented in Chui et al. (2016), showing that average private-sector foreign currency debt across EMs (for the period 2006-2014) as a percent of total (i.e. domestic- plus foreign-currency denominated) debt is a little over 20 percent. These targets imply $\theta = 0.41, \xi_b = 0.07$, and $\gamma = 2.58$. The implied value for the steady-state ratio of foreign liabilities to assets is $x = 0.18$ (note that x follows from our targets for ϕ and D^*/SD, via the balance sheet identity (25)).

4 Cross-Border Monetary Spillovers

This section uses the medium-scale model presented above to explore the transmission of monetary policy across borders. We begin by discussing the channels of spillovers in a frictionless economy, with an emphasis on the role of the expenditure-switching and expenditure-reducing effects. This analysis sets the stage for the next subsection, in which we examine spillovers in our baseline model with imperfect financial markets. We then analyze the implications of dollar trade invoicing—an empirically relevant trade pricing assumption for EMs—for the spillovers from a U.S. monetary policy shock. We conclude the section by exploring the transmission of domestic monetary policy.

4.1 Spillovers in a Frictionless Economy

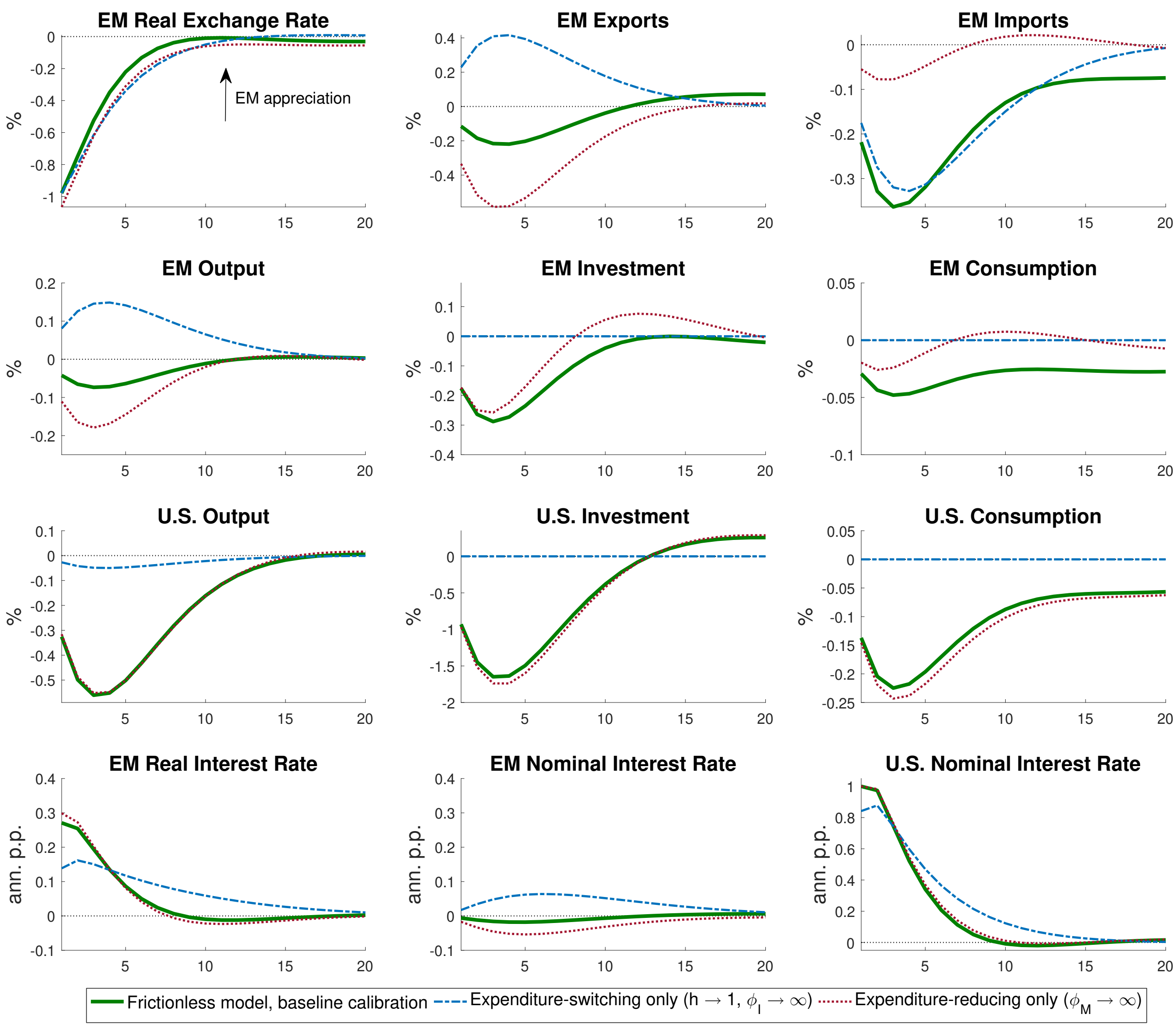
We first consider monetary spillovers in an economy featuring a complete set of contingent claims traded internationally, and no financing frictions. We also set $\beta^* = \beta$. The remaining model features are as described in Section 3.

The green solid line in Figure 2 shows the effects a U.S. monetary shock that leads to a 100 basis point rise in the U.S. nominal interest rate (the federal funds rate). Overall, the shock

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

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

Figure 2. U.S. Monetary Shock in a Frictionless Model



Note: The green solid line shows the effects of a 1 percent rise in the U.S. policy rate in the model with frictionless financial markets. The blue dash-dotted line sets the habit parameter h very close to 1 and the investment adjustment cost parameter ϕ_I to a very high value, keeping world expenditure constant and thus capturing only the expenditure-switching effect. The dark red solid line sets the trade adjustment cost parameter to a very high value (and h and ϕ_I back to their baseline values), thus capturing only the expenditure-reducing effect. All variables shown relative to steady state.

has empirically realistic effects on the United States, with U.S. GDP (third row, first column) falling nearly 0.60 percent at the trough—close to our identified vector autoregression (VAR) estimate (shown in Section 6.1), and broadly similar to those found by other authors, like

Christiano et al. (2005). The key observation from Figure 2 is that the effect of the U.S. tightening on activity in the EM is modest, with EM GDP falling by less than 0.10 percent (second row, first column).

To understand the mechanics of the effect of the foreign monetary policy shock on domestic activity, it is helpful to consider the following expression linking home's GDP to the sum of consumption, investment, and net exports, obtained by combining (43), (49), and (51) and log-linearizing:

$$\hat{y}_t = \alpha_{cy}\hat{c}_t + (1-\alpha_{cy})\,\hat{i}_t + \omega\left(\hat{m}_t^* - \hat{m}_t\right), \tag{54}$$

where $\hat{z}_t$ denotes the log deviation of any variable Z_t from its steady-state value, $\alpha_{cy} \equiv C/Y = 0.77$ is the steady-state share of consumption in output, $\omega = 0.20$ is trade openness, and $\hat{m}_t^* = \alpha_{cy}\hat{m}_{ct}^* + (1-\alpha_{cy})\hat{m}_{it}^*$ and $\hat{m}_t = \alpha_{cy}\hat{m}_{ct} + (1-\alpha_{cy})\hat{m}_{it}$ are total exports and imports respectively. Equation (54) indicates that log-deviations of output from steady state can be decomposed into domestic absorption, $\alpha_{cy}\hat{c}_t + (1-\alpha_{cy})\,\hat{i}_t$, plus net exports, $\omega\left(\hat{m}_t^* - \hat{m}_t\right)$.

The 100 basis point hike raises the U.S. real rate (not shown) by around 120 basis points, given some decline in U.S. expected inflation. Through the UIP condition (which holds in its standard form in this frictionless setting), the ensuing differential in long-run real interest rates puts downward pressure on home's real exchange rate (top left panel), which depreciates 1 percent upon impact and gradually appreciates thereafter. The expected appreciation then works to depress home's expected CPI inflation (through lower inflation in imported goods), which accounts for a rise in the home real interest rate R_t of about 25 basis points—roughly one-fifth the size of the increase in the U.S. real rate. The rising home real interest rate explains the drops in consumption and investment (middle row, second and third columns respectively), each falling by around one-fifth the size of the decline in the same variables in the United States—in line with the relative size of the increase in the real rate compared with the United States. Through the lens of (54), the drop in home GDP reflects the drag from domestic absorption, along with some offset from net exports, which increase somewhat—as imports fall by more than exports do (middle and right panels in the top row).

The model permits illustrating how the small response of home's GDP to the foreign monetary shock ultimately reflects the offsetting influences of the expenditure-switching and the expenditure-reducing channels, which move home GDP in opposite directions. The expenditure-switching channel captures the shift in spending toward home goods and away from U.S. goods driven by the decline in the relative price of the former. We can capture this channel by setting the habit and investment adjustment cost parameters to very high values, leading households and firms in both countries to keep consumption and investment spending constant despite rising real interest rates. The resulting dynamics (shown by the blue dash-dotted line in Figure 2, where we have re-sized the shock so it generates the same depreciation upon impact) reflect that consumers and firms at home and abroad reallocate expenditure toward home goods and away from U.S. goods, while keeping overall expenditure constant. Accordingly, home's net exports improve substantially, engendering a rise in home GDP of about 0.15 percent.

The expenditure-reducing channel, on the other hand, refers to the decline in the overall demand for both home and foreign products resulting from the rise in real interest rates (both abroad and at home). We capture this channel by setting the parameter ϕ_M (governing the cost of adjusting the share of imports in both consumption and investment) to a very high value—effectively imposing Leontief preferences across domestic- and foreign-produced goods, which implies that agents do not alter the share of imports in total consumption or investment despite the relative price change. Under these conditions, the movement in home output can be shown to equal a weighted average of the change in home and U.S. absorption, with weights $(1-\omega)$ and ω respectively.[28] Now home GDP drops as a result of the shock, by about 0.20 percent—with two-thirds of the decline accounted for by the U.S. absorption component, and one-third accounted for by domestic absorption.

Under the baseline calibration, both the expenditure-reducing and the expenditure-switching effects are present: there is a decline in overall spending, but also some reallocation of spending toward home goods. Home output still declines a bit as the expenditure-reducing channel is somewhat more powerful, but the drop is quantitatively modest.

4.2 Imperfect Financial Markets

Unlike the frictionless model studied above, our model with imperfect financial markets implies sizable spillover effects from the U.S. monetary tightening. The blue solid line in Figure 3 shows the effects of the same 100 basis point U.S. tightening in our baseline model with financial market frictions. GDP in the EM (bottom left panel) falls about 0.3 percent,

[28]Given $\phi_M \to \infty$, imports move in proportion with home absorption and exports move in proportion with U.S. absorption, so that equation (54) becomes simply

$$\hat{y}_t = (1-\omega)[\alpha_{cy}\hat{c}_t + (1-\alpha_{cy})\hat{i}_t] + \omega[\alpha_{cy}\hat{c}^*_t + (1-\alpha_{cy})\hat{i}^*_t]$$

.

more than three times as much as in the frictionless model, and the real exchange rate (second row, first column) depreciates by fifty percent more than without financial frictions. Tobin's Q falls nearly 1.5 percent, compared with 0.25 percent in the frictionless model. The bigger decline in GDP is driven by a much steeper drop in domestic absorption, with investment falling by more than 2 percent—eight times as much as in the frictionless economy—and consumption by about twice as much. At the same time, there is a stronger offset from net exports—with exports actually rising a bit, due to the the much sharper depreciation.

The presence of an endogenous currency premium and of dollar liabilities in balance sheets plays a key role in the financial amplification responsible for the much stronger effects just described. To clarify the mechanics, it is helpful to consider the loglinearized versions of equations (39) and (31), respectively given by the following:

$$\hat{n}_t \approx \sigma_b \left\{ \phi \left[(\hat{r}_{kt} - \hat{r}_t) - x \left(\hat{r}^*_t - \Delta \hat{s}_t - \hat{r}_t \right) \right] + \hat{r}_t + \hat{n}_{t-1} \right\}, \tag{55}$$

$$\hat{s}_t \approx -\Gamma \mathbb{E}_t \left\{ \hat{r}_{kt+1} - \hat{r}_{t+1} \right\} + \hat{r}_{t+1} - \hat{r}^*_{t+1} + \mathbb{E}_t \left\{ \hat{s}_{t+1} \right\}, \tag{56}$$

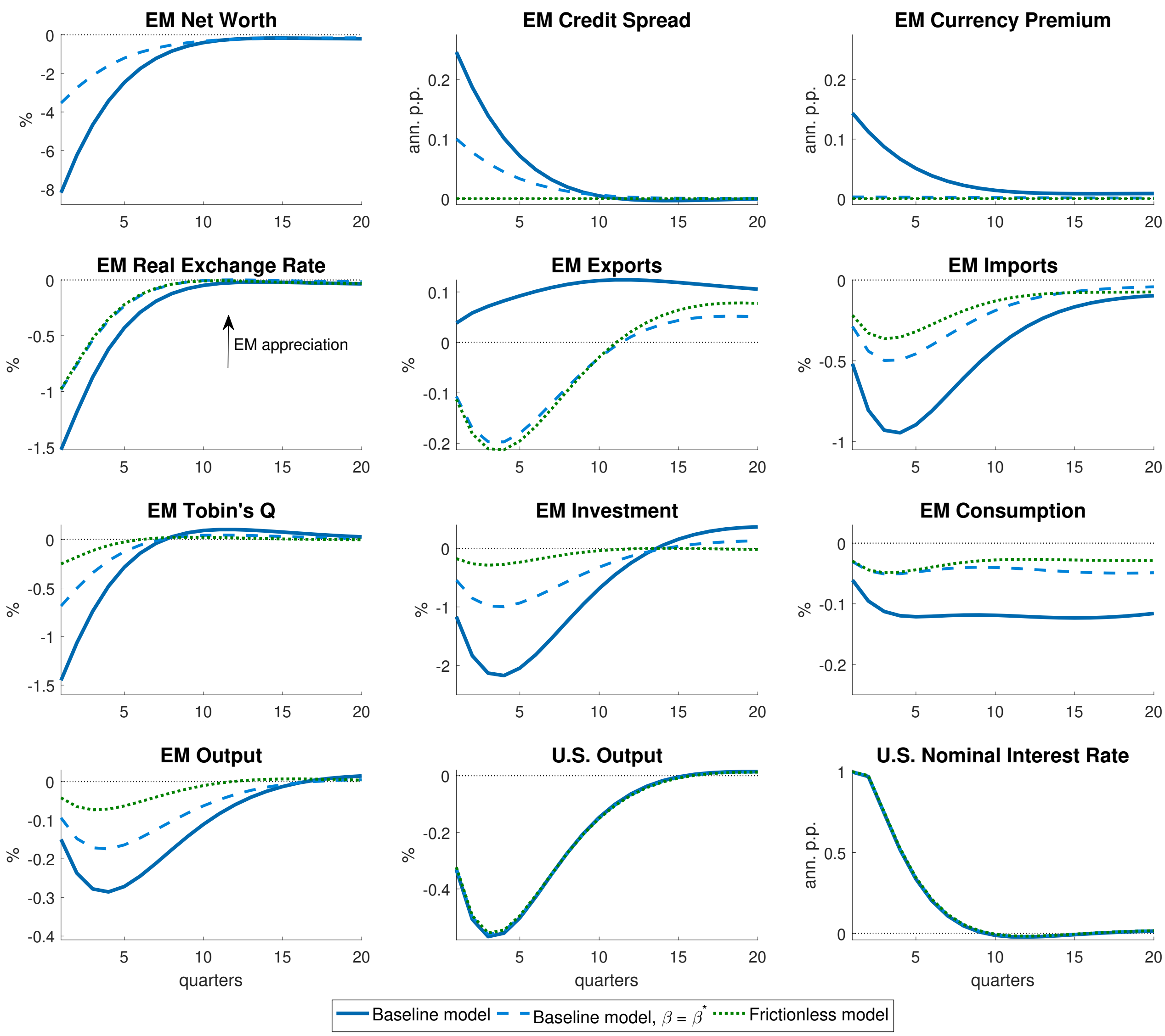
where $\phi = 5$ and $x = 0.18$ are the steady-state leverage ratio and the ratio of dollar debt to assets respectively, and where the coefficient Γ (itself an increasing function of both x and parameter γ) is $\Gamma = 0.5$.[29]

Equation (55) shows the evolution of aggregate net worth, which depends positively on the realized return to capital $\hat{r}_{kt}$ (a variable moves close to one-for-one with log-deviations in Tobin's Q) and inversely on the ex-post real exchange rate depreciation $\Delta \hat{s}_t$, where the latter effect is more powerful the larger the steady-state dollar debt share x (note that $\hat{r}_t$ and $\hat{r}^*_t$ are pre-determined as of period t). Equation (56) is our model's version of uncovered interest parity, which links the real exchange rate to the spread between the domestic return on capital and the domestic deposit rate (the first term) as well as to the real interest rate differential between the two countries and to the expectation of the following-period exchange rate. The first term captures the deviation from UIP, in a manner analogous to the simple model of Section 2 (with the coefficient Γ now replacing γ, due to $\Theta(x_t)$ being quadratic rather than linear).

As suggested by (55) and (56), to the extent that $x > 0$, the model involves two-way feedback between $\hat{n}_t$ and the real exchange rate $\hat{s}_t$, over and above the adverse feedback between net worth and Tobin's Q usually present in financial accelerator models: as net

[29]The expression for Γ is $\Gamma(x, \gamma) = \frac{x}{\gamma^{-1} - x^2/2}$. For expositional convenience, equations (55) and (56) abstract from terms that involve coefficients $(R_K - R), (R - R^*)$ or $(1 - \sigma_b)\xi_b$, all of which are orders of magnitude smaller than the coefficients on the terms shown in (55) and (56).

Figure 3. U.S. Monetary Shock with Imperfect Financial Markets



Note: The dark blue solid line shows the effects of 1 percent rise in the U.S. policy rate in our baseline model with frictions in financial markets. The light blue dashed line shows the effects in our baseline model with a tax on foreign borrowing such that steady-state domestic dollar debt is zero. The green dotted line shows the effects in the frictionless model.

worth deteriorates, the term $\mathbb{E}_t \{\hat{r}_{kt+1} - \hat{r}_{t+1}\}$ in (56) rises, pushing down $\hat{s}_t$, which in turn feeds back into net worth through the term $\Delta\hat{s}_t$. Thus, the model features *both* mutual feedback between $\hat{s}_t$ and $\hat{n}_t$ (for given $\hat{q}_t$) *and* between $\hat{q}_t$ and $\hat{n}_t$ (for given $\hat{s}_t$). This three-way interaction lies at the heart of the strength of financial amplification.

These considerations help understand how the dynamics presented in Figure 3 arise. Both the EM's exchange rate depreciation and the drop in Tobin's Q following the U.S. rate hike (which would take place even in a frictionless setting, as made clear in the previous subsection) work to initiate losses in EM banks' net worth. This triggers the three-way amplification described previously. The end result is a drop in net worth of almost 9 percent, a drop in Tobin's Q that is eight times larger than in the frictionless setting, and a much sharper depreciation. The accompanying rise in the domestic credit spread raises the effective cost of investment and effectively underlies the sharp drop in that variable.[30]

To illustrate the role of the interaction between dollar debt in balance sheets and the endogenous deviation from UIP, we consider the effects of the U.S. rate hike in an alternative economy in which $\beta = \beta^*$, which implies $x = 0$ (i.e. no steady-state dollar debt, given equality between steady-state autarky interest rates in both countries). Given $x = 0$, we have that $\Gamma = 0$ in (56)—that is, standard UIP holds (given that $\Theta(x)$ is flat at $x = 0$). Thus, the "second round" feedback effect—whereby lower net worth weakens the currency, which weakens net worth further—is absent. The blue dashed lines in Figure 3 show the responses in this case. Net worth declines by less than half as in the baseline model, and the domestic credit spread also rises by less than half as much—explaining the considerably smaller slowdown in investment spending, which ultimately drives the noticeably smaller GDP effects. Thus, the interaction between the endogenous UIP deviation and the presence of foreign debt plays a quantitatively large role, despite a modest value of the foreign debt share x—a result that is driven by the three-way feedback effects described earlier, which compound the model's financial amplification.

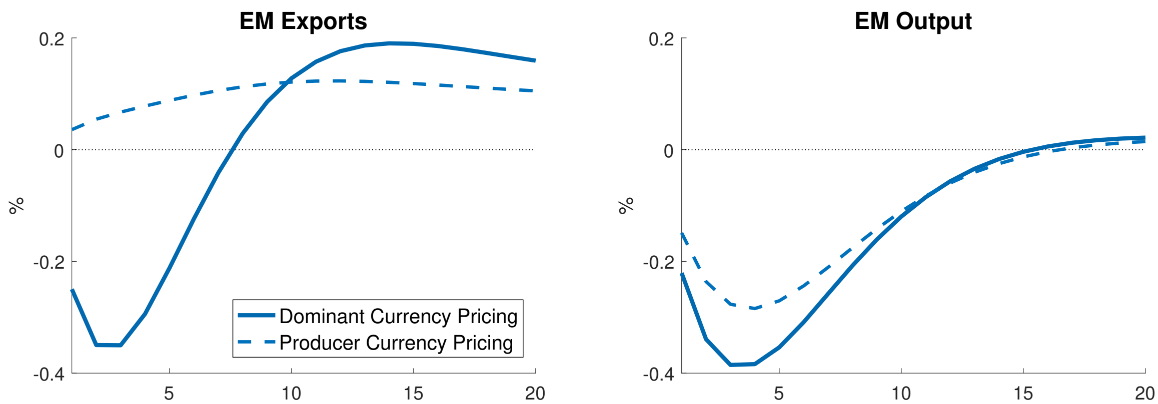
4.3 Imperfect Financial Markets and Dominant Currency Pricing

In this section we investigate the spillovers from U.S. monetary policy under the dominant currency paradigm (DCP) proposed by Gopinath et al. (2018). The DCP pricing assumption is motivated by empirical evidence suggesting that a large fraction of international trade is invoiced in a small number of dominant currencies, with the U.S. dollar playing an outsized role (see, for example, Goldberg and Tille 2008 and Gopinath et al. 2018).

Under DCP, firms in both countries set export prices in U.S. dollars. Thus, U.S. exporters continue to practice PCP, but now EM producers set one price in domestic currency for

[30] For comparability with empirical measures, we report the credit spread as a five-year maturity equivalent (with yields expressed in annual terms). That is, we show $\mathbb{E}_t \left(\sum_{i=1}^{20} r_{kt+i} - r_{t+i} \right) /5$, and similarly for the currency premium.

Figure 4. Dominant Currency Pricing v. Producer Currency Pricing



Note: The Figure performs the same experiment as in Figure 3 under the Dominant Currency Pricing (DCP) assumption. The dark blue solid line shows the effects of a 1 percent rise in the U.S. policy rate in the baseline model, the light blue dashed line shows the effects when steady-state dollar debt is zero, and the green dotted line shows the effects in the frictionless model.

goods sold in the domestic market, and another in dollars for goods sold in the United States. Home import prices continue to satisfy $P_{Mt} = e_t^{-1} P^*_{Dt}$, but now each domestic firm j also sets a dollar export price $P^*_{Mt}(j)$ subject to the Calvo price-setting friction. If firm j is not able to reset its export price, it follows indexation rule $P^*_{Mt}(j) = P^*_{Mt-1}(j)\pi^{*\iota_p}_{Mt-1}$, where $\pi^*_{Mt} = P^*_{Mt}/P^*_{Mt-1}$ is export price inflation.[31]

Figure 4 shows the effects of the U.S. monetary shock under DCP. The drop in EM GDP is now around 0.40 percent—noticeably larger than under PCP, and in fact nearing the drop in U.S. GDP itself. The key reason for the larger hit to EM activity is that under DCP, the depreciation of the home currency largely fails to translate into lower prices of home goods abroad, and thus its benefits in terms of boosting exports are sharply diminished: exports decline by almost 0.40 percent, in spite of the (real) currency's persistent depreciation by more than 1.5 percent. At the same time, for the reasons described in the previous subsection, the financial tightening continues to induce a large drag on GDP via lower domestic absorption. Put differently, under DCP the home economy's output still suffers the costs of a depreciating currency (which work to depress domestic absorption via the financial feedback effects described earlier) without the potential benefits (due to a boost to exports). Thus, in our model the *interaction* between the dollar's role as a funding currency and as a trade pricing currency is ultimately responsible for the much larger cross-border

[31]See Appendix B.3 for the detailed set of equilibrium conditions under DCP.

effects of U.S. monetary policy, compared with conventional models (as exemplified by the frictionless PCP setting shown in Figure 2).

4.4 Effects of Domestic Monetary Policy

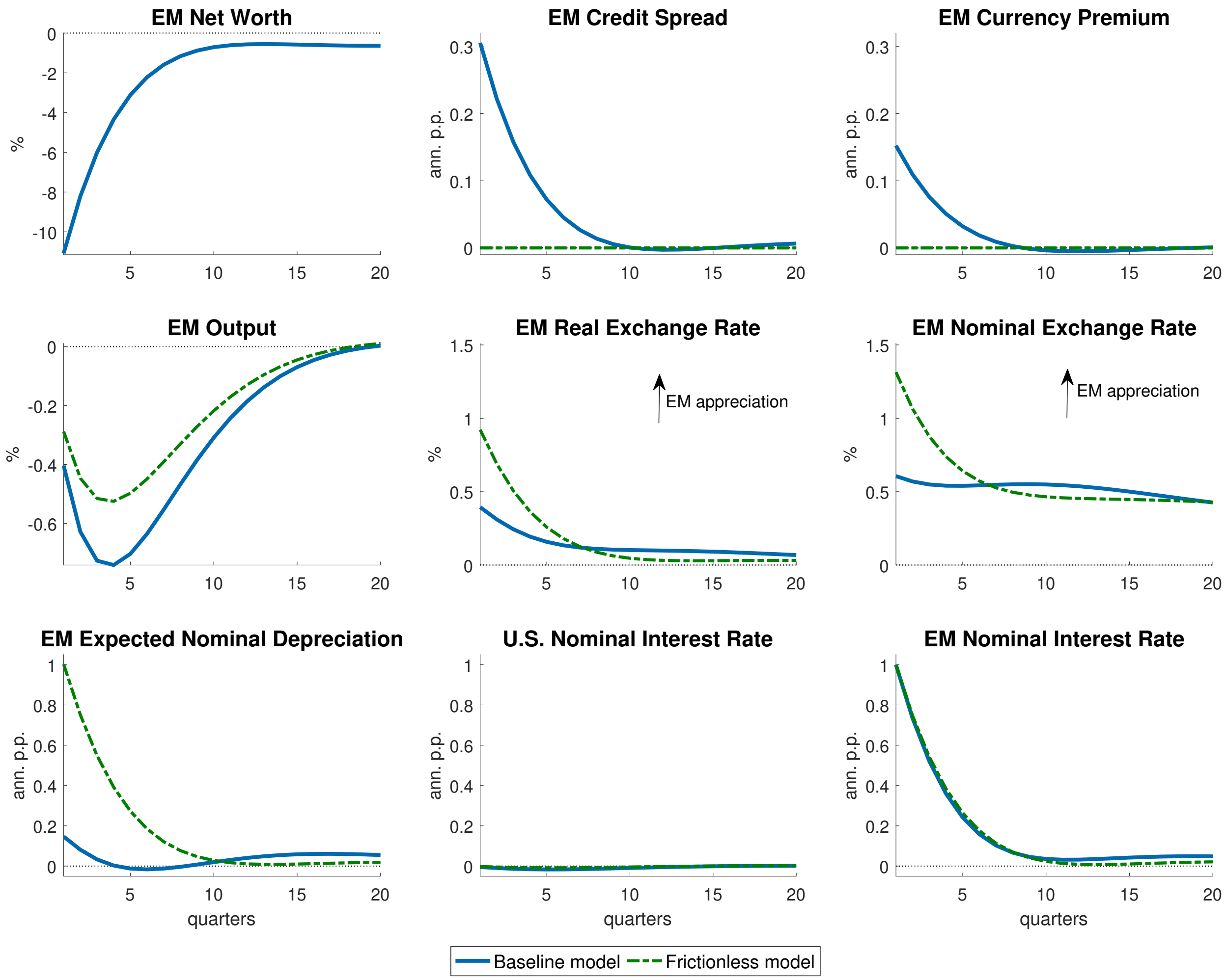
The three-way feedback between net worth, domestic asset prices, and the exchange rate also has significant implications for the transmission of domestic monetary policy. To illustrate this point, Figure 5 shows the dynamic effects of a positive innovation in ε_t^r that leads the EM's nominal interest rate to rise by 1 percentage point. We again compare the effects in our baseline model to those obtained in a frictionless, complete-markets setting—in both cases under the PCP assumption.

The first observation from Figure 5 is that the domestic monetary tightening is also amplified by financial factors: the higher real interest rate engineered by tight monetary policy induces a drop in Tobin's Q, which depresses net worth and leads to a 30 basis point rise in the EM's credit spread. As a consequence, investment declines by more than in the frictionless setting—explaining an overall larger output downturn. This is the standard amplification of monetary disturbances through the financial accelerator, which has been emphasized by numerous authors (e.g. Bernanke et al. 1999, Gertler and Karadi 2011).

The novelty in our setting lies in the implications for exchange rate dynamics, via the endogenous deviation from UIP. As we have emphasized throughout, the magnitude of the UIP deviation (the EM's currency premium, shown in the top-right panel in Figure 5) moves in proportion with the domestic credit spread (by half as much, given that $\Gamma = 0.5$ in (56))—and thus rises about 15 basis points in this experiment. The increase in the currency premium puts pressure on the EM's currency, an effect that goes in the opposite direction to the conventional UIP-based channel through which a higher interest rate in the EM relative to the United States appreciates the former's currency. These observations help understand the behavior of the nominal and real exchange rate seen in Figure 5: both appreciate by considerably less initially than predicted by the frictionless model, given the countervailing effect of the higher currency premium (which is strongest in the initial periods following the shock). For this reason, the model with frictions features much less overshooting in the nominal exchange rate than observed in the frictionless model.[32] Thus, the effectiveness of tighter domestic policy in engineering an exchange rate appreciation is diminished in the

[32] Schmitt-Grohé and Uribe (2018) estimate empirical models of exchange rates featuring both permanent and transitory monetary shocks, and find no overshooting in the exchange rate in response to either type of shock.

Figure 5. Domestic Monetary Shock, Frictionless Model v. Baseline Model



Note: The Figure shows the effects of a 1 percentage point increase in the domestic policy rate, in the frictionless model (green dotted line) and in the baseline model with frictions (blue solid line).

short-run compared to a frictionless environment.

The last row of Figure 5 underscores how our model can rationalize the *uncovered interest parity puzzle* (Engel 2014). In the frictionless model, in which UIP holds in its standard form, the EM's expected nominal depreciation moves one for one with the interest rate differential between the EM and the United States (note that the latter barely moves, as the spillovers to the United States from the EM monetary shock are very small)—as made clear by the green line in the bottom row of Figure 5. Thus as expected, the frictionless model predicts a coefficient of unity in a "Fama" regression of the change in the exchange rate on the interest differential (e.g. equation (6) in Engel 2014). This is not the case in our baseline model with financial frictions. Because the domestic tightening raises the currency premium, the magnitude of the expected depreciation is much smaller, and in fact close to zero—as shown in the bottom left panel. Thus, conditional on domestic monetary shocks (or more generally, as long as these shocks are sufficiently volatile), the model delivers the empirical observation that Fama regressions yield coefficients smaller than unity.

5 Monetary Spillovers and Exchange Rate Policy

We turn next to exchange rate policy. A long-standing debate in both academic and policy circles focuses on the appropriate policy stance of EM central banks facing spillovers from shifts in U.S. monetary policy—and in particular, whether it is desirable for the former to gear policy toward exchange rate stability.[33] An often-cited reason for the latter is the presence of dollar debt in balance sheets (e.g. Reinhart 2000). This policy prescription stands in contrast to textbook models like Gali and Monacelli (2005), which recommend that policy stabilize domestic objectives and allow the exchange rate to fluctuate. Our model can provide a useful perspective on this issue, given the presence of significant international monetary spillovers and the endogeneity of the share of dollar debt in local balance sheets.

To this end, we assume that instead of (53), the EM's monetary policy is conducted according to

$$R_{t+1}^{n} = \left(R_{t}^{n}\right)^{\gamma_r} \left(\beta^{-1} \pi_t^{\frac{1-\gamma_e}{\gamma_e}} \left(e_t/e\right)^{\frac{-\gamma_e}{1-\gamma_e}}\right)^{1-\gamma_r}, \tag{57}$$

where e (without a time subscript) denotes the steady-state nominal exchange rate (taken

[33]This question goes back to Friedman (1953). For recent contributions to this debate see, for example, Obstfeld (2015), Blanchard (2017), Bernanke (2017), Obstfeld and Taylor (2017), or Kalemli-Özcan (2019).

here to be the "target" exchange rate), and $\gamma_e \in [0,1]$. The specification in (57) is borrowed from Gali and Monacelli (2016). Whenever $\gamma_e \in (0,1)$ the EM monetary authority raises the policy rate both if inflation rises above target and if the exchange rate falls below target, with the latter motive more important the larger γ_e. Rule (57) nests the polar cases of strict inflation targeting ($\gamma_e = 0$) and exchange rate peg ($\gamma_e = 1$), but also allows parameterizing "hybrid" regimes in which monetary policy partly targets domestic inflation but also partly manages the exchange rate. While for space reasons we defer a more thorough policy analysis (including other policies such as foreign exchange interventions) to future research, rule (57) is a flexible and plausible way of capturing key elements of exchange rate regimes in practice, whose analysis yields useful insights.

We begin by analyzing the consequences for macroeconomic volatility of following rule (57) in the face of shocks to U.S. monetary policy. We next study the implications for banks' portfolio choice.

5.1 Macroeconomic Volatility and Exchange Rate Policy

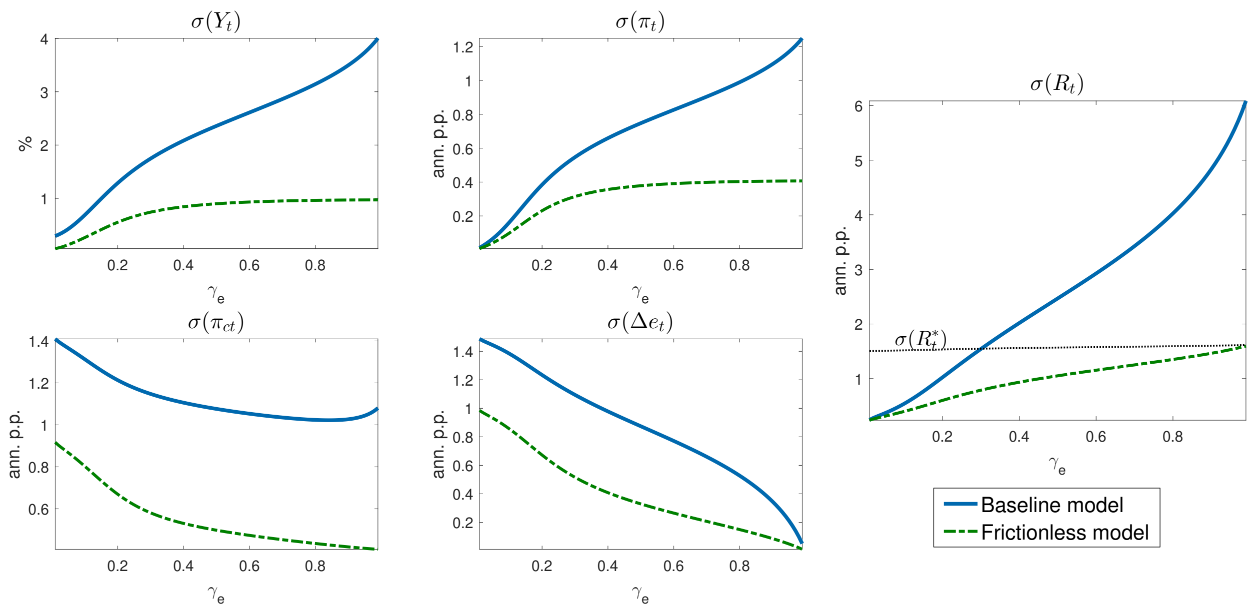
Figure 6 shows the standard deviations of key macroeconomic variables as a function of γ_e, in our baseline model with frictions (blue solid line) and in the frictionless model (green dotted line). The top two rows on the left side show the standard deviations of domestic output, $\sigma(Y_t)$, and of domestic inflation, $\sigma(\pi_t)$. The bottom rows show the standard deviations of CPI inflation $\pi_{ct} = P_t/P_{t-1}$ and of the nominal appreciation rate Δe_t.[34] The right panel shows the standard deviation of the domestic real interest rate. These standard deviations are calculated conditional on U.S. monetary shocks only (calibrated to match the data as described in Section 3.6).

The first observation is that all variables have higher standard deviations in our baseline model compared with the frictionless economy, for *any* value of the policy parameter γ_e. Thus, regardless of the exchange rate regime, shocks to U.S. monetary policy induce more volatility in the presence of financial frictions than they do in a frictionless setting—not just in variables which directly reflect external factors, like Δe_t and π_{ct}, but also in domestic variables like Y_t and π_t.

The second observation is that in our baseline model, the volatilities of Y_t and π_t rise steeply in the policy parameter γ_e—much more so than in the frictionless model—while the standard deviations of Δe_t, and especially π_{ct}, decline slowly as γ_e rises. For example, cutting

[34] Because e_t can be nonstationary in our model, we report the volatility of its first difference.

Figure 6. Exchange Rate Regimes and Volatility: Frictionless Model v. Baseline Model

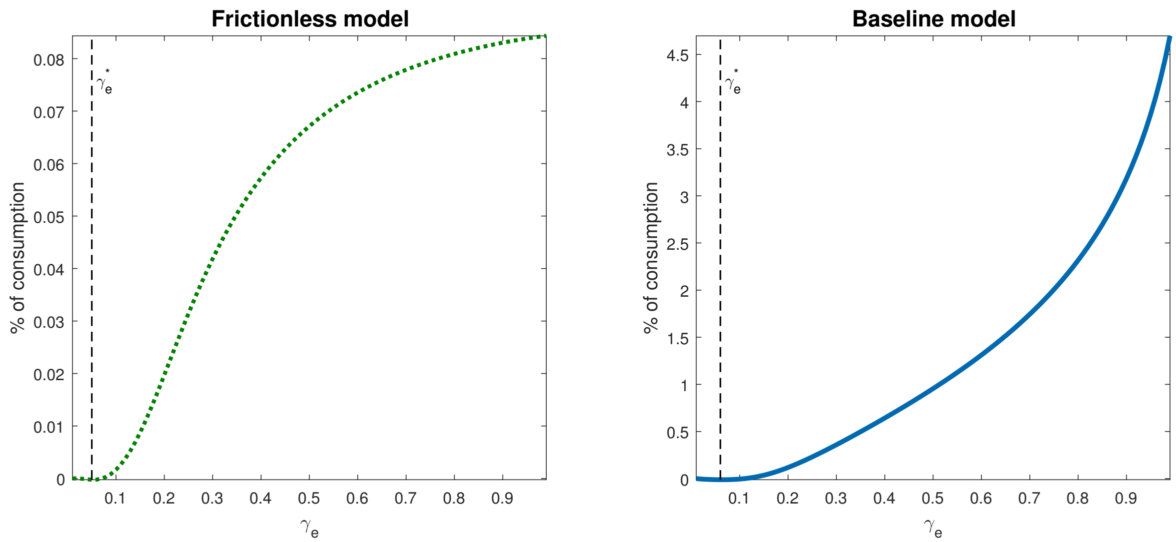


Note: The Figure shows the standard deviations of several variables under different values of γ_e (indexing the weight on nominal exchange rate stabilization in the monetary rule), in the frictionless economy (green dotted line) and in the baseline economy with frictions (blue solid line).

$\sigma(\Delta e_t)$ by half relative to its value when $\gamma_e = 0$ requires setting $\gamma_e = 0.3$ in the frictionless economy, but $\gamma_e = 0.62$ in the model with frictions. In words, moderating exchange rate volatility turns out to be much harder in the presence of financial frictions, in the sense that the policy rate needs to react much more strongly to a given deviation of the exchange rate from its target.

For intuition on these results, consider the behavior of $\sigma(R_t)$ as γ_e rises. The horizontal line in the right panel marks the standard deviation of the U.S. real interest rate. In the frictionless model, $\sigma(R_t)$ rises slowly with γ_e, and approaches $\sigma(R_t^*)$ as the monetary regime approaches a peg—as expected given that UIP holds in its standard form, and so eliminating exchange rate volatility calls for adjusting local rates one for one with U.S. rates. In stark contrast, in our baseline model $\sigma(R_t)$ rises much more steeply with γ_e. Even regimes with moderate weight on the exchange rate require $\sigma(R_t) > \sigma(R_t^*)$, and in the case of a full peg the standard deviation of local rates is nearly four times that of U.S. rates. Key to this result is the diminished ability of the EM monetary authority to affect the exchange rate, as a given change in the policy rate triggers variation in the currency premium that partly

Figure 7. Exchange Rate Regimes and Welfare: Frictionless Model v. Baseline Model



Note: The Figure shows the welfare losses associated with monetary regime γ_e relative to $\gamma_e = 0$, expressed as percent of quarterly consumption, in the frictionless model (left panel) and in our baseline model with frictions (right panel). Vertical lines mark the welfare-maximizing γ_e, denoted γ_e^*. Our method for calculating welfare is discussed in Appendix B.4.

offsets the direct effect of the policy rate change (see discussion in Section 4.4). This forces the domestic authority to adjust local rates more than one-for-one with U.S. rates if a low enough nominal exchange rate volatility is desired—resulting in greater domestic instability, as demonstrated by the top two panels on the left.

These observations also help understand why raising γ_e appears particularly ineffective at reducing $\sigma(\pi_{ct})$ in our baseline model. CPI inflation π_{ct} depends positively on domestic inflation π_t as well as on the percent change in the terms of trade (itself a function of the real exchange rate). Not only does the latter's volatility fall more slowly with γ_e compared with the frictionless economy, but the volatility of domestic inflation rises much faster for the reasons just outlined. The much higher volatility in domestic inflation partly offsets the lower terms-of-trade volatility as γ_e rises.

Perhaps not surprisingly in light of these observations, a model-based welfare criterion starkly recommends against pegging the exchange rate, as shown in Figure 7. In fact, the welfare losses from increasing γ_e are orders of magnitude larger in our model compared with the frictionless economy. Thus somewhat paradoxically, even if exchange rate volatility (working through dollarized balance sheets) is an important driver of financial amplification, attempting to damp this volatility using monetary policy turns out to be counterproductive. Key to this result is that the endogenous currency premium partly offsets the conventional effect of a change in the domestic policy rate on the exchange rate—effectively introducing a "disconnect" between the latter two variables and raising the amount of domestic instability necessary for a given reduction in exchange rate instability.

5.2 Banks' Portfolio Choice and Exchange Rate Policy

Within our model, the share of assets financed by foreign-currency debt, x_t, is determined endogenously as the solution to bankers' optimal portfolio problem. This permits investigating the implications of the monetary regime in place for the extent of currency risk that domestic borrowers choose to take on, an issue we examine in this section.

Rearranging the optimal liability portfolio condition (31) yields

$$x_t = f\left(\frac{\varrho_t}{\mu_t}\right), \tag{58}$$

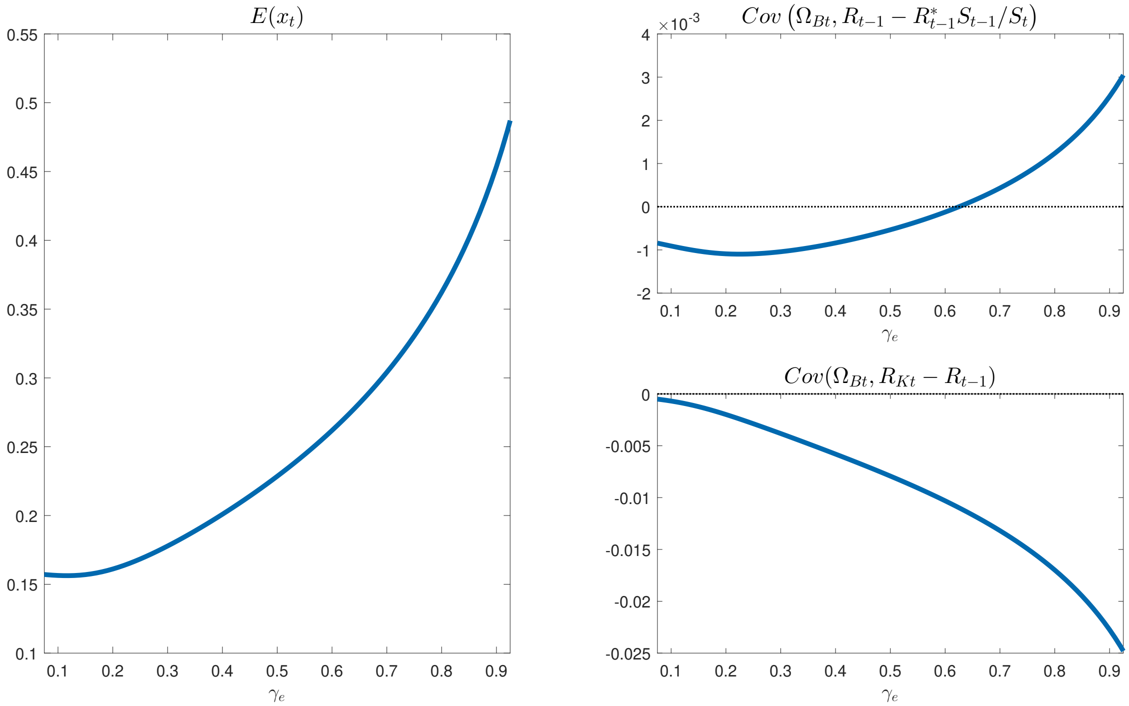
with $f' > 0$.[35] The optimal value of x_t depends positively on ϱ_t (capturing the benefit of borrowing in dollars instead of in local currency) and inversely on μ_t (capturing the cost, given that dollar borrowing tightens the incentive constraint and so entails foregoing the excess return μ_t).

We consider the behavior of the long-run average of x_t, $\mathbb{E}(x_t)$, conditional on a given value for policy parameter γ_e, calculated using a second-order approximation of the model. As seen in Figure 8, $\mathbb{E}(x_t)$ increases monotonically with γ_e: economies in which the monetary authority targets the exchange rate to a greater extent are characterized by larger average values of the dollar debt share x_t. For example, $\mathbb{E}(x_t)$ is around 0.3 when $\gamma_e = 0.75$, twice its value when monetary policy targets domestic inflation only.

The increase in $\mathbb{E}(x_t)$ arises due to second-order effects triggered by the rise in the policy parameter γ_e. Denoting the banker's effective discount factor by $\Omega_{Bt+1} \equiv \Lambda_{t,t+1}\Omega_{t+1}$, observe that $\mathbb{E}(\varrho_t)$ depends positively on $Cov\left(\Omega_{Bt}, R_t - R_t^* S_{t-1}/S_t\right)$: when the ex-post return differential $R_t - R_t^* S_{t-1}/S_t$ covaries more positively with the banker's marginal value of wealth, borrowing from foreigners becomes a better hedge, as it delivers gains when the marginal value of funds is high. Similarly, higher comovement between Ω_{Bt} and the ex-post domestic excess return $R_{Kt} - R_t$ raises the average value of lending $\mathbb{E}(\mu_t)$. As shown by

[35] The function f satisfies $f(\varrho_t/\mu_t) = (\varrho_t/\mu_t)^{-1}\left(-1 + \sqrt{1 + \frac{2}{\gamma}(\varrho_t/\mu_t)^2}\right)$.

Figure 8. Exchange Rate Regimes and Liability Dollarization



Note: The Figure shows the average value of the foreign liability ratio (left panel) and the covariances between the banker's SDF ($\Omega_{Bt} \equiv \Lambda_{t-1,t}\Omega_t$) and the foreign-domestic yield differential (top right panel) and between the SDF and the spread between the domestic return and deposit rate (bottom right panel), under different values of γ_e.

the right panels in Figure 8, $Cov\left(\Omega_{Bt}, R_t - R^*_t S_{t-1}/S_t\right)$ tends to be increasing in γ_e, while $Cov(\Omega_{Bt}, R_K - R_t)$, which is always negative, is decreasing. Both effects lead to higher $\mathbb{E}(x_t)$ as γ_e rises.[36]

Consider a U.S. monetary shock that raises the U.S. policy rate. The shock depreciates the EM's currency, thus increasing the ex-post cost of having borrowed in dollars. Because it tightens EM banks' constraints, the shock also increases Ω_{Bt}. In a regime with higher γ_e, the magnitude of the depreciation triggered by the shock is smaller, helping explain

[36] Note that the unconditional means of ϱ_t, μ_t can be written

$$\mathbb{E}(\varrho_t) = \mathbb{E}(\Omega_{Bt})\mathbb{E}\left(R_t - R^*_t S_{t-1}/S_t\right) + Cov\left(\Omega_{Bt}, R_t - R^*_t S_{t-1}/S_t\right)$$
$$\mathbb{E}(\mu_t) = \mathbb{E}(\Omega_{Bt})\mathbb{E}\left(R_{Kt} - R_t\right) + Cov(\Omega_{Bt}, R_K - R_t)$$

where we have employed a second-order approximation around the unconditional mean. In turn, a second-order approximation of (58) indicates that $E(x_t)$ is increasing in the ratio $\mathbb{E}(\varrho_t)/\mathbb{E}(\mu_t)$. The latter declines as γ_e rises, with the decline driven by both rising $Cov\left(\Omega_{Bt}, R_t - R^*_t S_{t-1}/S_t\right)$ and falling $Cov(\Omega_{Bt}, R_{Kt} - R_t)$.

why $Cov\left(\Omega_{Bt}, R_t - R_t^* S_{t-1}/S_t\right)$ increases with γ_e. At the same time, the domestic financial accelerator effect is stronger with higher γ_e, because the domestic policy rate is adjusted in a direction that reinforces the shock. Consequently, R_{Kt} falls more (through a larger decline in Tobin's Q) and Ω_{Bt} increases more, making $Cov(\Omega_{Bt}, R_K - R_t)$ more negative. These considerations help explain the behavior of the covariances in Figure 8 (Appendix B.5 includes additional details by showing responses to a U.S. monetary shock of the variables determining banks' portfolio, conditional on different values of γ_e).

This analysis thus highlights a potential pitfall of exchange-rate targeting regimes: they may have the unintended byproduct of encouraging domestic borrowers to take on more currency risk. The converse is also true: an added benefit of inflation targeting regimes (as captured by a low γ_e) may be enhanced incentives for local currency borrowing. While we have focused on interest rate policy, we anticipate that other forms of policies aimed at curbing exchange rate volatility, such as foreign exchange interventions (as recently studied in Basu et al. 2020, for example), would have similar implications on borrowers' portfolio choice.

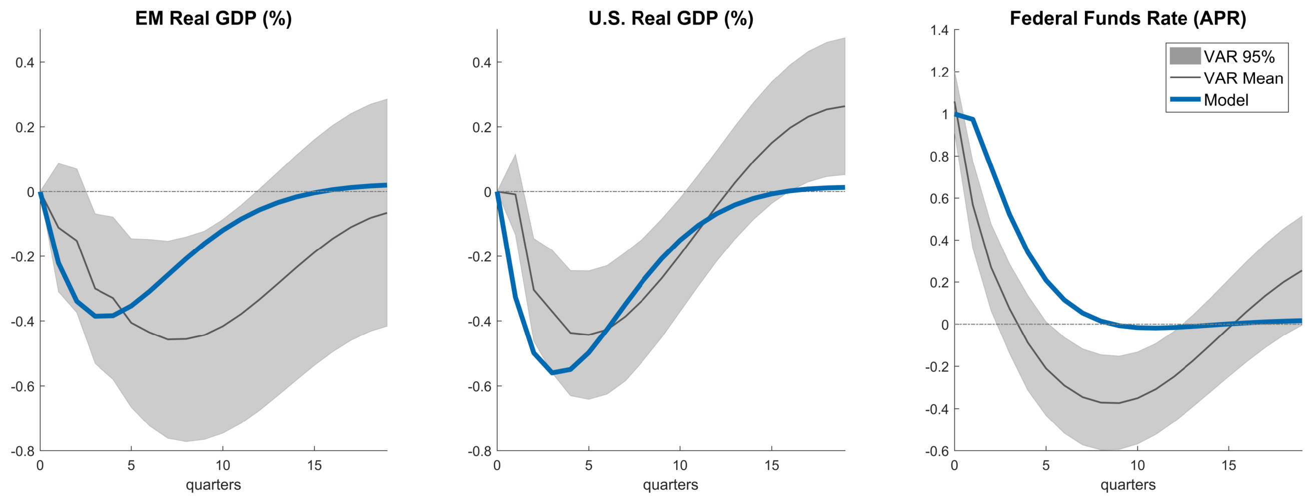
6 Empirical Evidence

In this section we formally compare the quantitative predictions of our model to the data. To this end, we conduct two different sets of empirical analyses. First, we estimate a VAR model that documents the effects of identified U.S. monetary policy shocks on output in the U.S. and in EMs. Here our purpose is to assess the ability of our DSGE model to account for the empirical responses of EM GDP to U.S. monetary policy shocks. Second, we take our model's version of UIP to the data: we test whether the deviation from the conventional UIP condition is associated to measures that proxy for domestic financial market frictions, as predicted by the model.

6.1 Effects of a U.S. Monetary Policy Shock: VAR Estimation

Our model's predictions for the cross-border spillovers from a U.S. monetary policy shock are consistent with those implied by VAR-based estimates of the dynamic effects of a U.S. monetary policy innovation (see, for example, Christiano et al. 2005, Christiano et al. 2010, or Christiano et al. 2018). In order to illustrate this point, we augment the VAR model of Christiano et al. (2010) to include quarterly GDP from a broad list of emerging

Figure 9. VAR Prediction of effects of 1 percent rise in federal funds rate



Note: EM GDP refers to an aggregate of emerging markets' GDP. The units are given in the titles of the subplots. % means percent deviation and APR means annualized percentage rate deviation, both expressed deviations from baseline path obtained in the absence of the shock.

economies. More specifically, we start from the original specification of Christiano et al. (2010) that includes U.S. macroeconomic variables such as GDP, inflation, unemployment, capacity utilization, consumption, investment, and the federal funds rate. We then estimate their model after incorporating data for EM GDP for the period 1978:I-2008:IV. The key identification assumption in the VAR model is that the only variable the U.S. monetary policy shock affects contemporaneously is the federal funds rate.[37]

The results are shown in Figure 9. The solid black line in the figure indicates the point estimates of the impulse response functions, while the gray area displays the corresponding 95 percent probability bands. The interest rate is in annualized percent terms, while the other variables are measured in percent. The solid blue line represents our DSGE model's response to the U.S. monetary policy shock. The model-implied effect of the shock on EM GDP is reproduced from Figure 4, corresponding to the model featuring financial imperfections and dollar trade invoicing.

Starting with the U.S. economy, the model captures the dynamic response of U.S. output to a U.S. monetary policy shock remarkably well. First, a monetary policy innovation that

[37]EM GDP is an aggregate across Argentina, Botswana, Brazil, Chile, China, Colombia, Ecuador, El Salvador, Hong Kong, India, Indonesia, Israel, Jordan, Korea, Malaysia, Mexico, Peru, Philippines, Singapore, South Africa, Taiwan, Thailand, Turkey, and Venezuela, and taken from the dataset compiled by Iacoviello and Navarro (2018). We restrict our sample to start from 1978 instead of 1951 as in Christiano et al. (2010) due to the fact that reliable EM GDP data start from the late 1970s.

raises the U.S. federal funds rate by 100 basis points induces U.S. output to fall around 0.50 percent at the trough, very close in magnitude to the decline implied by our model. Second, the U.S. economy displays a slow and hump-shaped response to a shock, peaking a little over one year after the monetary shock hits. Our DSGE model, which features habit persistence and costs of adjusting the flow of investment, captures this aspect of the data reasonably well, though the VAR-implied GDP response is a bit more sluggish than the model-implied one. Lastly, while the VAR-implied effect of the monetary shock on the federal funds rate is roughly gone after a year, the U.S. economy continues to respond well after that. The model predicts that U.S. GDP remains below its baseline path obtained in the absence of shock for more than three years, consistent with evidence, even though the effect of the shock on the interest rate dies after a year and a half. This suggests that our DSGE model can capture the dynamic effects of a monetary policy shock well thanks to the model's internal propagation channels.

We next turn to the ability of our DSGE model to replicate the empirical spillovers to EMs obtained from the VAR model. In response to the same shock EM output falls around 0.45 percent at the trough, broadly comparable in magnitude to the decline in U.S. GDP, and remains below its baseline path well after the effect of the shock on interest rates is gone. In this respect our model captures both the magnitude and the persistence of the response of EM output reasonably well (notice that the model-implied EM output response remains within the 95 percent probability bands obtained from the VAR model over the horizon of four years), although again the model-implied EME output response is somewhat less sluggish than the VAR-implied one. Overall, we conclude that the model's predictions on the spillover effects of a U.S. monetary policy shock on EM activity are broadly in line with the VAR-implied ones. We highlight that this is not the case for the standard model without financial frictions (as depicted by the green line in Figure 2), which predicts an effect on EM output that is very far from its empirical counterpart.

6.2 Exchange Rates and Credit Spreads: UIP Regressions

Unlike conventional open economy macroeconomic models such as Gali and Monacelli (2005) and subsequent literature, our model features endogenous deviations from UIP, with the currency premium moving in tandem with the domestic external finance premium. In this section, we examine empirical evidence from three major EMs to test this basic model prediction. Our approach relies on estimating versions of the forward-looking exchange rate equation implied by the model, as frequently done in the (large) empirical literature on the determinants of exchange rates.[38]

We begin with the equation linking the exchange rate to the domestic premium μ_t from the simple model in Section 2. Using the expression for μ_t in (4) and loglinearizing,

$$s_t = -\gamma \mathbb{E}_t \left\{ r_{kt+1} - r_{t+1} \right\} + r_{t+1} - r^*_{t+1} + \mathbb{E}_t \left\{ s_{t+1} \right\}, \tag{59}$$

where s_t, r_{kt+1}, r_{t+1}, and r^*_{t+1} denote the logs of S_t, R_{Kt+1}, R_{t+1}, and R^*_{t+1}, respectively.[39] Equation (59) resembles the familiar UIP condition for the real exchange rate present in conventional macroeconomic frameworks, but in addition to the real interest rate differential $r_{t+1} - r^*_{t+1}$, the right hand side also includes the domestic lending premium, $\mathbb{E}_t \left\{ r_{kt+1} - r_{t+1} \right\}$, multiplied by the parameter γ, capturing the relative degree of financial frictions in cross-border borrowing.

We follow Galí (forthcoming) and iterate (59) forward T periods:

$$s_t = -\gamma \sum_{j=1}^{T} \mathbb{E}_t \left\{ r_{kt+j} - r_{t+j} \right\} + \sum_{j=1}^{T} \mathbb{E}_t \left\{ r_{t+j} - r^*_{t+j} \right\} + \mathbb{E}_t \left\{ s_{t+T+1} \right\}. \tag{60}$$

Let $x_t \equiv \sum_{j=1}^{T} \mathbb{E}_t \left\{ r_{kt+j} - r_{t+j} \right\}$ and $r_t^{diff} \equiv \sum_{j=1}^{T} \mathbb{E}_t \left\{ r_{t+j} - r^*_{t+j} \right\}$, and assume that $s_t = f_t + \widehat{s}_t$ where f_t is a deterministic time trend and $\widehat{s}_t$ is stationary, so that if T is large enough, $\mathbb{E}_t \left\{ \widehat{s}_{t+T+1} \right\} \approx 0$. Below we verify that these assumptions are reasonable approximations for our data. Under these assumptions, (60) can be rewritten

$$s_t = -\gamma x_t + r_t^{diff} + f_{t+T+1}. \tag{61}$$

Equation (61) forms the basis for our empirical analysis. Our baseline estimation uses monthly data from South Korea. We then repeat the analysis for Brazil and Mexico. We measure s_t by the (log) bilateral real exchange rate against the dollar. We calculate the real exchange rate by multiplying the nominal exchange rate (the price of the local currency in dollars) by the ratio of the local to the U.S. CPI price level.

To approximate x_t, we use data on yields on Korean 3-year won-denominated corporate

[38] See, for example, Engel and West (2004), Engel and West (2005), Engel et al. (2007), Faust et al. (2007), Clarida and Waldman (2008), and more recently Galí (forthcoming). Our approach follows Galí (forthcoming)'s most closely. In earlier versions we followed the approach based on Fama (1984) and also found evidence linking UIP deviations with credit spreads, as we find here.

[39] In deriving this equation we let $R \to R^*$ and $R_K \to R$.

bonds (rated AA-) minus yields on government bonds of the same maturity. The resulting corporate bond spread measure is a widely used proxy for the "external finance premium" (Bernanke et al. 1999) arising due to the presence of financial market frictions.[40] Thus, we measure x_t as

$$x_t = \frac{T}{12}\Big(r_t^{corp} - r_t^{gov}\Big), \tag{62}$$

where r_t^{corp} is the Korean corporate bond yield (in annual terms) and r_t^{gov} is the Korean yield on 3-year Treasury bonds, and $T = 36$ months. Similarly, we construct a measure of r_t^{diff} as

$$r_t^{diff} = \frac{T}{12}\Big(r_t^{gov} - r_t^{gov*}\Big), \tag{63}$$

where r_t^{gov*} is the (real) 3-year U.S. Treasury yield. In (63) real yields are constructed by subtracting from nominal yields the expected inflation rate in each month, calculated as the average inflation rate over the past year.[41] These calculations make the simplifying assumption that the expected sum of one-period yields differentials in (60) are well approximated by the T-month maturity bond yields.[42]

Unlike for Korea, there is no available data for domestic-currency corporate yields from Mexico and Brazil with long enough duration. For these two countries, instead, we measure s_t by the spread between 5-year dollar-denominated BBB corporate bonds and U.S. Treasury bonds of the same maturity.[43] Accordingly, we set $T = 60$ for Mexico and Brazil, and measure r_t^{diff} by using 5-year local and U.S. government bond yields.

We found that the assumption above that real exchange rates are approximately back to trend, in expectation, after T months (with $T = 36$ for Korea and $T = 60$ for Mexico and Brazil), is a good approximation in these data. By fitting autoregressive models to detrended real exchange rates, we find that over 85 percent of the effects of the typical shock to $\widehat{s}_t$ dissipate after 36 months for Korea, and virtually all of the effects dissipate after 60

[40]For recent uses of this measure in empirical work see Christiano et al. (2014) or Gertler and Karadi (2015), for example.

[41]Note that expected inflation terms cancel in (62) given that r_t^{corp} and r_t^{gov} are in the same currency, so we can calculate s_t simply by using the difference of nominal yields.

[42]Thus, if the T-month maturity bonds include a term premium in addition to the expected path of short-term yields, our assumption is that the term premium is part of the regression error term.

[43]While in our baseline model R_{Kt} is denominated in local currency, Appendix A.5 shows that a relation similar to (61) emerges when local firms issue dollar bonds to domestic banks (with the corporate spread calculated relative to the U.S. government bond yield), so long as the agency friction continues to apply with greater severity to banks' foreign borrowing.

months for Mexico and Brazil, thus providing some reassuring evidence for the assumption used in (61) that $\mathbb{E}_t \{\widehat{s}_{t+T+1}\} \approx 0$.

We report OLS estimates of the regression equation

$$s_t = \alpha_0 + \alpha_1 t + \beta_x x_t + \beta_r r^{diff} + \varepsilon_t. \tag{64}$$

Comparing equations (64) and (61), note that our theory predicts $\beta_x = -\gamma < 0$ and $\beta_r = 1$. In the case of Brazil, we also include a quadratic trend term ($\alpha_2 t^2$) in the right-hand side of (64), as this term is highly significant in the Brazilian data (but insignificant for both Korea and Mexico).

The left part of Table 2 reports the results using Korean data. For reference, column (1) shows results when setting $\beta_x = 0$ in (64), resulting in the conventional UIP equation. Note that the coefficient in the interest rate differential is positive, as predicted by UIP, but is somewhat above unity, and is statistically significant (at 1% confidence).

Column (2) shows our baseline specification with both the interest differential and the corporate bond spread. The first key observation is that the coefficient on the spread is highly statistically significant, and large in absolute value—more than twice the coefficient on the interest rate differential. The second observation is that the presence of the spread improves the equation fit considerably: R^2 rises from less than 0.2 to over 0.5. Finally, note also that once the spread is present, the coefficient on the interest differential drops a bit, and is essentially equal to unity—exactly as predicted by the theory.

Columns (3) and (4) perform robustness checks by including additional regressors in equation (64). In column (3) we add a crisis dummy to ensure that the results are not driven by the large movements in exchange rates during times of extreme financial stress.[44] The coefficient on the corporate spread continues to be significant despite the presence of the dummy, and in fact becomes larger in absolute value. Column (4) adds the VIX to proxy for global risk aversion. Again, the spread continues to be significant even when this variable is included.

The middle and right columns of Table 2 perform the analysis for Brazil and Mexico. The coefficient on the corporate spread is highly significant for these two countries as well, and continues to be so when we add the crisis dummy and the VIX. For Brazil, the spread also improves the fit considerably relative to the "standard UIP" regression from column (1), while for Mexico less so. The absolute value of the coefficient on the corporate spread

[44] D_{crisis} equals unity in the months 1998:8–1999:3 and 2008:9–2009:3, and zero otherwise.

is considerably smaller for Brazil than for Korea, and lower still for Mexico. Turning to the interest differential, we find a positive and significant coefficient for Brazil (though smaller than unity) while the coefficient is insignificant for Mexico. Thus, evidence for the standard UIP condition predicting a coefficient of unity is weaker for these two countries. Note also that the coefficient on the VIX has the "wrong" sign (that is, the domestic currency appreciates against the dollar when the VIX rises) but this result appears linked to the fact that the VIX and the corporate bond spreads are quite highly correlated (we find that running the regressions in column (4) but excluding the corporate bond spread yields a negative and significant coefficient for the VIX).

As a second robustness check, we report results from the first-differenced version of (64). As discussed in Galí (forthcoming), this version is appropriate if the real exchange rate is an $I(1)$ stochastic process rather than trend-stationary as assumed previously. We estimate equation

$$\Delta s_t = \alpha_1 + \beta_x \Delta x_t + \beta_r \Delta r_t^{diff} + \tilde{\varepsilon}_t, \tag{65}$$

where the specification for Brazil also includes a linear time trend term.

Table 3 reports the corresponding results. The key finding that the corporate spread is highly significant reemerges here, as does the fact that the presence of the spread adds considerable explanatory power relative to a regression with the interest differential only, now including for Mexico as well. Except for Mexico, the coefficients on the spread are now somewhat lower in absolute value compared with the levels specification. On the other hand, coefficients on the interest rate differential are insignificant and often have the wrong sign. The VIX now has a negative sign for both Korea and Mexico (and is insignificant for Brazil).

Overall, we conclude that the empirical analysis above finds strong support for the link between exchange rates and credit spreads implied by the theory. In fact, the credit spread term is more consistently significant than the interest rate differential term in Tables 2 and 3.[45] The results also suggest that the calibration of the elasticity Γ in the medium-scale model (the equivalent of parameter γ) of 0.5 is relatively conservative in light of the empirical evidence just documented, as this value is at the lower end of the range of absolute values

[45]Interestingly, we found that this is not the case for advanced economies: we repeated the analysis using data for Canada, the euro area, Japan, and the UK, and found that the credit spread term is often not significantly different from zero, while the interest differential term is more often significant (see Appendix C). These results are consistent with a lower γ for cross-border borrowing between the U.S. and other advanced economies, than between the U.S. and emerging economies.

of the coefficients on the corporate spread found in Tables 2 and 3.

7 Conclusion

In this paper we develop a two-country New Keynesian model with imperfect domestic and international financial markets to study the cross-border spillovers from U.S. monetary policy. The model features strong financial amplification due to the powerful interaction between internal and external feedback effects. Consistent with the estimates we obtain from a monetary VAR model, this mechanism leads to large spillovers from U.S. monetary shocks to EMs, particularly when export prices are set in dollars. More generally, we believe our model is better tailored than existing macroeconomic models to some of the specific features of emerging market economies, which are often seen as being particularly vulnerable to volatile capital flows and other external pressures.[46]

Despite strong amplification working in part through exchange rate volatility, the model calls into question the common view that monetary policy should be used to mitigate exchange rate fluctuations. The reason is that the endogenous currency premium partly offsets the conventional effect of a change in the domestic policy rate on the exchange rate. The resulting "disconnect" between the exchange rate and the domestic policy rate implies that a higher amount of domestic macroeconomic volatility is necessary for a given reduction in exchange rate instability. Moreover, monetary regimes that target the exchange rate to a greater extent tend to make the balance sheet mismatch problem worse, by encouraging domestic borrowers to take on more currency risk.

Looking forward, it would be useful to use a version of the model developed here to consider the optimal policy and how it can be implemented in the context of interest rate policy and foreign exchange market inventions on the part of EM central banks. Given the endogenous deviation from UIP present in the model, there may be a role for interventions in foreign exchange over and above conventional interest rate policy. This extension is left for future research.

[46]Along these lines, in Akinci, Benigno and Queralto (2020) we use an extension of the model developed in this framework to assess the possible impact on EMs of the sudden stop in capital flows triggered by the Covid-19 pandemic.

Table 1. Model Calibration

Parameter	**Symbol**	**Value**
Home discount factor	β	0.9925
U.S. discount factor	β^*	0.9950
Habit parameter	h	0.78
Inverse Frisch elasticity of labor supply	χ	3.79
Trade price elasticity	$(1+\rho)/\rho$	1.5
Trade openness, home	ω	0.2
Trade openness, foreign	ω^*	0.2/3
Relative home size	ξ/ξ^*	1/3
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	ι_p	0.24
Price markup	θ_p	0.20
Prob. of keeping wage fixed	ξ_w	0.70
Wage indexation	ι_w	0.15
Wage markup	θ_w	0.20
Investment adjustment cost	Ψ_I	2.85
Home Taylor rule coefficients	γ_r	0.82
	γ_π	1.50
U.S. Taylor rule coefficients	γ_r^*	0.82
	γ_π^*	1.50
	γ_x^*	0.125
U.S. monetary shock persistence	ρ_r	0.25
U.S. monetary shock standard deviation	σ_u	0.20/100
Bank survival rate	σ_b	0.95
Bank fraction divertable	θ	0.41
Bank transfer rate	ξ_b	0.07
Home bias in bank funding	γ	2.58

Table 2. Empirical exchange rate equation: Level specification

	Korea				Brazil				Mexico			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Interest diff.	1.27***	0.97***	0.98***	0.87***	0.62***	0.55***	0.52***	0.42***	−0.10	−0.11	−0.13	−0.11
	(0.33)	(0.27)	(0.26)	(0.25)	(0.17)	(0.11)	(0.11)	(0.09)	(0.16)	(0.14)	(0.14)	(0.13)
Corp. spread		−2.72***	−3.56***	−2.17***		−1.09***	−1.25***	−1.61***		−0.47***	−0.37*	−0.93***
		(0.53)	(0.99)	(0.33)		(0.14)	(0.16)	(0.13)		(0.13)	(0.19)	(0.29)
D_{crisis}			0.16*				0.09**				−0.05	
			(0.09)				(0.05)				(0.04)	
VIX/100				−0.43***				0.66***				0.34**
				(0.16)				(0.11)				(0.17)
trend	*linear*	*linear*	*linear*	*linear*	*quadratic*	*quadratic*	*quadratic*	*quadratic*	*linear*	*linear*	*linear*	*linear*
R^2	0.19	0.53	0.55	0.58	0.63	0.87	0.88	0.91	0.58	0.62	0.62	0.63
Observations	281	281	281	281	148	148	148	148	219	219	219	219

Note: Dependent variable: Monthly bilateral real exchange rate against the United States. Regressions estimated by OLS. Standard errors shown in parentheses, computed using the Newey-West adjustment. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively. Sample periods: 1995:5–2018:9 (Korea), 2006:7–2018:10 (Brazil), 2000:8–2018:10 (Mexico). The baseline regression equation (column (2)) is

$$s_t = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \beta_x x_t + \beta_r r_t^{diff} + \varepsilon_t$$

with $\alpha_2 = 0$ for Korea and Mexico, and where s_t is the log real bilateral exchange rate against the dollar, x_t is the corporate bond spread, and r_t^{diff} is the government bond yield differential between the respective country and the United States.

Table 3. Empirical exchange rate equation: First-difference specification

	Korea				Brazil				Mexico			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
ΔInterest diff.	0.04	0.02	-0.07	0.07	-0.21^{*}	0.00	-0.06	0.00	-0.12	-0.10^{**}	-0.13^{***}	-0.09^{*}
	(0.10)	(0.11)	(0.09)	(0.11)	(0.11)	(0.09)	(0.08)	(0.09)	(0.08)	(0.04)	(0.04)	(0.05)
ΔCorp. spread		-1.27^{***}	-1.21^{***}	-1.26^{***}		-0.88^{***}	-0.81^{***}	-0.93^{***}		-0.82^{***}	-0.74^{***}	-0.58^{***}
		(0.13)	(0.06)	(0.15)		(0.07)	(0.08)	(0.13)		(0.14)	(0.14)	(0.15)
D_{crisis}			-0.05^{***}				-0.03^{***}				-0.02^{**}	
			(0.01)				(0.01)				(0.01)	
ΔVIX/100				-0.21^{***}				0.05				-0.16^{**}
				(0.05)				(0.08)				(0.06)
trend	*no*	*no*	*no*	*no*	*linear*	*linear*	*linear*	*linear*	*no*	*no*	*no*	*no*
R^2	0.00	0.45	0.53	0.51	0.06	0.48	0.51	0.48	0.03	0.33	0.35	0.37
Observations	280	280	280	280	147	147	147	147	218	218	218	218

Note: Dependent variable: log of change in monthly bilateral real exchange rate against the United States. Regressions estimated by OLS. Standard errors shown in parentheses, computed using the Newey-West adjustment. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively. Sample periods: 1995:6–2018:9 (Korea), 2006:8–2018:10 (Brazil), 2000:9–2018:10 (Mexico). The baseline regression equation (column (2)) is

$$\Delta s_t = \alpha_0 + \alpha_1 t + \beta_x \Delta x_t + \beta_r \Delta r_t^{diff} + \varepsilon_t$$

with $\alpha_1 = 0$ for Korea and Mexico, and where Q_t is the log real bilateral exchange rate against the dollar, s_t is the corporate bond spread, and r_t^{diff} is the government bond yield differential between the respective country and the United States.

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Appendix (For Online Publication)

A Simple model

A.1 Lagrangian for banker's problem

Let the multiplier on (3) be denoted λ_t. The Lagrangian associated with problem (2)-(3) is

$$\mathcal{L}_t = (1+\lambda_t)\left\{\left[(1-x_{it})\mu_t + x_{it}\mu_t^*\right] Q_t K_{it} + \beta R_{t+1} N_{it}\right\} - \lambda_t \theta(1+\gamma x_{it}) Q_t K_{it} \tag{A.1}$$

Taking first-order conditions with respect to K_{it} and x_{it} yields, respectively,

$$(1+\lambda_t)\left[(1-x_{it})\mu_t + x_{it}\mu_t^*\right] = \lambda_t \theta(1+\gamma x_{it}), \tag{A.2}$$

$$(1+\lambda_t)(\mu_t^* - \mu_t) = \lambda_t \theta \gamma. \tag{A.3}$$

Assume $\lambda_t > 0$. Dividing (A.2) by (A.3) yields, after some rearranging,

$$(1+\gamma)\mu_t = \mu_t^* \tag{A.4}$$

(equation (4) in the text). Given this equality, (A.2) can be re-written as

$$\mu_t = \theta \frac{\lambda_t}{1+\lambda_t}. \tag{A.5}$$

Thus, if $\mu_t > 0$ the constraint binds ($\lambda_t > 0$).

A.2 Derivation of balance of payments equation

From (8) at equality,

$$C_{Dt} + S_t^{-1} M_{Ct} + D_t = R_t D_{t-1} + \Pi_t - N_t. \tag{A.6}$$

Inserting aggregate profits of exiting bankers,

$$\Pi_t = \int \Pi_{it} dt = \int \left\{[Z_t + Q_t] K_{it-1} - R_t D_{it-1} - R_t^* S_t^{-1} D_{it-1}^*\right\} di, \tag{A.7}$$

yields

$$C_{Dt} + S_t^{-1} M_{Ct} + D_t = [Z_t + Q_t]\overline{K} - R_t^* S_t^{-1} D_{t-1}^* - N_t. \tag{A.8}$$

Aggregating bankers' budget constraints at equality, $Q_t K_{it} = D_{it} + S_t^{-1} D_{it}^* + N_{it}$, and using the resulting expression to eliminate $N_t = \int N_{it} di$ from (A.8) yields

$$C_{Dt} + S_t^{-1} M_{Ct} = Z_t \overline{K} - R_t^* S_t^{-1} D_{t-1}^* + S_t^{-1} D_t^*. \tag{A.9}$$

The market clearing condition for the home-produced good is the following:

$$C_{Dt} + M_{Ct}^* = Z_t \overline{K}. \tag{A.10}$$

Output of domestic firms ($Z_t \overline{K}$) is either consumed domestically (C_{Dt}) or exported (M_{Ct}^*). Inserting this condition into (A.9), we find

$$M_{Ct} = S_t M_{Ct}^* - R_t^* D_{t-1}^* + D_t^*. \tag{A.11}$$

Home's exports to the U.S. are $S_t M_{Ct}^*$ and imports are M_{Ct}, both expressed in dollars. Hence net exports expressed in dollars are

$$\begin{aligned} NX_t &= S_t M_{Ct}^* - M_{Ct} \\ &= \chi_m^* - \chi_m S_t. \end{aligned} \tag{A.12}$$

We can re-write (A.11) as

$$D_t^* - R_t^* D_{t-1}^* = \chi_m S_t - \chi_m^*, \tag{A.13}$$

as in equation (14) in the main text.

A.3 Steady state

Equations (14)-(17) can be used to solve for the steady-state values D^*, μ, Q, and S as a function of the model's parameters. From (15), $\mu = \gamma^{-1}(1 - \beta/\beta^*)$. Given μ, (16) gives the steady-state price of capital, $Q = \beta Z/(1 + \mu - \beta)$. The constraint (17) can be used to determine x, the share of assets financed by dollar debt: $x = \gamma^{-1}\left(\frac{\eta}{\theta-\mu} - 1\right)$. From the definition of x, we have $D^* = xSQ\overline{K}$, which expresses the stock of foreign debt as a function of the exchange rate (given that we have already determined x and Q). We can use this expression in (14) to determine the value exchange rate:

$$S = \frac{\chi_m^*}{r^* x Q \overline{K} + \chi_m}, \tag{A.14}$$

where $r^* \equiv \beta^{*-1} - 1$ is the net interest on foreign debt. The steady-state value of the domestic currency, S, depends on both trade and financial factors. It is positively linked to the foreign preference for the home good, χ_m^*, and inversely to the home preference for the foreign good, χ_m. In addition, it is decreasing in the net interest on net foreign borrowing, which is itself increasing in x (determining the amount of foreign borrowing permitted by the agency friction). When x is larger, the net interest required on foreign debt is larger. This implies a lower value of the domestic currency, needed to generate the net export surplus to cover the higher interest payment.

A.4 Solution with general Φ

We conjecture that the solution for $\hat{s}_t$ takes the form $\hat{s}_t = \psi_\eta \hat{\eta}_t - \psi_d \Phi^{-1} \hat{d}^*_{t-1}$. Imposing the conjectured relation into (18) and (22), one can solve for the undetermined coefficients ψ_η and ψ_d:

$$\Psi_d = \frac{\epsilon\gamma}{2}\left[1 + \gamma^{-1} - \Phi + \sqrt{\left(1 + \gamma^{-1} - \Phi\right)^2 + 4\Phi\left(\varepsilon\gamma\right)^{-1}}\right], \tag{A.15}$$

$$\Psi_\eta = \frac{\gamma\theta}{1 - \rho + \gamma\varepsilon\Phi + \Psi_d - \varepsilon(1+\gamma)}. \tag{A.16}$$

Given the solution for $\hat{s}_t$, from (18) $\hat{d}^*_t$ follows the process

$$\hat{d}^*_t = \Phi\Psi_\eta\hat{\eta}_t + (1 - \Psi_d)\hat{d}^*_{t-1}. \tag{A.17}$$

A.5 Version with dollar-denominated loans

Suppose that domestic non-financial firms now also issue dollar-denominated claims, and for simplicity suppose that all bank lending to non-financial firms is done in the form of these claims. Bank i's constraint is now

$$S_t^{-1} Q_t^f K_{it}^f = D_{it} + S_t^{-1} D_{it}^* + N_{it}, \tag{A.18}$$

where K_{it}^f is holdings of dollar-denominated claims issued by domestic non-corporations, and Q_t^f is the (dollar) price of those claims. Each of these claims pays gross returns $R_{Kt+1}^f \equiv (Z_{t+1}^f + Q_{t+1}^f)/Q_t^f$ in $t+1$, with Z_{t+1}^f denoting the claim's dividend (also in dollars). The bank's payoff in $t+1$, denoted Π_{it+1}, is

$$\Pi_{it+1} = S_{t+1}^{-1} R_{Kt+1} Q_t^f K_{it}^f - R_{t+1} D_{it} - R_{t+1}^* S_{t+1}^{-1} D_{it}^*. \tag{A.19}$$

We assume that the amount of assets the bank can divert is

$$\theta \left[(1-\gamma) D_{it} + S_t^{-1} D_{it}^* + N_{it} \right], \tag{A.20}$$

i.e. we modify slightly the formulation of the agency problem, by assuming that γ captures the degree to which domestic deposits are *less* divertable than foreign ones. This change makes the algebra simpler but is otherwise immaterial. Define the excess returns

$$\mu_t^f \equiv \beta \mathbb{E}_t \left[\frac{S_t}{S_{t+1}} \left(R_{Kt+1}^f - \frac{R_{t+1}}{S_t/S_{t+1}} \right) \right], \tag{A.21}$$

$$\mu_t^{*f} \equiv \beta \mathbb{E}_t \left[\frac{S_t}{S_{t+1}} \left(R_{Kt+1}^f - R_{t+1}^* \right) \right]. \tag{A.22}$$

Let also $\overline{K}_{it} \equiv S_t^{-1} Q_t^f K_{it}^f$ and $y_{it} \equiv D_{it}/\overline{K}_{it}$. The bank's problem is

$$\max_{y_{it}, \overline{K}_{it}} \quad \left[\mu_t^f y_{it} + \mu_t^{*f} (1 - y_{it}) \right] \overline{K}_{it} + \beta \mathbb{E}_t \left(S_t / S_{t+1} \right) R_{t+1}^* N_{it} \tag{A.23}$$

subject to

$$\left[\mu_t^f y_{it} + \mu_t^{*f} (1 - y_{it}) \right] \overline{K}_{it} + \beta \mathbb{E}_t \left(S_t / S_{t+1} \right) R_{t+1}^* N_{it} \geq \theta (1 - \gamma y_{it}) \overline{K}_{it}. \tag{A.24}$$

Whenever the constraint binds, the following optimal portfolio condition must hold:

$$\mu_t^f = (1-\gamma) \mu_t^{*f}. \tag{A.25}$$

Similar to the baseline case, the excess return relative to the domestic deposit rate is lower than relative to the foreign rate. Thus, we have $\mu_t^{*f} - \mu_t^f = \gamma \mu_t^{f*}$, or

$$\mathbb{E}_t \left[\frac{S_t}{S_{t+1}} \left(\frac{R_{t+1}}{S_t / S_{t+1}} - R^*_{t+1} \right) \right] = \gamma \mathbb{E}_t \left[\frac{S_t}{S_{t+1}} \left(R^f_{Kt+1} - R^*_{t+1} \right) \right]. \tag{A.26}$$

Loglinearizing the equation above and letting $R_K \to R \to R^*$, we arrive at the "modified" UIP condition

$$s_t = -\gamma \mathbb{E}_t \left\{ r^f_{kt+1} - r^*_{t+1} \right\} + r_{t+1} - r^*_{t+1} + \mathbb{E}_t \left\{ s_{t+1} \right\}, \tag{A.27}$$

where s_t, r^f_{kt+1}, r_{t+1}, and r^*_{t+1} denote the logs of S_t, R^f_{Kt+1}, R_{t+1}, and R^*_{t+1}, respectively. Thus, the UIP deviation (the first term on the right-hand side) now varies with the return on the (dollar-denominated) domestic claim over the safe dollar rate.

B Medium-scale model

B.1 Derivation of solution to bankers' problem

To solve the banker's problem, we begin by guessing that the value function is linear in the banker's net worth, $V_{it} = \alpha_t N_{it}$. We let the coefficients μ_t, ϱ_t, ν_t be given by

$$\mu_t = \mathbb{E}_t \left[\Lambda_{t,t+1} \left(1 - \sigma_b + \sigma_b \alpha_{t+1}\right) \left(R_{Kt+1} - R_{t+1}\right)\right] \tag{B.1}$$

$$\varrho_t = \mathbb{E}_t \left[\Lambda_{t,t+1} \left(1 - \sigma_b + \sigma_b \alpha_{t+1}\right) \left(R_{t+1} - R^*_{t+1} S_t / S_{t+1}\right)\right] \tag{B.2}$$

$$\nu_t = \mathbb{E}_t \left[\Lambda_{t,t+1} \left(1 - \sigma_b + \sigma_b \alpha_{t+1}\right) R_{t+1}\right] \tag{B.3}$$

Given the definition of the leverage ratio, $\phi_{it} \equiv \frac{Q_{it} A_{it}}{N_{it}}$, banker i's problem can be written as:

$$\alpha_t = \max_{\phi_{it}, x_{it}} \quad \left(\mu_t + x_{it} \varrho_t\right) \phi_{it} + \nu_t \tag{B.4}$$

subject to

$$\left(\mu_t + x_{it} \varrho_t\right) \phi_{it} + \nu_t \geq \Theta(x_t) \phi_{it} \tag{B.5}$$

The first-order conditions from the corresponding Lagrangian (with multiplier on (B.5) denoted λ_{it}) yield

$$\varrho_t = \frac{\lambda_t}{1 + \lambda_{it}} \Theta'(x_{it}) \tag{B.6}$$

$$\mu_t + x_{it} \varrho_t = \frac{\lambda_{it}}{1 + \lambda_{it}} \Theta(x_{it}) \tag{B.7}$$

Combining the above equations yields (31) in the main text. Given that μ_t and ϱ_t are not bank-specific, $x_{it} = x_t$ is common across banks. Given a binding incentive constraint, the leverage ratio $\phi_{it} = \phi_t$ is also common across banks, and given by

$$\phi_t = \frac{\nu_t}{\Theta(x_t) - \left(\mu_t + x_t \varrho_t\right)} \tag{B.8}$$

We can then solve for the undetermined coefficient α_t using (B.4):

$$\alpha_t = \left(\mu_t + x_t \varrho_t\right) \phi_t + \nu_t \tag{B.9}$$

B.2 Full set of equilibrium conditions

Home country.

$$1 = \mathbb{E}_t \left(\frac{\Lambda_{t,t+1}}{\pi_{ct+1}} \right) R^n_{t+1} \tag{B.10}$$

$$1 = \mathbb{E}_t \left(\Lambda_{t,t+1} \right) R_{t+1} \tag{B.11}$$

$$\Lambda_{t,t+1} = \beta U_{Ct+1} / U_{Ct} \tag{B.12}$$

$$U_{Ct} = (C_t - hC_{t-1})^{-1} - \beta h \mathbb{E}_t \left\{ (C_{t+1} - hC_t)^{-1} \right\} \tag{B.13}$$

$$p_{Dt} = \left((1-\omega) \frac{C_t}{C_{Dt}} \right)^{\frac{\rho}{1+\rho}} + \left(\omega \frac{C_t}{M^A_{Ct}} \right)^{\frac{\rho}{1+\rho}} x_{Ct} \widetilde{\varphi}_{Ct} - \mathbb{E}_t \left\{ \Lambda_{t,t+1} \pi_{ct+1} \left(\omega \frac{C_{t+1}}{M^A_{Ct+1}} \right)^{\frac{\rho}{1+\rho}} \frac{C_{Dt+1}}{C_{Dt}} x_{Ct+1} \widetilde{\varphi}_{Ct+1} \right\} \tag{B.14}$$

$$p_{Dt} \mathcal{T}_t = \left(\omega \frac{C_t}{M^A_{Ct}} \right)^{\frac{\rho}{1+\rho}} (\varphi_{Ct} - \widetilde{\varphi}_{Ct}) + \mathbb{E}_t \left\{ \Lambda_{t,t+1} \pi_{ct+1} \left(\omega \frac{C_{t+1}}{M^A_{Ct+1}} \right)^{\frac{\rho}{1+\rho}} \frac{M_{Ct+1}}{M_{Ct}} \widetilde{\varphi}_{Ct+1} \right\} \tag{B.15}$$

$$\varphi_{Ct} = 1 - \frac{\varphi_M}{2} \left(\frac{x_{Ct}}{x_{Ct-1}} - 1 \right)^2 \tag{B.16}$$

$$\widetilde{\varphi}_{Ct} = \varphi_M \left(\frac{x_{Ct}}{x_{Ct-1}} - 1 \right) \frac{x_{Ct}}{x_{Ct-1}} \tag{B.17}$$

$$x_{Ct} = \frac{M_{Ct}}{C_{Dt}} \tag{B.18}$$

$$M^A_{Ct} = \varphi_{Ct} M_{Ct} \tag{B.19}$$

$$p_{Dt} = \left((1-\omega) \frac{I_t}{I_{Dt}} \right)^{\frac{\rho}{1+\rho}} + \left(\omega \frac{I_t}{M^A_{It}} \right)^{\frac{\rho}{1+\rho}} x_{It} \widetilde{\varphi}_{It} - \mathbb{E}_t \left\{ \Lambda_{t,t+1} \pi_{ct+1} \left(\omega \frac{I_{t+1}}{M^A_{It+1}} \right)^{\frac{\rho}{1+\rho}} \frac{I_{Dt+1}}{I_{Dt}} x_{It+1} \widetilde{\varphi}_{It+1} \right\} \tag{B.20}$$

$$p_{Dt} \mathcal{T}_t = \left(\omega \frac{I_t}{M^A_{It}} \right)^{\frac{\rho}{1+\rho}} (\varphi_{It} - \widetilde{\varphi}_{It}) + \mathbb{E}_t \left\{ \Lambda_{t,t+1} \pi_{ct+1} \left(\omega \frac{I_{t+1}}{M^A_{It+1}} \right)^{\frac{\rho}{1+\rho}} \frac{M_{It+1}}{M_{It}} \widetilde{\varphi}_{It+1} \right\} \tag{B.21}$$

$$\varphi_{It} = 1 - \frac{\varphi_M}{2} \left(\frac{x_{It}}{x_{It-1}} - 1 \right)^2 \tag{B.22}$$

$$\widetilde{\varphi}_{It} = \varphi_M \left(\frac{x_{It}}{x_{It-1}} - 1 \right) \frac{x_{It}}{x_{It-1}} \tag{B.23}$$

$$x_{It} = \frac{M_{It}}{I_{Dt}} \tag{B.24}$$

$$M^A_{It} = \varphi_{It} M_{It} \tag{B.25}$$

$$p_{Dt}^{\frac{1}{\rho}} = 1 - \omega + \omega \mathcal{T}_t^{-\frac{1}{\rho}} \tag{B.26}$$

$$Y_t = K_t{}^{\alpha} L_t^{1-\alpha} / \Delta_{pt} \tag{B.27}$$

$$\Delta_{pt} = (1-\xi_p)\left(\pi_t^o/\pi_t\right)^{-(1+\theta_p)/\theta_p} + \xi_p \pi_t^{(1+\theta_p)/\theta_p} \pi_{t-1}^{-\iota_p(1+\theta_p)/\theta_p} \Delta_{pt-1} \tag{B.28}$$

$$\frac{w_t}{Z_t} = \frac{(1-\alpha)}{\alpha}\frac{K_t}{L_t} \tag{B.29}$$

$$mc_t = \left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{Z_t}{\alpha}\right)^{\alpha} \tag{B.30}$$

$$\pi_t = \left((1-\xi_p)(\pi_t^o)^{-\frac{1}{\theta_p}} + \xi_p(\pi_{t-1})^{-\frac{\iota_p}{\theta_p}}\right)^{-\theta_p} \tag{B.31}$$

$$\pi_t^o = (1+\theta_p)\frac{x_{1t}}{x_{2t}}\pi_t \tag{B.32}$$

$$x_{1t} = U_{Ct} mc_t Y_t + \beta\xi_p \pi_t^{-\iota_p \frac{1+\theta_p}{\theta_p}} \mathbb{E}_t\left\{x_{1t+1}\pi_{t+1}^{\frac{1+\theta_p}{\theta_p}}\right\} \tag{B.33}$$

$$x_{2t} = U_{Ct} p_{Dt} Y_t + \beta\xi_p \pi_t^{1-\iota_p \frac{1+\theta_p}{\theta_p}} \mathbb{E}_t\left\{x_{2t+1}\pi_{t+1}^{\frac{1+\theta_p}{\theta_p}-1}\right\} \tag{B.34}$$

$$\pi_{ct} = \frac{\pi_t}{p_{Dt}/p_{Dt-1}} \tag{B.35}$$

$$Y_t = C_{Dt} + I_{Dt} + \frac{\xi^*}{\xi}\left(M_{Ct}^* + M_{It}^*\right) + \frac{\psi_I}{2}\left(I_t/I_{t-1}-1\right)^2 I_t \tag{B.36}$$

$$R_{t+1}^n = \left(R_t^n\right)^{\gamma_r}\left(\beta^{-1}\pi_t^{\gamma_\pi}\right)^{1-\gamma_r}\varepsilon_t^r \tag{B.37}$$

$$K_t = (1-\delta)K_{t-1} + I_{t-1} \tag{B.38}$$

$$Q_t = 1 + p_{Dt}\left[\psi_I\left(\frac{I_t}{I_{t-1}}-1\right)\frac{I_t}{I_{t-1}} + \frac{\psi_I}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2\right] - \mathbb{E}_t\left\{\Lambda_{t,t+1} p_{Dt+1}\psi_I\left(\frac{I_{t+1}}{I_t}-1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right\} \tag{B.39}$$

$$x_t = (\varrho_t/\mu_t)^{-1}\left(-1 + \sqrt{1 + \frac{2}{\gamma}\left(\varrho_t/\mu_t\right)^2}\right) \tag{B.40}$$

$$N_t = \sigma_b\left[(R_{Kt}-R_t)q_{t-1}A_{t-1} + \left(R_t - R_t^* S_{t-1}/S_t\right)S_{t-1}^{-1}D_{t-1}^* + R_t N_{t-1}\right] + (1-\sigma_b)\xi_b Q_{t-1}A_{t-1} \tag{B.41}$$

$$\phi_t = \frac{\nu_t}{\theta\left(1+\frac{\gamma}{2}x_t^2\right) - (\mu_t + \varrho_t x_t)} \tag{B.42}$$

$$Q_t A_t = \phi_t N_t \tag{B.43}$$

$$S_t^{-1} D_t^* = x_t \phi_t N_t \tag{B.44}$$

$$\mu_t = \mathbb{E}_t\left[\Lambda_{t,t+1}\Omega_{t+1}(R_{Kt+1} - R_{t+1})\right] \tag{B.45}$$

$$\varrho_t = \mathbb{E}_t\left[\Lambda_{t,t+1}\Omega_{t+1}\left(R_{t+1} - R_{t+1}^* S_t/S_{t+1}\right)\right] \tag{B.46}$$

$$\Omega_t = 1 - \sigma_b + \sigma_b\left[\nu_t + (\mu_t + \varrho_t x_t)\phi_t\right] \tag{B.47}$$

$$\nu_t = \mathbb{E}_t\left(\Lambda_{t,t+1}\Omega_{t+1}\right)R_{t+1} \tag{B.48}$$

$$A_t = (1-\delta)K_t + I_t \tag{B.49}$$

$$R_{Kt} = \frac{Z_t + (1-\delta)Q_t}{Q_{t-1}} \tag{B.50}$$

$$w_t^o = (1+\theta_w)\frac{x_{1wt}}{x_{2wt}} \tag{B.51}$$

$$x_{1wt} = L_t^o U_{Ct} MRS_t + \beta\xi_w \mathbb{E}_t\left\{x_{1wt+1}\right\} \tag{B.52}$$

$$x_{2wt} = L_t^o U_{Ct} + \beta\xi_w \pi_{wt}^{\iota_w}\mathbb{E}_t\left\{x_{2wt+1}\pi_{ct+1}^{-1}\right\} \tag{B.53}$$

$$w_t = \left((1-\xi_w)(w_t^o)^{-\frac{1}{\theta_w}} + \xi_w(\pi_{wt-1}^{\iota_w} w_{t-1}\pi_{ct}^{-1})^{-\frac{1}{\theta_w}}\right)^{-\theta_w} \tag{B.54}$$

$$MRS_t = \frac{\chi_0 (L_t^o)^\chi}{U_{Ct}} \tag{B.55}$$

$$L_t^o = \left(\frac{w_t^o}{w_t}\right)^{-\frac{1+\theta_w}{\theta_w}} L_t \tag{B.56}$$

$$\pi_{wt} = \frac{w_t}{w_{t-1}}\pi_{ct} \tag{B.57}$$

Above, $p_{Dt} = P_{Dt}/P_t$ is the relative price of the home-produced good in terms of the home basket; $\pi_{ct} = P_t/P_{t-1}$ is CPI inflation; $\mathcal{T}_t = P_{Mt}/P_{Dt}$ is the terms of trade; Δ_{pt} is price dispersion; mc_t is firms' real marginal cost; $w_t = W_t/P_t$ is the real wage; and $\pi_{wt} = W_t/W_{t-1}$ is nominal wage inflation.

Equations (B.10)-(B.11) are the Euler equations for the nominal and real safe rate. Equations (B.14)-(B.25) characterize optimality of the choice of domestic and imported consumption and investment goods. Note that these conditions simplify to the standard CES demand equations when $\varphi_M = 0$: for example, (B.14) becomes $C_{Dt} = (1-\omega)p_{Dt}^{-(1+\rho)/\rho}C_t$. Equations (B.27)-(B.34) characterize the aggregate production function and domestic firms' optimality, including price-setting. Equations (B.51)-(B.56) characterize households' optimal wage setting.

Terms of trade and balance of payments.

$$S_t^{-1} = \mathcal{T}_t\left(\frac{1-\omega+\omega\left(\frac{1}{\mathcal{T}_t}\right)^{-\frac{1}{\rho}}}{1-\omega+\omega\left(\mathcal{T}_t\right)^{-\frac{1}{\rho}}}\right)^{-\rho} \tag{B.58}$$

$$D_t^* - R_t^* D_{t-1}^* = S_t\left[\frac{P_{Mt}}{P_t}(M_{Ct}+M_{It}) - \frac{P_{Dt}}{P_t}\frac{\xi^*}{\xi}(M_{Ct}^* + M_{It}^*)\right] \tag{B.59}$$

Equation (B.58) characterizes the (negative) relationship between the terms of trade $\mathcal{T}_t$ and the real exchange rate S_t. It can be obtained by combining the expression for the real exchange rate, $S_t = e_t P_t / P_t^*$, with the PCP conditions (45),(46) and the price level expression (44) in each country. The balance of payments equation (B.59) can be obtained by domestic agents' combining budget constraints with equilibrium conditions.

Foreign country.

$$1 = \mathbb{E}_t \left(\frac{\Lambda^*_{t,t+1}}{\pi^*_{ct+1}} \right) R^{n*}_{t+1} \tag{B.60}$$

$$1 = \mathbb{E}_t \left(\Lambda^*_{t,t+1} \right) R^*_{t+1} \tag{B.61}$$

$$1 = \mathbb{E}_t \left(\Lambda^*_{t,t+1} R^*_{Kt+1} \right) \tag{B.62}$$

$$\Lambda^*_{t,t+1} = \beta^* U^*_{Ct+1} / U^*_{Ct} \tag{B.63}$$

$$U^*_{Ct} = \left(C^*_t - hC^*_{t-1} \right)^{-1} - \beta^* h \mathbb{E}_t \left\{ \left(C^*_{t+1} - hC^*_t \right)^{-1} \right\} \tag{B.64}$$

$$p^*_{Dt} = \left((1-\omega) \frac{C^*_t}{C^*_{Dt}} \right)^{\frac{\rho}{1+\rho}} + \left(\omega \frac{C^*_t}{M^{A*}_{Ct}} \right)^{\frac{\rho}{1+\rho}} x^*_{Ct} \widetilde{\varphi}^*_{Ct} - \mathbb{E}_t \left\{ \Lambda^*_{t,t+1} \pi^*_{ct+1} \left(\omega \frac{C^*_{t+1}}{M^{A*}_{Ct+1}} \right)^{\frac{\rho}{1+\rho}} \frac{C^*_{Dt+1}}{C^*_{Dt}} x^*_{Ct+1} \widetilde{\varphi}^*_{Ct+1} \right\} \tag{B.65}$$

$$p^*_{Dt} \mathcal{T}_t^{-1} = \left(\omega \frac{C^*_t}{M^{A*}_{Ct}} \right)^{\frac{\rho}{1+\rho}} \left(\varphi^*_{Ct} - \widetilde{\varphi}^*_{Ct} \right) + \mathbb{E}_t \left\{ \Lambda^*_{t,t+1} \pi^*_{ct+1} \left(\omega \frac{C^*_{t+1}}{M^{A*}_{Ct+1}} \right)^{\frac{\rho}{1+\rho}} \frac{M^*_{Ct+1}}{M^*_{Ct}} \widetilde{\varphi}^*_{Ct+1} \right\} \tag{B.66}$$

$$\varphi^*_{Ct} = 1 - \frac{\varphi_M}{2} \left(\frac{x^*_{Ct}}{x^*_{Ct-1}} - 1 \right)^2 \tag{B.67}$$

$$\widetilde{\varphi}^*_{Ct} = \varphi_M \left(\frac{x^*_{Ct}}{x^*_{Ct-1}} - 1 \right) \frac{x^*_{Ct}}{x^*_{Ct-1}} \tag{B.68}$$

$$x^*_{Ct} = \frac{M^*_{Ct}}{C^*_{Dt}} \tag{B.69}$$

$$M^{A*}_{Ct} = \varphi^*_{Ct} M^*_{Ct} \tag{B.70}$$

$$p^*_{Dt} = \left((1-\omega) \frac{I^*_t}{I^*_{Dt}} \right)^{\frac{\rho}{1+\rho}} + \left(\omega \frac{I^*_t}{M^{A*}_{It}} \right)^{\frac{\rho}{1+\rho}} x^*_{It} \widetilde{\varphi}^*_{It} - \mathbb{E}_t \left\{ \Lambda^*_{t,t+1} \pi^*_{ct+1} \left(\omega \frac{I^*_{t+1}}{M^{A*}_{It+1}} \right)^{\frac{\rho}{1+\rho}} \frac{I^*_{Dt+1}}{I^*_{Dt}} x^*_{It+1} \widetilde{\varphi}^*_{It+1} \right\} \tag{B.71}$$

$$p^*_{Dt} \mathcal{T}_t^{-1} = \left(\omega \frac{I^*_t}{M^{A*}_{It}} \right)^{\frac{\rho}{1+\rho}} \left(\varphi^*_{It} - \widetilde{\varphi}^*_{It} \right) + \mathbb{E}_t \left\{ \Lambda^*_{t,t+1} \pi^*_{ct+1} \left(\omega \frac{I^*_{t+1}}{M^{A*}_{It+1}} \right)^{\frac{\rho}{1+\rho}} \frac{M^*_{It+1}}{M^*_{It}} \widetilde{\varphi}^*_{It+1} \right\} \tag{B.72}$$

$$\varphi^*_{It} = 1 - \frac{\varphi_M}{2} \left(\frac{x^*_{It}}{x^*_{It-1}} - 1 \right)^2 \tag{B.73}$$

$$\widetilde{\varphi}^*_{It} = \varphi_M \left(\frac{x^*_{It}}{x^*_{It-1}} - 1 \right) \frac{x^*_{It}}{x^*_{It-1}} \tag{B.74}$$

$$x^*_{It} = \frac{M^*_{It}}{I^*_{Dt}} \tag{B.75}$$

$$M^{A*}_{It} = \varphi^*_{It} M^*_{It} \tag{B.76}$$

$$p^{*1/\rho}_{Dt} = 1 - \omega^* + \omega^* \mathcal{T}_t^{1/\rho} \tag{B.77}$$

$$Y^*_t = K^{*\alpha}_t L^{*1-\alpha}_t / \Delta^*_{pt} \tag{B.78}$$

$$\Delta^*_{pt} = (1 - \xi_p) \left(\pi^{o^*}_t / \pi^*_t \right)^{-(1+\theta_p)/\theta_p} + \xi_p \pi^{*(1+\theta_p)/\theta_p}_t \pi^{*-\iota_p(1+\theta_p)/\theta_p}_{t-1} \Delta^*_{pt-1} \tag{B.79}$$

$$\frac{w^*_t}{Z^*_t} = \frac{(1-\alpha)}{\alpha} \frac{K^*_t}{L^*_t} \tag{B.80}$$

$$mc^*_t = \left(\frac{w^*_t}{1-\alpha} \right)^{1-\alpha} \left(\frac{Z^*_t}{\alpha} \right)^{\alpha} \tag{B.81}$$

$$\pi^*_t = \left((1-\xi_p)(\pi^{o*}_t)^{-\frac{1}{\theta_p}} + \xi_p \pi^{*\, -\frac{\iota_p}{\theta_p}}_{t-1} \right)^{-\theta_p} \tag{B.82}$$

$$\pi^{o*}_t = (1+\theta_p) \frac{x^*_{1t}}{x^*_{2t}} \pi^*_t \tag{B.83}$$

$$x^*_{1t} = U^*_{Ct} mc^*_t Y^*_t + \beta^* \xi_p \pi_t^{*-\iota_p \frac{1+\theta_p}{\theta_p}} \mathbb{E}_t \left\{ x^*_{1t+1} \pi^{*\frac{1+\theta_p}{\theta_p}}_{t+1} \right\} \tag{B.84}$$

$$x^*_{2t} = U^*_{Ct} p^*_{Dt} Y^*_t + \beta^* \xi_p \pi^{*\, 1-\iota_p \frac{1+\theta_p}{\theta_p}}_t \mathbb{E}_t \left\{ x^*_{2t+1} \pi^{*\frac{1+\theta_p}{\theta_p} - 1}_{t+1} \right\} \tag{B.85}$$

$$\pi^*_{ct} = \frac{\pi^*_t}{p^*_{Dt} / p^*_{Dt-1}} \tag{B.86}$$

$$Y^*_t = C^*_{Dt} + I^*_{Dt} + \frac{\xi}{\xi^*} (M_{Ct} + M_{It}) + \frac{\psi_I}{2} \left(I^*_t / I^*_{t-1} - 1 \right)^2 I^*_t \tag{B.87}$$

$$R^{n*}_{t+1} = \left(R^{n*}_t \right)^{\gamma_r} \left(\beta^{-1} \left(\pi^*_t \right)^{\gamma^*_\pi} \left(Y^*_t / Y^{pot*}_t \right)^{\gamma^*_y} \right)^{1-\gamma_r} \varepsilon^r_t \tag{B.88}$$

$$K^*_t = (1-\delta) K^*_{t-1} + I^*_{t-1} \tag{B.89}$$

$$Q^*_t = 1 + p^*_{Dt} \left[\psi_I \left(\frac{I^*_t}{I^*_{t-1}} - 1 \right) \frac{I^*_t}{I^*_{t-1}} + \frac{\psi_I}{2} \left(\frac{I^*_t}{I^*_{t-1}} - 1 \right)^2 \right] - \mathbb{E}_t \Big\{ \Lambda^*_{t,t+1} p^*_{Dt+1} \psi_I \left(\frac{I^*_{t+1}}{I^*_t} - 1 \right) \left(\frac{I^*_{t+1}}{I^*_t} \right)^2 \Big\} \tag{B.90}$$

$$R^*_{Kt} = \frac{Z^*_t + (1-\delta) Q^*_t}{Q^*_{t-1}} \tag{B.91}$$

$$w^{*o}_t = (1+\theta_w) \frac{x^*_{1wt}}{x^*_{2wt}} \tag{B.92}$$

$$x^*_{1wt} = L^{*o}_t U^*_{Ct} MRS^*_t + \beta^* \xi_w \mathbb{E}_t \left\{ x^*_{1wt+1} \right\} \tag{B.93}$$

$$x^*_{2wt} = L^{*o}_t U^*_{Ct} + \beta^* \xi_w {\pi^*}^{\iota_w}_{wt} \mathbb{E}_t \left\{ x^*_{2wt+1} {\pi^*_{ct+1}}^{-1} \right\} \tag{B.94}$$

$$w^*_t = \left((1-\xi_w)(w^{*o}_t)^{-\frac{1}{\theta_w}} + \xi_w ({\pi^*}^{\iota_w}_{wt-1} w^*_{t-1} {\pi^*_{ct}}^{-1})^{-\frac{1}{\theta_w}} \right)^{-\theta_w} \tag{B.95}$$

$$MRS^*_t = \frac{\chi_0 (L^{*o}_t)^{\chi}}{U^*_{Ct}} \tag{B.96}$$

$$L^{*o}_t = \left(\frac{w^{*o}_t}{w_t} \right)^{-\frac{1+\theta_w}{\theta_w}} L^*_t \tag{B.97}$$

$$\pi^*_{wt} = \frac{w^*_t}{w^*_{t-1}} \pi^*_{ct} \tag{B.98}$$

The "*pot*" superscript in the foreign Taylor rule (B.88) refers to the potential economy, given by the system above without price or wage rigidities: $\xi_p = \xi_w = 0$.

The system (B.10)-(B.98) characterizes the behavior of the 48 home variables $C_t, L_t, \Lambda_{t,t+1}, U_{Ct}, C_{Dt}, M_{Ct}, I_{Dt}, M_{It}, x_{Ct}, x_{It}, \varphi_{Ct}, \widetilde{\varphi}_{Ct}, \varphi_{It}, \widetilde{\varphi}_{It}, M^A_{Ct}, M^A_{It}, p_{Dt}, Y_t, \Delta_{pt}, Z_t, mc_t, \pi_t, \pi^o_t, x_{1t}, x_{2t}, \pi_{ct}, R_{t+1}, R^n_{t+1}, I_t, K_t, Q_t, x_t, N_t, \phi_t, A_t, D^*_t, \mu_t, \varrho_t, \Omega_t, \nu_t, R_{Kt}, w_t, w^o_t, x_{1wt}, x_{2wt}, MRS_t, L^o_t, \pi_{wt}$, the 39 foreign variables $C^*_t, L^*_t, \Lambda^*_{t,t+1}, U^*_{Ct}, C^*_{Dt}, M^*_{Ct}, I^*_{Dt}, M^*_{It}, x^*_{Ct}, x^*_{It}, \varphi^*_{Ct}, \widetilde{\varphi}^*_{Ct}, \varphi^*_{It}, \widetilde{\varphi}^*_{It}, M^{A*}_{Ct}, M^{A*}_{It}, p^*_{Dt}, Y^*_t, \Delta^*_{pt}, Z_t, mc^*_t, \pi^*_t, \pi^{o*}_t, x^*_{1t}, x^*_{2t}, \pi^*_{ct}, R^*_{t+1}, {R^*_{t+1}}^n, I^*_t, K^*_t, Q^*_t, R^*_{Kt}, w^*_t, w^{*o}_t, x^*_{1wt}, x^*_{2wt}, MRS^*_t, L^{*o}_t, \pi^*_{wt},$ and the two international prices $S_t, \mathcal{T}_t$.

B.3 Dominant Currency Pricing

Let the relative export price be $p^*_{Mt} \equiv P^*_{Mt}/P^*_t$, let π^{o*}_{Mt} denote reset export price inflation, and let z_{1t}, z_{2t} be the auxiliary Calvo variables for home firms' export prices. We use $p_{Mt} \equiv P_{Mt}/P_t$ for the price of the U.S. good at home, and drop the terms of trade variable $\mathcal{T}_t$ and replace it appropriately in the demand equations (e.g. p_{Mt} in place of $p_{Dt}\mathcal{T}_t$ in (B.15)). We drop equation (B.54) and instead use the PCP condition for U.S. goods prices:

$$p_{Mt} = S^{-1}_t p^*_{Dt} \tag{B.99}$$

We also replace (B.26) and (B.77) with

$$1 = (1-\omega) p^{-1/\rho}_{Dt} + \omega p^{-1/\rho}_{Mt} \tag{B.100}$$

$$1 = (1-\omega^*) p^{*-1/\rho}_{Dt} + \omega^* p^{*-1/\rho}_{Mt} \tag{B.101}$$

The additional equations for the home economy characterizing export price setting are as follows:

$$
\begin{aligned}
\left(\pi^*_{Mt}\right)^{-\frac{1}{\theta_p}} &= (1-\xi_p)\left(\pi^{*o}_{Mt}\right)^{-\frac{1}{\theta_p}} + \xi_p\left(\pi^*_{Mt-1}\right)^{-\frac{\iota_p}{\theta_p}} && \text{(B.102)}\\
\pi^{*o}_{Mt} &= (1+\theta_p)\frac{z_{1t}}{z_{2t}}\pi^*_{Mt} && \text{(B.103)}\\
z_{1t} &= U_{Ct}\left(M^*_{Ct}+M^*_{It}\right)mc_t + \beta\xi_p\mathbb{E}_t\left\{\left(\frac{\pi^*_{Mt+1}}{\pi^{*\iota_p}_{Mt}}\right)^{\frac{1+\theta_p}{\theta_p}} z_{1t+1}\right\} && \text{(B.104)}\\
z_{2t} &= U_{Ct}\left(M^*_{Ct}+M^*_{It}\right)p^*_{Mt}S_t^{-1} + \beta\xi_p\mathbb{E}_t\left\{\left(\frac{\pi^*_{Mt+1}}{\pi^{*\iota_p}_{Mt}}\right)^{\frac{1+\theta_p}{\theta_p}-1} z_{2t+1}\right\} && \text{(B.105)}\\
p^*_{Mt} &= \frac{\pi^*_{Mt}}{\pi^*_{Ct}}p^*_{Mt-1} && \text{(B.106)}
\end{aligned}
$$

On net, we have the 5 additional equations above and 5 new variables $p^*_{Mt}, \pi^*_{Mt}, \pi^{o*}_{Mt}, z_{1t}, z_{2t}$.

B.4 Welfare

We calculate welfare under different values of γ_e. In particular, letting household i's welfare $\mathcal{W}_{it}$ be

$$
\mathcal{W}_{it} = \log\left(C_t - hC_{t-1}\right) - \frac{\chi_0}{1+\chi}L_{it}^{1+\chi} + \beta\mathbb{E}_t\left(\mathcal{W}_{it+1}\right), \tag{B.107}
$$

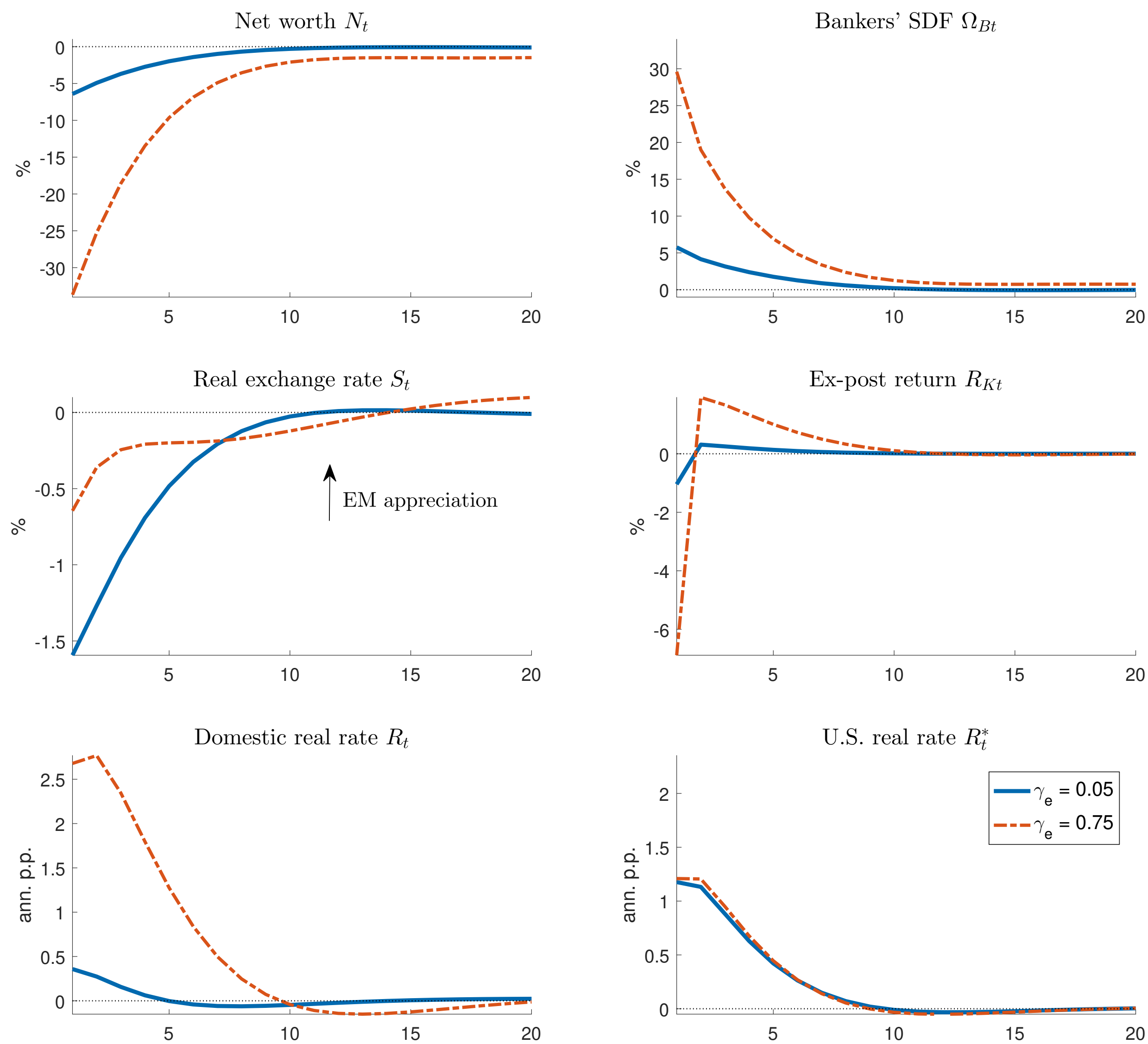
we calculate social welfare $\mathcal{W}_t$ as $\mathcal{W}_t = \int_0^1 \mathcal{W}_{it}\, di$.

We then compute the unconditional expectation $\mathbb{E}\left(\mathcal{W}_t\right)$ for each value of $\gamma_e \in [0,1]$. We express welfare in terms of consumption-equivalent losses relative to an economy with $\gamma_e = 0$: that is, for each $\gamma_e \in (0,1]$ we find the percent fall in consumption each period such that $\mathbb{E}\left(\mathcal{W}_t\right)$ is the same as in the economy with $\gamma_e = 0$. Thus, positive values indicate lower welfare than in the pure inflation-targeting regime $\gamma_e = 0$ (and regime $\gamma_e = 0$ has zero welfare losses by construction). As in Schmitt-Grohé and Uribe (2007), Gali and Monacelli (2016), and others, we compute $\mathbb{E}\left(\mathcal{W}_t\right)$ by first computing a second-order approximation of the model around the non-stochastic steady state.

B.5 Effect of U.S. policy shock on EM's financial variables

Figure B.1 clarifies how the shift in γ_e alters the second moments described in Section 5.2, by showing the effects of a U.S. monetary shock that engineers a 1 percent rise in the

Figure B.1. U.S. Monetary Shock and Exchange Rate Regimes, Response of Financial Variables



Note: The figure shows impulse responses to a 1 percent rise in the federal funds rate of selected financial variables, under a domestic inflation-focused monetary regime (blue solid line) and under a regime with a strong weight on exchange rate stabilization (orange dash-dotted line).

federal funds rate, conditional on $\gamma_e = 0.05$ (a very low value, shown by the blue solid line) and on $\gamma_e = 0.75$ (a high value, shown by the orange dashed line). Note first that the variation in the banker's stochastic discount factor is close to the mirror image of that of net worth: when aggregate banker wealth is low, bankers' constraints are tight. Consequently, an additional unit of net worth is highly valuable.

Consider the behavior of S_t and R_t and when $\gamma_e = 0.05$. In response to the Fed's tightening, the EM's real exchange rate depreciates sharply and R_t moves up just a bit. The large downward movement in S_t makes $R_t^* S_{t-1}/S_t$ (the ex-post cost of foreign loans) rise sharply—precisely when bankers' value of funds is high (Ω_{Bt} is up). This explains why $Cov(\Omega_{Bt}, R_t - R_t S_{t-1}/S_t)$ is negative for low values of γ_e, as seen in the bottom left panel of Figure 8. Next consider what happens when $\gamma_e = 0.75$. The response of S_t is now more muted, and at the same time there is a sharper rise in R_t. Thus, we expect $Cov(\Omega_{Bt}, R_t - R_t S_{t-1}/S_t)$ to rise with γ_e and eventually turn positive, as confirmed by Figure 8.

In addition, $Cov(\Omega_{Bt}, R_K - R_t)$ (which is always negative, as $R_{Kt} - R_t$ is procyclical and Ω_{Bt} countercyclical) turns more negative when γ_e is high. The reason is that the rise in Ω_{Bt} is sharper, and the decline in R_{Kt} is also amplified, as a consequence of the now more powerful financial accelerator.

C UIP regressions in advanced economies

Table C.1 reports the results from estimating equation (64) on data for Canada, the euro area (EA), Japan, and the UK. Table C.2 reports the results from the first-differenced version, equation (65).

Table C.1: Empirical exchange rate equation: Level specification: 5-Year Yields

	Canada				EA				Japan				UK			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Interest diff.	1.37***	1.38***	1.38***	1.33***	1.79***	1.71***	1.70***	1.74***	1.05***	1.01***	1.03***	0.98***	0.47***	0.50***	0.49***	0.47**
	(0.24)	(0.24)	(0.24)	(0.24)	(0.27)	(0.27)	(0.27)	(0.25)	(0.20)	(0.22)	(0.22)	(0.19)	(0.16)	(0.19)	(0.19)	(0.19)
Corp. spread		0.11	−0.08	0.44		0.59**	0.71*	2.02***		2.96*	2.29	1.01		0.17	0.32	0.91**
		(0.46)	(0.62)	(0.57)		(0.24)	(0.38)	(0.49)		(1.51)	(1.59)	(1.55)		(0.37)	(0.41)	(0.37)
D_{crisis}			0.06				−0.04				0.08*				−0.06*	
			(0.06)				(0.06)				(0.04)				(0.03)	
VIX/100				−0.17				−0.88***				0.33***				−0.45***
				(0.17)				(0.22)				(0.11)				(0.13)
trend	*linear*	*linear*	*linear*	*linear*	*linear*	*linear*	*linear*	*linear*	*linear*	*linear*	*linear*	*linear*	*linear*	*linear*	*linear*	*linear*
R^2	0.35	0.35	0.35	0.36	0.39	0.43	0.44	0.55	0.55	0.58	0.59	0.61	0.30	0.30	0.31	0.36
Observations	326	326	326	326	206	206	206	206	240	240	240	240	312	312	312	312

Note: Dependent variable: Monthly bilateral real exchange rate against the United States. Regressions estimated by OLS. Standard errors shown in parentheses, computed using the Newey-West adjustment. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively. Sample periods: 1992:3–2019:4 (Canada), 2001:8–2019:4 (EA), 2003:1–2019:4 (Japan), 1997:6–2019:3 (UK).

Table C.2: Empirical exchange rate equation: First-difference specification: 5-Year Yields

	Canada				EA				Japan				UK			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Interest diff.	0.12^{*}	0.06	0.05	0.09	0.47^{***}	0.42^{***}	0.42^{***}	0.45^{***}	0.01	0.01	0.02	0.00	0.22^{**}	0.19^{***}	0.14^{***}	0.19^{***}
	(0.07)	(0.06)	(0.06)	(0.06)	(0.08)	(0.08)	(0.08)	(0.08)	(0.07)	(0.07)	(0.06)	(0.06)	(0.09)	(0.07)	(0.05)	(0.07)
Corp. spread		-0.64^{***}	-0.56^{***}	-0.46^{***}		-0.37^{**}	-0.37^{**}	-0.22		2.31^{*}	1.89^{*}	2.56^{*}		-0.45^{*}	-0.33^{*}	-0.43^{*}
		(0.18)	(0.17)	(0.14)		(0.17)	(0.17)	(0.27)		(1.20)	(1.05)	(1.36)		(0.25)	(0.20)	(0.23)
D_{crisis}			-0.01^{*}				0.00				0.02				-0.03^{***}	
			(0.01)				(0.01)				(0.02)				(0.01)	
VIX/100				-0.17^{***}				-0.07				0.16^{***}				-0.01
				(0.03)				(0.07)				(0.03)				(0.04)
trend	*no*	*no*	*no*	*no*	*no*	*no*	*no*	*no*	*no*	*no*	*no*	*no*	*no*	*no*	*no*	*no*
R^2	0.01	0.08	0.09	0.21	0.15	0.18	0.18	0.19	0.00	0.03	0.05	0.11	0.05	0.07	0.12	0.07
Observations	325	325	325	325	205	205	205	205	239	239	239	239	311	311	311	311

Note: Dependent variable: Monthly bilateral real exchange rate against the United States. Regressions estimated by OLS. Standard errors shown in parentheses, computed using the Newey-West adjustment. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively. Sample periods: 1992:3–2019:4 (Canada), 2001:8–2019:4 (EA), 2003:1–2019:4 (Japan), 1997:6–2019:3 (UK).