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A Quantitative Microfounded Model for the Integrated Policy Framework

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A Quantitative Microfounded Model for the Integrated Policy Framework

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ABSTRACT: We develop a microfounded New Keynesian model to analyze monetary policy and financial stability issues in open economies with financial fragilities and weakly anchored inflation expectations. We show that foreign exchange intervention (FXI) and capital flow management tools (CFMs) can improve monetary policy tradeoffs under some conditions, including by reducing the need for procyclical tightening in response to capital outflow pressures. Moreover, they can be used in a preemptive way to reduce the risk of a "sudden stop" through curbing a buildup in leverage. While these tools can materially improve welfare, mainly by dampening inefficient fluctuations in risk premia, our analysis also highlights potential limitations, including the possibility that their deployment may forestall needed adjustment in the external balance. Finally, our results also emphasize the power of FXIs to provide domestic stimulus in a liquidity trap.

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Contents

1. Introduction

Unlike their advanced economy (AE) counterparts, many emerging market economy (EME) central banks with inflation targeting (IT) frameworks continue to rely on foreign exchange interventions (FXI) and some also use capital flow management tools (CFMs), particularly during episodes of volatile capital flows (Hoffmann et al., 2019). Relatedly, and as emphasized by Carstens (2019), many EME policy makers frequently list volatile capital flows as a predominant concern – one often conspicuously absent from the communications of their AE counterparts. The aim of this paper is to shed light on these intriguing asymmetries, quantifying the underlying monetary tradeoffs and analyzing how the use of FXI and CFMs can affect them.

At the heart of our analysis, and broadly in line with evidence in Ghosh et al. (2017), is an unpleasant monetary dilemma faced by EMEs with less well-anchored inflation expectations, substantial net foreign liabilities, unhedged FX exposures and shallower FX markets. The dilemma comprises two main elements. First, and unlike in their advanced economy counterparts, inflationary and financial stability concerns mean that an adverse external capital flow shock that depreciates the exchange rate cannot be met with monetary policy easing, which would otherwise cushion the effects of external tightening on domestic demand.[1] "Sudden stops" are the second key consideration.[2] Crucially, and as recently documented in Bianchi and Mendoza (2020), such episodes are not only more frequent in EMEs, but also significantly more severe than in most AEs. Mitigating the associated risks thus becomes an important factor in vulnerable emerging market economies.

Our main contribution is to analyze and quantify the underlying tradeoffs in a structural framework that is sufficiently rich to account for empirically relevant frictions, and yet parsimonious enough to allow key channels of transmission to be efficiently parsed out. Aspects of these policy dilemmas have already been studied in a number of papers discussed below. However, the existing analyses, including those based on structural models, typically rely on stylized setups, which do not jointly feature the financial, nominal and real frictions that are embedded into our model. In particular, while stylized models are very useful for isolating and explaining particular mechanisms, their ability to capture key aspects of emerging market economies relevant for monetary policy, such

[1] This is, arguably, why monetary policy responses to adverse capital flow shocks were *procyclical*, i.e., associated with a tightening, in about half of the emerging market sample in Vegh and Vuletin (2013). By contrast, in small open *advanced* economies domestic factors appeared to dominate, translating into *countercyclical* responses.

[2] These are typically defined as financial crises associated with large current account reversals and deep recessions.

as pass-through of exchange rate shocks to inflation and economic activity, is limited. Moreover, such models typically provide little guidance on the relative importance of the underlying market imperfections, an issue of key practical importance to policymakers. By addressing both of these points, we believe our work fills an important gap in the existing literature.

Specifically, our model features two key frictions in financial intermediation that are similar to those of the three-period model of Basu et al. (2020). The first, based on Gabaix and Maggiori (2015), captures the limited risk-bearing capacity of agents trading in the FX market and gives rise to inefficient fluctuations in the uncovered interest rate parity (UIP) risk premium. The second, in the spirit of the "sudden stop" literature (see, e.g., Arellano and Mendoza, 2002; Chari et al., 2005; Mendoza, 2010; Bianchi, 2011; Chang, 2019), is an occasionally binding external debt limit, which can trigger sharp increases in credit spreads, current account reversals and deep contractions in economic activity. Importantly, our model also allows for a range of empirically relevant nominal and real rigidities often incorporated into central bank policy models, including price and wage stickiness. We proxy for how medium-term inflation expectations may be destabilized by exchange rate changes through allowing the latter to potentially exert large and persistent effects on wage and price inflation via indexation mechanisms and high passthrough of exchange rate changes to import prices. Taken together, the combination of financial frictions and weakly anchored inflation expectations can translate into an important role for using FXI or CFMs, including to help avoid procyclical monetary tightening in the face of capital outflow pressures (see, e.g., Kalemli-Ozcan, 2019).

We calibrate our model to a "representative" small open emerging market economy using a rich dataset for EMEs, and also consider a "representative" small open advanced economy for comparative purposes. The model is consistent with recent empirical evidence suggesting that: (i) exchange rate changes tend to have larger and more persistent effects on inflation in EMEs than in AEs, so that depreciations may even be contractionary for output in the former; and (ii) exchange rate pass-through to inflation in EMEs is asymmetric, with depreciations having larger effects than appreciations. The higher sensitivity of inflation to exchange rate movements in many EMEs appears to a large extent attributable to less well-anchored inflation expectations, see e.g. Chapter 3 in the IMF World Economic Outlook (2018), Kamber et al. (2020) and Bems et al. (2021). Allowing for a nonlinear Kimball aggregator for intermediate goods helps our model capture the asymmetric inflation response to shocks, as in a recent paper by Harding et al. (2021) explaining the "missing deflation puzzle."[3]

Our model accounts for why many EME central banks may face more difficult monetary policy tradeoffs than their typical AE counterparts, especially in responding to external capital flow shocks. Importantly, we deliberately assume no systematic differences in the conduct of monetary policy between AEs and EMEs, and so our results apply to emerging market economies in which the central bank is committed to flexible inflation targeting, but has to deal with "legacy issues," manifesting themselves through shallow FX markets, unhedged FX exposures and differences in wage and price setting.[4]

To illustrate the tradeoff, we consider an adverse shock to foreign investor appetite for domestic currency that triggers an outflow of capital and causes the exchange rate to depreciate sharply. In advanced economies, the shock is not only more easily absorbed due to deeper FX markets, but also plays out like an expansionary shift in aggregate demand, boosting output through expenditure-switching channels while exerting only transient effects on inflation (which monetary policy can "look through"). By contrast, the shock poses difficult tradeoffs for economies with less well-anchored inflation expectations: inflation rises persistently, and the tighter policy required to keep inflation in check depresses output. The output contraction may be amplified substantially if the combination of FX mismatches coupled with a weaker exchange rate deteriorates the balance sheets and leads to a "sudden stop."

We then apply the framework to study how using FXI or CFM tools can improve upon an exclusive reliance on conventional monetary policy. This analysis involves several different facets, including assessing whether these tools: (i) can potentially improve monetary policy tradeoffs and "expand" policy space; (ii) can be used preemptively to reduce the risks of a crisis or sudden stop; and (iii) are likely to be effective once a crisis actually materializes. For this analysis, we consider not only modal outcomes, as captured by impulse responses, but also stochastic simulations to assess effects on the probability distributions of key variables.

[3] The Kimball aggregator introduces additional strategic complementarities in price setting. Apart from generating asymmetries when used in a non-linear framework, it also lowers the sensitivity of prices to marginal cost for a given degree of price stickiness.

[4] Expressed alternatively, our results should not be construed to imply that FXIs or CFMs can or should be seen as a substitute for sound monetary policy.

Our analysis shows sizeable potential benefits of using simple FXI and CFM rules to dampen capital flows driven by investor risk appetite shocks. Such policies smooth out inefficient movements in the UIP wedge arising from frictions in the FX market, and also help keep the economy away from the debt limit, thus reducing the frequency of "sudden stops." While, for obvious reasons, sudden stops have been a key focus of policymakers, our results highlight substantial welfare benefits from smoothing UIP fluctuations even if the debt limit constraint is not binding. This reflects the frequency and size of risk appetite shocks, as well as the difficult tradeoffs they pose for monetary policymakers in vulnerable EMEs. Indeed, the welfare benefits of strengthening monetary autonomy turn out to be largest in environments characterized by substantial balance sheet FX mismatches, low FX market liquidity, and weakly anchored inflation expectations.[5]

We also document a role for policies mitigating sudden stop risks by systematically "leaning" against a buildup of external debt – consistent with an expansive literature that has typically used more stylized models. Precautionary CFMs that involve imposing restrictions on capital inflows when external debt rises can yield considerable welfare improvements by reducing the likelihood and severity of a crisis. Such a tool may be particularly attractive to economies that are near the debt limit, but without a sufficient stock of reserves to implement FX sales to allay downward exchange rate pressures in a sudden stop event.

Importantly, however, utilizing FXI and CFM tools involves intertemporal tradeoffs that may significantly reduce their benefits. To illustrate concretely, FX sales may be helpful to limit exchange rate depreciation driven by the exit of foreign investors, and reduce the need to raise interest rates to contain inflation, possibly helping avoid or mitigate a "sudden stop." But such actions to support the exchange rate may forestall needed balance sheet adjustments, and may leave the economy more vulnerable to future crises. As a consequence, FXI or CFM rules that respond only to financial stress episodes can actually be detrimental to welfare in a stochastic environment, and may exacerbate macroeconomic costs as measured by a standard quadratic loss function with a weighted sum of inflation and output gap volatility. It is hence important for the FXI and CFM policies to be active also when financial conditions are favorable, and in particular to lean against overheating when investors' risk appetite is high.

[5] In our model, the existence of, and fluctuations in, the UIP premium are inefficient as they reflect frictions in financial intermediation and international borrowing. Because the limited risk-bearing capacity of agents trading bonds is an important reason why the premium emerges, therefore UIP fluctuations can be thought of as related to FX market liquidity.

Finally, we also highlight potential benefits of using IPF tools in countries constrained by the effective lower bound (ELB) on nominal interest rates. Notably, moving away from the small open economy assumption common in the literature allows us to consistently account for multilateral effects. Our analysis demonstrates that FXI applied by a large bloc of countries at the ELB can be associated with negative output spillovers in economies whose monetary policy is also constrained, but are fairly innocuous whenever the foreign economy still has ample policy space.

Our paper, which draws on the work by Adrian et al. (2020), is related to several strands of the literature. On the modeling side, we microfound the private- and UIP-borrowing spreads, which allows us to quantify the effects of a given sized FX intervention on the UIP risk-premium and the exchange rate. Methodologically, we improve on Adrian et al. (2020) by solving the model nonlinearly. This allows us to examine the merits of alternative policies with both a standard quadratic loss function in inflation and output gap, as well as with a fully normative household welfare criterion.

More generally, by offering a structural model, we complement a number of recent, empirically-oriented studies that stress the role of structural features in determining the tradeoffs faced by policymakers in open economies, see e.g. Kalemli-Ozcan and Varela (2021) as well as the large literature surveyed therein. In the same vein, we complement the empirical literature analyzing the use of FXIs or CFMs as an additional policy instrument. These contributions focus on the effects on the exchange rate (e.g. Adler et al., 2019; Blanchard et al., 2015; Daude et al., 2016; Fratzscher et al., 2019) or the broader economy (Qureshi et al., 2011; Ghosh et al., 2015; Blanchard et al., 2017b; Brandao-Marques et al., 2020), with other articles highlighting drawbacks due to fiscal costs (Adler and Mano, 2016) and a heightened incentive for FX leveraging by domestic corporations (Tong and Wei, 2019).

Our paper also contributes to the theoretical literature on the benefits of conducting FXI and CFM interventions to mitigate financial market imperfections (Jeanne and Korinek, 2010; Mendoza, 2010; Farhi and Werning, 2014; Jeanne, 2016; Cavallino, 2019; Lama and Medina, 2020; Brunnermeier et al., 2021; Agenor and Pereira da Silva, 2021). Similarly to papers dealing with "sudden stops," we also highlight how FXIs and CFMs can endogenously affect the *ex ante* probability of risky overborrowing, as well as the *ex post* severity of the resulting macroeconomic disruption. Compared to this line of papers, all of which rely on stylized models and strive for analytical tractability, we offer a more empirically-oriented, yet still fully microfounded, framework, an important feature of which is a rich menu of nominal rigidities. As we demonstrate, these frictions are essential for capturing the transmission of FX market shocks, especially in EMEs.

Finally, our paper connects to normative studies on the use of FXI in the context of the ELB, including the associated multilateral considerations (Fanelli and Straub, 2020; Caballero et al., 2020). Again, our contribution here is to cast the analysis in a more quantitatively oriented environment, and also highlight the role of monetary policy space in countries outside of the bloc intervening in FX markets.

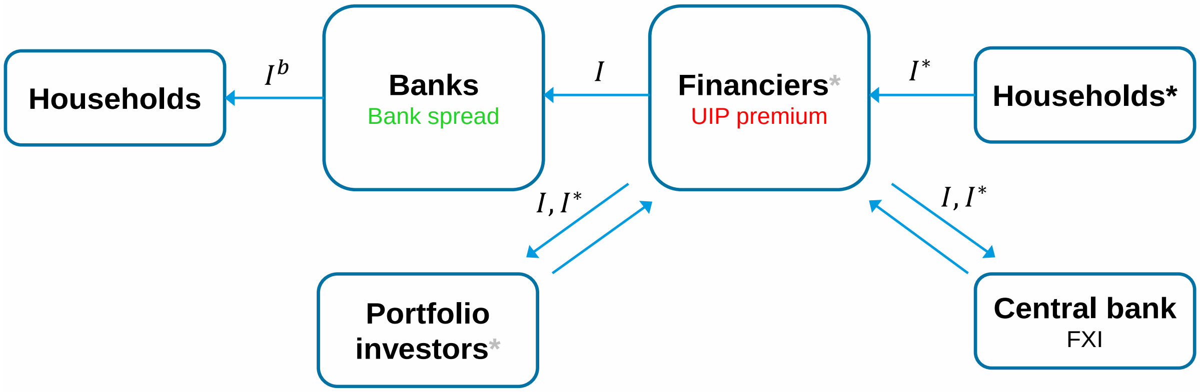
The remainder of the paper is organized as follows. Sections 2 and 3 outline the model environment. Impulse responses and stochastic simulations illustrating when and how FXI and CFMs could be helpful in achieving monetary policy objectives are presented in Sections 4, 5 and 6, with Section 7 demonstrating how FXIs could lift the country from a liquidity trap by effectively providing stimulus at the ELB. Section 8 concludes and summarizes the policy implications.

2. The Micro Founded Model

To enhance empirical realism and help capture key features of EMEs we extend the two-country New Keynesian workhorse along several dimensions. First, our model incorporates a broader array of real and nominal rigidities, including sticky wages and prices, strategic complementarities in price setting and imperfect passthrough of exchange rate changes to traded goods prices. Second, to capture less well anchored inflation expectations, we assume that some agents form expectations adaptively. This feature is important in accounting for how exchange rate changes may have large second round effects on inflation that often complicate monetary policy tradeoffs in EMEs. Third, our model allows for the possibility that policy rates, both at home and abroad, may be constrained by the effective lower bound. Fourth, and in contrast to the standard assumption of full international risk sharing, we assume incomplete financial markets, with frictions in both domestic credit markets and foreign exchange markets.

The structure of financial intermediation in our model is summarized in Figure 1. The two key financial frictions are those in the banking sector – related to an occasionally binding external borrowing constraint – and the foreign exchange market – arising on account of a moral hazard problem faced by agents trading in foreign currency. Thus, our model simultaneously allows for

Figure 1. Financial Market Structure



UIP deviations as well as "sudden stops," whenever the borrowing constraint becomes binding. In addition, the grey asterisks next to Financiers and Portfolio Investors in Figure 1 highlight that these entities may be co-owned by domestic and foreign households. As our subsequent analysis demonstrates, the exact ownership pattern effectively determines who ends up bearing exchange rate risk and can thus either significantly amplify international shocks or insulate the domestic economy from their impact.

In the rest of this section we provide an overview of the model, outlining the key building blocks and discussing the optimization problems solved by agents. In what follows, we assume that both countries are isomorphic, and hence, for parsimony, we only deal with one set of problems and derive one set of optimality and market clearing equations (those of the "home" country). Our chosen notational conventions largely follow Blanchard et al. (2017a), and are as follows: (i) capitalized variable names correspond to per-capita levels, (ii) asterisks correspond to variables in the foreign economy, (iii) variable names without time subscripts indicate their steady state values.

2.1. **Households.** We assume that households derive utility from consumption, leisure and real money balances. The utility functional for household h is,

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \varsigma_{t+j} \left\{ \frac{\left(C_{t+j}(h) - C\nu\right)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} - \chi_0 \frac{\left(N_{t+j}(h)\right)^{1+\chi}}{1+\chi} + \mu_0 F\left(\frac{\mathcal{M}_{t+j+1}(h)}{P_{C,t+j}}\right) \right\}, \tag{1}$$

where $0 < \beta < 1$, $\sigma, \nu, \chi, \chi_0, \mu_0 > 0$, and $C\nu$ is a steady state reference level of consumption. In the formula above, $C_t(h)$, $N_t(h)$ and $\mathcal{M}_t(h)$ denote household h's consumption, hours of labor and nominal money holdings, respectively, and $P_{C,t}$ is the consumer price index. We also allow for a shock to the discount factor ς_t, which has been widely used in the zero lower bound (ZLB) literature and beyond.

Following Eggertsson and Woodford (2003), the sub-utility function over real balances, $F(\cdot)$, is assumed to have a satiation point for $\overline{\mathcal{M}}/P$. Hence, inclusion of money – which is a zero nominal interest asset – provides a rationale for the zero lower bound on nominal interest rates. However, we maintain the assumptions that money enters additively and that μ_0 is small so that changes in real money balances have negligible implications for allocations and prices.

Household h faces a flow budget constraint in period t, which equates the combined expenditure on goods and on the net accumulation of financial assets to its disposable income

$$\begin{aligned}&(1+\tau_C)\, P_{C,t} C_t\,(h) + B_t(h) + B_{G,t}(h)\\ &\qquad = (1-\tau_N)\, W_t(h) N_t\,(h) + T_t + R_{K,t}K + I^b_{t-1}\,(B_{t-1}(h) + B_{G,t-1}(h)) + X_t + \Xi_t(h). \quad (2)\end{aligned}$$

We assume, in particular, that household h can trade in bonds issued in local currency. Bonds take the form of government debt $B_{G,t}(h)$ and claims on financiers $B_t(h)$. From a household's perspective, both assets are perfect substitutes, and so they pay the same gross risk-free nominal interest I^b_t from t to $t+1$. Each household earns labor income $W_t(h)N_t\,(h)$, owns a fixed stock of capital K, which is leased to firms at the rental rate $R_{K,t}$, and receives an aliquot share X_t of the profits of all firms (including financiers and banks, in line with the assumed ownership structure). Households also pay taxes on consumption and labor income at rates τ_C and τ_N respectively, and receive net lump sum transfers T_t from the government. Finally, we also assume the existence of perfect insurance schemes against idiosyncratic income risk due to staggered wage contracts, denoting the associated payments (equal to zero in the aggregate) as $\Xi_t\,(h)$.

2.1.1. *Consumption and savings decisions.* Maximization of utility functional (1) with respect to consumption and purchases of bonds, subject to budget constraint (2), results in a familiar consumption-Euler equation

$$\varsigma_t \Lambda_t = \beta \mathbb{E}_t \varsigma_{t+1} \Lambda_{t+1} \frac{I^b_t}{\Pi_{C,t+1}},$$

where

$$\Lambda_t = \frac{(C_t - C\nu)^{-\frac{1}{\sigma}}}{1+\tau_C},$$

with $\Pi_{C,t} = P_{C,t}/P_{C,t-1}$ denoting gross CPI inflation.

We additionally assume that household h derives utility from consuming quantity $C_{D,t}$ of a domestically produced basket of goods and quantity $M_{C,t}$ of imported varieties, with total consumption given by

$$C_t = \left((1-\omega_C)^{\frac{\rho_C}{1+\rho_C}} C_{D,t}^{\frac{1}{1+\rho_C}} + \omega_C^{\frac{\rho_C}{1+\rho_C}} M_{C,t}^{\frac{1}{1+\rho_C}} \right)^{1+\rho_C},$$

where $0 < \omega_C < 1$ and $-1 < \rho_C < 0$. This assumption implies that demand schedules for domestically-produced and imported goods equal

$$C_{D,t} = (1-\omega_C) \left(\frac{P_{D,t}}{P_{C,t}} \right)^{-\frac{(1+\rho_C)}{\rho_C}} C_t \qquad \text{and} \qquad M_{C,t} = \omega_C \left(\frac{P_{M,t}}{P_{C,t}} \right)^{-\frac{(1+\rho_C)}{\rho_C}} C_t, \tag{3}$$

where $P_{D,t}$ and $P_{M,t}$ denote the respective prices of the domestic and imported bundles, with expenditure minimization further implying,

$$P_{C,t} \equiv \left((1-\omega_C) P_{D,t}^{-\frac{1}{\rho_C}} + \omega_C P_{M,t}^{-\frac{1}{\rho_C}} \right)^{-\rho_C}.$$

2.1.2. *Wage Setting.* We assume that labor supplied by individual households is differentiated, with a constant elasticity of substitution between individual varieties controlled by parameter θ_w, which can be interpreted as the steady state (net) wage markup. The aggregate labor supply is then given by the following Dixit and Stiglitz (1977) formula

$$N_t = \left[\int_0^1 N_t(h)^{\frac{1}{1+\theta_w}} dh \right]^{1+\theta_w},$$

resulting in the labor demand schedule

$$N_t(h) = \left[\frac{W_t(h)}{W_t} \right]^{-\frac{1+\theta_w}{\theta_w}} N_t, \tag{4}$$

and aggregate wage

$$W_t = \left[\int_0^1 W_t(h)^{-\frac{1}{\theta_w}} \right]^{-\theta_w}. \tag{5}$$

Wages are set by households in a staggered, Calvo-style fashion. Each period, household h faces a fixed probability $1-\xi_w$ of being able to reoptimize its wage, while the remaining fraction of households mechanically index their wages $W_t^{ind}(h)$ using the following formula

$$W_t^{ind}(h) = \Pi_{W,t} W_{t-1}^{ind}(h) = \Pi_C^{1-\iota_w} \left[\Pi_{C,t-1}^{1-\iota_e} \left(\frac{\varepsilon_{t-1}}{\varepsilon_{t-2}} \right)^{\iota_e} \right]^{\iota_w} W_{t-1}^{ind}(h),$$

with $0 \leq \iota_w, \iota_e < 1$ and ε_t denoting the nominal exchange rate, defined as the price of a unit of foreign currency in terms of the domestic currency.[6] This specification implies that non-optimized wages can be indexed to past CPI inflation, exchange rate changes, and steady state CPI inflation. Taking into account household preferences, the budget constraint, and labor demand schedules in Equation (4), reoptimizing agents set their wage $W_t^{\diamond}(h)$ to maximize

$$\max_{W_t^{\diamond}(h)} \sum_{j=0}^{\infty} \xi_w^j \mathbb{E}_t \beta^j \varsigma_{t+j} \left[-\chi_0 \frac{\left(N_{t+j|t}(h)\right)^{1+\chi}}{1+\chi} + \Lambda_{t+j}(1-\tau_N) \Upsilon_{W,t+j} \frac{\Pi_{W,t,t+j}}{\Pi_{W,t}} \frac{W_t^{\diamond}(h)}{P_{C,t+j}} N_{t+j|t}(h) \right],$$

where we define $\Pi_{W,t,t+j} = \Pi_{W,t} ... \Pi_{W,t+j}$, and where the exogenous component $\Upsilon_{W,t+j}$ is a proxy for wage markup shocks and generates inefficient fluctuations in wages.[7]

The first-order condition of this problem is

$$\sum_{j=0}^{\infty} \xi_w^j \mathbb{E}_t \beta^j \varsigma_{t+j} \left[\Lambda_{t+j}(1-\tau_N) \Upsilon_{W,t+j} \frac{\Pi_{W,t,t+j}}{\Pi_{W,t}} \frac{W_t^{\diamond}(h)}{P_{C,t+j}} - (1+\theta_w)\chi_0 \left(N_{t+j|t}(h)\right)^{\chi} \right] N_{t+j|t}(h) = 0.$$

Given that all resetting households choose the same wage, an immediate implication of Equation (5) is that the evolution of the aggregate wage is given by

$$\frac{W_t}{P_{C,t}} = \left[(1-\xi_w)\left(\tilde{W}_{C,t}\right)^{-\frac{1}{\theta_w}} + \xi_w \left(\frac{\Pi_{W,t}}{\Pi_{C,t}} \frac{W_{t-1}}{P_{C,t-1}} \right)^{-\frac{1}{\theta_w}} \right]^{-\theta_w},$$

where $\tilde{W}_{C,t} \equiv W_t^{\diamond}/P_{C,t}$ denotes the real, optimal reset wage.

2.2. **Financiers.** Financiers intermediate cross-border borrowing and currency conversion by actively trading in FX markets and absorbing a portion of the currency risk originated by imbalanced global capital flows. Crucially, they face a limited commitment friction, which induces a downward sloping demand curve for their risk taking, with the exchange rate acting as the equilibrating price. Accordingly, a rise in global imbalances requiring financiers to increase their bond holdings has to be associated with a contemporaneous depreciation (and expected appreciation) compensating them for the greater risk exposure.

[6] It follows that an increase in the nominal exchange rate denotes a depreciation of the home currency.

[7] Wage markup shocks are frequently introduced in linearized New Keynesian models. To reconcile the presence of $\Upsilon_{W,t}$ in the wage setting problem with households' budget constraint (2), one can think of it as representing a stochastic tax or subsidy to labor income, rebated to households in a lump sum fashion.

Each period financiers take symmetric nominal positions $B_{F,t}$ in domestic bonds and $-B_{F,t}/\varepsilon_t$ in foreign bonds to maximize the present expected value of their profits

$$V_t = \frac{1}{I_t}\mathbb{E}_t\left\{(1-\tau_{F,t})I_tB_{F,t} - I_t^*\varepsilon_{t+1}\frac{B_{F,t}}{\varepsilon_t}\right\},$$

where $\tau_{F,t}$ denotes a tax on capital inflows, which we shall interpret as representing capital flow management (CFM) policies. Similarly to Gabaix and Maggiori (2015), we assume that after taking positions, but before shocks are realized, each financier can divert a portion $\min\left(1, \Gamma\cdot|\frac{B_{F,t}}{YP_{D,t}}|\right)$ of $B_{F,t}$, where Γ can be interpreted as financiers' risk-bearing capacity and effectively controls the degree of the underlying agency friction.[8] The corresponding incentive compatibility constraint then is

$$V_t \geq \Gamma\frac{B_{F,t}^2}{YP_{D,t}},$$

with the solution to the financiers' problem resulting in the following risk-augmented UIP condition

$$(1-\tau_{F,t})I_t = \mathbb{E}_t\left\{I_t^*\frac{\varepsilon_{t+1}}{\varepsilon_t}\right\} + \Gamma I_t\frac{B_{F,t}}{YP_{D,t}}. \tag{6}$$

We shall refer to Γ as FX market liquidity, with higher values of Γ corresponding to shallower markets. This is because high values of Γ make the UIP premium very sensitive to fluctuations in capital flows and changes in investor sentiment, which is broadly in line with what we observe in illiquid foreign exchange markets.

2.3. **Banks.** Perfectly competitive banks transfer funds in domestic currency between financiers and households. They choose the amount of intermediated funds to maximize profits

$$(I_t - I_t^b)B_t$$

subject to the borrowing constraint

$$-\frac{B_t}{P_{D,t}} \leq m\mathbb{E}_tY_{t+1}. \tag{7}$$

It might be worth stressing that the restriction on borrowing is not assumed to be always binding, and so the specification above does not imply a constant leverage ratio, but rather allows leverage

[8] The assumptions regarding the diversion of funds highlight the fact that financiers' outside options increase in the size and volatility, or complexity, of their balance sheet, broadly in line with the foundations and empirical evidence for Value-at-Risk constraints provided in Adrian and Shin (2014). The min operator additionally ensures that the share diverted is capped at 100%, a constraint which is always far from binding in subsequent simulations.

to fluctuate within bounds. Of course, the fact that the upper bound is assumed constant is chiefly for tractability and to establish contact with the sudden stop literature, where such specifications are standard. But, and as we discuss subsequently, this assumption is not innocuous and may have important implications for the relative importance of various frictions as well as the efficacy with which different tools can mitigate them.

The solution to banks' optimization problem is

$$I_t^b = I_t + \Theta_t, \tag{8}$$

where $\Theta_t \geq 0$ is the Lagrange multiplier on constraint (7).

2.4. **Portfolio Investors.** Portfolio investors take position $B_{P,t}$ in bonds denominated in the home country's currency, financing this operation by issuing foreign currency bonds of the same value, such that their net financial investment is always zero. Stochastic variation in the corresponding transactions can be interpreted as capturing swings in appetite for home currency assets.

From the perspective of a small economy, the assumed exogeneity of portfolio flows is consistent with their recent interpretation as reflecting uncertainty shocks in the US (Akinci et al., 2021). Still, it is also reasonable to think of these flows as at least partly driven by expected return differentials, which evolve endogenously in our model. Inspired by Blanchard (2017) and Gabaix and Maggiori (2015), we discuss such extensions in Appendix A. Notably, the derivations therein show that introducing a component of portfolio flows that responds to expected excess returns is observationally equivalent to increasing FX market depth.

2.5. **Financial Wedges.** In equilibrium, positions taken by financiers must match net demand for foreign currency. This implies that private debt holdings by home households, net of demand from portfolio investors, and net of sterilization bonds issued by the monetary authority, satisfy

$$B_{F,t} = -B_t - B_{P,t} + B_{M,t}, \tag{9}$$

where $B_{M,t}$ denotes the quantity of sterilization bonds issued by the central bank when it engages in FX interventions, see also Section 2.7.

We can also combine expressions for the UIP premium, due to financiers' agency friction (Equation 6), with the equation for the private borrowing spread, arising on account of the occasionally binding collateral constraint faced by banks (Equation 8), to arrive at a retail rate-based UIP condition

$$(1-\tau_{F,t})\ \underbrace{I_t^b = \mathbb{E}_t\left\{I_t^*\frac{\varepsilon_{t+1}}{\varepsilon_t}\right\}}_{\text{Standard UIP Condition}} + \underbrace{\Gamma I_t\frac{B_{F,t}}{YP_{D,t}}}_{\text{Gabaix and Maggiori (2015) wedge}} + \underbrace{(1-\tau_{F,t})\Theta_t}_{\text{“sudden stop” wedge}}.$$

This identity highlights the two key frictions accounting for deviations from uncovered interest rate parity in our model, with the latter strictly positive only when the credit constraint is active. The equation also clarifies how policy interventions such as CFMs (represented by $\tau_{F,t}$) and FXIs ($B_{M,t}$ that directly affects $B_{F,t}$) can be used to offset inefficient movements in the two wedges. Importantly, it shows that the efficacy of FXIs crucially depends on FX market shallowness, while CFMs can be potentially powerful also when the market is deep.

2.6. **Firms and Price-Setting.**

2.6.1. *Production of Domestic Final Goods.* We assume that a single final domestic output good $Y_{D,t}$ is produced using a continuum of differentiated intermediate goods $Y_t(f)$. The technology for transforming these intermediate goods into the final output good is specified as in Kimball (1995), which allows for strategic complementarities in price setting.[9] As in recent contributions by Harding et al. (2021), this is an important source of nonlinearity in our model, allowing us to obtain skewed responses of inflation to shocks.

More specifically, we assume that $Y_{D,t}$, the quantity produced from inputs $Y_{D,t}(f)$ satisfies

$$\int_0^1 G\left(\frac{Y_{D,t}(f)}{Y_{D,t}}\right)df = 1, \tag{10}$$

with

$$G(x) \equiv \frac{\phi}{1+\psi}\left[(1+\psi)x-\psi\right]^{\frac{1}{\phi}} - \frac{\phi}{1+\psi} + 1,$$

and where we further assume that ϕ, ψ, ϵ and θ_p are given by

$$\phi = \frac{\epsilon(1+\psi)}{\epsilon(1+\psi)-1}, \qquad \frac{\phi}{1-\phi} = -\epsilon(1+\psi), \qquad \epsilon = \frac{1+\theta_p}{\theta_p}.$$

This specification nests the popular Dixit and Stiglitz (1977) case when $\psi = 0$.

[9] Similar assumptions have subsequently been used e.g. in Dotsey and King (2005) and Yun et al. (2007).

Firms that produce the final output good are perfectly competitive in both product and factor markets. Thus, final goods producers minimize the cost of manufacturing a given quantity of the output index $Y_{D,t}$, taking as given the price $P_{D,t}(f)$ of each intermediate variety $Y_{D,t}(f)$. One can show that the final output good price $P_{D,t}$ is then given by

$$P_{D,t} = \frac{1}{1+\psi}\check{P}_{D,t} + \frac{\psi}{1+\psi}\int_0^1 P_{D,t}(f)\, df, \tag{11}$$

where

$$\check{P}_{D,t} = \left(\int_0^1 P_{D,t}(f)^{-\frac{1+\psi+\psi\theta_p}{\theta_p}} df\right)^{-\frac{\theta_p}{1+\psi+\psi\theta_p}},$$

i.e., the domestic producer price index will be a weighted average of a Dixit and Stiglitz (1977) price index and a linear one. Furthermore, demand for individual variety f equals

$$Y_{D,t}(f) = \left\{\frac{1}{1+\psi}\left(\frac{P_{D,t}(f)}{\check{P}_{D,t}}\right)^{-\frac{(1+\theta_p)(1+\psi)}{\theta_p}} + \psi\right\} Y_{D,t}, \tag{12}$$

which implies that firms' demand elasticity is state-dependent, an increasing function of relative prices, and that the demand curve is quasi-kinked.

2.6.2. *Production of Exported Final Goods.* We assume an analogous technology for goods produced for exports $Y^*_{M,t}$

$$\int_0^1 G\left(\frac{Y^*_{M,t}(f)}{Y^*_{M,t}}\right) df = 1. \tag{13}$$

As before, we can then write down formulae for the aggregate export price index

$$P^*_{M,t} = \frac{1}{1+\psi_m}\check{P}^*_{M,t} + \frac{\psi_m}{1+\psi_m}\int_0^1 P^*_{M,t}(f)\, df, \tag{14}$$

where

$$\check{P}^*_{M,t} = \left(\int_0^1 P^*_{M,t}(f)^{-\frac{1+\psi_m+\psi_m\theta_p}{\theta_p}} df\right)^{-\frac{\theta_p}{1+\psi_m+\psi_m\theta_p}},$$

and where demand functions faced by exporters are

$$Y^*_{M,t}(f) = \left\{\frac{1}{1+\psi_m}\left(\frac{P^*_{M,t}(f)}{\check{P}^*_{M,t}}\right)^{-\frac{(1+\theta_p)(1+\psi_m)}{\theta_p}} + \psi_m\right\} Y^*_{M,t}. \tag{15}$$

2.6.3. *Production of Intermediate Goods.* Intermediate good f is produced by a monopolistically competitive firm according to a Cobb-Douglas production function

$$Y_{D,t}(f) + Y^*_{M,t}(f) = K_t(f)^{\alpha}(Z_t N_t(f))^{1-\alpha},$$

where Z_t denotes a stationary, country-specific shock to the level of technology. Intermediate goods' producers face perfectly competitive factor markets for hiring capital and labor. Thus, each firm chooses $K_t(f)$ and $N_t(f)$, taking as given both the rental price of capital $R_{K,t}$ and the aggregate wage rate W_t. Accordingly, standard, static first-order conditions for cost minimization imply that all intermediate firms have identical marginal cost (equal to average cost)

$$MC_t = \left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{R_{K,t}}{\alpha}\right)^{\alpha}\frac{1}{Z_t^{1-\alpha}}$$

with the rental rate on capital $R_{K,t}$ linked to wages W_t via

$$R_{K,t} = \frac{\alpha}{1-\alpha}W_t\frac{N_t(f)}{K_t(f)}.$$

2.6.4. *Optimal Price Setting for Domestic Market.* Intermediate goods' producing firms set prices in staggered, Calvo-style contracts. We assume, in particular, that firm f faces a constant probability $1-\xi_p$ of being able to reoptimize the price it charges. In contrast, firms which do not reoptimize in period t (fraction ξ_p) mechanically index their prices $P^{ind}_{D,t}(f)$ according to

$$P^{ind}_{D,t}(f) = \Pi_{P,t}P_{D,t-1}(f) = \Pi^{\iota}_{D,t-1}\Pi^{1-\iota}_{D}P_{D,t-1}(f), \tag{16}$$

where $0 \leq \iota < 1$ and Π_D is the steady-state (gross) PPI inflation rate. Following Calvo (1983), reoptimizing firms set their price $P^{\diamond}_{D,t}(f)$ to maximize expected profits

$$\max_{P^{\diamond}_{D,t}(f)}\sum_{j=0}^{\infty}\xi_p^j\mathbb{E}_t\beta^j\frac{\varsigma_{t+j}}{\varsigma_t}\frac{\Lambda_{t+j}}{\Lambda_t}\frac{P_{C,t}}{P_{C,t+j}}\left[\frac{\Pi_{P,t,t+j}}{\Pi_{P,t}}P^{\diamond}_{D,t}(f) - \Upsilon^{-1}_{t+j}MC_{t+j}\right]Y_{D,t+j|t}(f), \tag{17}$$

subject to sequences specified in Equation (12), and where we define $\Pi_{P,t,t+j} = \Pi_{P,t}...\Pi_{P,t+j}$. Similarly to the case of wage setting, the optimization problem features an additional exogenous wedge Υ_t that generates inefficient variation in prices.[10]

[10] This additional stochastic term closely resembles markup shocks in standard New Keynesian models, i.e., one can think of Υ_t as representing a stochastic subsidy (or tax) rate to firms' costs, rebated to them in a lump sum fashion.

The first-order condition of this problem is

$$\sum_{j=0}^{\infty} (\beta \xi_p)^j \, \mathbb{E}_t \frac{\varsigma_{t+j} \Lambda_{t+j}}{P_{C,t+j}} \left[\frac{\Pi_{P,t,t+j}}{\Pi_{P,t}} P^{\diamond}_{D,t}(f) - \frac{(1+\psi)(1+\theta_p)}{1+\psi+\psi\theta_p} \Upsilon^{-1}_{t+j} MC_{t+j} \right] \left(\frac{\Pi_{P,t,t+j}}{\Pi_{P,t}} \frac{P^{\diamond}_{D,t}(f)}{P_{D,t+j}} \right)^{-\frac{(1+\theta_p)(1+\psi)}{\theta_p}}$$

$$\cdot \, \vartheta_{t+j}^{\frac{(1+\theta_p)(1+\psi)}{\theta_p}} Y_{D,t+j} = \frac{\psi\theta_p}{1+\psi+\psi\theta_p} \sum_{j=0}^{\infty} (\beta \xi_p)^j \, \mathbb{E}_t \frac{\varsigma_{t+j} \Lambda_{t+j}}{P_{C,t+j}} \frac{\Pi_{P,t,t+j}}{\Pi_{P,t}} P^{\diamond}_{D,t}(f) \, Y_{D,t+j},$$

where ϑ_t is the Lagrange multiplier associated with constraint (10).

Given that all resetting firms choose the same price, an immediate implication of Equations (11) and (16) is that the evolution of the final goods price is given by

$$P_{D,t} = \frac{1}{1+\psi} \left[(1-\xi_p) \left(P^{\diamond}_{D,t} \right)^{-\frac{1+\psi+\psi\theta_p}{\theta_p}} + \xi_p \int_0^1 \left(\Pi_{P,t} P_{D,t-1}(f) \right)^{-\frac{1+\psi+\psi\theta_p}{\theta_p}} df \right]^{-\frac{\theta_p}{1+\psi+\psi\theta_p}}$$
$$+ \frac{\psi}{1+\psi} \left[(1-\xi_p) P^{\diamond}_{D,t} + \xi_p \int_0^1 \left(\Pi_{P,t} P_{D,t-1}(f) \right) df \right]. \quad (18)$$

2.6.5. *Optimal Price Setting for Exports.* Export prices are set in the currency of the destination market (local currency pricing, LCP), so that domestic and export pricing decisions are separate. We assume similar Calvo-style contracts for exports as we did for domestic sales. Specifically, denoting the corresponding price resetting probability as $1-\xi_m$, non-optimizing firms are assumed to adhere to the following indexation scheme

$$P^{*,ind}_{M,t}(f) = \Pi^*_{PM,t} P^*_{M,t-1}(f) = \left(\Pi^*_{M,t-1} \right)^{\iota} \left(\Pi^*_M \right)^{1-\iota} P^*_{M,t-1}(f).$$

In parallel, reoptimizing exporters set their price $P^{*,\diamond}_{M,t}(f)$ to maximize

$$\max_{P^{*,\diamond}_{M,t}(f)} \sum_{j=0}^{\infty} \xi_m^j \mathbb{E}_t \beta^j \frac{\varsigma_{t+j}}{\varsigma_t} \frac{\Lambda_{t+j}}{\Lambda_t} \frac{P_{C,t}}{P_{C,t+j}} \left[\varepsilon_{t+j} \frac{\Pi^*_{PM,t,t+j}}{\Pi^*_{PM,t}} P^{*,\diamond}_{M,t}(f) - \Upsilon^{-1}_{t+j} MC_{t+j} \right] Y^*_{M,t+j|t}(f),$$

subject to sequences of demand curves specified in Equation (15), and where we define $\Pi_{PM,t,t+j} = \Pi_{PM,t} ... \Pi_{PM,t+j}$.

Proceeding as before, the first-order condition of this problem is

$$\sum_{j=0}^{\infty} (\beta\xi_m)^j \, \mathbb{E}_t \frac{\varsigma_{t+j}\Lambda_{t+j}}{P_{C,t+j}} \left(\frac{\Pi^*_{PM,t,t+j}}{\Pi^*_{PM,t}} \frac{P^{*,\diamond}_{M,t}(f)}{P^*_{M,t+j}} \right)^{-\frac{(1+\theta_p)(1+\psi_m)}{\theta_p}}$$

$$\cdot \left[\varepsilon_{t+j} \frac{\Pi^*_{PM,t,t+j}}{\Pi^*_{PM,t}} P^{*,\diamond}_{M,t}(f) - \frac{(1+\psi_m)(1+\theta_p)}{1+\psi_m+\psi_m\theta_p} \Upsilon^{-1}_{t+j} MC_{t+j} \right] \vartheta_{M,t+j}^{\frac{(1+\theta_p)(1+\psi_m)}{\theta_p}} Y^*_{M,t+j}$$

$$= \frac{\psi_m\theta_p}{1+\psi_m+\psi_m\theta_p} \sum_{j=0}^{\infty} (\beta\xi_m)^j \, \mathbb{E}_t \frac{\varsigma_{t+j}\Lambda_{t+j}}{P_{C,t+j}} \varepsilon_{t+j} \frac{\Pi^*_{PM,t,t+j}}{\Pi^*_{PM,t}} P^{*,\diamond}_{M,t}(f) \, Y^*_{M,t+j},$$

where $\vartheta_{M,t}$ denotes the Lagrange multiplier associated with constraint (13).

Since all resetting firms choose the same price, the final export goods price is given by

$$P^*_{M,t} = \frac{1}{1+\psi_m} \left[(1-\xi_m) \left(P^{*,\diamond}_{M,t} \right)^{-\frac{1+\psi_m+\psi_m\theta_p}{\theta_p}} + \xi_p \int_0^1 \left(\Pi^*_{PM,t} P^*_{M,t-1}(f) \right)^{-\frac{1+\psi_m+\psi_m\theta_p}{\theta_p}} df \right]^{-\frac{\theta_p}{1+\psi_m+\psi_m\theta_p}}$$

$$+ \frac{\psi_m}{1+\psi_m} \left[(1-\xi_m) P^{*,\diamond}_{M,t} + \xi_p \int_0^1 \left(\Pi^*_{PM,t} P^*_{M,t-1}(f) \right) df \right]. \quad (19)$$

2.7. **Monetary Policy.** Our benchmark model specification comprises a simple Taylor-type instrument rule for the short-term interest rate, specified as

$$I_t = I + \psi_\pi \left(\Pi_{D,t} - \Pi_D \right) + \psi_x \left(Y_t / Y_t^{pot} - 1 \right), \quad (20)$$

where $\Pi_{D,t} = P_{D,t}/P_{D,t-1}$ is domestic price inflation. As is standard, we assume that the central bank is concerned with deviations of inflation from target, as well as deviations of output from its potential level, the evolution of which is characterized in Section 2.11.[11]

The central bank can also engage in sterilized FXI by taking position $B^*_{M,t}$ in foreign bonds and issuing $B_{M,t} = \varepsilon_t B^*_{M,t}$ domestic (sterilization) bonds. The financial outcome of such operations (carry cost of FX reserves) is

$$T_{M,t} = \left(I^*_{t-1} \frac{\varepsilon_t}{\varepsilon_{t-1}} - I_{t-1} \right) B_{M,t-1}, \quad (21)$$

with the associated profits or losses fully borne by the fiscal authority.

[11] In some simulations we shall additionally allow for the possibility that policymakers directly respond to the private borrowing spread Θ_t.

2.8. **Fiscal Policy.** The evolution of nominal government debt $B_{G,t}$ is determined by the following flow budget constraint

$$B_{G,t} = I_{t-1}^{b} B_{G,t-1} + P_{G,t} G_t + T_t - \tau_C P_{C,t} C_t - \tau_N W_t N_t - \tau_{F,t-1} I_{t-1} (B_{F,t-1} + B_{P,t-1}) - T_{M,t}, \quad (22)$$

where $P_{G,t} G_t$ denotes nominal government expenditures. Changes in the government's net asset position and spending are hence mainly financed using distortionary taxes on private consumption and on labor income. Additionally, the fiscal balance can be affected by the financial outcome of holding FX reserves and proceeds from capital flow management measures. Government debt is stabilized with adjustments in lump sum transfers.

In parallel with private consumption, aggregate public consumption G_t, which we assume to be exogenous, is comprised of both domestically and foreign-produced bundles according to

$$G_t = \left((1-\omega_G)^{\frac{\rho_G}{1+\rho_G}} G_{D,t}^{\frac{1}{1+\rho_G}} + \omega_G^{\frac{\rho_G}{1+\rho_G}} M_{G,t}^{\frac{1}{1+\rho_G}} \right)^{1+\rho_G},$$

where $0 < \omega_G < 1$ and $-1 < \rho_G < 0$. As for private consumption, public demand for domestically-produced and imported bundles can be shown to equal

$$G_{D,t} = (1-\omega_G) \left(\frac{P_{D,t}}{P_{G,t}} \right)^{-\frac{(1+\rho_G)}{\rho_G}} G_t \qquad \text{and} \qquad M_{G,t} = \omega_G \left(\frac{P_{M,t}}{P_{G,t}} \right)^{-\frac{(1+\rho_G)}{\rho_G}} G_t,$$

where the cost of a unit of government consumption is given by

$$P_{G,t} = \left((1-\omega_G) P_{D,t}^{-\frac{1}{\rho_G}} + \omega_G P_{M,t}^{-\frac{1}{\rho_G}} \right)^{-\rho_G}.$$

2.9. **Market Clearing.** There are two types of goods market clearing conditions. The first equates the demand and supply of domestically produced intermediate goods, and can be stated as

$$P_{D,t}^{\#} Y_{D,t} + P_{M,t}^{*,\#} Y_{M,t}^{*} = K^{\alpha} \left(Z_t N_t \right)^{1-\alpha},$$

where the price dispersion terms associated with domestic sales and exports satisfy

$$P_{D,t}^{\#} \equiv \frac{\vartheta_t^{\frac{(1+\theta_p)(1+\psi)}{\theta_p}}}{1+\psi} \int_0^1 \left(\frac{P_{D,t}(f)}{P_{D,t}} \right)^{-\frac{(1+\theta_p)(1+\psi)}{\theta_p}} df + \frac{\psi}{1+\psi},$$

$$P_{M,t}^{*,\#} \equiv \frac{\vartheta_{M,t}^{\frac{(1+\theta_p)(1+\psi_m)}{\theta_p}}}{1+\psi_m} \int_0^1 \left(\frac{P_{M,t}^{*}(f)}{P_{M,t}^{*}} \right)^{-\frac{(1+\theta_p)(1+\psi_m)}{\theta_p}} df + \frac{\psi_m}{1+\psi_m}.$$

The second type of market clearing condition equates the quantity produced domestically to the sum of public and private demands,

$$Y_{D,t} = C_{D,t} + G_{D,t} \qquad \text{and} \qquad Y^*_{M,t} = \frac{\zeta^*}{\zeta}\left[M^*_{C,t} + M^*_{G,t}\right],$$

where we have adjusted by the size of the home and foreign economies, denoted by ζ and ζ^* respectively, to move from per-capita concepts to economy-wide aggregates.

Finally, the market clearing conditions for factor markets are

$$K = \int_0^1 K_t(f)\,df \qquad \text{and} \qquad N_t = \int_0^1 N_t(f)\,df.$$

2.10. **International Linkages.** We define the real exchange rate $\mathcal{Q}_t$ as the ratio of foreign and domestic consumer price levels expressed in a common currency

$$\mathcal{Q}_t \equiv \frac{\varepsilon_t P^*_{C,t}}{P_{C,t}}.$$

The domestic trade balance TB_t (in domestic currency) is defined as

$$TB_t \equiv \frac{\zeta^*}{\zeta}\varepsilon_t P^*_{M,t}\left[M^*_{C,t} + M^*_{G,t}\right] - P_{M,t}\left[M_{C,t} + M_{G,t}\right],$$

with the trade balance for the foreign economy simply equal to $-TB_t$.

By consolidating the budget constraints of all agents in the economy, we can then derive the following law of motion for net foreign assets

$$\begin{aligned} B_t = {} & TB_t + \left[(1-\omega_F)I_{t-1} + \omega_F I^*_{t-1}\frac{\varepsilon_t}{\varepsilon_{t-1}}\right]B_{t-1} \\ & + (1-\omega_B)\left(I^b_{t-1} - I_{t-1}\right)B_{t-1} + \left(I_{t-1} - I^*_{t-1}\frac{\varepsilon_t}{\varepsilon_{t-1}}\right)\left[(\omega_P - \omega_F)B_{P,t-1} - (1-\omega_F)B_{M,t-1}\right] \\ & + \tau_{F,t-1}I_{t-1}\left[(1-\omega_F)B_{F,t-1} + (1-\omega_P)B_{P,t-1}\right]. \end{aligned} \tag{23}$$

As alluded to before, this formula takes into account the fact that home households own fraction ω_F of financiers, fraction ω_B of banks, and fraction ω_P of portfolio investors. These three parameters jointly determine the degree of FX mismatches in the economy. As can be seen from the term in the square brackets in the top line, ω_F effectively controls the currency denomination of net foreign liabilities. Moreover, unless home agents own all financial market investors ($\omega_F = \omega_B = \omega_P = 1$), sudden stops (periods when banking spreads are positive, i.e. $I_t^b - I_t > 0$), FXIs ($B_{M,t}$), portfolio flows ($B_{P,t}$), and CFMs ($\tau_{F,t}$) are all associated with wealth transfers from home to foreign agents.

2.11. **The Potential Economy.** In the potential economy all firms can reset prices and all households can reoptimize wages in every period, without dynamic cost-push distortions introduced by fluctuations in $\Upsilon_{W,t}$ and Υ_t. This means, in particular, that there will be no distinction between the aggregate price level and the optimal reset price, and that there will be no price dispersion, with the flexible price level of aggregate output given by

$$Y_t^{pot} = K^{\alpha} \left(Z_t N_t^{pot} \right)^{1-\alpha},$$

and real marginal cost equal to

$$\frac{MC_t^{pot}}{P_{D,t}^{pot}} = \frac{\Upsilon}{1+\theta_p},$$

where the "potential" levels of all variables are denoted using the "pot" superscript. Similarly, all households in the flex price economy will choose the same wage rate, which will thus be given by the standard intratemporal optimality condition corrected for a constant markup

$$\frac{\chi_0 \left(N_t^{pot} \right)^{\chi}}{\Lambda_t^{pot}} = (1-\tau_N) \frac{\Upsilon_W}{1+\theta_w} \frac{W_t^{pot}}{P_{C,t}^{pot}}.$$

While defining the potential economy, we also assume that the debt limit is never binding and that there is no variation in portfolio investment $B_{P,t}$. Absent these two key financial frictions, there is no material role for FXI and CFMs, and hence we assume that FX reserves and the tax on capital are fixed at their steady state levels.

3. Model Calibration and Solution

Since the baseline case that we consider corresponds to that of a small open economy, therefore our benchmark parametrization makes the home country negligibly small.[12] The foreign economy is calibrated to represent the US, while the home country calibration comes in two variants, depending on whether our focus is on an advanced or emerging market economy. The model calibration is

[12] However, when discussing multilateral considerations, the home economy can be thought of as representing a large bloc of countries facing common shocks and policy challenges.

based on a rich dataset of established inflation targeting countries comprising the US, as well as 13 AEs and 16 EMEs.[13] In addition, we draw from the rich literature on estimated DSGE models.

Table 1. Steady State Calibration

	Foreign	AE	EME
Real Interest Rate (annual) $4(\frac{1}{\beta}-1)$	0.015	0.015	0.019
Inflation (annual) $4(\pi-1)$	0.02	0.02	0.04
Government Consumption (share of GDP) $\frac{G}{Y}$	0.15	0.14	0.14
Import Content (public) ω_G	-	0.1	0.1
Import Content (private) ω_C	-	0.3	0.3
Net Foreign Assets (to annual GDP) $\frac{B}{4Y}$	-	0	-0.22
FX Reserves (to annual GDP) $\frac{B_M}{4Y}$	-	0.2	0.2

We follow standard practice and first set parameters determining the key steady state variables and ratios listed in Table 1. According to our database, the median AE and EME have a very similar share of government purchases in GDP, import content of private and public consumption, and the stock of FX reserves as a proportion of GDP. However, while the net foreign asset (NFA) position in AEs is roughly balanced, it is typically negative in EMEs, making them vulnerable to swings in external financing conditions. On the other hand, the real interest rate and inflation (and hence the nominal interest rate) are higher in EMEs, translating into a lower probability of hitting the effective lower bound.

The responsiveness of inflation to marginal cost and of wages to the labor market wedge play a key role in determining how monetary policy actions affect output and inflation, as well as the extent to which medium-term inflation expectations respond to shocks. Accordingly, to capture less-well anchored inflation expectations in EMEs relative to AEs (or the US), we allow parameters governing price and wage formation to differ between the two calibration variants.

Table 2 lists our choices for the parameters describing the degree of nominal rigidities. Note that the reported slopes of price and wage Phillips curves (evaluated in the vicinity of the steady state) depend on the respective Calvo probabilities and, in the case of prices, also on the Kimball aggregation parameters. As discussed by Harding et al. (2021), the latter can generate strongly asymmetric responses of inflation to positive and negative shocks when the model is solved in its

[13] A detailed description of our dataset, which we also use to calibrate the properties of stochastic shocks as described in Section 6, can be found in Appendix B. Notably, and with important implications for any specific applications of the underlying model, there is considerable within-group heterogeneity both in advanced and emerging market economies.

Table 2. Calibration of Nominal Rigidities

Parameter	Foreign	AE	EME	Description
ι	0.23	0.23	0.75	Price indexation
ι_w	0.5	0.5	0.75	Wage indexation
ι_e	-	0	0.25	Weight on exchange rate in wage indexation
κ	0.007	0.007	0.014	Phillips curve slope (domestic production)
κ_w	0.007	0.007	0.011	Phillips curve slope (wages)
κ_m	-	0.012	0.006	Phillips curve slope (exports)
κ_m^*	-	0.012	0.06	Phillips curve slope (imports)

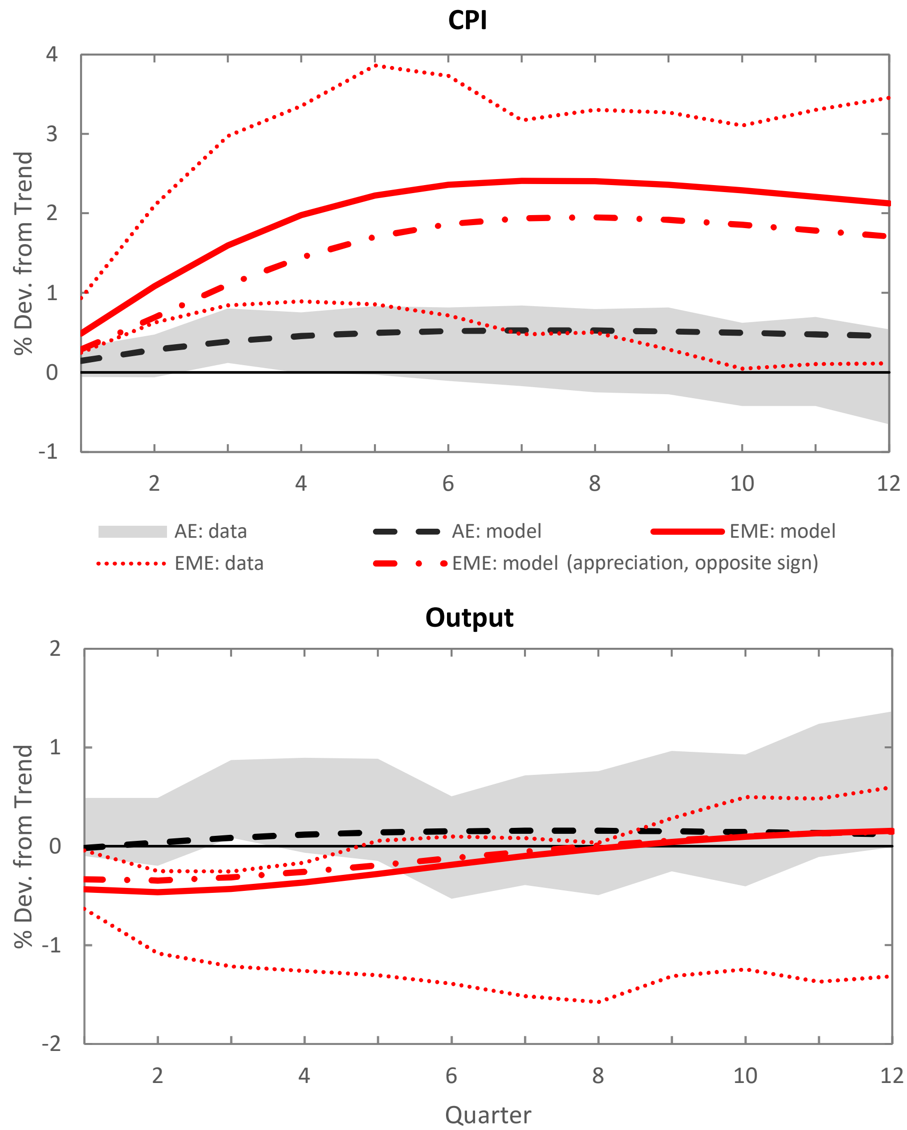
fully non-linear form. Our data suggests significantly positive skewness of CPI for median AE and EME economies, but not for the US. [14] Therefore, we set $\psi^* = \psi_m = 0$, obtaining the Dixit-Stiglitz case for goods purchased by the Foreign economy, but we allow for a fairly large degree of curvature in the Kimball aggregator for sales in the Home economy by setting $\psi = \psi_m^* = -12$.

Otherwise, our US and AE calibrations rely heavily on findings in the recent literature on estimated DSGE models (see Campbell et al., 2012; Del Negro et al., 2015; Lindé et al., 2016), specifically the low slopes of the price and wage curves (i.e. small κ_p and κ_w) and low structural persistence in price and wage inflation (i.e., small ι and ι_w). For EMEs, we rely on econometric evidence of relatively weaker anchoring of inflation expectations (Bems et al., 2021). Consistent with those findings, we set the parameters controlling the degree to which price and wage inflation depend on their past realizations at higher values than in AEs. Additionally, to reflect the role of the exchange rate as the nominal anchor in EMEs, we assume that wages are indexed to a weighted average of past inflation and change in the nominal exchange rate. The implied slopes of the price and wage Phillips curves are also set notably higher than in the AE case. Turning to the external sector, we assume that import and export prices are consistent with "local currency pricing." In line with empirical evidence (see e.g. Jasova et al., 2019), our calibration implies a significantly higher degree of exchange rate pass-through to import prices in EMEs relative to AEs. In addition, export prices are assumed to be particularly sticky in the foreign currency for EMEs, thus capturing a key feature of "dominant currency pricing" (Gopinath et al., 2020).

It is worth noting that our calibration choices for the nominal rigidities block allow us to closely match the empirical evidence on distinct reactions of AE and EME aggregates to an exogenous, 10

[14] It needs to be stressed that the positive skewness of CPI in our sample of AE and EME economies is not inherited from possibly asymmetric responses of the exchange rate, as the distribution of changes in the latter is close to symmetric.

Figure 2. Transmission of Exchange Rate Shocks: Model vs Data



percent exchange rate depreciation. Figure 2 presents the relevant model-based impulse responses (IRFs), which we discuss in more detail in Section 4. They are plotted against the 90% confidence intervals (shaded area for AEs, dotted lines for EMEs), estimated by Brandao-Marques et al. (2021) for an analogously defined depreciation impulse. As the figure shows, the model IRFs sit comfortably within the estimated ranges for both AEs and EMEs. Importantly, we can successfully account for contractionary depreciations in EMEs and a much larger response of inflation in this group of countries. Finally, due to the use of the Kimball variety aggregator, our model generates larger reactions of prices and output to an exchange rate depreciation compared to an appreciation of the same (absolute) size.

Table 3. Calibration of Financial Intermediation Block

Parameter	AE	EME	Description
m	∞	1.36	Debt limit parameter
Γ	0.02	0.06	Gabaix-Maggiori friction
ω_F	0.75	0.75	Home ownership of financiers
ω_P	0.75	0.75	Home ownership of portfolio investors
ω_B	1	1	Home ownership of banks

An important set of parameters, collected in Table 3, describes frictions in financial intermediation. We assume that sudden stops are episodes specific only to EMEs, for which we set the external borrowing limit parameter m to a number implying that in the steady state the ratio of debt to annual GDP is 12 percentage points below the constraint. This value ensures that, in stochastic simulations that we present subsequently, the emerging market economy stays in the constrained regime for about 3 percent of time, which is a typical target used in the sudden stop literature (Bianchi and Mendoza, 2020). We parameterize the measure of FX market shallowness Γ so that its value for EMEs implies that purchases of foreign currency worth 10% of GDP generate a roughly 15% exchange rate depreciation, in line with evidence presented by Adler et al. (2019). That paper also suggests that AEs typically have deeper FX markets, which we capture by choosing a significantly lower value of Γ. The share of financial intermediaries and portfolio investors owned by home agents (ω_F and ω_P), which effectively determine the economy's exposure to exchange rate risk when its NFA position is not balanced, are both set at 0.75. This allows us to obtain an unhedged FX exposure of a median EME equal to around 16% of GDP, in line with IMF (2021). Note that the value of these two parameters does not matter much for AEs as we calibrated their NFA to be zero on average. In the baseline parametrization we also assume that banks are fully domestically-owned so that $\omega_B = 1$.

The other parameters, which we summarize in Table 4, are the same for the US, as well as the AE and EME economies. We set the intertemporal substitution elasticity σ to 1, consistent with log utility. The Frisch elasticity of labor supply $\frac{1}{\chi} = 1$ and the capital share $\alpha = 0.3$ are in the typical range specified in the literature. As mentioned in the introduction, in both AEs and EMEs we assume full commitment to identical Taylor policy rules (20), in which $\psi_\pi = 1.5$ and

Table 4. Calibration of Other Parameters

Parameter	Value	Description
α	0.3	Coefficient on capital in the production function
χ	1	Inverse of Frisch elasticity of labor supply
χ_0	1	Relative weight on labor disutility (home)
ψ_π	1.5	Coeff. on domestic inflation in Taylor rule
ψ_x	0.0625	Coeff. on output gap in Taylor rule
σ	1	Intertemporal elasticity of substitution
τ_C	0.15	Consumption tax rate
τ_N	0.15	Labor income tax rate
θ_p	0.2	Steady state net markup in product markets
θ_w	0.5	Steady state net markup in labor market
Υ	1.2	Steady state price cost-push term
Υ_W	1.5	Steady state wage cost-push term

$\psi_y = .0625$. We also assume that monopolistic distortions in the product and labor markets are offset by appropriate subsidies, so that $\Upsilon = 1 + \theta_p$ and $\Upsilon_W = 1 + \theta_w$. This ensures that, absent taxation and when financial intermediaries hold zero positions, our model's steady state is efficient.

The exogenous shocks $s_t = \left\{\varsigma_t, \varsigma_t^*, G_t, G_t^*, Z_t, Z_t^*, \Upsilon_{W,t}, \Upsilon_{W,t}^*, \Upsilon_t, \Upsilon_t^*, B_{P,t}, B_{M,t}, \tau_{F,t}\right\}$ are assumed to follow independent AR(1) processes

$$s_t = (1-\rho_s)s + \rho_s s_{t-1} + e_{s,t}, e_{s,t} \sim i.i.d.\left(0, \sigma_s^2\right) \tag{24}$$

where the persistence ρ_s and standard deviation σ_s of each shock process will be discussed when they are used in the analysis. In addition, while running some stochastic simulations, the last two exogenous variables, describing FXIs and CFMs, respectively, will be specified as feedback rules, details of which will also be provided subsequently.

As our model features several occasionally binding constraints (external borrowing limit in the home economy, effective lower bound on the nominal interest rate in the home and foreign economies), it cannot be solved using standard methods. We use instead the Levenberg-Marquardt mixed complementarity problem (LMMCP) solver in Dynare (Adjemian et al., 2011).[15] Accordingly, even though the solution assumes certainty equivalence, it preserves all non-linearities.[16]

[15] As discussed in Kanzow and Petra (2004), the method involves a nonsmooth least squares reformulation of the complementarity problem, based on the Fischer-Burmeister function. The resulting nonsmooth Levenberg-Marquardt-type method turns out to be significantly more robust than corresponding equation-based methods as well as some of the other alternatives that we experimented with.

[16] Note that ignoring precautionary motives does not imply overestimating the unconditional probability of a sudden stop, which is matched by appropriately calibrating m. The solution method does, however, distort the decision rules of risk averse agents, especially when the economy is close to the external debt limit.

4. Monetary Policy Tradeoffs

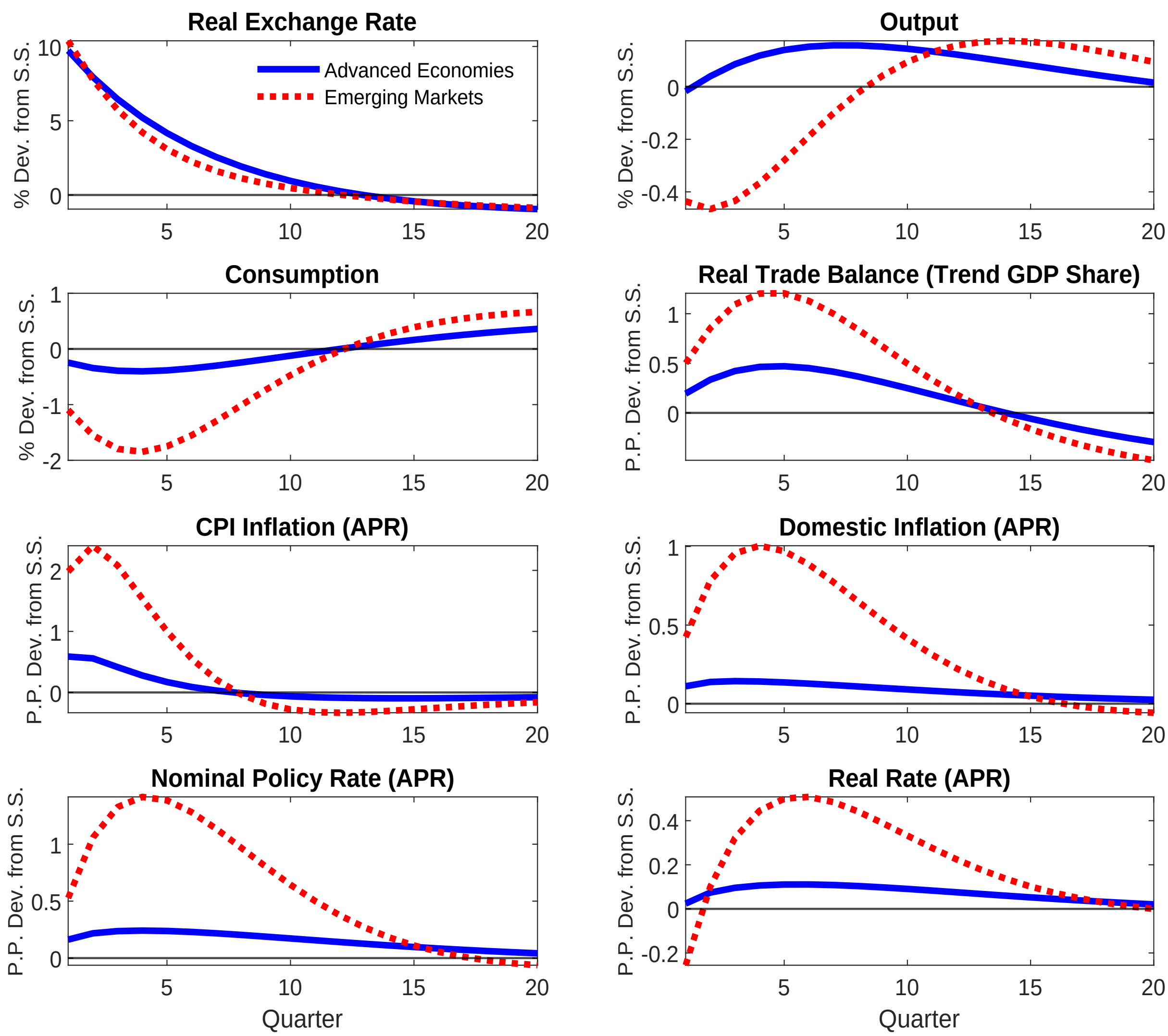
Our model features a number of frictions that can make countries vulnerable to large swings in financial investors' risk appetite, represented in our setup by exogenous portfolio flows $B_{P,t}$. This type of shock is found to be a key driver of exchange rate volatility and disconnect observed in the data, see e.g., Itskhoki and Mukhin (2021). Frictions that affect its transmission, which we treat as reflecting structural features of the economy, and which are typically more severe in EMEs compared to AEs, include shallow FX markets, external borrowing constraints, nominal rigidities and FX mismatches. For example, and as can be seen from Equations (6) and (9), when FX markets are deep (i.e., Γ is low), the economy is better insulated from portfolio flow shocks of a given magnitude. However, and as we will now demonstrate, shock propagation can also substantially depend on the degree to which inflation expectations are anchored.

4.1. **Risk Appetite Shock Transmission: AEs vs EMEs.** Figure 3 compares the effects of an exogenous capital outflow shock generated under the AE and EME calibration. The shock causes portfolio investors to be less willing to hold bonds issued by the home economy, and it is assumed to follow an AR(1) process with persistence of 0.95. It is also scaled so that the real exchange rate depreciates by about 10 percent in AEs. In addition, to highlight the role of frictions other than FX market depth, we temporarily abstract from differences in that parameter. We also assume away the possibility of the EME hitting the external debt limit, postponing the discussion of its role to the next section.

As Figure 3 shows, for the AE the shock does not pose a major policy challenge (blue lines), even when its FX market is relatively shallow. The exchange rate depreciation stimulates net exports, generating an expansion in economic activity. The combination of higher output and higher import prices causes inflation to rise, but, with well-anchored inflation expectations, monetary policy can "look through" the transient rise and focus on output. All told, the shock looks very similar to a standard aggregate demand shock.[17] Needless to say, the same shock would be even less problematic in an AE with a deeper FX market, and in the limiting case of $\Gamma = 0$ would have no effects on such an economy at all.

[17] Note that since portfolio flow shocks do not affect potential output, therefore the reaction of output depicted in Figure 3 coincides with that of the output gap.

Figure 3. Transmission of Risk Appetite Shocks in Advanced and Emerging Markets



The risk appetite shock, by contrast, generates a more difficult policy tradeoff in the EME economy (red dotted line). While the depreciation boosts real net exports, inflation expectations are less well anchored than in the AE, and the exchange rate depreciation has large and persistent effects on inflation. This induces the central bank to tighten monetary policy, which crowds out domestic demand, while higher stickiness of export prices in foreign currency moderates an increase in foreign demand (as in Gopinath et al., 2020). As a consequence, output contracts while inflation rises in parallel – clearly highlighting the potential problems associated with exchange rate depreciations.

Importantly, the disparate responses of output and inflation in AEs and EMEs are almost entirely due to differences in parametrization of the nominal rigidities block (described earlier in Table 2). More specifically, frictions representing less well-anchored inflation expectations, namely a higher degree of intrinsic persistence in price and wage setting, as well as stronger pass-through of the exchange rate to import prices, play a key role. In contrast, FX mismatches, represented by the negative net foreign asset position in EMEs, do not amplify the contractionary nature of exchange rate depreciations. This, however, is only the case because the debt constraint is slack. As we show subsequently, had adverse balance sheet effects caused the economy to hit the debt limit, then output would have contracted even more substantially.

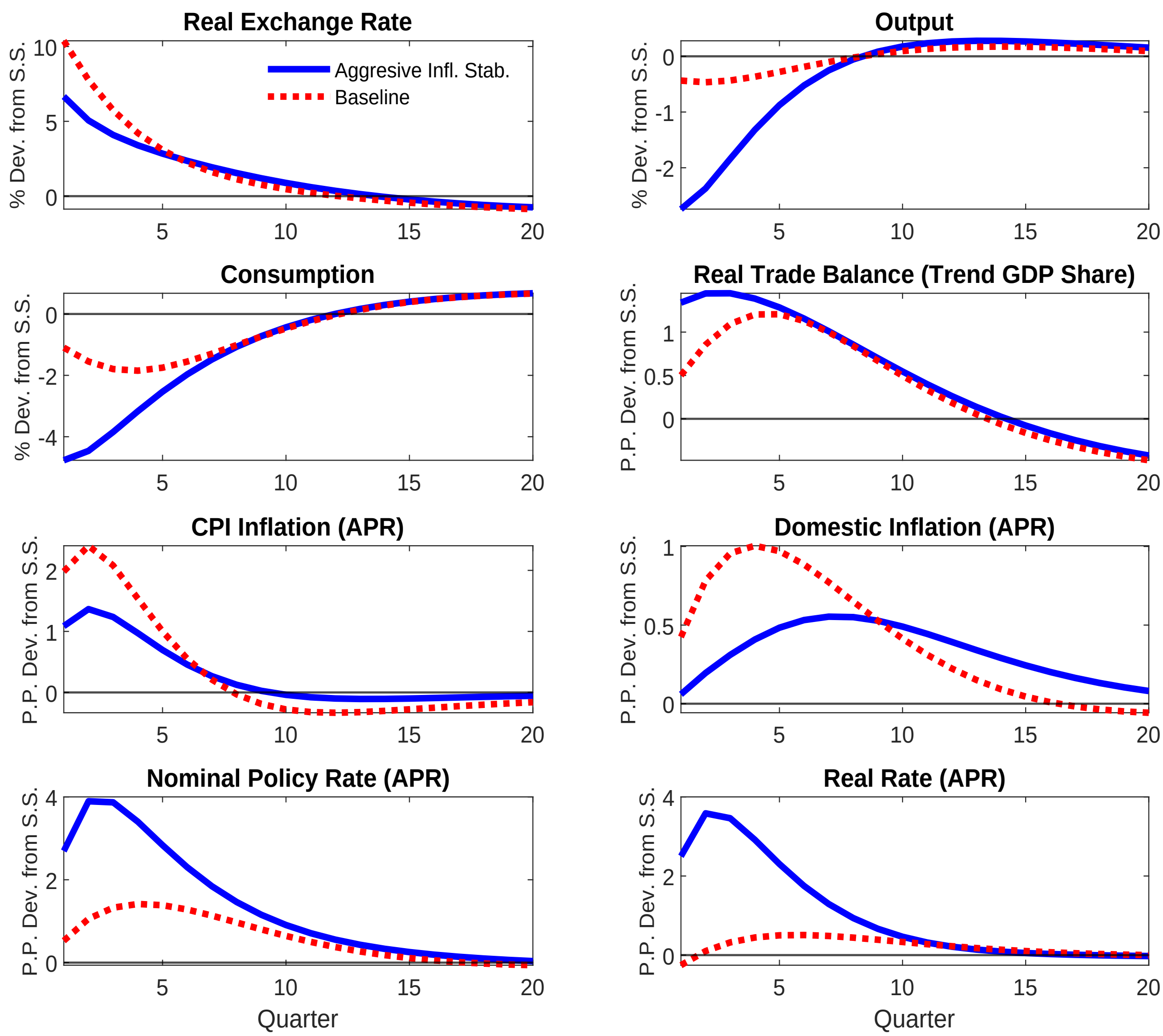
Our simulations illustrate that EMEs may face difficult policy tradeoffs in the face of capital flow shocks that generate large exchange rate movements. Figure 4 contrasts the effects of the risk appetite shock, sized as in the previous section, under two different policies. The red-dotted lines depict the effects under the baseline calibration (EME central bank follows a standard Taylor rule, same as in Figure 3). In this case, the central bank keeps output relatively stable but allows the exchange rate depreciation to have large and persistent effects on inflation, with potential adverse reputational implications. By contrast, tighter policy (solid blue lines) – i.e., more vigorous responses to both domestic and imported inflation – limits the size and persistence of increases in inflation, but generates a markedly sharper output contraction.

The figure also helps explain why using the policy rate to lean against exchange rate depreciation caused by risk appetite shocks is not an attractive option. In particular, for given FX market depth Γ, the UIP condition (6) implies that stabilization of the nominal exchange rate increases the degree to which portfolio shocks feed through to the domestic interest rate, potentially contributing to huge fluctuations in economic activity.

4.2. **"Flight to Safety" Episode.** We now consider a "flight to safety scenario," where an adverse external shock to global risk tolerance is coupled with a sharp fall in global output, aspects of which are reminiscent of the onset of the COVID pandemic. More specifically, apart from the portfolio capital outflow shock considered above, the exercise is driven by negative, persistent shocks to productivity and intertemporal preferences occurring domestically and abroad.[18] In this way we can capture the world-wide nature of the shock and account for both the supply and demand

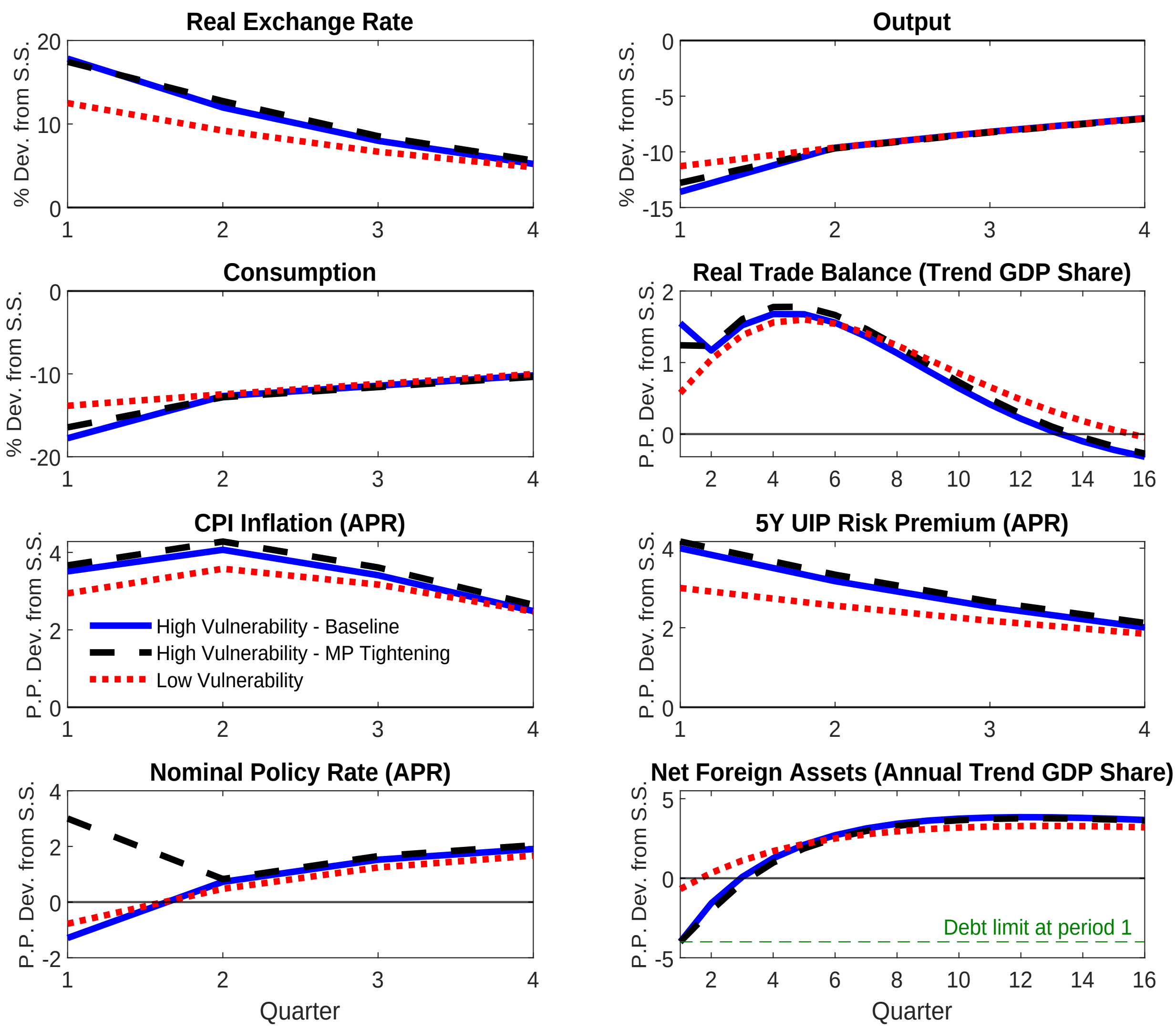
[18] All shocks follow AR(1) specifications with root 0.95, except for demand shocks that we assume to be somewhat less persistent (root 0.80).

Figure 4. Risk-Premium Shocks in Emerging Markets for Alternative Policy Rules



aspects of social distancing and lockdown measures (see e.g., Eichenbaum et al., 2020; Guerrieri et al., 2020), both of which are necessary to ensure a moderate response of global inflation despite a sharp contraction in economic activity. To highlight how initial conditions, and especially FX mismatches, influence transmission, we compare a "vulnerable" emerging market economy, with high net foreign liabilities and a shallow FX market (solid blue lines), to a "less vulnerable EME," with low net foreign liabilities and ample FX liquidity (red-dotted baseline).

Figure 5. Drop in Risk Appetite and External Demand in EMEs with Different FX Exposures



As shown in Figure 5, while we assume identical shocks, the decline in global risk tolerance engenders a much sharper rise in the UIP risk premium and larger exchange rate depreciation in the more heavily indebted, vulnerable EME. While the greater depreciation, due in part to the assumption of a shallower FX market, provides a larger boost to net exports, it also negatively hits domestic agents, as their balance sheets are characterized by FX mismatches. The resulting sharp increase in net foreign liabilities raises the risk of hitting the external borrowing limit. If this risk materializes, as is the case in Figure 5, the vulnerable EME experiences a "sudden stop," characterized by a sharp increase in credit spreads, contraction in economic activity, and a current account reversal.

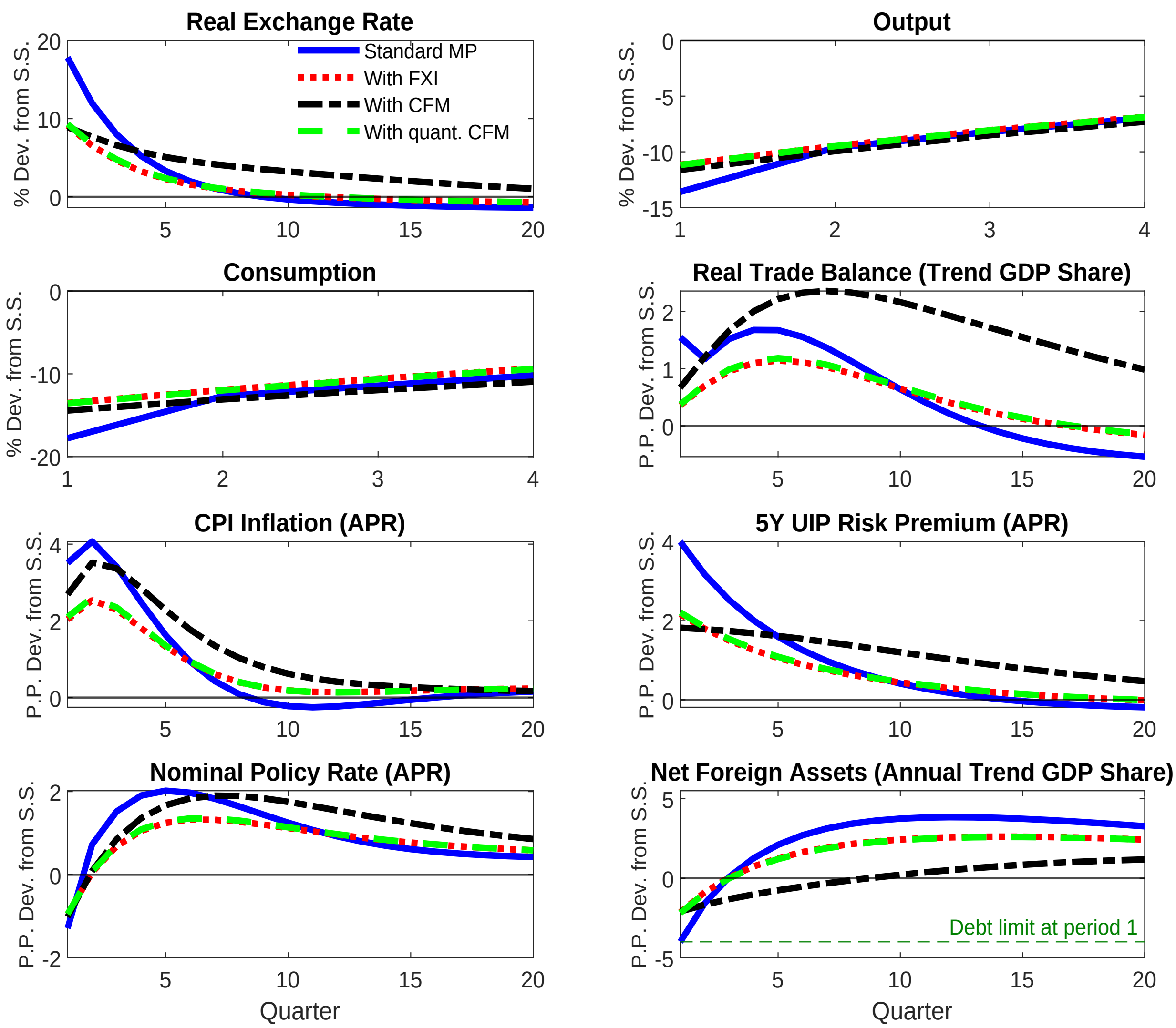
Once in a sudden stop, the policy dilemma facing EME monetary authorities is modified. To stimulate economic activity, one would actually need to tighten monetary policy, as this would limit the exchange rate depreciation, thus mitigating adverse balance sheet effects that were exacerbating the recession. The outcomes of such an intervention are plotted as dashed black lines in Figure 5, and these show that a large policy rate hike is needed to achieve a modest reduction in the output contraction. Moreover, as such an intervention slows down accumulation of net foreign assets, it pushes the UIP premium up even more. Overall, monetary policy is less powerful during sudden stop episodes and, as we shall now demonstrate, may be inferior to some alternative tools.

5. FXI and CFM Interventions

The scenarios discussed in the previous section illustrate that conventional monetary policy performs rather poorly in simultaneously achieving the central bank's inflation and output gap stabilization objectives, especially whenever inflation expectations are not solidly anchored, and with additional complications arising on account of "sudden stops." This, in turn, provides a potential rationale for using additional tools, which may improve output-inflation trade-offs by reducing the risk of a de-anchoring of expectations, thus allowing monetary policy to focus more on output stabilization.

To compare the efficacy of additional policy options, we now analyze how FXI and CFMs affect the policy frontier of a vulnerable EME. Figure 6 compares the consequences of the same shock considered in Figure 5 for a vulnerable EME that uses only monetary policy (solid blue lines), to cases in which the authorities also utilize FXI sales (red dotted lines), or use CFMs to lower the tax on capital inflows (the black dashed line). Additionally, the green dashed line depicts a CFM variant assuming that capital inflow taxes are rebated back in a lump sum fashion to agents paying them, so that the policy does not generate cross-country wealth transfers, and in that sense resembles (soft) quantity rather than price restrictions. To facilitate comparisons, we calibrate the magnitude of the three types of interventions such that they generate the same reaction of the real exchange rate on impact, and that they share the same degree of inertia (the autoregressive coefficient set to 0.9). Notably, and in contrast to Section 6, which focuses on intervention *rules*, our aim here

Figure 6. Effects of FXI and CFM in Adverse Scenario for EME with High FX Debt



is mainly to build intuition on policy transmission, which we do by assuming unanticipated but persistent interventions.

As Figure 6 demonstrates, FXIs can significantly reduce the depreciation of the exchange rate, which allows monetary policy to be more accommodative on account of less pronounced inflationary pressures. The upshot is that this policy allays the "stagflationary" effects of the crisis scenario, reducing inflation while boosting output and exerting even larger expansionary effects on domestic demand (since real net exports improve less). The gains in macroeconomic stability are particularly large if the intervention is strong enough for the economy to avoid a sudden stop, which is the case in the simulation shown in Figure 6. In the medium-run, however, the stronger exchange rate and domestic demand under FXI translate into less trade balance improvement, and, consequently, a slower accumulation of net foreign assets. This creates an intertemporal tradeoff for policymakers, as preventing a deep recession today comes at the cost of higher future vulnerability.

Turning to CFMs, Figure 6 shows that they too can successfully limit the magnitude of an exchange rate depreciation and thus have the potential to prevent a sudden stop in a vulnerable EME. However, deploying CFMs is also associated with a much slower accumulation of net foreign assets, which considerably worsens the intertemporal tradeoff. As the UIP risk premium stays elevated for longer, the exchange rate remains weak and inflation high over the medium run, which depresses consumption and improves the trade balance.

Fundamentally, the main reason why FXIs and CFMs end up having different effects is because they have different income implications for countries implementing them. To understand why, recall that the NFA law of motion (Equation 23) implies that supporting the exchange rate using CFMs requires a decrease in the tax on capital flows (or even subsidizing them), which is associated with negative income effects for the intervening country. In contrast, while deploying FXI also creates aggregate income effects (unless $\omega_F = 1$), their magnitude is much smaller. Indeed, as shown in the figure, assuming that CFMs take the form of quantity rather than price restrictions would eliminate most of the differences in income effects, and would generate outcomes very similar to those we document for foreign exchange interventions.

6. CFM and FXI Policy Rules

In addition to improving standard monetary policy tradeoffs in episodes of swings in risk appetite and financial tightening, CFM and FXI policies may play an insurance role by limiting the endogenous buildup of risk associated with higher foreign indebtedness. This may be achieved by responding to "favorable" risk premium shocks, associated with capital inflow surges, which cause the exchange rate to appreciate, or by responding directly to accumulation of foreign debt. In the parlance of Figure 6, doing so helps ensure a safe distance from the debt limit, making the economy less vulnerable to a sudden stop. Even so, this insurance may come at a cost, as such policies curb international borrowing, part of which helps smooth consumption. Moreover, as alluded to before, FXI and CFM interventions during periods of capital outflows engender an intertemporal tradeoff as, even though they improve financial conditions, they also preclude deleveraging, thus increasing the probability of future financial stress.

To provide a quantitative analysis of these tradeoffs, we now move away from one-off interventions and analyze the implications of implementing FXIs and CFMs systematically. We first present the policy rules considered before discussing how they play out during the crisis scenario, and how they can improve over the baseline in which only standard monetary policy is used.

For foreign exchange interventions we posit that

$$\tilde{B}_{M,t} = \psi_{m,1}\tilde{B}_{P,t} - \psi_{m,2}\Theta_t, \tag{25}$$

where $0 \leq \psi_{m,1} \leq 1$, $\psi_{m,2} \geq 0$, and where the tildes indicate deviations of variables from steady state, normalized by the steady state level of output in nominal terms, e.g. $\tilde{B}_{M,t} \equiv \frac{B_{M,t}-B_M}{YP_{D,t}}$. The rule thus speaks to two motives for intervening in foreign exchange markets. The first is related to inefficient fluctuations in exchange rates arising from financiers' limited risk-bearing capacity. Whenever $\psi_{m,1} > 0$, the central bank intervenes in the FX market in response to portfolio capital flows, affecting the amount of funds intermediated by financiers, and hence at least partly offsetting the corresponding movements in the UIP premium.[19] "Sudden stops", which occur when the economy hits the debt limit, and which lead to an increase in the borrowing spread, are the second key consideration. When $\psi_{m,2} > 0$, the central bank sells FX reserves in an attempt to compress positive spreads. This leads to an appreciation of the local currency, decreasing the value of foreign debt per unit of domestic production and ultimately limiting the sudden stop severity.

As regards the feedback rule for CFMs, we first note that setting $\tau_{F,t} = \Gamma\left[\psi_{m,1}\tilde{B}_{P,t} - \psi_{m,2}\Theta_t\right]$ would generate outcomes similar to those under the FXI rule in Equation (25), especially if the income effects associated with taxing foreigners were neutralized. In line with the discussion in the preceding section, this is because both instruments affect the UIP condition, and hence also the exchange rate, in a similar fashion. Arguably, such a rule is of limited practical interest, however, as it might imply subsidizing capital inflows as well as excessive volatility in what is essentially a fiscal instrument. For those reasons, and in line with a rich macroprudential literature, we assume

[19] In the limiting case, when $\psi_{m,1} = 1$ and $\psi_{m,2} = 0$, inefficient movements in the UIP premium caused by exogenous swings in appetite for home currency assets are fully offset. This follows from the fact that $\tilde{B}_{M,t} = \tilde{B}_{P,t}$, together with Equations (9) and (6), implies that $\tilde{B}_{F,t} \equiv \tilde{B}_t$.

instead that

$$\tau_{F,t} = \max(0, -\psi_f \tilde{B}_t), \tag{26}$$

where $\psi_f \geq 0$. This specification of the CFM rule can be thought of as targeting overborrowing arising due to the pecuniary externality associated with the debt limit. It achieves that by leaning against the buildup of net foreign liabilities, essentially weakening the local currency to help improve the domestic economy's international competitiveness. It has a precautionary flavor as it helps keep the economy further away from the constraint, reducing the probability of a "sudden stop." Importantly, and in line with the results in Chang (2019), the rule is asymmetric, i.e., it does not lean against the accumulation of net foreign assets above their steady state level. The non-negativity constraint on the tax rate also implies that CFMs can be used to limit capital inflows, but not to encourage them by effectively subsidizing domestic bond returns.

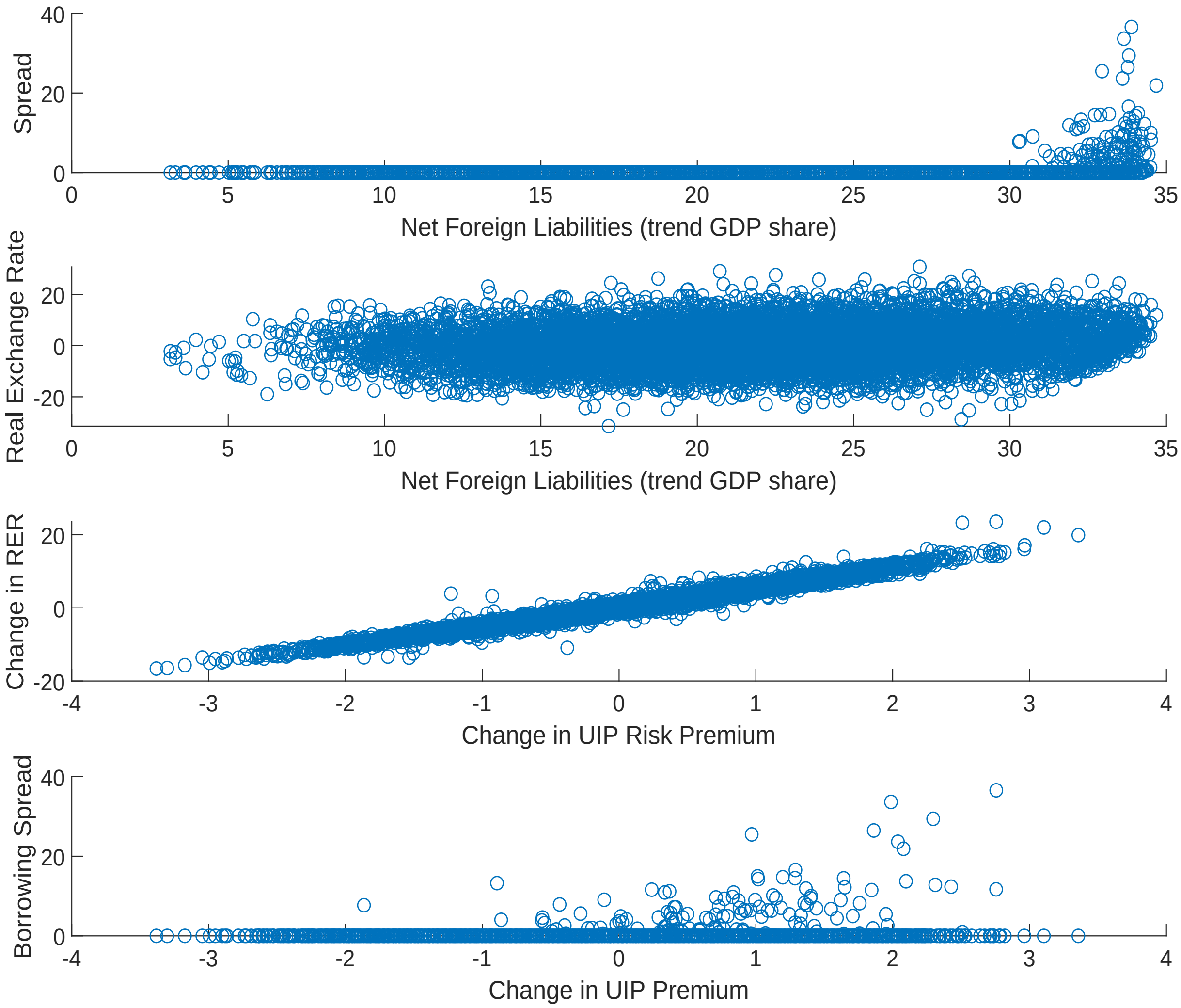
6.1. **Simulation Setup.** To run the simulations, we first need to take a stance on the drivers of macroeconomic fluctuations in the home and foreign economies. We focus on shocks to intertemporal preferences, productivity and wage markups, as they are representative of disturbances to demand, as well as efficient and inefficient (cost-push) shocks to supply, respectively. Additionally, we allow for exogenous variation in portfolio flows, which plays a crucial role in accounting for high exchange rate volatility.

The properties of stochastic shocks are calibrated using the simulated method of moments. For the US, we focus on output, inflation and short-term interest rates. The same series are selected for the representative EME economy, except that we additionally use the effective real exchange rate. The matched moments include: variances, first-order autocovariances, covariances with output, and covariances with their foreign counterparts. Using a small open economy version of our model allows us to proceed in two steps: first calibrating shocks specific to the foreign country, effectively treating it as closed; and then, conditional on the outcomes from the previous step, focusing on domestic shocks.[20] A description of the data transformations and outcomes of the moment matching procedure is provided in Appendix C.

6.2. **Unconditional Distributions.** Equipped with a fully calibrated stochastic specification, we first simulate a long-sample of $10,000$ observations in a version of the model, in which FXI

[20] To better describe international comovements, we allow preference and productivity shocks to spill over from the large to the small economy.

Figure 7. Relationship Between Selected Simulated Variables



and CFMs are not actively deployed (the rules are switched off) and only the policy rate is used for macroeconomic stabilization. Figure 7 explores linkages between key financial variables and presents baseline results. The upper panel highlights the fact that chances of severe financial stress (and high borrowing spreads) are low if the economy's foreign debt is at moderate or low levels. Clearly, however, the probability becomes much more elevated as net foreign liabilities expand and the economy edges towards "sudden stop" territory. The second panel shows that the relationship between foreign debt and the level of the real exchange rate is positive but not particularly strong.As panel three makes clear, this is because the exchange rate is mainly driven by risk appetite shocks, which, by construction, hit the emerging market economy independently of its net foreign asset position.[21] Finally, the bottom panel illustrates the fact that financial crises occur mainly when the UIP premium is elevated, as such episodes are usually characterized by capital outflows and exchange rate depreciations.

Figure 8. Unconditional Distributions in the Model without FXI and CFM

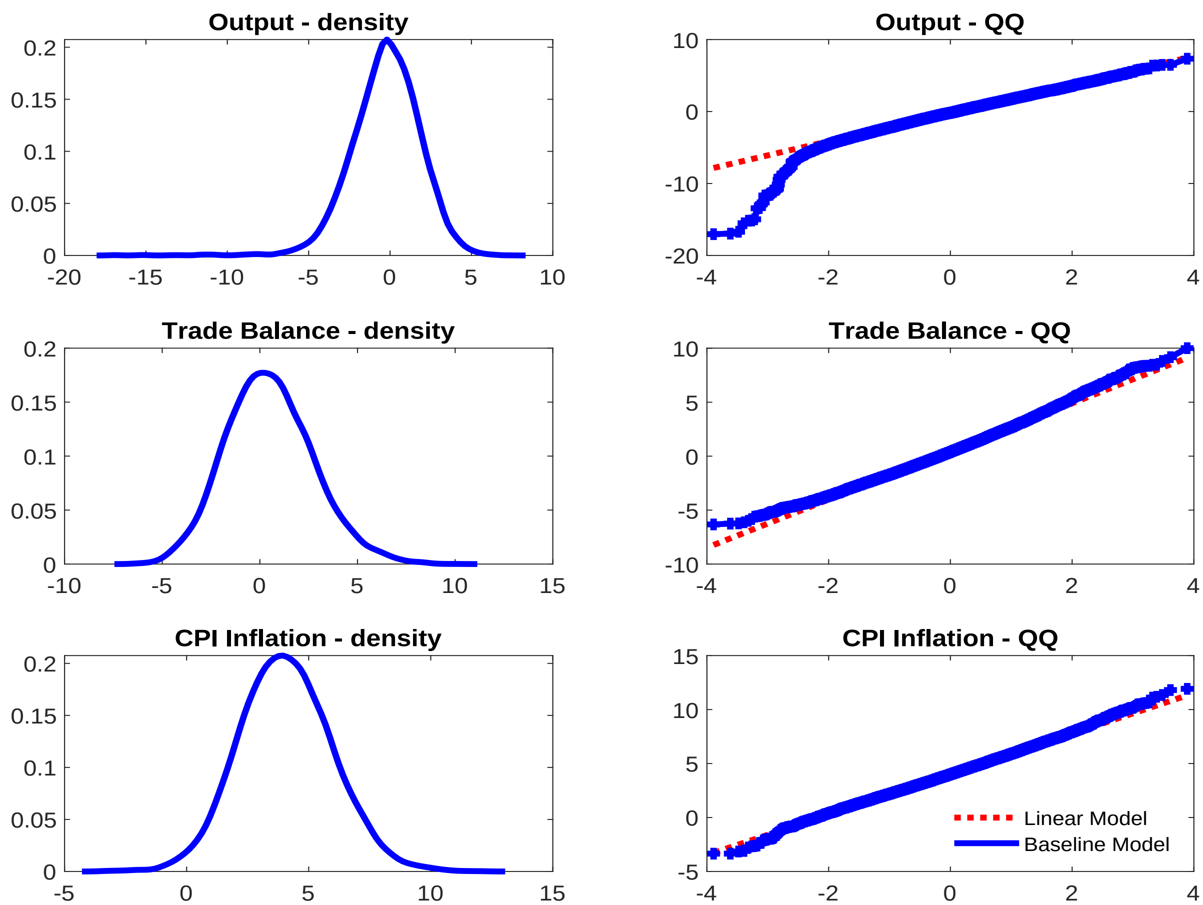


Figure 8 presents the probability distributions of key model variables, both in the form of standard kernel density estimates as well as quantile-quantile plots, meant to highlight non-normal tail dynamics. The first row shows that output is clearly "at risk" in vulnerable EME economies, with "sudden stops" generating a significantly heavier left tail. An occasionally binding debt limit

[21] This is in line with empirical evidence showing high synchronization of capital flows among very diverse EME economies.

also explains the asymmetry in the trade balance (second row) as it effectively curbs high deficits, occasionally leading to strong surpluses during "sudden stop" episodes. This also means that the trade balance works as an automatic stabilizer, confirmed by the fact that domestic absorption (not shown) has an even more negative left skew than output.

Interestingly, the distribution of CPI inflation is leptokurtic, with both the left and right tails more pronounced than its normal counterpart. The right tail is somewhat heavier and contributes to an overall positive skew. It arises as a consequence of the Kimball aggregator, which, as discussed, tends to generate disproportionately large increases in the price level whenever marginal cost is high or the exchange rate depreciates.[22] The somewhat heavier left tail, in turn, is a consequence of the occasionally binding debt limit, which can markedly depress economic activity and marginal cost. Notably, however, the impact of "sudden stops" on inflation is much smaller than on output. This is because they are typically accompanied by exchange rate depreciations, which push inflation up, while the Kimball aggregator makes prices less sensitive to cost when economic activity is low.

6.3. **The Ergodic Implications of FXI and CFM Policy Rules.** We now analyze the implications of authorities adjusting FXI and CFMs systematically, in response to fluctuations in the UIP premium, foreign debt and private borrowing spreads, as specified in Equations (25) and (26).

Importantly, while the policy rules we consider are not optimized, we choose their coefficient values such that they imply reasonably-sized interventions. More specifically, the standard deviation of FX reserves (expressed relative to annual GDP) implied by our most aggressive FXI rule that responds to portfolio capital flows is about 5 percent, which can be compared to the steady state level of this variable equal to 20 percent (see Table 1). As regards the capital flow tax rate, its standard deviation is equal to about 0.5 percent (annualized) when the CFM rule is used alone, and about half of that when used together with FXI.[23]

We evaluate rule performance by comparing how they affect a number of key statistics relative to the standard monetary policy benchmark. These include the fraction of time at the borrowing limit ("sudden stop") or when agents' consumption is constrained by the limit binding or being

[22] As in the data, however, positive skewness in inflation is not coincident with skews in the distribution of nominal exchange rates, which are virtually zero in our simulations.

[23] In our simulations, FX interventions never lead the central bank to run out of reserves. We stress that this is an equilibrium outcome, specific to the model parametrization and rules considered, rather than an assumption. Expressed alternatively, more aggressive rules, greater shock volatility, or lower steady state reserves could all occasionally lead to FX reserve depletion.

expected to bind ("financial stress"). We use a utility-based welfare criterion to gauge the benefits of the alternative rules that actively adjust FXIs and CFMs. The welfare gains – relative to a standard monetary policy rule in which the central bank refrains from using these tools – are expressed in consumption equivalent units. For robustness, we also report gains using a standard quadratic loss function that penalizes output gap and inflation gap volatility.[24] It is important to stress that, while the results presented in this section are obtained assuming the baseline calibration of the monetary policy rule, our conclusions are robust to using an optimized version of this rule that additionally allows it to react to the exchange rate or to the UIP premium. See Appendix D for details.

The main results of our experiments are reported in Table 5. The policy rule based on setting $\psi_{m,1}$ in Equation (25) to 0.5 (Column 3 in Table 5), the effects of which we additionally illustrate in Figure 9 using density plots, is beneficial for utility-based welfare for two key reasons. First, it calls for deploying FXIs to lean against inefficient movements in the UIP premium induced by swings in investor risk appetite. As such shocks are major drivers of movements in the exchange rate, the volatility of the latter is reduced substantially under the rule, and, relatedly, the rule reduces the volatility of inflation and the trade balance. Second, the rule has a precautionary flavor, as the fall in the volatility of the UIP premium helps reduce the probability of financial stress, with the latter largely driven by risk appetite behavior. In fact, in our setup, the FXI policy rule completely eliminates "sudden stops," with the associated reduction in the volatility and downward skew in output contributing to greater macroeconomic stability. As both inflation and output become less volatile, welfare clearly improves also under the quadratic loss criterion.

While the rule is beneficial on both grounds, it turns out that it would continue to improve welfare even if the precautionary rationale were entirely absent. This follows from noting that its benefits, on both measures considered, significantly exceed those associated with completely eliminating the debt limit, shown in the first column of Table 5. This observation underscores the fact that there are substantial benefits of smoothing inefficient fluctuations in the UIP risk premium, which are costly irrespective of whether or not they occasionally precipitate a crisis.

As alluded to previously, CFMs could in principle also be utilized to address both shifts in investor appetite and to limit the risk of "sudden stops." However, given that it seems likely in

[24] Specifically, the welfare calculations are based on mean period utility, while the loss function is defined as the sum of squared deviations of (annualized) inflation from the target and output from its potential level, with the relative weight on the latter equal to one-third.

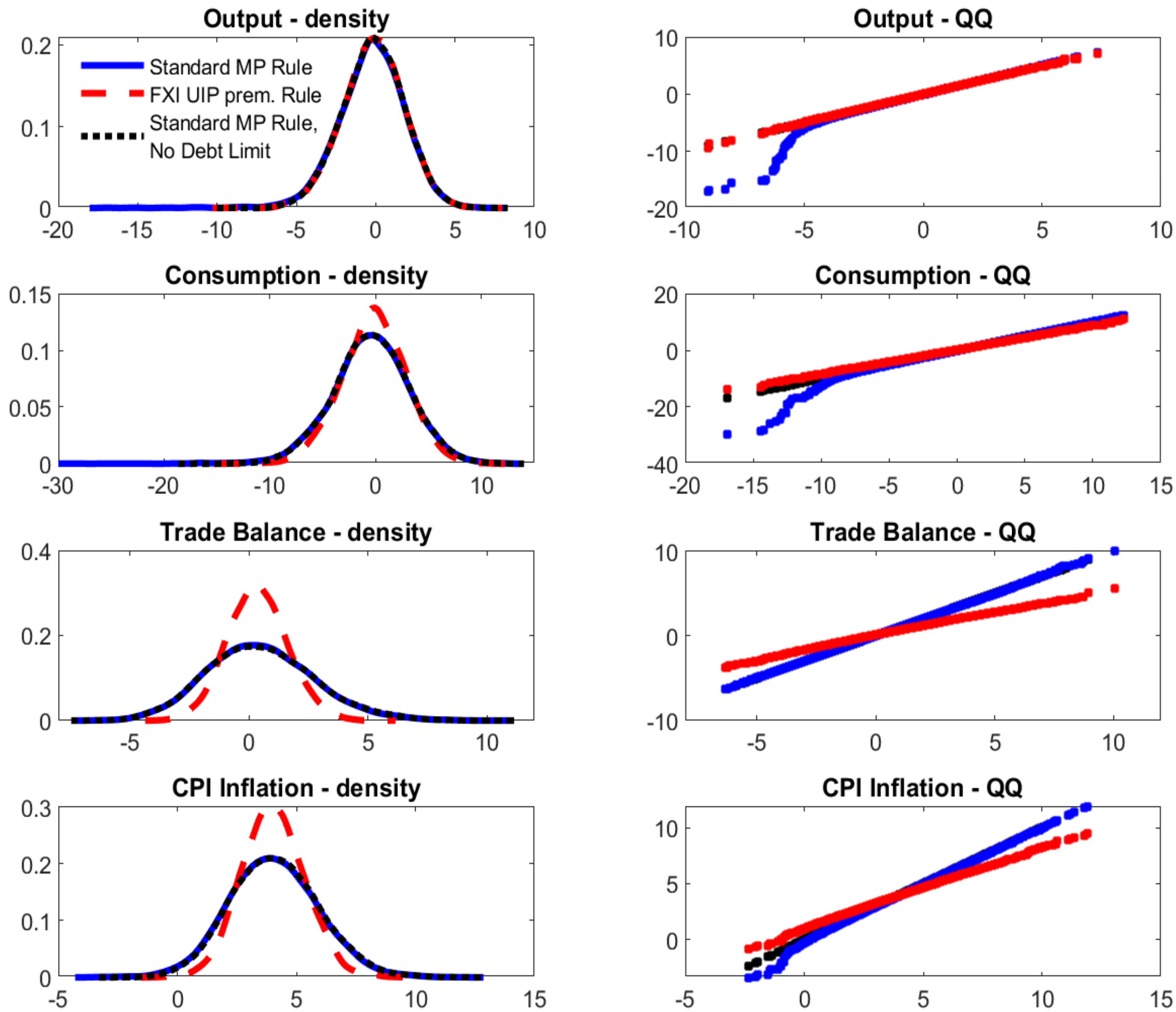
Table 5. Evaluation of FXI and CFM Policy Rules

No debt limit	Occasionally binding debt limit				
Standard MP Rule	Standard MP Rule	FXI UIP Prem. Rule	CFM Rule	FXI UIP & CFM Rules	FXI Spread Rule
		Sudden Stop Probability			
0.00	1.39	0.00	0.73	0.00	1.44
		Financial Stress Probability			
0.00	2.98	0.00	1.52	0.00	3.04
		Borrowing Spread (mean)			
0.00	0.09	0.00	0.05	0.00	0.09
		Output (mean)			
-0.17	-0.26	-0.16	-0.23	-0.17	-0.26
		Output (std)			
1.95	2.10	1.92	2.00	1.92	2.12
		Output (skewness)			
-0.11	-0.76	-0.13	-0.41	-0.13	-0.85
		CPI Inflation (std)			
1.87	1.90	1.33	1.83	1.32	1.91
		CPI Inflation (skewness)			
0.21	0.13	0.13	0.21	0.12	0.11
		Real Exchange Rate (std)			
7.50	7.49	4.23	7.27	4.14	7.51
		Welfare Gain Relative to Standard MP Rule			
0.03	0.00	0.27	0.16	0.34	-0.01
		Loss Decrease Relative to Standard MP Rule			
5.24	0.00	35.67	6.59	36.25	-0.92

Notes: Output and real exchange rate are expressed as 100 times log. Spread, probabilities and loss decrease are in percent. Inflation is expressed as an annualized percentage rate. Welfare gain is expressed as permanent consumption equivalent, in percent. The policy variants correspond to the following parameterizations: (i) Standard MP Rule: all feedback parameters in policy rules set to zero, except for ψ_π and ψ_x; (ii) FXI UIP Premium Rule: $\psi_{m,1} = 0.5$; (iii) CFM Rule: $\psi_f = 0.01$; (iv) FXI Spread Rule: $\psi_{m,2} = 1$;.

practice that FXI could be deployed more easily to respond to the former, we focus attention on the scope for using CFMs to mitigate the frequency of financial crises. This analysis is also interesting insofar as some vulnerable economies have small FX reserves, and hence limited scope to use FXI to allay portfolio outflows and exchange rate pressures during a crisis. In this vein, Column 4 in Table 5 shows the benefits of using this instrument in a precautionary way by leaning against the accumulation of net foreign liabilities, which is implemented by setting ψ_f in Equation (26) to 0.01. The policy significantly reduces the frequency of “sudden stops” and brings more stability to economic activity. It also generates substantial welfare gains, which exceed those associated with

Figure 9. Unconditional Distributions in the Model with and without FXI rule



eradicating sudden stops (first column). Most of these additional gains can be attributed to extra revenue collected by taxing foreign investors whenever net foreign liabilities rise above their steady state level. Moreover, by decreasing the average level of foreign debt, the rule also compresses the UIP premium and hence makes the real exchange rate stronger on average, thus addressing the terms of trade externality discussed in the NOEM literature (Corsetti et al., 2010).

Interestingly, and even though the FXI rule has the benefit of completely eliminating "sudden stops," using it in conjunction with the aforementioned CFM rule, which one could naturally motivate by overborrowing, generates even larger gains. This is illustrated in Column 5 of Table 5, which shows that these two rules combined make for a potent policy mix. Their complementarity is particularly effective when the economy is close to its external debt limit. In such circumstances, the CFM rule facilitates gradual decumulation of net foreign liabilities by keeping the exchange rate weak, while the FXI rule protects the economy against abrupt portfolio capital outflows that could otherwise disrupt this smooth adjustment by triggering a "sudden stop."[25] It is important to add that the scope for synergies between FXI and CFMs could be even larger in the presence of sectoral vulnerabilities, which CFMs may be better suited to deal with. In addition, problems with identifying the "portfolio component" of capital flows, as well as a stochastic debt limit, would both make it harder for FXIs to eliminate financial stress so efficiently, increasing the relative role of CFMs in stabilizing the economy.

Although our results suggest considerable scope for improving monetary autonomy by offsetting shocks to investor preferences (in practice, typically involving FXI), the stochastic simulations suggest possible limitations of using FXI and CFMs during crisis periods. In this vein, Column 6 in Table 5 illustrates the effects of an FXI rule responding to spreads, which postulates interventions only in reaction to the economy hitting the occasionally binding borrowing limit.[26] The policy attempts to prop up the exchange rate by selling FX reserves ($\psi_{m,2} = 1$ in Equation 25) to at least partly protect the balance sheets of agents with foreign exchange mismatches. By doing so, it attenuates the spike in credit spreads once the "sudden stop" occurs, making these episodes less painful. Even so, this prevents the needed adjustment in external debt and, by making the exchange rate stronger, it undermines the economy's external competitiveness, slowing down accumulation of net foreign assets during the recovery phase. As suggested by the discussion of intertemporal tradeoffs in the previous section, and as shown by the entries in Table 5, this rule makes the economy more vulnerable to financial crises in an ergodic sense, reducing the average level of output while amplifying its volatility and skewness. Thus, unsurprisingly, both the utility-based welfare criterion and the simple loss function point to, on balance, detrimental effects of such a rule.

[25] Of course, as alluded previously, welfare benefits accruing from the taxation of foreign investors and from addressing the terms of trade externality are also at play here and contribute to the welfare gains.

[26] A monetary policy rule additionally responding to spreads, or a CFM rule responding only to this variable, would yield qualitatively similar results.

6.4. **Additional Discussion.** In interpreting the results presented above, it is important to note that reacting directly to spreads may be welfare improving under different circumstances. As might be surmised from the impulse responses in Figure 6, FXI and CFM interventions can be beneficial during "sudden stops" if future shocks are unlikely to drive the economy back into crisis; and more generally, the welfare benefits of using these tools in a crisis depend both on the distribution of shocks, initial conditions, and structural features of the economy. In this vein, we have found that if sudden stops were relatively more disruptive for the economy, which we can proxy by assuming a sufficiently high share of foreign ownership of domestic banks $(1-\omega_B)$, then the welfare effects associated with rules only responding to spreads could flip sign and become positive. Overall, however, a key upshot is that it is critical to use stochastic simulations to assess the benefits of such policies, as their net benefits may be smaller than suggested by the on-impact effects.

Moreover, the implicit assumption while specifying the FXI rule (25) was that the central bank is able to precisely determine the UIP premium component attributable to portfolio investors' actions $(B_{P,t})$. If that were not the case, then a rule responding to $\tilde{B}_t + \tilde{B}_{P,t}$ would yield outcomes somewhat inferior to the one considered here, giving a greater potential role to complementary deployment of CFMs. Finally, if the UIP premium is difficult to estimate, some (but smaller) welfare gains can still be achieved by using an FXI rule that responds directly to the exchange rate, but only if portfolio flows account for a sufficiently large share of fluctuations in this variable, so that the benefits of reducing fluctuations in the UIP premium outweigh the losses from preventing efficient exchange rate adjustments in response to other shocks.

7. The Effects of FXI in a Liquidity Trap

We conclude by applying our model to an advanced economy to show that, under some conditions, FXI can potentially be useful when policy space is limited.[27] The example considered effectively illustrates Svensson's "foolproof way" (Svensson, 2003), whereby FXIs help facilitate exit from a liquidity trap by jump-starting inflation and reducing real interest rates.

7.1. **Liquidity Trap Scenario.** To construct our baseline, we follow the fiscal multiplier literature (e.g. Christiano et al., 2011; Erceg and Linde, 2014) and assume that the economy is hit by a mix of large adverse global and domestic shocks that trigger a deep recession and drive the nominal

[27] This could happen, for example, if policy rates were at their effective lower bound (ELB) and if unconventional monetary policy tools were insufficient to provide the stimulus required to stabilize inflation.

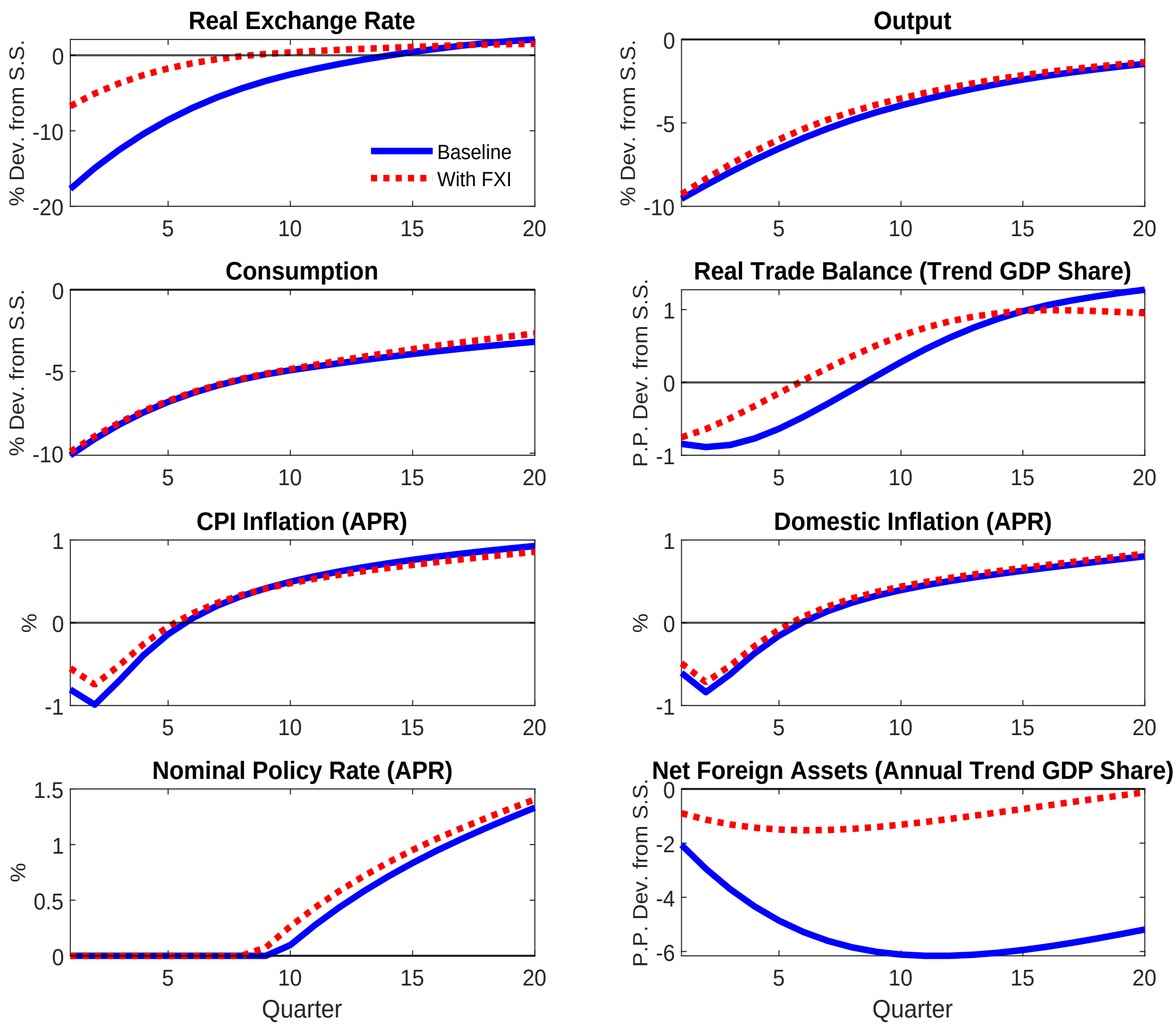
interest rate to zero (the assumed lower bound). The particular mix of shocks that we consider comprises negative realizations of home and foreign preference shocks, both of which follow AR(1) processes with root 0.95. We also assume a positive risk appetite shock (i.e. flight to safety flows, with root 0.90), which puts appreciation pressure on the exchange rate.[28] Against this backdrop, in which output and inflation are well below their target levels, the central bank purchases FX to boost inflation and economic activity. The intervention is also assumed to follow a fairly persistent AR(1) process (root of 0.95). As we have in mind an AE with fairly deep FX markets, which we model by resetting the steady state Gabaix-Maggiori friction Γ from the benchmark value of 0.06 to 0.02, the assumed magnitude of the FX purchases is large, amounting to 20% of annual trend GDP in the first quarter of the intervention.

Figure 10 presents the results for the AE calibration of our model. The blue solid lines show the baseline, in which the adverse global shocks lead to a deep recession and a fall in inflation that is reinforced by a domestic currency appreciation. Inflation falls below zero, output falls by about 8 percent, and the policy rate is pinned at zero. The red dotted line shows the effects of sterilized foreign exchange purchases. The depreciation induced by the FXI cushions the blow of recessionary shocks by raising net exports and stimulating output. Moreover, because the central bank does not react to higher inflation by raising policy rates until the ELB stops binding (which occurs somewhat earlier under the assumed foreign exchange intervention), real interest rates decline, which crowds in domestic demand. Furthermore, and importantly, the weaker exchange rate keeps CPI inflation closer to its target during the crisis, implying that the intervention helps stabilize both inflation and output.

While in the simulations above we focused on the case of a representative AE, some emerging market economies can also be close to their effective lower bound on policy rates. With more responsive inflation expectations, they may derive even more of a boost to inflation and output through the use of FXIs (or CFMs, which can elicit similar effects). For example, under our EME calibration, but keeping the initial conditions and FX market depth unchanged, the same-sized intervention as in Figure 10 would have notably larger stimulative effects on domestic absorption and the output gap, both of which would mainly be attributable to larger second round effects on inflation. This implies that FXI and CFMs may also be useful in alleviating monetary policy

[28] Erceg and Linde (2014) prove that, up to a first order approximation, the results are robust to different types of shocks used to generate the baseline.

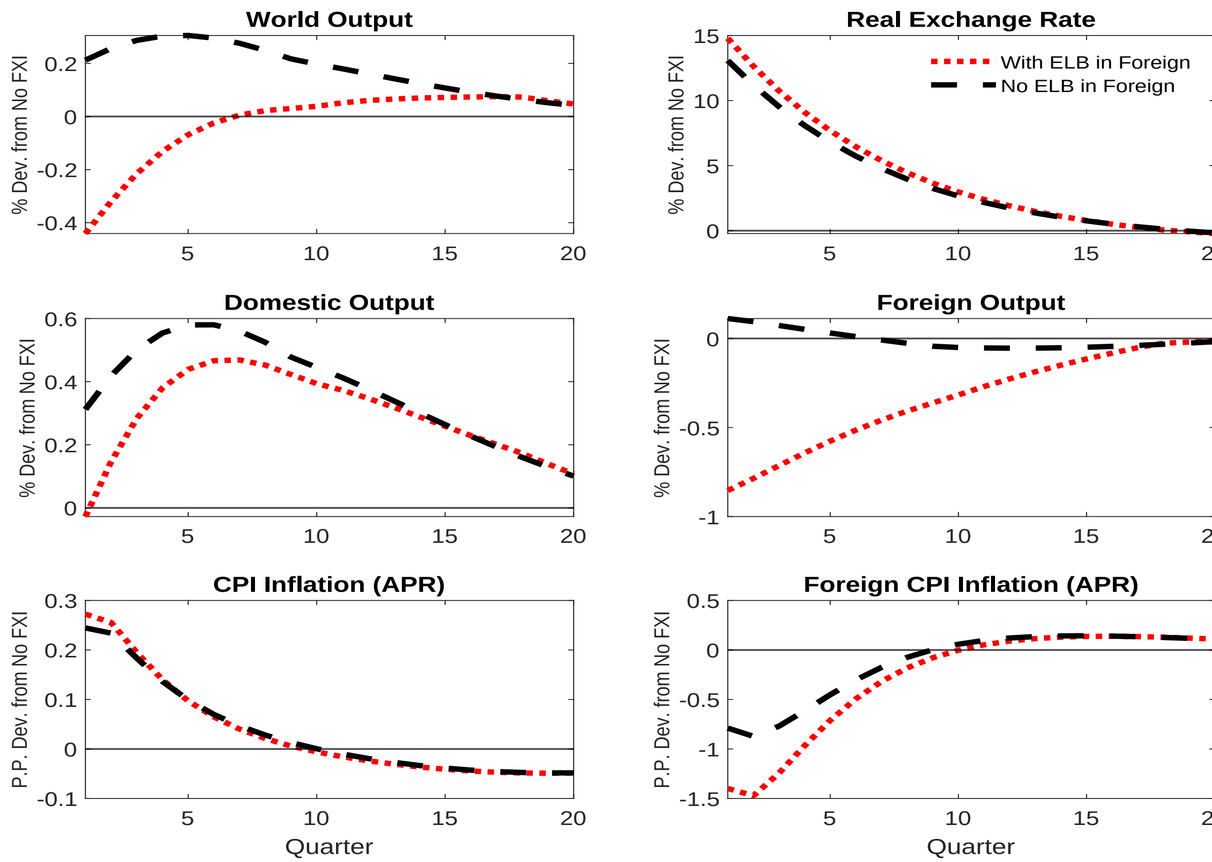
Figure 10. FX Intervention in a Liquidity Trap in Advanced Economies



tradeoffs stemming from the ELB, at least for those EMEs with indebtedness safely below the debt limit.

7.2. **Multilateral Effects.** As we have seen, the expansionary effects of FXI purchases in a liquidity trap are achieved both by stimulating domestic demand and improving the trade balance. The latter may not be a concern if, as we have assumed so far, the intervention is conducted by a *small* economy. But it could have a non-negligible impact on the rest of the world if it was instead

Figure 11. Spillovers of FXI and the Role of Foreign Policy Space



implemented by a large country or bloc of countries. This is precisely the issue that we investigate in this section by exploiting the two-country structure of our model.

More specifically, we consider the same scenario as in Figure 10, but we assume instead that the size of the home economy is equal to half, so that its policy actions matter for the world economy. Figure 11 plots the corresponding results, reporting differences between the scenarios with and without FXI in the home economy. It focuses on two situations: in the first, the foreign economy is itself in a liquidity trap (red dotted lines), while in the second it is assumed to be unconstrained and can set policy in line with a standard Taylor rule (black dashed lines). Our results suggest that, in a global liquidity trap, FXI may have sizable beggar-thy-neighbor effects, even to the extent of being globally contractionary in the short run. Interestingly, the outcomes become much more favorable when the foreign economy is not stuck in a liquidity trap, but can instead lean against deflationary pressures by providing conventional monetary stimulus. The output spillovers in that case are very small, as a result of which, the world economy ends up clearly benefitting from FX purchases in the constrained economy.

8. Conclusions

In this paper we developed a microfounded New Keynesian model to illustrate how augmenting conventional monetary policy with foreign exchange interventions and capital flow management measures may improve monetary policy tradeoffs and help mitigate downside risks to economic activity. Our results suggest that the potential benefits are substantial, and most notable in economies with less well anchored inflation expectations and significant foreign currency mismatches, and particularly so whenever debt levels are high and FX markets shallow.

There are several ways in which our model could be further extended to strengthen its policy implications. In parallel work the framework is estimated using Bayesian methods for a number of emerging and advanced small open economies, with the goal to better understand the empirical transmission of FXIs and CFMs, and how it varies with structural characteristics that may differ substantially across economies. The model could also be extended to include macroprudential policy, e.g., by adding a housing sector and/or bank capital.

While our framework highlights the fact that FXIs and CFMs can improve policy tradeoffs under certain conditions, additional considerations – not fully addressed by our model – must be taken into account when deciding whether or not to utilize these tools in practice. First, decisions on the use of these tools must often be made under considerable uncertainty about the underlying shocks and the distance from the unobserved debt limit. For instance, using FX sales to support the exchange rate may risk large and potentially destabilizing losses of reserves if the shock is more persistent than anticipated. Second, the use of FXIs and CFMs may have non-negligible longer-term costs. For example, they may impede financial market development and encourage an excessive buildup of foreign currency debt, potentially amplifying vulnerabilities. While future analytical work is needed to help better quantify these effects and to incorporate them into structural models, we see our framework as providing an important input into the associated cost-benefit analysis.

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Appendices

Appendix A. Extension with Behavioral Portfolio Investors

In this appendix we briefly discuss an extension of our model accounting for behavioral portfolio investors. More specifically, instead of assuming that portfolio flows are purely exogenous, we relate them to expected excess returns by positing that

$$\frac{B_{P,t}}{P_{D,t}Y} = \frac{\hat{B}_{P,t}}{P_{D,t}Y} + b\mathbb{E}_t\left\{(1-\tau_{F,t})I_t - I_t^*\frac{\varepsilon_{t+1}}{\varepsilon_t}\right\}, \tag{A.1}$$

where $b \geq 0$ and $\hat{B}_{P,t}$ is an exogenous component of the flows. Note that we obtain our baseline model by setting $b = 0$. Plugging Equation (A.1) into the solution of financiers' problem (6) yields

$$(1-\tau_{F,t})I_t = \mathbb{E}_t\left\{I_t^*\frac{\varepsilon_{t+1}}{\varepsilon_t}\right\} + \Gamma I_t\frac{\hat{B}_{F,t}}{P_{D,t}Y} - \Gamma I_t b\mathbb{E}_t\left\{(1-\tau_{F,t})I_t - I_t^*\frac{\varepsilon_{t+1}}{\varepsilon_t}\right\}, \tag{A.2}$$

where $\hat{B}_{F,t} = -B_t - \hat{B}_{P,t} + B_{M,t}$. This can further be rearranged to arrive at the following modified UIP condition

$$(1-\tau_{F,t})I_t = \mathbb{E}_t\left\{I_t^*\frac{\varepsilon_{t+1}}{\varepsilon_t}\right\} + \frac{\Gamma I_t}{1+b\Gamma I_t}\frac{\hat{B}_{F,t}}{P_{D,t}Y}. \tag{A.3}$$

Comparing this equation with its baseline counterpart (Equation 6) reveals that allowing portfolio flows to endogenously respond to return differentials effectively makes the FX market deeper, leaving other blocks in the model unchanged.

Appendix B. Data

To calibrate our model, we collect data for a sample of advanced and emerging market small open economies. In line with IMF classification, the two groups pursuing independent monetary policy, with either a managed or freely floating exchange rate, are:

- **AEs**: Australia, Canada, Czechia, Germany, Iceland, Israel, Japan, Korea, New Zealand, Norway, Sweden, Switzerland, United Kingdom;
- **EMEs**: Argentina, Brazil, Chile, China, Colombia, Hungary, India, Indonesia, Malaysia, Mexico, Peru, Philippines, Poland, South Africa, Thailand, Turkey.

Table A.1. Variable Definitions and Data Sources

Variable	Definition	Source
Real Output	Gross Domestic Product at Constant Market Prices in Domestic Currency, Seasonally Adjusted	Haver Analytics
Nominal Output	Gross Domestic Product at Market Prices in Domestic Currency, Seasonally Adjusted	Haver Analytics
Nominal Gov. Cons.	Government Consumption Expenditures in Domestic Currency, Seasonally Adjusted	Haver Analytics
Inflation	Core Consumer Price Index Excluding Food and Energy	WEO database, Haver Analytics
Interest Rate	Monetary Policy Rate	Haver Analytics
Real Exchange Rate	JPMorgan Real Broad Effective Exchange Rate Index, PPI Based	Haver Analytics
Trade Balance	Net Nominal Exports	Haver Analytics
Net Foreign Assets	Net International Investment Position in Domestic Currency, Non-Seasonally Adjusted	Haver Analytics
FX Reserves	Foreign Currency Reserves in Domestic Currency	Haver Analytics

Table A.1 presents the definitions and sources of data that we use in the paper. For most countries, the time series cover the period 2000Q1-2019Q4.

To compute the import content of domestic demand components reported in Table 1, we use the estimates provided by Bussiere et al. (2013).

Appendix C. Moment Matching Results

This Appendix discusses the moment matching procedure, which allows us to pin down the stochastic properties of shocks that are subsequently used to simulate the model (see also Section 6). Before calculating the moments, we transform the log of real output into year-over-year differences, convert the core inflation and interest rate into annualized percentage rates, detrend the log of real exchange rate with a linear-quadratic trend, and normalize the trade balance by dividing it by GDP. The resulting series are then multiplied by 100 to express them in percent.

To give an idea of model fit, Tables A.2 and A.3 then compare the unconditional second moments implied by the model to their data counterparts, defined as medians calculated for the group of EMEs listed in Appendix B.[29]

[29] Note that while correlations are more easily interpretable, which is why we report them in the tables, the actual matching procedure uses covariances instead.

Table A.2. Moment Matching for the Foreign Economy (US)

	Standard dev.		Autocorr.		Output corr.	
	Data	Model	Data	Model	Data	Model
Output	1.59	1.74	0.89	0.68	1.00	1.00
Inflation	1.01	1.40	0.76	0.96	0.22	0.14
Interest rate	2.75	2.74	0.99	0.91	0.29	0.15

Table A.3. Moment Matching for the Home Economy (median EME)

	Standard dev.		Autocorr.		Output corr.		Foreign corr.	
	Data	Model	Data	Model	Data	Model	Data	Model
Output	2.39	2.47	0.81	0.58	1.00	1.00	0.46	0.33
Inflation	1.91	1.28	0.68	0.96	-0.09	-0.03	0.13	0.21
Interest rate	2.01	2.21	0.94	0.90	-0.13	0.10	0.47	0.31
Real exchange rate	7.16	7.37	0.90	0.80	-0.16	-0.04	-	-
Trade balance	3.15	2.23	0.90	0.80	-0.04	-0.22	-	-

Appendix D. Robustness Check: Optimized Policy Rules

All simulation results presented in the paper assume that the central bank follows a Taylor-like rule given by Equation (20), with the feedback coefficients calibrated to standard values used in the literature, as explained in Section 3. Naturally, such a specification can be quite far from describing optimal monetary policy, raising concerns that some of our main conclusions on the effectiveness of FXI and CFM rules may be heavily influenced by this suboptimality.

In this appendix we check the robustness of our results by considering a monetary policy rule which additionally features a real exchange rate term, so that Equation (20) becomes

$$I_t = I + \psi_\pi \left(\Pi_{D,t} - \Pi_D\right) + \psi_x \left(Y_t/Y_t^{pot} - 1\right) + \psi_q \left(Q_t - 1\right), \tag{A.4}$$

and experiment with different values of the feedback coefficients. We have also considered a variant of Equation (A.4), in which the exchange rate is replaced with the UIP premium.

Using the stochastic simulation setup presented in Section 6, we find that both utility-based welfare and loss function-based measures can significantly improve if the policy rate reacts more aggressively to inflation and the output gap, but not necessarily when it responds to the exchange rate or UIP premium. The gains are large, as documented in Table A.4 for a rule with $\psi_\pi = 5$,

Table A.4. Evaluation of FXI and CFM under Aggressive Monetary Policy

Baseline model	Model with aggressive MP rule			
MP Only	MP Only	FXI UIP Prem. Rule	CFM Rule	FXI Spread Rule
		Sudden Stop Probability		
1.39	1.30	0.00	0.64	1.38
		Financial Stress Probability		
2.98	2.95	0.00	1.40	3.05
		Borrowing Spread (mean)		
0.09	0.09	0.00	0.05	0.09
		Output (mean)		
-0.26	-0.23	-0.15	-0.22	-0.23
		Output (std)		
2.10	1.55	1.33	1.49	1.56
		Output (skewness)		
-0.76	-0.92	-0.11	-0.77	-0.90
		CPI Inflation (std)		
1.90	1.37	0.89	1.34	1.38
		CPI Inflation (skewness)		
0.13	0.16	0.09	0.16	0.15
		Real Exchange Rate (std)		
7.49	7.03	4.12	6.87	7.04
		Welfare Gain Relative to Standard MP Rule		
0.00	0.09	0.32	0.23	0.09
		Loss Decrease Relative to Standard MP Rule		
0.00	52.09	74.58	54.57	51.86

Notes: Output and real exchange rate are expressed as 100 times log. Spread, probabilities and loss decrease are in percent. Inflation is expressed as annualized percentage rate. Welfare gain is expressed as permanent consumption equivalent, in percent. The policy variants correspond to the following parameterizations: (i) Standard MP Rule: $\psi_\pi = 1.5$, $\psi_x = 0.0625$, $\psi_q = \psi_\theta = 0$; (ii) Aggressive MP Rule: $\psi_\pi = 5$, $\psi_x = 0.5$, $\psi_q = 0$; (iii) FXI UIP Premium Rule: $\psi_{m,1} = 0.5$; (iv) CFM Rule: $\psi_f = 0.01$; (v) FXI Spread Rule: $\psi_{m,2} = 1$.

$\psi_x = 0.5$, $\psi_q = \psi_\theta = 0$, even though such an optimized rule actually elevates the frequency of financial stress periods. Most importantly, however, and as corroborated by Table A.4, our conclusions on the performance of FXI and CFM rules still hold, with sizable further gains possible when these rules are used in a preemptive way, but not when they are deployed exclusively during sudden stop episodes.

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