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Research Paper

External shocks and FX intervention policy in financially dollarized economies☆

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ABSTRACT

We examine the role of sterilized FX interventions as a monetary policy tool in response to external shocks for dollarized emerging market economies. Our model highlights an agency problem that limits banks' ability to secure funds in both domestic and foreign currencies, with its intensity linked to currency mismatches in the banking sector. This leads to endogenous deviations from the standard UIP condition, resulting in a non-neutral FX intervention policy. Sterilized FX interventions stabilize financial conditions not only by stabilizing real exchange rates but also by acting as a balance sheet policy that directly influences credit supply. Our quantitative analysis shows that FX policy rules that counteract exchange rate deviations reduce volatility in interest rate spreads including UIP deviations, credit, investment, and output, leading to significant welfare improvements compared to a flexible exchange rate regime.

1. Introduction

Emerging market economies (EMEs) frequently experience volatile external shocks that influence their capital flows and exchange rate dynamics. These capital flows, often triggered by global events, affect domestic financial conditions and credit growth, primarily through fluctuations in the availability of foreign currency-denominated funds and exchange rates. As a result, the domestic financial system becomes particularly vulnerable to international developments. In response, EMEs' central banks employ sterilized foreign exchange (FX) reserve accumulation and interventions (hereafter FX interventions) to smooth the effects of rapid capital flow shifts on financial conditions, reduce exchange rate volatility, and provide insurance against exchange rate risks.[1,2]

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[1] Sterilized FX interventions refer to the central bank's purchase/sells of FX reserves in exchange for domestic-currency-denominated bonds to offset any impact on domestic liquidity.

[2] See Céspedes et al. (2014) for a discussion of LATAM central banks' experiences in response to global events as the 2008 Global Financial Crisis.

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This paper examines the effectiveness of FX intervention policy rules in enhancing financial stability as a response to external shocks. We analyze the transmission mechanism of FX interventions and evaluate the welfare gains and losses associated with these policy rules in the context of domestic financial market imperfections and external shocks. The focus is on a family of policy rules that counteract exchange rate movements that exacerbate the impact of borrowing constraints on financial conditions, influence interest rate spreads, and lead to deviations from the uncovered interest parity (UIP) condition when the economy faces external shocks. Given the direct impact of exchange rates on financial stability, this study explores the role of FX interventions in mitigating associated risks.

We extend the small open economy DSGE model with nominal rigidities to include financial intermediaries (banks) and dollarization. Intermediate good firms face a "fund-in-advance-of-production" constraint, which requires them to secure external funding before starting production. Due to market segmentation and frictions in the financial market, households cannot lend directly to firms in the form of debt and face transactions cots when holding assets. In this context, banks collect household deposits and provide loans to firms. A key feature is that deposits and loans can be denominated in pesos (domestic currency) and dollars (foreign currency), and banks have access to external borrowing in dollars.[3] An agency problem, however, limits banks' access to funding and introduces an endogenous leverage constraint linking credit flows to banks' net worth, generating interest rate spreads between lending and funding interest rates (*lending interest rate spread*). Additionally, the severity of the bank's agency problem is linked to its currency mismatch ratio — the net foreign-currency liabilities relative to total assets, limiting banks arbitrage opportunities between domestic and foreign currency borrowing.[4] As a result, interest rate spreads between domestic and foreign currency liabilities (*UIP deviations*) emerge in equilibrium.

Taking international prices as given, commodity good producers accumulate stock of capital which is the only input needed to produce commodity goods. Commodity production is entirely exported abroad and any profit from this sector is entirely rebated to their owners. Thus, fluctuations in commodity prices not only affect the aggregate commodity sector activity, but they also spill over the non-commodity sector through their effect on households' resources. Furthermore, the source of uncertainty is an exogenous external sector, summarized in three interrelated components: global demand that determines domestic exports, foreign interest rates affecting foreign currency investments, and international commodity prices. In addition to controlling the nominal interest rate of deposits in pesos via a Taylor rule, the central bank intervenes in the FX market.

The central bank issues domestic bonds and maintains official FX reserves, which are invested in foreign assets. FX interventions are sterilized through adjustments in the supply of domestic bonds, which are exclusively held by banks. The sole purpose of central bank bonds is to operationalize sterilized FX interventions. In our framework, FX interventions operate through two key transmission mechanisms: the Foreign Exchange channel (FX channel) and the Balance Sheet channel (BS channel). When the central bank purchases foreign assets, it drives up the real exchange rate and creates expectations of future currency appreciation. The higher exchange rate reduces banks' net worth, as their foreign liabilities are revalued, while expectations of future appreciation increase currency mismatches (making external borrowing cheaper) and lower the leverage ratio. The resulting decline in banks' capital investment and economic activity constitutes the FX channel of FX policy and is associated with UIP deviations. Additionally, the sterilization of the central bank's FX purchases leads to a crowding-out effect on banks' portfolios, reducing credit supply. As banks hold more central bank bonds, fewer resources are available for lending, driving up the lending interest rate spread. This describes the BS channel of FX policy and is associated with lending interest rate spreads.

Under exchange rate flexibility, the real exchange rate amplifies the initial effects of an external shock (e.g., global demand shocks) by affecting banks' balance sheets, currency mismatches and credit constraints, creating financial instability that adversely impacts macroeconomic performance. Hence, FX policies that lean against real exchange rate movements are desirable.[5] As a consequence, an FX policy rule stabilizing real exchange movements shields the domestic economy from external shocks. For instance, a commodity price boom under a floating exchange rate regime appreciates the exchange rate, enhancing banks' net worth and intermediation capacity, thereby expanding credit availability. Conversely, active FX intervention during such shocks mitigates the exchange rate appreciation, restricts credit growth, and stabilizes consumption and investment through FS and BS channels.

We take the model to the data by considering the Peruvian economy as a representative inflation-targeter and commodity exporter with financial dollarization and active FX policy.[6] The parameters associated with the banking block of the model are calibrated to replicate financial targets for Peru's banking system. The rest of the parameterization is done by matching the impulse responses of our model to the impulse responses of an SVAR model identified with block exogeneity and zero restrictions under the small open economy assumption. Then, having the external sector as the unique source of shocks, we design numerical experiments to quantify the differences in the economy's response to external shocks under active FX policy and flexible exchange rates. Additionally, we measure the welfare consequences of the FX intervention regime relative to exchange rate flexibility.

Our main quantitative results suggest that FX intervention operations successfully reduce macroeconomic volatility relative to a free-floating regime. In particular, under the FX intervention regime, credit, investment, and output volatility fall by around 73, 51,

[3] Corrales and Imam (2021) show that in many EMEs, firms and households hold substantial foreign currency liabilities, exposing them — and by extension, their creditors — to significant exchange rate risks.

[4] The prominence of currency mismatches in amplifying the impact of financial market imperfections is consistent with the underdeveloped FX markets in many EMEs, where limited market depth and insufficient hedging instruments can lead to disorderly market conditions in response to sudden changes in capital flows.

[5] This holds true even if the UIP condition is met, as long as lending interest rate spreads depend on aggregate banks' balance sheets. In such cases, FX interventions act as unconventional balance sheet policies.

[6] Christiano et al. (2021) and Dalgic (2024) calibrate their models to Peruvian data arguing that Peru exemplifies economies facing significant currency mismatches, minimal capital controls, and a substantial gap between domestic and foreign currency interest rates.

and 55 percent, respectively, compared to a flexible exchange rate regime. Then, FX interventions play the role of an external shock absorber. These stability implications indicate that FX intervention might create significant welfare gains in response to external shocks. Standard welfare analysis reveals that non-intervention during external shocks would lead to a consumption welfare loss of 4.0 percent, highlighting the effectiveness of FX policy under external disturbances.

We evaluate the welfare gains of FX interventions across various scenarios to test the robustness of our findings. In some scenarios, the welfare gains are larger, such as when there is greater financial vulnerability, and, in others, the welfare gains are smaller, as in cases without financial dollarization or consumption habit formation. Nonetheless, the welfare gains remain significant.[7] We also explore an alternative managed float regime where the Taylor rule responds to exchange rate deviations, showing that while exchange rate stabilization occurs, it comes at the cost of real economic destabilization. This underscores the benefits of having FX interventions as an independent policy tool. Finally, to capture additional aspects of FX policies beyond our model, we introduce ad-hoc sterilization operations costs and find that welfare gains fluctuate between 1.5 and 5 percent of consumption.

Related Literature. Our paper is related to different strands of literature. It follows the frameworks of Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) for modeling the market imperfection of banking sector under limited commitment constraint. These studies primarily explore the role of unconventional monetary policy's role in closed economies during times of financial distress. We argue that FX intervention policies function as a form of unconventional monetary policy, but specifically in small open economies, serving as an additional tool to stabilize domestic financial conditions. This dimension of FX interventions (BS channel of FX policies) is highlighted by Chang and Velasco (2017) and Chang (2019), and has recently gained empirical support from Hofmann et al. (2019) and Ceron et al. (2023), who use granular bank data from Colombia and Peru, respectively. Building on these concepts, we construct a medium-scale macroeconomic model that captures key characteristics of EMEs (e.g., financial dollarization) and assesses the quantitative significance of an FX intervention rule that stabilizes the real exchange rate in shaping business cycle dynamics.

The paper builds on Gertler et al. (2012) and Aoki et al. (2021), introducing an interaction between the bank's agency problem and its debt structure. Gertler et al. (2012) uses the maturity debt structure (short vs. long-term debt) in closed economies, while (Aoki et al., 2021) the currency debt structure (domestic vs. external debt) in open economies.[8] Although our work is closely related to Aoki et al. (2021), we diverge by conceptually exploring the transmission mechanisms of FX interventions and quantitatively examining the impact of FX intervention rules in a financially dollarized small open economy.[9]

At the core of the FX channel lies the portfolio balance approach, originally proposed by Kouri (1976) and Branson et al. (1977), and recently revisited by Gabaix and Maggiori (2015). It suggests that FX interventions influence the exchange rate in segmented currency markets, where domestic and foreign assets are imperfect substitutes. An FX intervention increases the relative supply of domestic assets, raising the risk premium and creating depreciation pressure on the exchange rate.[10] We extend this framework by introducing currency mismatches as an additional factor influencing the financial constraint faced by banks, which influence asset substitutability and triggers revaluation effects on balance sheets due to exchange rate fluctuations and foreign liabilities.[11]

Several studies have leveraged segmented currency markets to examine the optimal Ramsey allocation (e.g., Cavallino (2019), Fanelli and Straub (2021), Itskhoki and Mukhin (2023), and Yakhin (2024)). These studies suggest that FX intervention rules responding to deviations to UIP, or UIP premiums, can implement optimal allocations in their settings, where currency mismatches play a minimal role in transmitting external shocks. We contend that in our model, the interaction between currency mismatches and market imperfections, and large revaluation effects make the real exchange rate a critical target for FX interventions.

The literature empirically evaluating the effectiveness of FX interventions in influencing exchange rate dynamics and stabilizing financial conditions is extensive.[12] However, the welfare gains of such interventions are less explored; notable exceptions include Faltermeier et al. (2022) and Yakhin (2024), who evaluate welfare improvements from adopting optimized FX intervention policies that stabilize UIP premiums. Our paper contributes by measuring the welfare gains from adopting FX intervention rules that counteract real exchange rate movements, in a setting where the domestic economy is exposed to commodity price, foreign interest rates, and global demand shocks.

Layout. The remainder of the paper is organized as follows. Section 2 provides cross-country evidence on financial dollarization and Section 3 describes a general equilibrium model with a special emphasis on the financial system and the implementation of FX interventions. Section 4 presents the parameterization strategy. The main results are discussed in Section 5. Section 6 concludes.

[7] An exception arises when UIP holds, either by households or banks engaging in unlimited arbitrage between foreign and domestic currency assets. In this case, while the FX policy rule still effectively reduces aggregate volatility (due to the BS channel of FX policy), the welfare gains are negligible.

[8] Aoki et al. (2021), and Mendoza and Rojas (2019), examine the role of macroprudential policies, such as capital controls, in economies with foreign liabilities.

[9] While the source of financial dollarization is beyond the scope of this paper, recent studies addressing this issue include (Bocola and Lorenzoni, 2020), Christiano et al. (2021), and Dalgic (2024).

[10] This approach has proved a fertile ground for understanding the use of FX intervention as a policy tool. See Liu and Spiegel (2015), Benes et al. (2015), Cavallino (2019), Fanelli and Straub (2021), Alla et al. (2020), Montoro and Ortiz (2023), Itskhoki and Mukhin (2023), Castillo et al. (2024), and Yakhin (2024).

[11] The revaluation of agents' net worth due to exchange rate movements is an important aspect of financially dollarized EMEs and their policy authorities. See Calvo (2001), Calvo and Reinhart (2002), Céspedes et al. (2003) and Céspedes et al. (2004).

[12] See Blanchard et al. (2015), Daude et al. (2016), Ghosh et al. (2018), Fratzscher et al. (2018), Adler et al. (2019), and Castillo et al. (2024) for studies exploiting aggregate cross-country data, and Hofmann et al. (2019) and Ceron et al. (2023) for analyses based on granular bank-level datasets.

Table 1
Dollarization statistics by income groups.
Source: Dataset from Corrales and Imam (2021).

	Mean	Q1	Q2	Q3
Low income				
Loan dollarization	31.16	19.27	28.78	42.55
Deposit dollarization	17.39	0.00	0.00	28.72
Middle income				
Loan dollarization	44.00	27.17	45.32	59.12
Deposit dollarization	25.09	0.37	10.19	44.69
High income				
Loan dollarization	56.86	49.76	58.47	68.37
Deposit dollarization	11.06	0.63	5.39	14.85

2. Evidence on financial dollarization across countries

We present summary statistics on loan and deposit dollarization across countries. To do so, we use the dataset used in Corrales and Imam (2021) which is constructed using the International Financial Statistics database (IFS) from the International Monetary Fund. The database covers the period 2001–2016 and includes a total of countries from levels of income.[13] Based on World Bank's classification of countries by level of income, the dataset comprises 22 high income countries, 20 low income countries, 35 lower-middle income countries, and 37 higher-middle income countries.[14] We group lower-middle and higher-middle income countries in only one category, say "middle income countries."

The database considers loan and deposit dollarization for firms and households. We study the main statistics of firms' loan dollarization (simply "Loan dollarization") and households's deposit dollarization (simply "Deposit dollarization"). The main reason to do so is that our model does not explicitly capture the omitted types of dollarization (say firms' deposit dollarization and households' loan dollarization). Table 1 summarizes the loan and deposit dollarization in this dataset. On average, loan dollarization increases with income level. Low-income countries exhibit an average loan dollarization of 31%, while middle-income countries show a higher level at 44%. High-income countries report the highest loan dollarization at 57%. Instead, deposit dollarization follows a non-monotonic relation with level of income. The average deposit dollarization stands at 17% for low-income countries, 25% for middle-income countries, and 11% for high-income countries. The fact that deposit dollarization is the lowest in high-income countries indicates a greater preference for local currency deposits as financial development progresses.

Examining the quartiles (Q1, Q2, Q3) reveals the distribution of dollarization across countries within each income group. In low-income countries, deposits show a median (Q2) of 0%, indicating that a significant share of countries has little to no deposit dollarization. In contrast, middle-income countries exhibit more balanced distributions, with deposit dollarization reaching 44.69% at Q3 and loan dollarization peaking at 59.12%. High-income countries display higher levels of loan dollarization (49.76% at Q1, 57.74% at Q2, and 68.37% at Q3), confirming the stronger reliance of firms on foreign currency financing.

The data reveals significant variation in financial dollarization across income levels. Loan dollarization rises with income, while deposit dollarization peaks in middle-income countries before declining in high-income economies, suggesting a shift toward local currency deposits as economies mature. Fig. 1 illustrates this pattern with a scatter plot of loan versus deposit dollarization, color-coded by income groups: red for low-income, blue for middle-income, and gray for high-income countries. The dashed 45-degree line indicates equality between the two measures. While loan dollarization is prevalent, especially in high-income countries, deposit dollarization remains notable in several cases. Notably, middle-income countries often exhibit both high loan and deposit dollarization. Finally, Fig. 2 examines the persistence of dollarization by showing the evolution of firms' loan dollarization and households' deposit dollarization over time, segmented by income groups.

Other empirical evidence on dollarization. Empirical studies demonstrate that financial dollarization and currency mismatches modeled in this paper are not unique to Peru but are common across many EMEs. For example, Yeyati (2014) studied 97 countries and found that many emerging markets exhibit high levels of liability dollarization, where a significant share of banking sector loans and deposits is denominated in foreign currency.

Corrales and Imam (2021) studies loan and deposit dollarization for households and firms. They show that these two groups account for 57.5 percent of deposits and 68.7 of loans being dollarized. These statistics point to the prevalence of currency mismatches beyond Peru, reinforcing the notion that our model's assumptions are reasonable across a broad set of countries. More recently, Dalgic (2024) finds similar results based on central banks and BIS datasets. Thus, many countries in Latin America, Eastern Europe, and Asia experience currency mismatches due to the widespread use of foreign currency in domestic banking activities.

While many international banks and large corporations attempt to minimize currency mismatches by hedging, banks and firms in EMEs often face a different reality. Using Chilean granular data for trade credit, international trade, foreign currency debt, and

[13] As noted in Corrales and Imam (2021), some caveats in this dataset are that: (i) many countries do not have refined data on household and firm credit or deposits, meaning that not all countries are included in the analysis; (ii) many countries, particularly developing ones, individuals and firms may not be properly captured, potentially biasing some of the statistics.

[14] Table A.1 enlists the country in each category. In the sample we do not consider countries that issue a reserve currency (namely, Japan and Euro area countries) as well as fully-dollarized countries.

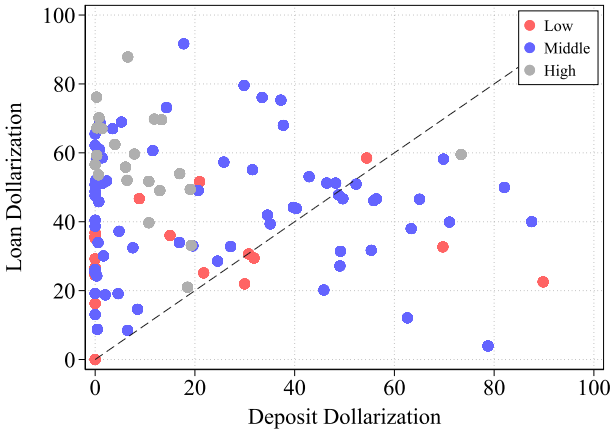

Fig. 1. Loans and Deposits Dollarization.

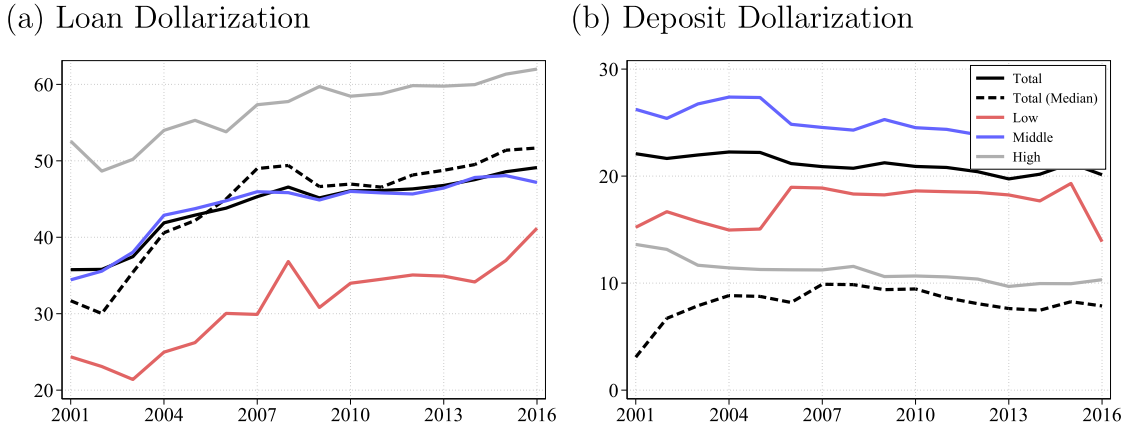

Fig. 2. Loans and Deposits Dollarization (Average).

FX derivative contracts with firms, Alfaro et al. (2021) document that operational hedging is quantitatively limited and that only large firms hedge this risk by actively using financial hedging. Moreover, using Hungarian administrative household credit registry data, Verner and Gyöngyösi (2020) show that the revaluation of debt burdens causes higher default rates and a collapse in spending.

3. A small open economy model

We extend the small open economy DSGE model with nominal rigidities to incorporate banks, dollarization, and a commodity sector. Due to financial frictions, households cannot lend directly to firms and face transaction costs when holding assets. Firms must secure external funding before production, relying on banks that collect deposits and issue loans in either domestic or foreign currency. An agency problem constrains banks' ability to obtain funds, making them vulnerable to external shocks, which in turn impact credit conditions and economic activity.

Commodity producers accumulate capital, the sole input for their production, and export all output abroad, with profits rebated to households. Thus, fluctuations in commodity prices influence both the commodity sector and the broader economy by affecting household income. The model features six agents: households, banks, non-commodity good producers, commodity good producers, non-commodity capital producers, and monopolistically competitive retailers. The latter introduces nominal price rigidities in the model. Moreover, a central bank conducts conventional (policy rate) and unconventional (FX interventions) monetary policy. In this setting, we study the role of FX interventions in financial intermediation, macroeconomic stabilization, and exchange rate volatility.

3.1. Households

There is a continuum of identical households with a unit measure. Each household consumes, saves and supplies labor. Households save by lending funds to competitive banks and purchasing private securities issued by intermediate good producers.

Within each household there are two types of members: workers and bankers. Workers supply labor and return labor income to their household. Each banker manages a bank and similarly transfers any earnings back to their household. Then, the household effectively owns the bank that its bankers manage; however, the deposits it holds are in banks that it does not own. Furthermore, within the family there is perfect consumption insurance. It is worth emphasizing that this simple form of heterogeneity allows us to introduce banks in a meaningful way within an otherwise representative agent framework.[15]

At any moment in time there is a constant fraction of workers and bankers. Over time each member can switch between the two occupations. A banker stays banker next period with probability $\sigma \in [0,1)$, which is independent of how long the member has been a banker. Upon retirement, bankers are replaced by an equal number of workers who randomly transition into banking roles, ensuring the proportion of bankers and workers remains constant. Newly appointed bankers receive some start-up funds from their household. This switching regime ensures that banks do not reach the point where they can fund all investments from their own net worth.

Let C_t be consumption and H_t the labor effort in terms of hours worked. Following Gertler et al. (2012), households preferences are given by

$$\mathbb{W}_t\left(\{C_{t+j}, H_{t+j}\}_{j=0}^{\infty}\right) = (1-\beta)\mathbb{E}_t\left[\sum_{j=0}^{\infty}\beta^j \frac{1}{1-\gamma}\left(C_{t+j} - \mathcal{H}C_{t+j-1} - \frac{\zeta_0}{1+\zeta}H_{t+j}^{1+\zeta}\right)^{1-\gamma}\right] \tag{1}$$

where $\beta \in (0,1)$ is the subjective discount factor, $\gamma > 0$ measures the elasticity of intertemporal substitution, and ζ_0 controls the dis-utility of labor. Additionally, the Frisch elasticity is determined by the interaction of $\zeta > 0$ and the degree of internal habit formation, $\mathcal{H} \in [0,1)$. For instance, if there is no habit formation (i.e., $\mathcal{H} = 0$), this specification abstracts from wealth effects on labor supply and the Frisch elasticity is $1/\zeta$.

We permit households to directly hold private securities and deposits in dollars but facing limits on their market participation, captured by convex transaction costs. For private securities, S_t, a household face holding costs equal to $\frac{\kappa_S}{2}(S_t - \overline{S})^2$; while for deposits in dollars, $D_t^{*,h}$, they face holding costs equal to $e_t\frac{\kappa_{D*}}{2}(D_t^{*,h} - \overline{D}^{*,h})^2$. Accordingly, there is a certain amount of each asset that the household can hold costlessly, $\overline{S}$ and $\overline{D}^{*,h}$, and parameters κ_S and κ_{D*} control the curvature of the marginal transaction cost. Moving away from these levels involves transaction costs that are increasing at the margin. We motivate this cost structure as capturing in a simple way limited participation in asset markets by households that leads to incomplete arbitrage.

Let D_t be the total real quantity of deposits in pesos, R_t the real return on peso deposits, R_t^* the real return on dollar deposits, R_t^{knc} the real return on non-commodity capital, e_t the real exchange rate, w_t denotes the real wage, Π_t is net payouts to the household from the ownership of firms, and T_t the lump-sum taxes. Accordingly, the household budget constraint becomes

$$\begin{aligned} C_t + D_t + T_t + e_t\left[D_t^{*,h} + \frac{\kappa_{D*}}{2}(D_t^{*,h} - \overline{D}^{*,h})^2\right] \\ + S_t + \frac{\kappa_S}{2}(S_t - \overline{S})^2 = w_t H_t + \Pi_t + R_t D_{t-1} + R_t^* e_t D_{t-1}^{*,h} + R_t^{knc} S_{t-1}. \end{aligned} \tag{2}$$

The representative worker chooses consumption, labor supply, and bank deposits to maximize (1) subject to (2). Defining $\Lambda_{t,t+1} \equiv \beta\frac{u_{c,t+1}}{u_{ct}}$ as the household's stochastic discount factor, the household's first order conditions for labor supply and consumption/saving decisions are $1 = \mathbb{E}_t[R_{t+1}\Lambda_{t,t+1}]$,

$$\zeta_0 H_t^{\zeta}\left(C_t - \mathcal{H}C_{t-1} - \frac{\zeta_0}{1+\zeta}H_t^{1+\zeta}\right)^{-\gamma} = \mathbb{E}_t u_{ct} w_t \tag{3}$$

$$\mathbb{E}_t\left[\Lambda_{t,t+1}\left(R_{t+1}^{knc} - R_{t+1}\right)\right] = \kappa_S(S_t - \overline{S}) \tag{4}$$

$$\mathbb{E}_t\left[\Lambda_{t,t+1}(R_{t+1} - \frac{e_{t+1}}{e_t}R_{t+1}^*)\right] = \kappa_{D*}(\overline{D}^{*,h} - D_t^{*,h}) \tag{5}$$

where $u_{c,t}$ is the marginal utility of consumption.[16] The demand of private securities above its frictionless level is increasing in the excess return of non-commodity capital. Instead, the demand of deposit in dollars is written as a decreasing function of their opportunity cost, i.e., the excess return of peso deposits relative to dollar deposits. Absent these transaction costs (i.e., $\kappa_{D*} = \kappa_S = 0$), households engage in frictionless arbitrage of asset returns.

The household asset demand structure captures three important features in a parsimonious way. First, there is a considerable size of persistent deposit dollarization in many emerging economies, specially for those countries that had suffered from hyperinflation episodes in the last five decades. Second, households differ in their ability to manage a sophisticated portfolio: A limited supply of "sophisticated" households accordingly prevents frictionless arbitrage of security and deposits returns. Third, a small fraction of non-financial firms (typically large, well-established entities) can obtain funds by issuing securities directly to households on the open market, complementing their borrowing from banks. Our model provides a very simple way to account for this pattern of asset holdings that is meant to be a stand-in for a more explicit treatment.

[15] This modeling strategy is standard in the literature on financial and labor market frictions. In particular, we are following a convention used in the study of unconventional monetary policy initiated by Gertler and Karadi (2011).

[16] That is, $u_{ct} = \left(C_t - \mathcal{H}C_{t-1} - \frac{\zeta_0}{1+\zeta}H_t^{1+\zeta}\right)^{-\gamma} - \mathcal{H}\beta\left(C_{t+1} - \mathcal{H}C_t - \frac{\zeta_0}{1+\zeta}H_{t+1}^{1+\zeta}\right)^{-\gamma}$.

3.2. Banks

Banks lend funds obtained from households and foreigners to non-financial firms. That is, foreign agents are precluded from lending directly to non-financial firms. All financial contracts offer by the bank are nominal, short-term, non-contingent, and, thus, nominal riskless. Although there is no friction in transferring funds between a bank and goods producers, an agency problem limits the ability of banks to obtain funds from households and foreigners.

Loans in pesos and dollars (l_t and l_t^*, respectively) and central bank's bonds (b_t) comprise the assets of banks, which are financed through a combination of household deposits in pesos and dollars (d_t and $d_t^{*,h}$, respectively), foreign borrowing ($d_t^{*,f}$), and banks' own net worth (n_t).[17] The bank's balance sheet expressed in real terms is

$$l_t + e_t l_t^* + b_t = n_t + d_t + e_t(d_t^{*,h} + d_t^{*,f}) \tag{6}$$

where e_t is the real exchange rate. Deposits and external funding are perfect substitutes from bankers' perspective. Net worth is accumulated through retained earnings, the difference between the gross return on assets and the cost of liabilities:

$$n_{t+1} = R_{t+1}^l l_t + R_{t+1}^{l*} e_{t+1} l_t^* + R_{t+1}^b b_t - R_{t+1} d_t - e_{t+1} R_{t+1}^* d_t^* \tag{7}$$

where $d_t^* \equiv d_t^{*,h} + d_t^{*,f}$ denotes the total funding in dollars and R_t^b, R_t^l, and R_t^{l*} are the real gross returns to the bank from government bonds, loans in pesos, and loans in dollars, respectively. Similarly, R_t and R_t^* are the real gross interest rates the bank pays on peso- and dollar-denominated liabilities.[18] Bankers' objective is to maximize the expected discounted stream of profits that are transferred back to the household, i.e., its expected terminal wealth,

$$V_t \equiv \mathbb{E}_t \sum_{j=1}^{\infty} \Lambda_{t,t+j} \sigma^{j-1}(1-\sigma) n_{t+j}$$

where $\Lambda_{t,t+j}$ is the stochastic discount factor of the representative household from $t+j$ to t and $\mathbb{E}_t[\cdot]$ is the expectation operator conditional on information set at t.[19] In addition to (6) and (7), banks face portfolio constraints that arise from an agency problem.

Agency problem. At the beginning of each period, bankers can act honestly or divert funds from their assets. If bank managers act honestly, assets will be retained until payoffs are realized in the next period, allowing them to repay their liabilities to creditors (both domestic and foreign). Conversely, if bank managers divert funds, those assets are secretly redirected from lending and consumed by their households. Consequently, bank managers abscond with funds if the amount they can divert exceeds the optimal continuation value of the bank. To ensure that creditors are willing to supply funds to the banker, any financial arrangement satisfies an incentive constraint:

$$V_t \geq \overbrace{\Theta(x_t)}^{\text{Composition}} \overbrace{\left[l_t + \varpi^* e_t l_t^* + \varpi^b b_t\right]}^{\text{Claim/Size}} \tag{8}$$

where $\varpi^*, \varpi^b \geq 0$, $\Theta(x) = \theta\left(1 + \frac{\varkappa}{2}x^2\right)$ with $\theta, \varkappa > 0$, and x_t is a bank-level currency mismatch measure which is defined as

$$x_t = (e_t d_t^* - e_t l_t^*)/(l_t + e_t l_t^* + b_t). \tag{9}$$

That is, we assume that the fraction of funds the bank may divert depends on its balance sheet composition, x_t. A higher currency mismatch increases the severity of the bank's incentive constraint. In this regard, x_t measures the exposure of the bank's balance sheet to abrupt foreign capital reversals and exchange rate movements. Hence, banks with higher x_t, being more vulnerable to unexpected economic conditions, face tighter financial constraints.[20]

Note that (8) indicates that some assets are more difficult to divert than others: a banker can divert a fraction $\Theta(x_t)$, $\Theta(x_t)\varpi^*$, and $\Theta(x_t)\varpi^b$ of domestic currency loans, foreign currency loans, and government bonds, respectively. This implies that, for some assets, the constraint on arbitrage is weaker.

Optimal contracting problem. Given a sequence of interest rates, government policies, and n_t, each bank chooses $\{l_t, l_t^*, b_t, d_t, d_t^*\}$ to maximize the franchise value:

$$V_t = \max_{l_t, l_t^*, b_t, d_t, d_t^*} \mathbb{E}_t \Lambda_{t,t+1} \left\{(1-\sigma) n_{t+1} + \sigma V_{t+1}\right\}$$

subject to (6), (7), (8), and (9). The necessary conditions for banks' optimal portfolio are associated with two types of interest rate spreads: (1) Spreads between asset returns and liability costs (Domestic interest rate spreads), and (2) Currency differentiated spreads between deposit interest rates and between loan returns (UIP deviations). To describe these spreads, let $\Omega_{t+1} \equiv \Lambda_{t,t+1}(1-\sigma + \sigma V_{t+1}/n_{t+1})$ be the shadow value of a unit of net worth to the bank at $t+1$, $\widetilde{R}_{t+1} \equiv x_t \frac{e_{t+1}}{e_t} R_{t+1}^* + (1-x_t) R_{t+1}$ be the weighted average of returns on bank liabilities, and λ_t^b be the Lagrangian multiplier for the portfolio restriction (8).

[17] We assume a strict segmentation on the market of central bank's bonds: Only banks can buy these assets, households cannot participate in this market.

[18] All real interest rates are ex-post. For instance, $R_t = \frac{1+i_{t-1}}{1+\pi_t}$ where i_t is the nominal interest rate on deposits (monetary policy rate).

[19] Notice that using $\Lambda_{t,t+j}$ to discount the stream of bank profits means that households effectively own the banks that their banker members manage.

[20] The significance of currency mismatches in determining the severity of the assumed financial friction aligns with the primary characteristics of underdeveloped FX markets, namely the limited depth of the FX market and insufficient hedging possibilities. These constraints make it challenging for market participants in EMEs to effectively manage currency risk, thereby amplifying the impact of currency mismatches on financial stability.

Domestic interest rate spreads. There are two spreads within this category: (i) the spread between the return on loans in pesos and its funding cost, $\Delta_t^l \equiv \mathbb{E}_t \Omega_{t+1}[R_{t+1}^l - \widetilde{R}_{t+1}]$, and (ii) the spread between the return on government bonds and its funding cost, $\Delta_t^b \equiv \mathbb{E}_t \Omega_{t+1}[R_{t+1}^b - \widetilde{R}_{t+1}]$. The optimal behavior of banks imply that these spreads are

$$\Delta_t^l = \frac{1}{\varpi^b}\Delta_t^b = \frac{\lambda_t^b}{1+\lambda_t^b}\Theta(x_t). \tag{10}$$

Banks invest in each asset to the point where the marginal benefit of an additional unit of each asset is equal to its marginal cost. The marginal benefit of each asset is given by the discounted excess of its return and its funding costs: an extra unit of l_t or b_t is funded by a fraction x_t of domestic currency deposits and a fraction $1-x_t$ of foreign currency deposits. Instead, the marginal cost of each asset is given by the tighter incentive constraint. It is worth emphasizing that domestic interest rate spreads are a consequence of banks' binding financial constraints ($\lambda_t^b > 0$). They do not depend on the effects of the composition of banks' balance sheet over the financial conditions.

UIP Deviations. The second type of interest rate spreads consists of deviations from the uncovered interest rate parity condition (UIP): (i) the spread between deposits in pesos and deposits in dollars, $\Delta_t^* \equiv \mathbb{E}_t \Omega_{t+1}\left(R_{t+1} - \frac{e_{t+1}}{e_t}R_{t+1}^*\right)$, and (ii) the spread between loans in pesos and loans in dollars, $\Delta_t^{l*} \equiv \mathbb{E}_t \Omega_{t+1}\left(R_{t+1}^l - \frac{e_{t+1}}{e_t}R_{t+1}^{l*}\right)$. The corresponding UIP deviations are obtained from banks' optimal condition for x_t, l_t^* and d_t^*:

$$\Delta_t^* = \frac{\lambda_t^b}{1+\lambda_t^b}\left(\frac{l_t + \varpi^* e_t l_t^* + \varpi^b b_t}{l_t + e_t l_t^* + b_t}\right)\frac{d\Theta(x_t)}{dx_t} \tag{11}$$

$$\Delta_t^{l*} = (1-\varpi^*)\Delta_t^l + \Delta_t^*. \tag{12}$$

Contrary to domestic interest rate spreads, non-trivial UIP deviations not only depend on binding financial constraints but on a positive marginal effect of the currency mismatch over the tightness of financial constraints (i.e., $\frac{d\Theta(x)}{dx} > 0$).

Leverage and Financial Accelerator. The optimal decisions on the bank's balance sheet are summarized by the following credit constraint: $l_t + \varpi^* e_t l_t^* + \varpi^b b_t \leq \Phi_t n_t$ where

$$\Phi_t = \frac{\upsilon_t}{\Theta(x_t) - \Delta_t^l} \tag{13}$$

is the maximum ratio of (weighted) assets to net worth that a bank can hold without violating the incentive constraint and $\upsilon_t \equiv \mathbb{E}_t\left[\Omega_{t+1} R_{t+1}\right]$ is the expected discounted value of having another unit of net worth. When the incentive constraint binds, banks are restricted in obtaining funds from creditors. The leverage ratio, Φ_t, is increasing in (1) the savings of deposit costs from another unit of net worth, υ_t, and (2) the discounted marginal benefit (or excess value) of lending in domestic currency, Δ_t^l. Conversely, Φ_t decreases with the fraction of assets that banks can abscond, $\Theta(x_t)$. As a result, a higher currency mismatch has two opposite effects on banks' leverage through $\Theta(x_t)$ and Δ_t^l.

Since the leverage ratio is independent of bank-specific factors, we can sum across individual banks to obtain the relation for the (weighted) total bank assets as a function of total net worth as

$$L_t + \varpi^* e_t L_t^* + \varpi^b B_t = \Phi_t N_t \tag{14}$$

where capital letters denote the aggregate counterpart of individual variables. Thus, aggregate bank balance sheet size is constrained by the aggregate bank capital. Note that this constraint acts as a financial accelerator of economic activity: as balance sheets strengthen with improved economics conditions, the external finance problem declines, which works to enhance credit, thus enhancing the boom. The power of this financial accelerator depends on the degree of financial vulnerability, measured by x_t. In particular, for shocks that induced a countercylical movement of x_t, the financial accelerator is more powerful.

It is worth emphasizing that Eq. (14) can be interpreted as the supply of total credit in the domestic economy. In particular, it determined the (weighted) value of bank assets. The composition of assets is undetermined from the supply side, so it is the demand of each type of lending (coming from firms and the government) that determines the composition.

Financially constrained regime. When the incentive constraint (8) does not bind, financial markets are frictionless, implying that the standard arbitrage conditions hold: $\Delta_t^l = \Delta_t^* = 0$. In this scenario, financial intermediaries are irrelevant for the macroeconomic allocation, rendering both balance sheet policies, such as FX interventions, neutral.

Conversely, when (8) binds, banks face limits to arbitrage portfolios, resulting in endogenous interest rate spreads. Under this "constrained" equilibrium, two possible scenarios emerge. If $\frac{d\Theta(x)}{dx} \neq 0$, banks cannot freely choose the currency composition of their deposits (in pesos or in dollars) or the size of their balance sheets. Their optimal portfolio decision depends on $\Delta_t^* \neq 0$ and $\Delta_t^l \neq 0$, both of which are determined by macroeconomic aggregates in equilibrium.[21] In this case, the non-neutrality of FX policy has two sources: (i) Binding financial conditions, $\lambda_t^b > 0$, and (ii) the dependence of the agency problem on currency mismatch (i.e., $\frac{d\Theta(x_t)}{dx_t} \neq 0$).

If $\frac{d\Theta(x)}{dx} = 0$, banks face no restrictions on the currency composition of their deposits, allowing them to arbitrage freely between domestic and foreign deposits. As a result, the UIP condition holds in equilibrium, implying $\Delta_t^* = 0$. However, financial frictions

[21] Gertler et al. (2012) and Aoki et al. (2021) use a similar financial structure for banks to analyze the role of balance sheet composition.

continue to limit the size of banks' balance sheet, leading to non-trivial domestic interest rate spreads, $\Delta_t^l \neq 0$.[22] Note, however, that FX operations might still affect the macroeconomic allocation through its effects on the banks' balance sheet and over Δ_t^l.

We assume that portfolio constraints are always binding and that a greater reliance on foreign currency borrowing exacerbates the moral hazard problem, i.e., $\frac{d\Theta(x)}{dx} > 0$.

3.3. Production sector

Four types of non-financial firms make up the production side of the model economy: (i) non-commodity final good producers, (ii) capital good producers, (iii) intermediate good producers, and (iv) commodity-sector firms which take global commodity prices and external demand as given.

Non-commodity final good producers. Final goods in the non-commodity sector are produced under perfect competition and using a variety of differentiated intermediate goods $\{y_{jt}^{nc}\}_{j\in[0,1]}$ according to a constant returns to scale technology

$$Y_t^{nc} = \left(\int_0^1 y_{jt}^{nc\,\frac{\eta-1}{\eta}} dj \right)^{\frac{\eta}{\eta-1}} \tag{15}$$

where $\eta > 1$ is the elasticity of substitution across non-commodity goods. The representative firm chooses $\{y_{jt}^{nc}\}_{j\in[0,1]}$ to maximize profits $P_t^{nc} Y_t^{nc} - \int_0^1 p_{jt}^{nc} y_{jt}^{nc} dj$ subject to the production function (15). The first-order condition for the jth input induces the demand schedule

$$y_{jt}^{nc} = \left(\frac{p_{jt}^{nc}}{P_t^{nc}} \right)^{-\eta} Y_t^{nc}.$$

The price index for non-commodity domestic product is $P_t^{nc} = \left(\int_0^1 p_{jt}^{nc\,1-\eta} dj \right)^{\frac{1}{1-\eta}}$. The final homogeneous good can be used either for consumption or to produce capital goods. In addition, part of the final good production is exported for foreign consumption.

Capital Good Producers. There is a continuum of capital producers operating in a competitive market. Using final goods as inputs in the form of non-commodity investments, as well as the undepreciated capital bought from intermediate good producers, new capital is produced according to $K_t^{nc} = I_t^{nc} + \lambda_{nc} K_{t-1}^{nc}$ where K_t^{nc} is sold to intermediate good producers at the price q_t^{nc}. Producing capital implies an additional adjustment cost of investment $\Phi^{nc}\left(\frac{I_t^{nc}}{I^{nc}}\right) I_t^{nc}$ where I^{nc} is the level of non-commodity investment at the steady-state.[23]

Intermediate good producers. There is a continuum of monopolistically competitive firms, indexed by $j \in [0,1]$, producing differentiated intermediate goods that are sold to final good producers. Combining capital k_{t-1}^{nc}, imported goods m_t, and labor h_t, each intermediate good producer operates the following constant return to scale technology

$$y_{jt}^{nc} = A^{nc} \left(\frac{k_{j,t-1}^{nc}}{\alpha_k} \right)^{\alpha_k} \left(\frac{m_{jt}}{\alpha_m} \right)^{\alpha_m} \left(\frac{h_{jt}}{1-\alpha_k-\alpha_m} \right)^{1-\alpha_k-\alpha_m}$$

where $\alpha_k > 0$, $\alpha_m > 0$, $\alpha_k + \alpha_m \in (0,1)$, and A^{nc} denotes the total factor productivity level of the representative intermediate good producer. Intermediate good producers face a "funds-in-advanced-of-production" constraint, which requires them to secure funds before starting production to buy capital from capital good producers. They have two sources of funding. First, the intermediate good producers issue private securities (equity), $\mathcal{S}_{j,t}$, that are purchased by domestic households. Second, they can borrow from banks to get final loan services, $\mathcal{F}_{j,t}$. Hence the purchase of capital is, $q_t^{nc} k_{j,t}^{nc} = \mathcal{S}_{j,t} + \mathcal{F}_{j,t}$.

Each intermediate good producer needs a combination of domestic and foreign currency-denominated loans to obtain final loan services. In particular, loans from different currencies are aggregated according to

$$\mathcal{F}_{j,t} = A^e l_{j,t}^{1-\delta^f} \left(e_t l_{j,t}^* \right)^{\delta^f}$$

where A^e is the productivity scale for aggregate loan services, $l_{j,t}$ and $l_{j,t}^*$ denote domestic and foreign currency-denominated bank loans respectively and the parameter δ^f controls for the degree of credit dollarization in the economy. At the end of each period, intermediate good producers sell back the undepreciated capital, $\lambda_{nc} k_{j,t-1}^{nc}$, to capital good producers.

Moreover, intermediate good producers sets prices facing nominal rigidities in the form of price adjustment costs as in Rotemberg (1982). That is, when setting the price of their output, p_t^{nc}, the producer of each differentiated intermediate goods face a convex cost $\frac{\kappa}{2}\left(\frac{p_{j,t}^{nc}}{p_{j,t-1}^{nc}} - 1\right)^2$ where $\kappa > 0$ controls the degree of price rigidities.

Hence, the optimal behavior for intermediate good producers are associated with three different objectives: (i) cost minimization, (ii) optimal borrowing from banks and equity issuing to households, and (iii) optimal price setting. We describe the key aspects of these decisions. Issuing equity and borrowing from banks are considered to be perfect substitutes to intermediate good producers.

[22] In this case, the model simplifies to a framework akin to those used for analyzing unconventional monetary policies in closed economies. See Gertler and Kiyotaki (2010), Gertler and Karadi (2011), and Gertler and Karadi (2013).

[23] The function $\Phi^{nc}(\cdot)$ must satisfy the following restrictions: $\Phi^{nc}(1) = \Phi^{nc\prime}(1) = 0$ and $\Phi^{nc\prime\prime}(\cdot) > 0$.

This generates a non-arbitrage condition that equalizes the discounted real funding costs to the discounted return of capital, $\mathbb{E}_t[\Lambda_{t,t+1}R^k_{t+1}]$, where $R^k_t \equiv \frac{z_t+\lambda_{nc}q^{nc}_t}{q^{nc}_{t-1}}$. The optimal composition of the demand for banks' loans are:

$$l_{j,t} = (1-\delta^f)\frac{\mathbb{E}_t[\Lambda_{t,t+1}R^k_{t+1}]}{\mathbb{E}_t[\Lambda_{t,t+1}R^l_{t+1}]}\mathcal{F}_{j,t} \quad \text{and} \quad e_t l^*_{j,t} = \delta^f \frac{\mathbb{E}_t[\Lambda_{t,t+1}R^k_{t+1}]}{\mathbb{E}_t[\Lambda_{t,t+1}\frac{e_{t+1}}{e_t}R^{l*}_{t+1}]}\mathcal{F}_{jt}.$$

In equilibrium, the degree of credit dollarization is an endogenous variable that depends on domestic financial conditions, in particular, on the UIP deviation Δ^{l*}_{t+1}. The higher Δ^{l*}_{t+1}, the higher the credit dollarization rate. It is worth emphasizing that this ad-hoc assumption is a modeling shortcut to determine the composition of firms' demand for loans in each currency, which in turn determines the extent of credit dollarization in equilibrium.[24]

From the first-order condition with respect to p^{nc}_{jt} evaluated under symmetric equilibrium $p^{nc}_{jt} = P^{nc}_t$, we obtain the following New Keynesian Phillips Curve (NKPC):

$$(1+\pi_t)\pi_t = \kappa^{-1}(1-\eta+\eta mc_t) + \mathbb{E}_t\left[\Lambda_{t,t+1}(1+\pi_{t+1})\pi_{t+1}Y^{nc}_{t+1}/Y^{nc}_t\right].$$

where $\pi_t = \frac{P^{nc}_t}{P^{nc}_{t-1}} - 1$ is the inflation rate of final non-commodity goods, which coincides with the consumer price inflation.[25]

Commodity good producer. Commodity production is entirely exported abroad and is conducted by a representative firm using physical capital as the only input.[26] The representative firm acquires capital directly from final good producers, without any lending from the banking, and uses a technology represented by $Y^c_t = A^c(K^c_{t-1})^{\alpha_c}$ where Y^c_t is the commodity production, K^c_t is the specific capital for the commodity sector, and A^c is the productivity scale in this sector. Given price of commodity and investment adjustment costs $\Phi^c(\cdot)$, the representative commodity producer chooses $\{K^c_{t+s}, I^c_{t+s}\}_{s\geq 0}$ to maximize profits

$$\sum_{s=0}^{\infty}\Lambda_{t,t+s}(1-\tau^c)\left(p^c_{t+s}A^c(K^c_{t+s-1})^{\alpha_c} - \left[1+\Phi^c\left(\frac{I^c_{t+s}}{I^c}\right)\right]I^c_{t+s}\right)$$

subject to $K^c_{t+s} = I^c_{t+s} + \lambda_c K^c_{t+s-1}$ for all $s \geq 0$, where τ^c is the profit tax rate. The ownership of the commodity firm is divided between domestic and foreign shareholders: domestic households own a fraction χ^c, while foreign families own $1-\chi^c$. Consequently, a fraction $1-\chi^c$ of the profits are transferred abroad to foreign owners.[27]

In this framework, fluctuations in commodity prices generate a wealth effect in the domestic economy through household profits and government tax revenues. This effect is further amplified by the strong co-movement between commodity prices and the real exchange rate. Since exchange rate dynamics directly influence the agency problem faced by banks, financial conditions ease when commodity prices rise and tighten when they decline, reinforcing the transmission of external shocks to the domestic economy.

3.4. Consolidated government

The consolidated government consists of a monetary authority (the central bank) and a fiscal authority. The central bank has two instruments to stabilize macroeconomic and financial business cycles: FX intervention and the conventional policy rate. In turn, the role of the fiscal authority is to collect taxes to finance central bank's operational results and government expenditure.

FX intervention. The central bank issues domestic bonds, denoted as B_t, and holds official FX reserves, F_t, which are invested in foreign assets. A sterilized FX intervention occurs when the central bank simultaneously buys or sells FX and offsets the impact of such operation over domestic liquidity by adjusting its holdings of domestic currency-denominated bonds. This procedure is captured by the central bank sterilization equation (or balance sheet)[28]:

$$B_t = e_t F_t. \tag{16}$$

As long as $R^b_t > R^*_t$, the central bank produces operational losses associated with the sterilization process that are transferred to the central government, representing a fiscal costs of FX interventions. Then, the central bank's quasi-fiscal deficit is:

$$CB_t = e_t(F_t - R^*_t F_{t-1}) - (B_t - R^b_t B_{t-1}) = \left(R^b_t - \frac{e_t}{e_{t-1}}R^*_t\right)B_{t-1}. \tag{17}$$

[24] Recall that the currency composition of the supply of loans is undetermined with the banks willing to supply any loan in pesos and dollars as long as their aggregate leverage is Φ_t. Therefore, the current assumption determines the extent of credit dollarization.

[25] In a Calvo style model in which each monopolistic producer can change its price according to a Bernoulli process with arrival rate $1-\varrho$, we get the same log-linearized version of NKPC if we choose $\kappa = \frac{(\eta-1)\varrho}{(1-\varrho)(1-\beta\varrho)}$.

[26] Terms-of-trade fluctuations constitute an important driver of business cycle fluctuations in EMEs. For example, episodes of persistently high commodity prices generate significant economic expansions as well as credit booms. For empirical evidence on this fact, see Fornero et al. (2015), Shousha (2016), Fernández et al. (2017), Garcia-Cicco et al. (2017), and Drechsel and Tenreyro (2018).

[27] We assume the foreign stochastic discount factor is the same as its domestic counterpart. Hence, $\Lambda_{t,t+1}$ is the discount factor for the future commodity sector's cash flows independent of ownership.

[28] The central bank's balance sheet is relevant solely for FX intervention operations. Central bank bonds serve as an independent policy tool to implement sterilized FX interventions, with banks being the only agents allowed to hold them. Households, in contrast, do not participate in the market for central bank assets.

where the second equality uses the sterilization Eq. (16). Furthermore, the central bank issues bonds systematically, according to the following FX intervention rule:

$$\ln B_t = \ln B - \upsilon_e(\ln e_t - \ln e) \tag{18}$$

where $\upsilon_e \geq 0$ measures the response of FX interventions to real exchange rate deviations from its steady state value (e) and B denotes the steady state level of central bank bonds. Thus, the central bank sells official FX reserves in response to a real depreciation (specifically, whenever the real exchange rate is above its steady state value).

Monetary policy. In addition to implementing the FXI policy rule (18), the monetary authority sets the short-term nominal interest rate i_t according to a simple rule that belongs to the class of Taylor-type rules given by:

$$i_t - i = \rho_i(i_{t-1} - i) + (1 - \rho_i)\left[\omega_\pi \pi_t + \omega_y \ln\left(\frac{\text{GDP}_t}{\text{GDP}}\right)\right] \tag{19}$$

where ρ_i measures the persistence of the policy rate and ω_π and ω_y controls the degree of the policy rate response to inflation and gross domestic product (GDP), respectively. It is worth emphasizing that this is the nominal return for deposits in pesos, while the real return of it and the other assets (included the return on government bonds) are determined in general equilibrium. That is, the central bank controls the interest rate of deposits, while only partially controls the real return of the bonds it offers through its effects on R_{t+1}.[29]

Fiscal policy. The consolidated government sector collects taxes from households and receives a fraction τ^c of the aggregate profits generated by commodity producers. These resources are then used to finance public consumption G and central bank operational losses, i.e.,

$$\tau^c \Pi_t^c + T_t = CB_t + G_t. \tag{20}$$

Eq. (20) indicates that commodity price movements as well as central bank operational losses affect household's decisions through variations in lump-sum taxes. For simplicity, our baseline analysis assumes that the central bank's operational results are financed through non-distortionary taxes. However, in Section 5.4, we explore how additional FX intervention costs may impact our main findings.

3.5. External sector

The foreign demand for non-commodity exports of the domestic final good $Y_t^{nc,x}$ is increasing with respect to the real exchange rate e_t, and global demand or foreign income Y_t^*, given by $Y_t^{nc,x} = e_t^{\varphi} Y_t^*$, where $\varphi > 0$ is the price elasticity. The external block has its own dynamics without any feedback from domestic variables. The variables considered in the external block are foreign output Y_t^*, the foreign interest rate R_t^*, and the commodity price index p_t^{wc}. The cyclical components of those variables are collected in vector $\hat{\mathbf{X}}_t = \left[\hat{Y}_t^* \;\; \hat{R}_t^* \;\; \hat{p}_t^*\right]'$ where $\hat{Y}_t^* = \ln \frac{Y_t^*}{Y^*}$, $\hat{R}_t^* = R_t^* - R^*$, and $\hat{p}_t^* = \ln \frac{p_t^{wc}}{p^{wc}}$. We assume that $\hat{\mathbf{X}}_t$ follows a first-order vector autoregressive system given by

$$\hat{\mathbf{X}}_t = \mathbf{C}\hat{\mathbf{X}}_{t-1} + \mathbf{B}\mathbf{u}_t^X \tag{21}$$

where $\mathbf{C}$ and $\mathbf{B}$ are 3×3 matrices that rule the dynamics of the vector $\hat{\mathbf{X}}_t$, and $\mathbf{u}_t^X$ is the vector of external structural shocks. Section 4 presents further details about the data, estimation, and identification strategy.

3.6. Market equilibrium

The non-commodity output net of adjustment, transaction, and "management costs" is either consumed, invested, or exported:

$$Y_t^{nc} = C_t + G_t + I_t^{nc} + I_t^c + Y_t^{x,nc} + \text{REST}_t \tag{22}$$

where REST_t captures additional costs in the model economy, such as investment and price adjustment costs, transaction costs for households' foreign currency deposits, and equity portfolio investments. REST_t also includes the difference between the aggregate amount of real loans received from the banking sector and the aggregate loan services that intermediate good producers use to buy capital. We interpret the latter as "management costs" that intermediate good producers incur to generate the optimal bundle of loans.[30]

Gross Domestic Product (GDP) is defined as the aggregate value added of the total production in the non-commodity and commodity sectors but evaluated at constant prices: $\text{GDP}_t = Y_t^{nc} - eM_t + p^c Y_t^c$ where p^c and e are the steady-state levels for the commodity price index and the real exchange rate, respectively. Therefore, GDP_t captures only real output movements and is unaffected by valuation effects.

The market-clearing condition for foreign currency implies that aggregate deposits denominated in foreign currency is composed by household's bank deposits and banks' foreign borrowing: $D_t^* = D_t^{*,h} + D_t^{*,f}$. The aggregate net foreign asset position of the

[29] Recall that R_{t+1}^b will be pinned down by Δ_t^b which verifies (10).

[30] $\text{REST}_t = \frac{\kappa}{2}\pi_t^2 Y_t^{nc} + e_t \frac{\kappa_{D^*}}{2}\left(D_t^{*,h} - \overline{D}^{*,h}\right)^2 + \frac{\kappa_S}{2}\left(S_t - \overline{S}\right)^2 + \Phi^c\left(\frac{I_t^c}{I^c}\right) + \Phi^{nc}\left(\frac{I_t^{nc}}{I^{nc}}\right) + L_t + e_t L_t^* - \mathcal{F}_t$.

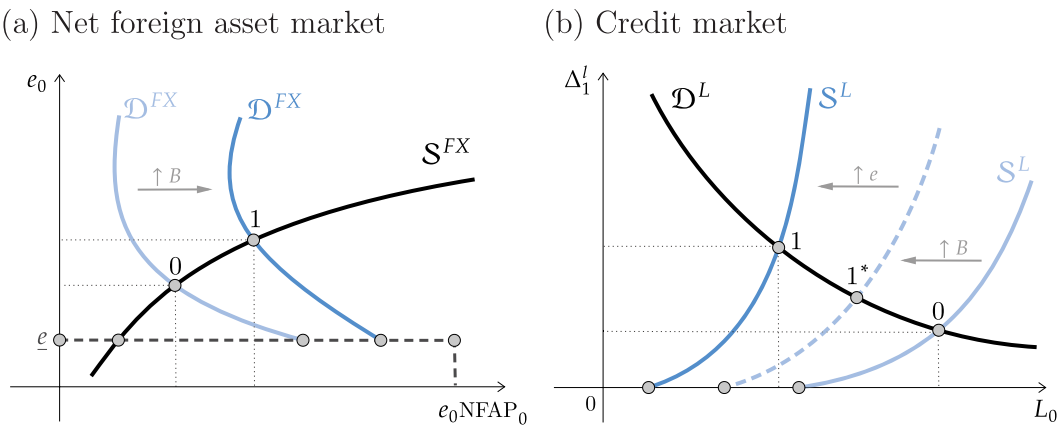

Fig. 3. Effects of FX interventions in Net foreign asset and Credit markets.

economy, NFAP_t, is equal to FX official reserves net of aggregate foreign liabilities in the baking system (i.e., $\text{NFAP}_t = F_t - D_t^{*,f}$), and evolves as a function of financial income of net foreign assets from the previous period plus the difference between the trade balance and the fraction of aggregate profits in the commodity sector transferred abroad,

$$e_t\left[\text{NFAP}_t - R_t^*\text{NFAP}_{t-1}\right] = Y_t^{x,nc} + p_t^c Y_t^c - e_t M_t - (1-\tau^c)(1-\chi^c)\Pi_t^c$$

Finally, as newly appointed bankers receive a fraction ξ of total assets from the household as start-up funds, the aggregate net worth for banks evolves according to:

$$N_t = (\sigma+\xi)\left(R_t^l L_{t-1} + R_t^{l*} e_t L_{t-1}^* + R_t^b B_{t-1}\right) - \sigma R_t D_{t-1} - \sigma e_t R_t^* D_{t-1}^*. \tag{23}$$

In period t, the composition of banks' balance sheets is given. Eq. (23) indicates that movements in N_t uniquely depend on the real exchange rate and real interest rates dynamics. Thus, when the currency mismatch is large enough, any increase in the real exchange rate reduces N_t, affecting aggregate credit conditions.

3.7. Inspecting the mechanisms

This section provides an overview of the primary mechanism by which FX interventions operate, using a simplified version of the model. The main simplifying assumptions are: (i) no domestic financial dollarization (i.e., $L_t^* = D_t^{*,h} = 0$ for all t), and (ii) bank assets are equally weighted in their incentive constraint (i.e., $\varpi^b = \varpi^* = 1$). Additionally, there are no government expenditures, no habits in consumption, full depreciation of capital after production, no adjustment costs of investment, no commodity sector, and fixed prices. To ensure tractability, we assume no aggregate uncertainty and focus on the temporary (partial) equilibrium under perfect foresight for credit and FX asset markets taking expectations as given. In particular, we develop a graphical tool to characterize the equilibrium in the FX and credit markets, where the exchange rate e_0 and the lending interest rate spread Δ_1^l are determined. To simplify the exposition, we provide intuitive arguments for the functions we plot, but details of the discussion below are in Appendix D.[31]

Partial equilibrium analysis. Fig. 3 shows the joint determination of e_0 and Δ_1^l in the interrelated FX and credit markets. For pedagogical reasons, we associate the supply of FX assets, $\mathcal{S}^{FX}$, with the resources disposable to accumulate foreign assets mainly determined by the net exports, while the demand of credit, $\mathcal{D}^L$, is pinned down by the firm's loan-in-advance decisions. As expected, a currency depreciation at $t = 0$ leads to increased global demand for domestic goods resulting in higher net exports, while a decrease in Δ_1^l boosts the demand for credit.

The supply of credit results, $\mathcal{S}^L$, from aggregate banks' leverage decisions, $\Phi_t N_t$, net of the central bank's bonds B_t. In turn, the demand of FX assets, $\mathcal{D}^{FX}$, assets reflects the central bank's foreign asset holdings, B_t expressed in pesos, net of private banks' foreign liabilities, $e_t D_t^*$. Consistent with our discussion in Section 3.2, these schedules exhibit two distinct regions. When the banks' balance sheet is sufficiently small — either due to low L_0 or low D_0^* — the portfolio constraint does not bind, and both curves are flat. This is the "frictionless" region, where neither interest rate spreads nor UIP deviations occur. Conversely, when the banks' balance sheet reaches a certain size, the borrowing constraints become binding, causing both the interest rate spread and UIP deviations to depend on the macroeconomic allocation. In this "constrained" region, an increase in the domestic lending spread raises the marginal benefits of lending and reduces the currency mismatch, leading to an unambiguous loosening of the borrowing constraint

[31] As discussed in Case 1 of Section 5.4, FX intervention policy remains efficient and welfare-improving even in the absence of dollarization. While the exchange rate channel is entirely muted, the balance sheet channel remains the primary transmission mechanism. Since banks remain financially constrained even without financial dollarization, the sterilization component of FX intervention effectively functions as a central bank balance sheet policy.

and an expansion of credit supply. On the other hand, an increase in the real exchange rate have mixed effects on the net demand for foreign assets, driven by how banks adjust their demand for external funds. These opposing effects arise from the impact of exchange rate changes on banks' net worth and leverage ratios, further amplified by x_t. Consistent with our baseline calibration, we focus on the scenario where $\mathcal{D}^{FX}$ is downward sloping.

Suppose the economy initially lies in the "constrained" region (represented by the gray dot marked as "0"). An exogenous accumulation of FX reserves by the central bank triggers the following immediate effects across the key markets involved in the transmission mechanism of FX intervention policies:

1. **Foreign Exchange (FX) Channel:** The central bank's purchase of foreign assets shifts the net FX asset demand curve to the right, leading to an immediate depreciation of the real exchange rate (shifting the FX market equilibrium from "0" to "1").
2. **Balance Sheet (BS) Channel:** The sterilization of this FX purchase reduces credit supply through a crowding-out effect on banks' portfolios. As banks holds more central bank bonds, fewer resources are available for lending, causing the domestic spread to rise at the initial exchange rate level (shifting the credit market equilibrium from "0" to"1*").[32]

Additionally, the increase in the real exchange rate tightens banks' borrowing constraints by reducing their net worth and leverage ratio, further contracting the credit supply. As a result, the credit supply curve shifts leftward, widening the domestic interest rate spread.[33] In the new equilibrium, the real exchange rate, the interest rate spread, and eNFAP all rise, while total credit diminishes (indicated by the "1" markers).[34,35]

General equilibrium analysis. The previous discussion of FX interventions focused on a partial equilibrium framework. In Appendix B.1, we numerically examine the broader general equilibrium effects of a 1% increase in FX reserves in this framework. In summary, the buildup of FX reserves causes real exchange rate depreciation, pushing the economy into a credit crunch and recession. As emphasized in the partial equilibrium analysis, the interaction between banks' net worth, leverage ratio, and balance sheets is central to the transmission mechanisms of FX interventions.

3.8. Discussion

Currency mismatches. Concerns about the role of currency mismatches in our framework may emerge in situations where financial markets offer instruments to hedge exchange rate risks. However, when banks lend in foreign currency to domestic borrowers whose revenues are in denominated in local currency, a depreciation increases the real burden of those loans, heightening the risk of default. Thus, even if banks appear hedged on paper, they remain indirectly exposed to substantial currency risk. This dynamic is common in many EMEs, where shallow FX markets provide limited hedging options. Consequently, small and medium-sized enterprises (SMEs) often lack the ability to hedge their foreign currency exposure, leaving both, them and their banks, vulnerable to exchange rate fluctuations.[36]

Financial frictions. The competitive equilibrium in our simple framework is inefficient due to imperfections in the credit market. Our analysis integrates two important strands of literature: (i) the role of financial frictions in interactions between domestic and foreign agents, particularly regarding foreign currency-denominated assets and liabilities, and (ii) the impact of balance-sheet policies during financial crises in closed economies.

At the core of our model is the portfolio balance approach revitalized by Gabaix and Maggiori (2015) to be consistent with imperfect financial markets. This approach introduces a moral hazard problem between international financiers that actively take risks in currency markets, who intermediate between domestic and foreign agents, and their creditors. In our model, these financiers are analogous to domestic banks when there is not domestic dollarization, $\sigma = 0$, $b_t = 0$ and $d_t = 0$.[37] The credit constraint, in the form of a limited commitment constraint, faced by financiers in these models typically takes the form:

$$\underbrace{\gamma \cdot \overbrace{\mathrm{Var}(e_{t+1}/e_t)}^{\text{Volatility}} \cdot \overbrace{l_t}^{\text{Size}}}_{\text{Diverted portion}} \cdot \overbrace{l_t}^{\text{Claim/Size}} \leq V_t.$$

[32] This aspect of FX interventions is conceptually emphasized by Chang and Velasco (2017), Céspedes and Chang (2019), and Chang (2019), and empirically supported by Hofmann et al. (2019) and Ceron et al. (2023).

[33] The exchange rate affects credit supply through a net worth effect and a leverage ratio effect. An increase in e_t reduces banks' net worth while the leverage ratio effect has opposing impacts: (i) Enhancing banks' lending profitability by making external funds cheaper through the expected appreciation and (ii) raising the currency mismatch. We assume that $\partial S^L/\partial e_0 < 0$.

[34] Second-round effects arise because shifts in Δ_1^l also influence the demand for FX. The schedules in Fig. 3 account for these interactions, ensuring that the equilibrium markers reflect the outcome after all adjustments.

[35] If the initial equilibrium lies in the "frictionless" region for the FX market and in the "constrained" region for the credit market, the FX channel remains muted, yet sterilized FX interventions can still have non-neutral effects due to their impact on the balance sheet. We quantitatively assess this scenario in our robustness checks (See Section 5.4).

[36] This approach captures the interaction between borrowers' currency mismatches and financial frictions in the literature (e.g., see Mendoza and Rojas (2019), Bocola and Lorenzoni (2020), and Christiano et al. (2021)). Moreover, Alfaro et al. (2021) document that operational hedging is quantitatively limited and that only large firms hedge this risk by actively using financial hedging.

[37] Similar frameworks have been applied by several authors, including Cavallino (2019), Fanelli and Straub (2021), and Itskhoki and Mukhin (2023).

Table 2
Calibrated parameters.

Description	Parameter	Value
Elasticity of intertemporal substitution	γ	2.00
Inverse Frisch elasticity	ζ	3.00
Elasticity of substitution of goods	η	6.00
Undepreciated NC capital rate	λ^{nc}	0.975
Undepreciated C capital Rate	λ^{c}	0.975
Domestic ownership on commodity firms	χ^{c}	0.00
Tax on commodity sector profit	τ^{c}	0.60
Banker's survival Rate	σ	0.945
MP rate smoothing	ρ_i	0.70
MP rate response to inflation	ω_π	1.50
MP rate response to output gap	ω_y	0.125
FXI efficiency cost	τ^{fx}	0.00

Note. Set of parameters that are calibrated based on external references.

This implies that financiers' risk-taking capacity is limited by the complexity of their financial positions, which encompasses the size, composition, and volatility of their balance sheets. Larger and riskier balance sheets result in more complex positions and complicate fund recovery in the event of default, increasing creditors' exposure.

Financial institutions in EMEs face heightened risks due to more complex balance sheets, often exacerbated by currency mismatches from dollarized assets and liabilities. These mismatches intensify exposure to exchange rate volatility, increasing financial fragility. Consequently, currency mismatches heighten banks' ability to divert funds by complicating their balance sheets. Our model reflects this type of complexity. Moreover, banks in our model are forward-looking and exposed to balance sheet effects from expected exchange rate fluctuations.[38],[39] Furthermore, this same portfolio constraint creates domestic inefficiencies in the intermediation of deposits and loans, resulting in positive domestic lending spreads. This structure, commonly used to study unconventional monetary policies in closed economies,[40] allows us to analyze the role of sterilized FX interventions in a small open economy. We argue that these interventions operate as a balance sheet policy in the domestic credit market, ultimately crowding out domestic lending.

FXI effectiveness and financial dollarization. The analysis in Section 3.7 has assumed that the economy does not exhibit domestic financial dollarization. In this, the strength of the FX channel depends on the UIP deviations which are first-order effects as the steady state exhibits currency mismatch due to banks' external liabilities. If banks could not borrow in dollars, the FX intervention might be still effective and efficient due to the sterilization effect on credit markets in a financially constrained equilibrium.

To study the effects of financial dollarization in our setting, consider Fig. 3 in our previous discussion. When households have access to bank deposits in dollars, the net demand for foreign assets shifts upwards with a stepper (flatter) slope if households' arbitrage frictions are quantitatively larger (smaller) than banks'. Instead, credit dollarization makes S^L less dependent on e_t as banks have more instruments to mitigate exchange rate risks by lending in foreign currency. Hence, the final effect of FX interventions on credit and economic activity is larger than in a non-dollarized economy if households' arbitrage limits are severe, and smaller otherwise. Additionally, since the macroeconomic variables are more volatile under a flexible exchange rate regime, the FX policy may become more desirable. We study how the lack of domestic financial dollarization affects our results in Section 5.4.

4. Parameterization strategy

We discipline the model to replicate relevant unconditional and conditional moments for the Peruvian economy.[41] We calibrate a subset of the parameters to be consistent with some steady-state targets associated with Peruvian historical averages. Following Schmitt-Grohe and Uribe (2018), we estimate another subset of parameters by using a limited information method based on an impulse response matching function estimator.

Data. We use quarterly data from the Peruvian economy between 2002Q1 and 2018Q4. Aggregate macroeconomic variables such as GDP, consumption, inflation, and the real exchange rate are sourced from the Central Reserve Bank of Peru (BCRP). Additionally, we combine aggregate bank data from individual bank reports to the Superintendencia de Banca *y* Seguros (SBS), the bank regulator, matching the aggregate bank balance sheets to the model variables. Further details are provided in Appendix A.

[38] The balance sheet effect of real exchange rate fluctuations originates in early 2000s literature. See Calvo (2001), Calvo and Reinhart (2002), Céspedes et al. (2003), and Céspedes et al. (2004).

[39] Aoki et al. (2021) explores a similar financial structure focusing on macroprudential policies such as capital controls. In contrast, we emphasize the role of sterilized FX intervention rules on the macroeconomic allocation and quantify their welfare gains.

[40] See Gertler and Kiyotaki (2010), Gertler and Karadi (2011), and Gertler and Karadi (2013).

[41] The Central Reserve Bank of Peru (BCRP) is constitutionally mandated to preserve monetary stability and is prohibited from financing the Public Treasury to maintain its autonomy. Since 2001, the BCRP has followed an inflation-targeting regime, using additional tools like foreign exchange (FX) interventions and reserve requirements to manage risks from financial dollarization. FX interventions help reduce exchange rate volatility without affecting long-term trends, mitigate balance sheet risks, and provide liquidity during periods of stress.

Table 3
IRF matching estimation results.

Description	Parameter	Value
Non-commodity capital adjustment cost	κ_{Inc}	0.05
Commodity capital adjustment cost	κ_{Ic}	0.15
FX intervention response to RER	υ_e	9.71
Non-commodity exports price elasticity	φ	0.09
Household FC deposit adjustment cost	κ_{D*}	3.00
Household capital adjustment cost	κ_S	0.02
Household habit formation	$\mathcal{H}$	0.90

Note. Set of parameters estimated to match model and empirical (SVAR) responses to external shocks.

Calibrated parameters. The following are parameters calibrated externally. The elasticity of intertemporal substitution for household preferences is 1/2. Households' preferences have a Frisch elasticity of the labor supply equal to 1/3. In the production sector, the elasticity of substitution among intermediate goods is set at six and the capital depreciation rate is set at 10 percent annually for both sectors. Only foreign agents own commodity firms (i.e., $\chi^c = 0$), and a commodity profit tax of 60 percent is in line with Garcia-Cicco et al. (2017). The parameters controlling the conventional monetary policy response (ρ_i ω_π ω_y) are set to standard values commonly used in the literature. Following Aoki et al. (2021), we fix the bank's survival rate, σ, at 0.945. Table 2 summarizes our calibration strategy.

Additionally, we parameterize (ϖ^*, ϖ^b, ξ, θ, $\varkappa$, δ^f) to be consistent with the following steady-state financial targets for Peru: an annual domestic currency lending rate of 6 percent, an annual foreign currency lending rate of 4 percent, an annual return of 4 percent for central bank bonds, a domestic currency leverage of 3.00, dollar deposits to total assets ratio of 60 percent, and a credit dollarization rate of 50 percent. See Figure A.2 and Figure A.1 for the evolution of the banking system variables in Peru from 2002 to 2018.

Similarly, the vector of parameters (A^e, ζ_0, Y^*, p^{wc}, A^{nc}) is calibrated to attain 8 percent of annual non-commodity capital return, 0.33 of worked hours and steady-state levels for the real exchange rate, the commodity price index, and GDP normalized at 1. Furthermore, the vector ($\overline{D}^{*,h}$, $\overline{S}$, α^c, A^c, α^k, α^m, B^{fx}) is parameterized to target empirical ratios, such as consumption to GDP, commodity to non-commodity investment or FX reserves to GDP, among others. Table A.2 in Appendix A summarizes our parameterization based on the steady-state targets.

Empirical VAR and impulse-response matching. The rest of the parameter set is estimated to match impulse responses to external shocks between an SVAR model and the DSGE model. We consider an SVAR model with two recursive blocks similar to Canova (2005), Cushman and Zha (1997), and Zha (1999). Let $\boldsymbol{X}_t = [Y_t^* \;\; R_t^* \;\; p_t^{wc}]^\top$ denote the vector of foreign variables and $\boldsymbol{D}_t = [\text{TB}_t, \;\; \text{GDP}_t, \;\; C_t, \;\; I_t, \;\; L_t, \;\; e_t L_t^*, \;\; e_t]^\top$ the vector of domestic variables. The external variables Y_t^*, R_t^*, and p_t^{wc} denote the real GDP index for the G-20 group of countries, the Baa U.S corporate spread, and a metal export price index relevant for the Peruvian economy given its status of an emerging market commodity exporter. The domestic variables GDP_t, C_t, I_t, L_t, and $e_t L_t^*$ denote real indexes for Peru's GDP, consumption, investment, and real bank lending in domestic and foreign currency, respectively, while e_t denotes the bilateral real exchange rate and tb_t the trade balance-to-GDP ratio.

Following Canova (2005), the baseline specification considers $\boldsymbol{X}_t$ as an exogenous block, with no feedback dynamics from the domestic block, $\boldsymbol{D}_t$, at any point in time. The main identification assumption is that an emerging small open economy such as Peru takes as given world prices and quantities. The baseline specification assumes that all variables are expressed in log levels.[42] Therefore, we consider an SVAR in levels with zero restrictions between the two recursive blocks, capturing the SOE property of the Peruvian economy, and a linear/quadratic time trends. Moreover, shocks within each block are identified recursively with zero contemporaneous restrictions.[43]

Let Ξ be the subset of parameters to be estimated by matching the impulse responses to external shocks, $\mathcal{M}^{\text{data}}$ the corresponding empirical impulse responses from the SVAR model, and $\mathcal{M}^{\text{model}}$ the theoretical counterpart of $\mathcal{M}^{\text{data}}$. Then, we set Ξ to be the solution to the following problem

$$\Xi^* = \arg\min_{\Xi} \sum_{i=1}^{k} \varrho_i^{-1} \cdot \left[\mathcal{M}_i^{\text{model}}(\Xi) - \mathcal{M}_i^{\text{data}}\right]^2 \tag{24}$$

where ϱ_i is a scalar containing the width of the 68% confidence interval associated with the ith variable in $\mathcal{M}^{\text{data}}$. This scalar penalizes the elements of the estimated impulse response functions associated with large error intervals.

Using the same foreign block in our model as in the empirical SVAR, $\Xi = \{\kappa_{Inc}, \kappa_{Ic}, \nu_e, \varphi, \kappa_{D*}, \kappa_S, \mathcal{H}\}$ are estimated matching the responses of GDP, consumption, investment, domestic currency denominated loans (DC loans), and the real exchange rate for the first 24 quarters to perform the matching estimation. Our estimation results are summarized in Table 3 and Fig. 4. Our empirical

[42] The only variables expressed in percentage terms are R_t^* and tb_t.

[43] We use quarterly data, covering from 2002Q1 to 2018Q4 for the domestic block and from 1980Q1 to 2018Q4 for the foreign block. Following Fernández et al. (2017), we first estimate the foreign block separately and impose the corresponding estimated parameters in the estimation of the domestic block. See Appendix A for methodological details. See Walerych and Wesolowski (2021) and Siklos (2018) for an alternative empirical approach to identifying the effects of external shocks in emerging market economies.

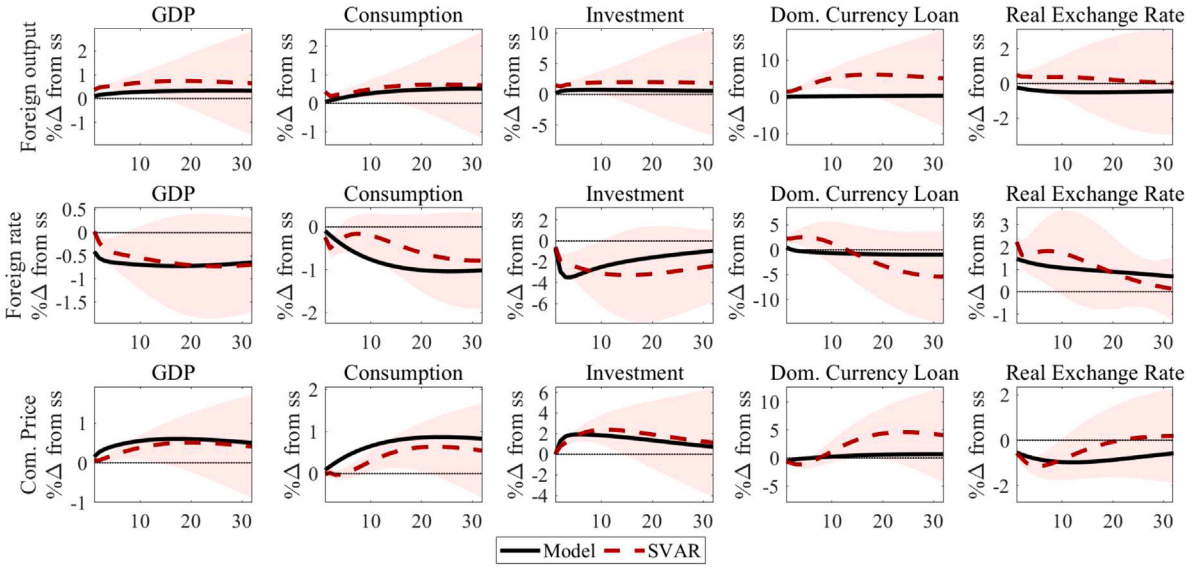

Fig. 4. Impulse response matching estimation.
Note. Solid-black (red-dashed) lines show point estimates of DSGE's (SVAR's) impulse response, while red-shaded areas depict 68% confidence bands associated with the SVAR's impulse response.

Table 4
Second moments of main macro variables: Data versus model.

	Gross dom. product	Consumption	Investment	Real exchange rate
Relative Standard Deviation w.r.t. GDP				
Data	1.00	0.98	5.10	2.24
Model	1.00	0.86	5.83	2.39
Autocorrelation (1st order)				
Data	0.91	0.87	0.91	0.93
Model	0.86	0.96	0.87	0.71

Note. Model-based first-order autocorrelation and relative standard deviations of key macroeconomic variables (w.r.t. GDP) are compared to their empirical counterparts.

model indicates that a foreign interest rate shock causes a real exchange rate depreciation and a contraction in aggregate credit and output. On the other hand, the global demand and the commodity price shocks are expansionary in terms of domestic output, investment, and total credit. These empirical responses are closely followed by the theoretical responses of our DSGE model (see Fig. 4).[44]

Table 4 shows a remarkable similarity between the model-based standard deviations relative to GDP and the first-order autocorrelation of GDP, consumption, investment, and the real exchange rate when compared to their empirical counterparts consistent with the estimated SVAR.[45] This indicates that our baseline parameterized model accurately captures the patterns observed in the aggregate business cycles of a typical small open economy that is a commodity exporter and has financial dollarization.

5. Numerical experiments

This section presents a series of simulations to explore the effects of FX intervention operations on credit markets and the broader economy. Our first simulation examines the transmission mechanisms for an exogenous, highly persistent unanticipated accumulation (purchase) of FX reserves. Next, we investigate the transmission of a sudden global commodity boom to financial and aggregate variables under two distinct policy-rule regimes (systematic responses consistent with (18)): Exchange Rate Flexibility (FER), where $\upsilon_e = 0$, and FX Intervention Policy (FXI), with υ_e at its baseline level. We also explore the effects of this systematic FX intervention on the macroeconomic variables' volatility when all external shocks hit the economy. Our last exercise evaluates the

[44] Except for some parameters associated with financial dollarization (δ^f, κ_{D^*}, and $\overline{D}^{*,h}$) as well as the endogenous response of FX operations (υ_e), our baseline parameterization is consistent with values for any typical emerging market economy. Moreover, in Section 5.4, we explore more general assumptions about the financial sector and find that our key results are still valid.

[45] See Appendix A for methodological details.

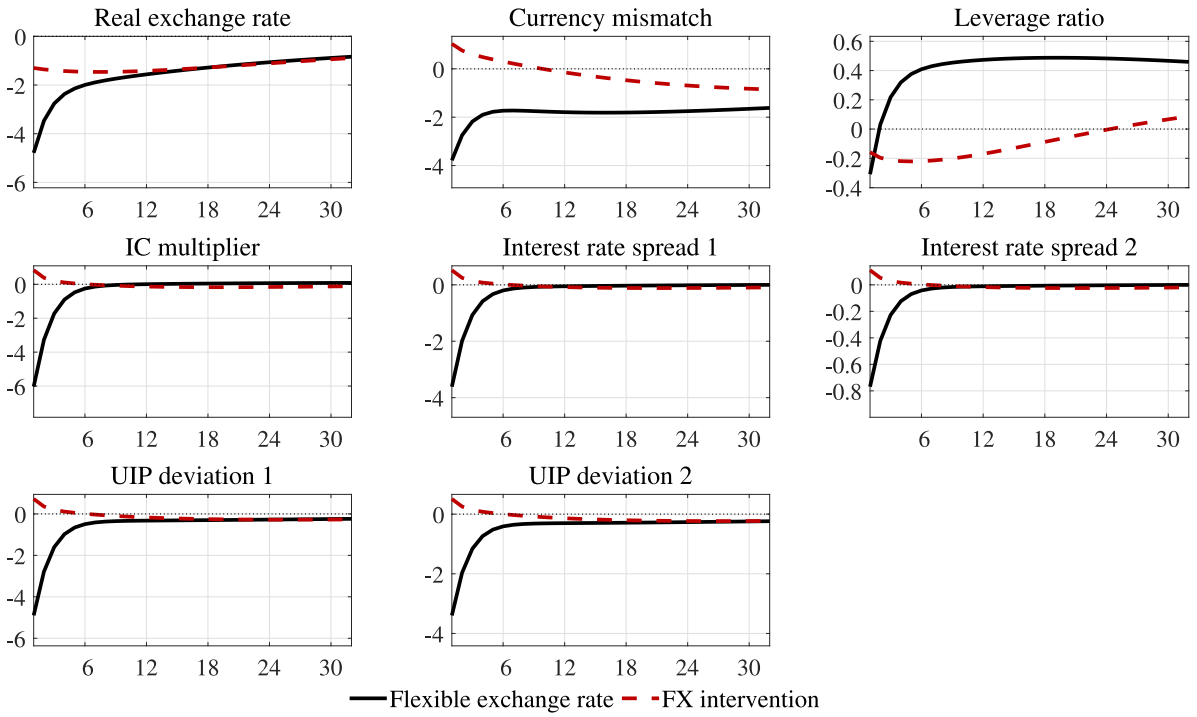

Fig. 5. Responses of financial variables to a commodity price shock.
Note. All variables are presented as percentage deviations from their steady state, except for interest rates, spreads, and the leverage ratio, which are displayed as deviations from their respective steady states.

welfare gains and costs associated with various exchange rate regime policy rules that range from FER to different degrees of FXI relative to our baseline scenario. This analysis includes examining the optimal FX intervention rule assuming that the central bank faces adjustment costs when implementing the associated sterilization operations.

In this and the subsequent section, we assign labels to the interest rate spreads and UIP deviations as follows: The spread between the return on pesos lending (correspondingly, dollars lending) and funding costs, Δ_t^l (correspondingly, Δ_t^b), will be referred to as "Interest rate spread 1" (correspondingly, "Interest rate spread 2"). Similarly, the UIP deviations defined by Δ_t^* and Δ_t^{l*} will be denoted as "UIP Deviation 1" and "UIP Deviation 2", respectively.

5.1. Responses to a commodity price shock

Fig. 5 , Fig. 6, and Fig. 7 shows the response of the main macroeconomic variables to a commodity price shock (one standard deviation) when the central bank intervenes in the FX market following the systematic rule (18). To maintain the clarity of our analysis, we isolate the impact of commodity price movements by mitigating its correlation with the rest of the foreign-block sector, i.e., global demand and the foreign interest rate do not deviate from their steady-state level. The black-solid line corresponds to the flexible exchange rate regime in these figures, while the red dashed line represents the FX intervention regime.

The flexible exchange rate regime. Under exchange rate flexibility, a persistent increase in commodity prices raises exports. A large fraction of the revenues from commodity exports remains in the economy, leading to a persistent exchange rate appreciation of around 4.5 percent at impact (see Fig. 5). The commodity sector experiences a prolonged economic boom that spreads to the rest of the economy through a significant wealth effect and a higher demand for investment goods. The response of the shadow price of the incentive compatibility constraint (IC multiplier in Fig. 5) indicates that banks are less constrained with a significant improvement in financial conditions. However, the leverage ratio declines at the outset of the commodity shock but improves persistently after. Notice that exchange rate appreciation relaxes the agency constraint that banks face through a significant currency mismatch reduction of 4.0 percentage points and a 6 percent increase in net worth see Fig. 6. But at the same time, both interest rate spreads decline at impact, producing a one-period contraction on the leverage ratio response.

These responses constitute an expansionary financial effect induced by the real exchange rate appreciation. Hence, lending in both currencies rises at impact (3 percent for domestic currency loans and 8 percent for foreign currency loans). Under exchange rate flexibility, agents expect a real exchange rate depreciation, making borrowing in dollars more expensive than borrowing in pesos. In contrast, lending in foreign currency becomes more profitable than lending in domestic currency. As a result, the banks' balance sheets experience a 1.0 p.p. increase in credit dollarization and a reduction of 3 percentage points in deposit dollarization at impact. The commodity boom and the subsequent expansionary financial conditions (credit boom) modify the dynamics of real

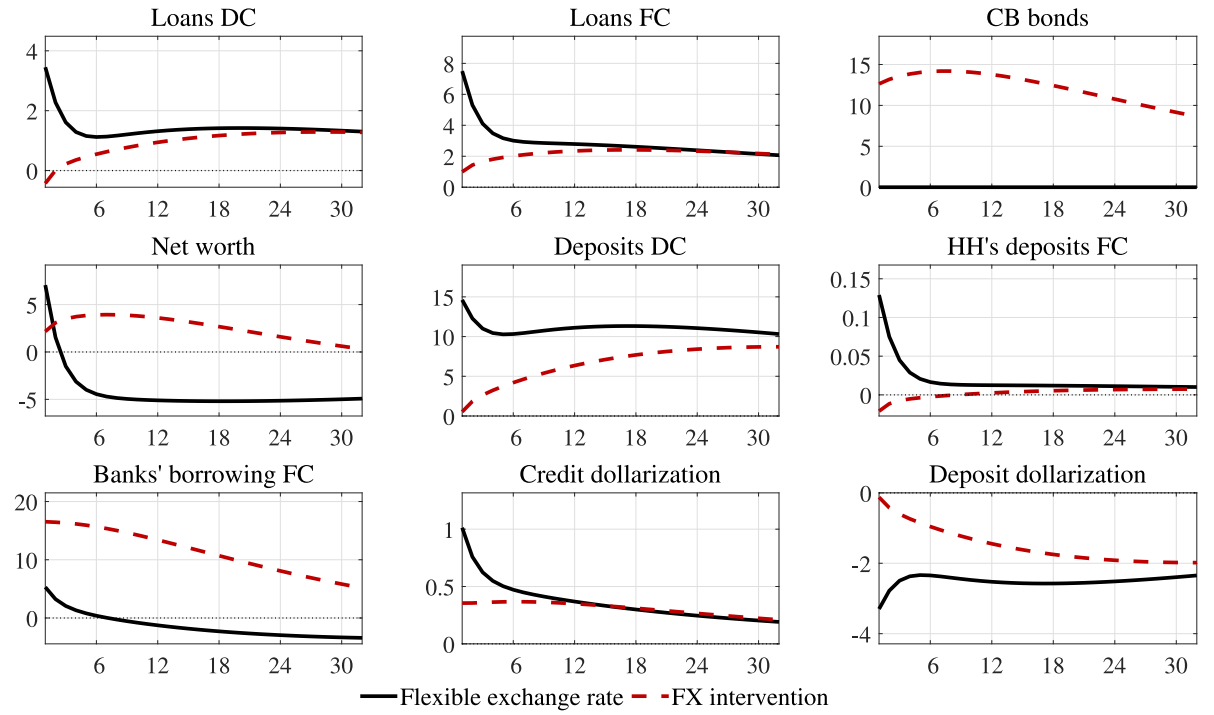

Fig. 6. Responses of financial variables to a commodity price shock.
Note. All variables are presented as percentage deviations from their steady state, except for interest rates, spreads, and the leverage ratio, which are displayed as deviations from their respective steady states.

macroeconomic variables. Investment and consumption increase persistently by around 8.0 percent and 1.6 percent at the peak of their responses, respectively (see Fig. 7). Under the flexible exchange rate regime, the commodity boom induces persistent economic expansion, with GDP increasing by 1.6 percent at impact.

The FX intervention regime. When faced with rising commodity export prices (and real exchange appreciation relative to its steady-state level), the central bank accumulates FX reserves and issues central bank bonds to counteract the downward pressure on the exchange rate. The potential for stabilization through these interventions aligns with the discussions presented in Section 3.7: due to the binding agency problem, the accumulation of FX reserves limits exchange rate appreciation, ultimately reducing bank credit expansion and hindering the growth of macroeconomic aggregates such as consumption, investment, and GDP. The effects of the systematic FX rule are divided into two main channels: Foreign Exchange (FX) and Balance Sheet (BS).

Foreign exchange channel. In response to a commodity price shock, the central bank intervenes by purchasing foreign exchange reserves, which modifies the net foreign asset position of the economy. Consequently, the dynamics of the exchange rate change in comparison to the flexible exchange rate regime. At impact, the real exchange rate appreciates by 1.6 percent instead of 4.5 percent (see Fig. 5). At the initial impact, banks' net worth increases less than under free-floating (2 percent instead of 6 percent). Subsequently, aligned with the negative response of the leverage ratio, the banks' net worth response is higher compared to the FER regime (see Fig. 6).

The enhanced stability of the real exchange rate has implications for the costs and returns associated with borrowing and lending in foreign and domestic currency, as demonstrated by the response of the spreads and UIP deviations in Fig. 5. In line with our discussion in Section 3.2, the response of banks' currency mismatch and leverage ratio reflects this increased stability, leading to smoother responses in financial and real variables compared to the FER regime (see Figs. 6 and 7). Indeed, the observed initially less expansionary credit conditions can be attributed to the less expansionary bank's net worth, which results from the balance sheet effect caused by the real exchange rate depreciation. However, as time progresses and we move into the second year, the lower leverage ratio assumes a more crucial role in influencing credit conditions.

Additionally, as households anticipate future exchange rate appreciation, they tend to decrease their deposits in dollars. Consequently, banks rely more on external borrowing instead of domestic deposits in both currencies. This trend is evident from the fact that external dollars deposits increase by 16 percent under FXI, in contrast to the 5 percent increase observed under the FER regime (see "Banks' borrowing FC" in Fig. 6). Furthermore, due to the expected real exchange rate appreciation, banks are inclined to offer more credit in dollars relative to credit in pesos. However, this same expectation also prompts intermediate goods producers to demand more dollars loans than pesos ones, increasing credit dollarization, albeit to a lesser extent than would be observed under a flexible exchange rate regime (see "Credit dollarization" in Fig. 6).

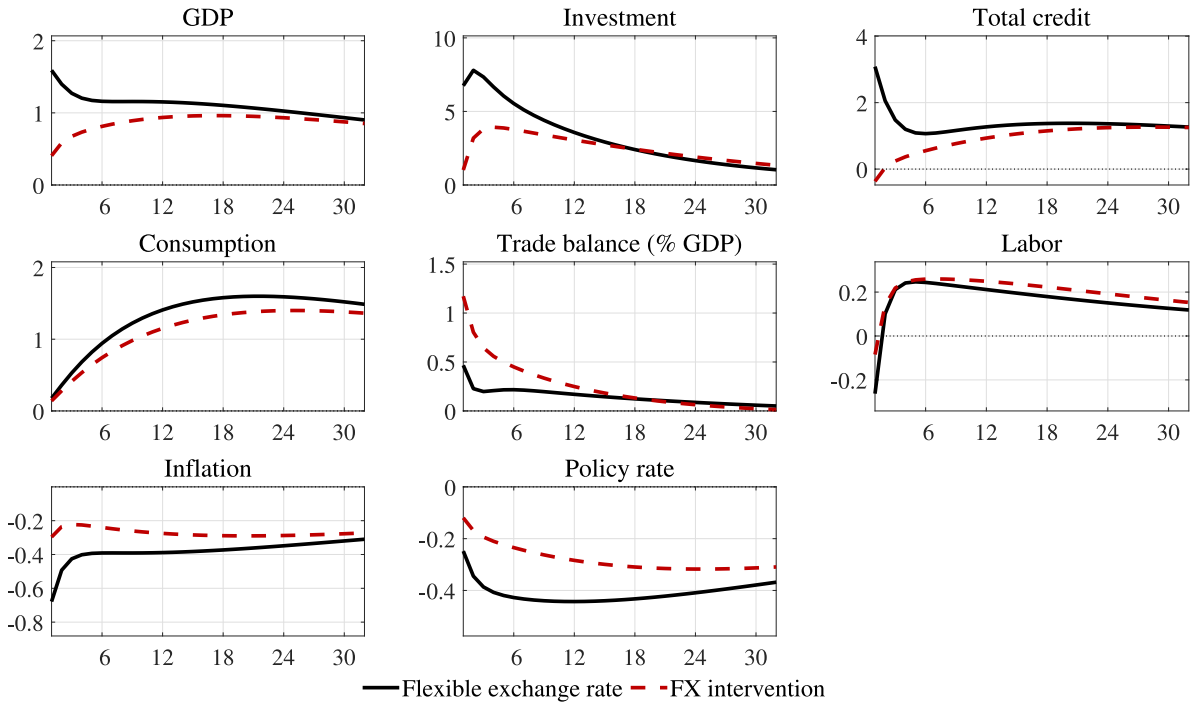

Fig. 7. Responses of macroeconomic variables to a commodity price shock.
Note. All variables are presented as percentage deviations from their steady state, except for interest rates and spreads which are displayed as deviations from their respective steady states.

Balance sheet channel. The central bank's response to building FX reserves is accompanied by a sterilization operation. This operation entails the central bank selling its own bonds to offset the impact on domestic liquidity. This operation leads to a significant shift in the banks' balance sheets: banks tend to allocate their additional funds to central bank bonds rather than lending, leading to a lower increase in lending in both currencies compared to what would be observed under a FER regime (as illustrated in Fig. 6).

Consequently, both the exchange-rate-smoothing and balance-sheet crowding-out channels play a critical role in the effectiveness of the FX policy rule in stabilizing economic credit conditions. This stability, in turn, extends to other macroeconomic variables, leading to a higher level of overall stability, as evidenced in Fig. 7.[46]

Notably, the responses of central bank bonds and the exchange rate closely aligns with periods of FX reserve accumulation in the Peruvian economy. In Appendix A.3, we show that these episodes are characterized by an average increase in reserves of approximately 15% and an exchange rate appreciation of 2% —movements that are consistent with our quantitative results (in the model, the behavior of central bank bonds determines the dynamics of central bank FX reserves).[47]

5.2. Aggregate volatility and external shocks

The simulation results clearly indicate the significant effectiveness of FX operations as an external shock absorber. The FX operations successfully mitigate the impact of external shocks on the economy, showcasing their role in maintaining stability and resilience in the face of such shocks. To measure the FX effectiveness, we quantify the reduction in the volatility of macroeconomic variables within the FXI regime compared to the FER regime. This evaluation is conducted when the economy experiences frequent external shocks and the foreign-sector block exhibits co-movements (as discussed in Section 3).

Under the FX intervention policy regime, macroeconomic volatility is substantially reduced, compared to the flexible exchange rate regime, when external shocks occur (see Table 5). Specifically, the volatility of the real exchange rate (RER) decreases by 62 percent, while total credit volatility declines by 73 percent. This outcome is consistent with considerable reductions in the volatility of financial variables such as interest rate spreads, UIP deviations, currency mismatches, banks' net worth, and leverage ratio. Additionally, the volatility of output, investment, and consumption decreases by approximately 55 percent, 51 percent, and

[46] The notable exception can be observed in the trade balance, which exhibits a higher response compared to the FER regime. This result can be explained by the less expansionary boom that reduces imported inputs, resulting in a more favorable trade balance outcome in this scenario.

[47] This serves as an alternative validation of our calibration strategy. In Appendix A.3 we also consider episodes of deaccumulation of FX reserves by the central bank.

Table 5
Aggregate volatility conditional on external shocks.

Financial variables				Real variables			
	FXI	FER	Δ%		FXI	FER	Δ%
Currency mismatch	1.79	4.35	−59	Real exchange rate	2.07	5.48	−62
Leverage ratio	44.71	68.90	−35	Total Credit	1.04	3.88	−73
Net worth	6.57	11.16	−41	Investment	5.03	10.31	−51
Interest rate spread 1	0.91	4.63	−80	Consumption	0.71	0.94	−24
Interest rate spread 2	0.19	0.99	−80	GDP	0.86	1.91	−55
UIP deviation 1	1.28	6.16	−79	Inflation	0.34	0.74	−53
UIP deviation 2	0.91	4.24	−79	Labor	0.40	0.51	−23

Note. FXI and FER denote Foreign Exchange Intervention and Flexible Exchange Rate policy regimes, respectively. The computation considers the external block as the only source of aggregate volatility. Results are based on 2500 replications of 120 periods of simulated trajectories.

24 percent, respectively. Consequently, our findings suggest that FX interventions effectively stabilize domestic macroeconomic volatility under external shocks.[48]

5.3. Welfare analysis

We identify the optimal FX policy intervention from a set of policy rules defined by Eq. (18). Following the approach of Schmitt-Grohe and Uribe (2007), we consider a policy rule to be implementable if it guarantees a locally unique rational expectations equilibrium. An optimal policy rule is both implementable and results in the highest level of lifetime utility, given the initial state of the economy, among the considered set of policy rules. Our objective is to determine the policy rule that satisfies these criteria.

Consider two monetary policy regimes: (i) the reference policy regime, denoted by $\mathcal{R}$, and (ii) the alternative policy regime, denoted by $\mathcal{A}$. A particular parameterization of the FXI and monetary policy rule characterizes each policy regime. In the $\mathcal{R}$−regime, each policy rule is parameterized as in our baseline model: $\rho_i = 0.7$, $\omega_\pi = 1.5$, and $\omega_y = 0.125$ for the interest rate rule, and $\upsilon_e = 9.7$ for the FX intervention rule.[49] The alternative policy regime $\mathcal{A}$ differs from $\mathcal{R}$ in the value of the policy response coefficients (ω_π, υ_e). The set of policy regimes we evaluate changes the dynamics of the model but not its steady state, i.e., welfare measures are conditioned upon the same initial steady state for $\mathcal{R}$ and $\mathcal{A}$.

Our welfare gain measure ς is the fraction of the consumption process of the reference regime $\mathcal{R}$ that a household would be willing to give up to be as well off under the alternative policy regime $\mathcal{A}$ as under regime $\mathcal{R}$, i.e.,

$$\mathbb{W}\left(\{C_t^{\mathcal{A}}, H_t^{\mathcal{A}}\}_{t\geq 0}\right) = \mathbb{W}\left(\{(1+\varsigma)C_t^{\mathcal{R}}, H_t^{\mathcal{R}}\}_{t\geq 0}\right). \tag{25}$$

If $\varsigma > 0$, there is a welfare gain, while if $\varsigma < 0$, there is a welfare loss under the alternative regime relative to $\mathcal{R}$. Hereafter, "welfare gains/losses" refers to welfare changes relative to $\mathcal{R}$. We approximate ς up to a second order of accuracy. Fig. 8 displays the welfare gains for different implementable FXI rules, keeping the Taylor coefficient at its baseline level ($\omega_\pi = 1.5$). The flexible exchange rate regime ($\upsilon_e = 0$) causes a welfare loss of 4.0 percent in consumption. Moreover, it turns out that the optimal FX policy coefficient, $\upsilon_e^* = 28.1$, is higher than its estimated level and associated with a welfare gain of 1.2 percent in terms of consumption. More aggressive FX intervention responses (in the region $\upsilon_e > 28.1$) reduce welfare gains as the benefits from macroeconomic stabilization do not compensate for the higher central bank operational losses.

Table 6 reports the welfare gains for various combinations of policy parameters (ω_π, υ_e). Conditional to external shocks, the FX policy and standard Taylor rules improve welfare in a considerable region of the reported (ω_π, υ_e)-space. The flexible exchange rate regime might be welfare-improving if the Taylor rule coefficient is high enough ($\omega_\pi \geq 3$). Nevertheless, the optimal FX intervention rule coefficient is non-zero. For instance, when $\omega_\pi = 3$, the optimal value for υ_e is around 10 (almost one third of υ_e^* when $\omega_\pi = 1.5$). Thus, the active use of FX interventions as an additional monetary policy tool is welfare-improving relative to a flexible exchange rate regime. The welfare gains of an optimal FX intervention rule are between 1 and 2.2 percent of consumption.[50]

Recently, Fanelli and Straub (2021), Itskhoki and Mukhin (2023), and Yakhin (2024) examine the optimal Ramsey allocation when market imperfections affect the trading of domestic and foreign bonds. They argue that FXI rules responding to UIP deviations can achieve optimal allocations in their settings, where currency mismatches are not significant in transmitting external shocks. In contrast, we contend that in our model, large balance-sheet effects make the real exchange rate a critical target for FX interventions.[51]

[48] Even though the FXI rule (18) implies a linear response to any deviation of the real exchange rate from its steady state, the reduction of macroeconomic volatility is not a necessary result. Below, we explore cases where the FXI regime does not succeed according to the volatility smoothing and welfare criterion.

[49] Recall that, in our baseline model, υ_e is one of the parameters estimated by impulse-response matching, while the parameterization of the interest rate rule follows the standard calibration found in the literature. Therefore, none of the parameterization of the reference regime is necessarily optimal.

[50] These numbers are large in the business-cycle literature. This is driven by the financial frictions generating endogenous UIP deviations and our focus only on external shocks.

[51] Exploring optimal allocations in settings where exchange rate depreciations impact balance sheets is a promising avenue for future research.

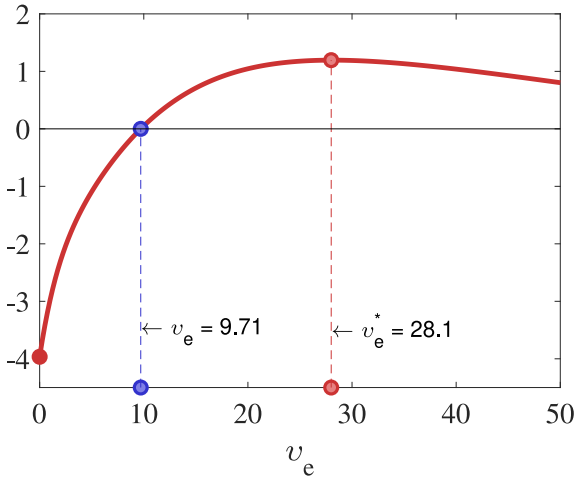

Fig. 8. Welfare gains of FX intervention policy.
Note. The welfare gain represents the proportion of consumption in the baseline calibrated model that a household would be willing to sacrifice in order to maintain the same level of welfare in an economy where the FX policy rule exhibits a distinct endogenous response to the real exchange rate, governed by υ_e.

Table 6
Welfare gains/losses of Taylor rule and FX policy rule.

$\omega_\pi \setminus \upsilon_e$	0.0	2.5	5.0	**9.71**	20.0	30.0	50.0	100.0
1.25	−14.4	−11.0	−8.9	−5.7	−1.9	−0.5	0.1	−0.3
1.50	−4.0	−2.0	−1.1	**0.0**	1.0	1.2	0.8	−0.2
2.00	−0.6	0.7	1.2	1.6	1.8	1.6	0.9	−0.2
3.00	0.5	1.5	1.8	2.1	2.0	1.7	1.0	−0.2
5.00	0.8	1.7	2.0	2.2	2.1	1.7	1.0	−0.3

Note. The parameter ω_π measures the interest rate response to fluctuations in inflation, while υ_e measures the response of FX interventions to real exchange rate deviations. For each combination of (ω_π, υ_e) we compute ς which is defined above and report $\varsigma \times 100\%$. Only external shocks are considered in this simulation.

5.4. Robustness exercises

We examine the effectiveness of FX interventions in response to external shocks across various scenarios ("Cases"), each designed to test the robustness of our findings under more general assumptions. This section outlines the key features of each case and highlights the general quantitative insights they provide. Further details are presented in Appendix C.

Case 1: Increased currency mismatch. Two noteworthy scenarios that increase the economy's currency mismatch are:

- *Case 1A: Non-Dollarized Financial System*. In this case, intermediate goods producers borrow from banks only in domestic currency, while households cannot hold foreign currency deposits.[52] Although FX interventions are still effective, their impact is less pronounced than in a financially dollarized economy. Although the banking sector has a higher currency mismatch, the non-financial sector is less exposed to exchange rate movements, leading to less desirable FX interventions.
- *Case 1B: Lower-cost external borrowing*. An international environment with more favorable access to foreign debt, modeled as lower R^* in the steady state, increases the incentive for banks to hold portfolios with larger steady-state currency mismatches, heightening financial risks. In this scenario, the economy becomes more financially fragile, and FX interventions become more effective at reducing volatility and delivering welfare gains. This is because interest rate spreads and UIP deviations are present but with a more severe financial friction.

Case 2: UIP conditions holds. This environment can arise under two sub-cases:

- *Case 2A: Frictionless households' arbitrage*. In this scenario, households are free to fully participate in foreign currency bank deposits, making their demand for these deposits infinitely responsive to arbitrage opportunities. As a result, the FX channel is muted. However, macroeconomic volatility still declines due to the sterilization leg of FX interventions, combined with ongoing borrowing constraints faced by banks.
- *Case 2B: Frictionless banks' arbitrage*. The severity of banks' agency problem is assumed to depend on an industry-wide measure of currency mismatch, which banks take as given, implying that $\Theta'(x) = 0$. This means banks no longer internalize the impact of dollar borrowing on their agency problem. As a result, the real exchange rate's response to external shocks is identical under

[52] This case attempts to extend our results for an emerging market economy without financial dollarization such as Chile, Colombia, Mexico, etc.

both FX interventions and exchange rate flexibility, effectively muting the FX channel. However, the sterilization aspect of FX interventions still plays a stabilizing role, as the balance sheet channel remains effective, helping to reduce macroeconomic volatility compared to the baseline case.

Case 3: Absence of habit formation. We explore the effects of removing habit formation, setting $\mathcal{H} = 0$, from household consumption decisions, a feature that can influence the quantitative implications of the FX intervention regime on macroeconomic volatility and welfare relative to exchange rate flexibility. Habit formation typically has two opposing effects: it increases the persistence of shocks while dampening their immediate impact, leading to an overall ambiguous effect on volatility that must be evaluated quantitatively. Our numerical results suggest that macroeconomic volatility remains largely unchanged. However, the welfare gains diminish, since our welfare measure is closely tied to this parameter: The benchmark welfare gain of 4% falls to 2.8% when habit formation is excluded.

Case 4: Uniformly divertible bank assets. The effectiveness of FX interventions in mitigating the impact of external shocks depends on the parameter ω^b, which governs how easily banks can divert central bank bonds. This parameter influences the tightness of the credit constraint banks face. We explore the scenario where $\varpi^* = \varpi^b = 1$, meaning the credit constraint treats all assets equally, and all domestic spreads are reduced to one. In this case, central bank bonds exert a greater influence on the total amount of divertible funds than in our baseline model, and consequently, on banks' lending capacity. As a result, FX interventions become more effective in absorbing external shocks compared to the baseline model, enhancing their stabilizing role in the economy.

Case 5: Alternative monetary policy regimes. We analyze the effects of implementing various monetary policy regimes in the absence of FX intervention. First, we compare the baseline FX intervention regime with an alternative policy regime where the Taylor rule is extended to respond to deviations in the real exchange rate from its steady state. Our analysis shows that while using the monetary policy rate to stabilize exchange rates can help mitigate financial instability, it does so at the expense of increased volatility in the real sector, particularly in investment. The welfare analysis reveals that the FX intervention regime delivers more consistent welfare gains compared to the extended Taylor rule, especially across different parameter values for the interest rate's sensitivity to exchange rate fluctuations.

Second, we address the concern of a central bank mitigating deposit rate spreads by extending the Taylor rule to respond to deviations of the UIP spread from its steady state. Our results are similar to a Taylor rule extended to response to exchange rate deviations: It reduces financial volatility but increases real sector volatility, as the monetary policy rate partially absorbs fluctuations in the UIP spread.

Case 6: Sterilization operational costs. To account for additional aspects of FX intervention and reserve management not explicitly modeled in our framework, we introduce adjustment costs associated with sterilization operations. Specifically, we assume that the central bank incurs costs proportional to the level of sterilization, CB_t. The central bank's quasi-fiscal deficit is then modeled as $\widehat{CB}_t = \exp(\tau^{fx}(B_t - B)CB_t)$., where τ^{fx} represents the adjustment cost parameter. As τ^{fx} increases from 0 to 5, the optimal FX policy coefficient declines from 28.1 to 3.5. Correspondingly, the welfare cost of maintaining a flexible exchange rate — relative to an optimized FX intervention — shrinks from 5 percent to 1.5 percent of consumption. This finding emphasizes that exchange rate flexibility leads to notable welfare losses compared to an optimized FX policy, particularly when sterilization costs are included.

Case 7: Alternative FX Intervention Rules. In this case, we examine whether different FX intervention (FXI) rules would significantly alter our results. While a full exploration of the optimal FXI rule lies beyond the scope of this paper, we show that the effects of external shocks remain similar when the central bank's FXI rule incorporates inertia and responds to both real exchange rate depreciation and UIP deviations. This closely aligns with our baseline scenario. As argued by Itskhoki and Mukhin (2023), an FXI rule targeting interest rate spreads would likely be less practical than one focused on exchange rate deviations, supporting the feasibility of our chosen approach.

6. Concluding remarks

We propose a macroeconomic model with financial frictions for a small open economy to analyze and quantify the effectiveness of FX interventions in stabilizing the impact of external shocks. Our model considers FX interventions as a balance-sheet policy induced by an agency problem between banks and their investors (domestic depositors and foreign lenders). Two key assumptions are important for our results. First, the severity of banks' agency problem depends directly on a measure of currency mismatch at the bank level. Second, FX intervention is such that the central bank leans against real exchange rate fluctuations but in a sterilized manner.

Our results shed light on the transmission mechanism of external shocks under an FX policy regime. We highlight two reinforcing effects when FX policy responds to external shocks: the foreign exchange and the balance sheet channels. The former channel is active whenever banks and households cannot fully exploit arbitrage opportunities between domestic and foreign currency-denominated portfolios. Instead, if either banks or households can engage in frictionless arbitrage between domestic and foreign currency-denominated assets, the standard UIP equation holds, and this channel is no longer active. In this case, even though the incentive constraint binds, the response of the real exchange rate to external shocks is the same under FX interventions and flexible exchange rates. On the other hand, the balance sheet channel stems from the sterilization operation associated with FX interventions, which modifies the supply of central bank bonds in banks' balance sheet and their asset composition together with interest rate spreads.

The financial friction view of FX interventions needs further research. FXI differs from the unconventional monetary policy framework for closed economies in several ways. First, FX interventions have been implemented effectively even in normal times

in EMEs, contrary to the unconventional monetary policy tools studied in closed economies. Second, what matters for EMEs is how tight financial constraints are, and not necessarily if they bind or not. Third, in practice, the communication of FX interventions is at odds with the communication of unconventional policies in closed economies. For example, there seems to be less forward guidance associated with FX interventions than with QE or LSAP. Finally, the effective lower bound for EMEs may not only be related to the nominal interest rate, but also to a non-negative amount of official FX reserves needed to implement FX interventions within an inflation-targeting regime.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jmacro.2025.103672.

Data availability

Data will be made available on request.

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