Dollar Liquidity Flows in Small-Open Economies

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Abstract

This paper investigates how local dollar liquidity conditions shape exchange rate dynamics in small open economies. In such economies, the financial system issues dollar liabilities to facilitate transactions, creating a structural demand for dollar reserves for settlement. We distinguish between reserve supply, which responds to external factors, and reserve demand, which fluctuates with domestic liquidity conditions. Using a policy shock as an instrumental variable for the Peruvian economy, we show that domestic dollar liquidity demand shocks significantly drive short-run exchange rate dynamics. We rationalize these findings using a small open economy model with banking liquidity frictions that accounts for observed interest rate dynamics and Covered Interest Parity (CIP) deviations. The model delivers a counterfactual framework that experiments with the central bank's quantity-based toolkit—including sterilized FX intervention, dual-currency reserve requirements, and derivative-position-motivated balance-sheet constraints. The main text focuses on sterilized FX intervention and shows that this instrument was particularly effective in suppressing Sol exchange rate volatility during Peru's 2007–2009 dollar liquidity stress episode.

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1 Introduction

The modern architecture of the international payments system relies on US dollar settlements to support the exchange of trade and capital flows. Non-US financial institutions create dollar-denominated liabilities, which circulate as an international medium of exchange. As long as these institutions are part of the international payments system, their customers can purchase foreign goods or assets pretty much anywhere. To guarantee the circulation of their liabilities, however, these institutions must also hold dollar reserves— correspondent account balances at US banks—to settle payments.

This dollar-based architecture is central to the expansion of global trade and finance. However, it introduces a specific form of financial fragility. Unlike US financial institutions, which enjoy direct access to Federal Reserve liquidity facilities, most institutions based in other countries, especially those in small-open economies (SOEs), may find themselves short of reserves when short-term foreign funds or domestic depositors rapidly reallocate funds to foreign accounts. The resulting scarcity of dollar reserves pressures exchange rates, a force distinct from interest rate differentials or risk premia. The consequences of this added volatility can be material: consider what it implies for the Sharpe ratio of foreign direct investment, where a fundamentally sound return can be crushed if its repatriation happens during a time of local dollar scarcity.

For decades, SOE central banks have acted on the conviction that capital flows can generate excessive exchange-rate volatility and that arbitrage forces alone cannot neutralize it. They have defied the prevailing orthodoxy—both of the textbook Mundell-Fleming framework and the Washington Consensus policy memos—by routinely deploying quantity-based exchange-rate interventions, alongside conventional interest rate policy. Only recently have theory and policy prescriptions caught up with central bank practice, a shift crystallized in Gopinath (2019)'s influential Jackson Hole address: "the challenge for central bankers is not just how to attain [price stability] when the main frictions are nominal rigidities...but how to do so when financial markets are imperfect, capital is globally but imperfectly mobile, and the international monetary and financial system is dominated by the dollar." What remains missing is a framework in which the dollar's role as the dominant settlement currency is explicit, capital moves too slowly to close arbitrage opportunities, and quantity-based interventions can be evaluated on their own terms.

This paper develops an SOE model in which the exchange rate is determined, in part, by dollar liquidity flows that settle within the domestic banking sector. Local banks issue dollar liabilities and hold dollar reserves to manage stochastic outflows;

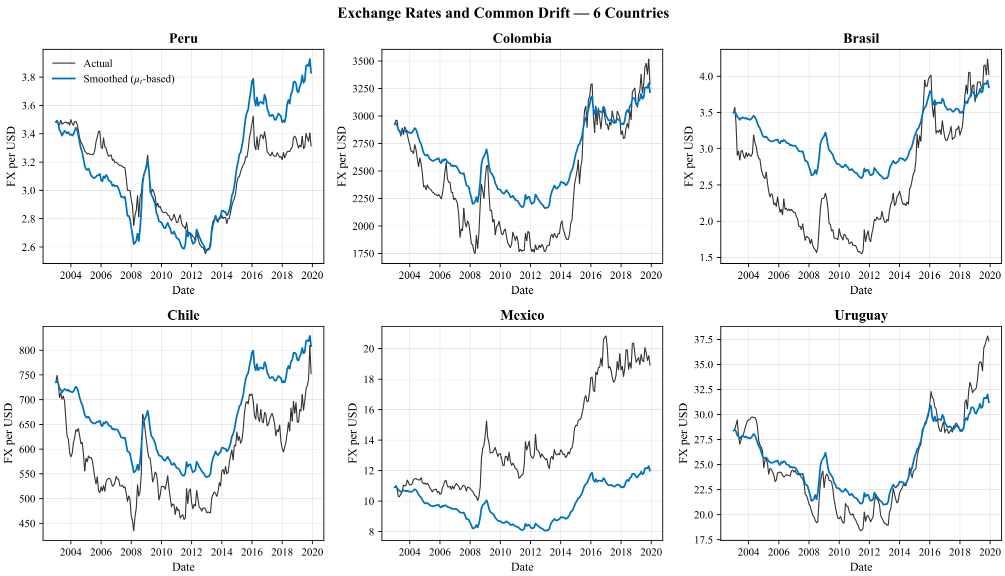

Figure 1: Exchange Rates in Southern American Countries

when shortfalls arise, they trade in a frictional dollar interbank market or borrow at penalty rates from foreign credit lines. Because foreign capital moves too slowly to close arbitrage opportunities, local dollar scarcity drives a wedge between the shadow values of dollar and domestic-currency liquidity. Analytically, this wedge maps one-to-one into spreads between dollar and domestic-currency loan, interbank, and deposit rates, generating distinct CIP deviations for each basis. The model incorporates the full suite of quantity-based instruments used in practice—dual-currency reserve requirements, derivative-position-motivated balance-sheet constraints, and sterilized and unsterilized FX intervention.

We motivate the framework with Peruvian data and, in turn, use the model to rationalize it. Peru offers an ideal testing ground because it combines the structural features common to most SOEs: a banking system that issues dollar liabilities, segmented interbank markets, and slow-moving capital, with an unusually rich set of quantity-based policy instruments. Indeed, its central bank, the BCRP, has actively innovated in the deployment of dual-currency reserve requirements, forward position limits, and FX intervention, making Peru the poster child for quantity-based exchange rate management. Moreover, the BCRP has successfully achieved a much more stable exchange rate relative to its neighbors. As Figure 1 shows, the Peruvian sol has exhibited roughly one-third the volatility of regional peers—and this despite a notoriously unstable political environment—without a cost in terms of inflation predicted by standard theories. Think of what that means: a threefold reduction in exchange rate volatility triples the risk-adjusted return to cross-border capital flows.

We begin by documenting a set of stylized facts that pose a puzzle for standard ex-

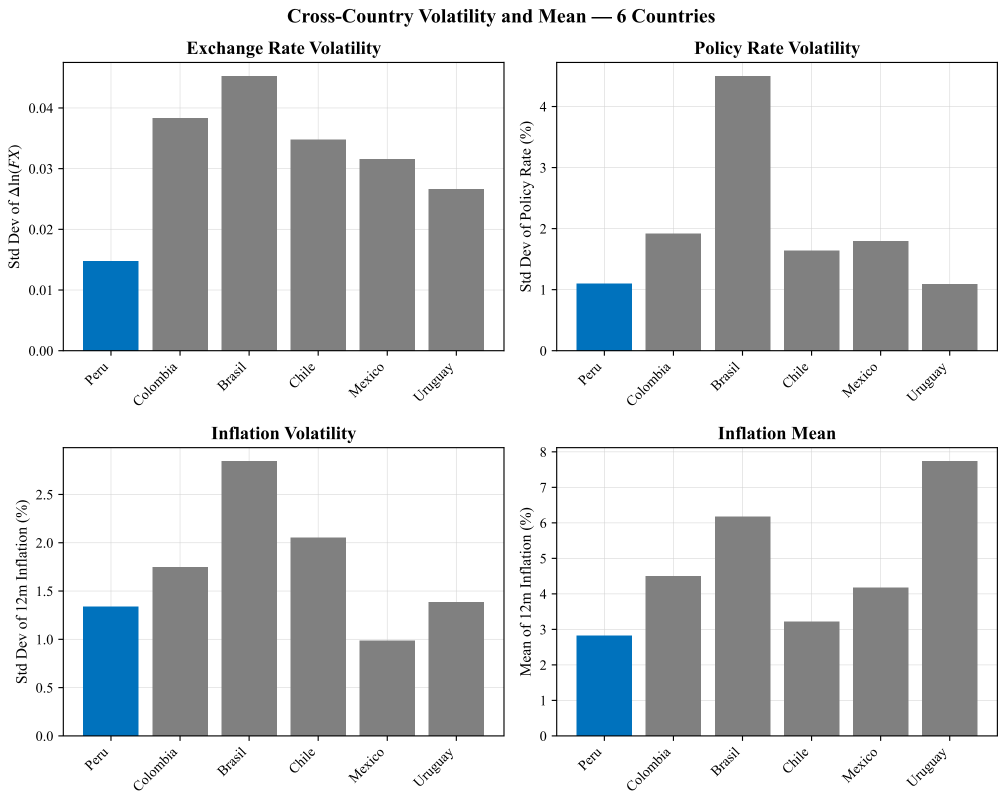

Figure 2: Cross-Country Volatility and Mean in Southern American Countries

change rate theories. In the Peruvian data, the banking sector's dollar liquidity ratio tracks UIP deviations closely, and spreads in the local dollar interbank market—a direct measure of funding scarcity—move nearly one-to-one with CIP deviations. These patterns suggest that the shadow cost of dollar liquidity within domestic intermediaries, rather than interest rate differentials or global risk factors alone, is a primary driver of arbitrage wedges. OLS regressions following Engel and Wu (2023) confirm that local liquidity variables carry significant independent explanatory power for exchange rate movements, even after controlling for a rich set of global and local factors.

A key empirical challenge is identifying the direction of causality: observed changes in dollar liquidity could reflect supply shocks (e.g., commodity booms increasing reserve supply) or demand shocks (e.g., precautionary hoarding by banks). To isolate demand-driven variation, we instrument for changes in the dollar liquidity ratio using unexpected adjustments to the Marginal Reserve Requirement on dollar liabilities, following the narrative identification of Gutierrez, Ivashina and Salomao (2023). Local projection estimates reveal that a demand-driven tightening of dollar liquidity leads to an immediate depreciation of the domestic currency and a widening of the cross-currency basis, effects that persist for approximately two months. This finding is robust to controlling for policy rate differentials and global risk factors, suggesting that for SOEs, the price of the dollar is determined not just by the risk-free rate differential, but also by the shadow value of dollar liquidity within the domestic banking sector.

Framework. Motivated by the evidence, we develop a dynamic small open economy model that explicitly incorporates a banking sector with settlement frictions. Building on Bianchi, Bigio and Engel (2024), local banks issue dollar liabilities to finance transactions and hold dollar reserves to manage stochastic payment outflows. When shortfalls arise, banks trade in a frictional interbank market or borrow at penalty rates from foreign credit lines. The exchange rate emerges as a relative price of liquidity services across the two currencies: banks' demand for domestic reserves is linked to their demand for dollar reserves through a liquidity-adjusted UIP condition, and the equilibrium exchange rate reflects the relative scarcity of settlement balances in each currency.

A central object in our model is the external dollar funding constraint: the aggregate supply of dollars available to local banks is determined by the trade balance, net investment income, the inherited external position, and central bank reserves. Unlike in Bianchi, Bigio and Engel (2024), where both countries can create their own currency and dollar liquidity is a global phenomenon, our small open economy cannot manufacture dollars. This real constraint is what gives quantity-based policies their bite. When the central bank accumulates dollar reserves, it directly reduces the pool available to local banks; because foreign capital moves too slowly to fill the gap, the intervention shifts the equilibrium exchange rate through a portfolio balance channel that the literature has long discussed but rarely micro-founded. The same logic applies to reserve requirements and forward position limits: each instrument operates on an identifiable margin of the bank's balance sheet, tightening or loosening dollar liquidity in a way that is both analytically tractable and empirically observable.

The model provides a structural rationalization for the breakdown of arbitrage conditions. We confront the model with Peruvian banking data through a filtering exercise. Most model variables—balance sheet quantities, reserve requirement ratios, policy rates– have direct empirical counterparts. The sole unobservable is the volatility of idiosyncratic bank funding shocks. These shocks capture how, for both currencies, deposits shift across domestic and foreign banks. We recover each shock by inverting the model's structural mapping from liquidity conditions to interbank rates. This procedure yields a monthly time series of latent liquidity stress for each currency, with spikes that align with known episodes of financial turbulence, including the 2008 crisis and the 2011–2013 period of acute dollar scarcity.

With these filtered funding risks in hand, the model generates predictions for objects it was not designed to match. It successfully replicates the dynamics of both dollar and domestic currency lending and deposit rates, capturing nearly all the local spikes—suggesting that settlement frictions are the dominant driver of bank pricing in the dollar segment.

More strikingly, the model reproduces the time series of CIP deviations, including a structural break in arbitrage conditions observed in the data: the shift from excess Sol returns (pre-2014) to excess USD returns (post-2014). When we extend the baseline to incorporate the BCRP's punitive reserve surcharge on excessive forward positions—a regulation introduced precisely in that period—the model also captures the full magnitude of the post-2014 widening. This result illustrates how a single quantity-based regulation, operating through an identifiable margin of the bank's balance sheet, can reshape arbitrage conditions in the forward market.

Counterfactual Analysis. We develop a counterfactual framework designed to isolate the banking sector's short-term liquidity channel and quantify the impact of the central bank's quantity-based policies on the exchange rate. To focus the exercise on this channel, the framework deliberately holds fixed all margins that adjust slowly at a monthly horizon: the trade balance, the net foreign asset position, monetary policy rates, and—crucially—the financial reallocations of domestic non-bank agents, including household deposits and firms' borrowing. The only two margins allowed to respond are the local banking sector's portfolio reallocation across currencies and the slow-moving inflow of external dollar funding, whose elasticity we estimate from the data. Within this framework, we can effectively experiment with the BCRP's full quantity-based toolkit: sterilized FX intervention, dual-currency reserve requirements, and derivative-position-motivated balance-sheet constraints such as the forward-position surcharge.

In the main text, we focus on sterilized FX intervention—one of the BCRP's most actively used quantity-based instruments.[1] We first derive a proposition that characterizes when and how strongly FX intervention moves the exchange rate under our assumptions. The exchange rate response decomposes into a relative liquidity channel and an external funding channel: intervention bites to the extent that (i) the liquidity friction in banks' dollar-deposit management is nontrivial, and (ii) foreign capital is slow-moving enough that external borrowing cannot promptly replenish the dollars absorbed by the central bank. In the limiting cases of perfectly elastic external supply or zero liquidity friction, the intervention is neutral—recovering the standard textbook irrelevance result. Quantitatively, the BCRP's FX intervention has

[1] Analogous exercises for the dollar reserve requirement and the post-2014 forward-position-motivated Sol reserve surcharge are reported in Appendix C.

been particularly consequential during 2007–2009: a commodity-boom-driven surge of dollar inflows in late 2007 generated strong appreciation pressure on the Sol, while the global dollar shortage triggered by the 2008–2009 financial crisis caused acute dollar scarcity for Peruvian banks. Absent the BCRP's two-sided response—purchasing dollars during the 2007 inflow and selling them during the 2008–2009 shortage—the model implies that the Sol would have experienced an additional appreciation of roughly 25% in 2007 and a depreciation of nearly 20% during 2008–2009. Outside these acute stress episodes, banks' own portfolio reallocation cushions much of the shock and the no-intervention path remains close to the historical one, indicating that the intervention's payoff is concentrated in the most disruptive periods of the sample.

All in all, our findings bridge the gap between the academic literature, which often views sterilized intervention as ineffective in the absence of portfolio balance effects and capital controls, and the practical reality of central banking in SOEs, where such interventions are a primary policy tool.

Related Literature. Our work connects several strands of literature in international finance: the resolution of exchange rate puzzles, the role of financial intermediaries in asset pricing, and the specific mechanics of dollar liquidity in emerging markets.

Standard models of international macroeconomics have long struggled to reconcile exchange rate volatility with fundamental drivers—a challenge famously characterized as the "exchange-rate disconnect" by Obstfeld and Rogoff (2000). A central empirical regularity is the failure of Uncovered Interest Parity (UIP), where high-interest rate currencies tend to appreciate rather than depreciate (Fama 1984). The initial wave of literature sought to resolve these anomalies through risk premia within frictionless arbitrage frameworks. These contributions introduced mechanisms such as long-run risk (Colacito and Croce 2008), habit formation (Verdelhan 2010), or rare disaster risk (Farhi and Gabaix 2016) to generate time-varying risk premia that could rationalize excess returns. However, these models typically assume symmetric currencies and perfect capital mobility, which does not reflect the reality of Small Open Economies (SOEs). In addition, while successful in explaining some disconnects, they have failed to explain the paradoxical patterns of the risk premium documented by Engel (2016). More recently, Valchev (2020) bridges this gap by proposing bond convenience yields as a driver of exchange rate dynamics, a concept our model endogenizes through settlement frictions.

A more recent literature abandons the assumption of perfect arbitrage, shifting focus to the constraints of financial intermediaries. This "intermediary asset pricing" view posits that exchange rates are determined by the balance sheet capacity of global financiers. Gabaix and Maggiori (2015) provide a seminal framework where capital flows are intermediated by global banks with limited risk-bearing capacity; in their model, exchange rate dynamics are driven by capital flow shocks that shift the demand for intermediation. Similarly, Itskhoki and Mukhin (2021) develop a dynamic general equilibrium model with segmented financial markets, identifying a "financial shock" related to the risk-bearing capacity of arbitrageurs as a primary driver of the exchange rate disconnect.

Our paper shares the view that financial frictions are central to exchange rate determination but departs from the focus on net worth constraints alone. While Gabaix and Maggiori (2015) emphasize the scarcity of *risk-bearing capacity* (wealth), we identify the scarcity of *settlement balances* (means of payment) described in Bianchi and Bigio (2022) as the binding friction. In our framework, banks may be well-capitalized yet still face acute pressure in the foreign exchange market if they lack the specific liquid assets required to settle dollar outflows.

Empirical evidence strongly suggests that the US dollar offers a "convenience yield" that is distinct from standard risk factors. Jiang, Krishnamurthy and Lustig (2021) and Jiang, Krishnamurthy and Lustig (2023) document that the dollar acts as a global safe asset, with its valuation driven by the global demand for safety and liquidity. This convenience yield creates a wedge in Euler equations, rationalizing why dollar assets often pay lower returns. Engel and Wu (2023) explicitly link these liquidity yields to exchange rate movements, showing that the liquidity value of government bonds is a key determinant of currency value. Devereux, Engel and Wu (2023) further explore how this collateral advantage affects global cycles. Our work complements this literature by providing a micro-foundation for these liquidity yields in an SOE context. Rather than modeling them as an exogenous preference for safety, we derive them endogenously from the banking sector's need to settle stochastic payment outflows.

The persistence of Covered Interest Parity (CIP) deviations since the Global Financial Crisis has sparked a specific sub-literature. Du, Tepper and Verdelhan (2018) and Du, Im and Schreger (2018) document these deviations across G10 currencies, attributing them to post-crisis banking regulations that make arbitrage costly. Liao (2020) highlights how credit migration and corporate bases interact with these deviations, while Ivashina, Scharfstein and Stein (2015) show how dollar funding shortages for European banks lead to cuts in lending. While these studies focus primarily on advanced economies and global regulatory changes, our paper investigates how similar deviations arise in a small open economy due to local regulatory frameworks. Du and Schreger (2016) highlight the importance of local currency sovereign risk, but our work emphasizes the quantity-based regulations (such as marginal reserve requirements) specific to emerging markets.

Most closely related to our empirical setting is the emerging literature on financial frictions in small open economies (SOEs). Kalemli-Özcan and Varela (2024) document that UIP premia in emerging markets are driven largely by country-specific risk and policy uncertainty, rather than just global risk factors. Keller (2024) provides evidence from Peru. Banks face binding funding constraints that prevent them from fully exploiting CIP deviations, and that these tighter financial conditions directly crowd out the supply of credit. Similarly, Leo, Zou and Keller (2024) explore how speculation and forward demand in emerging markets interact with intermediary constraints, while Dao and Gourinchas (2025) and Eugenio M Cerutti (2023) emphasize the prevalence of CIP deviations in these economies. We rely on the identification strategy of Gutierrez, Ivashina and Salomao (2023), who analyze dollar debt in Peru, to isolate exogenous liquidity shocks. Furthermore, by formalizing the transmission mechanism of quantity-based policies, we contribute to the literature exploring optimal intervention, such as Fanelli and Straub (2021) and Cavallino (2019).

Finally, our framework builds directly on Bianchi, Bigio and Engel (2024), who develop a model of exchange rates driven by the global supply of dollar reserves. The critical distinction lies in the level of segmentation and the source of variation. Bianchi, Bigio and Engel (2024) model a closed system of global banks where the *aggregate* supply of Federal Reserve liquidity determines the global shadow value of the dollar. In contrast, we model a small open economy where capital moves slowly enough that *local* liquidity conditions decouple from the global aggregate. In our model, the supply of dollars is locally constrained by the current account and central bank policy, and demand is driven by idiosyncratic domestic shocks. This allows us to study phenomena that a global model cannot address, such as the effectiveness of unilateral FX intervention and the impact of country-specific macroprudential regulations on local arbitrage conditions.

The remainder of the paper is organized as follows. Section 2 describes the institutional features of the Peruvian banking system and presents the empirical analysis, including data description, stylized correlations, and the identification of liquidity shocks using our instrumental variable approach. Section 3 develops the dynamic model, and Section 4 performs a filtering exercise to evaluate the model's ability to replicate lending, deposit rates of local banks, and historical CIP deviations. Section 5 conducts the policy counterfactual analysis, and Section 6 concludes.

2 Empirical Analysis: Dollar Liquidity and Exchange Rates

This section documents the link between local dollar liquidity conditions and exchange rate dynamics. We begin by describing the institutional details of Peruvian banks that require dollar liquidity, how they obtain it, and what frictions make dollar funding costly. By the end of this prelude, it should be clear why the Peruvian banking system is particularly prone to large swings in dollar reserve positions and that its central bank has been particularly active in quantity-based policy interventions. As a result, its time-series offers substantial variation to identify the liquidity channel of interest.

2.1 Dollar Liquidity in the Peruvian Banking Sector

Demand for Dollar Bank Reserves. Peru is a highly dollarized commodity-exporter small open economy. Given its limited financial development, banks serve as virtually the sole intermediary between domestic and foreign agents for dollar flows. De facto, the entire country's demand for dollar liquid asset holdings is supplied as the liabilities of a handful of banking institutions.[2] Banks perform three functions each of which requires maintaining dollar liabilities while holding liquid dollar balances.

First, banks facilitate cross-border trade settlement on behalf of Peru's export and import sectors, both taking in deposits in dollars from exporters and issuing deposit liabilities corresponding to credit lines to importers. Because Peru is a major commodity exporter, banks experience large swings in their dollar reserve positions resulting from cross-border flows which are settled with dollars. Moreover, throughout the last 30 years, Peru maintained a negative net foreign-asset position as shown in Panel (b) of Figure 3. Thus, its banking system was consistently vulnerable to sudden reversals in foreign dollar financing.

Second, while dollar liabilities are used to make international payments, as in most countries, Peru remains highly dollarized in that dollar deposits are used in many domestic transactions. For example, the entire real estate market transacts in dollars, most purchases of large-item durable goods are executed in dollars, and most large company acquisitions are paid in dollars. To sustain a domestic payment system in dollars, domestic banks also settle domestically using dollar reserve assets. Despite a consistent de-dollarization trend, the banking system remains fundamentally dual-currency as is clear from Figure 3. This feature makes the economy particularly vulnerable to flows from domestic savers. Indeed, banks have frequently experienced large outflows during political cycles. For example, during the 2021 election of Pedro Castillo, about 7.8 percentage points of GDP of domestic assets were moved abroad. Likewise, Peruvian pension funds holding assets abroad faced pension withdrawals that caused the repatriation of funds causing an increase of dollar liabilities

[2] The Peruvian banking system is highly concentrated. The four largest banks accounted for roughly 84% of total commercial banking assets as of 2014 (Ross 2015).

and reserves domestically. Since 2020, the Peruvian Congress has authorized eight withdrawals from pension funds, equivalent in total to 10 percentage points of GDP.[3]

Third, banks are the dominant market makers in foreign exchange. When a non-bank investor wants to switch from dollars to soles, it will swap a deposit account in different currencies. Banks offer terms for that exchange at the banks' exchange rate. Likewise, there's a market for sol and dollar reserves in which banks themselves trade. In addition to market-making across these spot trades, banks also take positions in forward and non-deliverable forward (NDF) markets.

Together, these three features mean that, for a reliable supply, banks must maintain liquid dollar positions to meet possible deposit outflows and contract settlements. These flows drive the scarcity of dollar positions and transmit directly into exchange rate dynamics. These flows also provide much of the variation driving the correlations we describe below.

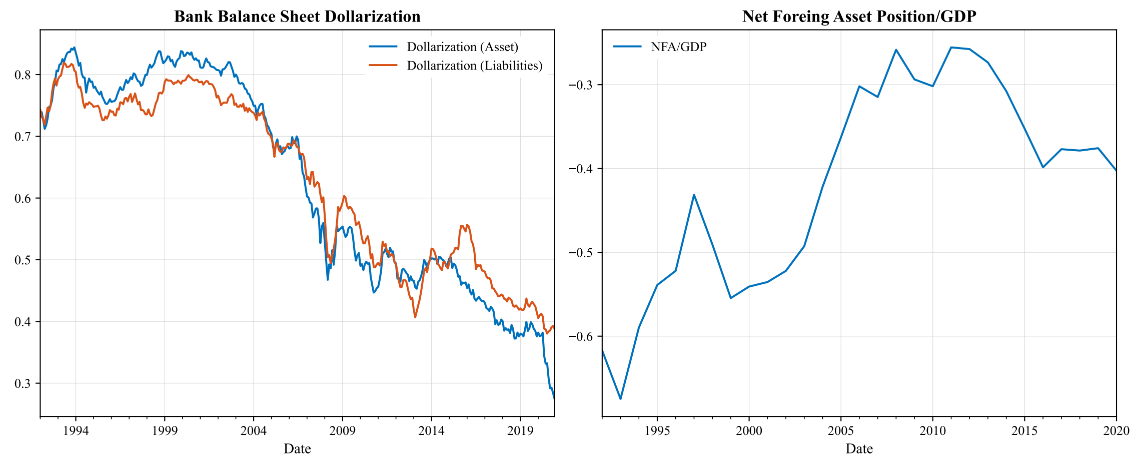

Figure 3: Balance Sheet Dollarization and Net Foreign Asset Position

Notes: Dollarization is measured as the share of USD-denominated liabilities (assets) in total liabilities (assets). Source: BCRP.

Quantity-Based Regulation. The BCRP has actively relied on a set of quantity-based instruments that affect the supply and demand for foreign-currency liquidity in the banking system (Armas, Castillo and Vega, 2014). These instruments operate through two broad channels. First, they offset short-run imbalances in banks' net foreign-currency positions and in hedging markets. Second, they alter the relative cost of intermediation in domestic and foreign currency, thereby affecting the currency composition of bank balance sheets and credit.

[3] Pension fund withdrawals were authorized on four occasions in 2020, and thereafter once a year in 2021, 2022, 2024, and 2025.

Foreign exchange intervention. The BCRP uses foreign exchange intervention to limit excessive exchange rate volatility and to provide foreign-currency liquidity when market conditions require it. Depending on the source of the imbalance, intervention may take the form of outright spot operations or derivative-based transactions, including swaps as described in Figure 4. In outright intervention, the central bank buys or sells U.S. dollars in the spot market against domestic currency. These operations directly affect the quantity of dollar liquidity available to the banking system and simultaneously change banks' holdings of domestic-currency reserves at the BCRP. Purchases of dollars inject domestic-currency liquidity, whereas sales withdraw it. In practice, these operations are typically sterilized through offsetting open-market operations as shown in Figure 4, so that changes in domestic-currency liquidity do not alter the intended monetary policy stance.

The BCRP also conducts swap operations with domestic banks. These transactions provide banks with a hedging instrument that allows them to manage temporary foreign-exchange exposures without requiring an immediate adjustment in the spot market. This is relevant because domestic banks are the main intermediaries in Peru's FX derivatives market. Demand for forward contracts arises primarily from non-resident investors hedging local-currency exposures, particularly holdings of domestic government bonds, and from domestic pension funds hedging the currency risk associated with their foreign asset positions. Banks absorb these client positions and subsequently seek to offset the resulting exposures in either the interbank forward market or the spot market. Their ability to do so, however, is constrained by balance-sheet limits and by the availability of dollar liquidity for settlement. In this setting, central bank swap auctions allow the BCRP to absorb temporary imbalances in hedging demand and to reduce pressures that would otherwise spill over into the spot exchange rate.

Reserve requirements. In addition to FX intervention, the BCRP operates a system of reserve requirements on bank liabilities in both domestic and foreign currency. Financial institutions must hold reserve assets in proportion to their liabilities, with separate requirement ratios by currency. Because these reserves are generally unremunerated, reserve requirements increase the cost of intermediation and widen the spread between deposit and lending rates in the corresponding currency. Through this channel, they affect funding conditions, liquidity creation, and credit supply.

The reserve requirement framework includes both an average requirement and a marginal requirement. The average requirement applies to the relevant stock of liabilities, whereas the marginal reserve requirement applies a higher rate to liabilities exceeding a specified reference level. This generates a convex cost schedule

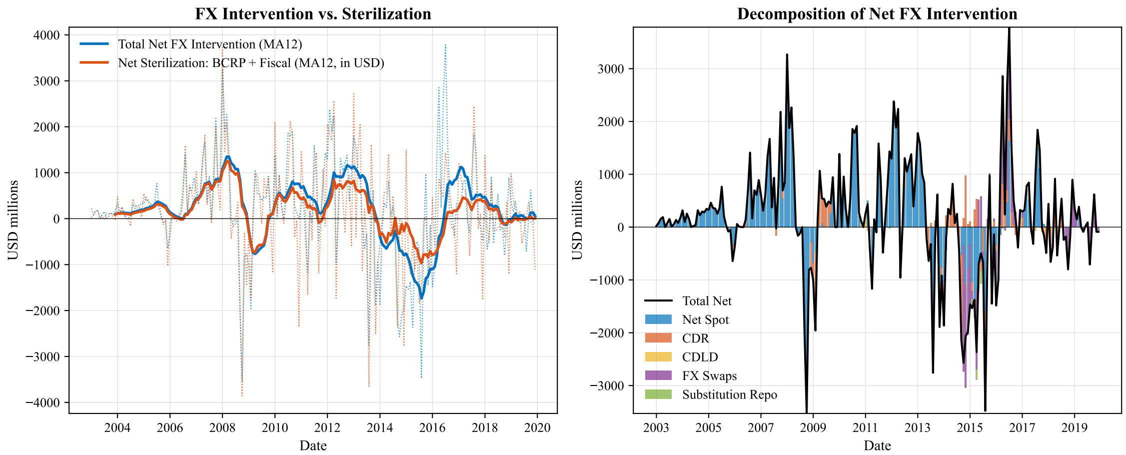

Figure 4: BCRP FX Intervention and Sterilization

Notes: The left panel plots the total net FX intervention alongside its net sterilization, both expressed in USD millions. Fiscal sterilization—driven primarily by seasonal income tax payments accumulating as government deposits at the BCRP—is included because the BCRP take this into consideration when they decide the size of the sterilization conducted through open market operations in response to FX intervention. The right panel decomposes total net FX intervention into its constituent instruments. *Net Spot* refers to direct purchases and sales of USD, *CDR* and *CDLD* are specialized certificates of deposit. *FX Swaps* are derivative contracts that reduce banks' need to purchase spot USD for hedging. *Substitution Repo* is for supporting credit de-dollarization by shifting bank funding from USD to Sol liabilities. Positive values indicate net USD purchases by the BCRP. Source: BCRP.

for balance-sheet expansion, since the marginal cost of additional funding rises once the reference threshold is surpassed. In the case of foreign-currency liabilities, this mechanism raises the cost of expanding dollar intermediation, strengthens banks' FX liquidity buffers, and increases the cost of maintaining large foreign-currency balance-sheet exposures. Cyclical changes in reserve requirements in both currencies allow the BCRP to tighten or ease financial conditions, influence credit growth, and affect the relative attractiveness of intermediation in soles and dollars.

Forward market regulation. The BCRP has also used quantity-based regulation to affect the cost of intermediary positions in the FX derivatives market. In the aftermath of the Taper Tantrum, expectations of a depreciation of the sol increased foreign investors' demand for dollars in the forward market. As the dominant market makers in this segment, local Peruvian banks took the opposite side of these positions by selling dollar forwards. To hedge the resulting short dollar forward exposure, banks purchased dollars in the spot market, thereby adding upward pressure on the exchange rate. These dynamics became particularly pronounced in 2014. In response, the BCRP introduced a regulation under which additional reserve requirements are imposed when banks' gross short dollar forward positions exceed pre-specified thresholds. Since December 2014, banks breaching these limits have been subject to a surcharge on domestic-currency reserve requirements. This regulation affects the effective cost of holding large short dollar forward positions and, as discussed below, is central to accounting for the persistent positive CIP deviations observed after 2014.[4] As we show below, this regulation is key to generating the persistent positive CIP deviations observed after 2014 in our model.[5]

Figure 5 shows some of the variables affecting the regulation. In the domestic currency segment (left panel), banks maintain a large surplus of liquid assets above regulatory minimums. The dollar segment (right panel) shows that liquidity buffers are much thinner, making regulatory costs more likely. For example, this tightness was especially pronounced during 2011–2013, when rapid hikes in reserve requirements compressed the banking sector's excess dollar liquidity. Compounding the squeeze, the BCRP purchased approximately USD 15 billion (roughly 8.7% of 2011 GDP) over this period, draining dollar settlement balances from the banking system even as regulatory demands on those balances were rising.

An important feature of the Peruvian quantity-based interventions is that these instruments were aimed at different objectives: the explicit goal of the BCRP was to reduce the short-run exchange rate volatility and induce a long-run financial de-dollarization. Shocks to dollar flows can push banks against their regulatory constraint. Thus, beyond the standard FX interventions, these quantity-based regulation actively alter the relative risk of issuing one liability or the other

For our purposes, active adjustments in these tools generate shifts in both the supply and demand for dollar settlement balances, creating variation that we can exploit to identify the role of dollar liquidity in exchange rate dynamics. Below, we use unexpected adjustments in MGRR as exogenous liquidity shocks to establish a causal link. In the counterfactual section, we then use the structural model to quantify the efficacy of FX intervention in stabilizing the exchange rate.

Funding Cost Asymmetry and Market Segmentation. The interaction of structural dollar demand and regulatory constraints means that liquidity shocks—whether from deposit withdrawals, regulatory tightening, or external outflow pressure—translate

[4] Let S_t denote the spot exchange rate (soles per dollar). If a bank's gross USD forward sales exceed the limit by X dollars, the bank must hold additional Sol reserves equal to $2 \times X \times S_t$ soles—that is, Sol reserves worth twice the dollar value of the excess position. Expressed as an increase in the average Sol reserve requirement ratio: $\Delta \text{Sol RR}_t = 2.0 \times \left(\frac{(\text{Gross USD Forward Sales}_t - \text{Limit}_t) \times S_t}{\text{Total Sol Liabilities}_t} \right) \times 100$. The factor of 2 makes the regulation highly punitive: for every dollar of excess forward exposure, the bank must immobilize two dollars' worth of unremunerated Sol reserves.

[5] In addition to reserve requirements, the BCRP enforces limits on banks' net FX exposure to mitigate currency mismatches. These regulations cap net long and short positions at a fraction of effective equity (typically 10% for spot, with separate limits for derivatives). When a bank approaches its regulatory short limit, its demand for dollar assets becomes highly inelastic, amplifying the shadow cost of liquidity during outflow episodes.

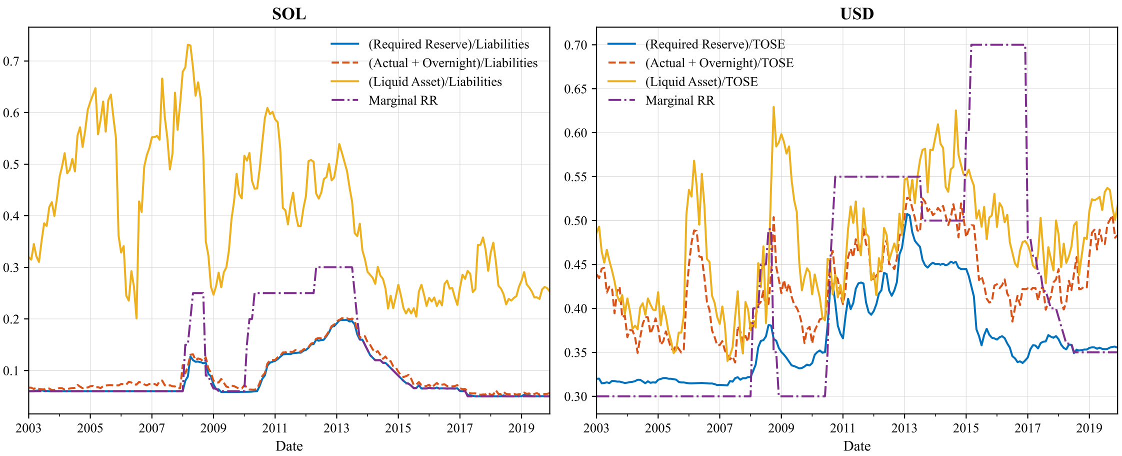

Figure 5: Sol and USD Reserve Requirement Ratio

Notes: Liquid assets include cash and fixed funds, deposits in domestic and foreign financial institutions, central government and BCRP debt instruments, net interbank funds, negotiable and bank certificates of deposit, and debt securities of the financial system and foreign insurance companies. Actual reserves are deposits held at the BCRP that count toward the reserve requirement but earn no remuneration. Overnight deposits are also held at the BCRP and are remunerated, but do not count toward the reserve requirement. All figures are reported at the aggregate level for the Peruvian banking sector. Source: BCRP.

quickly into funding stress. Banks must replenish dollar reserves through a hierarchy of increasingly costly sources: the local interbank market, the central bank's discount window, or external wholesale borrowing. Figure 6 reveals the sharp asymmetry between the two currency segments. Sol funding is well-backstopped: the BCRP can always act as lender of last resort in its own currency, and liquid asset buffers are ample. By contrast, dollar funding is fundamentally more fragile. The BCRP extended dollar repos to the banking sector on only two occasions in our sample, and no dollar-denominated discount window facility exists, underscoring that it cannot reliably serve as a dollar lender of last resort. External wholesale borrowing, the other margin of adjustment, is itself unreliable—gaps in the external funding rate data are indicative of periods in which local banks simply could not secure borrowing from foreign counterparties at any quoted rate. The costs of the remaining sources display significant volatility and persistent spreads across currencies and funding tiers. This asymmetry motivates the central friction in our model: a segmented market in which the local cost of dollar liquidity diverges from global benchmarks, driven by the scarcity of domestic dollar settlement balances rather than by movements in world interest rates.

2.2 Dollar Liquidity and Exchange Rate

Having established the importance of dollar liquidity in Peru, we now directly connect local dollar liquidity conditions to exchange rate dynamics. We first define the

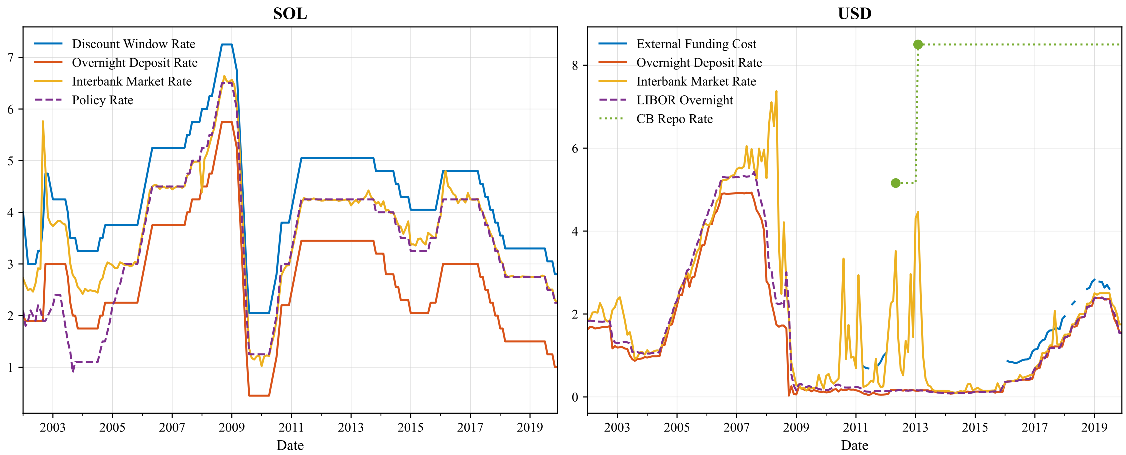

Figure 6: Bank Funding Costs

Notes: Dollar repo lending by the BCRP occurred in only two months in our sample, indicated by filled dots. External funding cost is the interest rate paid to foreign lenders on wholesale borrowing. Gaps in the external funding rate series reflect periods in which no external wholesale funding transactions were recorded. Source: BCRP, Bloomberg.

key variables and document a set of stylized facts—non-trivial arbitrage wedges. In particular, we note that non-trivial CIP deviations persist in Peru, from which we infer that the dollar supply curve is upward-sloping. Under this premise, local dollar demand shocks need not be fully absorbed by supply and can instead move the exchange rate. We present evidence of a striking correlation between local liquidity conditions and exchange rate movements, then move to formal analysis: first estimating Engel and Wu (2023) regressions to quantify the role of local dollar liquidity, and then exploiting the policy shocks identified by Gutierrez, Ivashina and Salomao (2023), which directly affect the dollar demand of the local banking sector, to establish causality.

Exchange Rates and Interest Rates. We denote the Sol/USD spot rate as S_t and the one-month forward rate as $F_{t,t+1}$. Let $s_t = \log(S_t)$ and $f_{t,t+1} = \log(F_{t,t+1})$. We denote the domestic Sol interest rate by i_t and the foreign dollar rate by i_t^*. In the following figures, for the domestic rate, we use the monetary policy rate and the local overnight interbank rate. For the dollar rate, we use the Federal Reserve's policy rate and the local dollar overnight interbank rate, at which Peruvian banks borrow and lend dollars to each other. This overnight rate is particularly informative, as it directly reflects onshore dollar liquidity conditions.[6]

Figure 7 plots exchange rates alongside interest rate differentials. The data show strong trends with a notable reversal following the 2013 Taper Tantrum. Standard UIP cannot rationalize these dynamics. Moreover, there are consistent sharp deviations

[6]A detailed description of data sources is provided in the regression section.

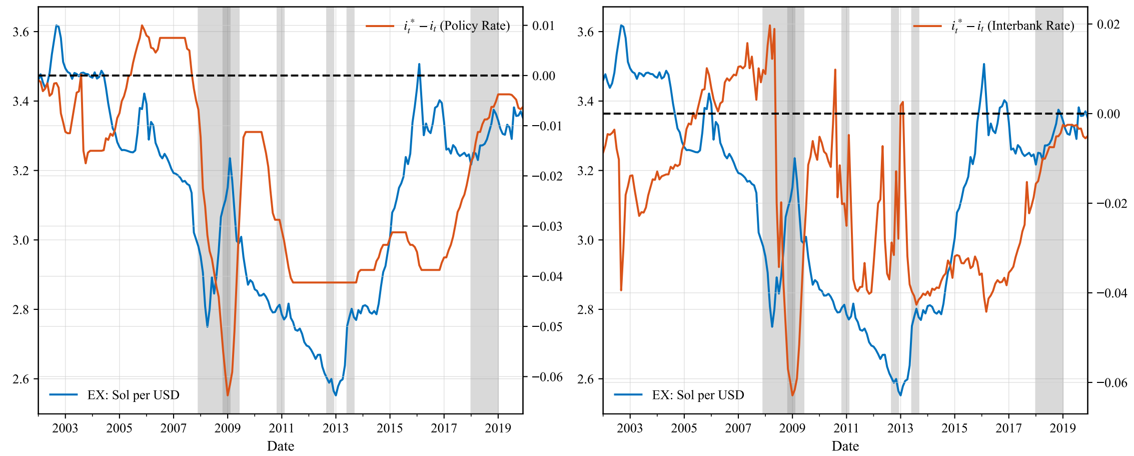

Figure 7: Interest Rate Differential and Exchange Rates

Notes: Shaded areas correspond to the Global Financial Crisis (GFC), QE1, QE2, QE3, the Taper Tantrum, the U.S.China trade war, and the COVID-19 pandemic. For the quantitative easing (QE) episodes, the shaded region covers the first three months of each program. The left panel plots the policy rate differential, while the right panel plots the interbank market rate differential. Source: BCRP.

from the trends, suggesting a role for factors beyond long-run fundamentals and interest rate differentials. To investigate this further, we formally construct measures of arbitrage deviations.

Parity Conditions and Deviations. To characterize the Sol-USD exchange rate further, following the literature, we construct deviations from UIP and CIP, denoted λ_t^{UIP} and λ_t^{CIP}. For the UIP deviation, we use the realized exchange rate at $t+1$ as a proxy for expectations under rational expectations:

$$\lambda_t^{UIP} = s_{t+1} - s_t + i_t^* - i_t, \quad \lambda_t^{CIP} = f_{t,t+1} - s_t + i_t^* - i_t. \tag{1}$$

A positive λ implies an excess return on holding dollar assets relative to Sol assets from the perspective of a Peruvian investor. We compute these measures using local interbank market rates to capture the incentives facing local banks, who serve as the primary market makers. Note that UIP deviations reflect currency risk premia, asset-specific risk premia, and the relative non-pecuniary benefits (e.g., liquidity benefits) of each currency or asset. CIP deviations, by contrast, are immune to currency risk premia since the forward contract hedges them, while the remaining components of UIP still exist in CIP deviations. This implies that UIP and CIP deviations may be positively correlated when driven by non-pecuniary benefits, but negatively correlated when currency risk premia are the primary driver of UIP deviations.

Figure 8 displays the evolution of these deviations: the left panel shows the raw series and the right panel a 12-month moving average to highlight trends. Interest rate

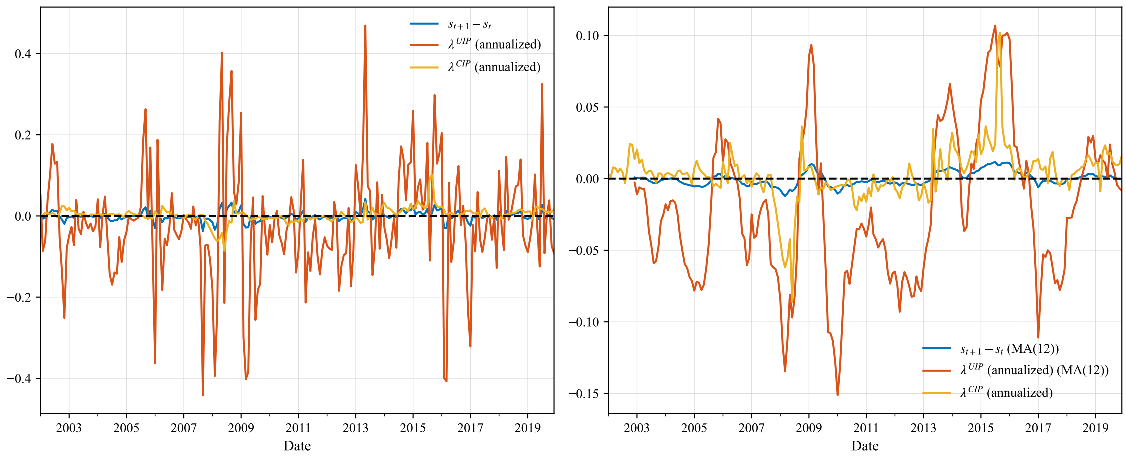

Figure 8: Deviations from the Parity Conditions

differentials are annualized, while exchange rate changes reflect realized monthly movements. Several features stand out. First, CIP deviations are persistently non-zero, rejecting frictionless arbitrage. Since forward contracts are traded between large local financial institutions and interest rates come from the local interbank market, counterparty risk is minimal. Unlike UIP deviations, CIP deviations cannot be explained by currency risk premia, since the forward contract eliminates exchange rate risk by construction. The persistent non-zero CIP wedge therefore points to effective limits to arbitrage rooted in local liquidity conditions rather than risk compensation, implying that the Sol-USD FX market faces an upward-sloping dollar supply curve.

Second, the co-movement between UIP and CIP deviations is time-varying. During periods when the two move together, this is consistent with non-pecuniary factors, such as differential liquidity benefits, being the common driver. By contrast, when currency risk premia are large and the primary driver of UIP deviations, the two measures may diverge since CIP deviations are immune to currency risk premia by construction, a rise in currency risk premia pushes UIP deviations without a corresponding movement in CIP deviations, generating a negative correlation between the two.

Local Liquidity Measures. We now turn to our primary hypothesis: that exchange rate dynamics are linked to local dollar liquidity conditions. To measure the quantity of available liquidity, we use banking sector balance sheet data from the BCRP to construct the dollar liquidity ratio ($DollarLALL$) and the Sol liquidity ratio ($SolLALL$) for the aggregate banking sector:

$$DollarLALL_t = \frac{\text{Dollar Liquid Assets}_t}{\text{Total Dollar Liabilities}_t}, \quad SolLALL_t = \frac{\text{Sol Liquid Assets}_t}{\text{Total Sol Liabilities}_t} \tag{2}$$

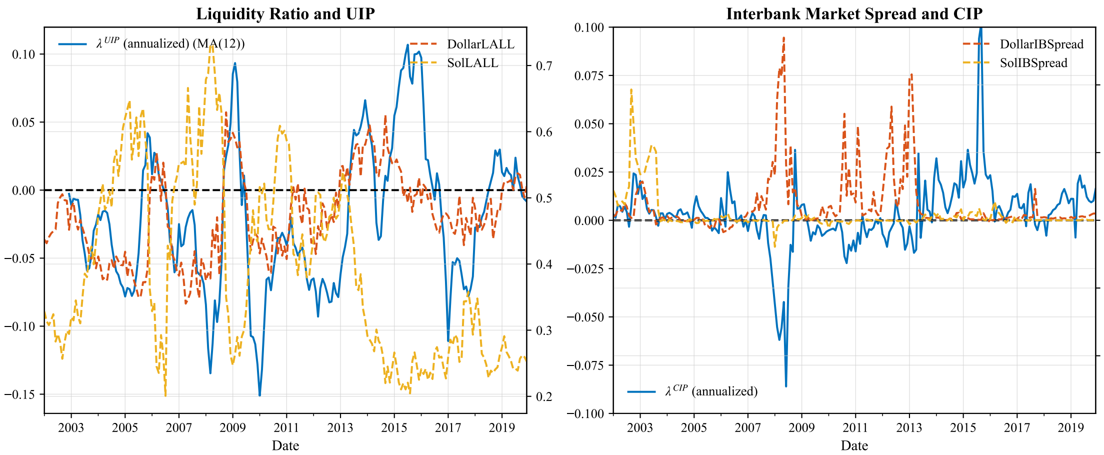

Figure 9: Local Liquidity and Breakdown of No-Arbitrage

Liquid assets include cash and fixed funds, domestic and foreign interbank deposits, government and BCRP debt instruments, net interbank funds, negotiable and bank certificates of deposit, securities representing financial-system debt, and foreign insurance-denominated securities.

To complement these quantity measures, we construct funding spreads that capture the price of liquidity. The dollar interbank spread ($DollarIBSpread$) and the Sol interbank spread ($SolIBSpread$) are defined as:

$$DollarIBSpread_t = \text{Local USD Interbank Rate}_t - \text{Overnight USD LIBOR Rate}_t, \quad (3)$$

$$SolIBSpread_t = \text{Local Sol Interbank Rate}_t - \text{BCRP Policy Rate}_t. \quad (4)$$

A widening of $DollarIBSpread$ indicates that local Peruvian banks face a higher funding cost relative to the global dollar benchmark, reflecting market segmentation and a scarcity of dollars in the local system. The same intuition applies to $SolIBSpread$: when Sol reserves are not adequately supplied, the interbank rate deviates from the policy rate, pushing the spread higher.

Figure 9 plots local liquidity conditions against the parity deviations. The left panel shows a tight comovement between the dollar liquidity ratio ($DollarLALL$) and the UIP deviation (λ^{UIP}): periods of dollar liquid asset accumulation coincide with excess returns on dollar assets, suggesting that dollar scarcity affects the return on dollar assets through a liquidity benefit channel. The right panel relates the price of liquidity to CIP. Spikes in the local dollar funding spread ($DollarIBSpread$)—reflecting acute onshore dollar shortages—line up closely with large CIP dislocations. Together, these patterns suggest that deviations from parity are not random but are driven by the availability and cost of local dollar liquidity.

Regression Analysis. The correlations documented above motivate a more systematic investigation. To examine whether local liquidity conditions have independent explanatory power for exchange rate dynamics, following Engel and Wu (2023), we regress monthly changes in the log exchange rate on our local liquidity measure, controlling for standard global and local macro-financial variables.

For this analysis, we assemble a comprehensive dataset covering exchange rates (spot and forward), market interest rates, bank balance-sheet composition, BCRP policy variables, and other measures of Peruvian macroeconomic and international financial conditions. Our primary data source is the BCRP, which provides detailed banking sector balance sheets decomposed by currency and asset class on both the assets and liabilities sides. Crucially, we observe the structure of external borrowing as well as local banks' dollar forward positions. The BCRP also reports a rich set of policy variables: the monetary policy reference rate, interest rates on reserves, discount window rates, reserve requirement ratios for both soles and dollars, foreign exchange intervention, and central bank dollar repo lending. For market interest rates, we use the local interbank overnight rate and three-month prime deposit and lending rates, also sourced from the BCRP. Finally, we obtain the VIX index and Peru-specific corporate and sovereign spreads from FRED and Bloomberg to capture country risk and global risk conditions.

Our sample spans January 2002 through December 2019 at a monthly frequency. We begin in January 2002 to avoid the structural break associated with the full adoption of the BCRP's inflation targeting framework, and end in December 2019 to exclude the COVID-19 period and its confounding effects. This represents our maximum sample period; we use the full sample whenever possible, though the coverage of some variables begins later, in which case we use all available observations.

The baseline OLS specification is:

$$\begin{aligned}\Delta s_t = \alpha &+ \beta_1 q_{t-1} + \beta_2 \Delta\lambda_t^{CIP} + \beta_3 \lambda_{t-1}^{CIP} + \beta_4 \Delta(i_t - i_t^*) + \beta_5 (i_{t-1} - i_{t-1}^*) \\ &+ \beta_6 \Delta\eta_t^{G10} + \beta_7 \eta_{t-1}^{G10} + \beta_8 \Delta \ln(VIX_t) + \beta_9 \ln(VIX_{t-1}) \\ &+ \beta_{10} \Delta\zeta_t + \beta_{11} \zeta_{t-1} + \beta_{12} \mathbb{1}_{\{t>\bar{t}\}} + \beta_{13} \Delta NLR_t + \beta_{14} NLR_{t-1} + \epsilon_t \end{aligned} \tag{5}$$

where s_t is the log Sol/USD spot rate, q_t is the log real exchange rate, $i_t - i_t^*$ is the difference between local Sol and USD interbank rates, and λ_t^{CIP} is the Peru–US CIP deviation computed from local interbank market rates in both currencies. Engel and Wu (2023) estimate this regression using the first three explanatory variables to study the role of liquidity in exchange rate determination among G10 currencies.

Peru, however, differs from G10 countries in important respects: as an emerging-market commodity exporter, it is subject to substantial influence from global uncertainty and country-specific risk. We therefore augment the specification with additional controls in the spirit of Kalemli-Özcan and Varela (2024). To capture global dollar funding conditions, we include η^{G10}, the G10 cross-currency basis from Du, Im and Schreger (2018).[7] To control for global uncertainty, we include the VIX. For country-specific risk, we use the J.P. Morgan EMBI Global Diversified Peru Sovereign Spread (ζ_t). Finally, given the pronounced trend reversal in s_t around the Taper Tantrum visible in Figure 7, we include a post-Taper Tantrum dummy, $\mathbb{1}_{\{t>\bar{t}\}}$.

The key variable of interest is NLR_t, defined as the dollar liquidity ratio net of the required reserve ratio, which captures the excess dollar liquidity available to the aggregate Peruvian banking sector.[8] Table 1 reports the results.

	EW2023	+GL	+GL/VIX	+GL/VIX/LR	+GL/VIX/LR/LI
q_{t-1}	-0.012	-0.013	-0.011	-0.028***	-0.021*
	(0.008)	(0.009)	(0.008)	(0.010)	(0.011)
$\Delta(i_t - i_t^*)$	0.449**	0.415**	0.369**	0.275*	0.363***
	(0.182)	(0.172)	(0.158)	(0.150)	(0.118)
$\Delta\lambda_t^{CIP}$	0.098	0.098	0.066	0.013	0.042
	(0.068)	(0.068)	(0.064)	(0.054)	(0.043)
$\Delta\eta_t^{G10}$		-0.656	-0.141	0.135	0.812
		(0.529)	(0.513)	(0.416)	(0.503)
$\Delta\ln(VIX)$			0.015***	0.003	0.006
			(0.005)	(0.005)	(0.005)
$\Delta\zeta$				1.257***	0.991***
				(0.301)	(0.251)
ΔNLR					**0.114*** **
					(0.028)
R-squared Adj.	0.109	0.109	0.142	0.242	**0.308**
N	215	215	215	215	215

Standard errors in parentheses. * p<.1, ** p<.05, ***p<.01. Monthly frequency regressions with HAC standard errors, 12-month lags. Period: 2002-02 to 2019-12.

Table 1: Exchange Rates and Local Liquidity (OLS)

First, consistent with Engel and Wu (2023), the coefficient on q_{t-1} is negative across all specifications, with significance varying by controls. In the full specification, the estimate of -0.021 implies a rate of mean reversion of approximately 2.1% per month toward the long-run equilibrium real exchange rate.

[7] While Du, Im and Schreger (2018) also construct a Peruvian government bond-based CIP measure, data limitations restrict its coverage to the period beginning in 2006:02. To maximize sample coverage, we use CIP deviations based on local interbank market rates. Using the Peru-specific CIP measure from Du, Im and Schreger (2018) instead yields no meaningful differences in the estimation results.

[8] We also explored including the Sol liquidity ratio net of the required reserve ratio, but found no significant results and excluded it from the baseline specification. This is consistent with the BCRP's effective management of Sol liquidity conditions.

Second, the coefficient on $\Delta(i_t - i_t^*)$ is positive—opposite in sign to the estimates in Engel and Wu (2023)—and relatively modest in magnitude. In the full specification, a 100-basis-point increase in the annualized Sol–Dollar interest rate differential is associated with a contemporaneous Sol depreciation of 0.36%. While the sign of this coefficient remains debated in the literature, our positive estimate likely reflects the emerging-market context, in which interest rate increases are correlated with rising risk premia and depreciation pressure.

Third, the non-significance of $\Delta\lambda_t^{CIP}$ is noteworthy. We interpret this as a consequence of the two large, persistent spikes in CIP deviations visible in Figure 9, which may have attenuated the monthly-frequency relationship between CIP changes and exchange rate movements. As we show below, the bank balance sheet variable, which more directly captures the liquidity position of the banking sector, exhibits considerably stronger explanatory power.

Fourth, global dollar funding conditions and uncertainty matter when country-specific risk is not controlled for (column +GL): a tightening of the global dollar basis ($\Delta\eta_t^{G10} < 0$) and a rise in the VIX are both associated with Sol depreciation, consistent with dollar scarcity and flight-to-safety effects. However, once the Peru sovereign spread is included, both variables lose significance, underscoring the importance of country-specific risk in explaining emerging-market exchange rate dynamics. The post-Taper Tantrum dummy, while carrying the expected positive sign consistent with the subsequent dollar appreciation trend, is not significant in any specification and is omitted from the table.

Finally, and most importantly, the coefficient on ΔNLR—our main variable of interest—is positive and statistically significant at the 1% level, even after controlling for the full set of variables emphasized in the literature. The estimate implies that a one-percentage-point increase in the excess dollar liquidity ratio is associated with a 0.12% depreciation of the Sol. We interpret this through the lens of a demand shock: when banks anticipate dollar scarcity or heightened liquidity risk, they accumulate precautionary dollar balances, raising the net liquidity ratio, and the resulting increase in dollar demand drives an appreciation of the dollar.

The economic magnitude is notable. The adjusted R^2 rises from 0.24 to 0.31 upon inclusion of ΔNLR—a substantial gain given the well-documented difficulty of explaining short-run exchange rate movements, and all the more striking because this improvement obtains on top of the full set of controls traditionally considered important in the literature. Moreover, NLR is a pure quantity-based measure constructed entirely from bank balance sheet data, with no exchange rate or interest rate component, whereas most other regressors are themselves functions of currency prices. The significant explanatory power of a quantity variable implies that the supply and demand for dollar reserves are finitely elastic, in contrast to the frictionless benchmark in which arbitrage renders such quantities irrelevant for pricing. This relationship is robust across subperiods, as reported in Appendix Table 6.

Identifying Dollar Liquidity Demand Shocks. The OLS results establish a systematic link between dollar liquidity and exchange rates but do not rule out potential confounders. In particular, the Peruvian banking sector is subject to both dollar supply shocks (e.g., commodity-driven reserve inflows) and demand shocks (e.g., precautionary hoarding), and the OLS coefficient likely reflects a weighted average of the two. To isolate the causal effect of demand-driven liquidity shocks, we employ a Local Projection Instrumental Variable (LP-IV) approach.

We instrument changes in the local liquidity variable (ΔNLR_t) using unexpected changes in the Marginal Reserve Requirement ($\Delta MGRR^{shock}$). Following the narrative identification strategy of Gutierrez, Ivashina and Salomao (2023), we isolate specific episodes of surprise regulatory adjustments that serve as valid instruments. These include the sharp increase in the marginal USD reserve requirement from 50% to 70% between December 2014 and February 2015, and the subsequent rapid reduction from 70% to 48% in December 2016.

To understand the mechanism, recall that the marginal reserve requirement applies to dollar liabilities above a specified threshold. When the marginal requirement rises to 70%, a bank that borrows an additional dollar from abroad can deploy only 30 cents for purposes other than meeting reserve requirements. This renders marginal dollar funding prohibitively costly, inducing banks to accumulate precautionary dollar reserves rather than risk a shortfall.

The validity of these instruments rests on several features documented by Gutierrez, Ivashina and Salomao (2023). The magnitude of the adjustments was unprecedented—a differential shift of 21.5 percentage points within less than two months—far exceeding typical policy responses, including those during the Global Financial Crisis. Moreover, these shifts appear orthogonal to contemporaneous macroeconomic conditions: in the majority of episodes involving large depreciations or capital flow reversals, differential reserve requirements remained at zero, supporting the interpretation that the specific spikes were unanticipated shocks rather than endogenous responses to the exchange rate. The adjustments also coincided with the phased introduction of capital requirements for indirect FX exposure, reinforcing their character as structural prudential measures rather than standard countercyclical policy.

	2002–2019 (OLS)	2002–2019 (IV)
q_{t-1}	-0.021*	0.005
	(0.011)	(0.028)
$\Delta(i_t - i_t^*)$	0.364***	0.790***
	(0.118)	(0.236)
$\Delta\lambda_t^{CIP}$	0.041	0.141
	(0.043)	(0.129)
$\Delta\eta_t^{G10}$	0.836*	4.841**
	(0.504)	(1.951)
$\Delta\ln(VIX)$	0.006	0.023**
	(0.005)	(0.012)
$\Delta\zeta$	1.023***	-0.614
	(0.262)	(0.515)
ΔNLR	**0.114*** **	**0.904*** **
	(0.028)	(0.184)
N	211	211
R-squared Adj.	0.309	—

Standard errors in parentheses. * p<.1, ** p<.05, ***p<.01. Monthly frequency regressions with HAC standard errors, 12-month lags. Period: 2002-02 to 2019-12.

Table 2: Exchange Rate and Liquidity

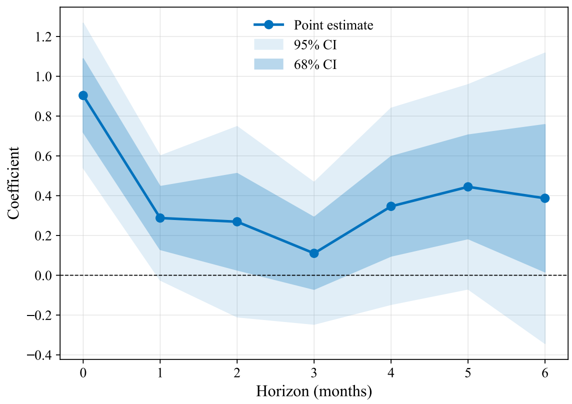

Figure 10: Local Projection β_{t+h}

The first-stage regression is:

$$\Delta NLR_t = \omega + \gamma Z_t + \sum_{k=0}^{4} \gamma_k \Delta MGRR_{t-k}^{shock} + e_t \tag{6}$$

where we include contemporaneous and four lagged values of the instrument to capture the persistent effects of regulatory shocks. The instrument is strongly relevant, with a partial F-statistic of 59.1, well above conventional thresholds (Appendix Table 5). The estimates carry the expected sign: an unexpected increase in the marginal reserve requirement induces banks to accumulate excess liquidity.

In the second stage, we estimate not only the contemporaneous response but also the dynamic response of the exchange rate over the horizon h:

$$\Delta s_{t+h} = \alpha_h + \beta_h^{IV} \widehat{\Delta NLR_t} + \Gamma_h X_t + \epsilon_{t+h}, \quad \text{for } h = 0, 1, \ldots, 12 \tag{7}$$

where X_t includes the full set of controls from the baseline specification. Results are reported in Table 2 and Figure 10. The IV coefficient $\hat{\beta}_0^{IV} \approx 0.904$ implies that a one-percentage-point increase in the excess dollar liquidity ratio, driven by an exogenous policy shock, leads to approximately a 0.9% depreciation of the Sol against the US dollar within the same month—an economically large effect. The standard error is relatively wide (0.184), as expected given that identification relies on rare, discrete policy episodes. Nevertheless, the effect is statistically significant at the 1% level.

The dynamic profile in Figure 10 shows that the effect persists for roughly one month after the initial shock. The impulse response gradually reverts toward zero but does not turn negative, suggesting that demand-driven liquidity shocks produce a persistent level shift in the exchange rate rather than a transitory overshooting.

Together with the strong correlations between liquidity variables and deviations from FX arbitrage conditions documented above, the IV results provide compelling evidence that local dollar liquidity conditions are a first-order driver of short-run exchange rate dynamics. These findings motivate the small open economy model with banking sector liquidity frictions developed in the next section.

3 Model

We develop a dynamic general equilibrium model of a small open economy in which local banks intermediate dollars between domestic agents and foreigners. The economy is partially dollarized—a salient feature of several South American countries—so that local banks operate with liabilities denominated in both domestic currency and US dollars. Banks fund themselves through household deposits in both currencies and domestic-currency equity, while foreign investors supply dollar funding following the slow-moving capital framework. Because banks face unexpected withdrawal shocks on their liabilities in either currency, they must hold liquid assets in both. Crucially, the aggregate stock of dollar liquidity available to the domestic economy is limited: it can expand only through a trade surplus, positive net investment income, or additional foreign borrowing. Meanwhile, banks' demand for dollar liquidity can shift rapidly with changes in the regulatory environment—such as reserve requirements or forward-market position limits—or with variation in the size of dollar withdrawal shocks. The central bank, in turn, can intervene in the foreign exchange market, altering the quantity of dollars accessible to the banking sector. The equilibrium exchange rate is then determined by the interaction of these supply and demand forces, each grounded in realistic institutional detail.

We begin with the real side of the economy—households, firms, and foreign investors—before turning to the core of the model: the local banking sector. We then specify the role of the central bank. With the model in place, we derive the aggregate dollar funding constraint and analyze the effects of quantity-based policies.

Households. The representative household family enters period t with state $\mathbf{S}_t^H = (d_{t-1}^H, d_{t-1}^{H,*}, n_{t-1}^H, X_t)$ and solves:

$$V(\mathbf{S}_t^H) = \max_{\substack{c_t, c_t^*, c_t^A, \\ h_t^H, h_t^{H,*}, \\ d_t^H, d_t^{H,*}, n_t^H}} \quad u(c_t) + u(c_t^*) + u(c_t^A) - \frac{(h_t^H)^{1+\nu}}{1+\nu} - \frac{(h_t^{H,*})^{1+\nu}}{1+\nu} + \beta\, \mathbb{E}_t[V(\mathbf{S}_{t+1}^H)] \quad (8)$$

subject to the deposit-in-advance constraints:

$$c_t \leq R_t^d \, d_{t-1}^H, \qquad c_t^* \leq R_t^{d*} \, d_{t-1}^{H,*}, \tag{9}$$

and the budget constraint:

$$d_t^H + d_t^{H,*} + n_t^H + c_t + c_t^* + c_t^A = \Pi_t^F + \Pi_t^{F,*} + \Pi_t^B + w_t \, h_t^H + w_t^* \, h_t^{H,*} \\ + R_t^d \, d_{t-1}^H + R_t^{d*} \, d_{t-1}^{H,*} + R_t^n \, n_{t-1}^H + \Gamma(n_{t-1}^H) + t_t, \tag{10}$$

where $\mathbf{S}_{t+1}^H = (d_t^H, d_t^{H,*}, n_t^H, X_{t+1})$.

The representative household family chooses Sol-denominated consumption c_t, Dollar-denominated consumption c_t^*, and an aggregate consumption good c_t^A to maximize its lifetime utility. The family's members supply differentiated labor: some work for Sol-currency firms for h_t^H hours at wage w_t, while others work for Dollar-currency firms for $h_t^{H,*}$ hours at wage w_t^*. The family holds Sol and Dollar deposits, d_t^H and $d_t^{H,*}$, at local banks, earning gross real returns R_t^d and R_t^{d*} on the inherited balances d_{t-1}^H and $d_{t-1}^{H,*}$, respectively.[9] Purchases of c_t and c_t^* must be financed from the corresponding deposit balances, giving rise to the deposit-in-advance (DIA) constraints. The family also invests in preferred equity n_t^H, which pays a gross return R_t^n on the inherited position n_{t-1}^H; as equity investment increases, the family receives compensation for adjustment costs $\Gamma(n_{t-1}^H)$, which can be interpreted as fees earned by an investment banking arm of the family. As implied by the budget constraint, c_t, c_t^*, and c_t^A are identical goods with the same price.[10] The family owns all firms and banks, receiving profits Π_t^F, $\Pi_t^{F,*}$, and Π_t^B, and t_t represents real transfers from the central bank. The aggregate exogenous states X_t—which include the foreign funding shock z_t introduced in the next section—are collected alongside the individual states in $\mathbf{S}_t^H$.

Firms. The Sol-firm produces a tradable good using a one-period-to-build technology, $y_{t+1} = f(h_t^F) = h_t^F$, hiring labor h_t^F at real wage w_t. Since production takes one period to materialize, the firm must finance the wage bill in advance by borrowing Sol-denominated loans b_t^F from local banks. The firm operates without equity, and its working capital constraint requires $b_t^F = w_t h_t^F$. The loan carries an expected real lending rate $\bar{R}_t^b = \mathbb{E}_t[R_{t+1}^b]$, reflecting the nominal lending rate i_t^b adjusted for realized

[9]Throughout the paper, we distinguish between nominal interest rates i_{t-1}, which are set at $t-1$ and predetermined, and realized gross real returns R_t, which depend on period-t inflation and are known only at t. For instance, $R_t^d \equiv (1 + i_{t-1}^d)/(1 + \pi_t)$, where $\pi_t \equiv P_t/P_{t-1} - 1$. This convention applies to all financial assets in the model.

[10]We adopt this structure to endogenize the supply of Sol and Dollar deposits. Since the family's saving dynamics are not the central focus of our analysis, we simplify this margin to maintain tractability.

inflation. The firm's problem is:

$$\max_{h_t^F, b_t^F} \quad y_{t+1} - \bar{R}_t^b \, b_t^F \tag{11}$$

$$\text{s.t.} \quad b_t^F = w_t \, h_t^F \tag{12}$$

Revenue is realized in the subsequent period, at which point the firm repays principal and interest. The tradable good serves as the numeraire, with the world dollar price fixed at $P^* = 1$ under the small open economy assumption. The realized profit distributed to the household family is:

$$\Pi_t^F = y_t - R_t^b \, b_{t-1}^F \tag{13}$$

The Dollar-firm is entirely symmetric: it borrows $b_t^{F,*}$ at expected rate $\bar{R}_t^{b*}$, hires labor $h_t^{F,*}$ at wage w_t^*, and distributes profit $\Pi_t^{F,*} = y_t^* - R_t^{b*} \, b_{t-1}^{F,*}$.

Foreign Investors. Foreign investors serve as the marginal source of external dollar funding for the domestic economy. They have access to a safe international asset paying the exogenous world interest rate R^{if*}, but lending to domestic banks involves frictions—such as limited market participation or informational asymmetries—that generate an upward-sloping supply curve for funds. Specifically, the supply of foreign dollar lending $d_t^{f,*}$ to local banks, scaled by the local dollar deposit $d_t^{H,*}$, is:

$$\frac{d_t^{f,*}}{d_t^{H,*}} = \Theta^f \left(\bar{R}_t^{d*} - R^{if*} \right)^{\epsilon_f} + z_t^* \tag{14}$$

where $\bar{R}_t^{d*} = \mathbb{E}_t[R_{t+1}^{d*}]$ is the expected return offered by local banks, R^{if*} is the world risk-free rate, Θ^f governs the depth of the foreign dollar credit market, ϵ_f captures the elasticity of supply, and z_t^* denotes an exogenous capital flow shock (e.g., a sudden stop or surge). The ratio form aligns with our empirical specification (Section 5.1), so that Θ^f and z_t^* are dimensionless. This specification embodies the slow-moving capital friction: local banks must pay a premium over the world rate to attract additional foreign capital, and the imperfect elasticity pins down the equilibrium net foreign asset position.

Local Banks. The banking sector consists of a continuum of banks owned by the household family, which maximize expected per-period profits under the household's stochastic discount factor Λ_{t+1}.[11] In addition to deposits, banks issue preferred equity

[11]Since banks are owned by the household family, they inherit the household's pricing kernel. We do not model dynamic equity accumulation, as financial frictions on bank net worth are not central to our analysis. This keeps the bank's problem static and the model tractable.

n_t^B to the household family, which carries a guaranteed dividend $\bar{R}_t^n$ and is subject to an adjustment cost $\Gamma(n_t^B)$ borne by the bank. The decision process within each period is divided into two sub-stages. In the *portfolio stage*, banks choose their balance sheet composition—reserves, loans, deposits, equity, and forward positions—before uncertainty is resolved. In the *balancing stage*, idiosyncratic withdrawal shocks are realized and banks settle payment imbalances through an interbank market with search frictions.

Portfolio Stage. In the portfolio stage, banks determine their balance sheet composition before liquidity shocks are realized. They choose liquid reserves $(m_t^B, m_t^{B,*})$, supply loans to firms $(b_t^B, b_t^{B,*})$, and accept deposits from households and foreign investors $(d_t^B, d_t^{B,*})$. Note that $d_t^{B,*} = d_t^{H,*} + d_t^{f,*}$, so banks fund their dollar liabilities from both households and foreign investors. The balance sheet identity requires:

$$m_t^B + b_t^B + m_t^{B,*} + b_t^{B,*} = d_t^B + d_t^{B,*} + n_t^B. \tag{15}$$

Banks face regulatory reserve requirements parameterized by q and q^*, which mandate that liquid reserves relative to deposits exceed a threshold: $m_t^B / d_t^B \geq q$ and $m_t^{B,*} / d_t^{B,*} \geq q^*$.[12] For a given bank j in the continuum, the surplus reserve position is:

$$s_{t,j}^B = m_{t,j}^B - q\, d_{t,j}^B \geq 0, \quad s_{t,j}^{B,*} = m_{t,j}^{B,*} - q^*\, d_{t,j}^{B,*} \geq 0. \tag{16}$$

Beyond regulatory compliance, banks hold excess reserves to insure against idiosyncratic withdrawal shocks realized in the balancing stage.

Balancing Stage: Withdrawal Shocks. After banks make portfolio choices, each bank j receives a mean-zero idiosyncratic withdrawal shock—$\omega_{t,j}$ for Sol deposits and $\omega_{t,j}^*$ for Dollar deposits—which redistributes deposits across banks while preserving the aggregate stock. We allow the variance of these shocks, σ_t and σ_t^*, to be time-varying, serving as key drivers of equilibrium exchange rate volatility. While σ_t and σ_t^* are known to banks at the portfolio stage, the realizations $\omega_{t,j}, \omega_{t,j}^*$ are revealed only at the balancing stage. Let $\phi(\cdot)$ and $\Phi(\cdot)$ denote the PDF and CDF of ω.

A negative realization ($\omega_{t,j} < 0$) represents a net withdrawal, a positive one ($\omega_{t,j} > 0$) a net inflow. Since the shock affects both liquid assets and deposit liabilities, the

[12] The BCRP applies separate reserve requirement ratios for each currency, often imposing stricter requirements on external dollar liabilities.

bank's realized surplus after the shock is:

$$\tilde{s}^B_{t,j} = m^B_{t,j} - q\, d^B_{t,j} + \omega_{t,j}\, d^B_{t,j}(1-q) \tag{17}$$

and symmetrically for Dollars:

$$\tilde{s}^{B,*}_{t,j} = m^{B,*}_{t,j} - q^* d^{B,*}_{t,j} + \omega^*_{t,j} d^{B,*}_{t,j}(1-q^*), \tag{18}$$

where $d^{B,*}_{t,j}$ includes both local dollar deposits $d^{H,*}_{t,j}$ and bank-j's external dollar funding $d^{f,*}_{t,j}$: both liability classes are subject to withdrawal risk and contribute to the dollar reserve requirement.[13] A bank falls into deficit when $\tilde{s}^B_{t,j} < 0$, which occurs if $\omega_{t,j} < -\frac{(m^B_{t,j} - q\, d^B_{t,j})}{[(1-q)\, d^B_{t,j}]}$, and analogously for the Dollar segment.

Balancing Stage: Interbank Market. We model the interbank market as an over-the-counter (OTC) market with search and matching frictions. This is a natural choice given that the interbank market is a credit market in which surplus and deficit banks must locate a willing counterparty (see Ashcraft and Duffie 2007; Afonso and Lagos 2015). Our specific formulation follows Bianchi and Bigio (2022) and Bianchi and Bigio (2025), which integrate elements from Atkeson, Eisfeldt and Weill (2015) and Afonso and Lagos (2015). Since the Sol and Dollar interbank markets operate symmetrically, we describe only the Sol market.

After the realization of shocks, surplus banks ($\tilde{s}^B_{t,j} > 0$) and deficit banks ($\tilde{s}^B_{t,j} < 0$) seek counterparties. The matching efficiency λ and lender bargaining power η determine the terms of trade; only a fraction of the aggregate surplus and deficit is successfully matched. Surplus banks lend a fraction Ψ^+ of their excess reserves in the interbank market at rate i^f_t, with the unmatched remainder earning the central bank reserve rate i^m_t. Deficit banks cover a fraction Ψ^- of their shortfall by borrowing at i^f_t, while any unmatched deficit is financed at the central bank's discount window at penalty rate i^w_t (or, for Dollars, via a foreign credit line at i^{w*}_t).

The matching probabilities Ψ^+ and Ψ^- depend on aggregate market tightness:

$$\theta_t = S^-_t / S^+_t, \tag{19}$$

where $S^+_t = \int_0^1 \max\{\tilde{s}^B_{t,j}, 0\}\, dj$ and $S^-_t = -\int_0^1 \min\{\tilde{s}^B_{t,j}, 0\}\, dj$ are the aggregate surplus and deficit, which depend on σ_t and the aggregate liquidity ratio m^B_t / d^B_t. We adopt a Cobb-Douglas matching function, in contrast to the Leontief specification used in

[13] Treating $d^{f,*}$ on equal footing with $d^{H,*}$ inside the dollar liquidity function reflects the fact that foreign creditors can pull funding in stress episodes and that the BCRP's dollar reserve requirement applies to bank dollar liabilities aggregated across funding sources.

Bianchi and Bigio (2022) and Bianchi, Bigio and Engel (2024); this allows the matching probabilities to vary smoothly with market tightness, providing a more flexible mapping between liquidity conditions and interbank rates. The equilibrium interbank rate i_t^f is pinned down by Nash bargaining between matched banks.

Given such structure, we summarize the realized payoff in the balancing stage for a given bank j through the *liquidity function* $\mathcal{L}$:

$$\mathcal{L}\left(\frac{m_{t,j}^B}{d_{t,j}^B}, \omega_{t,j}; \theta_t\right) = \begin{cases} \chi^+(\theta_t)\, \tilde{s}_{t,j}^B & \text{if } \tilde{s}_{t,j}^B \geq 0, \\ \chi^-(\theta_t)\, \tilde{s}_{t,j}^B & \text{if } \tilde{s}_{t,j}^B < 0, \end{cases} \tag{20}$$

where $m_{t,j}^B/d_{t,j}^B$ is bank j's portfolio choice, $\omega_{t,j}$ is the realized withdrawal shock, and θ_t is the aggregate market tightness. The marginal values of surplus and deficit are:

$$\chi^+(\theta_t) = \Psi^+(\theta_t)\left[i_t^f - i_t^m\right], \tag{21}$$

$$\chi^-(\theta_t) = \Psi^-(\theta_t)\left[i_t^f - i_t^m\right] + \left(1 - \Psi^-(\theta_t)\right)\left[i_t^w - i_t^m\right]. \tag{22}$$

The χ coefficients are defined in nominal terms (Sol or Dollar interest rates), which makes $\mathcal{L}$ a nominal liquidity payoff at $t+1$ in the corresponding currency. We convert $\mathcal{L}$ to real terms wherever needed by dividing by the relevant inflation factor. This function encapsulates the entirety of the settlement friction faced by banks: the kink at $\tilde{s}_{t,j}^B = 0$ reflects the asymmetry between the benefit of lending surplus reserves and the cost of financing a deficit.

Crucially, banks make their portfolio decisions in the portfolio stage *before* the idiosyncratic withdrawal shock $\omega_{t,j}$ is realized, so they evaluate $\mathcal{L}$ in expectation over its distribution. We denote this expected liquidity payoff by

$$\bar{\mathcal{L}}_t\left(\frac{m_t^B}{d_t^B}; \sigma_t\right) \equiv \mathbb{E}_\omega\left[\mathcal{L}\left(\frac{m_t^B}{d_t^B}, \omega_t; \theta_t\right)\right], \tag{23}$$

and analogously $\bar{\mathcal{L}}_t^*(m_t^{B,*}/d_t^{B,*}; \sigma_t^*)$ for the Dollar segment. Only σ_t enters as an explicit argument because it parameterizes the distribution of ω; the equilibrium market tightness θ_t is taken as given by individual banks (a consequence of the law of large numbers across the continuum of banks with idiosyncratic shocks) and enters only through $\chi^\pm(\theta_t)$ inside $\mathcal{L}$. It is $\bar{\mathcal{L}}_t$ that disciplines banks' choice of the liquidity ratio $m_{t,j}^B/d_{t,j}^B$—holding more reserves reduces the probability of a costly deficit but comes at the opportunity cost of forgone lending income.

Since banks are ex-ante identical—heterogeneity arises only after the realization of the idiosyncratic withdrawal shocks—all banks make identical portfolio choices in the portfolio stage. Consequently, the individual bank's optimal liquidity ratio $m_{t,j}^B/d_{t,j}^B$

coincides with the aggregate ratio m_t^B/d_t^B, and similarly for the dollar segment. We therefore drop the j subscript in what follows and work directly with aggregate bank variables.

Forward Contracts. As documented in the empirical section, local banks act as market makers in the forward market, standing ready to transact at the equilibrium forward rate $\hat{e}_t$ with no bid-ask spread. We denote the bank's net forward position by f_t, where $f_t > 0$ represents a short dollar position (selling dollars forward) and $f_t < 0$ a long position. The real dollar payoff from this position is:

$$\frac{1}{1+\pi^*_{t+1}}\left(\frac{\hat{e}_t}{e_{t+1}} - 1\right) f_t. \tag{24}$$

Bank's Problems Taking the liquidity function as given, a bank chooses its portfolio to maximize expected per-period profits under the household's stochastic discount factor:

$$\begin{aligned}\max_{\substack{b_t^B, b_t^{B,*}, m_t^B, m_t^{B,*},\\ d_t^B, d_t^{B,*}, n_t^B, f_t}} \mathbb{E}_t \Big\{ \Lambda_{t+1} \big[& R^b_{t+1}\, b_t^B + R^{b*}_{t+1}\, b_t^{B,*} + R^m_{t+1}\, m_t^B + R^{m*}_{t+1}\, m_t^{B,*} - R^d_{t+1}\, d_t^B - R^{d*}_{t+1}\, d_t^{B,*} \\ & - R^n_{t+1}\, n_t^B - \Gamma(n_t^B) + \tfrac{1}{1+\pi^*_{t+1}}\left(\tfrac{\hat{e}_t}{e_{t+1}} - 1\right) f_t \\ & + \tfrac{1}{1+\pi_{t+1}}\, \bar{\mathcal{L}}_t\left(\tfrac{m_t^B}{d_t^B}; \sigma_t\right) + \tfrac{1}{1+\pi^*_{t+1}}\, \bar{\mathcal{L}}^*_t\left(\tfrac{m_t^{B,*}}{d_t^{B,*}}; \sigma^*_t\right) \big] \Big\}\end{aligned} \tag{25}$$

subject to:

$$m_t^B + m_t^{B,*} + b_t^B + b_t^{B,*} = d_t^B + d_t^{B,*} + n_t^B. \tag{26}$$

The Central Bank. The central bank sets the nominal interest rate on reserves (i_t^m) and the discount window rate (i_t^w), manages the nominal money supply (M_t), and intervenes in the foreign exchange market. We denote the central bank's dollar reserve holdings by $M_t^{CB,*}$ and its holdings of securitized loans purchased from local banks by B_t^{CB}. When the central bank purchases dollars from local banks, it issues domestic currency reserves in exchange, simultaneously increasing M_t and decreasing the stock of dollar reserves available to the banking sector. Similarly, when the central bank purchases securitized loans from local banks, it provides domestic currency liquidity in exchange for illiquid assets on banks' balance sheets.

The central bank's flow budget constraint in nominal terms is:

$$M_t + e_t(1+i^{m*}_{t-1})\,M^{CB,*}_{t-1} + (1+i^{w}_{t-1})\,W_{t-1} + (1+i^{b}_{t-1})\,B^{CB}_{t-1}$$
$$= (1+i^{m}_{t-1})\,M_{t-1} + e_t\,M^{CB,*}_t + W_t + B^{CB}_t + T_t \qquad (27)$$

On the left-hand side, the central bank receives funds from issuing new domestic reserves (M_t), earning the gross return on its existing dollar holdings ($e_t(1+i^{m*}_{t-1})\,M^{CB,*}_{t-1}$), collecting repayments on discount window loans ($(1+i^{w}_{t-1})\,W_{t-1}$), and receiving repayments on its loan portfolio ($(1+i^{b}_{t-1})\,B^{CB}_{t-1}$). On the right-hand side, it pays interest on the outstanding money stock ($(1+i^{m}_{t-1})\,M_{t-1}$), purchases new dollar reserves ($e_t\,M^{CB,*}_t$), extends new discount window loans (W_t), purchases new securitized loans (B^{CB}_t), and provides nominal transfers (T_t) to the household family.

FX intervention operates through this budget constraint: an increase in $M^{CB,*}_t$ absorbs dollars from the local dollar market, tightening dollar liquidity in the banking sector. When the intervention is *unsterilized*, the corresponding increase in M_t simultaneously eases domestic currency conditions. When it is *sterilized*, the central bank offsets the domestic money creation—for instance, by selling securitized loans from its portfolio—leaving M_t unchanged so that only the relative supply of dollar liquidity is affected.

Competitive Equilibrium. A competitive equilibrium consists of prices, interest rates, and allocations such that the household family, firms, foreign investors, and banks optimize given prices, the central bank's budget constraint is satisfied, and all markets—for goods, labor, loans, deposits, equity, reserves, and forward contracts—clear. The formal definition is standard and omitted for brevity.

3.1 Theoretical Characterization

Exchange Rate Determination. The exchange rate in our model is pinned down by the relative liquidity demand for each currency. From the law of one price and domestic money market clearing, we have:

$$e_t = \frac{P_t}{P^*_t} = \frac{M_t/m^B_t}{P^*_t}. \qquad (28)$$

Given the nominal supply of domestic reserves M_t, the real demand for reserves m^B_t—which emerges from banks' liquidity management in the presence of settlement frictions—determines the value of domestic money $1/P_t$, as in Bianchi, Bigio and Engel (2024). A key distinction from their global two-country framework is that our small open economy takes the dollar price of goods as given, normalizing $P^*_t = 1$. The dollar thus serves as the numéraire, and the exchange rate reduces to $e_t = M_t/m_t^B$. Although the dollar reserve demand $m_t^{B,*}$ does not appear explicitly in this expression, it plays a central role in determining the exchange rate: as we show in the next paragraph, the real demand for Sol reserves is linked to the real demand for dollar reserves through a liquidity-adjusted Uncovered Interest Parity (UIP) condition. Moreover, unlike the domestic currency—whose nominal supply is set by the central bank—dollar liquidity is constrained by an aggregate real funding condition, as will be characterized later. Banks' portfolio decisions thus jointly determine their desired holdings of both currencies, subject to this real dollar funding constraint, and a shift in dollar liquidity demand alters the demand for Sol reserves as well. The exchange rate e_t therefore reflects the relative value of liquidity services across both currencies.

Liquidity Premium and UIP. From the first-order conditions with respect to m_t^B and $m_t^{B,*}$ of the local banks, we derive the following real liquidity-adjusted Uncovered Interest Parity (UIP) condition:

$$\mathbb{E}_t\left[\Lambda_{t+1}\left(R^m_{t+1} + \frac{1}{1+\pi_{t+1}}\frac{\partial \bar{\mathcal{L}}_t}{\partial m_t^B}\right)\right] = \mathbb{E}_t\left[\Lambda_{t+1}\left(R^{m*}_{t+1} + \frac{1}{1+\pi^*_{t+1}}\frac{\partial \bar{\mathcal{L}}^*_t}{\partial m_t^{B,*}}\right)\right]. \tag{29}$$

We can go one step further. Under the assumptions that domestic reserves and dollar deposits at US banks are safe assets, and that idiosyncratic withdrawal shocks are orthogonal to aggregate shocks, we derive the following nominal liquidity-adjusted UIP condition:

$$\mathbb{E}_t\left[\frac{e_t}{e_{t+1}}\right](1+i_t^m) - (1+i_t^{m*}) = \underbrace{\frac{\partial \bar{\mathcal{L}}^*_t}{\partial m_t^{B,*}} - \mathbb{E}_t\left[\frac{e_t}{e_{t+1}}\right]\frac{\partial \bar{\mathcal{L}}_t}{\partial m_t^B}}_{\text{Relative Liquidity Premium}} - \underbrace{\zeta_t\left(1 + i_t^m + \frac{\partial \bar{\mathcal{L}}_t}{\partial m_t^B}\right)}_{\text{Currency Risk Premia}}, \tag{30}$$

where $\tilde{\Lambda}_{t+1} \equiv \Lambda_{t+1}/\mathbb{E}_t[\Lambda_{t+1}]$ is the normalized stochastic discount factor and $\zeta_t \equiv Cov_t(\tilde{\Lambda}_{t+1}, e_t/e_{t+1})$ captures the currency risk premium. This equation demonstrates that exchange rate dynamics in this small open economy are driven not only by interest rate differentials and standard currency risk premia but also by the *relative liquidity premia* associated with each currency.

This condition tightly links the real demand for domestic reserves to the real demand for dollar reserves, making the exchange rate a relative price of liquidity services across the two currencies. In particular, the relative liquidity premium depends on both the liquidity conditions in each interbank market (surplus versus deficit) and the regulatory environment. For instance, if the central bank raises the Sol reserve requirement (q) while lowering the Dollar requirement (q^*), the marginal value of Sol liquidity $\frac{\partial \bar{\mathcal{L}}_t}{\partial m_t^B}$ increases while $\frac{\partial \bar{\mathcal{L}}^*_t}{\partial m_t^{B,*}}$ decreases. This widens the relative liquidity premium, causing the Sol to appreciate through the rebalancing of banks' reserve portfolios. Similarly, time-varying volatility in withdrawal shocks (σ_t, σ_t^*) affects exchange rate dynamics through these liquidity functions by altering the probability of costly deficits in each currency.

External Dollar Funding Constraint. While the relative demand for reserves is determined by banks' UIP condition, banks cannot acquire dollar reserves without limit. The amount of real dollar liquidity available to local banks is constrained by external factors. By substituting the profit functions and market-clearing conditions into the household's budget constraint, we arrive at the following law of motion for the country's external dollar position:

$$
\begin{aligned}
\underbrace{m_t^{B,*} - d_t^{f,*}}_{\text{Private NFA}} = & \underbrace{\left(y_t + y_t^* - c_t - c_t^* - c_t^A\right)}_{\text{Trade Balance}} \\
& + \underbrace{\left(R_t^{m*} - 1\right) m_{t-1}^{B,*} + \left(R_t^{m*} - 1\right) m_{t-1}^{CB,*} - \mathcal{L}_t^{Agg,*} - \left(R_t^{d*} - 1\right) d_{t-1}^{f,*}}_{\text{Net Investment Income}} \\
& + \underbrace{m_{t-1}^{B,*} - d_{t-1}^{f,*}}_{\text{Lagged Private NFA}} \\
& - \underbrace{\left(m_t^{CB,*} - m_{t-1}^{CB,*}\right)}_{\text{FX Intervention}}
\end{aligned} \tag{31}
$$

where $\mathcal{L}_t^{Agg,*} = \frac{1}{1+\pi_t^*}\left(1 - \Psi^{-*}(\theta_{t-1}^*)\right)\left(i_{t-1}^{w*} - i_{t-1}^{m*}\right) S_{t-1}^{-*}$ is the aggregate dollar liquidity cost—the penalty paid at t by unmatched deficit banks (from the previous-period deficit S_{t-1}^{-*}) to foreign credit lines, representing a net dollar outflow from the domestic banking system. Note that the only foreign assets in this economy are dollar liquid assets held by local banks ($m_t^{B,*}$) and the central bank ($m_t^{CB,*}$), while the sole external liability is the dollar funding supplied by foreign investors ($d_t^{f,*}$).

From the banking sector's perspective—or equivalently, from the perspective of this small open economy, where banks are the sole intermediaries of dollar flows—the available supply of dollar liquidity is determined by the trade balance, net investment income, the previous NFA stock, and any additional borrowing from foreign investors ($d_t^{f,*}$). Crucially, when the central bank accumulates dollar reserves—that is, when $m_t^{CB,*} - m_{t-1}^{CB,*} > 0$—this directly reduces the pool of dollars available to local banks, tightening their liquidity constraint. Given the relative reserve demand implied by the UIP condition, this supply of real dollar reserves jointly determines the price of the dollar—and hence the exchange rate—in our model.

An interesting feature emerges from the *Net Investment Income* term, which includes the aggregate dollar liquidity cost $\mathcal{L}_t^{Agg,*}$. This implies that larger liquidity frictions tend to deteriorate the country's external dollar position. The equation reveals a fundamental asymmetry faced by non-US small open economies: unlike the Federal Reserve, the domestic central bank cannot create dollar liquidity or serve as a dollar lender of last resort to local banks. As a result, when local banks face dollar shortfalls that cannot be matched in the domestic interbank market, they must turn to foreign credit lines, generating the aggregate liquidity cost $\mathcal{L}_t^{Agg,*}$. This cost represents a net transfer of dollars to foreigners—a pure leakage from the country's external position that arises solely from the inability to provide domestic dollar liquidity services. This is the flip side of the "Exorbitant Privilege" enjoyed by reserve currency countries such as the United States (Gourinchas and Rey, 2007): the Federal Reserve's ability to serve as a dollar lender of last resort means that the corresponding liquidity rents remain within the US, while non-US economies that depend on external dollar funding must pay these rents to foreigners. Although not the central focus of our paper, this specification illustrates why countries with superior access to dollar liquidity sustain positive net external returns.

Additionally, the external funding constraint, combined with the bank liquidity frictions, provides a natural stabilizing force that prevents the model from diverging, offering an alternative mechanism to close the small open economy model with exogenous world returns, related to the approach in Schmitt-Grohé and Uribe (2003).

Efficacy of FX Interventions. Equation (31) provides a transparent framework for understanding when and why FX intervention is effective. Note that y_t, y_t^*, Net Investment Income, and the previous NFA stock are all predetermined.[14] When the central bank intervenes by accumulating dollar reserves ($m_t^{CB,*}$), the only contemporaneous margins of adjustment are aggregate consumption c_t^A and new foreign borrowing $d_t^{f,*}$.[15]

For FX intervention to have real effects, it must be the case that neither c_t^A nor $d_t^{f,*}$ adjusts freely enough to fully offset the change in $m_t^{CB,*}$. If c_t^A could adjust without friction, the household would immediately alter its import expenditure to acquire whatever dollars are needed to neutralize the intervention. If $d_t^{f,*}$ could adjust freely, local banks would simply borrow from foreign investors to replenish the dollars absorbed by the central bank, rendering the intervention ineffective.

The efficacy of FX intervention therefore depends on two key frictions: the curvature of the household's utility function—which governs the cost of deviating from

[14]Goods production takes one period, and Net Investment Income reflects the realization of previous-period decisions. Moreover, our small open economy assumption $P^* = 1$ implies that realized real returns are also predetermined.

[15]We assume that the deposit-in-advance constraints bind, so that c_t and c_t^* are predetermined.

consumption smoothing—and the degree of capital mobility. In the textbook case of perfectly mobile capital, foreign borrowing adjusts one-for-one with the intervention, and sterilized FX purchases have no effect on the exchange rate. However, as our empirical analysis demonstrates, this assumption is far from realistic. The slow-moving capital friction embedded in the foreign investor supply function, combined with the institutional frictions in the banking sector, activates the *portfolio balance channel* that the literature has long discussed (see, e.g., Fanelli and Straub, 2021). In this environment, even sterilized intervention can influence the exchange rate by altering the effective supply of dollar liquidity available to local banks.

Sterilized vs. Unsterilized FX Intervention. Our framework accommodates both sterilized and unsterilized interventions, and the distinction between them operates through the central bank's budget constraint and the resulting market-clearing conditions.

Consider first an *unsterilized* intervention in which the central bank purchases dollars from the domestic market, so that $\Delta M_t^{CB,*} \equiv M_t^{CB,*} - M_{t-1}^{CB,*} > 0$. This reduces the pool of real dollar reserves available to local banks. Given the slow-moving capital friction, foreign investors cannot fully replenish the absorbed dollars, leaving banks with a tighter dollar liquidity position. Moreover, because the intervention is unsterilized, the central bank finances the dollar purchase by issuing additional domestic reserves, expanding M_t. The domestic money market clearing condition becomes:

$$M_t + M_t^{CB,*} e_t = m_t^B P_t, \tag{32}$$

where $M_t^{CB,*} e_t$ is the domestic currency value of the dollar reserves purchased by the central bank. The unsterilized intervention therefore affects the exchange rate through two channels simultaneously: tightening dollar liquidity and loosening domestic currency liquidity.

Under a *sterilized* intervention, the central bank offsets the expansion of domestic reserves by selling loan securities from its portfolio, so that $\Delta B_t^{CB} \equiv B_t^{CB} - B_{t-1}^{CB} < 0$. This absorbs the additional domestic reserves injected during the dollar purchase. The loan market clearing condition is:

$$b_t^F = b_t^B + b_t^{CB}, \tag{33}$$

and because the sale of securities absorbs the newly created reserves, the domestic money market clearing condition remains unchanged:

$$M_t = m_t^B P_t. \tag{34}$$

The sterilized intervention therefore affects the exchange rate only through the dollar liquidity channel, leaving the domestic currency side of the balance sheet undisturbed.

4 Quantitative Analysis: Model Validation

Before conducting counterfactual analysis, we first validate the model by assessing its ability to rationalize the observed patterns in exchange rates and interest rates. The validation proceeds in three steps. We (i) calibrate the structural parameters of the interbank market and the liquidity-penalty rates to BCRP data; (ii) recover the latent withdrawal-shock volatilities σ_t and σ_t^* by matching the model's predicted interbank rates to their observed counterparts; and (iii) feed the filtered shocks into the model to make predictions for the lending and deposit rates, as well as for CIP deviations, and confront these predictions with the data—including a refinement that incorporates the BCRP's post-2014 forward-position regulation.

Calibration. The structural parameters of the interbank market—the matching technology and the liquidity-penalty rates—are calibrated as in Table 3.

Parameter	Sol	USD
Matching efficiency (λ)	2.0	1.0
Borrower's bargaining power (η)	0.50	0.50
Penalty spread ($i_t^w - i_t^m$)	$8.65\% + 5\%$	$8.65\% + 5\%$

Table 3: Calibrated Parameters

The interbank market follows a Cobb–Douglas matching technology, providing a smoother mapping between liquidity conditions and the interbank rate than the Leontief form used in Bianchi and Bigio (2022) and Bianchi, Bigio and Engel (2024). The matching efficiency λ is set higher for the Sol market than the Dollar market, reflecting the deeper domestic-currency interbank market in Peru. The bargaining power η and the shock distribution parameter p are both set symmetrically at 0.50. The liquidity penalty i_t^w is set 13.65 percentage points above the policy rate i_t^m for both currencies (in annualized terms), decomposed as a base discount-window penalty of 8.65 pp plus an additional stigma premium of 5.00 pp. The stigma premium captures more than just the direct cost of accessing emergency facilities (the discount window for Sol, foreign credit lines for Dollar): frequent recourse to these facilities signals balance-sheet weakness, which can damage a bank's reputation with counterparties and raise its future funding costs. The overall magnitude is consistent with the BCRP's discount-window cost and the spread on emergency dollar credit lines during stress periods, following Bianchi and Bigio (2022).

Filtering Exercise. Most model variables have direct empirical counterparts—bank balance sheets, reserve requirement ratios, and the policy rates i_t^m and i_t^{m*} are observed in the BCRP and Bloomberg data described in Section 2—but the volatility of the idiosyncratic withdrawal shock, σ_t for Sol and σ_t^* for Dollar, is unobservable. We recover the time series of these latent volatilities by exploiting the structural mapping between interbank rates and liquidity conditions implied by the model, taking the parameters in Table 3 as given.

The key identification insight is the following. Under Cobb–Douglas matching with Nash bargaining inside matched pairs, the equilibrium interbank rate is a convex combination of the policy rate and the penalty rate,

$$i_t^f \;=\; \bar{\eta}(\theta_t)\, i_t^w \;+\; \big(1-\bar{\eta}(\theta_t)\big)\, i_t^m, \tag{35}$$

where the equilibrium weight $\bar{\eta}(\theta_t) = \chi^+(\theta_t)/\big[\Psi^+(\theta_t)\,(i_t^w - i_t^m)\big]$ depends only on aggregate market tightness θ_t. The convex-combination form has a clear intuition. A surplus bank can let its reserves earn the policy rate i_t^m or lend in the interbank market, while a deficit bank can tap the emergency facility at the penalty rate i_t^w or borrow in the interbank market. Each side weighs the matching probability under the Cobb–Douglas matching technology and bargains over the gains from trade, so the equilibrium i_t^f falls between i_t^m and i_t^w, drifting toward i_t^w when the market is tight (deficits abundant) and toward i_t^m when liquidity is plentiful. The driver of tightness is the realized magnitude of withdrawal shocks: a larger σ_t pushes more banks into the deficit region, raising θ_t and pulling i_t^f closer to i_t^w. Formally, tightness is a deterministic, monotone function of the latent volatility together with the observed liquidity ratio and the reserve requirement,

$$\theta_t \;=\; \theta\big(\sigma_t;\, m_t^B/d_t^B,\, q_t\big). \tag{36}$$

Since every ingredient on the right of (35) other than σ_t is either observed in BCRP data or pinned down by Table 3, we invert (35) period-by-period—equivalently, solve $\bar{\eta}(\theta(\sigma_t;\cdot)) = (i_t^f - i_t^m)/(i_t^w - i_t^m)$—for the unique σ_t that equates the model-implied Sol interbank rate to its observed counterpart. An analogous procedure applied to the Dollar interbank rate recovers σ_t^*. This yields the full time series $\{\sigma_t, \sigma_t^*\}_{t=0}^T$ of time-varying withdrawal-shock volatilities, which serve as the primary exogenous drivers of liquidity premia in our framework.

Model-Implied Lending and Deposit Rates. A natural way to examine whether the filtered σ_t and σ_t^* are capturing meaningful liquidity shocks is to use them—together with the calibrated parameters—to construct model-implied predictions for bank rates that were *not* used in the filtering, and confront those predictions with the data. The natural targets are the lending and deposit rates. From the bank's first-order conditions with respect to b_t^B and d_t^B,

$$\bar{R}_t^b = \bar{R}_t^m + \mathbb{E}_t\left[\frac{e_t}{e_{t+1}}\right]\frac{\partial \bar{\mathcal{L}}_t}{\partial m_t^B}, \tag{37}$$

$$\bar{R}_t^d = \bar{R}_t^m + \mathbb{E}_t\left[\frac{e_t}{e_{t+1}}\right]\left(\frac{\partial \bar{\mathcal{L}}_t}{\partial m_t^B} + \frac{\partial \bar{\mathcal{L}}_t}{\partial d_t^B}\right), \tag{38}$$

and symmetrically for Dollar rates.[16] The lending rate exceeds the reserve rate by the marginal liquidity value of reserves, while the deposit rate additionally incorporates the marginal liquidity cost of accepting one more deposit. Substituting the filtered σ_t, σ_t^* and the observed liquidity ratios into these expressions yields a model-implied series for $\bar{R}_t^b$ and $\bar{R}_t^d$ (and their Dollar counterparts) that we can compare directly with bank-level data.

Sol Segment. Figure 11 presents the estimation results for the Sol segment. As expected, the top-left panel confirms that the model-implied interbank rate matches the data exactly, validating our inversion procedure. The filtered σ_t (top-right panel) exhibits a sharp spike during the 2008 Global Financial Crisis, consistent with anecdotal evidence of severe liquidity stress during this period. The bottom panels compare the model-predicted lending and deposit rates against the data: although the fit is not perfect, the model successfully captures the upward trend and key time-varying patterns of both the lending (i_t^b) and deposit (i_t^d) rates.[17] This suggests that the liquidity friction identified through the interbank market is a significant factor shaping broader bank pricing.

USD Segment. Figure 12 presents the estimation results for the USD segment. As in the Sol case, the top-left panel confirms that the model matches the interbank rate exactly. The recovered volatility σ_t^* (top-right panel) shows a sharp spike during the 2008 Global Financial Crisis (consistent with widespread dollar shortages) and additional spikes in 2011 and 2013, periods that coincide with large observed CIP deviations. Crucially, the bottom panels demonstrate that the model captures

[16] For this exercise, we assume random walk expectation, $\mathbb{E}_t\left[\frac{e_t}{e_{t+1}}\right] = 1$ for simplicity.

[17] One source of remaining slack, particularly in the late-sample widening of the deposit and bond spreads, is the gradual phase-in of the Liquidity Coverage Ratio (80% over 2014–2017, 90% in 2018, and 100% from January 2019). The final steps may have generated temporary money-market frictions unrelated to monetary policy and outside the scope of our framework, suggesting that the interbank market alone may not perfectly summarize all liquidity stress in the Sol segment.

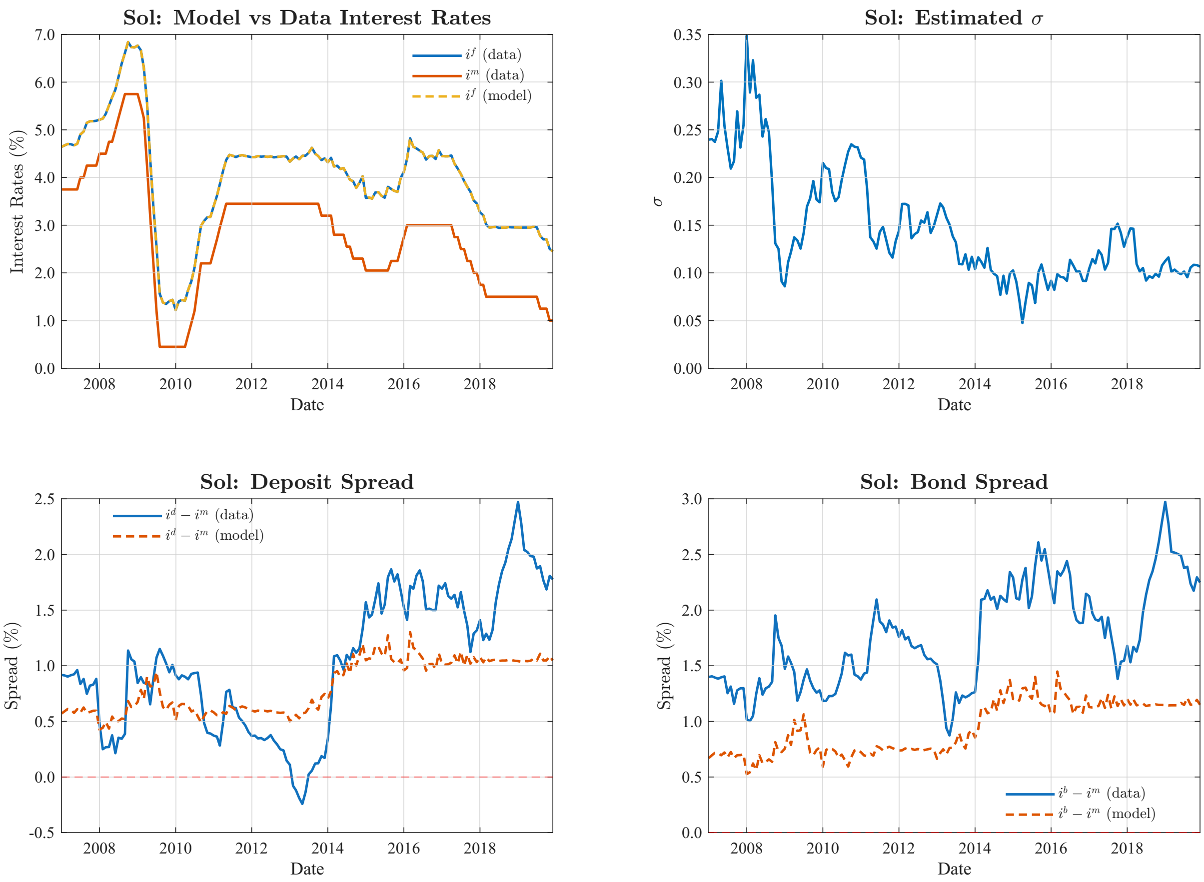

Figure 11: Filtered σ_t and Predicted i_t^f, i_t^d and i_t^b (Sol)

the dynamics of dollar deposit and loan rates with high precision, replicating nearly all local spikes. The fit is noticeably superior to the Sol case, suggesting that dollar liquidity frictions are a dominant driver of bank pricing behavior in the dollar segment. This asymmetry is intuitive: dollar liquidity is structurally scarce in this small open economy and lies outside the domestic central bank's direct control, so idiosyncratic funding shocks pass through more forcefully into dollar bank pricing than the analogous Sol shocks do into Sol pricing.

Model-Implied CIP Deviation. We now examine whether the calibrated model, fed with the filtered shocks $\{\sigma_t, \sigma_t^*\}$ recovered above, can generate CIP deviations consistent with the observed series. From the bank's first-order condition with respect to the forward position f_t, we have

$$\mathbb{E}_t\left[\Lambda_{t+1}\left(\frac{\hat{e}_t}{e_{t+1}} - 1\right)\right] = 0 \quad \Leftrightarrow \quad \mathbb{E}_t\left[\frac{e_t}{e_{t+1}}\right] = \frac{e_t}{\hat{e}_t} - \mathrm{Cov}_t\left(\tilde{\Lambda}_{t+1}, \frac{e_t}{e_{t+1}}\right). \tag{39}$$

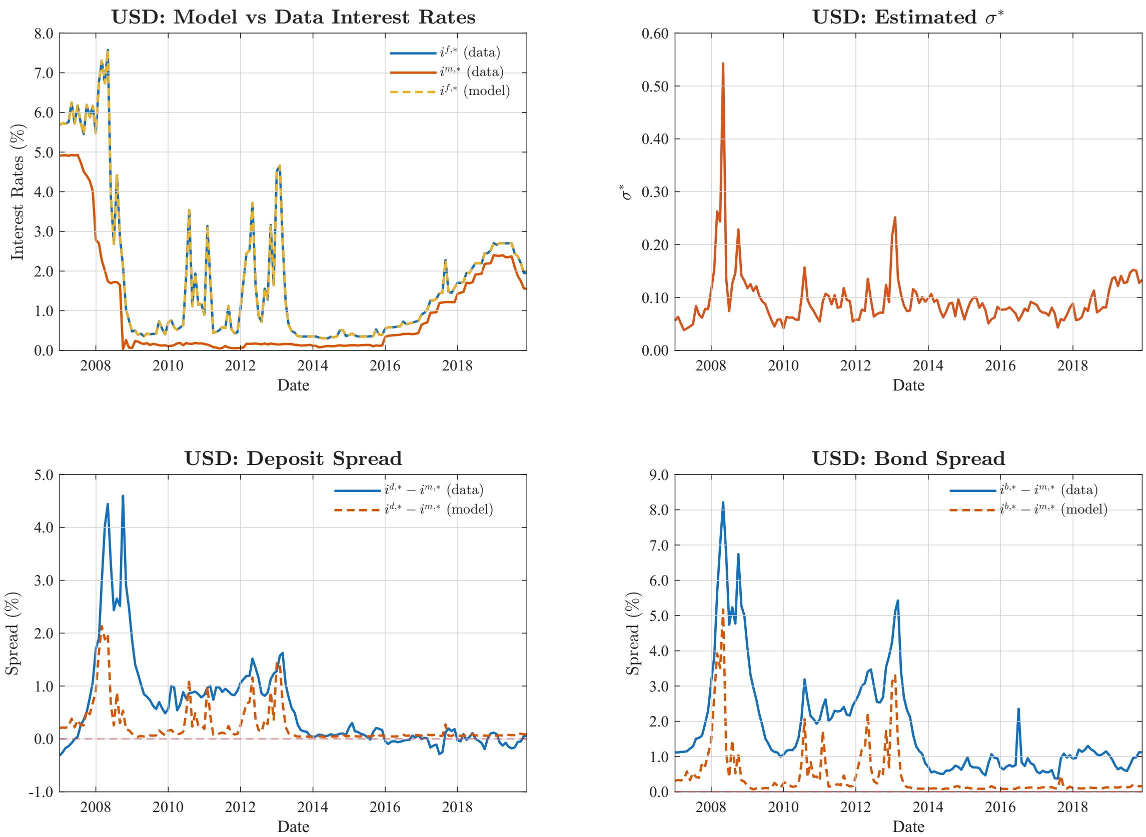

Figure 12: Filtered σ_t^* and Predicted i_t^{f*}, i_t^{d*} and i_t^{b*} (USD)

Combining this with the liquidity-adjusted UIP condition in equation (30) yields

$$\frac{\hat{e}_t}{e_t} = \frac{1 + i_t^m + \frac{\partial \bar{\mathcal{L}}_t}{\partial m_t^B}}{1 + i_t^{m*} + \frac{\partial \bar{\mathcal{L}}_t^*}{\partial m_t^{B,*}}}, \tag{40}$$

and substituting into the standard CIP definition gives

$$\mathcal{CIP}_t \equiv (1 + i_t^{m*}) \frac{\hat{e}_t}{e_t} - (1 + i_t^m) = (1 + i_t^{m*}) \underbrace{\left(\frac{1 + i_t^m + \frac{\partial \bar{\mathcal{L}}_t}{\partial m_t^B}}{1 + i_t^{m*} + \frac{\partial \bar{\mathcal{L}}_t^*}{\partial m_t^{B,*}}} \right)}_{\text{Relative Total Return}} - (1 + i_t^m). \tag{41}$$

The intuition is straightforward: exploiting CIP deviations is equivalent to executing a carry trade while hedging the currency risk with a forward contract. Because the forward rate equilibrates the total marginal returns across currencies, the currency risk premium cancels, and the CIP deviation reduces to the relative liquidity spread net of the interest-rate differential. CIP deviations are therefore driven primarily by the relative magnitudes of $\frac{\partial \bar{\mathcal{L}}_t}{\partial m_t^B}$ and $\frac{\partial \bar{\mathcal{L}}_t^*}{\partial m_t^{B,*}}$, which in turn respond to central bank policies such as reserve requirements and FX intervention.

Model Predictions on CIP Deviations. Substituting the filtered shocks $\{\sigma_t, \sigma_t^*\}$ into the marginal liquidity premia $\partial\bar{\mathcal{L}}_t/\partial m_t^B$ and $\partial\bar{\mathcal{L}}_t^*/\partial m_t^{B,*}$ in equation (41) produces a model-implied CIP deviation series that we compare directly against the data. Figure 13 presents the result. Remarkably, the model captures not only the relative magnitude of the spikes but also correctly predicts the structural reversal of the deviation—shifting from excess Sol returns to excess Dollar returns—around 2014. This predictive success validates the model's explanatory power and suggests that relative liquidity shocks are indeed the primary driver of CIP deviations in Peru. One limitation of the baseline specification, however, is that it underestimates the

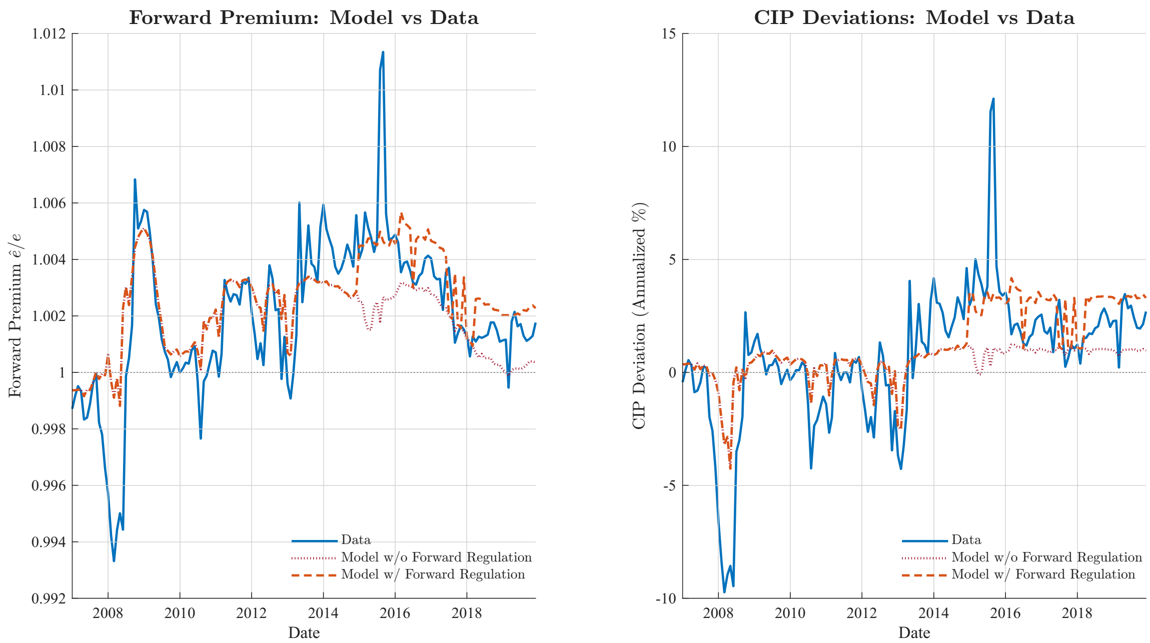

Figure 13: Model Prediction on Forward Premium and CIP Deviations

magnitude of the positive CIP deviations observed after 2014. We attribute this discrepancy to a specific BCRP policy that is not in the baseline model. We show below that with a simple modification—incorporating the BCRP's regulatory limits on local banks' forward positions—the model successfully replicates the post-2014 widening.

Forward Position Regulation. In the aftermath of the 2013 Taper Tantrum, expectations of a rapid dollar appreciation led foreign investors to buy dollar forwards in large volumes. Local banks, as the dominant market makers in this segment, were forced to take the opposite side and accumulated substantial gross short dollar forward positions, hedging them by buying dollars in the spot market and intensifying depreciation pressure on the Sol. In December 2014, the BCRP responded by introducing a punitive reserve requirement on excessive forward positions: if a bank's gross forward USD sell position exceeds a specified threshold, the bank must hold additional Sol reserves equivalent to twice the value of the excess dollar amount. Figure 14 shows the magnitude of these over-limit forward positions relative to total Sol liabilities. At its peak, this ratio reached 0.7%, implying an effective increase in the average Sol reserve requirement of 1.4%.

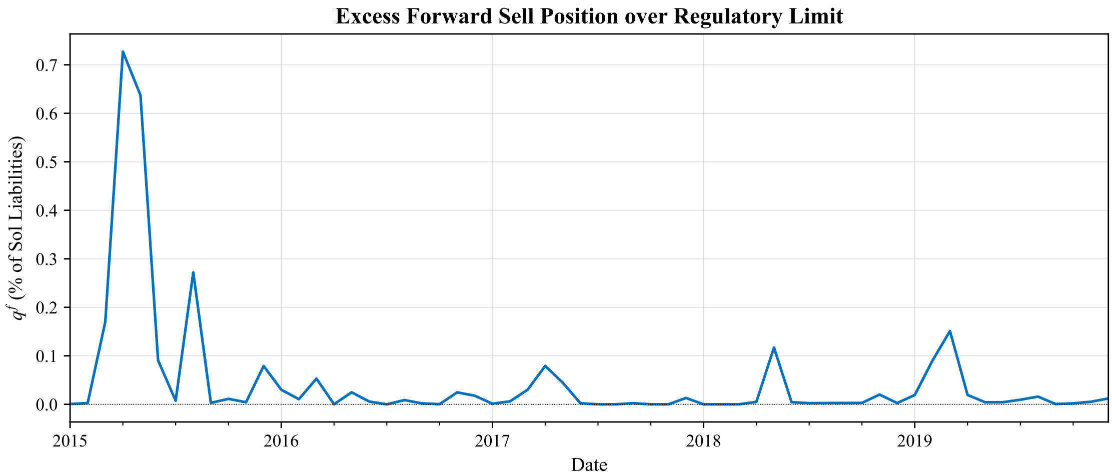

Figure 14: Excess Dollar Forward Sell Position of Local Banks

Extended Model with Forward Regulation. To capture this institutional detail, we extend the model to incorporate the regulatory cost. We model the regulation as a penalty on the bank's Sol liquidity position. When a bank holds a forward position f_t that exceeds the regulatory threshold $\bar{f}_t$, it faces an additional reserve requirement scaled by a factor of two. The bank's *ex-ante* Sol surplus, previously $s_j = m_j - q\, d_j$, becomes

$$s_j = m_j - (q + q_{f,j})\, d_j, \qquad q_{f,j} = \frac{2\,|f_j - \bar{f}_j|}{d_j}, \tag{42}$$

where the term $2\,|f_j - \bar{f}_j|$ represents the punitive Sol reserve surcharge that the central bank imposes on the bank's over-limit forward position. Consequently, the realized Sol surplus after the withdrawal shock is

$$\tilde{s}_j = (m_j + \omega_j d_j) - q\, d_j(1 + \omega_j) - 2\,|f_j - \bar{f}_j|. \tag{43}$$

Holding large forward positions therefore directly increases the bank's domestic-currency reserve requirement and raises the probability of incurring a costly deficit. Since f_t now enters the Sol surplus, the expected liquidity function $\bar{\mathcal{L}}_t$ depends on f_t as well; abusing notation slightly, we write $\bar{\mathcal{L}}_t(m_t^B/d_t^B,\, f_t/d_t^B;\, \sigma_t,\, \bar{f}_t)$.

The bank's first-order condition with respect to the forward position f_t is modified accordingly:

$$\mathbb{E}_t\left[\Lambda_{t+1}\left(\frac{\hat{e}_t}{e_{t+1}}-1\right)\right]+\mathbb{E}_t\left[\Lambda_{t+1}\,\frac{e_t}{e_{t+1}}\right]\frac{\partial\bar{\mathcal{L}}_t}{\partial f_t}=0, \tag{44}$$

where the regulation implies $\partial\bar{\mathcal{L}}_t/\partial f_t = -2\,(\partial\bar{\mathcal{L}}_t/\partial m_t^B)\,\mathbf{1}\{f_t > \bar{f}_t\}$, a result that follows directly from the surplus specification. This in turn alters the equilibrium CIP condition: the forward rate must now compensate not only for the relative liquidity of the two currencies but also for the regulatory cost. Combining the modified forward FOC with the liquidity-adjusted UIP condition gives

$$\mathcal{CIP}_t \;=\; (1+i_t^{m*})\left[\underbrace{\frac{1+i_t^m+\frac{\partial\bar{\mathcal{L}}_t}{\partial m_t^B}}{1+i_t^{m*}+\frac{\partial\bar{\mathcal{L}}_t^*}{\partial m_t^{B,*}}}}_{\text{Relative Liquidity}}-\underbrace{\frac{\partial\bar{\mathcal{L}}_t}{\partial f_t}}_{\text{Forward Regulatory Cost}}\right]-(1+i_t^m). \tag{45}$$

Discussion. Equation (45) illustrates the core mechanism: the forward-position regulation acts as a wedge that widens the CIP deviation. Even if the relative liquidity conditions of Sol and Dollar reserves remain constant, the penalty on forward holdings forces banks to charge a higher forward premium to cover the regulatory cost. This additional premium sustains the larger CIP deviations observed in the post-2014 period. The red line in Figure 13 confirms that, with this mechanism incorporated, the model successfully generates the strong positive CIP deviation seen after 2014. The result underscores how quantity-based regulations can significantly shape exchange-rate dynamics through the banking sector's liquidity channel—a theme we develop further in the counterfactual analysis below.

5 Counterfactual Analysis

Having validated the model, we now use it to evaluate counterfactual policy scenarios. In the previous literature, counterfactual analyses of FX intervention and macroprudential policy operate at a high level of abstraction, which yields clean qualitative insights but leaves the data–model connection loose. Our counterfactual exercises depart from this tradition by feeding the actual monthly realizations of all policy variables and bank balance-sheet data directly into the model's equilibrium system. We provide a framework in which researchers can evaluate counterfactuals for three quantity-based instruments: sterilized FX intervention ($m_t^{CB,*}$), the dollar reserve requirement (q_t^*), and the forward-position-motivated Sol reserve surcharge (q_t^f). The main text focuses on sterilized FX intervention—the BCRP's most actively used instrument.[18] We view this exercise as a prototype of a quantitative policy toolkit that an SOE central bank can deploy in real time—structural enough to incorporate the microfoundations of dual-currency balance-sheet management, yet sufficiently disciplined by data to deliver magnitudes a policymaker can act on.

5.1 Counterfactual Framework

Assumptions. Our counterfactual analysis focuses on the liquidity channel in the banking sector at a monthly horizon. We hold fixed all non-liquidity factors—real domestic deposit and loan balances, external variables such as the trade balance and the net international investment position, monetary policy rates, the global risk-free rate, exchange rate expectations, and the currency risk premium—at their historical values.[19] What we allow to adjust in response to policy perturbations are domestic banks' portfolio allocations—their reserve holdings in both currencies and equity—and external dollar funding, which is slow-moving with finite elasticity estimated from the data. As a result, the exchange rate and deviations from interest rate parity conditions change across counterfactual scenarios. In effect, the exercise isolates how quantity-based policies can move the exchange rate through the banking sector's liquidity channel at short horizons.

Equilibrium System. Under these assumptions, equilibrium reduces to a system of five equations in five unknowns (m_t^B, $m_t^{B,*}$, $d_t^{f,*}$, e_t, n_t^B), with three policy variables: $\Delta m_t^{CB,*}$ (FX intervention), q_t^* (dollar reserve requirement), and q_t^f (forward-position surcharge). Variables with $\widehat{\cdot}$ are held fixed at their historical values:

$$m_t^B + m_t^{B,*} + \widehat{b}_t^B + \widehat{b}_t^{B,*} = \widehat{d}_t^B + \widehat{d}_t^{H,*} + d_t^{f,*} + n_t^B, \tag{46}$$

$$(\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t)\left(1 + \widehat{i}_t^m + \frac{\partial \bar{\mathcal{L}}_t(m_t^B, q_t^f)}{\partial m_t^B}\right) = (1 + \widehat{i}_t^{m*}) + \frac{\partial \bar{\mathcal{L}}_t^*(m_t^{B,*}, d_t^{f,*}, q_t^*)}{\partial m_t^{B,*}}, \tag{47}$$

$$\widehat{M}_t = m_t^B e_t, \tag{48}$$

$$m_t^{B,*} - d_t^{f,*} = \widehat{NX}_t + \widehat{NII}_t + \widehat{NFA}_{t-1} - \Delta m_t^{CB,*}, \tag{49}$$

$$\frac{d_t^{f,*}}{\widehat{d}_t^{H,*}} = \Theta^f \left(\widehat{R}_t^{m*} + \frac{\partial \bar{\mathcal{L}}_t^*(m_t^{B,*}, d_t^{f,*}, q_t^*)}{\partial m_t^{B,*}} + \frac{\partial \bar{\mathcal{L}}_t^*(m_t^{B,*}, d_t^{f,*}, q_t^*)}{\partial d_t^{f,*}} + \widehat{EDP}_t - \widehat{R}_t^{if*}\right)^{\epsilon_f} + \widehat{z}_t^*. \tag{50}$$

[20]

[18] We offer counterfactuals on q_t^* and q_t^f in Appendix C.

[19] Examining the full dynamic interaction of quantity-based policies with household consumption, the trade balance, and changes in the net foreign asset position over longer horizons is an important direction for future research. A fully general equilibrium approach in which all of these objects are endogenous would be a natural next step. Here, we isolate the pure liquidity component of policy transmission, which we believe is of independent interest.

The Sol liquidity function $\bar{\mathcal{L}}_t$ also depends on the regular Sol reserve requirement $\widehat{q}_t$, the local Sol deposit base $\widehat{d}_t^B$, and the Sol withdrawal shock, while the dollar liquidity function $\bar{\mathcal{L}}_t^*$ also depends on the local dollar deposit base $\widehat{d}_t^{H,*}$ and the dollar withdrawal shock; we suppress these as explicit arguments because they are fixed at their historical values across all counterfactual scenarios.[21]

Calibration. The hatted variables in the system above are pinned down as follows. The balance-sheet variables $\widehat{b}_t^B, \widehat{b}_t^{B,*}, \widehat{d}_t^B, \widehat{d}_t^{H,*}$ in (46) are taken directly from the consolidated balance sheet of the Peruvian banking sector reported by the BCRP. Exchange rate expectations $\mathbb{E}_t[e_t/e_{t+1}]$ in (47) are extracted from a Kalman filter applied to the exchange rates of five South American countries, under the assumption that country-specific idiosyncratic movements are unpredictable but there is information in the common regional component driven by global shocks.[22] Given expectations and all other observables—the policy rates $\widehat{i}_t^m$ and $\widehat{i}_t^{m*}$, the reserve requirements $\widehat{q}_t$, q_t^*, q_t^f, the filtered shock volatilities $\widehat{\sigma}_t$ and $\widehat{\sigma}_t^*$ from the previous section, and the liquidity ratios—at their historical values, we back out $\widehat{\xi}_t$ as the residual that makes the liquidity-adjusted UIP condition hold exactly at each date. The remaining hatted variables—$\widehat{M}_t$, $\widehat{NX}_t$, $\widehat{NII}_t$, $\widehat{NFA}_{t-1}$—in (48) and (49) are reconstructed as functions of bank balance-sheet variables via the equilibrium conditions and calculated using observed data. For (50), the external funding equation was originally specified as $\frac{d_t^{f,*}}{\widehat{d}_t^{H,*}} = \Theta^f(\bar{R}_t^{d*} - \widehat{R}_t^{if*})^{\epsilon_f} + \widehat{z}_t^*$. We endogenize $\bar{R}_t^{d*}$ using the bank's first-order condition, $\bar{R}_t^{d*} = \bar{R}_t^{m*} + \frac{\partial \bar{\mathcal{L}}_t^*}{\partial m_t^{B,*}} + \frac{\partial \bar{\mathcal{L}}_t^*}{\partial d_t^{f,*}}$, so that external funding responds to changes in liquidity conditions and central bank policies.[23] In practice, the observed deposit rate may contain a component not captured by the liquidity friction alone. We therefore introduce an exogenous deposit premium $\widehat{EDP}_t$ and recover it as the residual: $\widehat{EDP}_t = i_t^{d*} - i_t^{m*} - \frac{\partial \bar{\mathcal{L}}_t^*}{\partial m_t^{B,*}} - \frac{\partial \bar{\mathcal{L}}_t^*}{\partial d_t^{f,*}}$.[24] This premium is held fixed across counterfactual scenarios. A detailed description of each step is provided in the Appendix.

[21]Note that for dollar deposit liabilities of banks, we decompose them into domestic one and external one, $d^{B,*} = d^{H,*} + d^{f,*}$, and set domestic one fixed while setting external one as a major driver in short-term.

[22]Given the strong common trends in exchange rates of five South American countries over our sample, this approach disciplines the expectation term. In practice, the monthly variation in $\mathbb{E}_t[e_t/e_{t+1}]$ is modest, and because the currency risk premium $\widehat{\xi}_t$ absorbs the residual, the counterfactual results are not sensitive to this choice.

[23]Since the dollar liquidity function depends on the total deposit base $d_t^{B,*} = \widehat{d}_t^{H,*} + d_t^{f,*}$ and $\widehat{d}_t^{H,*}$ is fixed, $\partial \bar{\mathcal{L}}_t^* / \partial d_t^{f,*} = \partial \bar{\mathcal{L}}_t^* / \partial d_t^{B,*}$.

[24]Since the model uses the tradable good and the dollar as numéraire, using nominal rates from the data is not problematic. $d_t^{f,*}/\widehat{d}_t^{H,*}$ depends on the real spread between two dollar interest rates, which equals the corresponding nominal spread as the dollar inflation rate cancels out.

External Dollar Funding. The remaining objects to be calibrated are Θ^f, ϵ_f, and $\widehat{z}_t^*$ in (50). These are central to the entire counterfactual exercise: if foreign investors could supply dollars to local banks with infinite elasticity, any policy-induced tightening of dollar liquidity would be immediately offset by additional external borrowing, rendering the liquidity channel irrelevant. The effectiveness of all three policy instruments therefore hinges on how slowly external capital moves in practice. To estimate these objects, we run the following regression:

$$\ln\left(\frac{d_t^{f,*}}{d_t^{H,*}}\right) = \alpha + \beta_1 \ln(i_t^{d*} - i_t^{if*}) + \beta_2 \ln(\text{VIX}_t) + \beta_3 \ln(\text{Peru Sov. Spread}_t) + \beta_4 \mathbf{1}\{t \geq 2014\} \times \ln(i_t^{d*} - i_t^{if*}) + u_t. \quad (51)$$

We include a post-2014 interaction with the spread to capture the change in external funding elasticity associated with BCRP regulations and the Basel III accord. The corresponding level dummy is statistically indistinguishable from zero in our sample and is therefore omitted for parsimony. For the dependent variable, we use the ratio of external dollar liabilities to total domestic dollar liabilities of the aggregate banking sector. For the spread, we use the average three-month dollar deposit rate charged by Peruvian banks as i_t^{d*} and the three-month US T-bill rate as i_t^{if*}. We control for global supply factors to isolate the elasticity of interest. The estimation results are reported in Table 4.

Table 4: External Dollar Supply Elasticity

	Coefficient
Constant	2.147
	(3.690)
$\ln(i_t^{d*} - i_t^{if*})$	**1.347*****
	(0.500)
$\ln(\text{VIX}_t)$	-0.495
	(0.431)
$\ln(\text{Peru Sov. Spread}_t)$	-0.193
	(0.428)
Post-2014 × Spread	-0.372**
	(0.159)
R-squared Adj.	0.432
N	161

HAC standard errors with 12 lags. Standard errors in parentheses. Sample period: 2006-08–2019-12. ***, **, * denote significance at 1%, 5%, 10%.

The results are consistent with the slow-moving capital friction: as the domestic dollar deposit rate rises relative to the global funding rate, external capital flows into the Peruvian banking sector, while higher global risk (VIX) and sovereign spreads reduce the supply of foreign funding. The estimated pre-2014 elasticity is $\hat{\epsilon}_f = 1.347$, falling to 0.975 after 2014, indicating that post-crisis regulations reduced the responsiveness of external dollar funding to interest rate differentials. The regression maps into the structural parameters as follows: $\Theta^f = e^{\hat{\alpha}}$ is held constant across the sample, while $\epsilon_f = \hat{\beta}_1$ shifts after 2014 via the slope interaction $\hat{\beta}_4$. We recover $\widehat{z}_t^*$ as the sum of the regression residual and the fitted contributions from VIX and the sovereign spread, which we treat as exogenous supply shifters in the counterfactual.

Implementation. By construction, when we feed all hatted variables at their historical values and set the policy instruments to their historical realizations, the system of five equations reproduces the actual historical exchange rates, bank liquidity ratios, and external funding positions exactly. In the counterfactual experiments that follow, we hold all calibrated objects fixed and perturb only the policy variables—$\Delta m_t^{CB,*}$, q_t^*, or q_t^f—away from their historical values. We then solve the system for the counterfactual paths of the exchange rate e_t, the liquidity ratios $m_t^B/\widehat{d}_t^B$ and $m_t^{B,*}/(\widehat{d}_t^{H,*} + d_t^{f,*})$, and the external dollar funding ratio $d_t^{f,*}/\widehat{d}_t^{H,*}$, tracing out how each policy instrument affects these outcomes through the banking sector's liquidity channel.

5.2 Counterfactual Experiments: No FX Intervention

We now use the calibrated framework to evaluate the BCRP's most actively used quantity-based instrument: sterilized FX intervention. Peru is widely recognized for achieving substantially lower exchange rate volatility than its South American peers, a feat attributed to its active use of quantity-based instruments. Our counterfactual exercise asks: how much of this stability is attributable to FX intervention? We answer this by setting $\Delta m_t^{CB,*} = 0$ throughout the sample—i.e., asking what would have happened had the BCRP conducted no FX intervention at all. As documented in Figure 4, the BCRP's FX intervention has been almost entirely sterilized, so removing the intervention does not alter the nominal money supply $\widehat{M}_t$. We trace out the counterfactual paths of the exchange rate, banking-sector portfolio allocations, and external dollar funding under this no-intervention scenario, and compare the resulting exchange rate volatility to the historical benchmark and to regional peers.

Before turning to the quantitative results, we characterize analytically how sterilized intervention affects the exchange rate through the five-equation system.

Proposition 1 (Effectiveness of Sterilized FX Intervention)**.** *Consider a sterilized intervention $d\delta \equiv d(\Delta m_t^{CB,*}) > 0$, holding $\widehat{M}_t$ and all other hatted variables fixed. The exchange* *rate response is*

$$\frac{de_t}{d\delta} = \frac{\alpha_{L,t}}{1 + \alpha_{F,t}} > 0, \tag{52}$$

*where the **relative liquidity channel** and the **external funding channel** are*

$$\alpha_{L,t} \equiv \frac{e_t}{m_t^B}\left(\phi_t + \frac{\phi_{f,t}\,\psi_t}{1-\rho_t}\right), \qquad \alpha_{F,t} \equiv -\frac{\psi_t}{1-\rho_t}, \tag{53}$$

defined in terms of the primitive coefficients

$$\phi_t \equiv \frac{\bar{\mathcal{L}}^*_{m^*m^*}}{\left(\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t\right)\bar{\mathcal{L}}_{mm}} > 0, \qquad \phi_{f,t} \equiv \frac{\bar{\mathcal{L}}^*_{m^*d^*}}{\left(\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t\right)\bar{\mathcal{L}}_{mm}} < 0, \tag{54}$$

$$\psi_t \equiv \widehat{d}_t^{H,*}\,\Theta^f \epsilon_f \left(\bar{R}_t^{d*} - \widehat{R}_t^{if*}\right)^{\epsilon_f - 1}\left(\bar{\mathcal{L}}^*_{m^*m^*} + \bar{\mathcal{L}}^*_{m^*d^*}\right), \tag{55}$$

$$\rho_t \equiv \widehat{d}_t^{H,*}\,\Theta^f \epsilon_f \left(\bar{R}_t^{d*} - \widehat{R}_t^{if*}\right)^{\epsilon_f - 1}\left(\bar{\mathcal{L}}^*_{m^*d^*} + \bar{\mathcal{L}}^*_{d^*d^*}\right). \tag{56}$$

[25] *In the limiting cases:*

1. *No external funding response ($\epsilon_f = 0$): $\psi_t = \rho_t = 0$, so $\alpha_{F,t} = 0$ and $de_t/d\delta = (e_t/m_t^B)\,\phi_t$. The full liquidity channel operates.*
2. *No liquidity friction ($\bar{\mathcal{L}} = \bar{\mathcal{L}}^* = 0$): $\phi_t = \phi_{f,t} = 0$, so $\alpha_{L,t} = 0$ and $de_t/d\delta = 0$. Standard irrelevance result.*

Proof. The proof is provided in Appendix D.1. □

The proposition shows that the effectiveness of sterilized intervention depends on two factors, $\alpha_{L,t}$ and $\alpha_{F,t}$. The $\alpha_{L,t}$ in the numerator captures the *relative liquidity channel*: the central bank's dollar purchase tightens dollar liquidity, which through the liquidity-adjusted UIP condition reduces banks' demand for Sol reserves relative to dollar reserves, depreciating the exchange rate. The $\alpha_{F,t}$ in the denominator captures the *external funding channel*: tighter dollar liquidity raises the local deposit rate, attracting foreign capital that partially replenishes the absorbed dollars. A larger $\alpha_{F,t}$ (more elastic external capital) dampens $de_t/d\delta$ through the $1 + \alpha_{F,t}$ denominator. The intervention thus moves the exchange rate to the extent that external funding is insufficiently elastic to fully close the gap—precisely the slow-moving capital friction

[25] $\bar{\mathcal{L}}^*_{m^*d^*}$ and $\bar{\mathcal{L}}^*_{d^*d^*}$ are cross-derivatives with respect to the dollar deposit base $\widehat{d}_t^{H,*} + d_t^{f,*}$; differentiating with respect to either component yields the same derivative by symmetric entry. The stated signs $\phi_{f,t} < 0$, $\psi_t < 0$, and $\rho_t \in (0,1)$ hold whenever $m_t^{B,*}/(\widehat{d}_t^{H,*} + d_t^{f,*}) < 1$, which is satisfied in the data.

estimated in the previous section. The condition $\rho_t < 1$ ensures that $\alpha_{F,t}$ itself is finite: ρ_t is the supply-side self-feedback coefficient, since an additional unit of foreign funding raises the deposit rate and attracts ρ_t more units, then ρ_t^2, and so on. The geometric series converges only if $\rho_t < 1$.

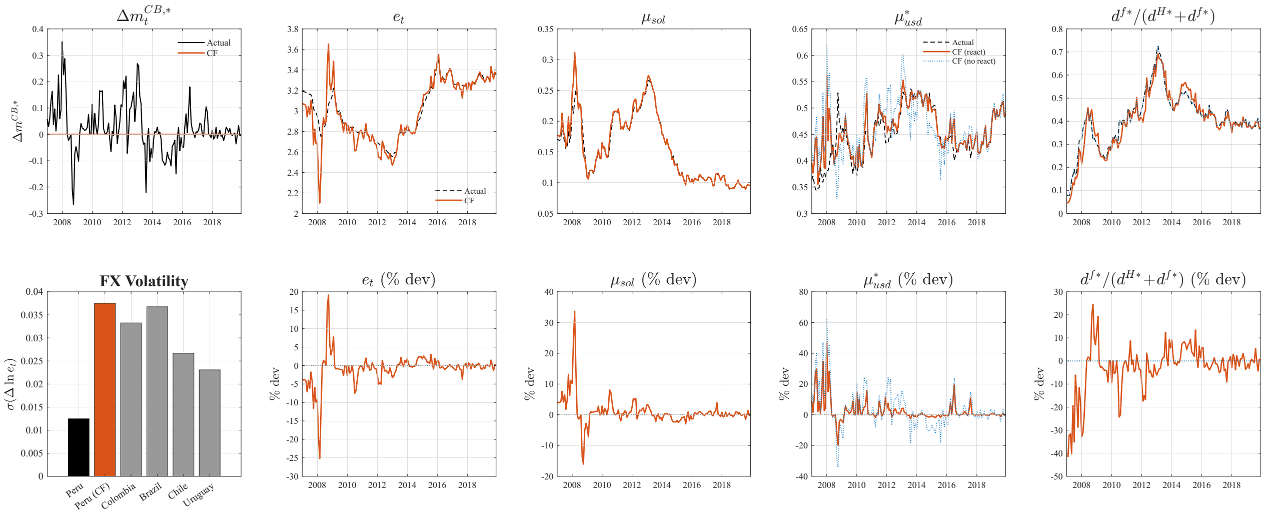

Figure 15: Counterfactual: No FX Intervention

Figure 15 shows the counterfactual paths of the exchange rate, the Sol liquidity ratio, the dollar liquidity ratio, and the external dollar funding ratio under the assumption that the BCRP conducts no FX intervention at all. The first column plots the BCRP's historical FX intervention scaled by the total dollar liabilities of the banking sector, together with a bar-chart comparison of exchange rate volatility across historical Peru, the no-intervention counterfactual, and other South American countries. The intervention has been substantial relative to the size of the local banking sector's dollar liabilities, and the volatility bars indicate that without it, the Sol's exchange rate volatility would have risen to levels comparable to those of its regional peers.

The 2007–2009 period is the most interesting episode in the sample. In late 2007, a global commodity boom drove a surge of dollar inflows into Peru, generating strong appreciation pressure on the Sol. From mid-2008 through 2009, the dynamic reversed sharply: the global financial crisis triggered a worldwide dollar shortage, and Peruvian banks faced an acute scarcity of dollar liquidity. The intervention time series in the first column shows that the BCRP actively intervened on both sides of the market to counteract these flows—purchasing dollars during the 2007 inflow and selling dollars during the 2008–2009 shortage. Absent this intervention, the model implies that the Sol would have experienced an additional appreciation of roughly 25% in 2007 and an additional depreciation of nearly 20% during 2008–2009.

As an emerging economy for which external dollar funding would have been particularly difficult to obtain during the 2008–2009 crisis, the BCRP's FX intervention proved highly effective in stabilizing the exchange rate during the most disruptive episode of the sample. Outside this window, in contrast, exchange rate volatility would not have been dramatically larger even in the absence of intervention—suggesting that in calmer periods the local banking sector was able to absorb shocks through a combination of external funding and endogenous portfolio reallocation. The fourth column of Figure 15 illustrates this pattern: the blue dotted line shows the counterfactual dollar liquidity ratio assuming no FX intervention and no bank portfolio response, while the orange line incorporates the endogenous rebalancing of bank balance sheets. The gap between the two lines reveals that banks themselves would have cushioned a substantial portion of the shock through their portfolio decisions. The long-run de-dollarization of the Peruvian banking sector also appears to play a meaningful role: as bank dollar liabilities have steadily declined over the sample, a given dollar liquidity shock translates into a smaller proportional disruption, mechanically dampening the exchange rate volatility that would have prevailed under the no-intervention counterfactual.

Overall, the counterfactual confirms that the BCRP's FX intervention has been effective in suppressing excessive exchange rate volatility, particularly during the most disruptive episodes of the sample.

6 Conclusion

This paper argues that the exchange rate in dollarized small open economies is shaped, in important ways, by the scarcity of dollar settlement balances within the domestic banking sector. We develop this argument in three steps.

First, using Peruvian banking data, we document that the dollar liquidity ratio of local banks tracks UIP deviations closely, and that spreads in the local dollar interbank market move nearly one-for-one with CIP deviations. To move beyond correlation, we instrument for changes in dollar liquidity using unexpected adjustments to marginal reserve requirements, following the narrative identification of Gutierrez, Ivashina and Salomao (2023). Local projection estimates show that a demand-driven tightening of dollar liquidity causes an immediate and persistent depreciation of the Sol, with effects lasting roughly two months—even after controlling for interest rate differentials and global risk factors.

Second, we build a dynamic small open economy model in which banks manage dual-currency balance sheets and trade in frictional interbank markets. The exchange rate emerges as a relative price of liquidity services: a liquidity-adjusted UIP condition links the demand for domestic reserves to the demand for dollar reserves, and an external dollar funding constraint—absent from global models like Bianchi, Bigio and

Engel (2024)—limits the supply of dollars available to local banks. This constraint is what gives quantity-based policies their bite. The model incorporates the full toolkit used by the BCRP: dual-currency reserve requirements, derivative-position-motivated balance-sheet constraints, and sterilized and unsterilized FX intervention, each operating on an identifiable margin of the bank's balance sheet.

Third, we confront the model with data. A filtering exercise recovers the latent time series of funding shock volatilities for each currency by inverting the model's structural mapping from liquidity conditions to interbank rates. With these filtered shocks, the model generates predictions for lending rates, deposit rates, and CIP deviations that it was not calibrated to match. It successfully replicates the dynamics of bank pricing in both currencies and reproduces the structural reversal in CIP deviations—from excess Sol returns to excess dollar returns—observed around 2014. Extending the baseline with the BCRP's punitive forward position regulation accounts for the full magnitude of the post-2014 CIP widening, illustrating how a single quantity-based regulation can reshape arbitrage conditions in the forward market.

Armed with the validated model, we focus the counterfactual analysis on the BCRP's most actively used quantity-based instrument: sterilized FX intervention. Removing it entirely would have generated substantially greater exchange rate volatility—reaching levels comparable to regional peers—with particularly large swings during the 2008–2009 crisis. The analysis confirms that the BCRP's intervention was well-timed, purchasing dollars during domestic liquidity stress and selling them during dollar shortages, and that the slow-moving capital friction prevented foreign borrowing from fully offsetting the policy. Analogous exercises for the dollar reserve requirement and the forward-position surcharge—reported in Appendix C—confirm that quantity-based regulations meaningfully shape exchange-rate dynamics by altering the relative scarcity of currency reserves.

Several broader implications follow. The framework provides a micro-founded rationale for the quantity-based exchange rate management that SOE central banks have practiced for decades, often in defiance of textbook prescriptions. Because settlement frictions segment the local dollar market from global benchmarks, the central bank gains an additional degree of freedom: it can use the policy rate to target inflation while deploying reserve requirements and FX intervention to manage exchange rate volatility. The model also reveals a structural asymmetry between reserve-currency and non-reserve-currency economies. When local banks face dollar shortfalls that cannot be matched domestically, the resulting penalty payments to foreign credit lines represent a net transfer abroad—the flip side of the exorbitant privilege enjoyed by the United States.

We see several directions for future work. Our counterfactual holds domestic absorption fixed, corresponding to an extreme case of low intertemporal elasticity. Relaxing this assumption and studying the dynamic general equilibrium response to intervention—where consumption, the trade balance, and the external position adjust jointly—would provide a more complete welfare analysis. Estimating the model structurally, rather than through the semi-structural filtering approach used here, would allow for a richer characterization of optimal policy. Finally, extending the framework to incorporate central bank swap lines and other forms of official dollar provision could shed light on the international dimension of dollar liquidity management.

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A First Stage Regression Result

	ΔNLR
R^2	**0.22**
Partial F-Statistics	**59.1**
P-Value	**1.867e-11**
Distribution	**chi2(5)**
$\Delta MGRR_t^{shock}$	0.0002
	(0.0004)
$\Delta MGRR_{t-1}^{shock}$	0.0006***
	(0.0002)
$\Delta MGRR_{t-2}^{shock}$	0.0006***
	(9.169e-05)
$\Delta MGRR_{t-3}^{shock}$	0.0006***
	(0.0001)
$\Delta MGRR_{t-4}^{shock}$	-0.0004***
	(0.0001)

Standard errors in parentheses. * p<.1, ** p<.05, ***p<.01. First-stage OLS with HAC standard errors, 12-month lags. Instruments: unexpected MGRR shocks (contemporaneous + 4 lags). Period: 2002-02 to 2019-12.

Table 5: First Stage Regression

B Regression Result for Different Periods

	Full	Pre-GFC	Post-GFC	Pre-TT	Post-TT	w/o GFC
q_{t-1}	-0.021*	0.035	-0.074***	-0.009	-0.113**	-0.017
	(0.011)	(0.046)	(0.022)	(0.011)	(0.053)	(0.012)
$\Delta(i_t - i_t^*)$	0.363***	0.201	0.090*	0.381***	1.149***	0.186**
	(0.118)	(0.182)	(0.052)	(0.142)	(0.432)	(0.083)
$\Delta\eta_t$	0.042	-0.015	-0.023	0.054	-0.067*	0.025
	(0.043)	(0.152)	(0.035)	(0.085)	(0.037)	(0.046)
$\Delta\eta_t^{G10}$	0.812	-0.760	0.478	0.484	-1.404	-0.061
	(0.503)	(1.016)	(1.066)	(0.579)	(1.722)	(0.577)
$\Delta\ln(VIX)$	0.006	-0.012	0.003	-0.004	0.009	0.003
	(0.005)	(0.009)	(0.005)	(0.005)	(0.007)	(0.006)
$\Delta\zeta$	0.991***	0.806***	2.990***	0.930***	3.624***	1.139***
	(0.251)	(0.278)	(0.599)	(0.232)	(0.849)	(0.340)
ΔNLR	**0.114*****	**0.025**	**0.083*****	**0.115*****	**0.099****	**0.073*****
	(0.028)	(0.025)	(0.031)	(0.034)	(0.045)	(0.020)
R-squared Adj.	0.308	0.375	0.411	0.285	0.426	0.313
N	215	70	126	135	80	197
Sample	02/2002–12/2019	02/2002–11/2007	07/2009–12/2019	02/2002–04/2013	05/2013–12/2019	02/2002–12/2019

Standard errors in parentheses. * p<.1, ** p<.05, ***p<.01. OLS with HAC standard errors, 12-month lags.

Table 6: Across Different Periods

C Additional Counterfactuals

C.1 Counterfactual: Equalized Reserve Requirements ($q^* = q$)

In the second experiment, we ask what would have happened had the BCRP not imposed a higher reserve requirement on dollar liabilities than on Sol liabilities. Historically, q_t^* has been substantially above q_t, reflecting the BCRP's prudential concern with dollar liquidity risk. We set $q_t^* = \widehat{q}_t$ throughout the sample, effectively lowering the dollar reserve requirement to match the Sol requirement.

Proposition 2 (Effectiveness of Dollar Reserve Requirement)**.** *Consider a marginal increase $dq_t^* > 0$ in the dollar reserve requirement, holding $\Delta m_t^{CB,*}$, q_t^f, and all hatted variables fixed. The exchange rate response is*

$$\frac{de_t}{dq_t^*} = -\frac{e_t}{m_t^B}\left[\phi_{q^*,t} + \frac{(\phi_t + \phi_{f,t})\,\psi_{q^*,t}}{(1-\rho_t) - \psi_t}\right], \tag{57}$$

where $\phi_t, \phi_{f,t}, \psi_t, \rho_t$ are defined as in Proposition 1, and

$$\phi_{q^*,t} \equiv \frac{\bar{\mathcal{L}}^*_{m^*q^*}}{(\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t)\,\bar{\mathcal{L}}_{mm}}, \tag{58}$$

$$\psi_{q^*,t} \equiv \widehat{d}_t^{H,*}\,\Theta^f \epsilon_f\,(\bar{R}_t^{d*} - \widehat{R}_t^{if*})^{\epsilon_f - 1}(\bar{\mathcal{L}}^*_{m^*q^*} + \bar{\mathcal{L}}^*_{d^*q^*}). \tag{59}$$

[26] *In the limiting cases:*

1. *No external funding response ($\epsilon_f = 0$): $\psi_t = \rho_t = \psi_{q^*,t} = 0$, so $de_t/dq_t^* = -(e_t/m_t^B)\,\phi_{q^*,t} > 0$. The Sol depreciates through the direct dollar-liquidity tightening only.*
2. *No liquidity friction ($\bar{\mathcal{L}}^* = 0$): all primitive coefficients vanish and $de_t/dq_t^* = 0$. Standard irrelevance result.*

Proof. The proof is provided in Appendix D.2. □

The dollar reserve requirement affects the Sol through two channels. The *direct channel*—captured by $\phi_{q^*,t} < 0$—tightens dollar liquidity by increasing the required reserve ratio, raising the marginal value of dollar reserves and appreciating the dollar via the UIP condition. The *indirect channel* works through the external funding margin: the higher deposit rate attracts additional foreign capital, which enlarges

[26]Adopting the same dollar deposit base convention as in Proposition 1, the cross-derivatives $\bar{\mathcal{L}}^*_{m^*q^*}, \bar{\mathcal{L}}^*_{d^*q^*}$ satisfy $\phi_{q^*,t} < 0$ and $\psi_{q^*,t} > 0$ whenever the dollar liquidity ratio $m_t^{B,*}/(\widehat{d}_t^{H,*} + d_t^{f,*}) < 1$, which holds in the data.

the dollar deposit base and feeds back through the UIP coupling $(\phi_t + \phi_{f,t})$ and the supply-side amplifier $\psi_{q^*,t}/\big((1-\rho_t) - \psi_t\big)$. The indirect channel has ambiguous sign because $\phi_{f,t} < 0$ partially offsets $\phi_t > 0$. When external funding is sufficiently slow-moving (small ϵ_f), the direct channel dominates and $de_t/dq_t^* > 0$; the empirical estimates in Section 5.1 are consistent with this regime. Conversely, lowering q_t^* to match q_t eases dollar liquidity and appreciates the Sol, while the external funding channel partially counteracts the appreciation as easier dollar liquidity lowers the deposit rate and reduces external borrowing.

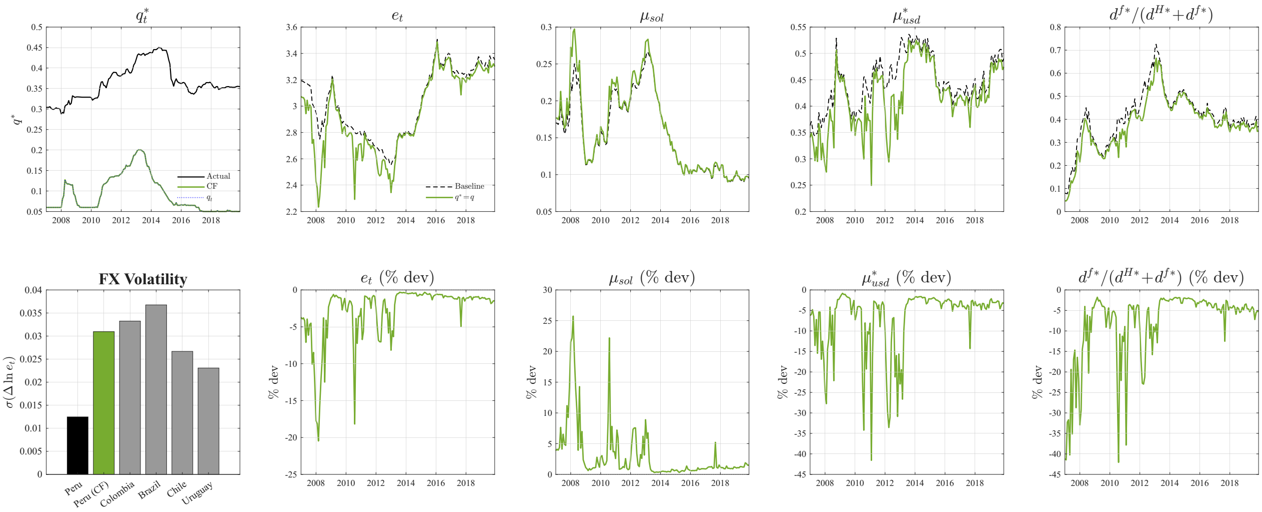

Figure 16: Counterfactual: Equalized Reserve Requirements ($q^* = q$)

Figure 16 shows the counterfactual paths of the exchange rate, the Sol liquidity ratio, the dollar liquidity ratio, and the external dollar funding ratio under the counterfactual scenario in which the BCRP equalizes the dollar reserve requirement to the Sol reserve requirement ($q_t^* = \widehat{q}_t$) throughout the sample.

C.2 Counterfactual: No Forward-Position-Motivated Sol Reserve Requirement

In the third experiment, we remove the post-2014 forward-position surcharge by setting $q_t^f = 0$. This regulation, introduced in December 2014, imposes additional Sol reserve requirements on banks whose gross short dollar forward positions exceed specified thresholds. As documented in Section 2, the regulation was highly punitive and is central to explaining the post-2014 widening of CIP deviations. Removing it effectively lowers the Sol reserve requirement.

Proposition 3 (Effectiveness of Forward-Position Sol Reserve Surcharge)**.** *Consider a marginal increase $dq_t^f > 0$ in the forward-position surcharge, holding $\Delta m_t^{CB,*}$, q_t^*, and all* *hatted variables fixed. The exchange rate response is*

$$\frac{de_t}{dq_t^f} = -\frac{e_t}{m_t^B} \cdot \phi_{q^f,t}, \qquad where \quad \phi_{q^f,t} \equiv -\frac{\bar{\mathcal{L}}_{mq^f}}{\bar{\mathcal{L}}_{mm}}. \tag{60}$$

[27] *Moreover, the dollar liquidity ratio* $m_t^{B,*}/(\widehat{d}_t^{H,*} + d_t^{f,*})$ *and external dollar funding* $d_t^{f,*}$ *are unaffected: the surcharge operates exclusively through the Sol liquidity channel. In the limiting case of no Sol liquidity friction* ($\bar{\mathcal{L}}_t = 0$), $\phi_{q^f,t} = 0$ *and* $de_t/dq_t^f = 0$.

Proof. The proof, which follows the same four-step structure as Proposition 1 but with q_t^f entering only the Sol liquidity function (so the dollar side does not respond), is provided in Appendix D.3. □

The starkly different transmission of q_t^f relative to the other instruments is notable. Because the surcharge targets Sol reserves—not dollar reserves—it does not alter the dollar deposit rate and therefore triggers no external funding response. The entire effect flows through a single channel: higher q_t^f raises the marginal value of Sol reserves, increasing banks' demand for Sol liquidity, which appreciates the domestic currency through the money market. This clean separation makes the forward-position surcharge a particularly targeted tool for managing the exchange rate without disturbing external dollar funding conditions. Conversely, removing the surcharge ($q_t^f = 0$) depreciates the Sol without affecting the dollar liquidity ratio—implying that the post-2014 regulation has contributed to Sol appreciation and exchange rate stability through a pure domestic liquidity channel.

A caveat is in order. The complete absence of dollar-side response in Proposition 3 also reflects a modelling asymmetry: because the dollar is the numéraire ($p_t^* \equiv 1$), our equilibrium imposes the Sol money-market clearing condition $\widehat{M}_t = m_t^B e_t$ but no analogous dollar money-market constraint that would pin down $m_t^{B,*}$ separately. As a result, dollar reserves adjust purely through the NFA constraint and the external supply curve, and a Sol-targeted policy has no foothold on the dollar side. A richer model in which the Federal Reserve's policy stance directly constrained $m_t^{B,*}$ could in principle generate a balance-sheet spillover from Sol-side policies to dollar liquidity. We abstract from that channel and view the pure-Sol-channel result as an idealized benchmark.

Figure 17 shows the counterfactual paths of the exchange rate, the Sol liquidity ratio, the dollar liquidity ratio, and the external dollar funding ratio under the counter-

[27] $\bar{\mathcal{L}}_{mq^f}$ is the cross-derivative of the Sol liquidity function with respect to m_t^B and q_t^f. The sign $\phi_{q^f,t} > 0$ holds whenever the Sol liquidity ratio $m_t^B/\widehat{d}_t^B < 1$, which is satisfied in the data; hence $de_t/dq_t^f < 0$ and the surcharge appreciates the Sol.

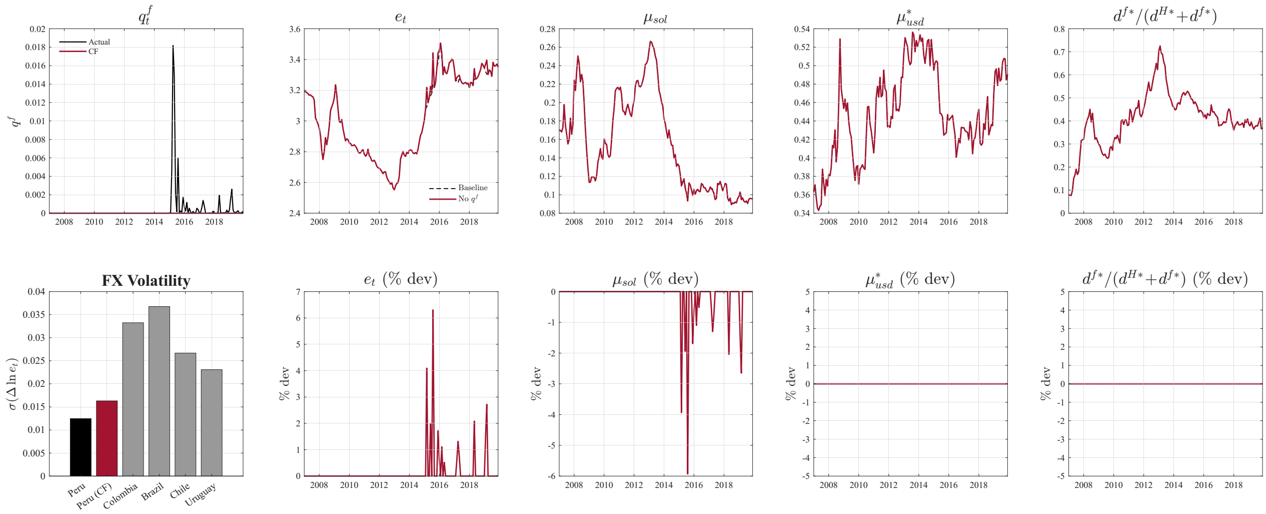

Figure 17: Counterfactual: No Forward-Position Sol Reserve Surcharge ($q^f = 0$)

factual scenario in which the BCRP removes the post-2014 forward-position surcharge ($q_t^f = 0$).

D Proof of Propositions

D.1 Proof of Proposition 1: Sterilized FX Intervention

We proceed in four steps. The dollar liquidity function depends on the sum of local and external dollar liabilities, $\widehat{d}_t^{H,*} + d_t^{f,*}$, which both contribute symmetrically to dollar withdrawal risk. Because $\widehat{d}_t^{H,*}$ is fixed, any change in external funding directly shifts $\bar{\mathcal{L}}_t^*$, and we have $\partial \bar{\mathcal{L}}_t^* / \partial \widehat{d}_t^{H,*} = \partial \bar{\mathcal{L}}_t^* / \partial d_t^{f,*}$ by symmetry; we denote this common derivative by $\bar{\mathcal{L}}_{d^*}^*$.

Step 1 (Money market). Since the intervention is sterilized, $\widehat{M}_t = m_t^B e_t$ is unchanged. Totally differentiating:

$$de_t = -\frac{e_t}{m_t^B} dm_t^B. \tag{61}$$

Step 2 (UIP link between Sol and Dollar reserves). Holding $\mathbb{E}_t[e_t/e_{t+1}]$, $\widehat{i}_t^m$, $\widehat{i}_t^{m*}$, $\widehat{\xi}_t$, and $\widehat{q}_t$, $\widehat{q}_t^*$, q_t^f fixed, the liquidity-adjusted UIP can be rearranged as

$$\text{const} = \bar{\mathcal{L}}_{m^*}^* \left(m_t^{B,*}, \widehat{d}_t^{H,*} + d_t^{f,*}\right) - \left(\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t\right) \bar{\mathcal{L}}_m(m_t^B),$$

where the right-hand side collects all terms that vary with the endogenous reserves and const $\equiv (\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t)(1 + \widehat{i}_t^m) - (1 + \widehat{i}_t^{m*})$. Totally differentiating (with $\widehat{d}_t^{H,*}$

fixed so $d(\widehat{d}^{H,*}_t + d^{f,*}_t) = dd^{f,*}_t$):

$$0 = \bar{\mathcal{L}}^*_{m^*m^*}\, dm^{B,*}_t + \bar{\mathcal{L}}^*_{m^*d^*}\, dd^{f,*}_t - (\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t)\, \bar{\mathcal{L}}_{mm}\, dm^B_t, \tag{62}$$

where $\bar{\mathcal{L}}_{mm} < 0$ and $\bar{\mathcal{L}}^*_{m^*m^*} < 0$ by concavity, while $\bar{\mathcal{L}}^*_{m^*d^*} > 0$ because adding deposits raises the marginal value of dollar reserves.[28] Solving for dm^B_t (using $\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t > 0$, since this object equals the positive expectation $\mathbb{E}_t[\widetilde{\Lambda}_{t+1}\, e_t/e_{t+1}]$):

$$dm^B_t = \underbrace{\frac{\bar{\mathcal{L}}^*_{m^*m^*}}{(\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t)\, \bar{\mathcal{L}}_{mm}}}_{\equiv \phi_t > 0} dm^{B,*}_t + \underbrace{\frac{\bar{\mathcal{L}}^*_{m^*d^*}}{(\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t)\, \bar{\mathcal{L}}_{mm}}}_{\equiv \phi_{f,t} < 0} dd^{f,*}_t. \tag{63}$$

The term $\phi_{f,t}\, dd^{f,*}_t$ captures the indirect channel through which an external funding inflow feeds back into the UIP by enlarging the dollar deposit base. Substituting (63) into (61):

$$de_t = -\frac{e_t}{m^B_t}\left[\phi_t\, dm^{B,*}_t + \phi_{f,t}\, dd^{f,*}_t\right]. \tag{64}$$

Step 3 (External funding response). The bank's first-order condition with respect to the dollar deposit base $d^{B,*}_t = \widehat{d}^{H,*}_t + d^{f,*}_t$ yields the deposit rate $\bar{R}^{d*}_t = \bar{R}^{m*}_t + \bar{\mathcal{L}}^*_{m^*} + \bar{\mathcal{L}}^*_{d^*}$, which is paid uniformly to households and foreign investors alike. Differentiating the deposit rate spread:

$$d\big(\bar{R}^{d*}_t - \widehat{R}^{if*}_t\big) = \big(\bar{\mathcal{L}}^*_{m^*m^*} + \bar{\mathcal{L}}^*_{m^*d^*}\big)\, dm^{B,*}_t + \big(\bar{\mathcal{L}}^*_{m^*d^*} + \bar{\mathcal{L}}^*_{d^*d^*}\big)\, dd^{f,*}_t. \tag{65}$$

Both parenthetical objects can be signed. The first is negative: $\bar{\mathcal{L}}^*_{m^*m^*} + \bar{\mathcal{L}}^*_{m^*d^*} = \frac{(\chi^- - \chi^+)\, \phi(\omega^*)\, (m^{B,*}_t/(\widehat{d}^{H,*}_t + d^{f,*}_t) - 1)}{(1-q^*_t)\, (\widehat{d}^{H,*}_t + d^{f,*}_t)} < 0$, since the dollar liquidity ratio is below 1 in the data. The second is positive: $\bar{\mathcal{L}}^*_{m^*d^*} + \bar{\mathcal{L}}^*_{d^*d^*} = \frac{(\chi^- - \chi^+)\, \phi(\omega^*)\, m^{B,*}_t\, (\widehat{d}^{H,*}_t + d^{f,*}_t - m^{B,*}_t)}{(1-q^*_t)\, (\widehat{d}^{H,*}_t + d^{f,*}_t)^3} > 0$.[29] Differentiating the external supply equation $d^{f,*}_t/\widehat{d}^{H,*}_t = \Theta^f(\bar{R}^{d*}_t - \widehat{R}^{if*}_t)^{\epsilon_f} + \widehat{z}^*_t$ and substituting:

$$dd^{f,*}_t = \psi_t\, dm^{B,*}_t + \rho_t\, dd^{f,*}_t, \tag{66}$$

[28] Direct calculation gives $\bar{\mathcal{L}}^*_{m^*d^*} = \frac{(\chi^- - \chi^+)\, m^{B,*}_t\, \phi(\omega^*)}{(1-q^*_t)\, (\widehat{d}^{H,*}_t + d^{f,*}_t)^2} > 0$.

[29] The second uses $\bar{\mathcal{L}}^*_{d^*d^*} = -\frac{(\chi^- - \chi^+)\, (m^{B,*}_t)^2\, \phi(\omega^*)}{(1-q^*_t)\, (\widehat{d}^{H,*}_t + d^{f,*}_t)^3} < 0$ (concavity in the deposit base).

with

$$\psi_t \equiv \widehat{d}_t^{H,*}\,\Theta^f \epsilon_f \left(\bar{R}_t^{d*} - \widehat{R}_t^{if*}\right)^{\epsilon_f - 1} \left(\bar{\mathcal{L}}^*_{m^*m^*} + \bar{\mathcal{L}}^*_{m^*d^*}\right) < 0, \tag{67}$$

$$\rho_t \equiv \widehat{d}_t^{H,*}\,\Theta^f \epsilon_f \left(\bar{R}_t^{d*} - \widehat{R}_t^{if*}\right)^{\epsilon_f - 1} \left(\bar{\mathcal{L}}^*_{m^*d^*} + \bar{\mathcal{L}}^*_{d^*d^*}\right) > 0. \tag{68}$$

The coefficient ρ_t captures the supply-side self-feedback: an exogenous unit inflow of foreign funding enlarges the dollar deposit base, raises $\bar{R}_t^{d*}$, and attracts ρ_t additional units, which in turn attracts ρ_t^2 more, and so on. The geometric sum $1 + \rho_t + \rho_t^2 + \cdots = 1/(1-\rho_t)$ converges—and the equilibrium response is well-defined—only when $\rho_t < 1$, which is naturally satisfied under the slow-moving capital assumption (bounded ϵ_f). Solving (66) for $dd_t^{f,*}$ under this stability condition:

$$dd_t^{f,*} = \frac{\psi_t}{1-\rho_t}\, dm_t^{B,*}. \tag{69}$$

Step 4 (NFA constraint and combining). From the external funding constraint $m_t^{B,*} - d_t^{f,*} = \widehat{C}_t - \delta$, totally differentiating gives $dm_t^{B,*} - dd_t^{f,*} = -d\delta$. Substituting (69):

$$\frac{(1-\rho_t) - \psi_t}{1-\rho_t}\, dm_t^{B,*} = -d\delta \quad\Longrightarrow\quad dm_t^{B,*} = -\frac{(1-\rho_t)\, d\delta}{(1-\rho_t) - \psi_t}. \tag{70}$$

Since $\psi_t < 0$ and $\rho_t \in (0,1)$, we have $(1-\rho_t) - \psi_t > 1 - \rho_t > 0$: external funding partially absorbs the intervention. Substituting (70) and (69) into (64):

$$\frac{de_t}{d\delta} = \frac{e_t}{m_t^B} \cdot \frac{(1-\rho_t)\phi_t + \phi_{f,t}\psi_t}{(1-\rho_t) - \psi_t} = \frac{\alpha_{L,t}}{1 + \alpha_{F,t}} > 0, \tag{71}$$

where $\alpha_{L,t}$ and $\alpha_{F,t}$ are as defined in Proposition 1. Note that $\phi_{f,t}\psi_t > 0$ (negative times negative), so the indirect deposit-base channel *amplifies* the direct liquidity channel. □

D.2 Proof of Proposition 2: Dollar Reserve Requirement

The proof proceeds in four steps, paralleling the proof of Proposition 1. The two new ingredients are (i) the direct effect of q_t^* on $\bar{\mathcal{L}}^*_{m^*}$ and $\bar{\mathcal{L}}^*_{d^*}$, and (ii) the absence of the FX shock in the NFA constraint, which forces $dm_t^{B,*} = dd_t^{f,*}$.

Step 1 (Money market). Since $\Delta m_t^{CB,*}$ is fixed, $\widehat{M}_t = m_t^B\, e_t$ is unchanged, yielding

$$de_t = -\frac{e_t}{m_t^B}\, dm_t^B. \tag{72}$$

Step 2 (UIP with direct q_t^* effect). The UIP, with the dollar liquidity function evaluated at the deposit base $\widehat{d}_t^{H,*} + d_t^{f,*}$, becomes (after rearrangement)

$$\text{const} = \bar{\mathcal{L}}^*_{m^*}\left(m_t^{B,*}, \widehat{d}_t^{H,*} + d_t^{f,*}, q_t^*\right) - \left(\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t\right) \bar{\mathcal{L}}_m(m_t^B),$$

with $\text{const} \equiv (\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t)(1 + \widehat{i}_t^m) - (1 + \widehat{i}_t^{m*})$. Differentiating ($d(\widehat{d}_t^{H,*} + d_t^{f,*}) = dd_t^{f,*}$):

$$0 = \bar{\mathcal{L}}^*_{m^*m^*}\, dm_t^{B,*} + \bar{\mathcal{L}}^*_{m^*d^*}\, dd_t^{f,*} + \bar{\mathcal{L}}^*_{m^*q^*}\, dq_t^* - \left(\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t\right) \bar{\mathcal{L}}_{mm}\, dm_t^B. \tag{73}$$

Solving for dm_t^B and using the definitions of ϕ_t, $\phi_{f,t}$ from Proposition 1:

$$dm_t^B = \phi_t\, dm_t^{B,*} + \phi_{f,t}\, dd_t^{f,*} + \underbrace{\frac{\bar{\mathcal{L}}^*_{m^*q^*}}{\left(\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t\right) \bar{\mathcal{L}}_{mm}}}_{\equiv \phi_{q^*,t} < 0} dq_t^*. \tag{74}$$

The coefficient $\phi_{q^*,t}$ has the opposite sign of ϕ_t because $\bar{\mathcal{L}}^*_{m^*q^*} > 0$ while $(\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t)\, \bar{\mathcal{L}}_{mm} < 0$.[30]

Step 3 (External funding response with direct q_t^* effect). The deposit rate spread now depends on $m_t^{B,*}$, $\widehat{d}_t^{H,*} + d_t^{f,*}$, and q_t^*:

$$\begin{aligned} d\left(\bar{R}_t^{d*} - \widehat{R}_t^{if*}\right) = &\left(\bar{\mathcal{L}}^*_{m^*m^*} + \bar{\mathcal{L}}^*_{m^*d^*}\right) dm_t^{B,*} + \left(\bar{\mathcal{L}}^*_{m^*d^*} + \bar{\mathcal{L}}^*_{d^*d^*}\right) dd_t^{f,*} \\ &+ \left(\bar{\mathcal{L}}^*_{m^*q^*} + \bar{\mathcal{L}}^*_{d^*q^*}\right) dq_t^*. \end{aligned} \tag{75}$$

The first two parentheses have known signs (Step 3 of Proposition 1); the third is positive: a higher q_t^* raises both $\bar{\mathcal{L}}^*_{m^*}$ and $\bar{\mathcal{L}}^*_{d^*}$, so the deposit rate must rise. Differentiating the external supply equation and substituting:

$$dd_t^{f,*} = \psi_t\, dm_t^{B,*} + \rho_t\, dd_t^{f,*} + \psi_{q^*,t}\, dq_t^*, \tag{76}$$

with $\psi_t < 0$ and $\rho_t \in (0,1)$ as in Proposition 1, and

$$\psi_{q^*,t} \equiv \widehat{d}_t^{H,*}\, \Theta^f \epsilon_f \left(\bar{R}_t^{d*} - \widehat{R}_t^{if*}\right)^{\epsilon_f - 1} \left(\bar{\mathcal{L}}^*_{m^*q^*} + \bar{\mathcal{L}}^*_{d^*q^*}\right) > 0. \tag{77}$$

Solving for $dd_t^{f,*}$:

$$dd_t^{f,*} = \frac{\psi_t}{1-\rho_t}\, dm_t^{B,*} + \frac{\psi_{q^*,t}}{1-\rho_t}\, dq_t^*. \tag{78}$$

[30] $\bar{\mathcal{L}}^*_{m^*q^*} = \frac{(\chi^- - \chi^+)\,\phi(\omega^*)\,(\widehat{d}_t^{H,*} + d_t^{f,*} - m_t^{B,*})}{(1-q_t^*)^2\,(\widehat{d}_t^{H,*} + d_t^{f,*})} > 0$ when the dollar liquidity ratio is below 1.

Step 4 (NFA constraint and combining). With $d(\Delta m_t^{CB,*}) = 0$, the NFA constraint differentiates to $dm_t^{B,*} - dd_t^{f,*} = 0$, i.e., $dm_t^{B,*} = dd_t^{f,*}$. Substituting (78):

$$\frac{(1-\rho_t) - \psi_t}{1-\rho_t}\, dm_t^{B,*} = \frac{\psi_{q^*,t}}{1-\rho_t}\, dq_t^* \implies dm_t^{B,*} = dd_t^{f,*} = \frac{\psi_{q^*,t}}{(1-\rho_t) - \psi_t}\, dq_t^* > 0. \quad (79)$$

Substituting (79) into (74) and using $dd_t^{f,*} = dm_t^{B,*}$:

$$dm_t^B = (\phi_t + \phi_{f,t})\, dm_t^{B,*} + \phi_{q^*,t}\, dq_t^* = \left[\phi_{q^*,t} + (\phi_t + \phi_{f,t}) \cdot \frac{\psi_{q^*,t}}{(1-\rho_t) - \psi_t}\right] dq_t^*. \quad (80)$$

Substituting into (72):

$$\frac{de_t}{dq_t^*} = -\frac{e_t}{m_t^B}\left[\phi_{q^*,t} + (\phi_t + \phi_{f,t}) \cdot \frac{\psi_{q^*,t}}{(1-\rho_t) - \psi_t}\right]. \quad (81)$$

The bracket combines the negative direct channel $\phi_{q^*,t} < 0$ (raising q_t^* tightens dollar liquidity and contracts m_t^B via UIP) and the indirect channel $(\phi_t + \phi_{f,t}) \cdot \psi_{q^*,t}/((1-\rho_t) - \psi_t)$. The indirect channel has ambiguous sign because $\phi_{f,t} < 0$ partially offsets $\phi_t > 0$. When external funding is sufficiently slow-moving (ϵ_f small), the direct channel dominates and the bracket is negative, yielding $de_t/dq_t^* > 0$ (Sol depreciates). □

D.3 Proof of Proposition 3: Forward-Position Sol Reserve Surcharge

The proof again proceeds in four steps. The key observation is that q_t^f enters *only* the Sol liquidity function $\bar{\mathcal{L}}_t(\widehat{q}_t, q_t^f)$ and not the dollar liquidity function $\bar{\mathcal{L}}_t^*$. Consequently, the dollar deposit rate, the external funding response, and (via the NFA constraint with no FX intervention) the dollar liquidity ratio are all unchanged. The entire effect operates through the Sol side of the UIP condition.

Step 1 (Money market). With $\Delta m_t^{CB,*}$ fixed, the money supply $\widehat{M}_t = m_t^B e_t$ is unchanged. Totally differentiating:

$$de_t = -\frac{e_t}{m_t^B}\, dm_t^B. \quad (82)$$

Step 2 (UIP with direct q_t^f effect). The Sol liquidity function $\bar{\mathcal{L}}_t(m_t^B; \widehat{q}_t, q_t^f)$ now depends on q_t^f. Holding $\mathbb{E}_t[e_t/e_{t+1}]$, $\widehat{i}_t^m$, $\widehat{i}_t^{m*}$, $\widehat{\xi}_t$, $\widehat{q}_t$, and q_t^* fixed, totally differentiating the UIP condition:

$$0 = \bar{\mathcal{L}}_{m^*m^*}^*\, dm_t^{B,*} \;-\; (\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t)\left[\bar{\mathcal{L}}_{mm}\, dm_t^B + \bar{\mathcal{L}}_{mq^f}\, dq_t^f\right], \quad (83)$$

where $\bar{\mathcal{L}}_{mq^f} \equiv \partial^2 \bar{\mathcal{L}}_t / (\partial m_t^B \partial q_t^f) > 0$ when the Sol liquidity ratio satisfies $m_t^B / \widehat{d}_t^B < 1$, by the same argument used in Step 2 of the proof of Proposition 2.[31]

Step 3 (External funding response). Because q_t^f does not enter the dollar liquidity function $\bar{\mathcal{L}}_t^*$, the dollar deposit rate $\bar{R}_t^{d*} = \bar{R}_t^{m*} + \bar{\mathcal{L}}_{m^*}^* + \bar{\mathcal{L}}_{d^*}^*$ is independent of q_t^f. Differentiating the deposit rate spread (with $\widehat{d}_t^{H,*}$ fixed so $d(\widehat{d}_t^{H,*} + d_t^{f,*}) = dd_t^{f,*}$):

$$d\left(\bar{R}_t^{d*} - \widehat{R}_t^{if*}\right) = \left(\bar{\mathcal{L}}_{m^*m^*}^* + \bar{\mathcal{L}}_{m^*d^*}^*\right) dm_t^{B,*} + \left(\bar{\mathcal{L}}_{m^*d^*}^* + \bar{\mathcal{L}}_{d^*d^*}^*\right) dd_t^{f,*}. \tag{84}$$

There is no direct dq_t^f term. The external supply equation gives the feedback system

$$dd_t^{f,*} = \psi_t \, dm_t^{B,*} + \rho_t \, dd_t^{f,*} \iff dd_t^{f,*} = \frac{\psi_t}{1-\rho_t} dm_t^{B,*}, \tag{85}$$

with $\psi_t < 0$ and $\rho_t \in (0,1)$ defined as in Proposition 1.

Step 4 (NFA constraint and combining). With $d(\Delta m_t^{CB,*}) = 0$, the NFA constraint $m_t^{B,*} - d_t^{f,*} = \widehat{C}_t - \Delta m_t^{CB,*}$ implies

$$dm_t^{B,*} - dd_t^{f,*} = 0. \tag{86}$$

Substituting (85): $\frac{(1-\rho_t)-\psi_t}{1-\rho_t} dm_t^{B,*} = 0$. Since $\psi_t < 0$ and $\rho_t \in (0,1)$, we have $(1-\rho_t) - \psi_t > 0$, hence

$$dm_t^{B,*} = 0 \text{ and hence } dd_t^{f,*} = 0. \tag{87}$$

The dollar reserves and external funding are entirely unaffected: there is no dollar-side response to a Sol-only policy. Substituting (87) into the UIP differentiation in Step 2:

$$0 = -(\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t) \left[\bar{\mathcal{L}}_{mm} \, dm_t^B + \bar{\mathcal{L}}_{mq^f} \, dq_t^f\right], \tag{88}$$

which, since $(\mathbb{E}_t[e_t/e_{t+1}] + \widehat{\xi}_t) \neq 0$, simplifies to

$$dm_t^B = -\frac{\bar{\mathcal{L}}_{mq^f}}{\bar{\mathcal{L}}_{mm}} dq_t^f = \phi_{q^f,t} \, dq_t^f, \tag{89}$$

with $\phi_{q^f,t} > 0$ since $\bar{\mathcal{L}}_{mq^f} > 0$ and $\bar{\mathcal{L}}_{mm} < 0$. Substituting (89) into (82):

$$\frac{de_t}{dq_t^f} = -\frac{e_t}{m_t^B} \phi_{q^f,t} \; < \; 0, \tag{90}$$

[31] The explicit formula is $\bar{\mathcal{L}}_{mq^f} = \frac{(\chi^- - \chi^+)\,\phi(\omega)\,(\widehat{d}_t^B - m_t^B)}{(1-\widehat{q}_t - q_t^f)^2 \, \widehat{d}_t^B} > 0$.

i.e., the surcharge appreciates the Sol. The bank balance sheet identity adjusts through equity: with $dm_t^{B,*} = 0$ and $dd_t^{f,*} = 0$, the differentiated balance sheet $dm_t^B + dm_t^{B,*} = dd_t^{f,*} + dn_t^B$ implies $dn_t^B = dm_t^B > 0$. □