

Foreign Exchange Interventions and Intermediary Constraints

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Abstract

The dollar intermediation channel of foreign exchange interventions (FXI), a form of the portfolio balance channel, arises from the imperfect substitutability between domestic currency and USD, the dominant global currency, along with financial frictions limiting USD liquidity access. This channel plays a key role in Banco Central do Brasil's FXI. High-frequency data on over 8,000 FXI events (1999–2023) show that unanticipated spot sales appreciate the domestic currency, reduce covered interest parity deviations, and crowd out private intermediation, especially when intermediaries are constrained. Our results support an extended Gabaix and Maggiori (2015) model, in which constrained intermediaries amplify intervention effectiveness.

JEL classification: E44; E58; F31; G14

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1 Introduction

Researchers in international finance have long studied how central banks influence currency markets through foreign exchange interventions (FXI). While it is widely accepted that non-sterilized interventions affect exchange rates by altering the money supply, the effectiveness of sterilized interventions and the mechanisms through which they operate remain subjects of ongoing debate (see [Sarno and Taylor, 2001](#), for a review that remains relevant today).

This debate persists largely because identifying the causal effects of FXI on financial and macroeconomic variables poses two significant empirical challenges. Specifically, clean identification requires interventions that are unanticipated by market participants and not driven by the central bank’s endogenous responses to current economic conditions, as [Fratzscher et al. \(2019\)](#) emphasize.

We make significant progress on these empirical challenges by employing a high-frequency dataset released in 2023 that details every intervention by the Banco Central do Brasil (BCB) since 1999—over 8,000 interventions in total. This comprehensive dataset enables us to distinguish between interventions that were pre-announced and those that surprised market participants. In this paper, we focus on the precise timing of FXI announcements and their effects on market variables using a high-frequency event study methodology. Our study contributes to the growing literature on the effects of BCB monetary policy (see [Carvalho et al., 2013](#), for a review of BCB policy communications). By incorporating extensive controls for the BCB’s endogenous response to economic conditions, our approach helps mitigate identification concerns.¹

Our main contribution is to show that the impact of FXI depends on the degree to which global FX dealers are constrained in supplying U.S. Dollar (USD) liquidity. When intermediaries are constrained, FXI has a greater capacity to affect spot and forward

¹From an econometric point of view, the use of market surprises in event studies is widely accepted, as these surprises are considered news relative to the information sets of market participants (see [Gürkaynak et al., 2021](#), for a discussion). However, identifying structural policy shocks and their causal effects on macroeconomic variables requires an instrument that captures innovations that are both news to market participants and orthogonal to the economic state. The orthogonality assumption may be violated if the information sets of policymakers and market participants diverge. To address this concern, we include extensive controls for the economic state in our econometric analysis. We emphasize that any residual endogeneity not absorbed by the controls would produce *downward* rather than upward bias in our estimates.

rates because the supply of cross-border capital is less elastic. We identify this mechanism as the *dollar intermediation* channel, which can be seen as a version of the standard *portfolio balance channel* discussed in the literature. The channel arises from the imperfect substitutability of domestic currency and USD, and from the existence of financial frictions limiting access to USD liquidity.²

To shed further light on the dollar intermediation channel, we study the effect of FXI on the volume of intermediation provided by private financial institutions. We document a crowding-out effect of FXI, and relate this effect to interactions between currency and interest rate markets through the covered interest rate parity (CIP) condition. Violations of CIP can indicate a relative scarcity of USD liquidity in cross-border financial markets. Central banks can alleviate this scarcity by supplying USD liquidity, improving market efficiency but limiting the ability of private intermediaries to profit from CIP violations. We show that unanticipated sales of USD reserves by the BCB lead to systematic domestic currency appreciation, a decline in CIP violations, and an attendant reduction in the volume of private intermediation.

To motivate our empirical framework, we extend the Basic Gamma Model of [Gabaix and Maggiori \(2015\)](#), where financial frictions play a central role. In our extension, we distinguish between spot and swap interventions and allow for partially or fully anticipated interventions. The model involves two countries, Home and Foreign, each with a representative household, domestic tradable and non-tradable goods, and a domestic bond. Households consume domestic and international goods but only hold domestic bonds due to a lack of access to international bond markets.

A foreign exchange Financier intermediates bond trade, constructing a zero-cost portfolio of Home and Foreign bonds to maximize expected profit subject to a credit constraint. The Central Bank conducts swap interventions that are unwound after one period and spot interventions that are maintained for two periods, intervening when trade shocks exceed set thresholds. These thresholds are communicated as distributions to manage anticipation of interventions.

²The BCB does not have an active foreign-currency liquidity swap line with the Federal Reserve and must rely on FXI to alleviate USD liquidity shortages and supply USD to domestic financial firms.

The model yields three key empirical predictions: unanticipated spot interventions have larger effects on exchange rates because they persistently alter portfolio compositions after agents have formed expectations, interventions crowd out private intermediation by reducing the Financier’s expected profits, and tighter credit constraints amplify the effects of interventions by rendering the Financier’s supply of intermediation less elastic.

To test the model’s predictions, we exploit a large historical database of BCB interventions. The database includes a high-frequency timestamp for each intervention announcement, as well as the type (spot or swap), sign (buy or sell of USD), and size of the intervention. We classify interventions as unanticipated when they are implemented on the same day that they are announced.

We combine the BCB’s database of interventions with spot and futures prices at 5-minute intervals from Thomson Reuters Tick History. Using this high-frequency data, we measure the effects of FX buy and sell interventions on exchange rates, the quantity of private intermediation, CIP violations, and interest rates. Our analysis uses the local projections method of [Jordà \(2005\)](#), and controls for the intervention size, feedback effects in prices, and a host of factors that capture the endogeneity of the BCB’s intervention with respect to the economic state.

First, we estimate the impact of unanticipated interventions conditional on intervention type. In response to BCB spot sell interventions, the Brazilian Real (BRL) appreciates by approximately 2 percentage points over a seven-hour horizon per 1 billion USD sold. In response to BCB spot buy interventions, the BRL depreciates by approximately 10 basis points over the same horizon. The asymmetry in effect sizes suggests an important role for the dollar intermediation channel, whereby spot sell interventions improve USD liquidity and loosen intermediary constraints. Historically, the BCB has sold USD in periods of economic stress for Brazil: 2001–02, 2009, and 2020–21. These periods saw sharp drops in intermediary capital ratios, as we show in Appendix Figure [B.3](#). In contrast, the BCB has tended to buy USD in periods with healthy intermediary capital ratios. Our theoretical model predicts stronger FXI effects when intermediaries are constrained, and the data support this prediction when constraints are measured using capital ratios for a panel of

dealer banks active in emerging-market currencies. In response to BCB swap interventions, both traditional and reverse, the BRL shows a weaker response, again consistent with the predictions of our theoretical model.

Second, we examine the effects of FXI on market intermediation by analyzing its impact on BRL/USD spot trading volume. The total volume of intermediation consists of both public intermediation, supplied by the BCB through FXI, and private intermediation, provided by financial institutions. If FXI crowds out private intermediation, total trading volume should increase by less than the size of the intervention. Our empirical findings confirm this: BCB spot sales lead to an increase in BRL/USD trading volume, but by less than one-to-one, indicating a crowding-out effect on private intermediaries. In contrast, spot purchases do not significantly affect private intermediation.

The crowding-out effect can be understood as the response of private intermediaries to weaker profit incentives, as reflected in both exchange rate movements and a lower cross-currency basis—a premium paid by market participants to swap BRL into USD, that rises when USD funding is scarce. We measure the cross-currency basis response to FXI and find that it declines following BCB spot sales of USD. By alleviating USD scarcity, FXI can reduce the relative cost of borrowing USD through forward markets. However, this effect comes at the cost of reducing the incentive for private financial institutions to intermediate, creating an important trade-off for policy-makers to consider when conducting FXI.

Third, we test whether the impact of FXI on spot prices and CIP violations is more pronounced during periods of tighter intermediary constraints. When USD liquidity is limited, the central bank conducts USD sale operations, anticipating stronger FXI price effects due to the inelastic USD supply. We construct a dealer capital ratio following [He et al. \(2017\)](#) as a proxy for intermediary constraints, measuring the capital-to-assets ratio for key global FX dealers. Our findings show that spot sale FXI has significant effects primarily during periods of tighter intermediary constraints. Additionally, while traditional swap FXI generally has no significant effect on the spot rate, its effect becomes significant when intermediary constraints are tighter.

Finally, we explore an alternative FXI channel: signaling future interest rates. Using high-frequency and daily interest rate data, we analyze the immediate and long-term effects of unanticipated FXI on interest rates. Our findings suggest that unanticipated spot sales of USD lead to an economically insignificant short-term increase in interest rates based on intra-day data, consistent with the sterilization mechanism. We also investigate FXI's impact on long-term interest rate dynamics. Our analysis over a longer macroeconomic horizon provides weak evidence of a systematic effect on interest rates following both spot and swap FXI. Overall, the evidence lends less support to the signaling channel than to the dollar intermediation channel as the relevant theory explaining our findings.

Related Literature. Our paper contributes to a literature on the channels through which FXI affects exchange rates (e.g. [Sarno and Taylor, 2001](#); [Neely, 2005](#); [Vitale, 2006](#); [Menkhoff, 2010](#)). These studies discuss primarily two channels through which sterilized FXI may operate: the portfolio balance and signaling channels. In a standard sterilized intervention, the Central Bank sells foreign currency reserves while simultaneously purchasing domestic bonds. In the portfolio balance channel, the relative price of foreign currency must fall to induce private agents to absorb the additional supply into their portfolios. In the signaling channel, selling foreign currency reserves signals an anticipated increase in domestic interest rates. In our paper, the *dollar intermediation* channel, a variation of the portfolio balance channel, emphasizes how financial constraints affect intermediaries' ability to supply USD liquidity. We find strong empirical support for the dollar intermediation channel of FXI in Brazil, but weak support for the signaling channel.

Our paper relates to empirical studies on the impact of FXI on exchange rates and other markets (e.g. [Kearns and Rigobon, 2005](#); [Menkhoff et al., 2021](#); [Fratzcher et al., 2019, 2020](#); [Naef, 2024](#); [Dominguez et al., 2013](#); [Arango-Lozano et al., 2020](#)), as well as studies on BCB interventions ([Nakashima, 2012](#); [Kohlscheen and Andrade, 2013](#); [Janot and Macedo, 2016](#); [Santos, 2021](#)). For example, [Kohlscheen and Andrade \(2013\)](#) found an impact of 29 basis points per billion USD using intra-day spot and futures prices, while [Nedeljkovic and Saborowski \(2019\)](#) reported up to 100 basis points per billion USD with

an IV approach. [Barroso \(2019\)](#) estimated impacts between 51 and 118 basis points using IV analysis, and [Santos \(2021\)](#) found a peak effect of 30 basis points using intra-day data on futures. Turning to swap interventions, [da Costa Filho \(2021\)](#) identified a smaller effect of 3-5 basis points per billion USD. We find larger effect sizes when considering BCB spot sell interventions separately, but similar effect sizes when considering buy and sell interventions jointly.

We contribute to the literature on FXI as a central banking policy tool (e.g. [Ferreira et al., 2019](#); [Fratzscher et al., 2019, 2020](#); [Levy-Yeyati and Gómez, 2022](#); [Naef, 2024](#); [Rodnyansky et al., 2023](#); [Bertsch et al., 2024](#)). [Fratzscher et al. \(2019\)](#) show that central banks use FXI to stabilize exchange rates by countering private market trades, while [Rodnyansky et al. \(2023\)](#) find that FXI mitigates spillovers from foreign monetary policy, protecting firms with high foreign-currency debt. While our focus is on the effects and operating channels of FXI rather than central bank motivations or policy goals, our theoretical model assumes an FXI reaction function aimed at exchange rate stabilization, consistent with empirical evidence ([Ferreira et al., 2019](#); [Fratzscher et al., 2019](#); [Rodnyansky et al., 2023](#)). This reaction function allows the central bank to remain inactive until intervention is warranted and to surprise market participants when it acts.

We also engage with theoretical work on FXI in models with financial frictions (see [Gabaix and Maggiori, 2015](#); [Maggiori, 2021, 2022](#); [Agénor et al., 2020](#); [Fanelli and Straub, 2021](#); [Agénor and da Silva, 2023](#); [Bacchetta et al., 2023](#); [Beltran and He, 2024](#); [Candian et al., 2024](#); [Pelin, 2024](#); [Yago, 2024](#)). [Agénor et al. \(2020\)](#) and [Agénor and da Silva \(2023\)](#) highlight real macroeconomic effects of sterilized interventions through a bank portfolio channel. [Beltran and He \(2024\)](#) model FXI in EMEs experiencing currency demand shocks. [Candian et al. \(2024\)](#) develop a framework to study how the informational effects of FXI depend on the communication transparency of the central bank. [Yago \(2024\)](#) models FXI and monetary policy combinations that mitigate the inflation-output trade-off. Relative to these models, we introduce distinctions between spot versus swap and anticipated versus unanticipated interventions that interact with financial frictions and yield predictions that motivate our empirical analysis.

Finally, we contribute to the literature on emerging market CIP violations (Du and Schreger, 2016; Hartley, 2020; Bahaj and Reis, 2020; Cerutti and Zhou, 2024; Hertrich and Nathan, 2023; De Leo et al., 2024), which explores CIP violations, sovereign risk, and central bank swap lines. We find that BCB spot sell interventions reduce CIP violations for BRL/USD, complementing the work of Hertrich and Nathan (2023), who find that Bank of Israel spot *purchase* interventions increase CIP violations for ILS/USD. Relative to Hertrich and Nathan (2023), we analyze more interventions over a longer time period using higher-frequency data, distinguish between anticipated and unanticipated spot and swap interventions, provide a formal explanation for our findings, and highlight a new trade-off faced by policy-makers.

In summary, we provide a modern interpretation of the portfolio balance channel, highlighting the role of constrained intermediaries in shaping intervention effectiveness. First, by emphasizing this dollar intermediation channel of FXI, we provide empirical support for models with financial frictions. Second, we differentiate between unanticipated and anticipated spot and swap interventions, using high-frequency data to identify strong exchange rate effects for spot sell interventions, especially when intermediaries are constrained. Third, we find that FXI crowds out private intermediation by lowering the cross-currency basis, thereby strengthening FX market efficiency but weakening intermediaries' profit incentives. Together, these findings clarify which types of FXI are most effective, when they are most effective, and what trade-offs they entail.

The remainder of the paper is structured as follows. In Section 2, we introduce a theoretical model of FXI with predictions for exchange rates and the impact of FXI on market intermediation. In Section 3, we introduce the BCB's institutional setting and describe our data. In Section 4, we present our findings on the effects of FXI on exchange rates, trading volume and CIP deviations, and test for the signaling channel. In Section 5, we conclude.

2 Theoretical Model

We extend the Basic Gamma Model of [Gabaix and Maggiori \(2015\)](#) and derive predictions that motivate our empirical investigation of Central Bank interventions in foreign exchange markets. In our extension, we introduce a simple distinction between spot and swap interventions and we allow interventions to be partially or fully anticipated.

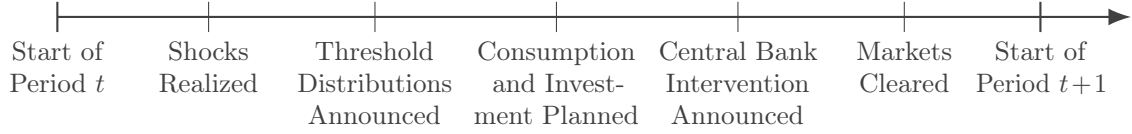
There are two countries, Home and Foreign, each with a representative Household, a domestic tradable and non-tradable good, and a domestic bond. Households receive endowments of domestic tradable and non-tradable goods and consume baskets of domestic and international goods. As in the Basic Gamma Model, Households have access to international goods markets but no access to international bond markets, and therefore hold only domestic bonds, as in the original model.

A representative FX dealer intermediates bond trade, known as a Financier in [Gabaix and Maggiori \(2015\)](#). The Financier begins each period with zero assets and constructs a zero-cost portfolio of Home and Foreign bonds to maximize expected single-period profit. By trading in both bond markets, the Financier absorbs imbalances in demand for Home and Foreign bonds. However, creditors impose constraints on the Financier that limit its ability to intermediate optimally.

A Central Bank conducts two types of sterilized FXI: short-lived swap interventions that are unwound after one period and long-lived spot interventions that are maintained for two periods.³ The Central Bank intervenes when trade shocks exceed thresholds that it sets exogenously. The Central Bank withholds its exact threshold values from the Household and Financier and instead communicates distributions of possible values. The Central Bank sets the parameters of the distributions (through a unmodeled communication policy) to control the anticipation of its interventions. Households and the Financier form plans based on the probability of an intervention, before the Central Bank announces its

³We model swaps as short-lived to capture the distinction the IMF makes between “the outright sale or purchase of FX assets for local currency” and “the temporary provision of FX liquidity to the private sector by way of a loan or swap contract” ([International Monetary Fund, 2023](#)). Viewed in this way, swaps are temporary, self-reversing transactions that central banks use to counteract transitory market conditions rather than to effect lasting policy change. This view is similar to how the monetary policy literature sees repurchase agreements ([Mishkin and Eakins, 2012](#), Ch. 10).

Figure 1: Phases of Periods Zero and One in the Gamma-Eta Model



Notes. Periods zero and one are divided into five phases. In the first phase, preference shocks are realized and observed by all. In the second phase, the Central Bank announces distributions for its intervention thresholds. If trade shocks exceed the thresholds, the Central Bank will carry out a foreign exchange intervention. In the third phase, the Home and Foreign Households and the Financier form consumption and investment plans. In the fourth phase, the Central Bank reveals its foreign exchange intervention. In the fifth phase, prices are determined and markets clear.

intervention decision each period. Figure 1 illustrates these timing assumptions.

The model makes four central empirical predictions: first, that long-lived spot interventions have larger exchange rate effects than short-lived swap interventions because they alter portfolio compositions for longer; second, that unanticipated interventions have larger effects than anticipated ones because agents cannot adjust consumption and investment plans to offset them; third, that interventions crowd out private intermediation; and fourth, that tighter credit constraints amplify the effects of all interventions by rendering the Financier’s supply of intermediation less elastic. We present the model primitives and empirical predictions below, and provide additional derivations and proofs in Appendix A.

The Home Household. The Home Household solves an intertemporal utility maximization problem,

$$\max_{\{C_{NTs}, C_{Hs}, C_{Fs}\}_{s=t}^2} \sum_{s=t}^2 \beta^s \mathbf{E}_t^{(\cdot)} [\varphi_s \ln C_s],$$

for $t \in \{0, 1, 2\}$, where $\mathbf{E}_t^{(\cdot)}[\cdot]$ denotes a conditional expectation operator that includes period- t information on realized preference shocks but excludes information on the exact intervention thresholds the Central Bank sets in period t , β is the subjective discount factor, $\varphi_t \equiv \chi_t + \alpha_t + \iota_t$ is a sum of stochastic preference shocks, and

$$C_t \equiv [(C_{NTt})^{\chi_t} (C_{Ht})^{\alpha_t} (C_{Ft})^{\iota_t}]^{\frac{1}{\varphi_t}} \quad (1)$$

denotes the Home Household consumption basket, a consumption composite composed of Home non-tradable goods C_{NTt} , Home tradable goods C_{Ht} , and Foreign tradable goods C_{Ft} . The intertemporal maximization is subject to period budget constraints of the form

$$Q_{Ht} + p_{Ht}C_{Ht} + p_{Ft}C_{Ft} + C_{NTt} = Y_{NTt} + p_{Ht}Y_{Ht} + R_{Ht}Q_{Ht-1}, \quad (2)$$

where Q_{Ht} denotes the real value of Home holdings of the Home bond, with $Q_{H-1} = Q_{H2} = 0$, p_{Ht} and p_{Ft} are relative prices of the Home and Foreign tradable goods, and Y_{NTt} and Y_{Ht} are stochastic endowments of the Home non-tradable and tradable goods, respectively. The Home non-tradable good is the numéraire for the Home economy.

The Home Household's intertemporal utility maximization problem yields the following optimality conditions,

$$\mathbf{E}_t^{(\cdot)}[\lambda_s] = \mathbf{E}_t^{(\cdot)}[\chi_s/C_{NTs}] \quad \text{and} \quad \mathbf{E}_t^{(\cdot)}[\lambda_s] = \beta \mathbf{E}_t^{(\cdot)}[\lambda_{s+1}R_{Hs+1}], \quad (3)$$

where λ_s denotes the Lagrange multiplier on the Home Household's period- t budget constraint and R_{Hs+1} is the gross real return on the Home bond, with $t \leq s < 2$.

The Home Household also solves an intratemporal utility maximization problem, allocating expenditure across domestic and international goods. Specifically, the Home Household maximizes the logarithm of the consumption composite in (1),

$$\max_{C_{NTt}, C_{Ht}, C_{Ft}} \chi_t \ln C_{NTt} + \alpha_t \ln C_{Ht} + \iota_t \ln C_{Ft},$$

subject to a consumption expenditure constraint,

$$p_t C_t = C_{NTt} + p_{Ht}C_{Ht} + p_{Ft}C_{Ft}, \quad (4)$$

where p_t denotes the Home price index in terms of the Home non-tradable numéraire, and where the Home Household takes total consumption expenditure $p_t C_t$ as fixed in the intratemporal problem. The Home Household's intratemporal problem yields the following

optimality conditions for consumption expenditure on Home and Foreign tradable goods,

$$p_{Ft}C_{Ft} = (\chi_t/C_{NTt})\iota_t \quad \text{and} \quad p_{Ht}C_{Ht} = (\chi_t/C_{NTt})\alpha_t. \quad (5)$$

We maintain several simplifying assumptions that [Gabaix and Maggiori \(2015\)](#) make in their Basic Gamma Model: namely, that the Home non-tradable endowment adjust proportionally to fluctuations in the Home preference for non-tradable goods, $Y_{NTt} = \chi_t$, and that the Home Household does not discount future utility, $\beta = 1$. These assumptions simplify the model and focus our investigation on understanding the impact of Central Bank interventions on the real exchange rate.

The maximization problems of the Foreign Household are analogous to those of the Home Household, and we maintain a similar set of simplifying assumptions for the Foreign Household. We present details of the Home Household's maximization problems and our specification of the Foreign Household in [Appendices A.1](#) and [A.2](#).

The Financier. The Financier intermediates bond trade and absorbs cross-country imbalances in Home and Foreign Household demand for bonds. While Households borrow and lend only in their respective domestic bonds, they trade in international goods markets where cross-country imbalances can arise. The Financier maximizes single-period firm value,

$$V_t = \beta \mathbb{E}_t^{(-)} \left[R_{Ht+1} Q_{Ht}^f + \frac{e_{t+1}}{e_t} R_{Ft+1}^* Q_{Ft}^f \right], \quad (6)$$

where V_t denotes the Financier's value. The Financier's holdings of Home and Foreign bonds are denoted Q_{Ht}^f and Q_{Ft}^f , respectively, and the real return on the Foreign bond is R_{Ft+1}^* . The real exchange rate e_t is defined in units of the Home numéraire per unit of the Foreign numéraire. The Financier transfers any gains or losses to the Foreign Household each period, as in [Gabaix and Maggiori \(2015\)](#).

The Financier has limited capacity to bear risk. This limitation derives from a constraint that creditors impose to prevent the Financier from diverting funds. The

constraint aligns incentives such that the value to the Financier of ceasing to intermediate and diverting funds never exceeds the value of continuing to intermediate bond trade. To motivate the functional form of the constraint, [Gabaix and Maggiori \(2015\)](#) suggest that the Financier can more easily divert funds when its portfolio is larger. The constraint is given by

$$\frac{V_t}{\mathbb{E}_t^{(-)}[e_t]} \geq \underbrace{\left| \frac{Q_{Ht}^f}{\mathbb{E}_t^{(-)}[e_t]} \right|}_{\text{Creditor Claims}} \times \Gamma \underbrace{\left| \frac{Q_{Ht}^f}{\mathbb{E}_t^{(-)}[e_t]} \right|}_{\text{Divertible Fraction}}, \quad (7)$$

where the parameter $\Gamma > 0$ governs the Financier's ability to divert funds, and therefore governs the risk-bearing capacity of the Financier. When Γ approaches zero, the Financier's risk-bearing capacity approaches infinity. When Γ approaches infinity, the Financier's risk-bearing capacity approaches zero and the economy approaches financial autarky.⁴

We assume the Financier begins each period with zero assets, so its balance sheet constraint is given by

$$Q_{Ht}^f + Q_{Ft}^f = 0, \quad (8)$$

and any bond position the Financier takes must cost nothing to construct.⁵

The Financier's profit maximization problem yields the following optimality condition, which pins down the amount of bond trade the Financier chooses to intermediate,

$$\frac{Q_{Ht}^f}{\mathbb{E}_0^{(-)}[e_t]} = \frac{1}{\Gamma} \mathbb{E}_0^{(-)} \left[R_{Ht+1} - \frac{e_{t+1}}{e_t} R_{Ft+1}^* \right]. \quad (9)$$

The expression shows how higher Γ corresponds to lower risk-bearing capacity and less intermediation.

⁴[Gabaix and Maggiori \(2015\)](#) allow Γ to depend positively on the variance of the real exchange rate. We find limited empirical support for a positive relationship between financial constraints on intermediaries and the variance of the real exchange rate in our data, outside of crisis periods. See the Appendix Section [B.2](#) for more details. For this reason, we treat Γ as a fixed parameter.

⁵We assume the microfoundation in [Gabaix and Maggiori \(2015\)](#) to be operating in the background. In their setup, a measure of individual households populates each economy, and a new Household is randomly selected to serve as Financier each period. Households enter this occupation with zero assets, and maximize their single-period profits. Our representative agent model is isomorphic to the micro-founded model.

Central Bank. The Central Bank conducts sterilized foreign exchange interventions by constructing zero-cost portfolios of Home and Foreign bonds. The Central Bank has no currency liabilities and transfers any gains or losses from its interventions to the Foreign Household each period, mirroring the assumption that [Gabaix and Maggiori \(2015\)](#) make for the Financier. Accordingly, the Central Bank's balance sheet satisfies the following condition,

$$Q_{Ht}^{cb} + Q_{Ft}^{cb} = 0,$$

where Q_{Ht}^{cb} and Q_{Ft}^{cb} denote the real values of the Central Bank's holdings of Home and Foreign bonds.

The Central Bank intervenes when trade shocks rise above or fall below intervention thresholds that the Central Bank sets exogenously. In particular, the Central Bank's interventions take the form of bond purchases or sales defined by the following equation,

$$Q_{Ht}^{cb} = q[H(\Delta\iota_t - \bar{\iota}_t) - H(\underline{\iota}_t - \Delta\iota_t)] = q\Delta H_t, \quad \underline{\iota}_t \leq \bar{\iota}_t, \quad (10)$$

where $q > 0$ governs the scale of the intervention, $H(\cdot)$ denotes a Heaviside function defined to equal one when its argument is strictly positive and zero otherwise, $\Delta\iota_t \equiv \iota_t - \iota_t^*$ defines a trade shock as the cross-country difference between Home and Foreign preferences for imports, and $\bar{\iota}_t$ and $\underline{\iota}_t$ denote the Central Bank's upper and lower intervention thresholds. The Heaviside functions govern the sign of the Central Bank's interventions, and to lighten notation we define their difference as $\Delta H_t \equiv H(\Delta\iota_t - \bar{\iota}_t) - H(\underline{\iota}_t - \Delta\iota_t) \in \{-1, 0, 1\}$. Because the intervention thresholds are chosen by the Central Bank, we treat ΔH_t as an exogenous policy variable.

Our model allows for two stylized intervention types: swap and spot interventions. In a swap intervention, the Central Bank takes a bond position in period zero and unwinds the position in period one.⁶ In a spot intervention, the Central Bank takes a bond position in period zero and maintains the position in period one. These stylized interventions capture two features of real-world foreign exchange interventions: first, because they operate

⁶We show in [Appendix A.8](#) that swaps modeled as bond market transactions provide the same payoff as standard swaps in spot and forward currency markets.

entirely through bond markets, they are sterilized; second, because the swap intervention is unwound after one period while the spot intervention persists, the spot intervention is longer-lived.

The Central Bank responds to sufficiently large positive trade shocks by buying Home bonds and selling Foreign bonds, or to sufficiently large negative trade shocks by selling Home bonds and buying Foreign bonds. In the former case Q_{Ht}^{cb} is positive, in the latter case Q_{Ht}^{cb} is negative. The balance sheet constraint then implies the opposite sign for Q_{Ft}^{cb} . The Central Bank does not intervene when trade shocks remain within its intervention thresholds.

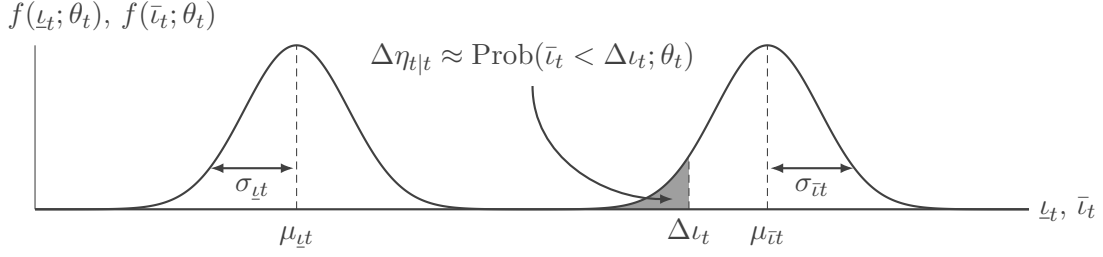
To gain intuition for the cause and effect of a Central Bank intervention, consider the currency flows leading to and resulting from an intervention.⁷ A relative rise in the Home preference for Foreign goods (a positive trade shock) induces the Home Household to import more. The Home Household exchanges Home currency for Foreign currency and Home currency weakens. The Central Bank responds by buying Home bonds and selling Foreign bonds. The Central Bank exchanges Foreign currency for Home currency and Home currency strengthens. Thus, the Central Bank buys Home bonds to strengthen Home currency in response to a positive trade shock. The parallel construction also holds for a negative trade shock.

The Household and the Financier have imperfect information about the Central Bank's intervention thresholds. In period zero, the Central Bank communicates distributions with parameters θ_0 for its thresholds, $F(\bar{\iota}_t; \theta_0)$ and $F(\underline{\iota}_t; \theta_0)$ for $t \in \{0, 1\}$, but not the exact values of the thresholds. In period one, the Central Bank can update the distributions for its period-one thresholds, $F(\bar{\iota}_1; \theta_1)$ and $F(\underline{\iota}_1; \theta_1)$. Withholding information about its intervention thresholds allows the Central Bank to conduct unanticipated interventions with larger exchange rate effects, as we later show.⁸

⁷When we refer to currency flows, we abuse the word currency to mean a claim to the numéraire of the economy, mirroring the language in [Gabaix and Maggiori \(2015\)](#), as described in their footnote 5.

⁸Since the Central Bank can intervene twice at most, we abstract from credibility considerations and do not require the Central Bank's actions to be consistent with its communications. However, the model's empirical predictions are more sensible when the Central Bank's actions and communications are reasonably consistent—for example, when it avoids communicating that it will buy bonds before intervening to sell them. Given the limited number of Central Bank interventions, we do not allow agents to learn from Central Bank actions.

Figure 2: Distributions of Intervention Thresholds



Notes. The figure shows normal density functions $f(\underline{l}_t; \theta_t)$, $f(\bar{l}_t; \theta_t)$ for the Central Bank's intervention thresholds \underline{l}_t and \bar{l}_t , as perceived by Households and the Financier in period t . The distributions are characterized by means and standard deviations, $\theta_t = (\mu_{\underline{l}_t}, \mu_{\bar{l}_t}, \sigma_{\underline{l}_t}, \sigma_{\bar{l}_t}, \dots)$, which the Central Bank communicates to the Household and Financier. The shaded region shows the probability, as perceived by the Household and Financier, that the Central Bank will intervene positively by purchasing Home bonds and selling Foreign bonds to strengthen Home currency. The value $\Delta\eta_{t|t}$ approximately equals the shaded probability in the figure, because the probability of a negative intervention is approximately zero. That is, $\Delta\eta_{t|t} \approx \text{Prob}(\bar{l}_t < \Delta l_t; \theta_t) - 0$.

The parameters θ_0 and θ_1 govern the ability of Households and the Financier to anticipate interventions when forming consumption and investment plans. In period t , the expected intervention in period $s \geq t$ is

$$\mathbb{E}_t^{(-)} [Q_{Hs}^{cb}] = q \mathbb{E}_t^{(-)} [\Delta H_s] = q \Delta\eta_{s|t}, \quad (11)$$

where we define $\Delta\eta_{s|t} \equiv \text{Prob}(\bar{l}_s < \Delta l_s; \theta_t) - \text{Prob}(\Delta l_s < \underline{l}_s; \theta_t) \in [-1, 1]$. We treat $\Delta\eta_{s|t}$ as an exogenous policy variable controlled by the Central Bank.⁹ The Central Bank cannot forecast future iid trade shocks, but if it responds to an observed shock in period zero, it may wish to signal that its intervention will persist into period one; therefore, we require that any non-zero $\Delta\eta_{1|0}$ be of the same sign as and no larger than $\Delta\eta_{0|0}$. Figure 2 depicts distributions of the Central Bank's upper and lower intervention thresholds

⁹The expectation of the Heaviside function equals the probability that its argument is positive. For example, the probability of a positive intervention in $s = t$ is given by

$$\mathbb{E}_t^{(-)} [H(\Delta l_t - \bar{l}_t)] = \int_{-\infty}^{\infty} H(\Delta l_t - \bar{l}_t) dF(\bar{l}_t; \theta_t) = \int_{-\infty}^{\Delta l_t} 1 dF(\bar{l}_t; \theta_t) = \text{Prob}(\bar{l}_t < \Delta l_t; \theta_t),$$

where the trade shock Δl_t is known and the Central Bank controls the parameters in θ_t through communication policy that we do not model. A similar expression holds for the expectation of a negative intervention in the current period. For the expectation of interventions in future periods ($t < s$), the trade shock Δl_s is random and the joint distribution of Δl_s and \bar{l}_s must be considered. But the joint distribution will also depend on θ_t and can therefore be controlled by the Central Bank. Hence, we treat $\Delta\eta_{s|t}$ as an exogenous policy variable for $t \leq s < 2$, and impose only mild regularity conditions.

and the probability that the Household and the Financier assign to the event that the Central Bank intervenes positively in response to an observed trade shock. The figure assumes normally distributed thresholds with means and standard deviations such that the probability of a positive intervention is positive and the probability of a negative intervention is approximately zero.

Equilibrium Real Exchange Rate. We work with linearized equations in deviations from the non-stochastic steady state of the economy for the remainder of our analysis. We use hats to denote deviations from steady state.

Bond markets clear in equilibrium. With bonds in zero net supply, market clearing for the Home bond requires that the demands of the Home Household, the Financier, and the Central Bank sum to zero,

$$\hat{Q}_{Ht} + \hat{Q}_{Ht}^f + \hat{Q}_{Ht}^{cb} = 0. \quad (12)$$

Bond holdings are zero for all parties in the non-stochastic steady state, so we linearize bond holdings in levels and divide by the non-stochastic steady state value of the Household preference for imports as a normalization.¹⁰ To obtain an expression for the real exchange rate, we combine linearized demand equations for the Home Household, the Financier, and the Central Bank with the Home bond market clearing condition in (12).

Home Household demand for Home bonds derives from the period budget constraints in (2). Under our simplifying assumptions, after imposing market clearing for the Home good, the budget constraints take the following forms,

$$\begin{aligned} \hat{Q}_{H0} &= \hat{e}_0 - \Delta \hat{l}_0 + O(\epsilon^2) \\ \hat{Q}_{H1} &= \hat{e}_0 + \hat{e}_1 - \Delta \hat{l}_0 - \Delta \hat{l}_1 + O(\epsilon^2) \\ 0 &= \hat{e}_0 + \hat{e}_1 + \hat{e}_2 - \Delta \hat{l}_0 - \Delta \hat{l}_1 - \Delta \hat{l}_2 + O(\epsilon^2), \end{aligned} \quad (13)$$

¹⁰For example, for the Home Household, we define $\hat{Q}_{Ht} \equiv (Q_{Ht} - Q_H)/\iota$, where $Q_H = 0$ is the Home Household's steady-state bond demand and $\iota \equiv 1$ is the Home Household's steady-state preference for imports. Because bond holdings are linearized in levels, the clearing condition in (12) is an exact condition rather than a first-order approximation. We linearize most other variables in logs, and the bond demand expressions in (13) are first-order approximate.

where the third constraint requires that total variation in the real exchange rate equals total variation in trade shocks and gives rise to the “boomerang” effect of Central Bank interventions that [Gabaix and Maggiori \(2015\)](#) find. For a given sequence of trade shocks, interventions that shifts the real exchange rate in one period must be offset by compensating shifts in future periods. The strength of this effect depends on the model’s finite horizon.

The Financier’s demand for Home bonds derives from the Financier’s optimality condition in (9). Linearizing this condition leads to the following demand,

$$\hat{Q}_{Ht}^f = \frac{1}{\Gamma} E_t^{(-)}[\hat{e}_t - \hat{e}_{t+1}] + O(\epsilon^2), \quad (14)$$

which again shows that higher Γ reduces the intermediation undertaken by the Financier, all else equal. The gross real returns on Home and Foreign bonds that appear in (9) are zero to a first-order approximation; this result derives from the simplifying assumption that non-tradable endowments adjust proportionally to fluctuations in preference parameters for non-tradable goods.¹¹

Finally, we rewrite the Central Bank’s policy rule in (12) as follows,

$$\hat{Q}_{Ht}^{cb} = q\Delta H_t, \quad (15)$$

where we use the fact that the Central Bank’s intervention is zero in the non-stochastic steady state.¹² We provide derivations of the linearized demand equations in (12)–(15) in [Appendix A.3](#).

Combining the linearized demand equations with the market clearing condition for the Home bond, we obtain solutions for the path of expected and realized real exchange rates in periods zero, one, and two. Our primary interest lies in the response of the real exchange

¹¹As [Gabaix and Maggiori \(2015\)](#) explain, this simplification renders the Household’s marginal utility of non-tradable consumption constant; bonds are denominated in the non-tradable good, so precautionary and intertemporal consumption smoothing motives cancel and bond returns are also constant.

¹²Recall that we linearize bond holdings in levels. For the Central Bank, we have $\hat{Q}_{Ht}^{cb} \equiv (Q_{Ht}^{cb} - Q_H^{cb})/\iota = Q_{Ht}^{cb}$, where the last equality follows from $Q_H^{cb} = 0$ and $\iota = 1$. Hence, (15) is an exact expression, not an approximation of (10).

rate in period zero to Central Bank interventions in the anticipated and unanticipated cases when financial constraints are tight or loose. For this reason, we relegate the full set of solutions and a brief analysis of exchange rate dynamics to Appendices A.4 and A.5. The real exchange rate in period zero is given by

$$\begin{aligned} \hat{e}_0 = & \Delta\hat{i}_0 - \frac{2\Delta\hat{i}_0 - E_0^{\leftarrow}[\Delta\hat{i}_1] - E_0^{\leftarrow}[\Delta\hat{i}_2]}{3 + \Gamma} + \Gamma \frac{\Delta\hat{i}_0 - E_0^{\leftarrow}[\Delta\hat{i}_2]}{(1 + \Gamma)(3 + \Gamma)} \\ & - q \frac{\Delta H_0 - \Delta\eta_{0|0}}{1 + \Gamma} - \Gamma q \frac{\Delta H_0}{1 + \Gamma} - \Gamma q \frac{\Delta\eta_{1|0} - \Delta\eta_{0|0}}{(1 + \Gamma)(3 + \Gamma)} + O(\epsilon^2). \end{aligned} \quad (16)$$

To build intuition for the terms that appear in (16), consider separately the first and second lines on the right-hand side of the expression, focusing on the extreme cases of zero and infinite credit constraints.

If the Central Bank is passive ($q = 0$), the real exchange rate has three determinants in the first line on the right-hand side of (16): the pure effect of the trade shock, the intertemporal smoothing effect of bond trade, and a credit constraint friction. With severe credit constraints ($\Gamma \rightarrow \infty$), only the first term survives and trade shocks drive the real exchange rate in autarky. Without credit constraints ($\Gamma \rightarrow 0$), the first and second terms survive and bond trade smooths the real exchange rate optimally. With limited credit constraints ($0 < \Gamma < \infty$), all three terms survive and the real exchange rate deviates from the frictionless ideal. If trade shocks follow a random walk, zero bond holdings are optimal and the second and third terms again vanish.

If the Central Bank is active ($q > 0$), interventions operate through three channels in the second line on the right-hand side of (16): a surprise channel, a private intermediation replacement channel, and a private intermediation support channel. Without credit constraints ($\Gamma \rightarrow 0$), only the first term survives and Central Bank interventions are effective when they surprise the Household and Financier. With severe credit constraints ($\Gamma \rightarrow \infty$), only the second term survives; the Central Bank completely replaces the Financier and intermediates all bond trade. With limited credit constraints ($0 < \Gamma < \infty$), all three terms survive and the Central Bank supports the Financier by reducing its intermediation burden.

Empirical Predictions. The Gamma-Eta Model yields an intuitive expression for the real exchange rate that captures the interplay between Central Bank interventions, market anticipation, and credit constraints. We now derive qualitative predictions from the model to motivate the empirical analysis that follows. Specifically, we derive predictions on the direction of intervention effects, on the effects of anticipated versus unanticipated interventions, on the effects of swap versus spot interventions, on the crowding out of private intermediation, and on the effect of interventions during periods of looser and tighter credit constraints. We provide proofs for the predictions in Appendix A.6.

Prediction 1 (Direction of Intervention Effects). *Consider a Central Bank intervention $\Delta H_0 \neq 0$, whereby the Central Bank constructs a portfolio of Home and Foreign bonds. The real exchange rate responds to the currency flows arising from the portfolio construction. The direction of the response depends on the direction of the intervention as follows,*

$$\text{sign} \frac{\partial \hat{e}_0}{\partial q} = - \text{sign} \Delta H_0 .$$

A positive intervention ($\Delta H_0 > 0$), whereby the Central Bank buys Home bonds and sells Foreign, strengthens Home currency relative to Foreign and the real exchange rate falls. A negative intervention ($\Delta H_0 < 0$), whereby the Central Bank sells Home bonds and buys Foreign bonds, weakens Home currency relative to Foreign and the real exchange rate rises.

Prediction 2 (Anticipated versus Unanticipated Interventions). *Consider a Central Bank communication that raises the expectation of a positive intervention in period zero ($\Delta \eta_{0|0} > 0$). The Financier anticipates stronger Home currency in period zero and sells Home bonds to buy Foreign bonds. This anticipation weakens Home currency and causes the real exchange rate to rise,*

$$\frac{\partial^2 \hat{e}_0}{\partial q \partial \Delta \eta_{0|0}} > 0 .$$

If the Central Bank carries out a positive intervention in period zero, the real exchange rate will fall by less if the Financier anticipates the intervention.

If the Financier faces no credit constraint ($\Gamma = 0$) and the period-zero intervention is

fully anticipated ($\Delta\eta_{0|0} = \Delta H_0 \neq 0$), then

$$\frac{\partial \hat{e}_0}{\partial q} = 0$$

and interventions have no effect. In this case, the Central Bank can build foreign exchange reserves without disturbing the real exchange rate.

Prediction 3 (Spot versus Swap Interventions). *To isolate the effect of persistence in long-lived spot interventions, consider an anticipated period-zero intervention ($\Delta\eta_{0|0} = \Delta H_0 \neq 0$) that the Financier knows will either persist ($\Delta\eta_{1|0} = \Delta H_0$) or not persist ($\Delta\eta_{1|0} = 0$). If the Financier is constrained ($\Gamma > 0$), then*

$$\left| \frac{\partial \hat{e}_0}{\partial q} \right|_{\Delta\eta_{1|0}=\Delta H_0} > \left| \frac{\partial \hat{e}_0}{\partial q} \right|_{\Delta\eta_{1|0}=0}$$

and the exchange rate effect will be larger if the intervention persists. This result holds also when a Central Bank communication raises the period-zero expectation of persistence, and therefore holds for partially unanticipated interventions.

Prediction 4 (Private Intermediation). *Consider a Central Bank communication that raises the expectation of an intervention in period zero. The Financier responds to the Central Bank's communication by adjusting the amount of its private intermediation as follows,*

$$\text{sign} \frac{\partial \hat{Q}_{H0}^f}{\partial q} = - \text{sign} \Delta\eta_{0|0}.$$

Suppose the Financier expects the Central Bank to intervene positively by buying Home bonds and selling Foreign. The Financier will then expect to earn a reduced excess return on the home bond, and will therefore reduce the amount of private intermediation it undertakes.

Prediction 5 (Credit Constraints). *Consider a tightening of credit constraints. If the Central Bank is passive ($q = 0$), tighter credit constraints lower the amount of*

intermediation the Financier undertakes,

$$\text{sign} \frac{\partial \hat{Q}_{H0}^f}{\partial \Gamma} = - \text{sign} \hat{Q}_{H0}^f.$$

The Financier's Home and Foreign bond positions shrink when credit constraints tighten, limiting the ability of Households to smooth consumption intertemporally.

If the Central Bank is active ($q > 0$), then tighter credit constraints amplify the effects of interventions,

$$\text{sign} \frac{\partial^2 \hat{e}_0}{\partial q \partial \Gamma} = \text{sign} \frac{\partial \hat{e}_0}{\partial q}.$$

including both unanticipated interventions and partially or fully anticipated period-zero swap interventions ($\Delta\eta_{0|0} > \Delta\eta_{1|0} \rightarrow 0$) and spot interventions ($\Delta\eta_{0|0} = \Delta\eta_{1|0} > 0$).¹³

To map these predictions to the empirical analysis that follows, we treat Brazil as Home, with currency BRL, and the U.S. as Foreign, with currency USD. In this setup, the central bank is the BCB, and a positive intervention refers to an intervention to sell USD, either through a spot or swap transaction. In the following sections, we describe the data and present the results of our empirical analysis, motivated by the predictions of the Gamma-Eta Model.

3 Datasets

In our empirical analysis, we focus on the Brazilian case and employ a public dataset released by the BCB in 2023, along with a number of supporting datasets on foreign exchange, interest rates, intermediary constraints, and macroeconomic aggregates. We briefly describe the BCB's policy framework before introducing the data and defining key variables.

¹³Define a positive spot intervention as $(\Delta H_0 = 1) \cap (\Delta H_1 = 1)$. If the Financier expects only spot interventions, then $\text{Prob}(\Delta H_1 = 1 \mid \Delta H_0 = 1) = \text{Prob}(\Delta H_0 = 1 \mid \Delta H_1 = 1) = 1$. It follows that

$$\begin{aligned} \text{Prob}(\Delta H_0 = 1 \cap \Delta H_1 = 1) &= \text{Prob}(\Delta H_0 = 1) \times \text{Prob}(\Delta H_1 = 1 \mid \Delta H_0 = 1) = \text{Prob}(\Delta H_0 = 1) \\ &= \text{Prob}(\Delta H_1 = 1) \times \text{Prob}(\Delta H_0 = 1 \mid \Delta H_1 = 1) = \text{Prob}(\Delta H_1 = 1). \end{aligned}$$

The same holds for negative spot interventions. Definitions of $\Delta\eta_{0|0}$ and $\Delta\eta_{1|0}$ then imply $\Delta\eta_{0|0} = \Delta\eta_{1|0}$.

3.1 Policy Framework

Since early 1999, Brazil's monetary system has operated under an inflation-targeting framework established by Presidential Decree No. 3,088. The National Monetary Council, composed of the finance and planning ministers and the BCB governor, sets the inflation target based on the Extended National Consumer Price Index (IPCA).

The BCB uses the Selic rate as its primary tool to achieve this inflation target. The Selic rate is the weighted average interest rate on overnight interbank loans, which are collateralized by federal government securities and settled through the Special System for Settlement and Custody (Selic, in Portuguese). The BCB's Monetary Policy Committee (Copom) meets regularly to set the target for the Selic rate, with the goal of keeping the IPCA inflation rate within a predefined range, specified by upper and lower bands, over the relevant monetary policy horizon.

Regarding exchange rate policy, the BCB operates a floating regime, which the IMF defines as a largely market-determined exchange rate without a predictable path, where intervention is permitted to prevent excessive volatility and manage liquidity but not to maintain a specific rate. The BCB's exchange rate regime does not meet the IMF's *free-floating* definition, which requires that authorities intervene at most three times in any six-month period, with each intervention lasting no more than three business days (Nowzad et al., 2021).

3.2 BCB FX Interventions

The primary goals of the BCB's FXI are to maintain an orderly market, control volatility, and ensure liquidity, while also accumulating reserves during periods of capital inflows (Central Bank of Brazil, 2019). To achieve these goals, the BCB uses spot and swap interventions. Spot interventions are often used to address persistent or severe market imbalances. In contrast, swap interventions are often used to hedge temporary currency mismatches on bank balance sheets; for example, currency swap interventions helped mitigate the spillovers of the US Taper Tantrum on bank balance sheets (Chamon, 2019; Gonzalez et al., 2019; da Costa Filho, 2021).

To execute interventions, the BCB's International Reserve Department transacts with 14 accredited financial institutions known as Dealers-14. These institutions are mainly large banks authorized by the BCB to operate in an inter-dealer market. They play a crucial role in supplying USD liquidity to customers in the Brazilian FX market.

In 2023, the BCB released a comprehensive public dataset of its historical foreign exchange interventions since 1999.¹⁴ The dataset details the sign of each intervention (USD purchase or sale), the auction amount, the announcement date and high-frequency announcement timestamp, the operation date, and the intervention type. Four intervention types are reported: spot purchases, spot sales, traditional swaps, and reverse swaps.

In *spot operations*, the BCB buys or sells USD in exchange for BRL in the interbank foreign exchange market for settlement in two business days.

In *traditional swap operations*, the BCB takes a buying position in swap contract auctions. While classified as swaps, these contracts function as non-deliverable futures (NDFs) settled in BRL (Nedeljkovic and Saborowski, 2019). Unlike a standard swap, there is no exchange of principals. Instead, the BCB pays the dealer the variation in the BRL/USD exchange rate, plus the onshore USD rate known as the *cupom cambial*, and receives the domestic BRL Selic rate.¹⁵ A buying position in these swaps is analogous to the BCB taking a long NDF position, meaning it is long BRL (short USD). Therefore, the traditional swap helps dealers hedge against USD appreciation and is useful for managing net USD liabilities.

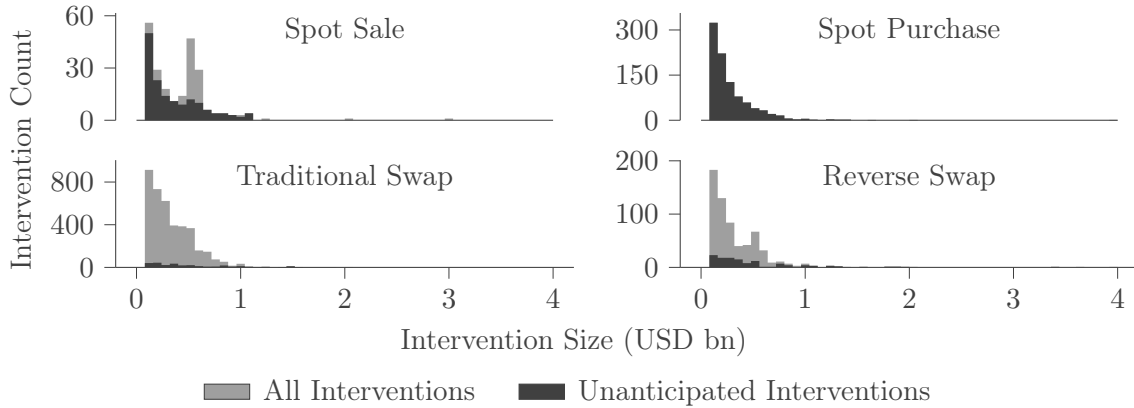
In *reverse swap operations*, the BCB takes a selling position in swap contracts. Similar to traditional swaps, there is no exchange of principals. Here, the BCB pays the BRL Selic rate, while the dealer pays the *cupom cambial* plus the BRL/USD exchange rate variation. A selling position is equivalent to the BCB taking a short NDF position, meaning it is short BRL (long USD). This allows dealers to hedge against USD depreciation and manage net USD asset positions.¹⁶

¹⁴The database can be found on the BCB's Dados Abertos portal <https://www.bcb.gov.br/conteudo/dadosabertos/BCBDepin/historico-atuacoes-mercado-cambio.csv>.

¹⁵The *cupom cambial* is the spread between the overnight interbank deposit rate and expected BRL/USD depreciation. See Nedeljkovic and Saborowski (2019) for details.

¹⁶For institutional details on swap operations, see <https://www.bcb.gov.br/estabilidadefinanceira/swapcambial>.

Figure 3: Histograms of BCB FX Market Interventions

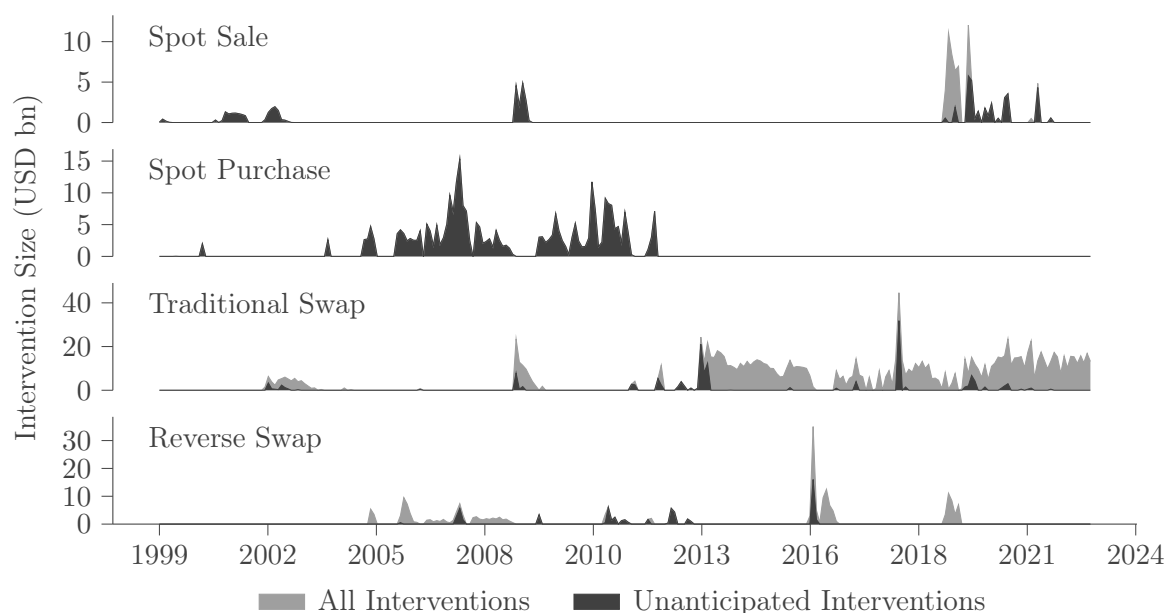


Notes. These figures show 50-bin histograms of BCB’s interventions in the FX markets, by intervention type. The horizontal axes show the intervention size in USD billions, after aggregating at daily frequency. The lighter shade shows all interventions, both anticipated and unanticipated, while the darker shade shows the subset of unanticipated interventions. Unanticipated interventions are defined as interventions with an announcement equal to the operation date, while anticipated interventions are defined as interventions with an announcement date that precedes the operation date. Traditional swaps involve the sale of USD while reverse swaps involve the purchase of USD at the spot leg of the swap contract. The sample period runs from 1999-01-22 to 2023-04-27.

The intervention announcement date and high-frequency timestamp in the database indicate when the BCB informed the public about a future foreign exchange intervention or, in the case of auctions in interbank spot or forward markets, when an intervention had begun. The intervention operation date specifies when the day the intervention was conducted, but includes no high-frequency timestamp. The announcement and operation dates allow us to classify interventions as unanticipated or anticipated. We classify interventions as unanticipated if the operation date equals the announcement date and as anticipated if the operation date occurs after the announcement date.

Figure 3 illustrates the size distribution of interventions by type. The mean unanticipated spot buy (sell) intervention in the database is 0.19 (0.17) billion USD with a standard deviation of 0.24 (0.22) billion USD, and the mean unanticipated traditional (reverse) swap intervention is 0.43 (0.35) billion USD with a standard deviation of 0.41 (0.45) billion USD. Unanticipated interventions are generally larger than anticipated interventions for all intervention types. There are 1,483 (385) unanticipated and 0 (87) anticipated spot buy (sell) interventions in the database, while there are 345 (174) unanticipated and 5,094 (846)

Figure 4: Time Series of BCB FX Market Interventions



Notes. These figures show BCB FX market interventions over time, by intervention type. The horizontal axes show the intervention size in USD billions, after aggregating at monthly frequency. The lighter shade shows all interventions, both anticipated and unanticipated, while the darker shade shows the subset of unanticipated interventions, defined as interventions with an announcement equal to the operation date.

anticipated traditional (reverse) swap interventions. Table B.1 in the Online Appendix provides additional summary statistics on the BCB’s foreign exchange interventions.

Figure 4 illustrates patterns in BCB interventions over time, showing a shift towards swaps as the principal policy instrument in recent years and suggesting two distinct periods of FXI use (Central Bank of Brazil, 2019).¹⁷ From 2005 to 2012, the BCB primarily used FXI to lean against capital flows and accumulate foreign reserves through USD spot purchases, except during periods of economic stress, like the Global Financial Crisis in 2008 and 2009, when it conducted spot sales to provide USD liquidity to the FX market. Since 2012, the BCB has used swaps extensively to manage FX liquidity imbalances, providing hedging options when market supply is limited or abundant (Gonzalez et al., 2019; Nedeljkovic and Saborowski, 2019), except during the COVID-19 pandemic, when spot sales were again used.

FX swaps are attractive instruments for the BCB, likely because they provide USD

¹⁷Figure B.1 in the Online Appendix shows cumulative intervention amounts by type over time.

hedging without depleting its international reserves. Historically, central banks have used FX swaps primarily to address short-term liquidity pressures rather than as persistent interventions in FX markets (McCauley and Schenk, 2020). Additionally, the balance sheet effects of swaps are short-lived: with a traditional swap, the BCB provides USD hedging rather than directly lending reserves, as there is no exchange of principals.¹⁸ In contrast, spot sales of USD may have longer-lasting effects, as they directly reduce the BCB’s precautionary savings and weaken its insurance against periods of tight intermediary constraints (Cheng, 2015; Jeanne and Sandri, 2020).

While the BCB does not explicitly differentiate between anticipated and unanticipated swaps in its official framework, empirical patterns suggest that unanticipated swaps typically have short maturities (less than 2 days), whereas anticipated swaps have a broad range of maturities, from overnight to 3 months. Figure B.2 in the Online Appendix shows the maturity breakdown of traditional and reverse currency swaps for both anticipated and unanticipated interventions.

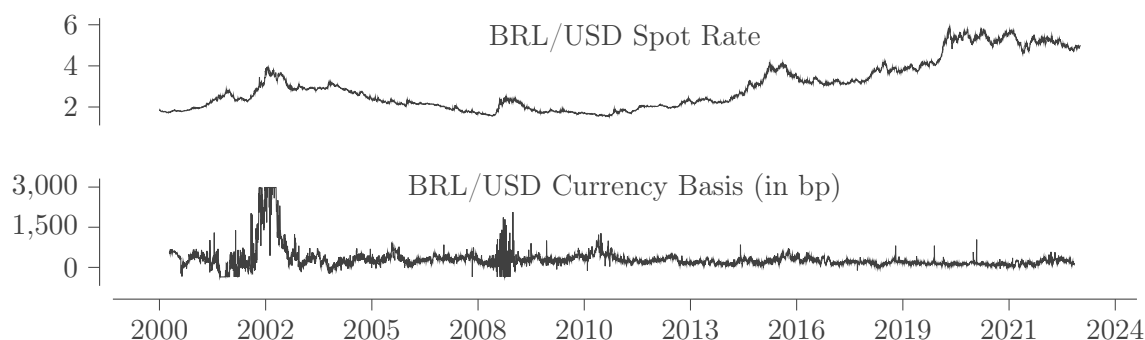
3.3 Additional Data Sources

B3 Exchange Tick Database. We use tick-by-tick data on futures and interest rates, obtained from Brazil’s main stock exchange, B3, via an FTP link that was available for a limited time. The dataset covers transactions from 28/02/2019 to 23/01/2020, spanning 224 trading days, and includes trading prices, volumes, aggressor buy-sell signals, market participant trading codes, and bid-ask quotes. For this study, we focus on the BRL/USD WDO contract, a mini USD futures contract traded on B3.¹⁹ Each contract represents an exposure of 10,000 USD and is quoted in BRL per USD. WDO contracts expire monthly and allow investors to take positions on the future BRL/USD exchange rate. An alternative contract, the DOL futures contract, offers similar characteristics

¹⁸Earlier in this section, we outline the mechanics of BCB’s traditional and reverse swap contracts. In a traditional swap, the BCB takes a position equivalent to a long NDF in BRL (short USD), paying the dealer the variation in the BRL/USD exchange rate plus the onshore USD rate, known as the *cupom cambial*, while receiving the BRL Relic rate. Upon maturity, the swap’s cash flows reflect exchange rate changes and interest rate differentials, with only a marginal impact on the BCB’s USD reserves.

¹⁹For more details, see the B3 official website: https://www.b3.com.br/en_us/products-and-services/trading/exchange-rates/mini-u-s-dollar-futures.htm

Figure 5: BRL/USD Spot Rate and Currency Basis



Notes. The upper panel plots the spot exchange rate expressed in units of BRL per USD. An increase in the exchange rate indicates a depreciation of BRL and an appreciation of USD. The lower panel plots the daily 1-month maturity BRL/USD currency basis measured in basis points. A positive currency basis is a violation of CIP and indicates a premium to swap BRL into USD in forward and swap markets. To improve legibility in the plot, we winsorize the BRL/USD currency basis at the 1% level. The sample period runs from 1999-01-22 to 2023-04-27.

but represents a larger 50,000 USD exposure. We analyze the WDO contract instead of the DOL contract for our analysis due to its higher liquidity and trading activity in our sample.

Reuters Benchmark Spot and Forward Data. We supplement the B3 data with high-frequency spot and forward indicative quotes from Thomson Reuters Tick History. The quotes are given at 5-minute intervals, include bid and ask prices, and cover the period 1999 to 2023. While the Reuters quotes are lower frequency than the B3 tick-by-tick data, the Reuters quotes offer a longer time series that better aligns with the BCB’s historical intervention dataset. For this reason, we use the Reuters quotes for our primary econometric analysis in Section 4. For that analysis, we derive the mid-quote from bid and ask prices for spot and forward rates.

The upper panel of Figure 5 plots the BRL/USD spot rate. We express the spot rate in units of BRL per USD, so an increase indicates a BRL depreciation. The USD has strengthened against BRL since 2010, rising from below 2 BRL per USD in 2010 to above 5 BRL per USD in 2020.

Interest Rates. We obtain daily interest rates from the Brazilian Financial and Capital Markets Association (ANBIMA) through the Institute of Applied Economic Research (IPEA) data repository. For our baseline analysis, we use the 1-month maturity, based on the yield curve of the National Treasury Bill (LTN) with a term of 21 business days.²⁰

BRL/USD Trading Volume. We obtain interbank BRL/USD spot trading volume data from the BCB.²¹

The FX market in Brazil is highly regulated, with most transactions in both the primary and interbank markets recorded in the BCB's systems. This regulatory framework ensures broad data coverage, as the BCB tracks a wide range of operations, including FX transactions related to exports, imports, and cross-border transfers involving non-banking institutions and financial intermediaries. These recorded transactions are primarily reflected in the interbank foreign exchange market, ensuring that this database captures the majority of FX intermediation.

The spot trading volume is defined as the sum of T+1 and T+2 contract volumes.²² In this context, T+1 and T+2 refer to the settlement conventions in the interbank foreign exchange market. A T+1 contract settles one business day after the transaction date, while a T+2 contract settles two business days after. By summing these volumes, we capture the total interbank spot trading activity in BRL/USD.

Cross-Currency Basis. The CIP condition states that equivalent assets denominated in different currencies should earn equal returns after hedging exchange rate risk with a forward contract.²³ Empirically, the CIP condition is frequently violated, and the cross-currency basis, which we denote $x_{t,t+h}$, quantifies the CIP violation. Following Du

²⁰ANBIMA uses Svensson (1994) to estimate the term structure of interest rates from Treasury securities. See https://www.anbima.com.br/data/files/12/D0/11/B0/C7CFD71028DFACD76B2BA2A8/Metodologia_estrutura-termo_out21_ingles.pdf for more details

²¹The data is sourced from the BCB's time series portal: <https://www3.bcb.gov.br/sgspub/localizarseries/localizarSeries.do?method=prepararTelaLocalizarSeries>.

²²Specifically, we use the following two series: (i) Series 20205 – Foreign exchange interbank spot volume – USD – T+2, and (ii) Series 20359 – Foreign exchange interbank spot volume – USD – T+1. The total interbank spot trading volume is computed as the sum of these two series.

²³To illustrate, an investor can invest one USD at t to receive a risk-free payment in USD at $t+h$, or exchange one USD for BRL and invest in BRL at t to receive a risk-free payment in BRL at $t+h$. In the latter case, the investor can hedge exchange rate risk by entering a forward contract at t to exchange BRL for USD at $t+h$. The CIP condition states that both strategies should offer the same return.

et al. (2018), we define the cross-currency basis as a wedge between the *synthetic* and direct USD risk-free rate,

$$\left(1 + r_{t,t+h}^{USD}\right)^h = \left(1 + r_{t,t+h}^{BRL} - x_{t,t+h}\right)^h \frac{S_t}{F_{t,t+h}}, \quad (17)$$

where $r_{t,t+h}^{USD}$ denotes the U.S. nominal risk-free rate in USD, $r_{t,t+h}^{BRL}$ denotes the Brazilian nominal risk-free rate in BRL, S_t is the nominal spot exchange rate expressed in BRL per USD, and $F_{t,t+h}$ is the nominal h -period forward exchange rate in BRL per USD. From this expression, we approximate the cross-currency basis as

$$x_{t,t+h} \approx r_{t,t+h}^{BRL} - r_{t,t+h}^{USD} - \rho_{t,t+h}, \quad (18)$$

where $\rho_{t,t+h} \equiv (f_{t,t+h} - s_t)/h$ is the forward premium, using lower-case variables to denote logs of the spot and forward exchange rates.

A positive BRL/USD currency basis ($x_{t,t+h} > 0$) indicates a CIP violation such that market participants require a premium to swap BRL into USD, suggesting a relative scarcity of USD funding in cross-border markets. The BRL/USD currency basis is measured in basis points and is persistently positive over the period from 1999 to 2023, as shown in the lower panel of Figure 5.

Intermediary Constraints. The Gamma-Eta model predicts that foreign exchange interventions have greater effects when intermediaries are constrained, as measured by the model's parameter Γ . To measure intermediary constraints empirically, we adopt the *intermediary capital ratio* of He et al. (2017) as an empirical proxy for Γ . The ratio, denoted HKM_t , is defined as

$$HKM_t = \frac{\sum_i \text{Market Equity}_{it}}{\sum_i (\text{Market Equity}_{it} + \text{Book Debt}_{it})}, \quad (19)$$

where book debt is computed by subtracting total common equity from total assets, and where i indexes individual intermediaries. We follow Cerutti and Zhou (2024) and construct a daily measure of HKM_t using the subset of primary dealers that deal with

emerging market currencies based on the Euromoney FX survey.²⁴

A decline in HKM_t indicates lower risk-bearing capacity at the largest emerging-market currency dealers. The intuition is that intermediaries with lower capital ratios face tighter borrowing constraints and demand fewer risky assets to comply with regulatory capital requirements. Thus, HKM_t is an important indicator of the ability of primary dealer banks to intermediate USD transactions in cross-border financial markets. If Prediction 5 of the Gamma-Eta model holds, we would expect tighter intermediary constraints to reduce USD intermediation and strengthen the exchange rate response to Central Bank interventions.

Macroeconomic Variables. Finally, we use monetary announcements of the Federal Reserve and BCB, NBER recession dates, and measures of global and sovereign risk as control variables. To measure global risk, we use the VIX index. To measure sovereign risk for emerging markets, we use the JPMorgan EMBI+ (Emerging Markets Bond Index Plus) from the IPEA data repository. The EMBI+ tracks the daily performance of debt securities from emerging markets relative to U.S. Treasury securities.

4 Empirical Analysis

We divide our empirical analysis into five sections. In Section 4.1, we use tick-by-tick data to closely examine two dates on which the BCB conducted both unanticipated and anticipated spot sales of USD. This case study provides preliminary support for the Gamma-Eta Model’s Prediction 1 on the direction that FXI affects the exchange rate, as well as Prediction 2 on the relative impact of anticipated and unanticipated FXI. In Section 4.2, we analyze nearly twenty-five years of BCB interventions using the BCB’s historical FXI database, strengthening and extending our case study findings. In addition

²⁴The entities used in our analysis include BNP Paribas, Barclays, Bank of America, Citigroup, Credit Suisse, Deutsche Bank, Goldman Sachs, HSBC, JP Morgan, Morgan Stanley, Societe Generale, Standard Chartered, State Street, and UBS. Several of these institutions—BNP Paribas, Bank of America, Citigroup, Credit Suisse, Goldman Sachs, JP Morgan, and Morgan Stanley—are part of the BCB’s Dealers-14, reinforcing the relevance of this HKM measure for our study. See: <https://www4.bcb.gov.br/pec/dealers/principal.asp>.

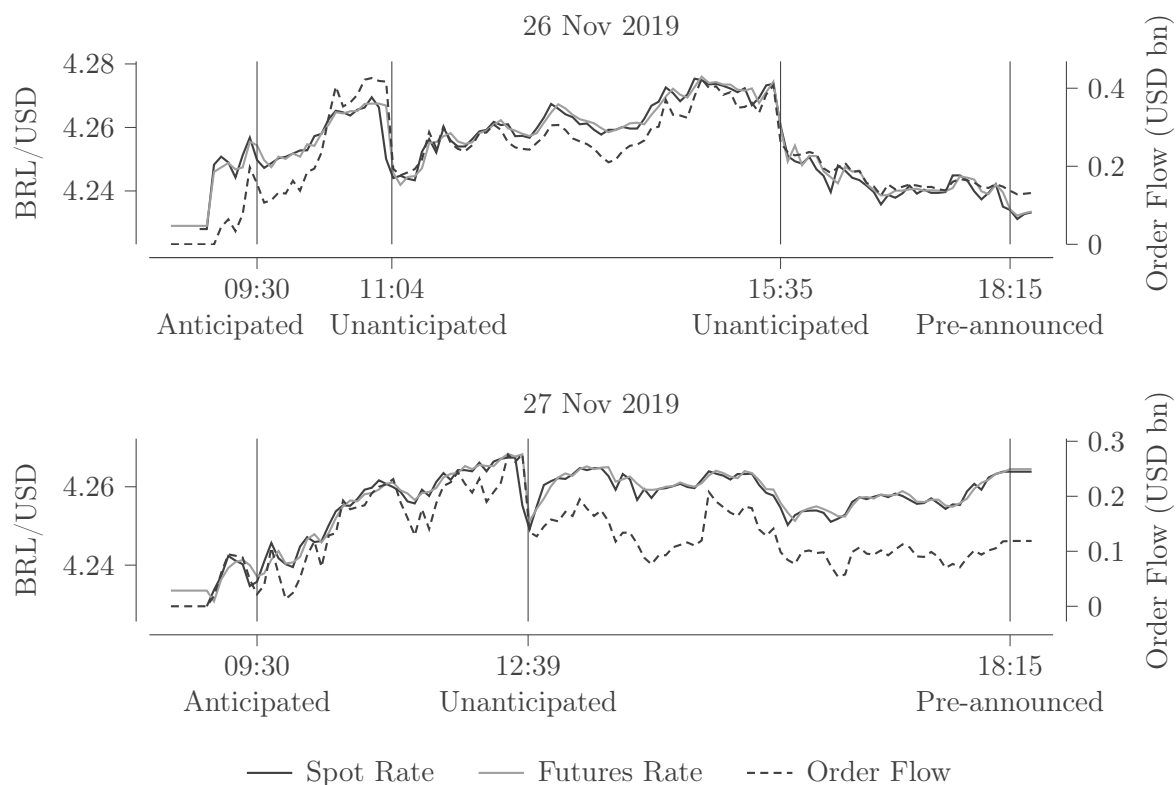
to Predictions 1 and 2, we test Prediction 3 on spot versus swap FXI. In Section 4.3, we examine how BCB interventions affect the return to private intermediation and the quantity of private intermediation. We use BRL/USD spot trading volume as a proxy for the total amount of private and public intermediation and the cross-currency basis, an indicator of CIP violations, as a proxy for the return to intermediation for Financiers. In line with Prediction 4, we find that BCB's USD spot sales crowd out private intermediation. In Section 4.4, we explore the effects of BCB interventions in periods with tighter and looser intermediary constraints. We find that tighter constraints amplify the exchange rate and cross-currency basis responses to FXI, in line with Prediction 5. Finally, in Section 4.5, we investigate an alternative to the dollar intermediation channel by testing whether FXI signals a change in future interest rates.

4.1 High-Frequency BCB FXI Case Study

To initiate our analysis, we examine the impact of interventions on 26 and 27 November 2019, when the BCB carried out both unanticipated and anticipated spot sales of USD. We focus on these intervention dates due to the availability of tick-by-tick data on transaction prices and order flow for the liquid BRL/USD futures contracts from the B3 exchange.

The upper and lower plots in Figure 6 depict intra-day BRL/USD spot and futures prices, as well as cumulative order flow on these dates. In the plots, the left vertical axes measure spot and futures prices and the right vertical axes measure cumulative order flow. Vertical lines mark intervention times. Order flow refers to net initiated buy orders over sell orders, a measure of buying pressure derived from aggressor buy-sell indicators in our data. An increase in order flow indicates an increase in net buying pressure for USD. On 26 November, the BCB implemented an anticipated spot sale of USD at 09:30, unanticipated spot sales of USD at 11:04 and 15:35, and pre-announced an intervention at 18:15 that it planned to implement the following morning. On the following day, the BCB implemented the pre-announced (and therefore anticipated) spot sale of USD at 09:30, and an unanticipated spot sale of USD at 12:39, before pre-announcing a future intervention at 18:15.

Figure 6: High-Frequency Case Study of Two BCB Intervention Days



Notes. The figures show the BRL/USD exchange rate and cumulative order flow on two dates when the BCB conducted anticipated and unanticipated spot sales of USD. The vertical axes on the left show the BRL/USD exchange rate, and the vertical axes on the right show cumulative order flow in USD billions. Order flow is defined as the net of buyer initiated transaction volume in the 1 month BRL/USD futures market. The upper figure plots the exchange rate and order flow for 26 November 2019, when the BCB conducted one anticipated and two unanticipated interventions and pre-announced an intervention to be conducted on the following day. The lower figure plots the exchange rate and order flow for 27 November 2019, when the BCB conducted one anticipated and one unanticipated intervention and pre-announced an intervention to be conducted on the following day.

The plots show a sharp appreciation of BRL spot and futures prices around unanticipated interventions and an equally sharp decrease in order flow, indicating an accelerated execution of seller-initiated orders in the minutes following unanticipated announcements. In contrast, the plots show muted responses to anticipated interventions and pre-announcements of future interventions. On these two dates, the BCB appears to be reacting to BRL depreciation. In the lead-up to these interventions, BRL volatility had increased and BRL had weakened against USD. For instance, on November 25, 2019, the PTAX reference rate for dealers in the B3 currency futures market rose sharply. In the preceding months, from late July to that date, the PTAX bid rate had increased,

marking an almost 12% depreciation of BRL. This depreciation was likely driven by a mix of domestic and international factors, including a reduction in the benchmark Selic rate from 6.4% to 4.9% and trade tensions between the U.S. and China.

This case study provides initial evidence at tick-by-tick frequency that the BCB can strengthen the BRL by intervening in spot markets to sell USD and purchase BRL, and achieve stronger effects by using unanticipated interventions, consistent with Predictions 1 and 2 of the Gamma-Eta Model. In the following section, we examine the BCB’s historical interventions database, where we strengthen and extend these preliminary findings.

4.2 Historical BCB FXI Analysis

The BCB’s database of historical FXI allows us to examine a greater number and variety of interventions over a longer time series than our B3 data. Specifically, we analyze over 8,000 unanticipated and anticipated spot and swap interventions in buy and sell directions between 1999 and 2023, utilizing indicative BRL/USD spot exchange rate quotes at 5-minute intervals from Thomson Reuters Tick History.

For our baseline empirical specification, we adopt the local projections method of [Jordà \(2005\)](#). This procedure is useful for identifying the impulse response of outcome variables to FXI, while controlling for feedback effects through lags of the outcome variable and appropriate controls. Specifically, we test the effects of FXI on outcome variable y_{t+h} at horizon h ,

$$\begin{aligned}
 y_{t+h} - y_{t-1} = & \beta_h^z INT_t^z \times SAD_{t+h} + \gamma_h^z INT_t^z \times (1 - SAD_{t+h}) \\
 & + \delta_h SAD_{t+h} + \theta_h HKM_t \\
 & + \text{Daily-Freq Controls}_t + \text{High-Freq Controls}_t + u_{t+h},
 \end{aligned} \tag{20}$$

where the outcome variables are BRL/USD spot prices, forward premia, and the level of CIP violations. Both spot and forward prices are expressed in logarithms.

In this specification, HKM_t denotes the intermediary capital ratio, INT_t^z denotes the BCB intervention amount in USD, with z indicating the intervention type (spot sale, spot purchase, traditional swap, or reverse swap), and SAD_{t+h} indicates whether y_{t+h} falls on

the same day as y_t , when the intervention was announced. For example, if an intervention occurs at 10am, SAD_{t+h} takes a value of one for values of h until the close of trading on that day, allowing us to control for gaps in trading between consecutive days. Formally, INT_t^z and SAD_{t+h} are defined as

$$INT_t^z \equiv \begin{cases} \text{USD Amount} & \text{if intervention } z \text{ announced at } t, \\ 0 & \text{otherwise,} \end{cases}$$

$$SAD_{t+h} \equiv \begin{cases} 1 & \text{if } t+h \text{ on the same day as } t, \\ 0 & \text{otherwise.} \end{cases}$$

Daily frequency controls include interest rates, term interest rate spreads, spot rate volatility, the total amount of interventions in USD at date t across all instruments, US and Brazilian monetary policy announcement dates, and the EMBI+ emerging-market sovereign risk measure. Up to 10 days of lagged values are included for the total amount of interventions. High-frequency controls include up to 10 lags of the outcome variable.

We begin by studying the direction and strength of the exchange rate response to interventions. Our empirical findings relate to Predictions 1 through 3 of the Gamma-Eta Model. We then examine the role of intermediaries in the BRL/USD foreign exchange market and how interventions affect the quantity of intermediation supplied in this market. Our findings with respect to intermediation relate to Prediction 4 of the Gamma-Eta Model.

We focus our analysis on unanticipated interventions, which are news with respect to the information set of market participants and not yet reflected in market prices, providing a clear identification of market responses. Importantly, high-frequency announcement timestamps are available for unanticipated interventions, but not for anticipated interventions. Anticipated interventions are pre-announced before markets close on the preceding day, allowing exchange rates to adjust before the auctions take place the following day. Furthermore, anticipated interventions are expected to have weaker effects, due to the forward looking behavior of rational agents, and in line with Prediction 3 of the Gamma-Eta

Model. We document empirical support for this prediction in Online Appendix [B.6](#), using Brazilian market opening times as event dates for anticipated interventions.

Exchange Rate Response to Unanticipated FXI. To understand how different types of unanticipated interventions impact the exchange rate, we categorize the BCB’s historical interventions based on type (spot or swap) and direction (buy or sell). We then estimate our baseline local projections specification in [\(20\)](#) for each category separately.

The plots in [Figure 7](#) displays our exchange rate results. Unanticipated spot sale interventions have the most significant effect on the BRL/USD exchange rate, leading to an approximate 2 percentage point BRL appreciation within 7 hours of the announcement. In contrast, unanticipated spot purchase interventions have much weaker effects. After a spot purchase, we observe a 0.1 percentage point BRL depreciation 5 hours post-intervention. For unanticipated swap interventions, we again find weaker and more transitory effects. Unanticipated traditional swap interventions result in a 10 basis point BRL appreciation over a 1-hour period, while unanticipated reverse swap interventions lead to a 15 basis point BRL depreciation over the same horizon.

To shed light on the speed of adjustment, we report coefficient estimates for select horizons of 15 minutes, 1, 3 and 7 hours in Online Appendix [B.3](#). Focusing on spot sell interventions, where effects are strongest, we find the BRL appreciates by 33 basis points within 15 minutes of the intervention, and continues to appreciate over a 7-hour horizon after the intervention. The speed of adjustment that we estimate over the full sample period is influenced by a subset of intervention dates, such as the 26 November 2019 date from our case study in [Section 4.1](#), where multiple interventions are clustered within a span of several hours. Roughly one third of the 385 unanticipated spot sale interventions in the BCB’s historical interventions database are clustered in this way. We find that clustering strengthens and prolongs the effects of interventions, and that second or third interventions produce larger effects than the first intervention in a cluster. Online Appendix [B.8](#) discusses these results in more detail.

Taken together, our results suggest that USD sale interventions appreciate BRL, while purchase interventions depreciate BRL. Spot interventions have stronger effects than

swap interventions, and unanticipated interventions have stronger effects than anticipated interventions. These empirical findings are broadly consistent with Predictions 1 through 3 of the Gamma-Eta Model.

Our disaggregation of interventions by type and direction reveals clear heterogeneity in effects. Permanent effects on the spot rate appear to arise solely from spot sale interventions, while effects from swap interventions are transitory. The Gamma-Eta Model, by distinguishing between long-lived spot interventions and short-lived swaps, provides a coherent, though stylized, theoretical explanation for this empirical finding.²⁵

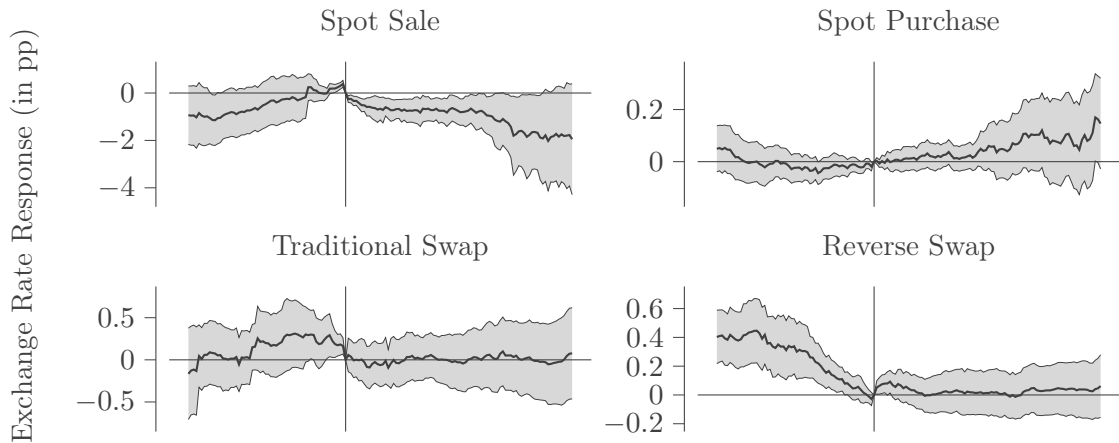
Interestingly, we find that spot purchase interventions are less effective than sale interventions. One reason for this asymmetry may be that USD purchase interventions are typically conducted during periods of relaxed intermediary constraints. During these periods, the Gamma-Eta Model predicts weaker effects on spot exchange rates, as intermediaries with loose constraints are well-positioned to absorb the excess supply of BRL without assistance from the Central Bank. We examine the role of intermediary constraints in more detail in the following section.

We also observe that unanticipated interventions tend to follow intra-day periods of depreciation. This is consistent with the case study of unanticipated interventions on 26-27 November 2019 in Section 4.1. The BCB reacts to developments that lead to a weakening of the domestic currency. Comparing the different types of instruments, we find the strongest pre-trends for spot sales, which is intuitive because spot sale interventions historically occur in periods with scarce USD liquidity in Brazilian FX markets. For spot sales, we find an approximate 1 percentage point BRL depreciation in the hours leading up to the intervention. Therefore, a clear reversal follows the intervention, suggesting that FXI is a useful stabilization tool.

We briefly compare our findings to prior studies on the exchange rate effects of BCB interventions (Kohlscheen and Andrade, 2013; Nedeljkovic and Saborowski, 2019; Barroso, 2019; Santos, 2021), which typically estimate a 30 to 100 basis point impact from a 1

²⁵Figure A.2 in the Online Appendix illustrates the dynamic response of the exchange rate to Central Bank interventions as implied by the Gamma-Eta Model for a variety of calibrations. The figure shows, among other things, that the exchange rate response to an unanticipated swap intervention is shorter-lived than the response to an unanticipated spot intervention.

Figure 7: Exchange Rate Responses to Unanticipated BCB Interventions



Notes. These figures show BRL/USD exchange rate responses to unanticipated BCB interventions, by intervention type. The exchange rate is measured in percentage points (pp). Traditional swaps involve the sale of USD while reverse swaps involve the purchase of USD at the spot leg of the swap contract. Shading indicates a 95% confidence interval using White’s heteroscedasticity-robust standard errors. The sample period runs from 1999-01-22 to 2023-04-27.

billion USD sale of reserves. The differences in our estimates are partly due to differences in the time periods studied (previous work often focuses on 2011-2013 and shorter subsamples) and in the identification and estimation strategies employed. More importantly, we estimate separate effects for interventions in each direction—buy versus sell in the case of spot interventions and traditional versus reverse in the case of swap interventions. Our impact estimates are attenuated when interventions in both directions are pooled together, as shown in Appendix B.5. In the pooled analysis, we estimate the exchange rate response to BCB spot interventions at approximately 50 basis points, in line with previous literature.

4.3 Volume of Intermediation and FXI

Prediction 4 of the Gamma-Eta model states that the Financier adjusts its private supply of intermediation in the opposite direction of the Central Bank intervention. For example, if the Financier expects the Central Bank to buy Home bonds and sell Foreign bonds to strengthen the Home currency, the Financier will buy fewer Home bonds and sell fewer Foreign bonds. While the total volume of intermediation rises, the intervention crowds out some private intermediation.

Intuitively, the Central Bank’s intervention pushes bond prices and the exchange rate in directions that lower the Financier’s expected profit, reducing the Financier’s incentive to intermediate. This mechanism would be strengthened if Central Bank interventions also reduced CIP deviations (which we do not model) by alleviating liquidity shortages.

We test the prediction in two ways. First, we test whether the total volume of intermediation in the BRL/USD spot market rises in response to BCB interventions, and whether it rises one-for-one or less than one-for-one with the size of the intervention. Second, we test whether the cross-currency basis falls when the Central Bank intervenes to provide USD liquidity. Both tests lend empirical support to Prediction 4 of the Gamma-Eta model.

Volume of Intermediation. We use daily BRL/USD spot trading volume from the BCB as an empirical proxy for the total volume of intermediation. The total volume equals the sum of public and private intermediation, where public intermediation is provided by the BCB’s FXI, and private intermediation is provided by private Brazilian financial institutions. If the BCB’s FXI crowds out private intermediation, we would expect the total volume of intermediation to rise by less than the total volume of FXI.

The crowding-out effect of FXI on private intermediation relates to the mechanism described in [Dunne et al. \(2015\)](#), who show that dealers adjust their intermediation between customer and inter-dealer markets in response to inventory constraints. Their results suggest that when market conditions shift liquidity demand and inventory imbalances arise, intermediaries reduce their risk exposure, leading to lower private liquidity provision. Similarly, in our setting, FXI influences the incentives of intermediaries by altering liquidity conditions in the BRL/USD market, leading to adjustments in private intermediation volume.

We regress the total volume of intermediation on the amount of spot buy and sell interventions and report the results in Table 1. Column one presents the response of BRL/USD spot trading volume to BCB spot sell interventions, and shows that volume increases by 0.403 billion USD for every 1 billion USD that the BCB sells. The coefficient is positive but less than one, suggesting that while BCB spot sell interventions raise total

Table 1: Spot Trading Volume Response to BCB Interventions

Intervention Type	Coefficients from Regression of Trading Volume on FXI		
	(1)	(2)	(3)
Spot Sell Only	0.403** (0.188)		
Spot Buy Only		1.050*** (0.133)	
Pooled Buy and Sell			0.794*** (0.127)
Controls	Yes	Yes	Yes
Observations	7444	7444	7444
Adjusted R^2	0.324	0.312	0.325

Notes. The table coefficients from a regressions of daily BRL/USD spot trading volume on BCB FXI amounts and a set of control variables. The first and second specifications regress trading volume on USD spot buy and sell interventions separately. The third specification regresses trading volume on pooled buy and sell interventions. In each regression, we control for the capital ratio HKM_t , interest rates, term interest rate spreads, US and Brazilian monetary policy announcement dates, the EMBI+ emerging-market sovereign risk measure, and up to 10 lags of the dependent variable. White heteroscedasticity-robust standard errors are reported in parentheses. Results are reported in percentage points. Stars *, **, and *** denote 10%, 5%, and 1% significance levels, respectively. The sample period is from 1999-01-22 to 2023-04-27.

intermediation volume, they also crowd out some private intermediation. In contrast, Column two shows that BRL/USD spot trading volume increases by approximately 1 billion USD for every 1 billion USD purchased by the BCB, indicating that spot purchase interventions do not affect private intermediation. Column three shows the trading volume response to pooled spot buy and sell interventions, which lies between the separately-estimated spot buy and sell responses.

To further examine whether FX intervention affects private intermediation, we turn to the cross-currency basis, which is available at higher frequency. A crowding out of private intermediation should manifest as a decline in the financier’s profit from intermediation, which would result from a narrowing of the cross-currency basis.

Cross-Currency Basis. The cross-currency basis measures the premium that market participants pay to swap currencies in forward markets. The Financier’s profit from

intermediation in (9) derives from the return differential between Home and Foreign bonds. Outside of our model, we show that this differential equals the forward premium plus the cross-currency basis in (18). In this sense, the cross-currency basis contributes to the Financier’s profit. A positive cross-currency basis indicates scarcity of USD funding in cross-border markets. If the BCB’s FXI crowds out private intermediation, we would expect an accompanying decline in the cross-currency basis, reducing the incentive to intermediate.

To test this prediction, we estimate our baseline local projection specification in (20) with the cross-currency basis as the outcome variable. Figure 8 plots the results. Spot sales of USD have the largest effect among all intervention types, narrowing the cross-currency basis by approximately 100 basis points over a 7-hour horizon per 1 billion USD sold. In Appendix B.7, we find a rise in the forward premium, consistent with these results and with equation (18) linking the cross-currency basis to the relative demand for currency forwards. We find weaker and less significant effects for swap FXI (both traditional and reverse) and a widening of the cross-currency basis by approximately 50 basis points over a 7-hour horizon following spot purchase FXI.

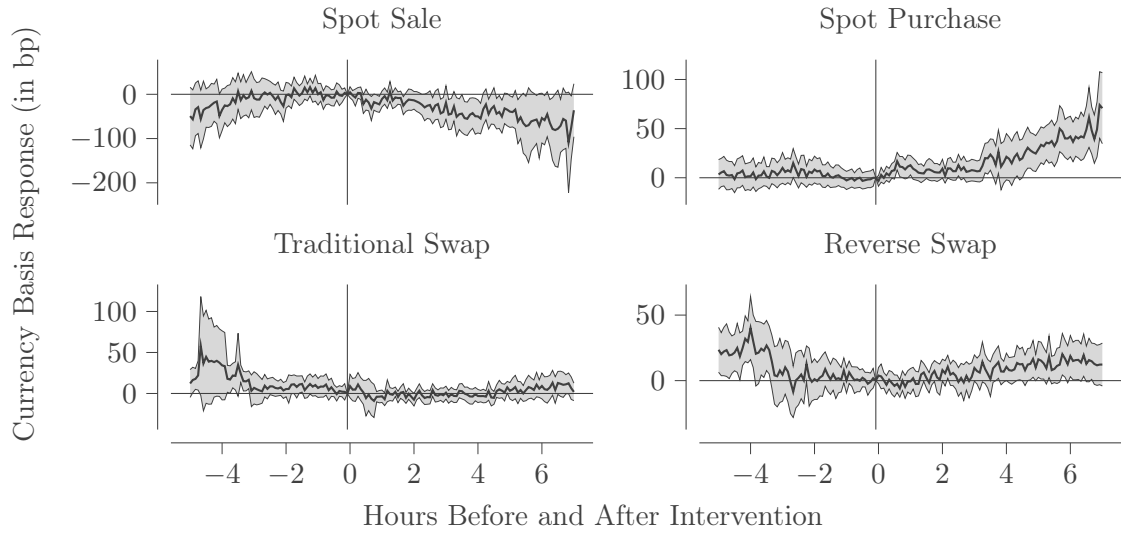
While the cross-currency basis results are outside of the model, they nevertheless align with the model’s core intuition: the Financier chooses a volume of intermediation that maximizes expected profit derived from an interest rate differential. Expected profit falls when the interest rate differential narrows—whether from expected exchange rate movements or a lower cross-currency basis—and the Financier’s incentive to intermediate weakens.

Taken together, the empirical evidence on the volume of intermediation and the cross-currency basis suggests that BCB spot sales of USD crowd out private intermediation by reducing the profit incentive of private financial institutions to intermediate.

4.4 FXI and Intermediary Constraints

Prediction 5 of the Gamma-Eta Model states that tighter intermediary constraints strengthen the exchange rate response to FXI and lower the quantity of intermediation

Figure 8: Currency Basis Responses to Unanticipated BCB Interventions



Notes. These figures show BRL/USD currency basis responses to unanticipated BCB interventions, by intervention type. The currency basis is measured in basis points (bp). Traditional swaps involve the sale of USD while reverse swaps involve the purchase of USD at the spot leg of the swap contract. Shading indicates a 95% confidence interval using White’s heteroscedasticity-robust standard errors. The sample period runs from 1999-01-22 to 2023-04-27.

that Financiers supply. Applied to the Brazilian case, the Gamma-Eta Model predicts that intermediaries will limit USD liquidity to the Brazilian economy when constraints are tight, and BCB operations to sell USD and counteract the constraints will have larger exchange rate effects.

To test Prediction 5, we augment the baseline specification in (20) by including dummy variables that indicate the state of intermediary constraints as either tight or loose. The intermediary capital ratio HKM_t defined in (19) serves as our measure of intermediary constraints, with low HKM_t values indicating a tight constraint.

We adopt the following augmented version of our baseline specification in (20),

$$\begin{aligned}
 y_{t+h} - y_{t-1} = & \beta_h^z INT_t^z \times SAD_t \times D_{HKM,t} \\
 & + \gamma_h^z INT_t^z \times SAD_{t+h} \times (1 - D_{HKM,t}) + \delta_h SAD_{t+h} + \theta_h HKM_t \\
 & + \text{Interactions}_t + \text{Daily-Freq Controls}_t + \text{High-Freq Controls}_t + u_{t+h},
 \end{aligned} \tag{21}$$

where the outcome variable y_{t+h} is either the BRL/USD exchange rate or the cross-currency basis, and $D_{HKM,t}$ denotes an indicator for intermediary constraints, taking a value of

one when the intermediary capital ratio HKM_t lies below its 50th percentile and zero otherwise. We interact $D_{HKM,t}$ with intervention size INT_t^z for intervention type z .²⁶

The upper group of plots in Figure 9 illustrates how FXI and intermediary constraints interact to influence the exchange rate, plotting the conditional exchange rate response to unanticipated BCB spot and swap interventions. We find that BCB spot USD sales under tight intermediary constraints ($D_{HKM,t} = 1$) appreciate BRL against USD by approximately 2 percentage points over a 7-hour horizon per USD 1 billion sold. This effect is similar in magnitude to the unconditional effect reported in Section 4.2, suggesting that the unconditional effect is primarily driven by periods of tight intermediary constraints.

For traditional swaps under tight constraints ($D_{HKM,t} = 1$), the BCB can appreciate the BRL by approximately 20 basis points over a 7-hour window per USD 1 billion. In contrast, no statistically significant effect is observed for traditional swaps under loose constraints, although we do detect a noisy 40 basis point depreciation of the BRL against the USD. For spot purchases of USD and reverse swaps, we find no statistically significant effects.

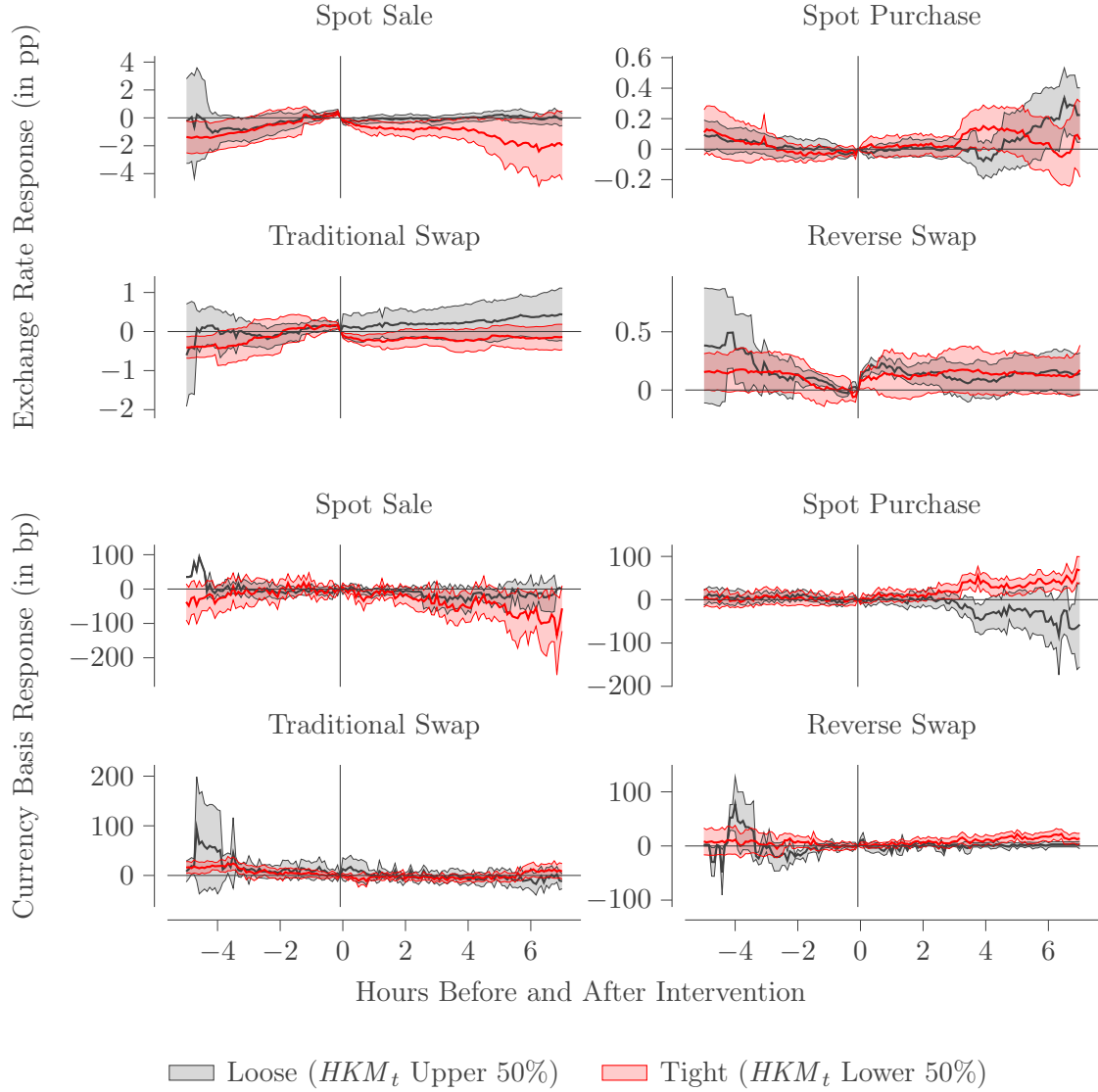
Next, we examine how intermediary constraints affect the quantity of intermediation, using the BRL/USD cross-currency basis as a high-frequency proxy. The cross-currency basis measures the premium market participants pay to swap currencies in forward markets, and serves as an indicator of the profitability of intermediation. If intermediation is tighter during periods of high constraints, FXI should have larger effects not just on the spot rate but also on expected intermediation profits, as captured by movements in the cross-currency basis.

While outside of the model, we would expect sales of USD to improve USD liquidity and lower the BRL/USD cross-currency basis. The lower group of plots in Figure 9 shows the conditional response of the cross-currency basis to unanticipated BCB interventions.²⁷ While we find no effects for swap interventions, significant effects emerge

²⁶Additional interactions in the specification are between $1 - SAD_t$ with periods of tight ($D_{HKM,t} = 1$) and loose ($D_{HKM,t} = 0$) constraints.

²⁷For robustness, Section B.4 in the Online Appendix uses intermediaries' FX positions and CIP violations as alternative proxies for constraints. We find similar results: spot sales during above-median CIP violations lead to BRL appreciation and a narrowing basis, consistent with FXI alleviating constraints.

Figure 9: Conditional Exchange Rate and Currency Basis Responses to Unanticipated BCB Interventions



Notes. The upper group of figures show BRL/USD exchange rate responses to unanticipated BCB interventions in percentage points (pp), while the lower group figures show BRL/USD currency basis responses to unanticipated BCB interventions in basis points (bp). Within each group, the figures show responses to the BCB’s spot sale, spot purchase, traditional swap, and reverse swap interventions. Each figure plots responses conditional on the state of FX dealers’ balance sheet constraints on the intervention day. We measure balance sheet constraints by constructing the intermediary capital ratio HKM_t in equation (19). Red indicates tight constraints, defined as periods with HKM_t in the lower 50% of values in our sample. Gray indicates loose constraints, defined as periods with HKM_t in the upper 50% of values in our sample. Shading indicates a 95% confidence interval using White’s heteroscedasticity-robust standard errors. The sample period runs from 2003-11-24 to 2023-04-27.

for spot interventions when accounting for intermediary constraints. Similar to the exchange rate results, we find that the impact of spot USD sales on the cross-currency basis is amplified during periods of tight intermediary constraints ($D_{HKM,t} = 1$), leading to

an approximate 50 basis point reduction in CIP violations. In contrast, spot USD purchases under tight constraints widen CIP violations by 70 basis points, with no significant effects for traditional or reverse swaps.

In summary, our empirical findings support Prediction 5 of the Gamma-Eta Model, showing that unanticipated interventions are more effective when intermediaries are constrained. The economic intuition behind this result is clear: the BCB's spot USD sales and traditional swaps increase USD liquidity. When intermediaries face tighter constraints, their USD supply becomes more inelastic, making exchange rates more sensitive to added liquidity and intermediation volume. However, when intermediaries are unconstrained or during spot USD purchases or reverse swaps, existing USD liquidity is sufficient for efficient intermediation, resulting in no significant exchange rate effects.

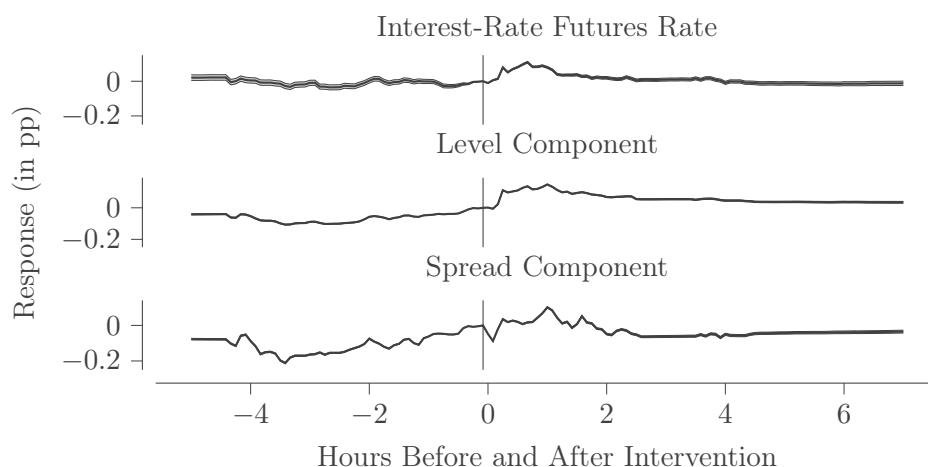
4.5 Signaling Channel

So far, we have found evidence for the dollar intermediation channel, which is a specific case of the portfolio balance channel with constrained financial intermediaries. We now test the effects of FXI on the future path of interest rates, contributing to the debate on the relative importance of the signaling and portfolio balance channels of FXI (Sarno and Taylor, 2001). The signaling channel posits that FXI provides information to market participants on the future path of interest rates. For example, a spot sale of USD reserves can signal that the central bank intends to strengthen the domestic currency in the future, which, all else being equal, requires higher future domestic interest rates.

Intra-day Interest Rate Futures. We first test the signaling channel using intra-day interest rate futures data from B3 as the outcome variable in our baseline specification in (20). At this frequency, our data covers only four events from 2019.²⁸ Figure 10 plots the response of interest rate futures to the unanticipated spot sale interventions in this limited sample. The 1-month interest rate futures increase by up to 15 basis points 2 hours after the announcement, and then drop to approximately 2.5 basis points 6 hours

²⁸Similar to our B3 case study in Section 4.1, this includes unanticipated interventions on 27 August, 26 November, and 27 November 2019, for which we have intra-day transaction data from the B3 exchange.

Figure 10: High-Frequency Interest Rate Response to Unanticipated BCB Spot Sell Interventions



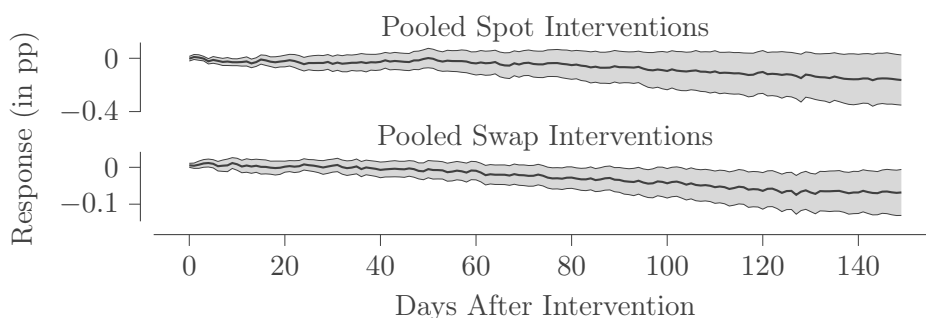
Notes. The figures show high-frequency responses of Brazilian interest rates to BCB spot sale interventions in the BRL/USD FX market measured in percentage points (pp). The upper figure shows the overall response of B3 interest-rate futures for the most liquid contract. The middle figure shows the response of the level component of interest-rate futures rates. The bottom figure shows the response of the spread component of interest-rate futures rates. The sample period of B3 interest rate futures runs from 2019-02-08 to 2020-01-23. Four unanticipated spot sale interventions occurred during the sample period, in total 2.481 billion USD. Shading indicates a 95% confidence interval using White’s heteroscedasticity-robust standard errors.

after the announcement.

Additionally, we plot the level component (average across maturities) of interest rate futures contracts and the spread between 5-year and 1-month interest rates. The average interest rate increase peaks at 20 basis points and declines to 10 basis points after 7 hours, while the spread between 1-month and 5-year yields rises initially but returns to near zero by the end of the day. These effects are quantitatively and economically insignificant: a USD 1 billion change increases interest rates by 2.5 basis points for the 1-month maturity and up to 10 basis points when averaged across maturities. In comparison, a USD 1 billion spot sale results in a 2 percentage point (approximately 200 basis points) intra-day appreciation in the spot rate and a 50-100 basis point narrowing of the cross-currency basis.

Daily Interest Rates. In addition to the intra-day data, we use daily interest rates as the outcome variable in our baseline specification in (20), to test the signaling channel in

Figure 11: Daily-Frequency Interest Rate Response to Pooled Unanticipated BCB Interventions



Notes. The figures show 1-month interest rate responses to pooled unanticipated BCB spot and swap interventions at daily frequency, in percentage points (pp). Unanticipated interventions are measured in USD Billion. In the case of spot interventions, we pool spot sales with spot purchases in a single regression. In the case of swap interventions, we pool traditional swaps with reverse swaps in a single regression. Shaded indicates a 95% confidence interval using White heteroscedasticity-robust standard errors.

our longer historical sample. At a daily frequency, we control for potential endogeneity by identifying a reaction function of FXI. We use macroeconomic variables to estimate the reaction function, including the level and volatility of exchange rates, interest rates, recession dates, the HKM dealer capital ratio, and the VIX index. In our regressions, we use the residual intervention component that is unexplained by macroeconomic fundamentals and is, therefore, plausibly exogenous to interest rates. This approach addresses the potential feedback from interest rates to FXI in our daily-frequency analysis. For supplementary information on the construction of our residualized FXI, we refer readers to Appendix [B.9](#).

For spot and swap FXI at daily frequency, we examine the effect of pooled buy and sell interventions. We find no significant effects of FXI on daily interest rates, as shown in Figure [11](#). Interest rates decline weakly by up to 25 basis points in response to (pooled) spot FXI over 6 months, however the effects are statistically insignificant. In summary, we find weak evidence for the central bank signaling changes in interest rates through either spot or swap interventions.

5 Conclusion

In this paper, we investigate the importance of the *dollar intermediation* channel of FXI, hypothesizing that the effects of FXI are more pronounced during periods of tight intermediary constraints.

To motivate our empirical analysis, we extend the Basic Gamma Model of [Gabaix and Maggiori \(2015\)](#), distinguishing between anticipated and unanticipated spot and swap interventions. The model involves two countries with Households that consume domestic and international goods but hold only domestic bonds. A foreign exchange Financier intermediates bond trade subject to credit constraints. The Central Bank uses interventions in the FX market to respond to trade shocks, with thresholds communicated as distributions to manage intervention anticipation. The model predicts that long-lived spot interventions and unanticipated interventions have larger exchange rate effects, and that interventions are more impactful under tighter credit constraints.

Our empirical analysis uses an extensive database of BCB interventions from 1999 to 2023, combined with high-frequency data on spot and forward prices, enabling us to examine the intra-day effects of FXI. We highlight three key findings. First, unanticipated sell interventions of USD reserves lead to an appreciation of BRL by approximately 2 percentage points per 1 billion USD, whereas buy interventions have insignificant effects. Second, FXI crowds out private intermediation, strengthening market efficiency by lowering the cross-currency basis while weakening the profit incentive of intermediaries. Third, the impact of FXI is more pronounced during periods of tighter intermediary constraints, with significant effects observed primarily during these times. While we find strong support for the dollar intermediation channel, we find weaker support for the signaling channel.

Our findings are salient for central banks intervening in foreign exchange markets to pursue policy goals. We provide new evidence on the types of FXI that are most effective, the market conditions under which they are effective, the channels through which they operate, and the trade-offs they entails. We show that FXI can alleviate constraints on global financial intermediaries, enhancing market efficiency, with unanticipated spot sales of USD reserves being the most effective instrument.

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