Foreign Exchange Interventions, Signalling and Intermediary Constraints

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Abstract

We analyze the impact of unanticipated foreign exchange intervention in the Brazilian market. Using 20 years of data, we find surprise spot sales of USD reserves by the Brazilian Central Bank lead to an appreciation of the Brazilian Real and reduced covered interest rate parity violations. Spot interventions have a greater impact than swaps, especially during periods of global intermediary constraints. These results suggest that dollar liquidity provision lowers the relative cost of borrowing USD through FX markets, enhancing efficiency. However, evidence supporting the signaling channel is weak, with insignificant interest rate changes observed in intra-day data and survey-based forecasts.

Keywords: Exchange Rate; Central Bank; Interventions; Yield Curve; Asset pricing

JEL Classifications: E44; E58; F31; G14

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1 Introduction and Motivation

There is a large empirical literature studying the potential channels through which a foreign exchange intervention (FXI) can impact currency markets (Sarno and Taylor 2001). Within this literature, a less studied question is documenting the effect of interventions in periods when global intermediaries are constrained in their supply of USD liquidity. In this paper we test the role of intermediation constraints, which we identify as a *dollar intermediation* channel. When intermediaries are constrained, FXI have more capacity to affect spot and forward rates as the supply of cross-border capital is inelastic, with changes in the relative quantities having a more significant impact on the exchange rate.

To shed light on the dollar intermediation channel, we can study the interaction between currency and interest rate markets through the covered interest rate parity (CIP) condition. An important no-arbitrage condition in international finance, CIP violations can indicate a relative scarcity of dollar liquidity in cross-border financial markets. FXI can play an important role in alleviating dollar scarcity and reduce frictions in intermediating dollars in FX markets. Using Brazil as a case study, we can test whether unanticipated sales of USD reserves by the BCB lead to a systematic appreciation of the BRL and a narrowing of the CIP deviation. This is consistent with FXI being a useful policy tool in improving efficiency in the FX markets.

To motivate our empirical framework, we introduce a simple model of FXI on dollar intermediation following Gabaix and Maggiori (2015). The analysis involves two countries, the US (home) and Brazil (foreign), across two periods. Households in each country make consumption decisions subject to intertemporal budget constraints. The foreign exchange market involves financiers who fund in dollars and lend to Brazilian firms, aiming to maximize the value of their investments. The study introduces a model of FXI by the BCB, which sells USD reserves in the initial period. The intervention affects the spot exchange rate and dollar intermediation by financiers. First, an FXI of selling USD and buying BRL leads to the appreciation of BRL through portfolio balance effects: financiers require the relative price of USD to fall to absorb the excess supply of dollars by the central bank. The effectiveness of the intervention on the spot rate is shown to increase with the magnitude of intermediation constraints. Second, the FXI reduces the size of dollar intermediation by financiers. Tighter intermediary constraints lead to a larger decline in net dollar intermediation, and in turn a larger decline in the relative costs of intermediating dollars in financial markets. Third, we find stronger effects on the spot rate and dollar intermediation costs for spot FXI relative to a swap FXI, in which the central bank re-purchases USD in the second period.

To test model predictions, we study the high frequency effects of FXI by the Brazilian Central Bank (BCB). We exploit a large historical database on Brazil Central Bank interventions. The database includes a high frequency timestamp of the transaction,

the type of intervention (spot, swap), the sign (buy or sell of USD) and amount of the auctions. We can also classify interventions either as anticipated or unanticipated depending on whether the announcement of the intervention occurs on the same day as the auction. We combine our database on interventions with tick level data on spot and futures prices at the 5 minute level from Thomson Reuters Tick history. Using this data, we measure the effects of using the local projections method in Jordà (2005). We estimate the effects of FX buy and sell interventions on prices, interest rates and CIP deviations using the method of local projections, a procedure that controls for feedback effects in prices and the intervention amount.

First, we test for the impact of unexpected buy and sell interventions. The level of the spot rate appreciates by approximately 1.5 percentage points per USD Billion for a sell intervention. In contrast, we observe smaller transitory effects (10 basis points) on the spot exchange rate from FX swap interventions. We do not find exchange rate effects for buy interventions, suggesting the dollar intermediation channel is important in explaining the asymmetric effect between USD buy and sell interventions.

Second, we test for effects on cross-border funding through measuring the difference in borrowing costs in USD and BRL. In practice, it is more costly to borrow dollars synthetically by converting BRL to dollars in the forward market. This inefficiency is measured by the CIP deviation, which records the difference in USD and BRL interest rates after hedging exchange rate risk with a forward contract. CIP deviations reflect a combination of factors. One is the scarcity of dollar liquidity, as dollars are the reserve currency and there are constraints in the global supply of dollars. We test whether FXI impact CIP deviations. This connects to an emerging literature on whether FXI can be used as a policy tool to target inefficiency in cross-border dollar funding markets. Our findings suggest unanticipated sell interventions lead to a decline in the magnitude of CIP deviations. This improves efficiency of cross-border markets as it reduces the relative cost of borrowing USD using forward markets. and is consistent with our model predictions of FXI alleviating the constraints on global financial intermediaries.

Third, we test whether the effect of FXI on spot prices and CIP deviations is more pronounced during periods of tight intermediary constraints. During constrained periods, the limited supply of dollar liquidity to Brazilian firms prompts the central bank to conduct operations, expecting stronger FXI price effects when the dollar supply is more inelastic. Intermediary constraints are proxied using the dealer capital ratio from He, Kelly, and Manela (2017), which measures the level of the dealer capital to assets ratio for a set of global systemically important dealers. Three key findings emerge. First, spot sales exhibit effects mainly during periods of tighter intermediary constraints, which are an above median measure, contrasting with no or limited effect during slack constraints (below median). Similar effects are observed for swap FXI. In particular, while swap FXI

unconditionally does not significantly impact the spot rate, we find significant effects conditioned on periods of tight intermediary constraints.

Finally, we contribute to the debate on portfolio balance vs signalling channels of FXI by testing for spillover effects into interest rate markets. The signalling channel posits that FXI can convey information to market participants about future interest rate movements. For instance, a spot sale of USD reserves might signal the central bank's intent to strengthen the domestic currency, indicating the likelihood of higher future domestic interest rates. To test this channel, we utilize both high frequency intra-day data on interest rate futures available from the Brazil B3 exchange, and interest rate forecasts from the private sector regarding the Selic (central bank) rate at upcoming meetings. Using intra-day data, we find small short-term increases of up to 10 basis points in interest rates consistent with spot sales reducing money supply, and sterilization of money supply effects occurring $T + 2$. However, by the end of trading the effects on interest rates are weak. Longer-term analysis using interest rate forecasts also finds weak evidence of a sysetmatic effect on interest rates following both spot and swap FXI. In summary, our evidence suggests that the portfolio balance channel, operating through intermediary constraints, is the more relevant theory to explain our findings.

The remainder of the paper is structured as follows. Section 2 reviews the related literature. Section 3 introduces a model framework with testable predictions on the effects of FXI on spot rates and CIP violations. In section 4 we introduce the institutional setting of FXI conducted by the BCB. In section 5 we present our findings of FXI effects on the exchange rate, interest rates and the CIP violation. Section 6 concludes.

2 Related Literature

Sarno and Taylor (2001) survey theoretical and empirical literature on central bank interventions in foreign exchange markets up to the turn of the century.[1] They discuss primarily two channels through which sterilized foreign exchange intervention may operate: a portfolio balance channel Mussa (1981) and a signalling channel (Mussa 1981), and identify more support in the empirical literature for the signalling channel than for the portfolio balance channel. In a standard sterilized intervention, the Central Bank engages in selling foreign currency while simultaneously purchasing domestic bonds. This action results in a change in the composition of the Central Bank's balance sheet, characterized

1. There are a number of additional surveys, see (Neely 2005; Vitale 2006; Menkhoff 2010). Neely (2005) discusses the limitations of several event study methodologies that authors in this literature have used, including the use of high-frequency data, and emphasizes problems of identification and simultaneity bias that can arise in event studies in the specific context of foreign exchange intervention. Menkhoff (2010) surveys empirical studies of foreign exchange intervention that use high-frequency data, and groups the studies according to high-frequency data quality: quoted prices by dealing banks and news reports of interventions; precise transaction data with price, volume, and time; order flow data. Menkhoff (2013) surveys empirical studies of foreign exchange intervention in emerging markets.

by a decrease in foreign reserves followed by a rise in the stock of domestic bonds. Conversely, the private sector's balance sheet undergoes an opposite shift as the proportion of foreign currency holdings increases, while the percentage of domestic bonds decreases. If holding foreign currency is perceived as riskier than holding domestic bonds, private agents will be willing to absorb a higher share of foreign currency in their portfolio if they expect a higher return. Consequently, the portfolio balance channel necessitates a corresponding decrease in the relative price of foreign currency, all other factors remaining constant (ceteris paribus). Alternatively, in the signaling channel, the act of selling dollar reserves by the Central Bank signals an anticipated increase in domestic interest rates, which, in turn, triggers a decrease in the spot rate.

We contribute to an empirical literature studying the exchange rate effects and spillovers to other financial markets (Menkhoff, Rieth, and Stöhr 2021; Payne and Vitale 2003; Dominguez 2003; Fratzscher et al. 2019; Fratzscher et al. 2020; Fratzscher et al. 2022; Kearns and Rigobon 2005; Naef 2023; Naef and Weber 2023). Menkhoff and Taylor (2007) conducted a study on the effects of foreign exchange interventions using a new proxy-SVAR methodology and daily data for currency pairs from developed economies. They found that interventions permanently raise stock prices of large firms and temporarily lower stock prices of small firms. Additionally, their research revealed that interventions temporarily lower longer-term (2-yr and 10-yr) interest rates. In a study by Payne and Vitale (2003), high-frequency tick-by-tick data from 1986 to 1995 was used to analyze the effects of sterilized intervention operations by the Swiss National Bank (SNB) on the USD/CHF spot market. Using an event study approach, they find interventions had a persistent effect on exchange rates. They also observed that coordinated and with-the-trend interventions had a more significant impact on exchange rates. Notably, the exchange rates showed a "anticipation effect," moving in the same direction 15 minutes before SNB interventions. The impact of these interventions was immediate and persistent, with the cumulative effect remaining significant even after a few hours. Dominguez (2003) analyzed the effects of interventions by the USA, Japan, and Germany Central (G3) Banks in the USD-DEM and USD-JPY markets between 1987 and 1995. Empirical evidence indicated that Fed intervention operations significantly influenced both USD-DEM and USD-JPY intra-day returns and volatility.

Turning to emerging markets, a number of studies have focused on interventions by the central bank of Brazil (Nakashima 2012; Kohlscheen and Andrade 2013; Janot and Macedo 2016; Santos 2021). In the study by Nakashima (2012), the authors analyzed BRL/USD futures contracts returns in relation to CBB FXI auctions. They found statistically positive abnormal returns shortly after the auction opening and negative returns after the auction closing. They also noted that the timing of the auction had only a minor effect on the returns. Kohlscheen and Andrade (2013) conducted a study using

high-frequency data and an event study approach to examine the effects of FX swap auctions on exchange rates. They found that the most significant impact on exchange rates occurred 60 to 70 minutes after the CBB announcement, which was attributed to the release of auction results. In the research by Janot and Macedo (2016), the authors analyzed CBB interventions' effects on intraday returns and volatility between October 2011 and March 2015. They discovered that non-programmed interventions had a more substantial and persistent impact on the foreign exchange market than programmed ones. In the study by Santos (2021), the impact of pre-announced and unexpected CBB FXI on the exchange rate was investigated. The findings indicated that unexpected interventions were more effective than pre-announced ones, with their effects persisting on the intervention day and the following day.

As well as studying effects on the spot market, we contribute to a literature on emerging market CIP deviations (Du and Schreger 2016; Cerutti and Zhou 2023; Hartley 2020). One key determinant of CIP deviations is sovereign risk. This can be due to higher default rates and the lower credit worthiness of emerging markets, and explain why covered interest rate parity violations exist. A less studied role is the impact of policies such as FXI or central bank swap lines. There is some evidence that China's central bank swap lines can be used to internationalize the Renminbi, however it aims to facilitate export credit and increase the share of invoicing trade in Renminbi (Bahaj and Reis 2020). The dollar intermediation channel proposed in Gabaix and Maggiori (2015) and in related theoretical literature (Fanelli and Straub 2021) suggests that FXI can impact emerging markets through alleviating the demand for dollar liquidity. In our paper, we study the extent to which these policies through using CIP deviations as a proxy for dollar scarcity in cross-border funding markets.

3 Model

To motivate the effects of FXI on dollar intermediation, we adopt the basic Gamma model of Gabaix and Maggiori (2015) with a small modification that allows us to study separately the effects on spot versus swap FXI . In the model, there are two countries, the US (home) and Brazil (foreign), and two periods, $t = 0$ and $t = 1$. In each country, there is a unit measure of households. There are four goods: a non-tradable (NT) and a tradable good in each country. For simplicity, NT are endowments and tradables are produced with inelastically supplied labor. Each country can either borrow or lend in a risk-free bond that is priced in units of the domestic numéraire (the NT good) for each economy.

3.1 Households

We present the primitive equations for the Home economy. Home households maximize the expected present value of lifetime utility,

$$\max_{(C_{NT,t},C_{H,t},C_{F,t})_{t=0,1}} \theta_0 \ln C_0 + \beta \mathbb{E}[\theta_1 \ln C_1] \,, \tag{1}$$

where $C_t \equiv [(C_{NT,t})^{\chi_t} (C_{H,t})^{a_t} (C_{F,t})^{\iota_t}]^{\frac{1}{\theta_t}}$ denotes the household consumption basket, composed of Home non-tradables and Home and Foreign tradables, and where $\theta_t = \chi_t + a_t + \iota_t$ denotes a stochastic preference shock. The household's consumption decisions each period are constrained by an intertemporal budget constraint,

$$\sum_{t=0}^{1} R^{-t} \left(C_{NT,t} + p_{H,t} C_{H,t} + p_{F,t} C_{F,t}\right) \leq \sum_{t=0}^{1} R^{-t} \left(Y_{NT,t} + p_{H,t} Y_{H,t}\right) \,, \tag{2}$$

where $Y_{NT,t}$ and $Y_{H,t}$ denote stochastic endowment processes and where $p_{H,t}$ and $p_{F,t}$ are relative prices of the Home and Foreign tradable goods. The problem facing households in the Foreign country is analogous to the problem facing Home households, except that Foreign households are assumed to receive an additional stream of income deriving from ownership of global financiers, which we introduce in the following section. From the first order conditions for the household problem, the import and export shares of goods in the home country are given by

$$p_{F,t} C_{F,t} = \iota_t \quad \text{and} \quad p^*_{H,t} C_{H,t} = \xi_t \,. \tag{3}$$

The Home and Foreign risk-free rates are determined by the Home and Foreign Euler equations,

$$1 = \mathbb{E}\left[\beta R \frac{\chi_1 / C_{NT,1}}{\chi_0 / C_{NT,0}}\right] \quad \text{and} \quad 1 = \mathbb{E}\left[\beta R^* \frac{\chi^*_1 / C^*_{NT,1}}{\chi^*_0 / C^*_{NT,0}}\right] \,. \tag{4}$$

The Euler equations simplify under the assumption in Gabaix and Maggiori (2015) that non-tradable endowments adjust proportionately with fluctuations in household preference parameters for non-tradable goods, $Y_{NT,t} = \chi_t$ and $Y^*_{NT,t} = \chi^*_t$. With this assumption in place, Home and Foreign risk-free rates become $R = R^* = \frac{1}{\beta}$.

3.2 Financiers

Households borrow and lend in their respective domestic "risk-free" bonds, and global financiers intermediate all bond trading. Financiers absorb any imbalances in global capital flows that result from Home and Foreign demand for bonds. The financiers

maximize the value of this intermediation business,

$$V_0 = E\left[\Lambda\left(\frac{R^*}{R}\frac{e_1}{e_0} - 1\right)\right] Q_0\,, \tag{5}$$

where V_0 denotes the value of the financiers' intermediation business, Q_0 denotes the dollar value of Foreign bonds, and e_t denotes the nominal exchange rate defined as the Home-currency price of one unit of Foreign currency.[2]

Crucially, financiers have limited capacity to bear risk. The limitation derives from borrowing constraints that creditors impose on financiers in order to prevent financiers from diverting funds. The constraints limit financiers' borrowing, such that the value to financiers of abandoning the intermediation business and diverting borrowed funds lies weakly below the value to financiers of continuing to run their intermediation business. To motivate the functional form of the constraint, Gabaix and Maggiori (2015) suggest that financiers can more easily divert funds when their positions are bigger, riskier, and more complex. The constraint is given by

$$\frac{V_0}{e_0} \geq \underbrace{\left|\frac{Q_0}{e_0}\right|}_{\substack{\text{Claims to}\\ \text{Creditors}}} \times \underbrace{\Gamma\left|\frac{Q_0}{e_0}\right|}_{\substack{\text{Diverted}\\ \text{Portion}}}. \tag{6}$$

where Γ parameterizes the financier's ability to divert funds, and therefore governs the risk bearing capacity of financiers. When Γ approaches zero, financiers attain maximal risk bearing capacity and interest parity holds. When Γ approaches infinity, risk-bearing capacity approaches zero and the economy approaches a state of financial autarky.

The financiers' net demand for foreign (BRL) bonds, and corresponding supply of dollars, is given by the following optimality condition from the financiers' value maximization problem subject to the credit constraint,

$$Q_0 = \frac{1}{\Gamma}\mathbb{E}\left[\frac{R^*}{R}e_1 - e_0\right]. \tag{7}$$

The optimality condition states that demand for Foreign bonds will be higher when Γ is low so that risk bearing capacity is high, or when the relative return on Foreign bonds is high after accounting for expected movements in exchange rates.

2. We forgo the distinction between individual financiers and the aggregate financier to keep our exposition of the model as simple as possible. This distinction and other important details of the model can be found in the original paper, Gabaix and Maggiori (2015).

3.3 FX Intervention

The balance of payments constraint records the net demand for dollars each period. Under the constraint, the current account and the capital account of the Home country must balance. The current account records the Home country's net exports while the capital account records the Home country's net flow of investments. The balance of payments conditions for periods 0 and 1 are given by

$$e_0\xi_0 - \iota_0 - FXI - Q_0 = 0 \quad \text{and} \quad e_1\xi_1 - \iota_1 + \eta FXI + Q_0 = 0\,, \tag{8}$$

where we introduce exogenous parameters FXI and η to model foreign exchange interventions by the Brazilian Central Bank. Specifically, we model an intervention by the central bank of Brazil to sell USD at $t = 0$ and buy a fraction η of the BRL back at $t = 1$. If $\eta = 0$ the FXI is a spot sale of USD. If $\eta = 1$ we have a swap FXI in which the sale of USD by the central bank in period 0 is reversed in period 1. In our analysis, we will analyze the effects on the exchange rate and intermediation for the specific cases of $\eta = 0$ and $\eta = 1$.

Substituting equation (7) for the financiers' supply of dollars at $t = 0$ and corresponding demand for dollars at $t = 1$, and making the simplifying assumption that $R = R^* = \iota = \xi = 1$, we derive the following equilibrium spot exchange rate at $t = 0$ and expected spot rate at $t = 1$:

$$e_0 = \begin{cases} 1 + FXI\frac{\Gamma+1}{\Gamma+2} & \text{if } \eta = 0 \text{ (spot FXI)}\,, \\ 1 + FXI\frac{\Gamma}{\Gamma+2} & \text{if } \eta = 1 \text{ (swap FXI)}\,, \end{cases} \tag{9}$$

$$\mathbb{E}[e_1] = \begin{cases} 1 + FXI\frac{1}{\Gamma+2} & \text{if } \eta = 0 \text{ (spot FXI)}\,, \\ 1 - FXI\frac{\Gamma}{\Gamma+2} & \text{if } \eta = 1 \text{ (swap FXI)}\,. \end{cases} \tag{10}$$

In Figure 1, we compare the equilibrium values of the spot exchange rate for a spot and swap FXI. While a swap FXI features an appreciation of the domestic currency in period 0 is offset by a symmetric depreciation of the domestic currency in period 1, we find more persistent effects on the spot exchange rate when using a spot FXI.

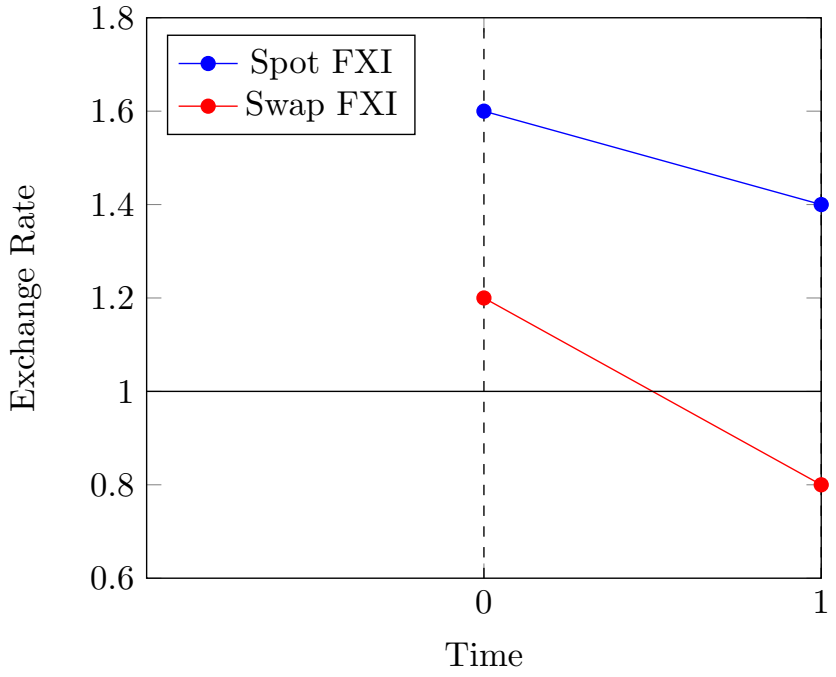

Figure 1: **Exchange rates.** Plots e_0 and $\mathbb{E}[e_1]$ for spot and swap FXI. Parameter calibration: $\Gamma = 0.5$, $FXI = 1$.

This framework yields the following testable implications on the effects of FXI on the spot exchange rate and the intermediation of dollars.

Prediction 1: An FXI of selling USD reserves and buying BRL leads to an appreciation (depreciation) of the BRL (USD) at $t = 0$. The effectiveness of the intervention on the spot rate at $t = 0$ is increasing in the magnitude of intermediation constraints, and is more effective for spot than swap FXI.

$$\frac{\partial e_0}{\partial FXI} = \begin{cases} \frac{\Gamma+1}{\Gamma+2} & \text{if } \eta = 0 \text{ (spot FXI)}, \\ \frac{\Gamma}{\Gamma+2} & \text{if } \eta = 1 \text{ (swap FXI)}. \end{cases} \tag{11}$$

This supports the portfolio balance channel of exchange rates as discussed in Sarno and Taylor (2001). Selling USD reserves requires the relative price of USD to fall in order to induce the financiers to absorb the excess supply of dollars in the balance of payments constraint.

Turning to the role of intermediation constraints, we can show that the sensitivity of the spot rate to FXI is increasing in Γ. An increase in Γ is associated with a decline in risk bearing capacity of the financiers, and their supply of dollars is more inelastic. Therefore an FXI elicits a larger price change in the spot rate.

$$\frac{\partial e_0}{\partial FXI \partial \Gamma} = \begin{cases} \frac{1}{(\Gamma+2)^2} & \text{if } \eta = 0 \text{ (spot FXI)}, \\ \frac{2}{(\Gamma+2)^2} & \text{if } \eta = 1 \text{ (swap FXI)}. \end{cases} \tag{12}$$

Prediction 2: An FXI of selling USD reserves and buying BRL reduces the size of the dollar intermediation by financiers.

The equilibrium level of dollar intermediation Q_0 is given by equation (13). Note that in this simplifying setup, the FXI requires financiers to absorb the excess supply of dollars by the central bank. Therefore their net dollar intermediation is negative. In particular, financiers have to absorb a larger supply of dollars if they face tighter intermediary constraints ($\Gamma \uparrow$).

$$Q_0 = \begin{cases} -FXI \frac{1}{\Gamma+2} & \text{if } \eta = 0 \text{ (spot FXI)}, \\ -FXI \frac{2}{\Gamma+2} & \text{if } \eta = 1 \text{ (swap FXI)}. \end{cases} \tag{13}$$

While the amount of dollar intermediation by financiers is not directly observable in the data, we can test this indirectly through measuring covered interest rate parity deviations in the BRL/USD pair. In the model framework, the CIP violation can be written as the difference between interest rates on foreign and domestic currencies after hedging exchange rate risk with a forward contract. If forward markets are efficient, and the forward rate is an unbiased predictor of the future spot rate, $f = \mathbb{E}[e_1]$, the dollar intermediation by financiers is proportional to the CIP violation. Therefore we can test whether FXI affect the net intermediation of dollars through measuring the CIP violation.

4 Definitions and Data

4.1 BCB FXI

In this section we introduce the BCB intervention database and interventions we study in the paper.

4.2 BCB institutional details

The spot market operates as a decentralized, multiple-dealer market. By July 2020, a total of 181 financial institutions, including banks and brokers, were authorized to participate in this market. Interventions are carried out by the Central Bank of Brazil (CBB) through the International Reserve Department (DEPIN) by trading with a subset

of these institutions, specifically 14 accredited financial institutions, which are referred to as dealers-14. These institutions, primarily large banks, play several key roles. According to the CBB, they attend PTAX consultations to set the daily reference price for the market, act as CBB dealers during foreign exchange interventions, provide quotes for purchase and sale rates for foreign currencies upon request and participate in conference calls with the CBB to ensure coordinated market operations.

These interventions' timing and details are publicly announced and documented by the "BC Correio" platform and Estadão Broadcast. "BC Correio" provides detailed accounts of the CBB auctions, while Estadão Broadcast offers ex- tensive coverage of financial news.

4.3 Instrument types

Spot Purchase and Spot Sales: Operations in which the BCB buys or sells US dollars in the interbank foreign exchange market for immediate delivery, settling within two business days, with the corresponding counterpart in Brazilian Reais.

Traditional Swap: Auctions when the BCB assumes a buying position in the Swap contracts. The central bank exchanges USD for BRL at the spot leg. Interest repayments on the swap are exchanged at regular intervals until maturity, with the central bank paying USD Libor to the dealer, and the dealer paying the Selic interest rate in BRL. At maturity of the swap, the central bank and dealer re-exchange BRL for USD.

Reverse Swap: Auctions when the BCB assumes a selling position in the Swap contracts. The central bank exchanges BRL for USD at the spot leg. Interest repayments on the swap are exchanged at regular intervals until maturity, with the central bank paying the Selic interest rate in BRL to the dealer, and the dealer paying the USD Libor rate. At maturity of the swap, the central bank and dealer re-exchange USD for BRL. Figure 2 shows the spot, interest rate and maturity legs of a traditional and reverse swap contract.

We define *unexpected interventions*: as those where the operational date is on the same day as the date of announcement, while *expected interventions* are those for which the operational date is later than the date of announcement.

Date and Time of Announcement: The date and time at which the BCB informed the public that there would be, at a future time or date, an intervention in the foreign exchange market, or, in the case of auctions in the interbank spot or forward markets, that an intervention had begun.[3]

Operational Date: The date on which the intervention occurred. BCB only pub-

3. With the exception of direct operations in the spot market between July 1999 and February 2003 when the corresponding Announcements were disclosed at the end of the day, making public that the BCB had intervened in the exchange on that day.

lishes the date but not the exact time of the operations.

Table 1 provides summary statistics on the Brazilian Central Bank's (BCB) foreign exchange (FX) interventions, categorized into the different types. Examining unexpected interventions, spot sales, the mean unexpected intervention amount is 0.17 billion USD, with a standard deviation (S.D) of 0.22 billion USD. For traditional (reverse) swaps, the mean unexpected intervention amount is 0.43(0.35) billion USD, with an S.D of 0.41 (0.45) billion USD. Turning to expected interventions, the amounts are generally smaller for each category, however there is big difference in the number of interventions. For spot sales, most are conducted intra-day with the date of announcement and operation being the same, with 385 unexpected and 87 expected announcements. All spot purchases are unexpected. In contrast, for swap transactions, there are more expected announcements, for example over 5000 expected announcements for the traditional swap, in contrast to 345 unexpected.

Figures 5 and 6 plot the time series of FXI and the distribution of expected and unexpected distribution in amounts offered. Figure 7 shows the cumulative interventions of each category over time. There has been a general move by the BCB to traditional swaps over time as the principal policy instrument, and reduced reliance of using USD. The motivations for switching toward derivative contracts is that they are balance sheet neutral for the central bank. A traditional FX swap is essentially a USD loan collateralized by BRL, and the central bank maintains their USD reserves after maturity of the FX swap. In contrast, selling USD spot results in a permanent reduction in the central bank reserves, which can be costly due to the need for reserves as a level of precautionary savings or as insurance against periods of tight intermediary constraints (Cheng 2015; Jeanne and Sandri 2020). For example, spot sales of USD reserves, after being used very little in 2010-2019, were reintroduced in 2020 during the pandemic in response to dollar scarcity in cross-border markets and an increase in dollar funding costs as measured by CIP deviations.

Finally, Figure 8 plots the maturity of traditional and reverse currency swaps for both expected and unexpected announcements. Unexpected swaps are typically of short maturities (less than 2 days), whereas expected swaps have a wide distribution of maturities that range from overnight to 3 months. The motivation for expected and unexpected currency swaps may differ: unexpected swaps may be typically used for short-term liquidity provision to specific dealers to address roll-over risk and ensure the functioning of interbank money markets. In contrast, long-term liquidity provision may be to address the maturity and currency mismatch of bank balance sheets.

4.4 CIP deviation

CIP states that the interest rate differential between two currencies should be equal to the differential between the forward and spot exchange rates. The idea behind Covered Interest Rate Parity is simple. An investor with one US dollar in hand at time t can either: a) Invest in US and earn a risk free interest rate. Or b) Exchange her dollar for at spot market for foreign currency and earn a risk free interest rate in foreign currency. She can sign currency forward contract at time t to convert the foreign currency earned back to US dollar at time $t+n$.

The CIP violation states that two strategies should give investor same return, i.e.,

$$(1 + r_{t,t+n})^n = (1 + r^*_{t,t+n})^n \frac{S_t}{F_{t,t+n}} \tag{14}$$

where $r_{t,t+n}$ is the risk-free interest rates between t and $t+n$ in US dollar, and $r^*_{t,t+n}$ is the corresponding risk-free interest rate in foreign currency. S_t is the spot rate in units of US dollar per foreign currency, and $F_{t,t+n}$ is the corresponding forward rate.

Violations of CIP can be quantified by the cross currency basis $x_{t,t+n}$. Follow Du, Tepper, and Verdelhan (2018), the Cross-Currency Basis is defined as the difference between the direct U.S. dollar interest rate and the synthetic dollar interest rate:

$$(1 + r_{t,t+n})^n = (1 + r^*_{t,t+n} + x_{t,t+n})^n \frac{S_t}{F_{t,t+n}} \tag{15}$$

In log terms, the cross currency basis is equal to:

$$x_{t,t+n} = (r_{t,t+n} - r^*_{t,t+n}) + \rho_{t,t+n} \tag{16}$$

where $\rho_{t,t+n}$ denotes the forward premium:

$$\rho_{t,t+n} \equiv \frac{1}{n}(f^{bid}_{t,t+n} - s^{ask}_t) \tag{17}$$

4.5 Data sources

4.5.1 B3 Exchange data

We use tick-level data on futures and interest rates obtained from Brazil's main stock exchange, B3. This was accessible via an FTP on their website for a specific period. This dataset encompasses tick-by-tick trading prices, volume, aggressor buy-sell signals, market participants' trading codes which are indicative of market players' behaviors and bid and ask quotes. This dataset records transactions from 28/02/2019 to 23/01/2020, covering 224 days of tick-by-tick trades.

4.5.2 Reuters benchmark Spot and forward prices

To supplement our B3 data, we obtain tick-by-tick high-frequency data for spot and forward indicative quotes from Thomson Reuters Tick History and interdealer trades from the Thomson Reuters D3 platform. These quotes are given at 5 minute intervals and include bid and ask prices, and cover a longer sample from 2002 to 2023, and is used for our econometric analysis in section 5. We use the mid-quote of the spot and forward price for our analysis. Figure 9 plots both the BRL/USD Spot Rate and The BRL/USD Currency Basis, where the spot exchange rate S_t is expressed in units of Brazil Real per U.S. dollar, where an increase in S_t denotes a depreciation of the Brazilian Real and an appreciation of the U.S. dollar. The spot exchange rate has been on a trend appreciation since 2008, depreciating from 2 Real per USD to above 5 Real per USD in 2020. The currency basis is measured in basis points, and is persistently negative over the sample. This is consistent with a premium to swap Brazilian Real into USD, and suggests a relative scarcity of USD funding in cross-border markets.

4.5.3 Interest rates

We obtain daily interest rates from the IPEA Brazil Government dataset. For a given maturity (eg. 1 month) it is constructed using the rates of return for different maturity dates of a given security. For the 1 month maturity, it uses the yield curve of the National Treasury Bill (LTN) with a term of 21 business days. In addition, the IPEA dataset includes daily interest rate forecasts at the 1 month maturity. Figure 10 plots the BCB's Selic rate target, the median and standard deviation of the surveyed Selic rate expectations as conducted by the BCB. The selic interest rate target and forecasts range widely from 0 to 20 per cent, with a recent BCB tightening cycle occurring from late 2020 to 2023. The standard deviation of interest rate forecatss is 0.1-0.2 percentage points.

4.5.4 Intermediary constraints

Following He, Kelly, and Manela 2017 and Cerutti and Zhou 2023, we use a set of primary dealers that serve as trading counterparties to the Federal Reserve Bank of New York in its implementation of monetary policy. These institutions are large and active intermediaries who are likely to be marginal in almost all financial markets.

Specifically, we use the *intermediary capital ratio*.[4]

$$HKM_{it} = \frac{\sum_i Marketequity_{it}}{\sum_i Marketequity_{it} + Bookdebt_{it}} \tag{18}$$

4. The data is obtained from the website of Zhiguo He: https://voices.uchicago.edu/zhiguohe/data-and-empirical-patterns/intermediary-capital-ratio-and-risk-factor/.

where book debt is computed by subtracting total common equity from total assets. We follow Cerutti and Zhou 2023 and construct an index using the subset of primary dealers that deal with emerging market currencies based on the Euromoney FX survey. [5]

A decline in the intermediary capital factor captures declining risk-bearing capacities of the largest EM currency dealers. The intuition is that a decline in the intermediary's capital ratio tightens the borrowing constraints of primary dealers and thus reduces their demand for risky assets in the presence of capital requirements such as the Tier 1 capital ratio. The capital ratio of primary dealers is important for their ability to intermediate dollars in cross-border financial markets. Changes in the elasticity of supply of intermediaries matter for the price effects of FXI, which we will discuss formally in the model framework and empirical evidence.

4.5.5 Credit risk

One issue with measuring CIP deviations for emerging markets is accounting for differences in credit risk across currencies (Du and Schreger 2016). To control for credit risk, we use EMBI+ (Emerging Markets Bond Index Plus), which estimates the daily performance of emerging countries' debt securities in relation to United States Treasury bonds, obtained from the IPEA Brazilian government dataset. The index is based on the bonds (debt securities) issued by this group of countries and shows the financial returns obtained each day by a selected portfolio of securities.

5 Empirical Evidence

5.1 Intra-day case study: November 27, 2019

In the days leading up to the November interventions, the BRL experienced heightened volatility and a depreciation trend against the USD. On November 25th, the PTAX bid rate on the B3 exchange rose from 3.7643 BRL/USD in July's end to 4.2083 BRL/USD, reflecting almost a 12% weakening of the real. Various domestic and international factors, including a drop in Brazil's benchmark interest rate (SELIC) from 6.40% to 4.90% by November 2019, contributed to the BRL's instability. Trade tensions between the United States and China, coupled with domestic political uncertainties, further dampened investor interest in the BRL.

The analysis of spot BRL/USD price variations within the trading day on the 27th of November reveals an overall price change of 0.80% for the entire trading period, from

5. The listed entities we use for our analysis includes 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.

09:00:00 to 18:15:00 (Figure 3). The price changes during the anticipated CBB interventions were positive and minimal, at 0.02% and 0.06%, occurring from 09:30:00 to 09:35:00 and from 11:30:00 to 11:40:00, respectively. However, an unexpected CBB auction led to a significant price decrease of -0.38% between 12:38:00 and 12:45:001.

One of the most liquid contract in terms of traded volume in the futures market on this day was the WDOZ19. The WDO contract is denominated in Brazilian Reais (BRL) per USD 1,000, with each contract representing a USD 10,000.00 exposure. A number of 1,536,144 contracts were traded, to- talling, 15,361,440,000 USD. These contracts are scheduled to mature on the first business day of the month following their designation. For instance, in November 2019, the WDOZ19 contract was among the most actively traded, with its maturity set for December 2019. Additionally, the market features the DOL contract, similar in structure to the WDO but differing in tick size, representing USD 50,000. Despite a lower number of DOLZ19 contracts traded, 323,530, their trading volumes surpassed those of the WDO, totaling 16,176,500,000 USD.

The WDO tick-by-tick dataset encompasses 383,518 observations (trades) during the trading session. Aggregating the trades with the same price to the nearest millisecond decreases the total to 157,781 observations. Analysis of trading intervals reveals 9 hours of trading, with an additional 15 minutes of after-hours, totaling 555 minutes or 33,300 seconds. This corresponds to an average of approximately 11.5 transactions per second and 690 per minute, with the possibility of each transaction involving multiple contracts. Trades are frequent within this timeframe. An examination of the top 3 intervals without trade shows that two of them occured after official trading hours, specifically after 18:00. The longest interval without any trades is 15.130 miliseconds, observed at 16:52:46.177 towards the trading session's ending. Prices aggregated on a millisecond basis are depicted in Figure 3, together with the cumulative *order flow*. The latter term denotes the net initiated buy orders over sell orders, derived from our dataset that includes aggressor buy-sell indicators.

The upward trend in the future price during the early part of the day is visible in Figure 3, where the price of the WDO contract is represented on the left vertical axis and the cumulative order flow in billions of USD is depicted on the right vertical axis. Shaded areas in the figure indicate the timing of the Central Bank interventions. Visual inspection suggests that these interventions, particularly the first and second, marked by their respective shaded areas, moderate the pace of the price increase. The third intervention, unexpectedly executed and highlighted with a light gray shade, coincides with a significant downward jump in the exchange rate.

The chart not only shows a decline in future prices but also a substantial decrease in order flow, indicating an accelerated execution of seller-initiated orders in the minute following the public announcement. This acceleration is likely due to limit orders that

remained in the order book failing to adjust promptly to the news or other factors causing a lag in market participants' responses.

The high-frequency nature of our dataset enables a clear identification strategy for the intervention shock, a challenge in intervention studies using low-frequency data. This difficulty arises from distinguishing intervention announcement effects from other news and identifying suitable instrumental variables closely related to interventions but not to exchange rate changes, as emphasized by Fratzscher et al. 2019.

To test for more systematic effects, we use the local projections method for the forward rate specified in equation (19), where f_{t+h} denotes the natural logarithm of the forward contract price f_t for the WDO contract at time t over various horizons h; Δ stands for the first difference; β is the coefficient for the order flow variable ρ at time $t+h$; D_1, D_2, and D_3 are dummy variables that correspond to the start of the first, second, and a third intervention, respectively; γ_1, γ_2, and γ_3 are the coefficients linked to these dummy variables; ϵ_{t+h} represents the error term at time $t+h$. The analysis is conducted across multiple horizons (in minutes), with h ranging from 0 to 30 as shown in Figure 4.

$$\Delta f_{t+h} = \alpha + \beta \rho_{t+h} + \gamma_1 D_1 + \gamma_2 D_2 + \gamma_3 D_3 + \epsilon_{t+h} \tag{19}$$

The first two panels illustrate the effects of the initial and subsequent anticipated interventions, predominantly show local projection coefficients within confidence intervals encompassing zero. This suggests statistically insignificant impacts on the forward rate at most horizons. Notably, the BRL/USD rate exhibits a decrease a few minutes before the expected intervention, making it challenging to pinpoint the precise moment when the market adjusts for the upcoming FX auction. The last panel of the Figure depicts the unexpected intervention's impact. Estimated coefficients reveal a substantial negative impact on the forward rate, with relatively narrow confidence intervals. This implies a rapid and significant effect lasting only two minutes, yet persisting at the forward rate level.Our significant impact finding is robust to the inclusion of order flow as a control variable.

5.2 Impact of FXI: BCB event database (1999-2023)

We use the following specification to test the effects of FXI on the outcome variable y_t, which includes BRL/USD spot prices, forward premia and CIP deviations.

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

Where HKM_t is the HKM Intermediary Capital Risk Factor, and INT_t^z represents the amount of BCB's intervention at time t in US dollar, $z \in \{$*Spot sale, Spot Purchase, Traditional Swap, Reverse Swap*$\}$. SAD_{t+h} indicates whether y_{t+h} is on the same day as y_t, when the announcement of intervention occurred.

$$INT_t^z = \begin{cases} \text{Amount in USD} & \text{if intervention of type } z \text{ was announced at } t \\ 0 & \text{otherwise} \end{cases}$$

$$\text{SAD}_{t+h} = \begin{cases} 1 & \text{if } t+h \text{ is on the same } \textbf{day} \text{ as } t \\ 0 & \text{otherwise} \end{cases}$$

Daily frequency controls include lagged value up to 10 days for interest rates, the term interest rate spread, spot market volatility, the total amount of interventions in USD (of all instruments) at date t, Brazilian Emerging Markets Bond Index Plus (EMBI+), which measures the sovereign risk of Brazil. High-frequency controls include lags of the outcome variable, and lagged spot rate bid-ask spreads up to 10 lags.

5.2.1 Spot prices

The results of our local projections method are shown in Figure 11. [6] Our results dis-aggregate interventions into spots and swaps and further classifying whether they are buy or sell. Spot sale interventions have the largest effect on spot prices–reaching a 1.5 percentage point appreciation intra-day over a 7 hour window. In contrast, buy interventions have no effect. Turning to FX swaps, we find weak transitory effects of unexpected traditional FX swap interventions, with a a 10 basis point appreciation within 1 hour of the shock. Similarly, we observe a short-term transitory depreciation of the BRL for an unexpected reverse swap of approximately 15 basis points over a 1 hour horizon. For both a traditional and reverse swap, the effects are transitory and insignificant over a longer horizon.

A number of studies have quantitative results regarding the effect of a FXI on the spot rate (Kearns and Rigobon 2005; Santos 2021; Dominguez, Fatum, and Vacek 2013; Naef and Weber 2023; Arango-Lozano et al. 2020). In the Brazil case, Santos (2021) estimated that for each USD 1 billion discretionary intervention, the BRL appreciated by 29.4 basis points (bps) in the futures market. These results are quantitatively smaller

6. For our analysis, we focus on unexpected interventions as we have a high frequency timestamp of the announcement. In contrast, we do not observe the high frequency timestamp of expected interventions, and as these interventions are anticipated the effects on spot and forward markets are more likely to be priced prior to operations. However, we provide results for expected interventions in Appendix B, and use the Brazilian market opening time as an event date for the operations. In general, we do not find any significant effects of expected interventions.

than the effects of the unexpected spot sales, however are larger than the effects we find for traditional and reverse swap auctions. To reconcile our findings, we note that the dis-aggregation of interventions shows clear heterogeneity in the effects. In particular, any permanent effects on the spot rate are derived from spot sale interventions, whereas swap interventions are transitory. This is supportive of the model framework in distinguishing between spot and swap interventions. While swap FXI typically lead to a reversal in the exchange rate, spot FXI can have more persistent effects.[7] Another interesting result is that spot purchase interventions are less effective. One potential reason for the asymmetry is that USD buy interventions are typically conducted during periods of relaxed intermediary constraints. During these periods, we expect weaker effects on spot exchange rates as intermediaries can absorb the excess supply of BRL on their balance sheet. We test the asymmetry of interventions more concretely when we proxy for intermediary constraints in section 5.3.

5.2.2 CIP deviations

The CIP deviation measures the difference between the synthetic and direct dollar interest rate. Based on the model framework, we hypothesize that a FXI to sell USD and buy BRL will reduce the amount of USD that is absorbed by global financiers. All else equal, this will reduce the risk premium associated with providing USD in FX forward and swap markets, narrowing the CIP deviation. The local projections method estimates the intra-day effects of FXI on the CIP deviation. The results in Figure 12 suggest that of the different policy instruments, spot sales have the most persistent effects on the CIP deviation. The positive coefficients report an attenuation of the CIP deviation, which reduces the relative cost of swapping BRL into USD using forward and swap contracts. This makes it easier to obtain dollar liquidity in FX markets, and is consistent with our model framework. In contrast, we find weak and insignificant effects of swap FXI (traditional and reverse), and a short-term widening of CIP deviations of approximately 50 basis points after 2 hours for spot purchase FXI, which becomes insignificant over a 7 hour window. While we expect traditional swaps to have an impact on CIP deviations, we note that traditional swaps occur much more frequently than spot sale transactions, and occur during periods where intermediaries are unconstrained. We now turn to testing the heterogeneity of FXI across intermediary constraints.[8]

7. See Figure 1 for a simple calibration of the model for spot and swap FXI.

8. We provide additional results on the forward premium in Appendix C. The forward premium responds in a way that is consistent with the observed response of CIP deviations. This is important to link the behavior of CIP to the relative demand for currency forwards. If the FXI increases USD liquidity in FX swap markets, it will increase the forward premium (denominated in units of BRL per USD). This is what we find, with strongest results for spot FXI sales of USD reserves.

5.3 Intermediary constraints and FXI

The model framework suggests that the effects of FXI are stronger during periods of intermediary constraints. The price effects of the FXI are dependent on the relative elasticity of supply of dollars by the global intermediary. When global intermediaries are constrained, there is a limited supply of dollar liquidity to Brazilian firms, and the supply of dollars is relatively inelastic. The central bank therefore conducts operations to supply dollars (in either spot or forward/swap markets) to alleviate the demand for dollar liquidity. When the supply of dollars are more inelastic, we expect stronger price effects of FXI.

To proxy for intermediary constraints, we use the measure of dealer capital ratio in He, Kelly, and Manela (2017). This measures shocks to the daily growth in dealer capital. The specification we run is shown in equation (21).

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

A dummy variable $D_{HKM,t}$ takes a value of 1 for periods in which the HKM is above and below the 50th percentile, and is interacted with the size of the FXI INT for spot and swap transactions. Periods of tight intermediary constraints are characterized by a below median HKM, which is precisely when the ratio of dealer capital to total assets is low.

We present our results for the effects on the spot rate in Figure 13. We examine the effects of only the interaction of the below median HKM and the FXI is significant. For spot FXI, a 1 USD Billion spot sale of USD reserves corresponds to an intra-day appreciation of the BRL of 2 percentage points over a 7 hour window. There is no significant spot rate changes during periods For comparison, the unconditional effect of 1 USD Billion spot sale was approximately 1.5 percentage points over the same period. Turning to swap FXI, for traditional swaps, we similarly find a clear difference between periods of tight and slack intermediary constraints. While tight intermediary constraints result in an approximate 20 basis point appreciation over a 7 hour window, we find a weak but insignificant depreciation of 40 basis points during periods of slack intermediary constraints. This suggests that the state of intermediary constraints matter for the effectiveness of swap FXI. The results for spot FXI purchases and reverse swaps are insignificant in periods of tight and slack intermediary constraints. This is intuitive: when the central bank purchases USD and conducts an unexpected swap to buy USD spot and sell USD forward, there is ample USD liquidity in Brazilian financial markets. Therefore the necessary change in currency and the funding costs for dealers to intermediate USD

liquidity are unaffected.

We present our results for the effects on CIP deviations in Figure 14. Our second model prediction shows that FXI relax intermediation constraints and reduce the aggregate amount of USD intermediation, with a decline in the magnitude of CIP violations. While swap FXI did not have any effects on CIP violations unconditionally, we observe clear effects after conditioning for the degree of intermediary constraints.[9]

5.4 Interest rates

So far we have found evidence for the dollar intermediation channel–which is a specific case of the portfolio balance models with constrained financial intermediaries. We now test the effects of FXI on the future path of interest rates. This contributes to a debate on whether the signalling or portfolio balance channel are quantitatively important for the transmission of FXI (Sarno and Taylor 2001). The signalling channel of monetary policy is that FXI can provide 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 wants to strengthen the domestic currency in the future. All else equal, this requires higher future domestic interest rates.

We test the signalling channel using intra-day interest rate futures data from B3, and daily interest rate forecasts based on survey data provided by the Government IPEA database.

5.4.1 High frequency interest rates

Figure 15 plots the response of interest rate futures to the unexpected spot sale interventions on August 27, and November 26 and November 27, 2019. [10]

The 1 month interest rate futures increases by up to 15 basis points 2 hours after the announcement, and then drops to approximately 2.5 basis points 6 hours after announcement. In addition, 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 reaches a peak of 20 basis points, and declines to 10 basis points after 7 hours, and the spread between the 1 month and 5 year yields increases in the immediate hours but is close to zero over the day.

Our results are consistent with an announcement effect for interventions that have not been sterilized. The spot sales of USD are consistent with a decrease in the money

9. We consider alternative ways to measure intermediary constraints in Appendix D. Using the absolute value of CIP deviations as a proxy for intermediary constraints, we observe similar patterns: FXI of spot sales and the traditional swap during periods of above median $|CIP$ lead to a BRL appreciation and a narrowing of the CIP basis.

10. We select these dates as they are the only unexpected interventions during the sample coverage of the B3 exchange data.

base. As spot sale transactions are processed $T+2$, the sterilization of the money supply occurs 2 days after announcement, by the open money market operations of the BCB.[11] The effects are quantitatively and economically insignificant: a 1 USD Billion change in USD increases interest rates by between 2.5 basis points for the 1 month and by up to 10 basis points averaging across maturities. In comparison, a 1 USD Billion spot sale leads to a 1.5 percentage (150 basis point) change in the spot appreciation, and a 50-100 basis point narrowing of the CIP basis.

5.4.2 Interest rate forecasts

The prior analysis examined a limited set of unexpected spot sale announcements, and examined intra-day effects. We now turn to longer-term effects using interest rate forecasts of the private sector of what will happen to the Selic (central bank) rate at the next meeting.[12] Our baseline specification in equation (20) is estimated using interest rate forecasts as the outcome variable.

For spot and swap FXI, we examine the effect of net (sell-buy) interventions for spot and swap. Using the net variable is important as the signalling channel ex ante should have symmetric effects with respect to whether it is a buy or sell intervention. Figure 16 reports the results of the local projections.[13]

We find no significant effects of FXI on interest rate forecasts. Interest rates decline (weakly) by up to 25 basis points with respect to both (net) spot and swap FXI over 2 months however over a 6 month period there are no significant effects. In summary, we find weak evidence for the central bank signalling high interest rates in response to a spot sell intervention.

6 Conclusion

The empirical literature on foreign exchange (FX) interventions has focused on the dynamics of the spot exchange rate, but a less explored area is understanding the spillover effects of these interventions on interest rate markets. This study aims to investigate this relationship, particularly concerning the signaling channel and the covered interest rate parity (CIP) condition, which is a critical no-arbitrage benchmark in international finance. To address these questions, we analyze high-frequency FXI conducted by the Brazilian Central Bank (BCB). We have access to a comprehensive historical database of these interventions, including their type, volume, and timing. Combining this intervention data with tick-level information on spot and futures prices, we employ the local projections method to measure the effects of FXI.

11. For details on the sterilization, please see Appendix A
12. There are 8 scheduled meetings of the BCB each year
13. The results are quantitatively similar when using realized interest rates than interest rate forecasts.

Our findings reveal several key insights. First, our high-frequency examination of FXI reveals that unanticipated sales of USD reserves by the Brazilian Central Bank systematically appreciate the BRL and narrow the Covered Interest Rate Parity (CIP) deviation. This suggests that FXI serves as a policy tool to enhance efficiency in foreign exchange markets.

Second, the paper highlights the importance of the dollar intermediation channel, showing that the effects of FXI are more pronounced during periods of tight intermediary constraints. Spot sales exhibit significant effects in such periods, whereas interventions during slack constraints show limited impact. Additionally, FXI reduces the size of dollar intermediation by financiers, leading to a decline in net dollar intermediation and relative costs of intermediating dollars in financial markets, which we measure as a reduction in CIP violations.

Third, we contribute to the ongoing debate on portfolio balance vs. signaling channels of FXI by testing for spillover effects into interest rate markets. Using both intra-day data and survey-based interest rate forecasts, USD sales of foreign reserves by the BCB are not correlated with a significant change in interest rates, with limited evidence supporting the signalling channel.

Taken together, our findings show that FXI can alleviate constraints on global financial intermediaries, and reduce the cost of obtaining dollars in FX markets. We have shown that while both spot and swap FXI are effective at alleviating constraints, spot interventions have a more persistent and quantitatively larger impact on spot rates and the currency basis.

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Figures

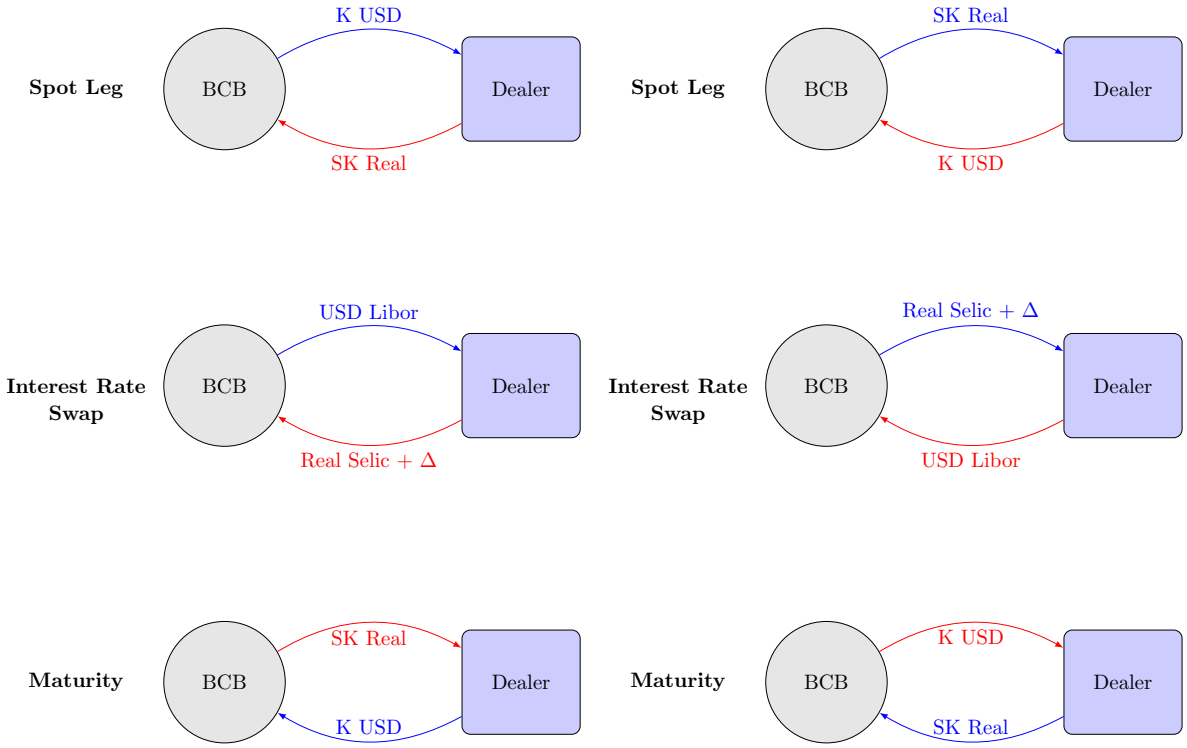


Figure 2: **Traditional and Reverse Cross-Currency Swap.** In the traditional swap (left panel), the central bank exchanges USD for BRL at the spot leg. Interest repayments on the swap are exchanged at regular intervals until maturity, with the central bank paying USD Libor to the dealer, and the dealer paying the Selic interest rate in BRL plus the addition of the cross-currency basis Δ. At maturity of the swap, the central bank and dealer re-exchange BRL for USD. In the reverse swap (right panel), the central bank exchanges BRL for USD at the spot leg. Interest repayments on the swap are exchanged at regular intervals until maturity, with the central bank paying the Selic interest rate in BRL to the dealer plus the addition of the cross-currency basis Δ, and the dealer paying the USD Libor rate. At maturity of the swap, the central bank and dealer re-exchange USD for BRL.

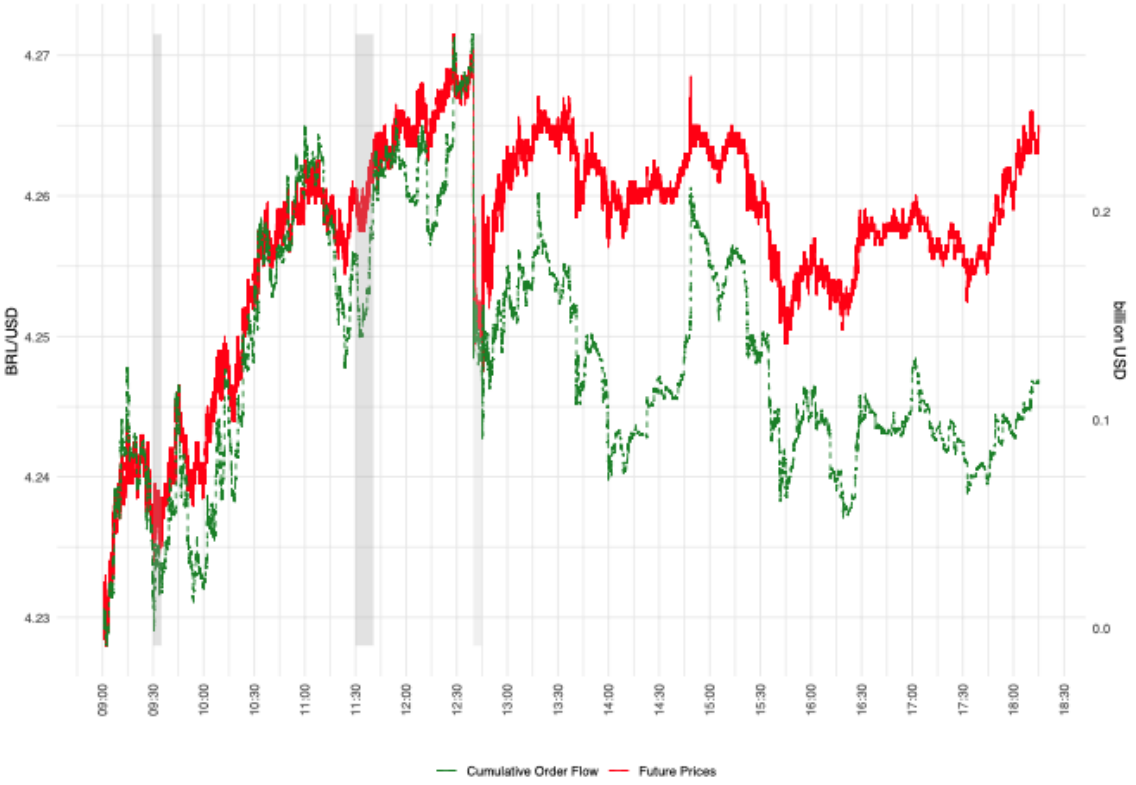


Figure 3: **This plot shows the BRL/USD spot rate on announcement day November 27, 2019.**

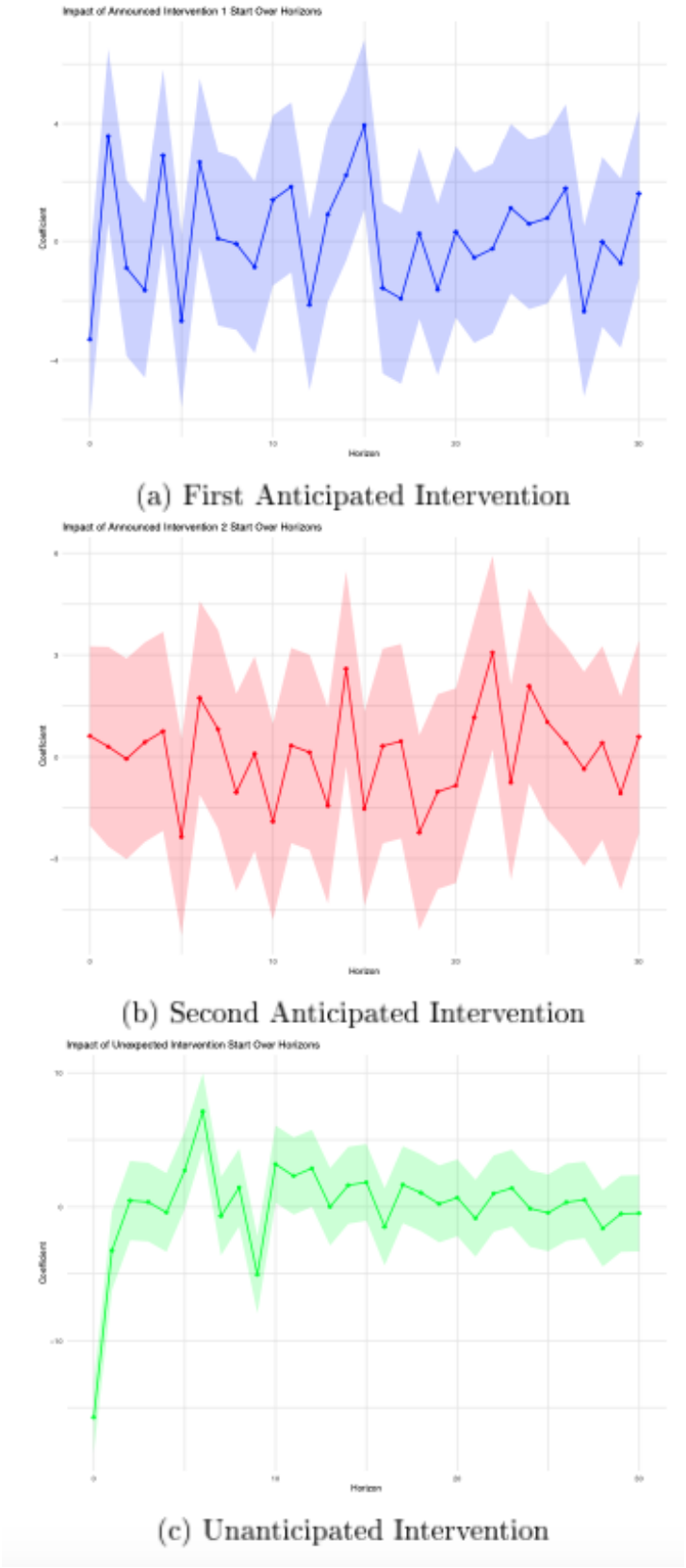


Figure 4: **Local Projections of Forward Rate - Impact of Central Bank of Brazil Interventions on 27th of November, 2019.**

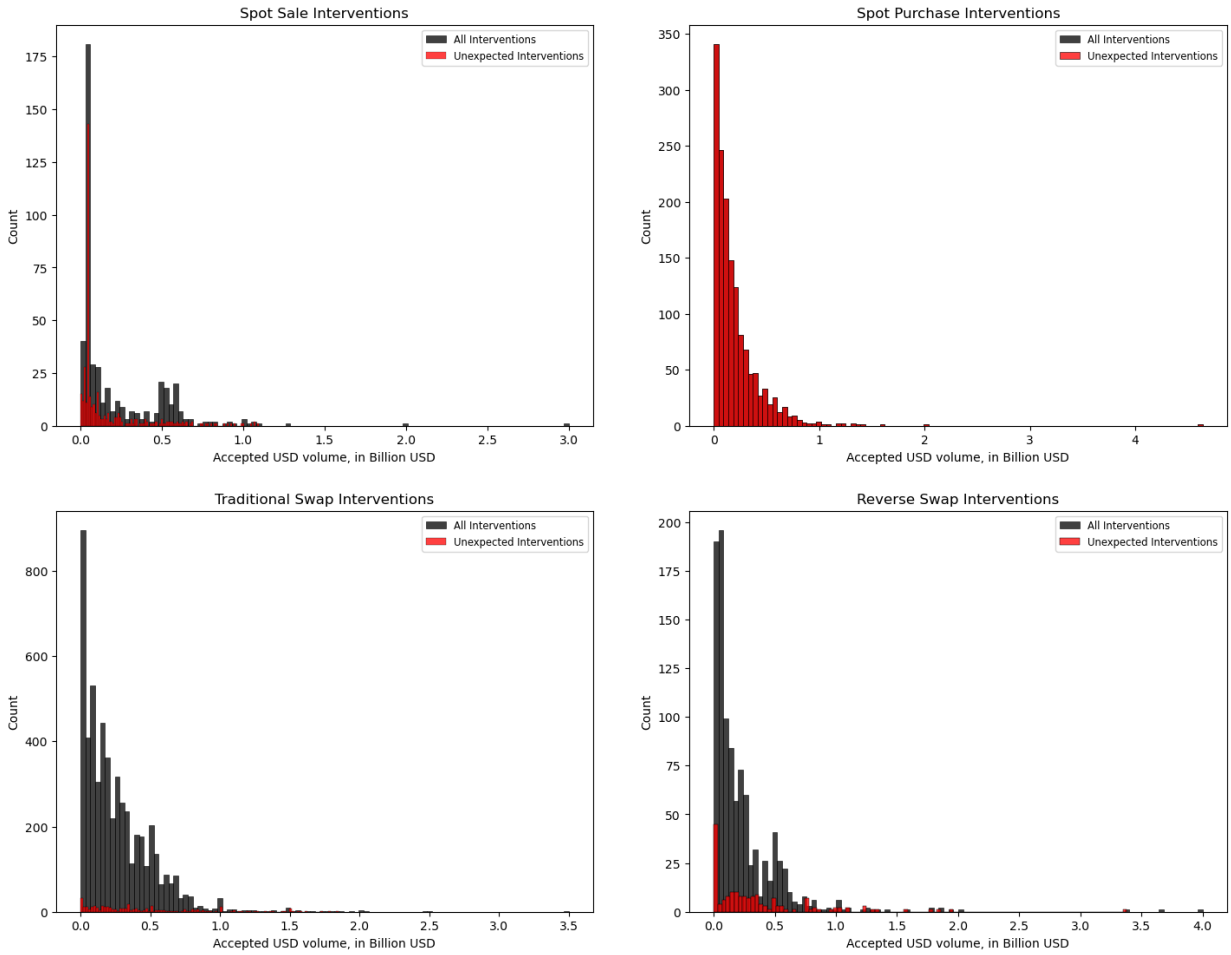


Figure 5: **Distribution of The BCB's Interventions in FX market.** These figures show the distribution of BCB's interventions in the FX markets. The amount of intervention is in billion USD, and is aggregated at daily level. For unexpected interventions the announcement date is equal to the operation date. For expected interventions the announcement date precedes the operation date. Traditional (reverse) swap is the sale (purchase) of USD at the spot leg of the swap contract. Sample period is from 1999-01-22 to 2023-04-27.

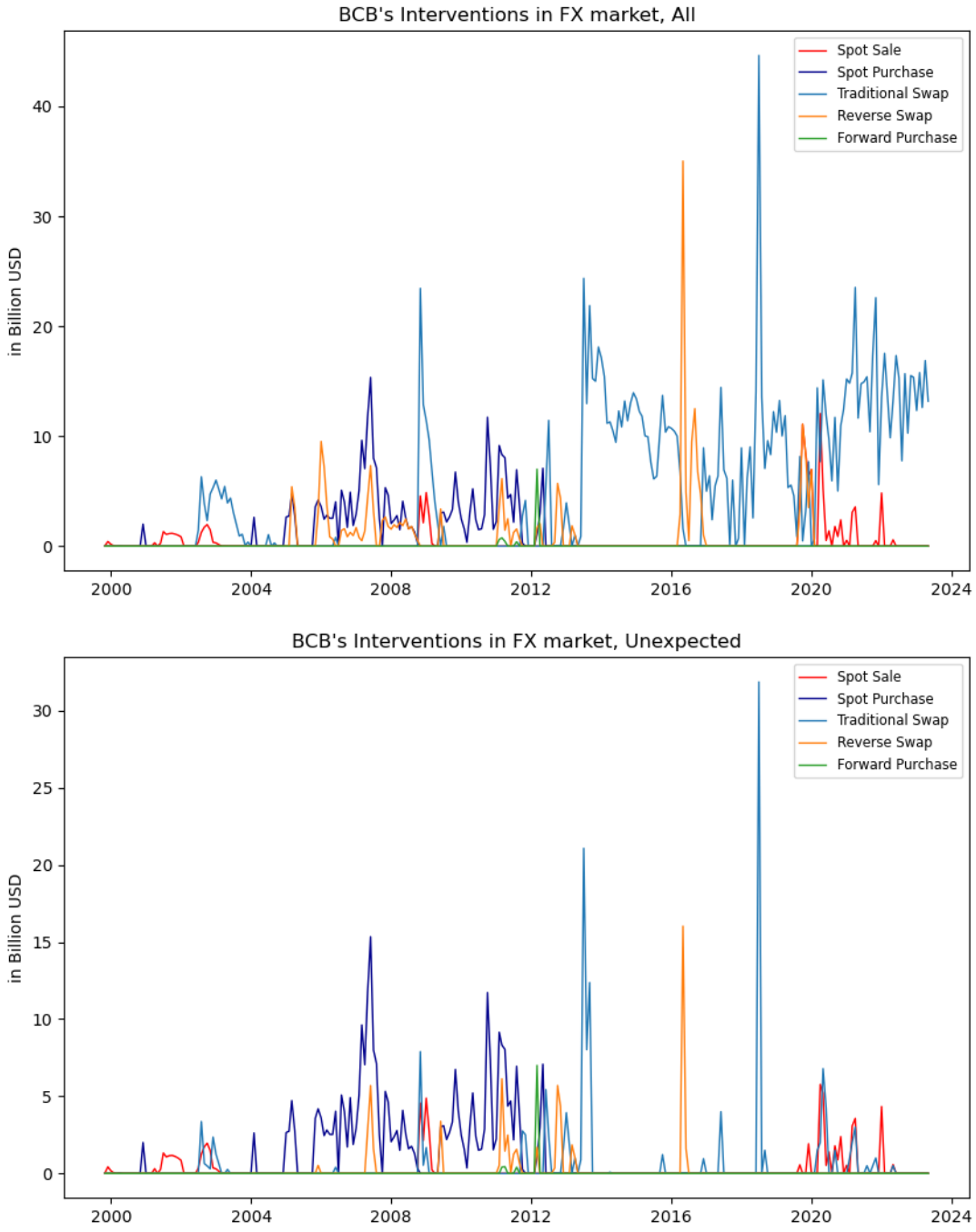


Figure 6: **The BCB's Intervention in FX markets since 2000.** These figures show the monthly USD amount of BCB's interventions in the FX markets. The figure at the top shows all interventions, while the figure at the bottom shows the unexpected interventions. For unexpected interventions the announcement date is equal to the operation date. For expected interventions the announcement date precedes the operation date. Traditional (reverse) swap is the sale (purchase) of USD at the spot leg of the swap contract. Sample period is from 1999-01-22 to 2023-04-27.

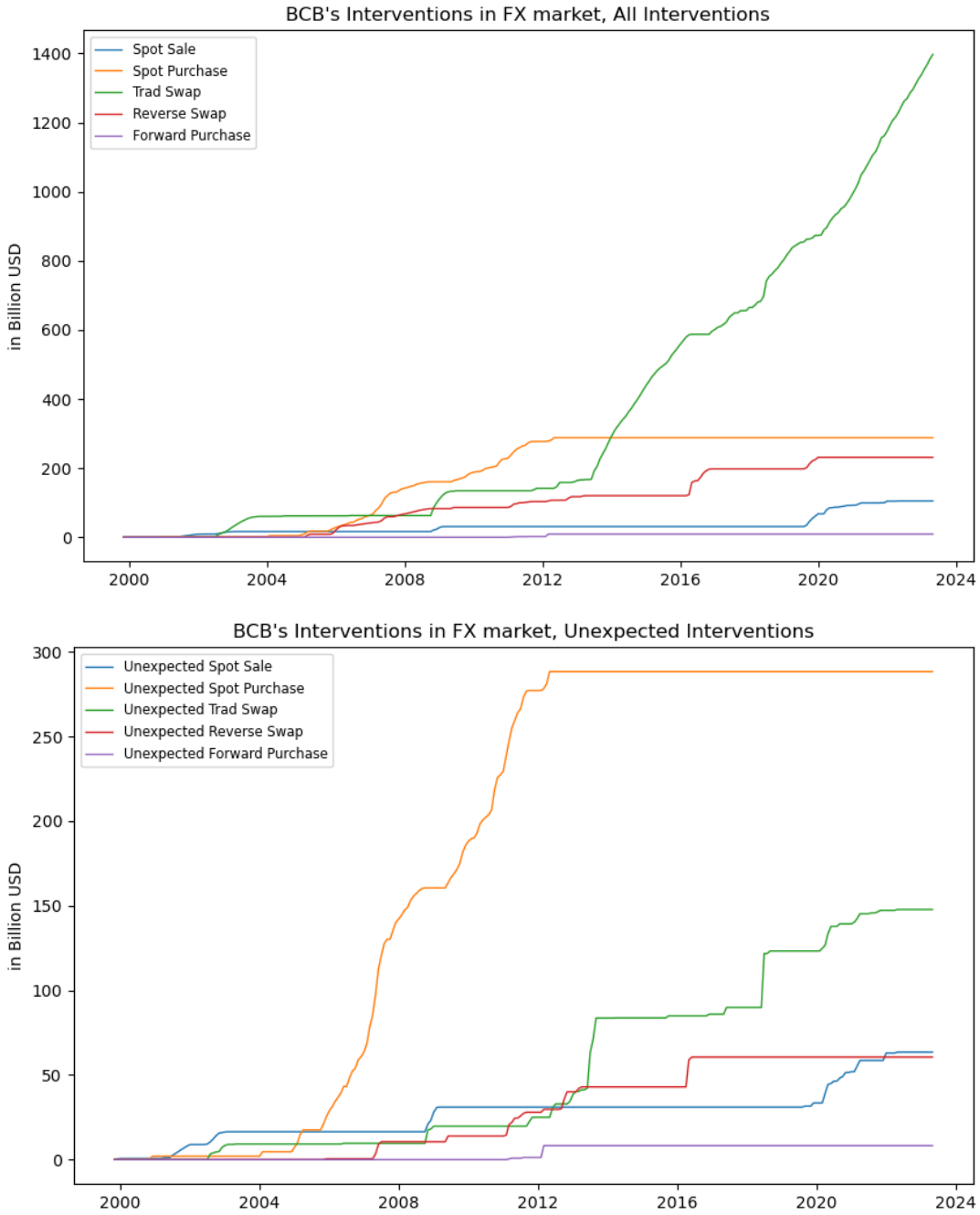


Figure 7: **The Cumulative BCB's Intervention in FX markets since 2000.** These figures show the cumulative USD amount of BCB's interventions in the FX markets. The figure at the top shows all interventions, while the figure at the bottom shows the unexpected interventions. For unexpected interventions the announcement date is equal to the operation date. For expected interventions the announcement date precedes the operation date. Traditional (reverse) swap is the sale (purchase) of USD at the spot leg of the swap contract. Sample period is from 1999-01-22 to 2023-04-27.

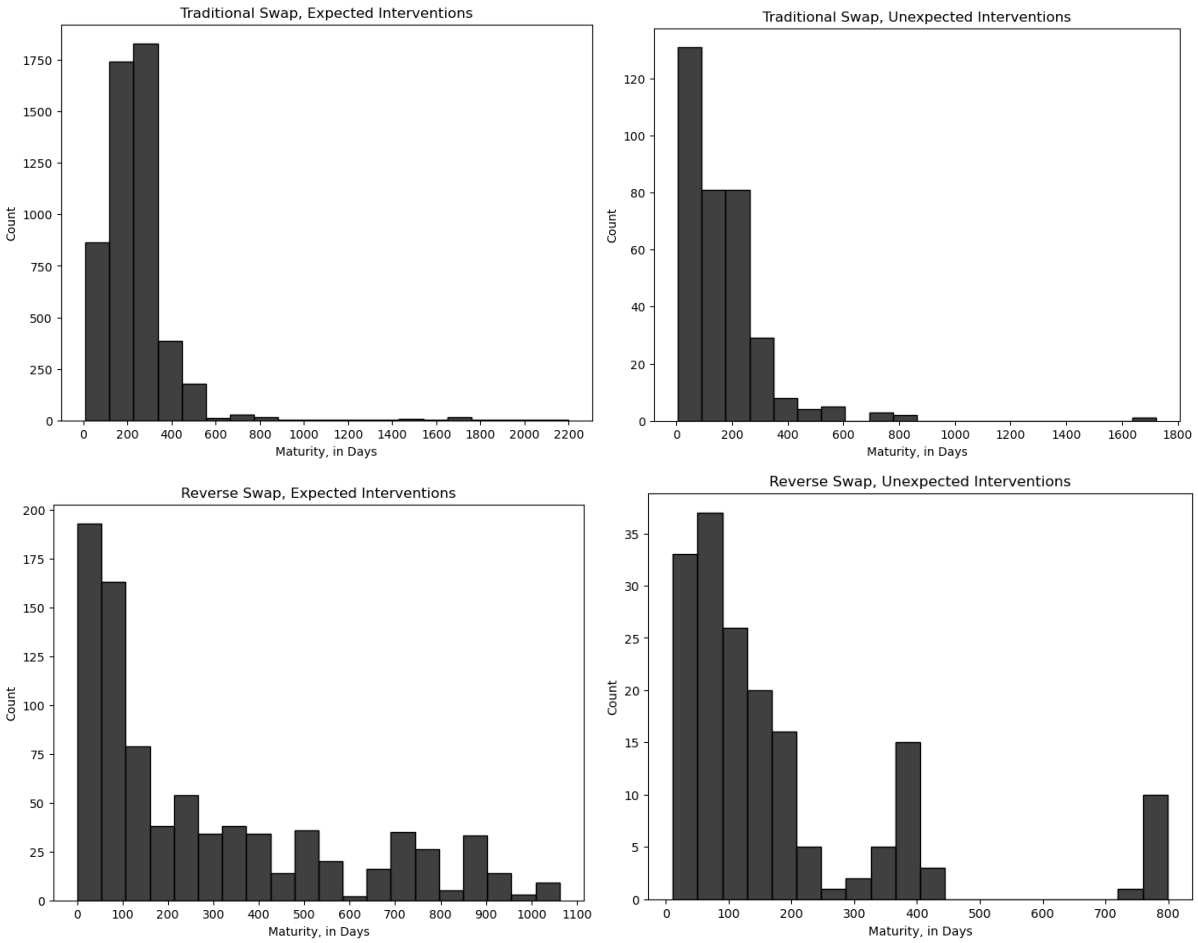
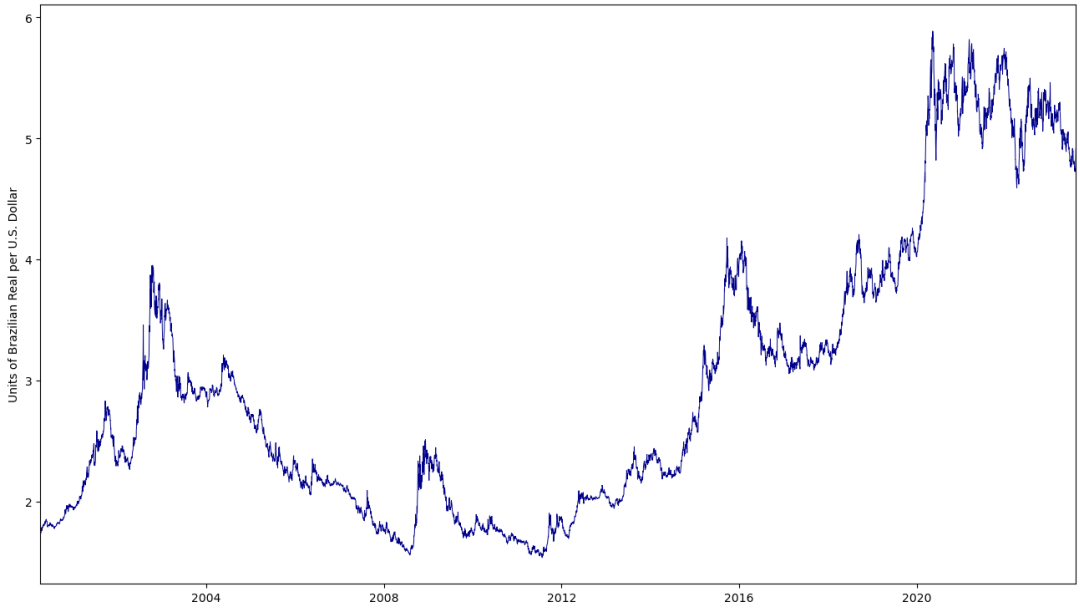
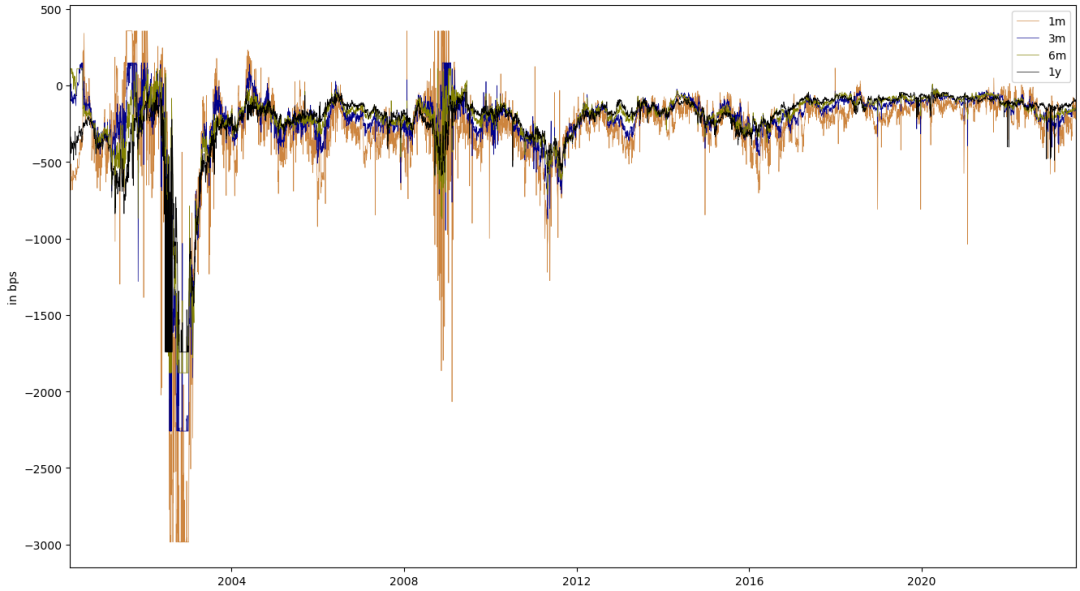


Figure 8: **Maturity breakdown of BCB's Swap Line Interventions.** These figures show the breakdown of maturities of traditional swap expected (top left), traditional swap unexpected (top right), reverse swap expected (bottom left) and reverse swap unexpected (bottom right). For unexpected interventions the announcement date is equal to the operation date. For expected interventions the announcement date precedes the operation date. Traditional (reverse) swap is the sale (purchase) of USD at the spot leg of the swap contract. The figure at the top shows all interventions, while the figure at the bottom shows the unexpected interventions. Sample period is from 1999-01-22 to 2023-04-27.



(a) **Panel (a):** The BRL/USD Spot Rate



(b) **Panel (b):** The BRL/USD Currency Basis

Figure 9: The BRL/USD Spot Rate and The BRL/USD Currency Basis. Panel (a): The spot exchange rate S_t is expressed in units of Brazil Real per U.S. dollar: an increase in S_t thus denotes a depreciation of the Brazilian Real and an appreciation of the U.S. dollar. Panel (b): this shows daily BRL/USD currency basis measured in basis points for 1 month, 3 months, 6 months, and 1 year maturity. A negative currency basis indicates a premium to swap BRL into USD in FX forward and swap markets. The BRL/USD currency bases are winsorized at the 1% level.

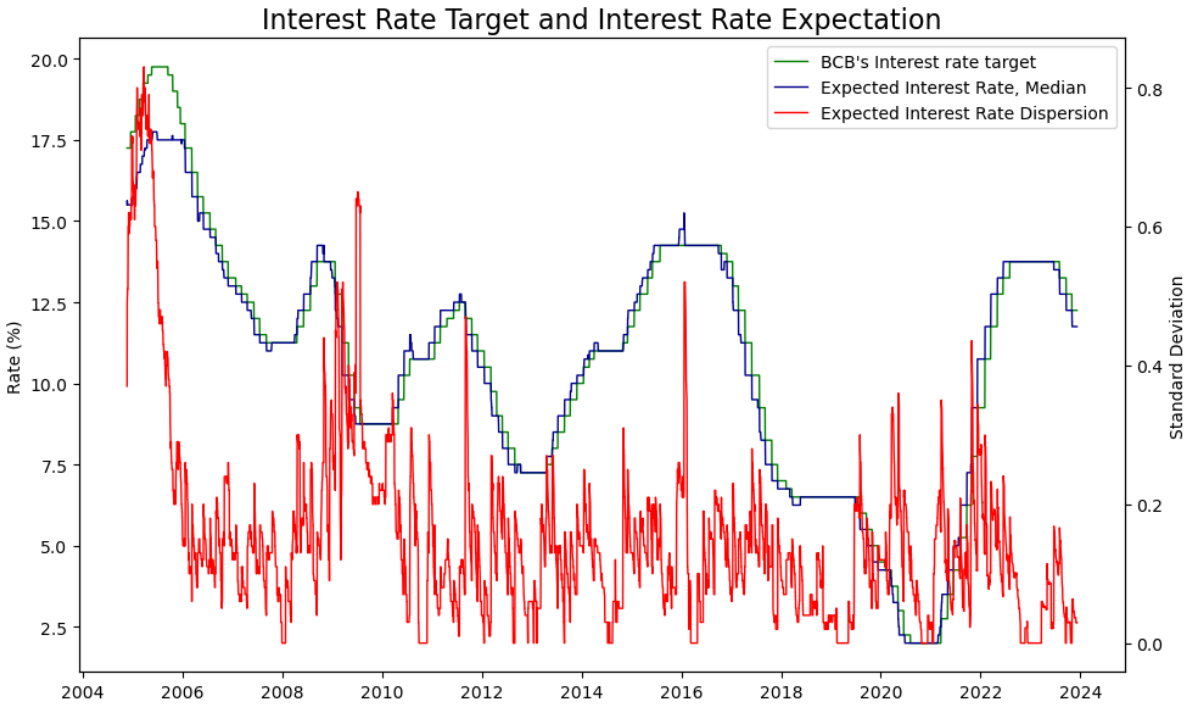


Figure 10: **The Selic Rate Target and Rate Expectations.** This plot shows the BCB's Selic rate target, along with the median and standard deviation of the surveyed Selic rate expectations as conducted by the BCB.

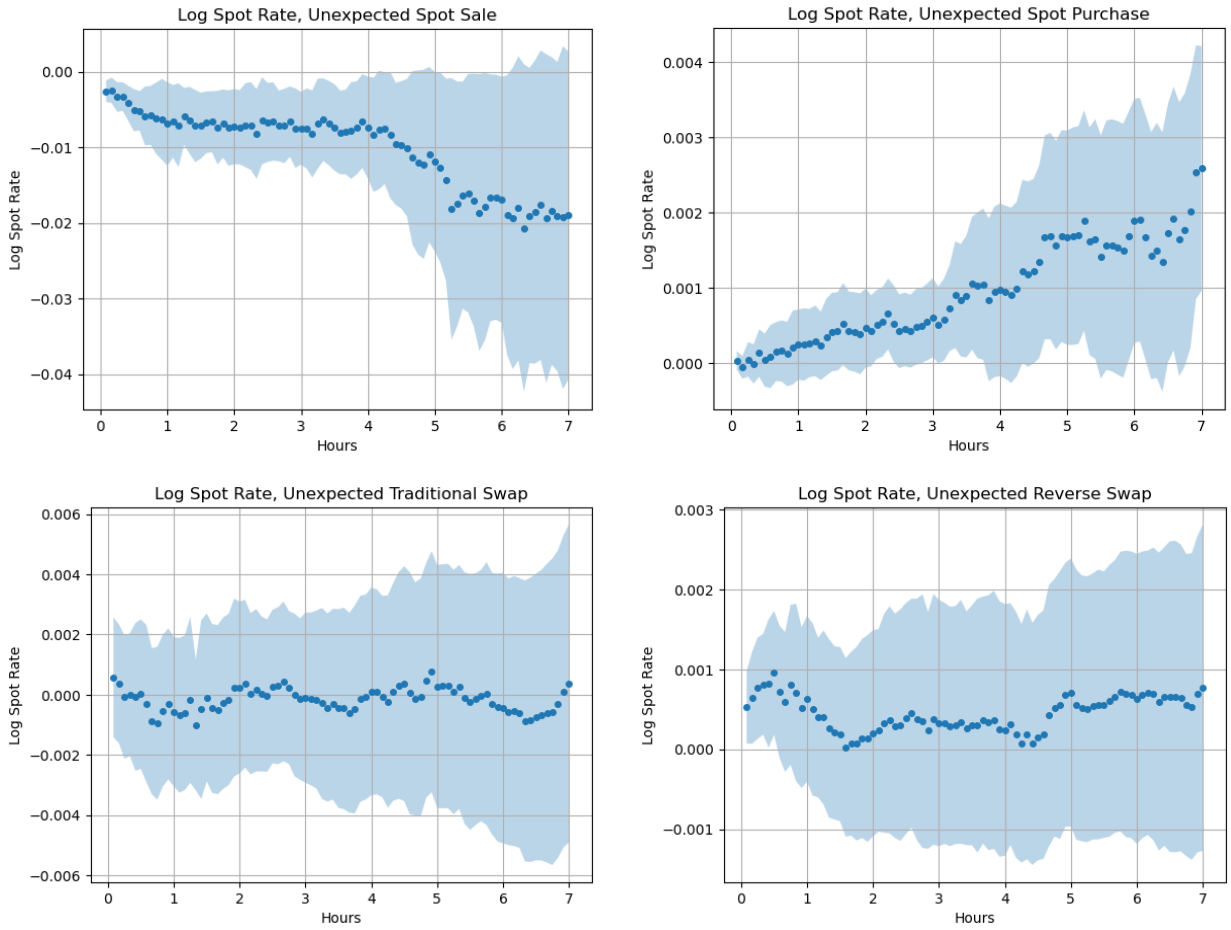


Figure 11: **Dynamic Response of Log Spot Rate to BCB's Unexpected Interventions.** Spot sales (top left), spot purchase (top right), traditional Swap (bottom left), and reverse Swap (bottom Right). Unexpected interventions are measured in USD Billion. Traditional (reverse) swap is the sale (purchase) of USD at the spot leg of the swap contract. Shaded area denotes 95% confidence interval using White heteroscedasticity-robust standard errors.

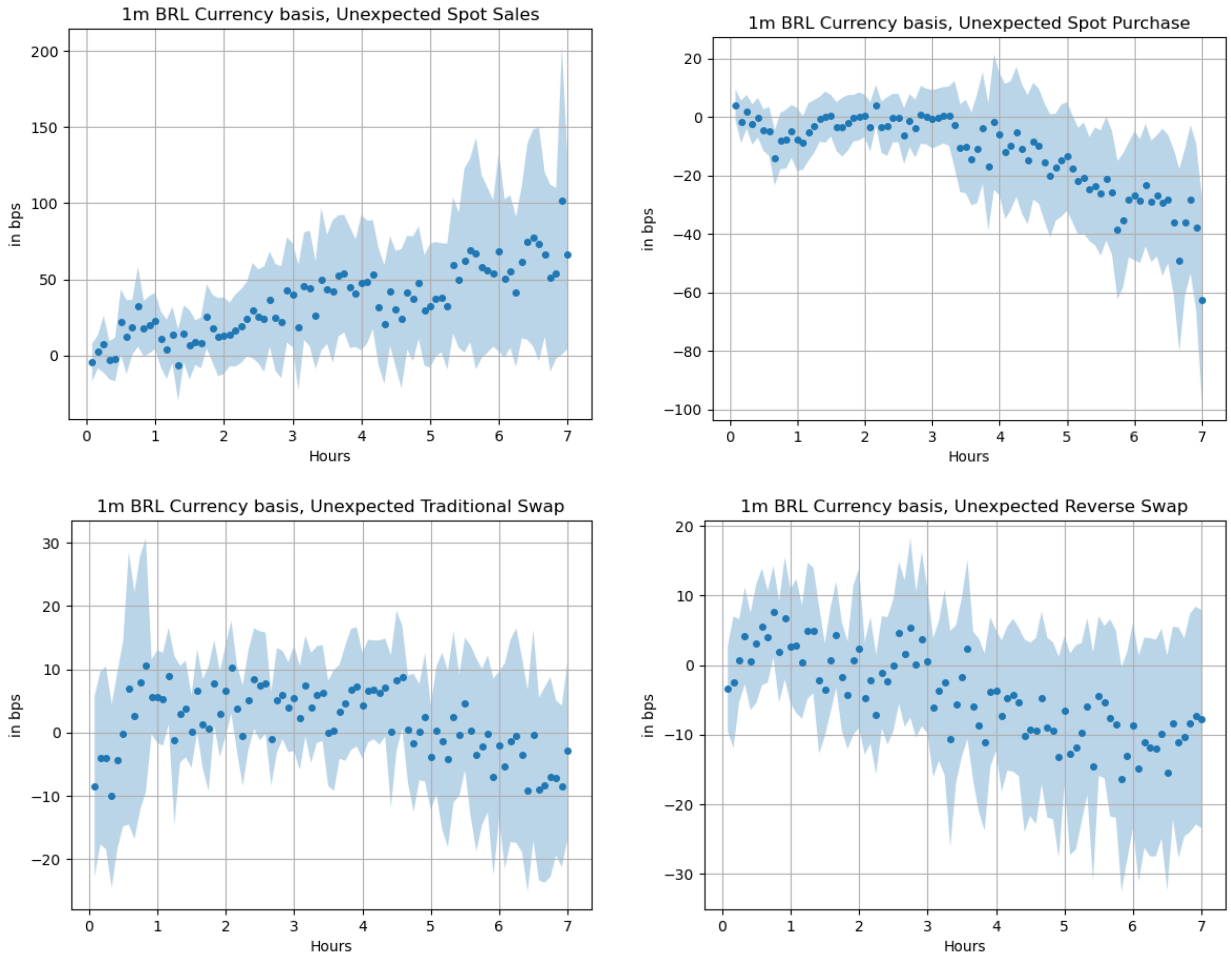


Figure 12: **Dynamic Response of 1m BRL/USD Currency Basis to BCB's Unexpected Interventions.** Spot sales (top left), spot purchase (top right), Traditional Swap (bottom left), and Reverse Swap (bottom Right). Unexpected interventions are measured in USD Billion. Traditional (reverse) swap is the sale (purchase) of USD at the spot leg of the swap contract. Shaded area denotes 95% confidence interval using White heteroscedasticity-robust standard errors.

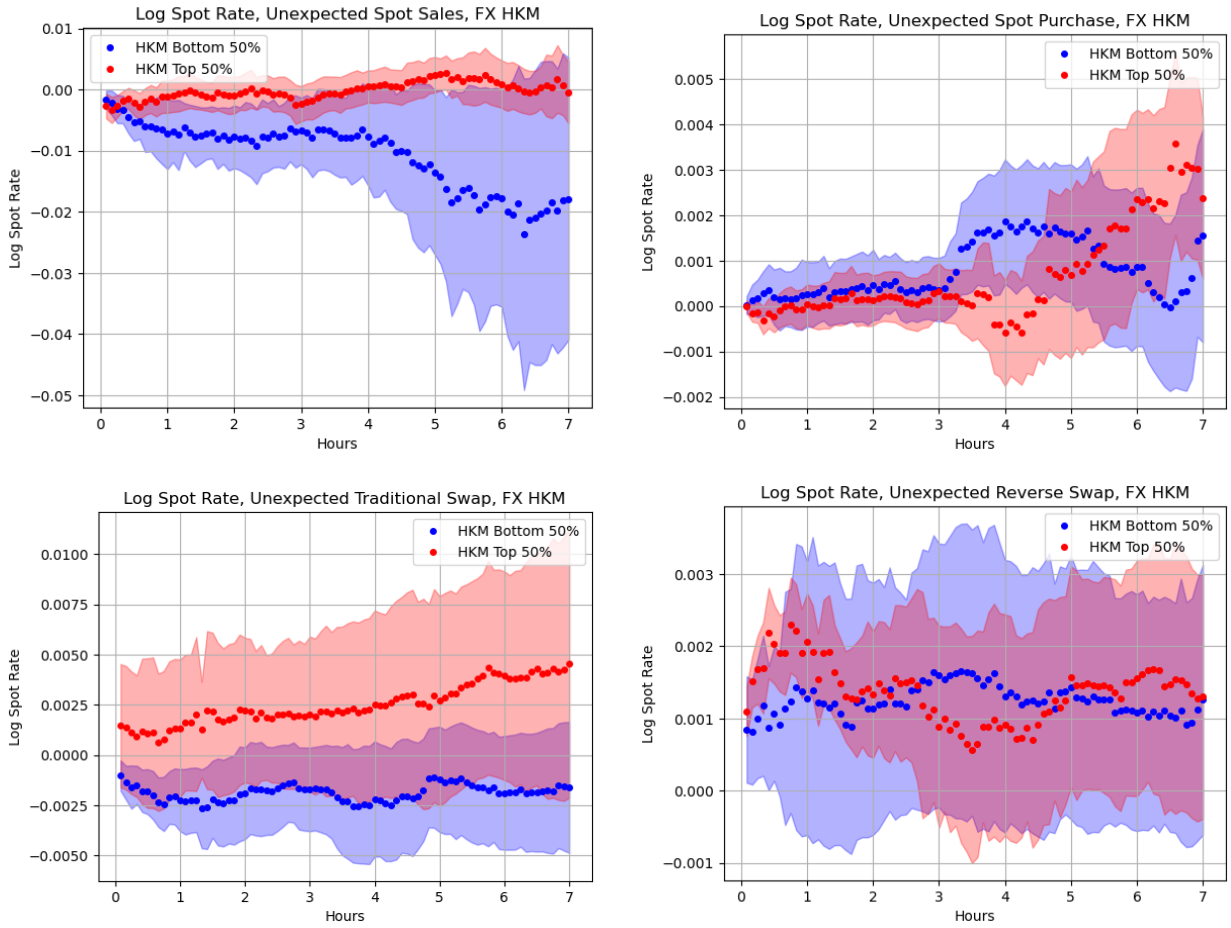


Figure 13: **Heterogeneous Response of Log Spot Rate to BCB's Unexpected Interventions, HKM Ratio.** Spot sales(top left), spot purchase(top right), Traditional Swap (bottom left), and Reverse Swap (bottom Right). Unexpected interventions are measured in USD Billion. Traditional (reverse) swap is the sale (purchase) of USD at the spot leg of the swap contract. FX Dealer HKM is a measure of FX dealer balance sheet constraints based on the intermediary capital risk factor in He, Kelly, and Manela (2017), constructed using the list of FX dealer banks following Cerutti and Zhou (2023). Bottom 50% HKM correspond to periods of lower intermediary capital and tighter constraints. Shaded area denotes 95% confidence interval using White heteroscedasticity-robust standard errors.

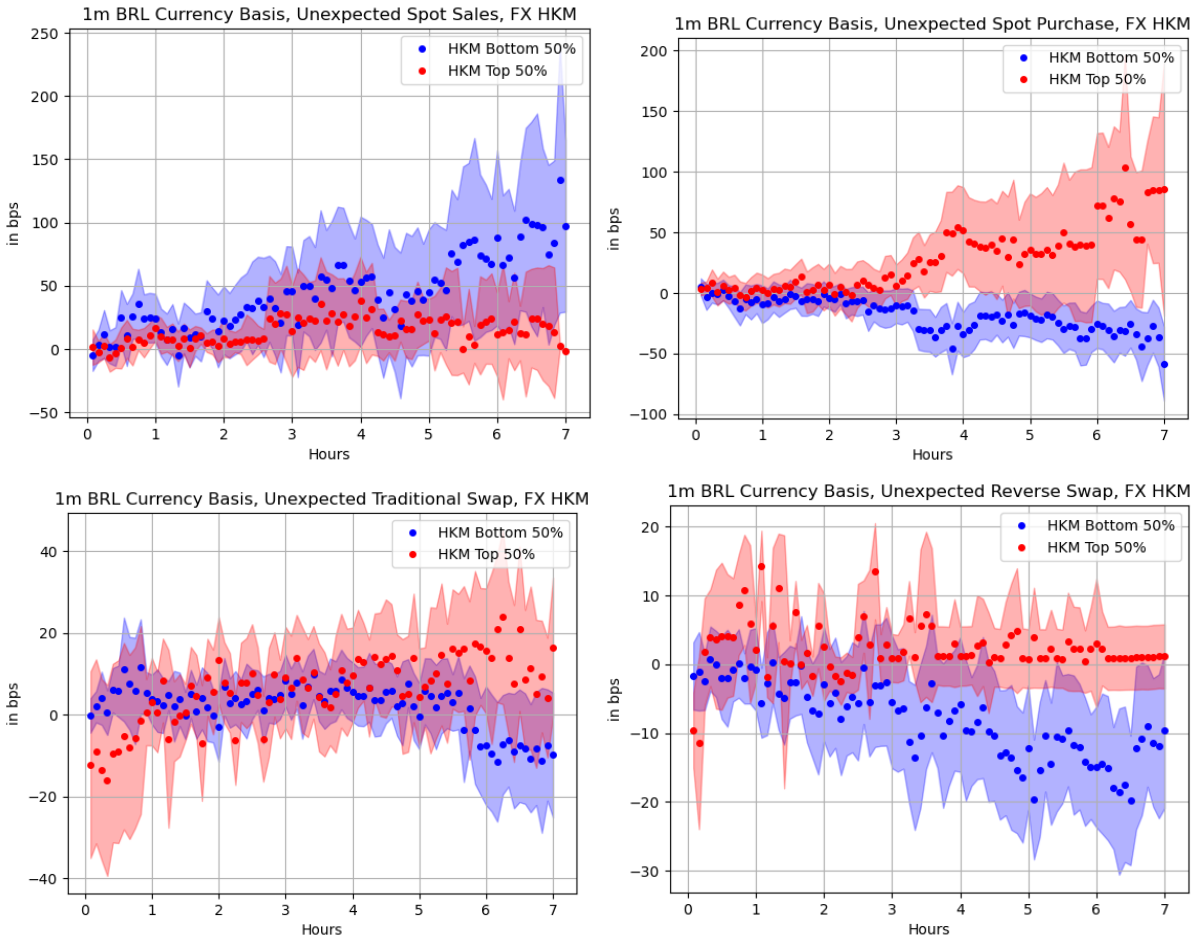


Figure 14: **Heterogeneous Response of 1m BRL/USD Currency Basis to BCB's Unexpected Interventions, HKM Ratio.** Spot sales (top left), spot purchase (top right), Traditional Swap (bottom left), and Reverse Swap(bottom Right). Unexpected interventions are measured in USD Billion. Traditional (reverse) swap is the sale (purchase) of USD at the spot leg of the swap contract. FX Dealer HKM is a measure of FX dealer balance sheet constraints based on the intermediary capital risk factor in He, Kelly, and Manela (2017), constructed using the list of FX dealer banks following Cerutti and Zhou (2023). Bottom 50% HKM correspond to periods of lower intermediary capital and tighter constraints. Shaded area denotes 95% confidence interval using White heteroscedasticity-robust standard errors.

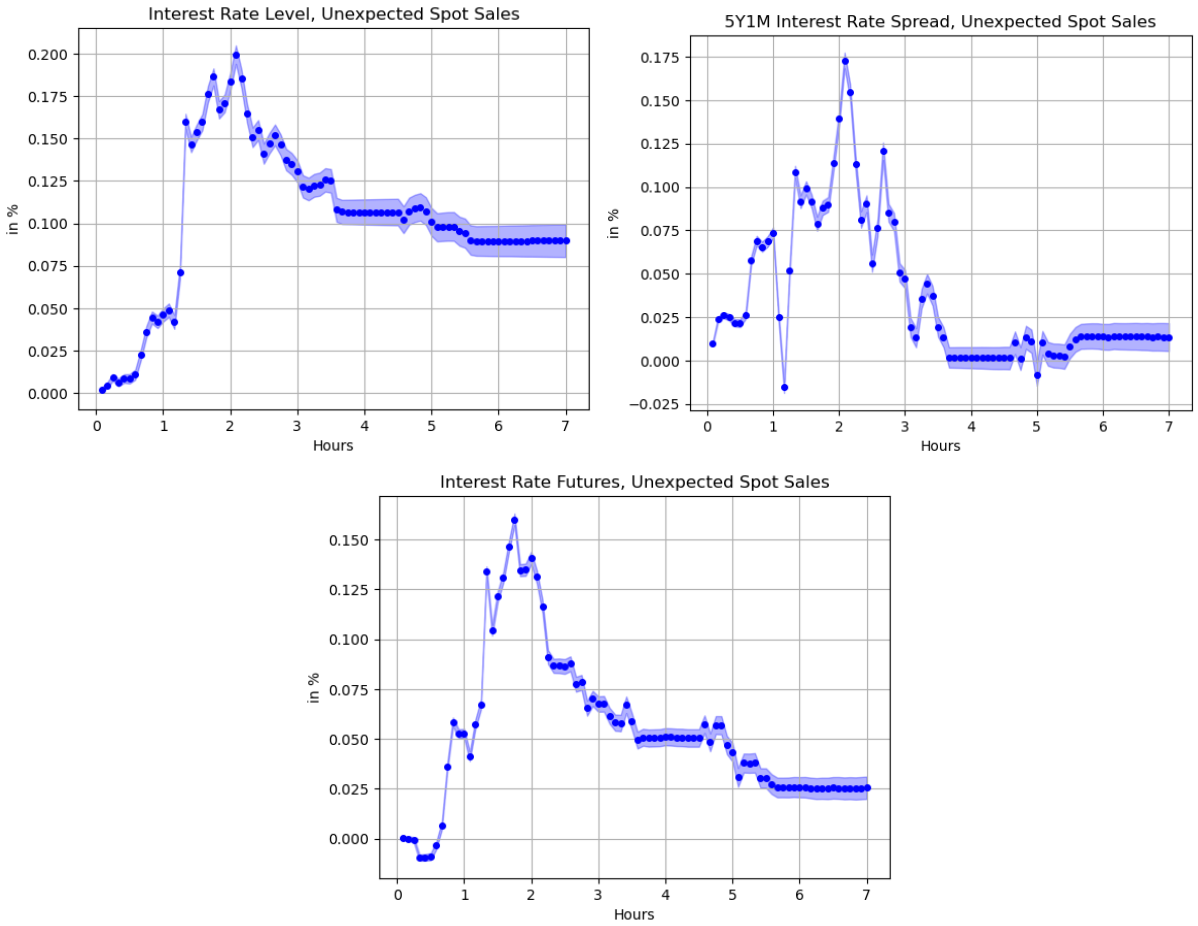


Figure 15: **Dynamic Response of High Frequency Interest Rate Futures to BCB's Unexpected Spot Sale Interventions.** Levels of Interest Rate futures(top left), Spread of Interest Rates futures(top right), and the generic most liquid interest rate futures contract(bottom). The sample period of B3 interest rate futures is 08/02/2019 - 23/01/2020. 4 unexpected spot sale intervention occurred during the sample period, in total 2.481 billion USD. Shaded area denotes 95% confidence interval using White heteroscedasticity-robust standard errors.

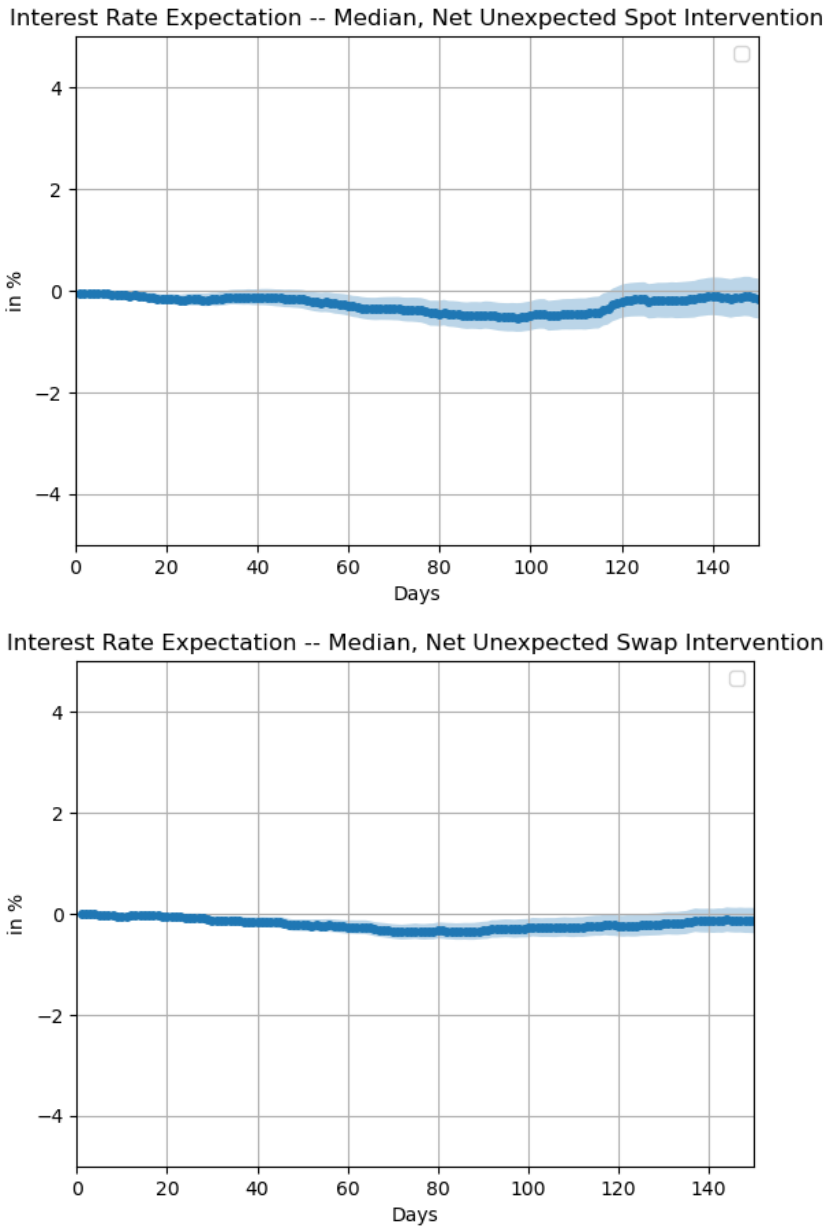


Figure 16: **Response of the Interest rate expectation to BCB's net Unexpected Interventions**. Net unexpected spot intervention (left), Net unexpected swap intervention. Regression is at daily frequency. Unexpected interventions are measured in USD Billion. Net unexpected spot intervention is the amount of unexpected spot sale minus the amount of unexpected spot purchase. Net unexpected swap intervention is the amount of unexpected traditional swap minus the amount of unexpected reverse swap. Shaded area denotes 95% confidence interval using White heteroscedasticity-robust standard errors.

Tables

	Spot Sale		Spot Purchase	
	Unexpected	Expected	Unexpected	Expected
Mean	0.17	0.48	0.19	NaN
S.D	0.22	0.39	0.24	NaN
Max	1.10	3.00	4.64	NaN
Count	385	87	1483	NaN

	Traditional Swap		Reverse Swap		Forward Purchase	
	Unexpected	Expected	Unexpected	Expected	Unexpected	Expected
Mean	0.43	0.25	0.35	0.20	0.39	0.16
S.D	0.41	0.24	0.45	0.28	1.05	0.17
Max	1.85	3.50	3.38	4.00	4.00	0.45
Count	345	5094	174	846	21	6

Table 1: **BCB's FXI Summary Statistics.** This table shows mean, standard deviation, maximum, and the total number of counts for BCB's FXI. For unexpected interventions the announcement date is equal to the operation date. For expected interventions the announcement date precedes the operation date. Traditional (reverse) swap is the sale (purchase) of USD at the spot leg of the swap contract. Sample period is from 1999-01-22 to 2023-04-27. Mean, S.D, and max are denominated in USD billion.

Appendix

A Mechanics of sterilized intervention

Central banks may seek to manage exchange rates without altering the money supply through sterilized intervention. Consider spot purchase intervention as an example. In a non-sterilized intervention, the central bank purchases foreign currency with domestic currency, leading to an increase in the domestic money supply. To "sterilize" the impact on the money supply, the central bank sells domestic-currency bonds to absorb the excess domestic currency in the money market. If the sterilization is perfect, the money supply would remain constant, while the relative ratio of domestic currency and foreign currency bonds held by the public(and the central bank) would change.

A sterilized intervention therefore can be viewed as a combination of two transactions. First, in the FX market, the central bank a non-sterilized intervention by purchasing foreign currency with domestic currency that it issues

Central Bank Balance Sheet	
Assets	Liabilities
Assets in Foreign Currency(+1)	Currency in Circulation(+1)

Second, in the money market, the central bank "sterilize" the effect on money supply by selling the same amount of domestic bonds to absorb the initial increase in money supply.

Central Bank Balance Sheet	
Assets	Liabilities
Assets in Domestic Currency(-1)	Currency in Circulation(-1)

The net effect of a sterilized spot purchase is the change in the relative ratio of domestic currency assets and foreign currency assets held by the central bank(and the public).

Central Bank Balance Sheet	
Assets	Liabilities
Assets in Foreign Currency(+1) Assets in Domestic Currency(-1)	Currency in Circulation(–)

B Expected Interventions

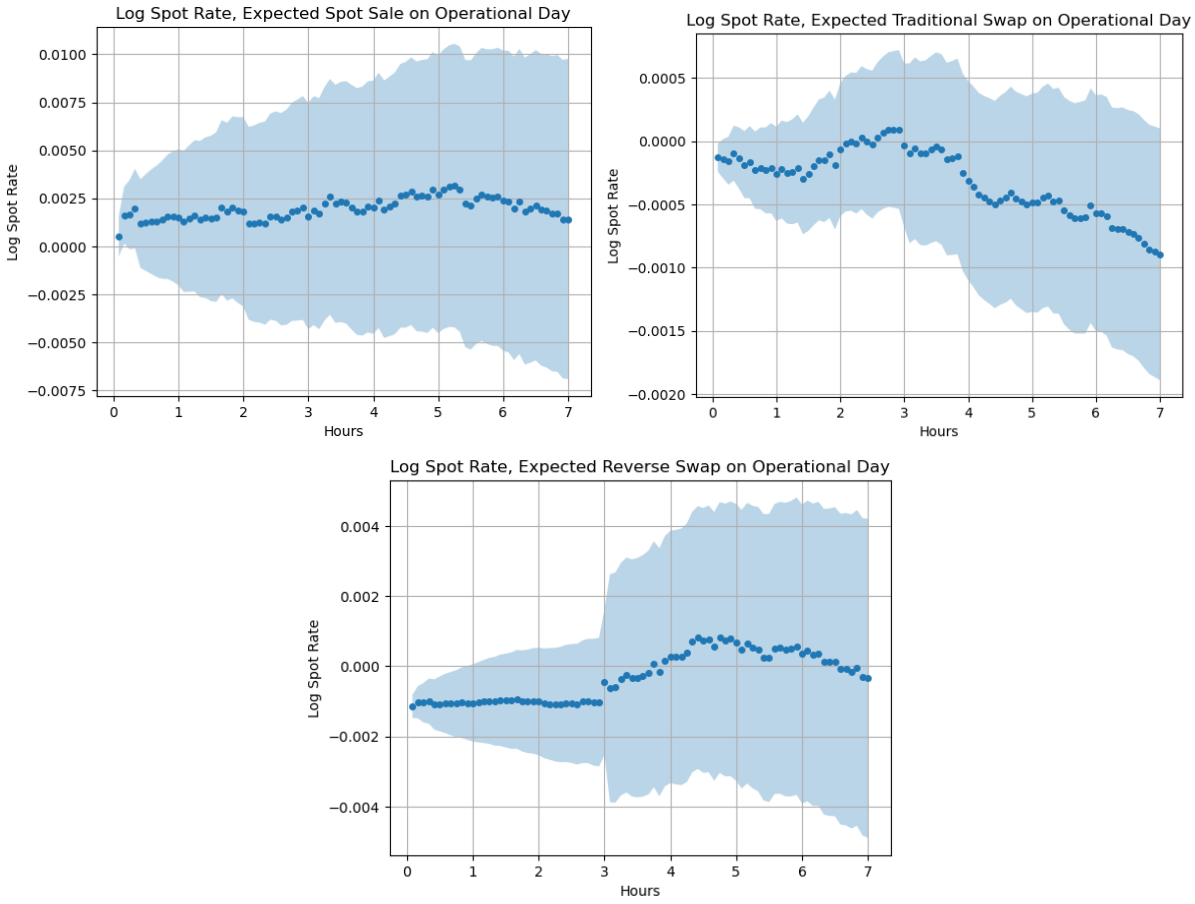


Figure 1: **Dynamic Response of Log Spot Rate to BCB's Expected Interventions on Operational Date.** Spot sales(top left), traditional swap(bottom left), and reverse swap(bottom Right). Spot sales(top left), spot purchase(top right), traditional Swap(bottom left), and reverse Swap(bottom Right). Expected interventions are measured in USD Billion, and are defined as interventions where the date of announcement is on a day preceding the operation date. Traditional (reverse) swap is the sale (purchase) of USD at the spot leg of the swap contract. Shaded area denotes 95% confidence interval using White heteroscedasticity-robust standard errors.

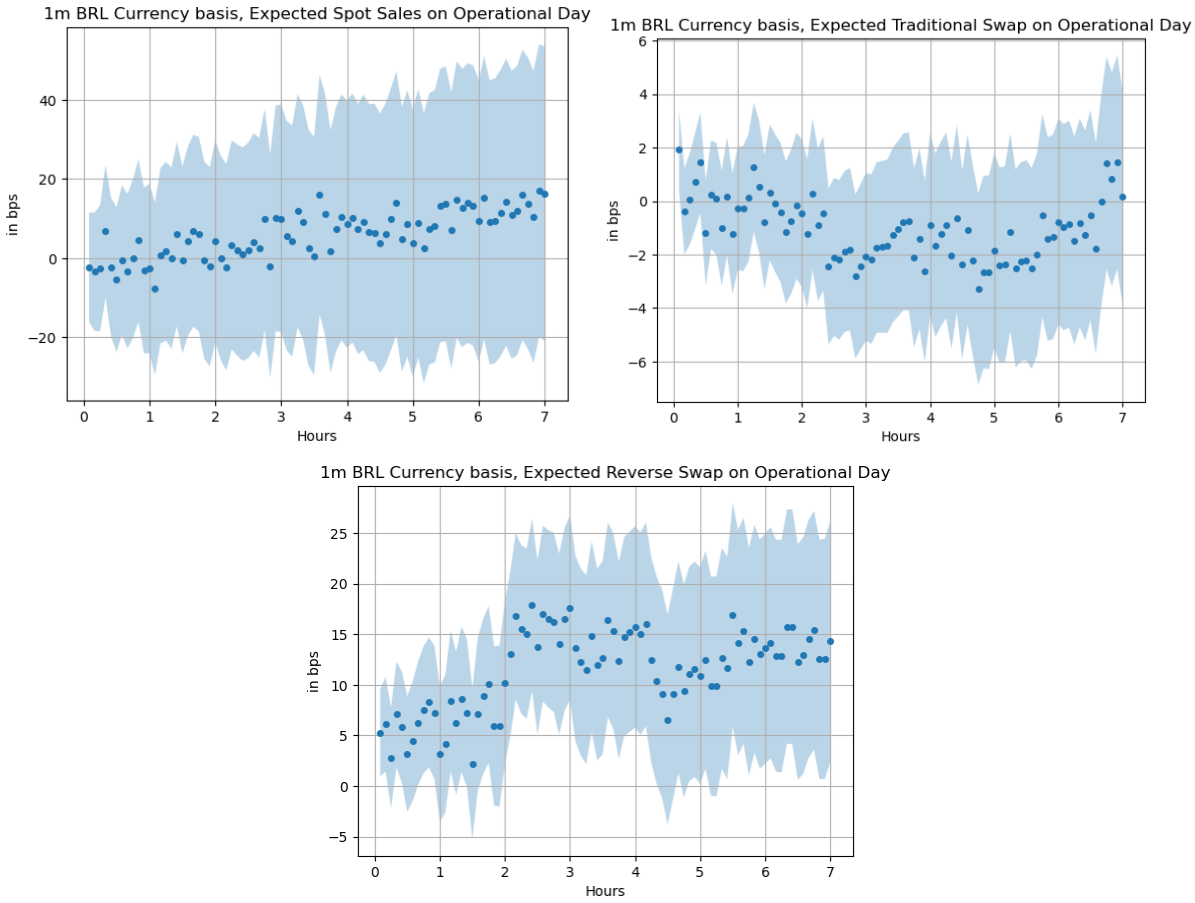


Figure 2: **Dynamic Response of 1 month BRL/USD Currency Basis to BCB's Expected Interventions on Operational Date.** Spot sales(top left), traditional swap(bottom left), and reverse swap(bottom Right). Spot sales(top left), spot purchase(top right), traditional Swap(bottom left), and reverse Swap(bottom Right). Expected interventions are measured in USD Billion, and are defined as interventions where the date of announcement is on a day preceding the operation date. Traditional (reverse) swap is the sale (purchase) of USD at the spot leg of the swap contract. Shaded area denotes 95% confidence interval using White heteroscedasticity-robust standard errors.

C Forward premium

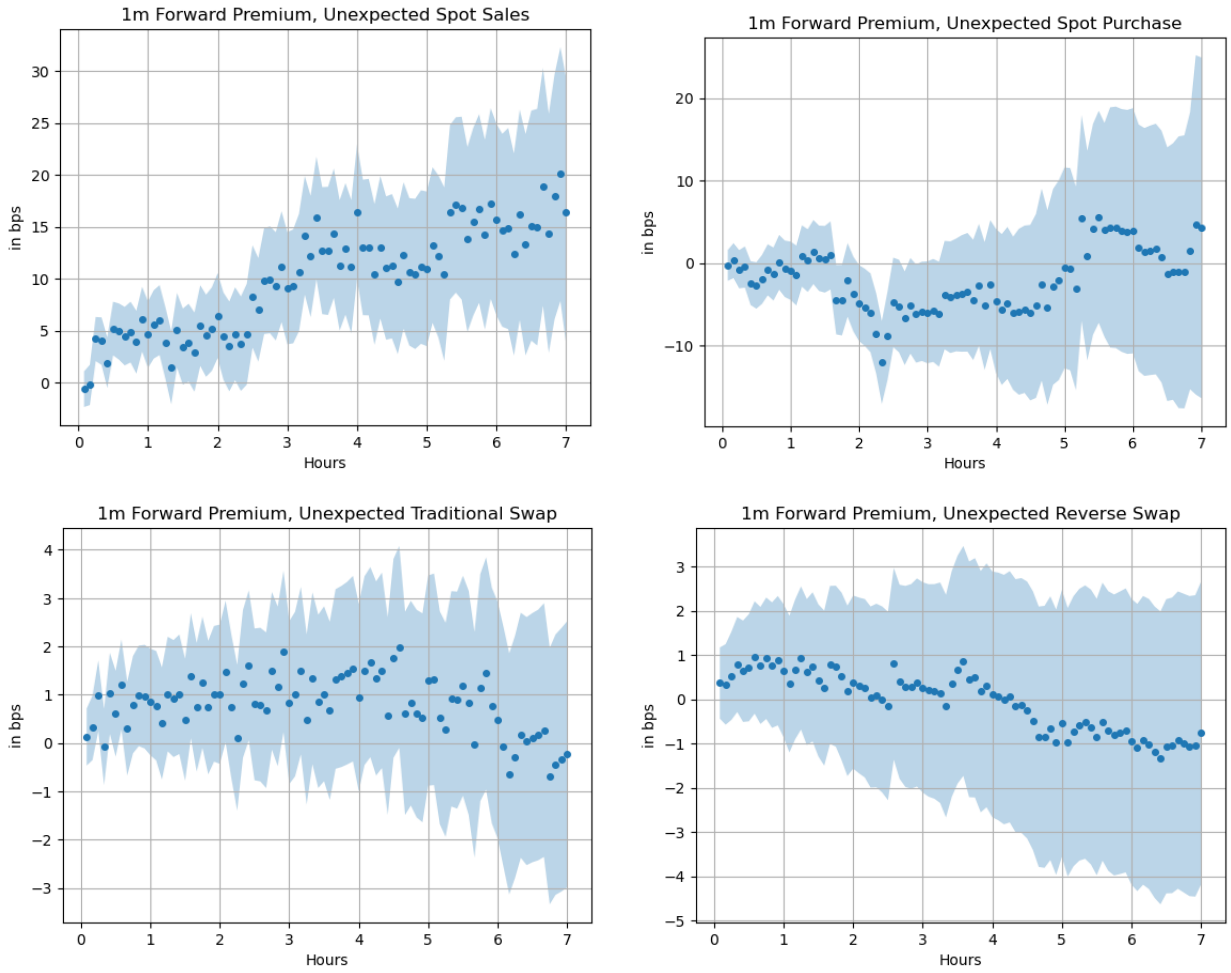


Figure 3: **Dynamic Response of forward premium to BCB's Unexpected Interventions.** Spot sales(top left), traditional swap(bottom left), and reverse swap(bottom Right). Spot sales(top left), spot purchase(top right), traditional Swap(bottom left), and reverse Swap(bottom Right). Forward premium is the difference between forward and spot BRL/USD rates, measured in basis points. Traditional (reverse) swap is the sale (purchase) of USD at the spot leg of the swap contract. Shaded area denotes 95% confidence interval using White heteroscedasticity-robust standard errors.

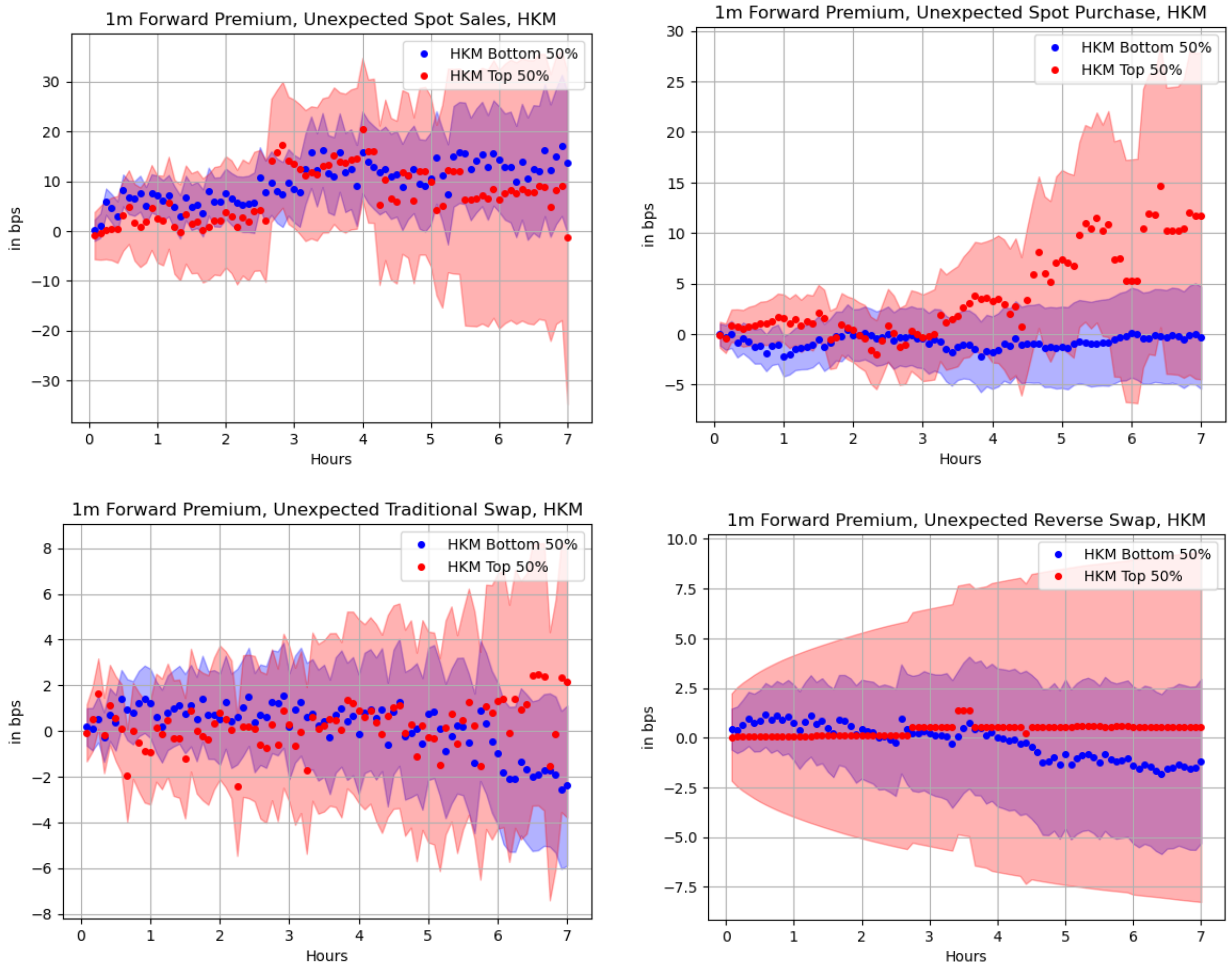


Figure 4: **Hetergeneous Response of forward premium to BCB's Unexpected Interventions, HKM Ratio** Spot sales(top left), traditional swap(bottom left), and reverse swap(bottom Right). Spot sales(top left), spot purchase(top right), traditional Swap(bottom left), and reverse Swap(bottom Right). Forward premium is the difference between forward and spot BRL/USD rates, measured in basis points. HKM is a measure of dealer balance sheet constraints based on the intermediary capital risk factor in He, Kelly, and Manela (2017). Bottom 50% HKM correspond to periods of lower intermediary capital and tighter constraints. Traditional (reverse) swap is the sale (purchase) of USD at the spot leg of the swap contract. Shaded area denotes 95% confidence interval using White heteroscedasticity-robust standard errors.

D Heterogeneity effects: level of CIP deviation

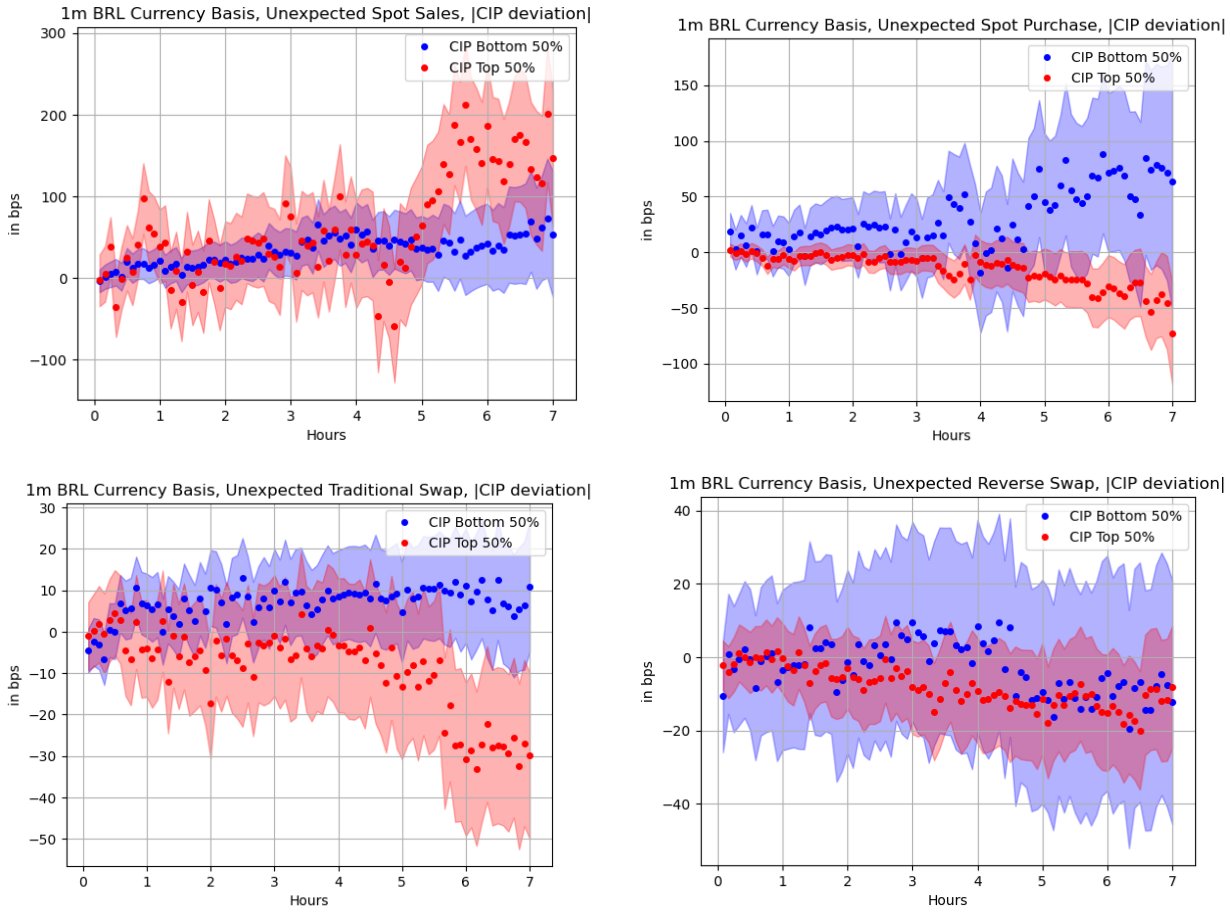


Figure 5: **Heterogeneous Response of 1m BRL/USD Currency Basis to BCB's Unexpected Interventions, Absolute Value of CIP Deviation.** Spot sales(top left), spot purchase(top right), Traditional Swap (bottom left), and Reverse Swap (bottom Right). Unexpected interventions are measured in USD Billion. Traditional (reverse) swap is the sale (purchase) of USD at the spot leg of the swap contract. IRFs plot the coefficients of the interaction of FXI with periods of above (below) median level of absolute CIP deviations. Shaded area denotes 95% confidence

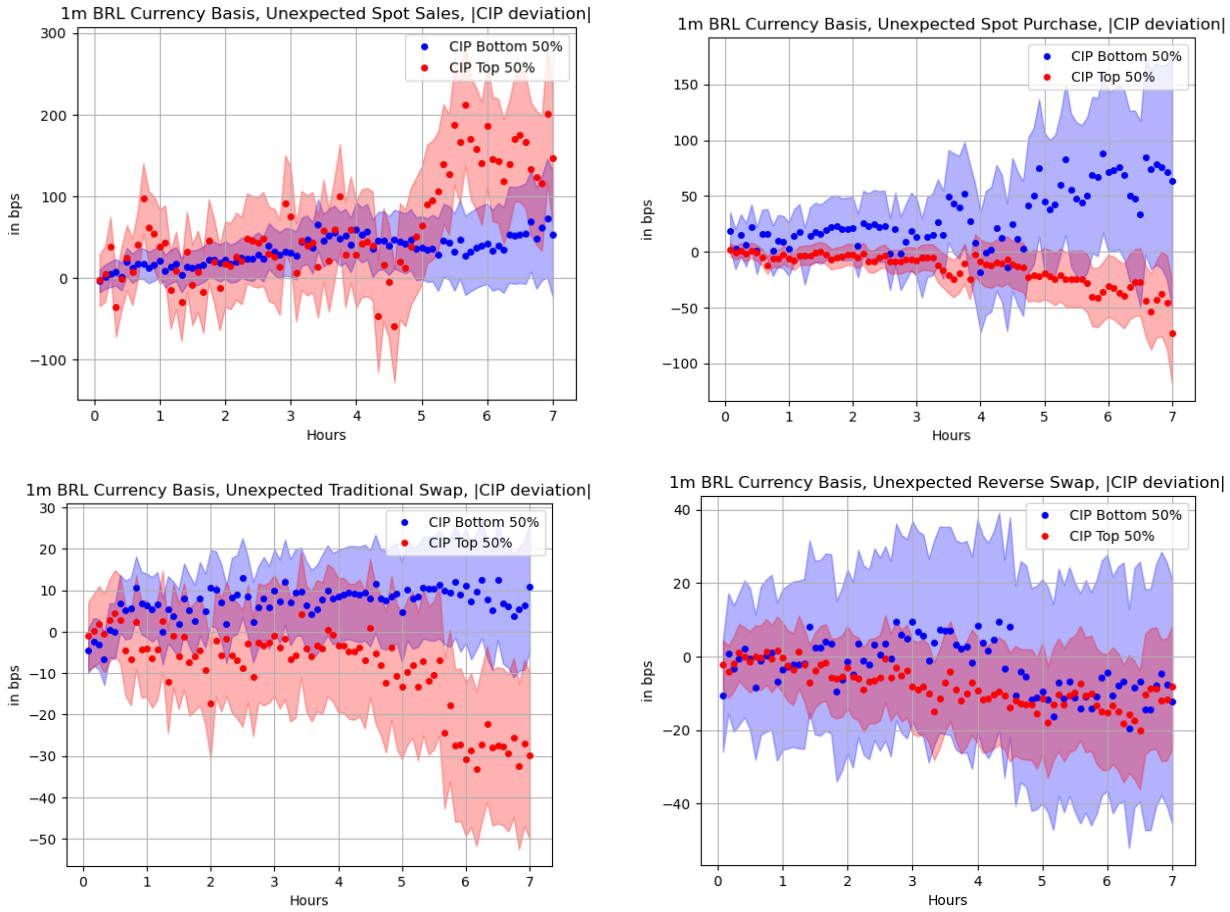


Figure 6: **Heterogeneous Response of 1m BRL/USD Currency Basis to BCB's Unexpected Interventions, Absolute Value of CIP Deviation.** Spot sales(top left), spot purchase(top right), Traditional Swap (bottom left), and Reverse Swap (bottom Right). Unexpected interventions are measured in USD Billion. Traditional (reverse) swap is the sale (purchase) of USD at the spot leg of the swap contract. IRFs plot the coefficients of the interaction of FXI with periods of above (below) median level of absolute CIP deviations. Shaded area denotes 95% confidence