Pontifícia Universidade Católica
do Rio de Janeiro

Alexandre Borelli de Mello

Foreign Exchange Interventions in Brazil: Spillover Effects on Asset Prices

Dissertação de Mestrado

Thesis presented to the Programa de Pós–graduação em Economia, do Departamento de Economia da PUC-Rio in partial fulfillment of the requirements for the degree of Mestre em Economia.

Advisor : Prof. Márcio Gomes Pinto Garcia
Co-advisor: Prof. Carlos Viana de Carvalho

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Prof. Márcio Gomes Pinto Garcia
Advisor
Departamento de Economia – PUC-Rio

Prof. Carlos Viana de Carvalho
Departamento de Economia – PUC-Rio

Prof. Marcelo Cunha Medeiros
Departamento de Economia – PUC-Rio

Samer Shousha
Departamento de Economia – Insper

Rio de Janeiro, April the 13th, 2022

Alexandre Borelli de Mello

B.A. in Economics, Universidade de São Paulo (USP), 2018

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Abstract

Borelli de Mello, Alexandre; Gomes Pinto Garcia, Márcio (Advisor); Viana de Carvalho, Carlos (Co-Advisor). **Foreign Exchange Interventions in Brazil: Spillover Effects on Asset Prices**. Rio de Janeiro, 2022. 61p. Dissertação de Mestrado – Departamento de Economia, Pontifícia Universidade Católica do Rio de Janeiro.

We study if the FX interventions of the Central Bank of Brazil impact other asset prices beyond the exchange rate, e.g., interest rates or stock prices. We do that by classifying the interventions into three types, according to the surprise level, and by using minute-by-minute data. Our results show that, for both USD sales (or swap issuance) and USD purchase (or reverse swap issuance), the BRL/USD reacts in the expected direction, the stock prices increase, and the interest rates increase as well. Noteworthy, the announcement impacts much more than the intervention itself. Furthermore, longer-dated rates yields tend to present greater responses to the interventions than shorter-term yields. Finally, across the interventions' types, we find remarkably heterogeneity in terms of moving asset prices within a half-hour window, as in terms of sustaining the movement for a nine hours (trading day) window.

Keywords

Foreign Exchange Intervention; Exchange Rate; Asset Prices; Local Projection;

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Resumo

Borelli de Mello, Alexandre; Gomes Pinto Garcia, Márcio; Viana de Carvalho, Carlos. **Intervenções Cambiais no Brasil: Impacto em Preços de Ativos**. Rio de Janeiro, 2022. 61p. Dissertação de Mestrado – Departamento de Economia, Pontifícia Universidade Católica do Rio de Janeiro.

Estudamos se as intervenções cambiais do Banco Central do Brasil impactam, além da taxa de câmbio, outros preços de ativos (taxas de juros e preços de ações). Fazemos isso classificando as intervenções em três tipos, de acordo com o nível de surpresa, e usando dados minuto a minuto. Nossos resultados mostram que, tanto para a venda de USD (ou emissão de swap) quanto para a compra de USD (ou emissão de swap reverso), o BRL/USD reage na direção esperada, os preços das ações aumentam e as taxas de juros também aumentam. Vale ressaltar que o anúncio impacta muito mais do que a própria intervenção. Além disso, os vértices longos dos juros tendem a responder mais as intervenções do que os vértices curtos. Finalmente, entre os tipos de intervenções, encontramos uma notável heterogeneidade em termos de movimentação dos preços dos ativos dentro de uma janela de meia hora, como em termos de sustentação do movimento por uma janela de nove horas (duração do pregão).

Palavras-chave

Intervenções Cambiais; Taxa de Câmbio; Preços de Ativos; Projeção Local;

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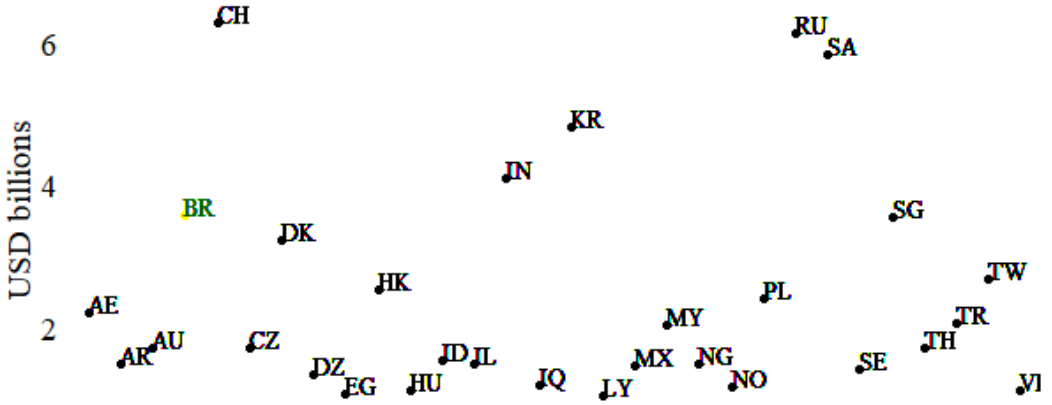
1
Introduction

In the past few decades, central banks worldwide made significant foreign exchange (FX) interventions. In free-floating regimes, the reasons for those interventions involve the risk of a large pass-through to inflation, the desire of international reserves accumulation for safety, and the risk of financial instabilities. The Central Bank of Brazil (BCB), in specific, acknowledges intervening for the last two motives. Controlling financial instabilities- nowadays the main motive given Brazil's significant reserves level- might be understood as "to ensure the smooth functioning of the foreign exchange market", according to the BCB.

The theme, as a whole, is controversial: FX interventions are widely adopted worldwide (Adler et al. (2021)), despite not having much theoretical literature supporting (Engel (2014)) nor clear empirical effects (Sarno & Taylor (2001); Menkhoff (2013)). The theme, in Brazil, is even more necessary to be investigated, given the volume of interventions (Figure 1.1). The country it is in the 7^{th} place in terms of interventions, among 122 countries.

Figure 1.1: FX Interventions Monthly Average Worldwide (2000-2021)



The figure contains the monthly absolute average of FX interventions for 122 countries. For a matter of clarity, we only present averages above USD 1 billion, excluding China's outlier statistics of USD 20 billions. The dictionary for the abbreviations is: Algeria=DZ, Argentina=AR, Australia=AU, Brazil=BR, Czech Republic=CZ, Denmark=DK, Egypt=EG, Hong Kong SAR=HK, Hungary=HU, India=IN, Indonesia=ID, Iraq=IQ, Israel=IL, Korea=KR, Libya=LY, Malaysia=MY, Mexico=MX, Nigeria=NG, Norway=NO, Poland=PL, Russia=RU, Saudi Arabia=SA, Singapore=SG, Sweden=SE, Switzerland=CH, Taiwan Province of China=TW, Thailand=TH, Turkey=TR, United Arab Emirates=AE, Venezuela=VE. Source: Adler et al. (2021).

This dissertation aims to answer the following question: do Brazilian FX interventions have spillover effects on asset prices? Notwithstanding aiming only the FX market efficiency, the lack of a theoretical framework, the lack of effectiveness consensus and the volume of Brazilian FX interventions induce us to believe there might be spillovers to other markets. Indeed, the BCB has as mission, beyond protecting the currency purchasing power, a financial stability mandate. Therefore, possible spillovers must enter into the monetary authority consideration when practising FX policy.

The empirical approach consists of estimating impulse responses. Half of the data set comprises FX interventions through derivatives and spot markets[1]. We develop a web scrapping algorithm, helping us categorize the interventions in three types, depending on the market's level of knowledge of the intervention, at the exact moment it happens. On top of that, the other half of the data set is composed of minute-by-minute prices of futures exchange rate, futures stock market index and futures interest rates (short, medium and long maturities).

[1]The swap derivatives are an instrument in which the BCB pays the exchange rate variation plus the *Cupom Cambial* (onshore dollar rate, i.e., USD interest rate traded in Brazil and settled in BRL), and receives the monetary policy rate. The opposite is true for the reverse swaps. Note that the Brazilian swaps are singular since they settle in local currency, as a non-deliverable forward, which evolves convertibility risk, a theme explored by Garcia & Volpon (2014).

The estimations are divided into a short window (20 minutes before the intervention, 30 minutes after intervention) and a longer window (20 minutes before intervention, but 9 hours after, which is a trading day). The results show, as a sanity check, that a USD sales (or swap issuance) induces a BRL/USD appreciation, and a USD purchase (or reverse swap issuance) a depreciation[2]. Our contribution regarding the exchange rate is to show that results are quite heterogeneous across the several interventions categories and the two horizons. The estimations for the other asset prices can all be considered contributions since they were only done for Japan[3] (Menkhoff et al. (2021)). Those estimations show an increase in the stock market index and the futures interest rates, independently if there is a USD sales or purchase.

Our results show three main outcomes. If an intervention comes as a surprise, it's effect is larger, as one would expect. Less intuitively, the longer tenors of the yield curve react more strongly to the interventions. Finally, the effects on the Brazilian stock market are often not statistically significant.

Observing the trading day post-intervention window, the persistence of the shocks are completely different from each other. For the Intraday type[4]- where we believe our approach adds the most given the surprise level of the shock and granularity of our data- all three shock variations (swap, reverse swap and spot sales) have three different persistence on the exchange rate and interest rates. Concerning the BRL/USD, the swap shock response increases during the following trading day, the response to the reverse swap shock fades away, and the reaction to the spot shock stabilized. On rates, the swap shock is associated with a constant increase, contrary to the reverse swap associated with a minutes-lasting increase that does not prevent a final day decline, and, finally, the spot sales shock impact on rates dies out.

Our paper relates to the literature which empirically investigates the FX intervention impact on the following variables: (i) asset prices, (ii) exchange rate and (iii) macroeconomic variables.

Up to our knowledge, Menkhoff et al. (2021) was the only paper that explores the dynamic impact of FX interventions on asset prices. The authors look to Japan's daily data and found that a one standard deviation shock

[2]It is essential to always have in mind that a swap is equivalent to a USD sale in the futures market. The opposite is valid for the reverse swap.

[3]Literature points to significant interventions differences in terms of frequency and power comparing developed countries and emerging countries. The latter group tends to intervene more frequently and larger (relative to the exchange rate market), having, therefore, more significant effects (Sarno & Taylor (2001); Menkhoff (2013)). All this turns our novel emerging market investigation even more necessary.

[4]Those are the most surprising among the three types, as we will detail in the data section. The BCB announces the intervention in the middle of a trading day and does the operation after a few minutes.

(equivalent to USD 2 billion) or USD purchase means a 0.1 percent increase in the large caps stock market index and a 0.001 percentage point decrease in two-year and five-year rates. We believe we add in the literature since ours is the first paper to analyze an emerging market and use high-frequency data. Moreover, our results point to an opposite effect direction on the interest rates.

There is a reasonable number of papers that investigate the impact of interventions on the BRL/USD. On those papers, usually there is a discussion about the endogeneity around the FX interventions, which occurs in specific days, and we are going to analyze further this issue in our next section. The three main empirical strategies to address the endogeneity are instrumental variables (Stone et al. (2009), de Freitas Vervloet (2010), Barroso & others (2014), Nedeljkovic & Saborowski (2017)), ArCo (Chamon et al. (2017)) and, in a certain way, intraday data (Kohlscheen et al. (2013),Janot & Macedo (2016),Santos (2021)). Across all those papers we have estimates from 0.1 to 1.18 percent for each USD 1 billion operation. Across our estimations, the heterogeneity is huge over the interventions types, ranging from non significant effects to a maximum of 1.5 percent for each USD 1 billion on the Intraday swap shock on a trading day (9 hours) horizon.

Regarding exclusively the intraday approach- as it is the one we adopt- Kohlscheen et al. (2013) observe 27 swap auctions during 2011-2012 and considering interventions as dummies, found a 0.33 percent impact per intervention after 2 hours and found that the maximum impact occurs 60 to 70 minutes after the intervention. Once more, we highlight that our results depend on the intervention type since we have shocks whose effect fades away and shocks that increase until the end of a trading day horizon. Janot & Macedo (2016) explore 2011-2015 interventions and, until 25 minutes after intervention, spot interventions have a 0.1 percent effect (per USD billion), and swap interventions practically do not affect the exchange rate, except for the pre-taper tantrum program ones (2011-2013), which has a 0.5 percent impact. Our short term (30 minutes) evidence reinforce the paper's findings because the Intraday spot sales shock showed more power than the Intraday swap one. Santos (2021) inspecting 2011-2013 swap interventions[5], concluded that the auctions have an effect of 0.18 percent on the intervention day (per USD billion), and a 0.29 percent total impact, which 0.28 percent concentrates on the first two days after the auctions.

There is also a macroeconomic perspective of the Brazilian FX interventions impact. For example, Tobal & Yslas (2016) found that a one standard

[5]The paper also analyses the massive swap program post taper tantrum in 2013-2015, which is not our focus. However, one must say that discretionary interventions the author uses and are here described, are more effective per USD billion than the taper program ones.

deviation USD purchase (authors consider derivative and spot interventions altogether) is associated with a maximum 0.7 percent increase in interest rates after five months. Last but not least, da Costa Filho (2021) found that a USD 1 billion swap shock reduce risk premium up to 2.5 percent and increase interest rates up to 0.04 percent after seven months. Although, both papers found no contemporaneous effects. As the two papers use monthly data, we could consider them medium-term investigations, different from our high-frequency approach.

The rest of the paper is organized as follows. Section 2 presents the data description. Section 3 explains the econometric method. Section 4 shows the results. In the end, section 5 concludes.

2
FX Interventions and Asset Prices Data

Before explaining our dataset, we come back to the endogeneity issue. The FX interventions are not done on random days but in the most chaotic ones, where there is a market malfunctioning; that is why daily data estimations face simultaneity problems. We do not treat that endogeneity directly; however, we show descriptive visual statistics regarding asset prices movements on each intervention type day as an indirect way to illustrate the monetary authority reaction function. What we do is- conditional on the fact that intervention happens- try to estimate the causal effect. This reasoning suggests that there should be some homogeneity regarding the motives for the interventions, at least among a certain type of FX intervention. Indeed, we will next explain a taxonomy that we use to separate the different types of FX interventions. The intuition is that, at that specific minute, the only relevant event is the intervention. Hence, the minute-by-minute approach is useful, as it is our database, composed of very liquid markets (trades every minute).

Now discussing the data, on the FX interventions side, we explore either derivative and spot markets, as we explore either USD sell and purchase courses. Moreover, we develop an algorithm that reads the written press releases of the BCB and transforms them into a database merged with the commonly known intervention volume database. Our algorithm is a web scraping code, which reads all written intervention announcements. It grabs the exact time the release was uploaded online, and time the FX operation was promised. Then, the code permits us to have the exact time press releases were known by the market, as the exact time intervention happened. Indeed, it allows us to categorize interventions in three different types, in addition to the derivative/spot standard division.

The first category we call Program and are the slightest surprise shocks in our estimations. On those, the monetary authority communicates to the market a considerable time before an intervention period is coming. Generally, the BCB announces that it will intervene for a certain number of USD billions or for a certain amount of time (e.g. weeks). We analyze the exact moment of each intervention within the category.

Given all the interventions that are not a Program one, we have two more

categories. The Day Before consists of situations where the BCB announces on the closing market hours of a particular day t that an intervention will happen on $t + 1$. This kind of operation permits us to analyze the announcement effect (opening minutes of the following day) and the intervention effect (exact moment of each market operation itself, as in the Program type).

The third type is the Intraday, the most surprising shock in our estimations. On those, the central bank communicates to the market, during the trading hours, that an intervention is going to happen in a few minutes[1]. Once again, we investigate the announcement and intervention moments.

All intervention types' details are in Tables 2.1 and 2.2. Swaps or spot sales have negative signs and the opposite for reverse swaps or spot purchases. Moreover, we situate the reader in Figure 2.1. We might say there is no Program reverse swap and Day Before spot sales interventions in our data set. Noteworthy, the spot market interventions were all in USD sales direction during our period.

Table 2.1: Derivative Interventions Descriptive Statistics

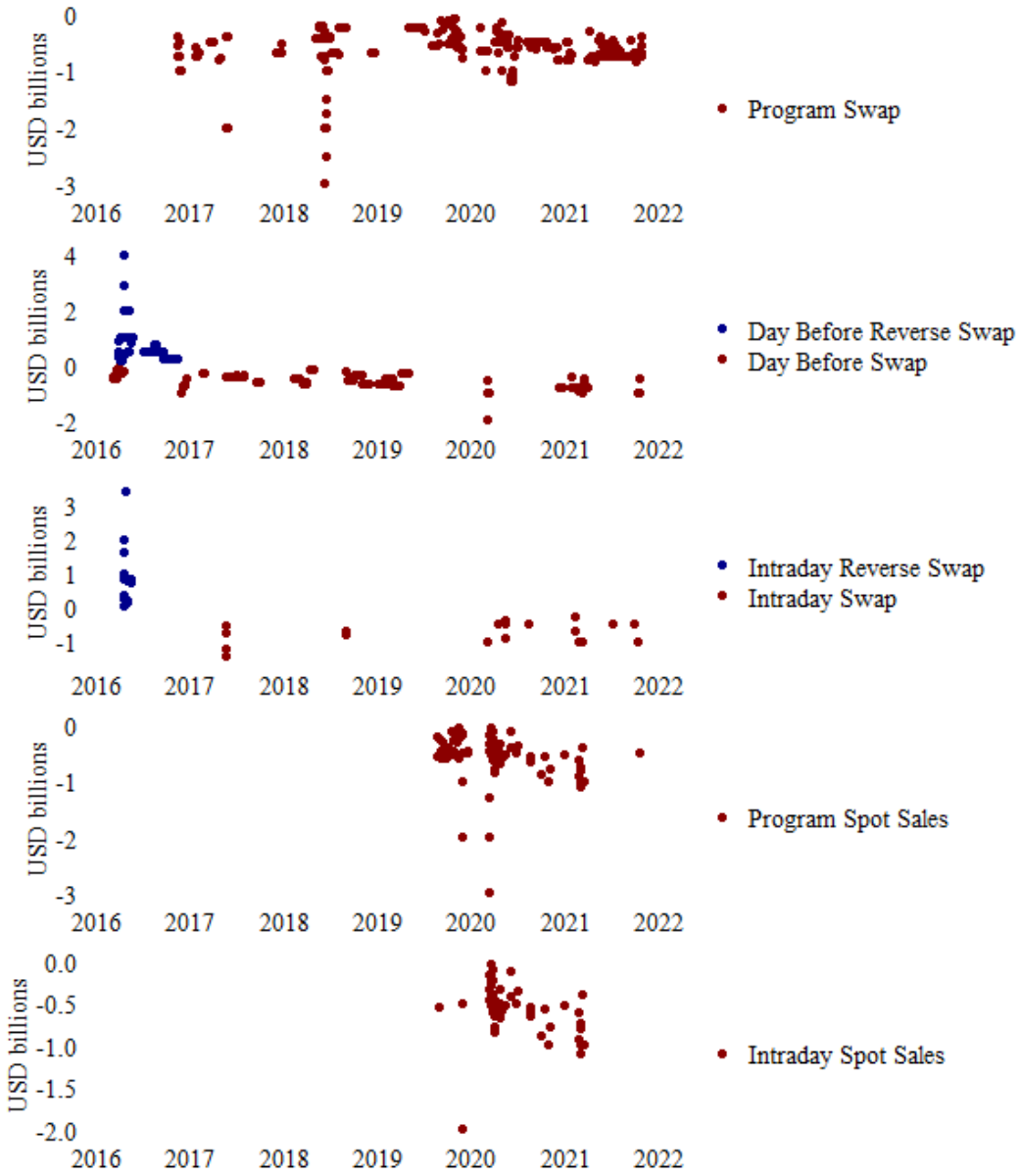
(in USDbn)	Swap	Reverse Swap	Program Swap	Day Before Swap	Day Before Reverse Swap	Intraday Swap	Intraday Reverse Swap
Mean	−0.60	0.61	−0.62	−0.55	0.56	−0.75	0.88
Median	−0.60	0.50	−0.60	−0.55	0.50	−0.72	0.78
s.d.	0.28	0.65	0.30	0.21	0.60	0.30	0.84
Min	−3.00	0.05	−3.00	−2.00	0.15	−1.46	0.05
Max	−0.08	4.00	−0.08	−0.10	4.00	−0.29	3.44
N	973	128	594	354	108	25	20

[1]The interregnum period between announcement and intervention is, on average, 16 minutes for the Intraday swaps, 11 minutes for the Intraday reverse swaps, and 1 minute for the Intraday spot sales.

Table 2.2: Spot Interventions Descriptive Statistics

(in USDbn)	Spot Sales	Program Spot Sales	Intraday Spot Sales
Mean	−0.54	−0.46	−0.56
Median	−0.53	−0.53	−0.54
s.d.	0.36	0.17	0.32
Min	−3.00	−1.00	−2.00
Max	−0.03	−0.05	−0.03
N	131	75	52

Figure 2.1: Brazilian FX Interventions By Type



On the asset prices side, our data set was gently sourced by B3, the largest trading platform in Brazil. The sample consists of tick-by-tick data from 03/01/2016 to 11/30/2021, and the analysis is during the futures market trading time (9:00 am to 6:00 pm). We discretize the time interval to 1 minute[2], totalling 540 intervals per day.

For the BRL/USD and the stock market measure, we use the futures exchange rate contract (DOL is the official name) and futures Ibovespa[3] contract (IND is the official name). We use the 1-month maturity on both contracts, where almost all liquidity is. In addition, we use the futures interest rates contracts (DI1 is the official name). Nevertheless, for this asset, there is liquidity on several maturities. Therefore, we investigate the effects on 6-month, 1-year, 3-year and 5-year yields[4]. We choose futures rates contracts instead of government bonds because the former is more liquid in Brazil, different from the United States, for example. A descriptive overview of the assets can be found in Table 2.3 and Figure 2.2.

Table 2.3: Asset Prices Descriptive Statistics

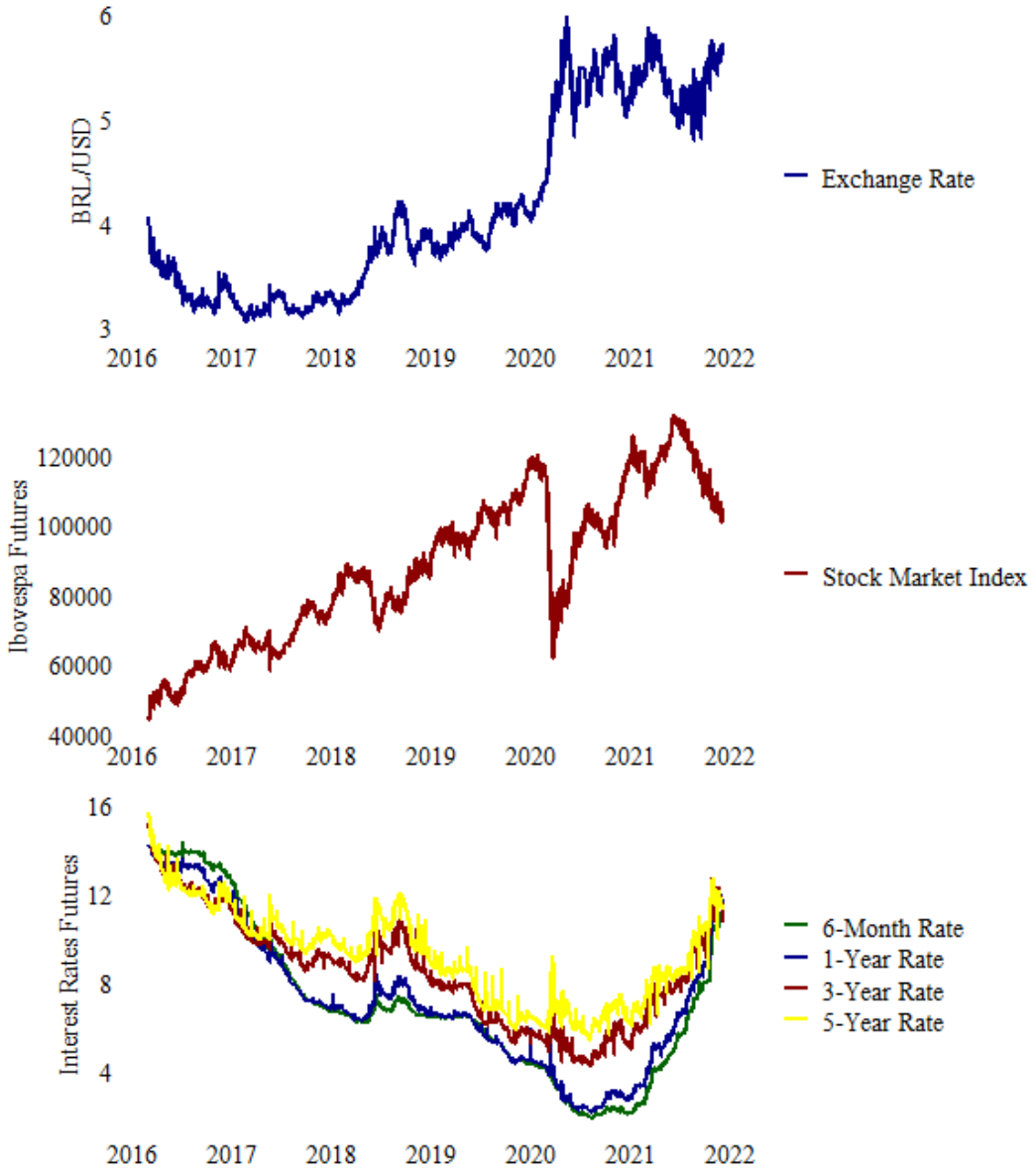
		Stock				
	BRL/USD	Market Index	6-M Rate	1-Y Rate	3-Y Rate	5-Y Rate
Mean	4.12	87914.62	7.08	7.24	8.43	9.11
Median	3.85	86761.96	6.51	6.79	8.51	9.26
s.d.	0.88	21803.69	3.56	3.21	2.44	2.15
Min	3.05	43687.07	1.88	2.19	4.01	5.28
Max	5.98	131303.39	14.35	14.24	15.47	15.59
N	760308	760308	760308	760308	760308	760308

[2]The literature usually adopts 5 to 15 minutes intervals; however, we use a shorter interval, as we note that the majority of the impact is in the first-minute post-intervention.

[3]Main Brazilian stock market index.

[4]As there is a necessity of high liquidity in our approach (i.e. transactions every minute), we do the following for the rate yields: if there is not much liquidity in a specific yield at a particular time, we consider a contract three months shorter or longer. We do that because the Treasury auctions in Brazil concentrate in January, April, July, October, so that guarantees us greater liquidity.

Figure 2.2: Asset Prices



Finally, Figures 2.3 to 2.8 illustrate- per asset- what would be the "natural" movement on each intervention type day and no-intervention day. Figures 2.9 to 2.14 illustrate the variability associated with each asset, depending on the intervention type. Those two groups of figures will be helpful in the section where we discuss the estimations effects.

Regarding the expected asset movements charts, we note that the USD sales direction interventions are correlated with negative asset movements (BRL/USD depreciation, rates increase, and stock market decrease), as the opposite for the USD purchase, suggesting that the BCB sells USD in crisis times, and vice-versa. These correlations suggest that there is much more of

systemic risk generating asset prices movements than would be the case during FX interventions in developed economies. Furthermore, Figures 2.3 to 2.8 show that Intraday type interventions stand out versus the other types. On those intervention days the asset prices levels change the most.

Figure 2.3: Exchange Rate Delta On The Intervention Day

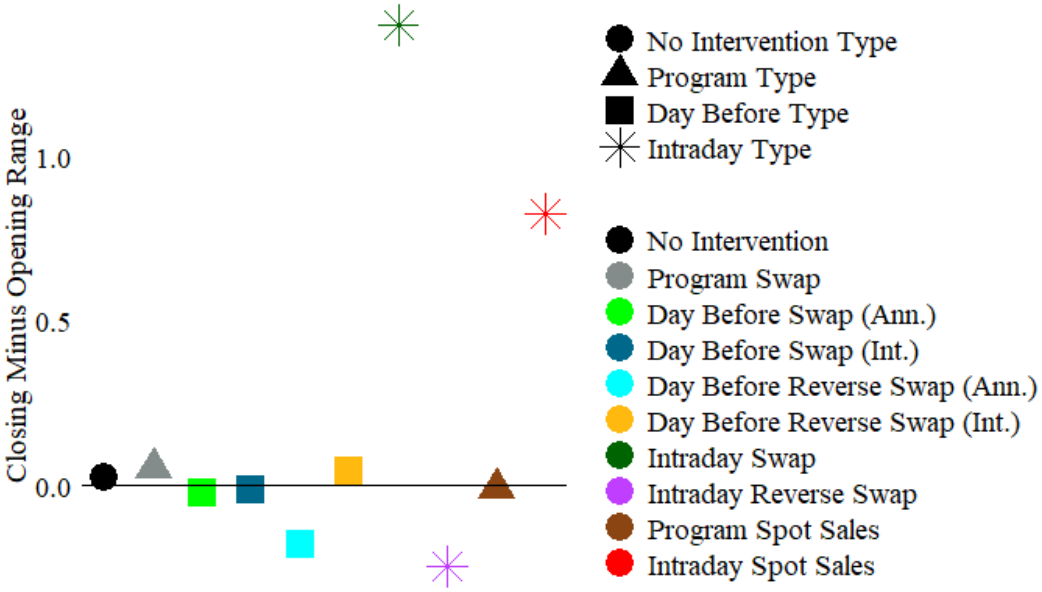


Figure 2.4: Stock Market Delta On The Intervention Day

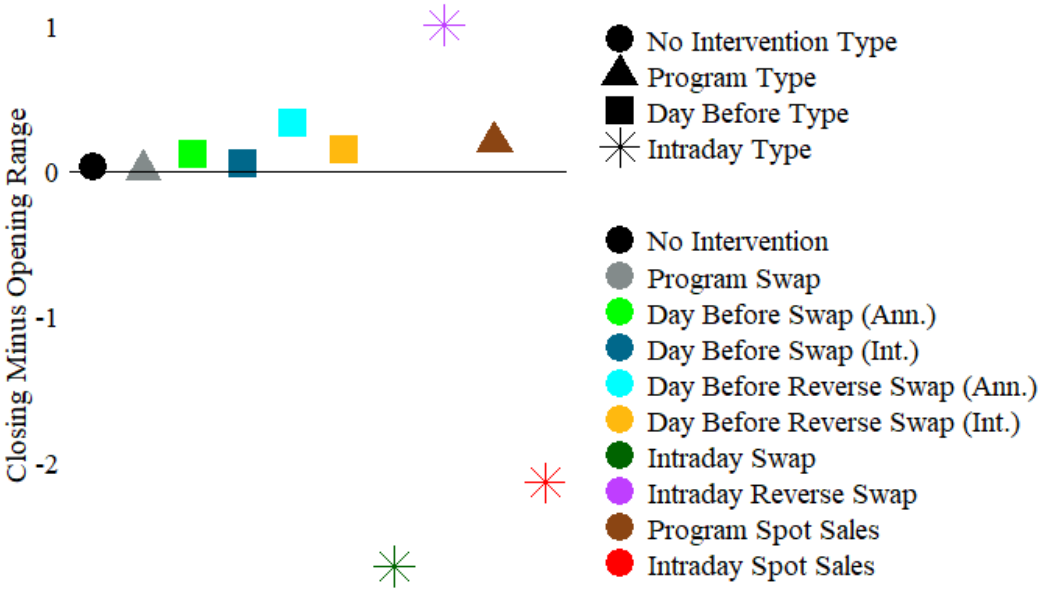


Figure 2.5: 6-Month Rate Delta On The Intervention Day

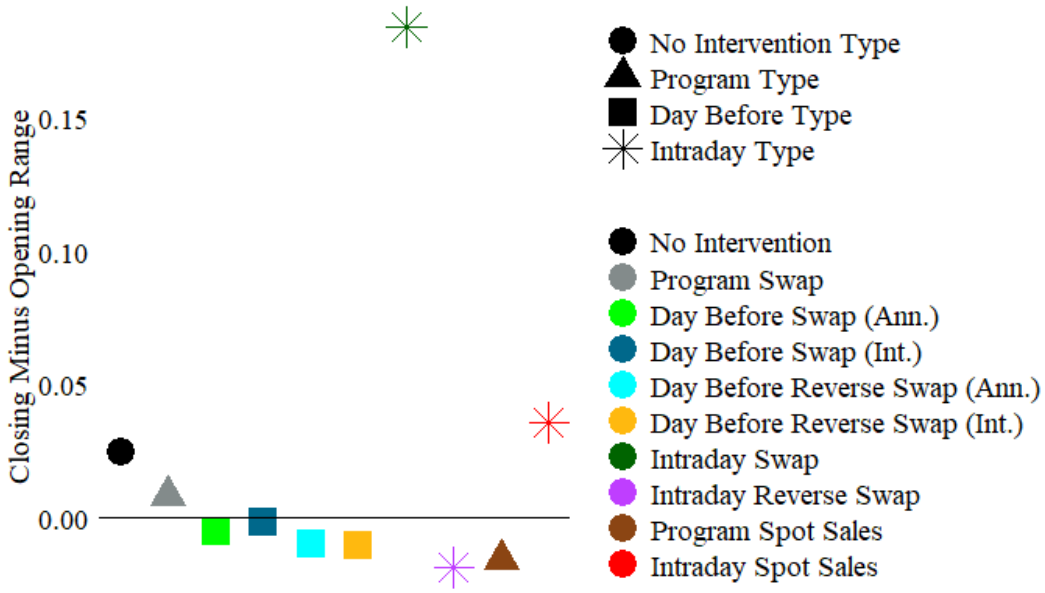


Figure 2.6: 1-Year Rate Delta On The Intervention Day

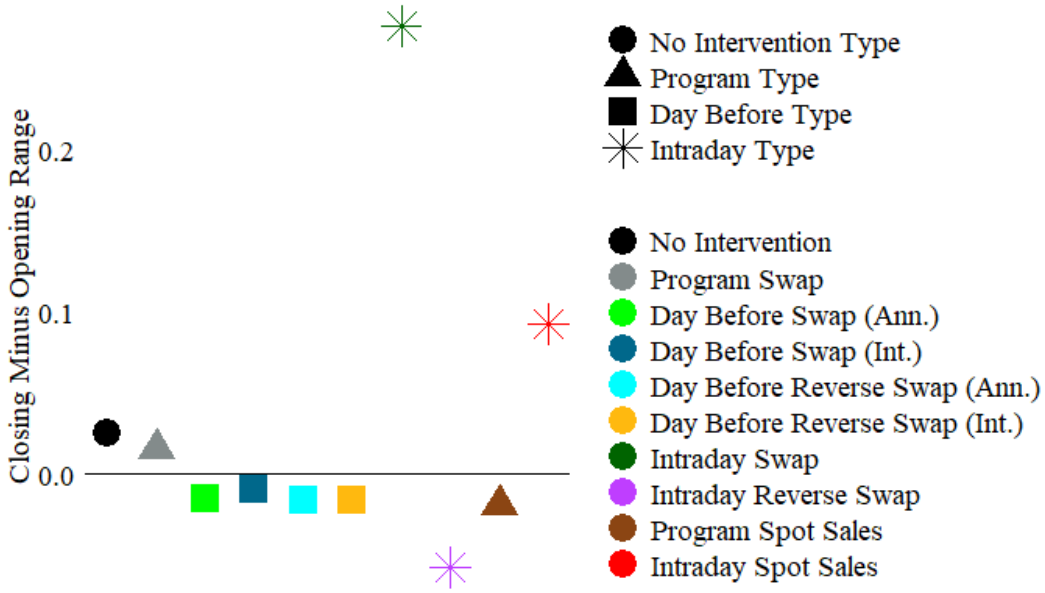


Figure 2.7: 3-Year Rate Delta On The Intervention Day

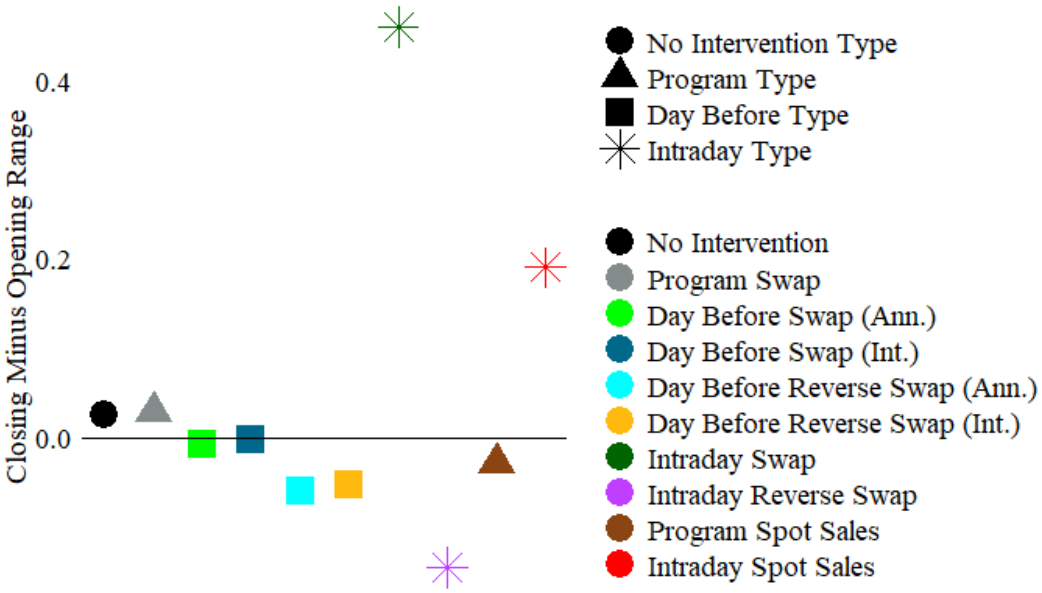
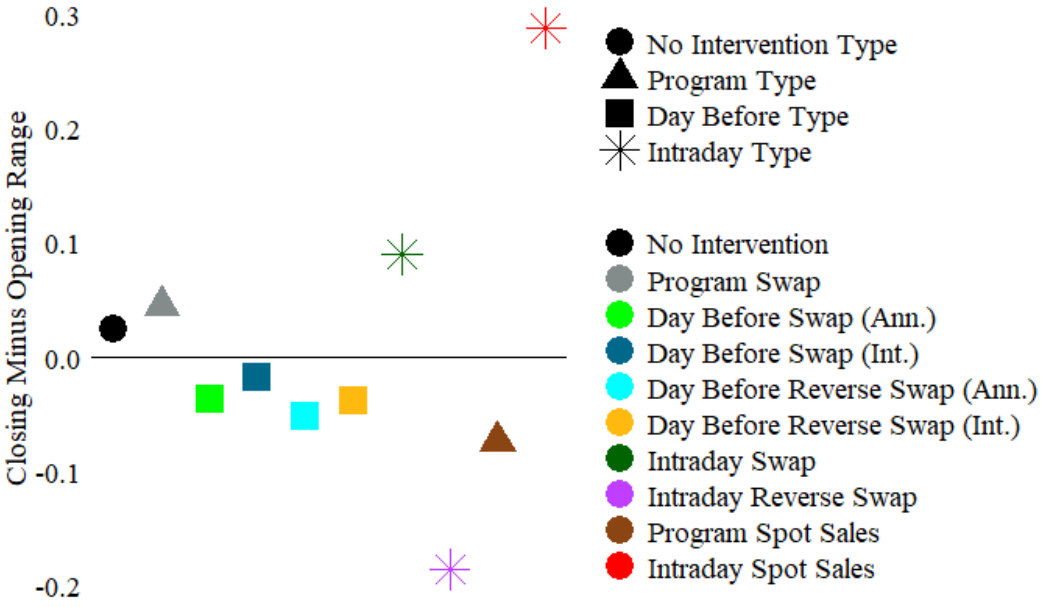


Figure 2.8: 5-Year Delta On The Intervention Day



Concerning variability charts (Figures 2.9 to 2.14 below), it calls our attention that, on the one hand, the Intraday type operations are associated with very volatile days, and, on the other hand, a Program period is correlated with days even less volatile than no-intervention days. Moreover, it is interesting to observe that the Intraday reverse swap days present a different pattern, regarding the rates movements, compared with the Intraday swap or

spot sales days. Observing the exchange rate and stock market index, all three Intraday variations have similar variability. Albeit, the rates charts show that Intraday reverse swaps are associated with less volatile days (as Day Before and Program), versus the other two Intraday types.

Figure 2.9: Exchange Rate Variability On The Intervention Day

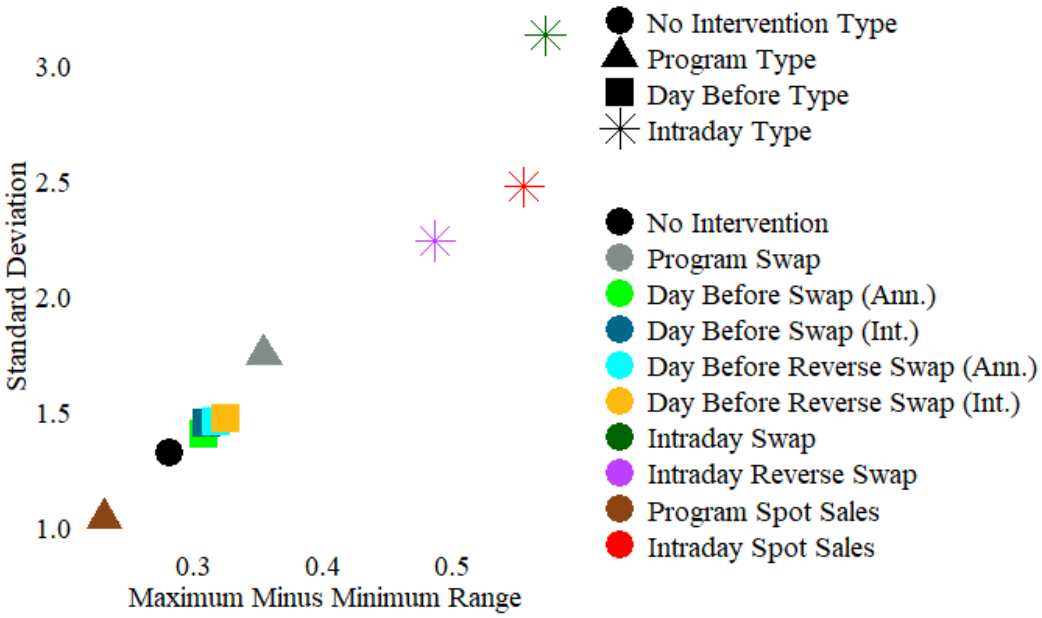


Figure 2.10: Stock Market Variability On The Intervention Day

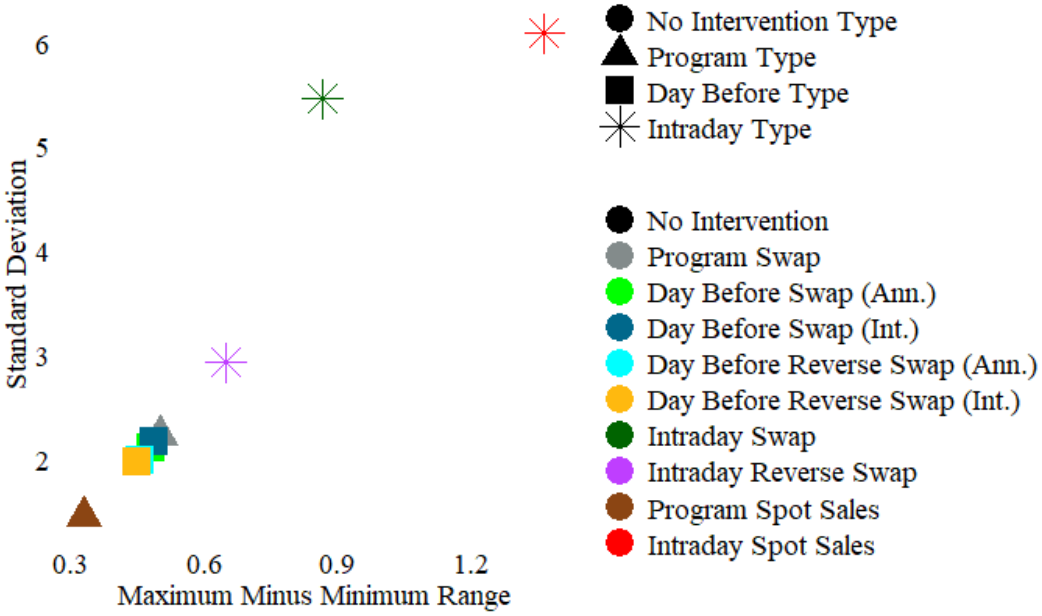


Figure 2.11: 6-Month Rate Variability On The Intervention Day

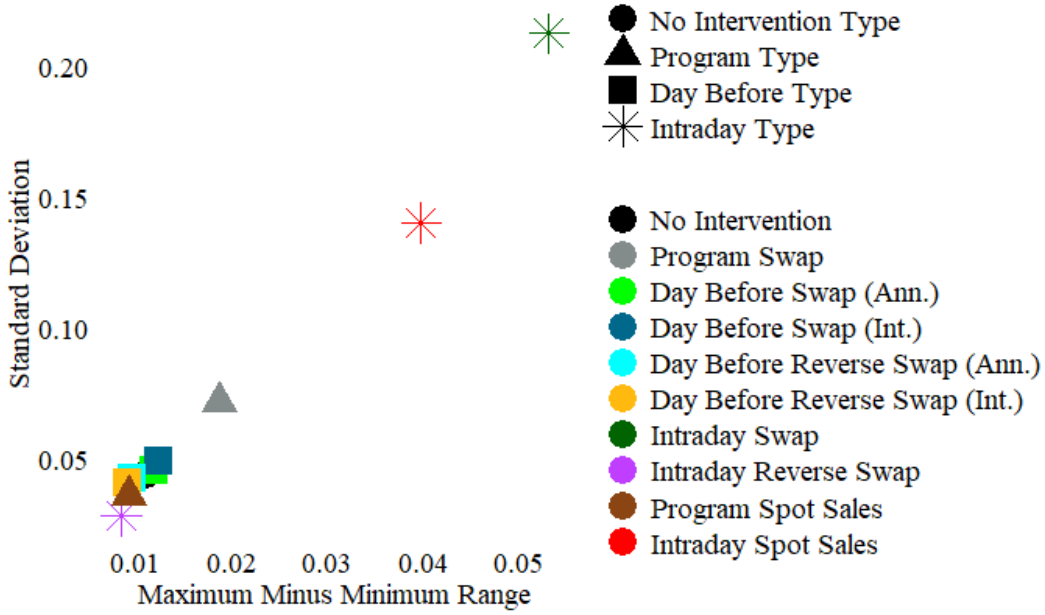


Figure 2.12: 1-Year Rate Variability On The Intervention Day

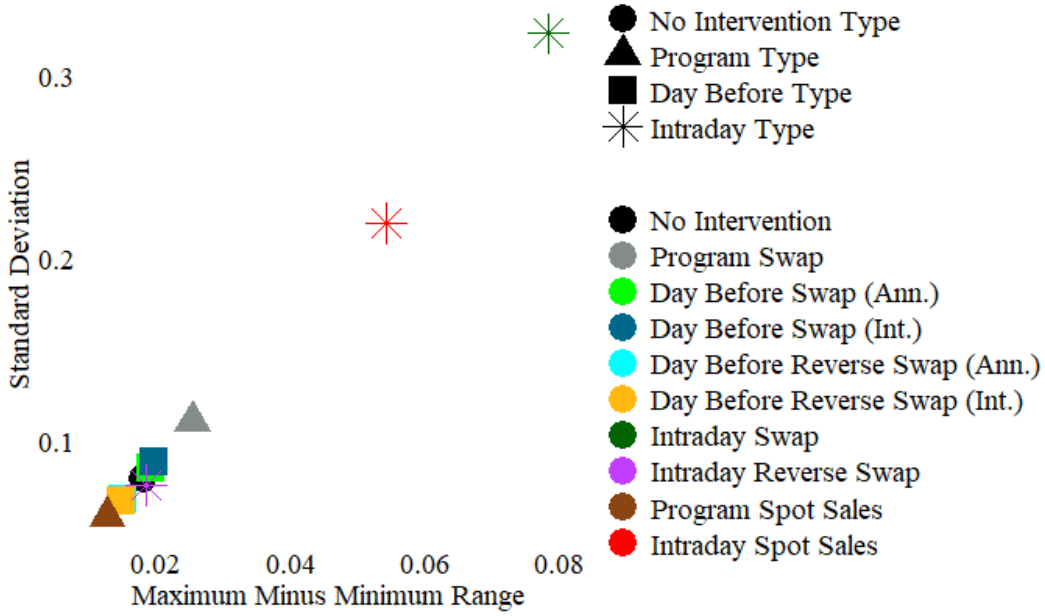


Figure 2.13: 3-Year Rate Variability On The Intervention Day

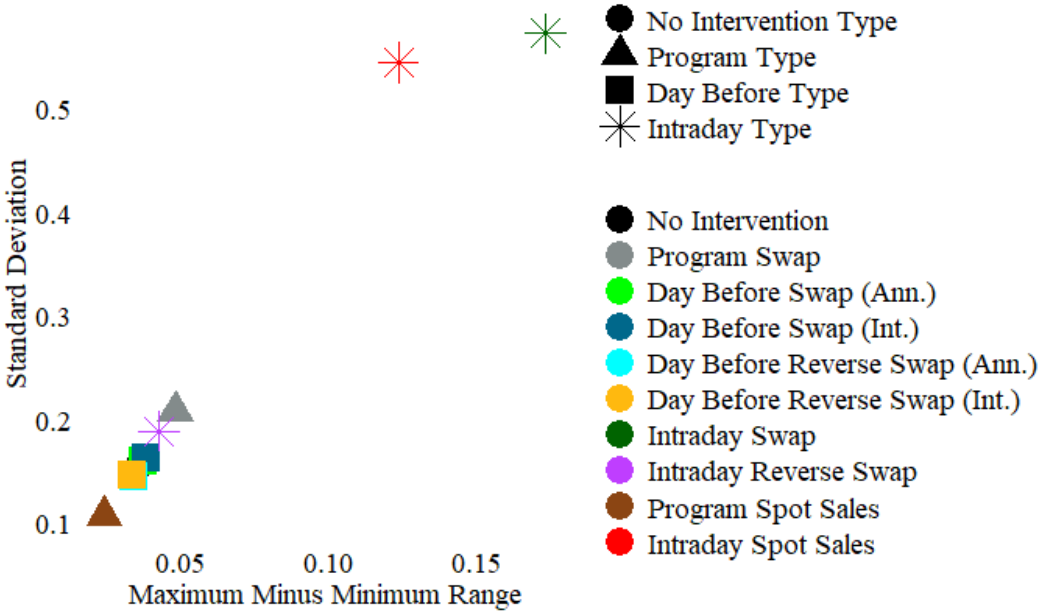
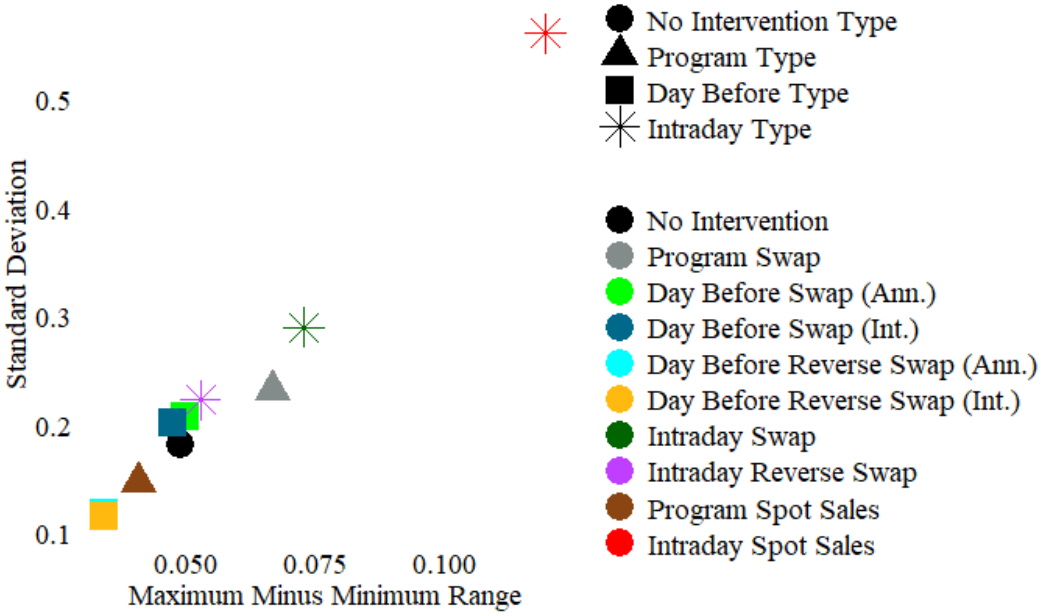


Figure 2.14: 5-Year Rate Variability On The Intervention Day



3
Local Projection Method

We use Jordà (2005) Local Projection (LP) to our dynamic estimations of impulse responses. The method basically consists in direct linear regressions of future outcomes on current covariates. It's worth to mention that LP it's quite established in the macroeconomics field[1]. Below we exhibit the procedure, following Jordà (2005).

As an impulse response is a difference between two forecasts:

$$\mathrm{IR}\left(t,s,\mathbf{d}_i\right)=E\left(\mathbf{y}_{t+s}\mid\mathbf{v}_t=\mathbf{d}_i;\mathbf{X}_t\right)\quad -E\left(\mathbf{y}_{t+s}\mid\mathbf{v}_t=\mathbf{0};\mathbf{X}_t\right)\qquad s=1,2,\ldots,h \tag{3-1}$$

where the operator $E(.\mid.)$ denotes the best mean squared error predictor; $\mathbf{y}_t$ is an $n\times 1$ random vector; $\mathbf{X}_t\equiv\left(\mathbf{y}_{t-1},\mathbf{y}_{t-2},\ldots\right)'$; $\mathbf{0}$ is of dimension $n\times 1$; $\mathbf{v}_t$ is the $n\times 1$ vector of reduced-form disturbances; and D is an $n\times n$ matrix, whose columns $\mathbf{d}_i$ contain the shocks.

Projecting $\mathbf{y}_{t+s}$ onto the linear space generated by $\left(\mathbf{y}_{t-1},\mathbf{y}_{t-2},\ldots,\mathbf{y}_{t-p}\right)'$:

$$\mathbf{y}_{t+s}=\mathbf{B}_1^s\mathbf{y}_{t-1}+\mathbf{B}_2^s\mathbf{y}_{t-2}+\cdots+\mathbf{B}_p^s\mathbf{y}_{t-p}+\mathbf{u}_{t+s}^s\qquad s=1,2,\ldots,h \tag{3-2}$$

where $\mathbf{B}_i^s$ are matrices of coefficients for each lag i and horizon s.

Then, the group of h regressions in (3-2) are the local projections, as illustrated below:

$$\begin{cases}\mathbf{y_{t+1}}=\mathbf{B}_1^1\mathbf{y}_t+\mathbf{B}_2^1\mathbf{y}_{t-1}+\ldots+\mathbf{B}_p^1\mathbf{y}_{t-p}+\mathbf{u}_{t+1}\\ \mathbf{y}_{t+2}=\mathbf{B}_1^2\mathbf{y}_t+\mathbf{B}_2^2\mathbf{y}_{t-1}+\ldots+\mathbf{B}_p^2\mathbf{y}_{t-p}+\mathbf{u}_{t+2}\\ \qquad\qquad\vdots\\ \mathbf{y}_{t+h}=\mathbf{B}_1^h\mathbf{y}_t+\mathbf{B}_2^h\mathbf{y}_{t-1}+\ldots+\mathbf{B}_p^h\mathbf{y}_{t-p}+\mathbf{u}_{t+h}\end{cases} \tag{3-3}$$

Hence, by (3-1), the impulse responses from the local projections in (3-2) are:

$$\widehat{\mathrm{IR}}\left(t,s,\mathbf{d}_i\right)=\hat{\mathbf{B}}_i^s\mathbf{d}_i\qquad s=1,2,\ldots,h \tag{3-4}$$

There is a fruitful discussion comparing LP with the classic Vector Autoregression (VAR) method. We support ourselves on Jordà (2005), and

[1]Brugnolini (2018) presents meta-data on the Jordà (2005)'s citations to make this point. Indeed, relevant macro papers illustrate the acceptance, e.g. Romer & Romer (2010), Ramey (2016), Ramey & Zubairy (2018), Angrist et al. (2018), Nakamura & Steinsson (2018), Stock & Watson (2018).

Montiel Olea & Plagborg-Møller (2021), listing the following advantages of the LP: (i) greater pointwise robustness to model misspecification, (ii) greater robustness to long horizons estimations and (iii) greater accommodation of highly nonlinear or flexible specifications.

Finally, our h regressions which give us minute-by-minute impulse responses, are calculated according to:

$$Asset_{t+s} = \sum_{i=0}^{p} a_i^s Asset_{t-i} + \sum_{i=0}^{p} b_i^s Intervention_{t-i} + u_{t+s} \qquad s = 1, 2, \ldots, h \tag{3-5}$$

The inference follows the OLS approach, and we address serial correlation by Newey West robust standard errors, as suggested by Jordà (2005).

3.1
Brief Identification Discussion

The R language package we use to estimate the LPs is lpirfs, developed by Adämmer (2019). As the identification method there uses Cholesky, we would like to let that explicit and argue that in our case the method suits perfectly.

There is a longer discussion of the method in the Appendix, but here let us suppose an arbitrarily simple second order vector to make our point.

$$\begin{pmatrix} Asset_t \\ Intervention_t \end{pmatrix} = \boldsymbol{A}_1 \begin{pmatrix} Asset_{t-1} \\ Intervention_{t-1} \end{pmatrix} + \boldsymbol{A}_2 \begin{pmatrix} Asset_{t-2} \\ Intervention_{t-2} \end{pmatrix} + \boldsymbol{B} \begin{pmatrix} u_t^A \\ u_t^I \end{pmatrix} \tag{3-6}$$

The Cholesky decomposition, giving us a recursive identification basically involves transform the $\mathbf{B}$ matrix into a lower triangular matrix $\widetilde{\mathbf{B}}$.

$$\begin{pmatrix} Asset_t \\ Intervention_t \end{pmatrix} = \boldsymbol{A}_1 \begin{pmatrix} Asset_{t-1} \\ Intervention_{t-1} \end{pmatrix} + \boldsymbol{A}_2 \begin{pmatrix} Asset_{t-2} \\ Intervention_{t-2} \end{pmatrix} + \underbrace{\begin{pmatrix} b_{1e} & 0 \\ b_{2e} & c_{2e} \end{pmatrix}}_{\widetilde{B}} \begin{pmatrix} \varphi_t^A \\ \varphi_t^I \end{pmatrix}. \tag{3-7}$$

The equation above, through $\widetilde{\mathbf{B}}$, tells us we took out the simultaneity from the intervention on the asset. At t, the asset only receives his own shock. Real issues emerged when there is a case of monthly, quarterly or annually data. Nonetheless, we use minute-by-minute data, therefore, the method suits just fine for us. Once again, all details are in the Appendix.

4
Impulse Responses Results

We split the results' presentation into two parts: (i) a short term focal estimation (20 minutes before the intervention, 30 minutes after intervention), and (ii) a medium-term estimation (20 minutes before the intervention, but 9 hours after, which is a trading day period[1]). Furthermore, we try to present the announcement and intervention cases side-by-side.

The impulse response functions (IRFs) regarding aggregate derivative and spot interventions (without our categorization), as the IRFs regarding Program type, are in the Appendix. We focus on describing Day Before and Intraday more surprise types, where our minute-by-minute approach adds more. Moreover, the shorter (6-Month) and longer (5-Year) yields estimations are also in the Appendix. Finally, we focus on 1-Year and 3-Year liquid medium-term yields.

Note that all the charts shocks are one USD billion, as standard in the literature. We control for 10 lags, despite running for a number of lags from 1 to 30 without verifying major differences. The responses are all accumulated, and we use a 90% confidence band.

4.1
30 Minutes Horizon

First of all, it is worth mentioning that analyzing the Day Before announcement has the drawback that overnight events can impact asset prices on the opening market. We organize the IRFs in two columns: the first looks at the announcement; and the second, at the intervention minute. Each line corresponds to a different asset price. Figure 4.1 shows that neither the Day Before swap (the equivalent of a futures USD sales) announcement nor the Day Before swap issuance moment seems to move significantly the BRL/USD. The announcement is associated with a statistically significant increase in the stock market index and 1-year rate, which is not the case for the intervention. The 3-year rate, as the BRL/USD, has a mild variation with dubious statistical significance.

[1]On those longer horizon estimations, we change a little our original data structure for use suitability. The minute-by-minute data turns to be 10 minutes interval data.

Figure 4.1: Day Before Swap Shock (Announcement Moment;LHS) and Day Before Swap Shock (Intervention Moment;RHS)

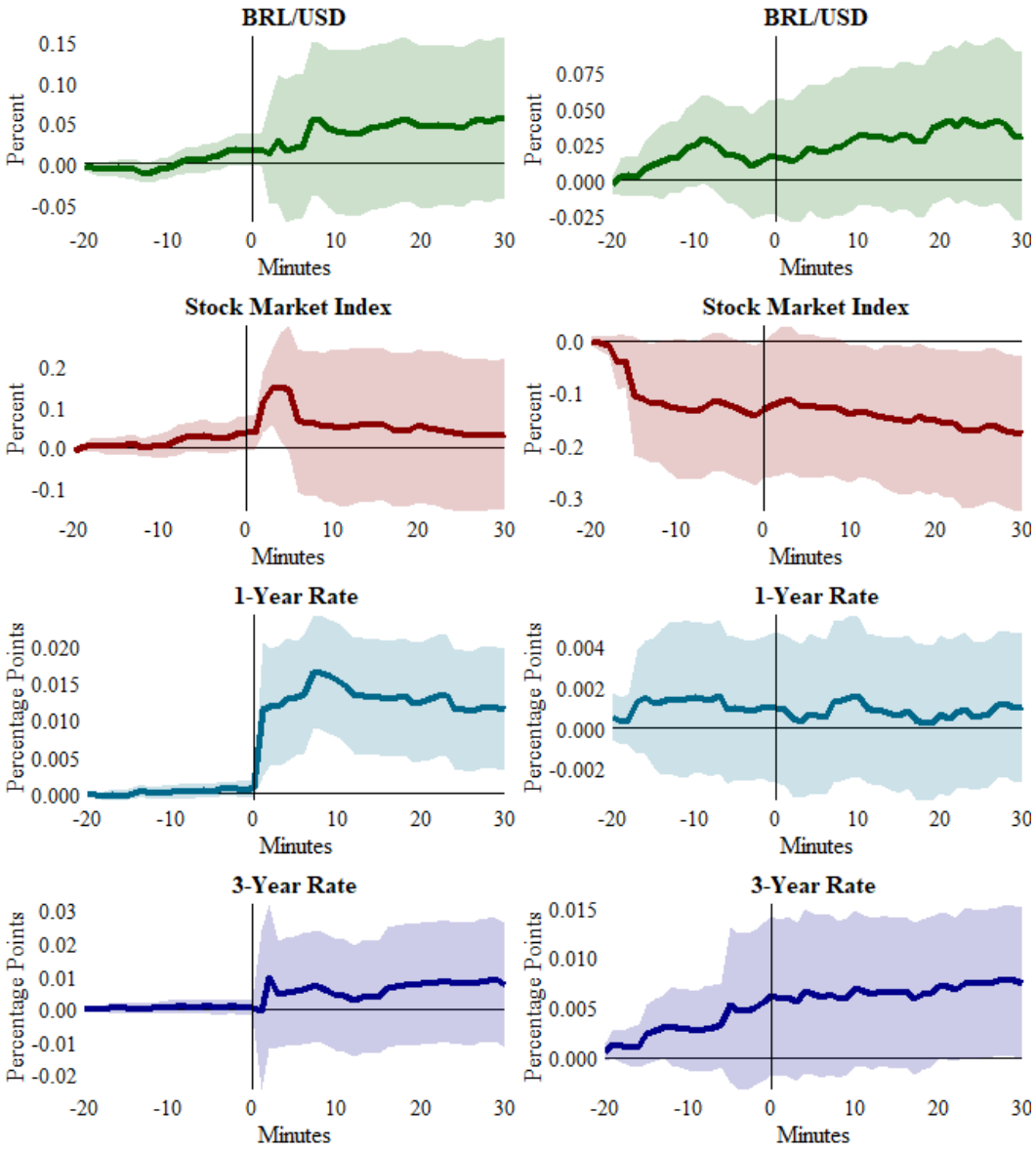
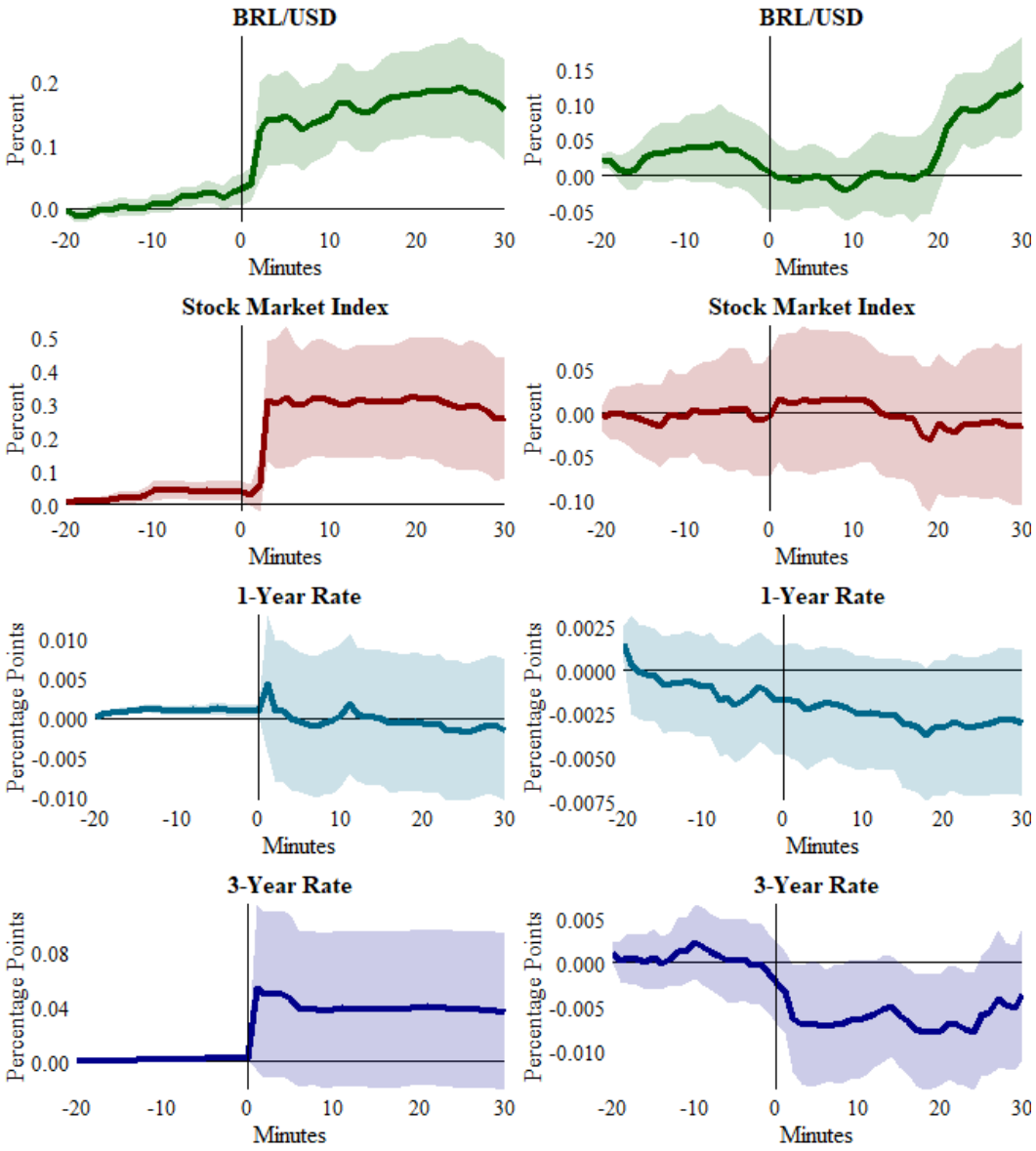


Figure 4.2, regarding Day Before reverse swaps (the equivalent of a futures USD purchase), reveals BRL/USD depreciation (as expected) during the opening minutes in the following day the operation was known, as it reveals for the operation per se. Concerning the other assets, the intervention moment seems to decrease the 3-year rates slightly but does not impact the others. The announcement, though, stresses both rate yields upwards and goes along with a relevant increase in the stock market.

Figure 4.2: Day Before Reverse Swap Shock (Announcement Moment;LHS) and Day Before Reverse Swap Shock (Intervention Moment;RHS)



We now enter the Intraday field, where we believe add the most, given the surprise level of the shock and granularity of our data. Figure 4.3 shows how Intraday swap announcement can induce an exchange rate appreciation of 0.4 percent. By the left-hand side (LHS) BRL/USD chart, we also observe a sharp depreciation (already in a day of BRL value loss and volatility as shown in Figures 2.3 and 2.9) precedes the announcement, which may work as a trigger. By the right-hand side (RHS) BRL/USD chart, we note that the expected appreciation impact occurs before the auction, which should be the announcement effect (16 minutes between them, on average, as mentioned previously). Concerning the other assets, the announcement is correlated with

an increase of around 0.2 percent of the futures of ibovespa and an increase of around 0.03 percentage points in the futures interest rates.

Figure 4.3: Intraday Swap Shock (Announcement Moment;LHS) and Intraday Swap Shock (Intervention Moment;RHS)

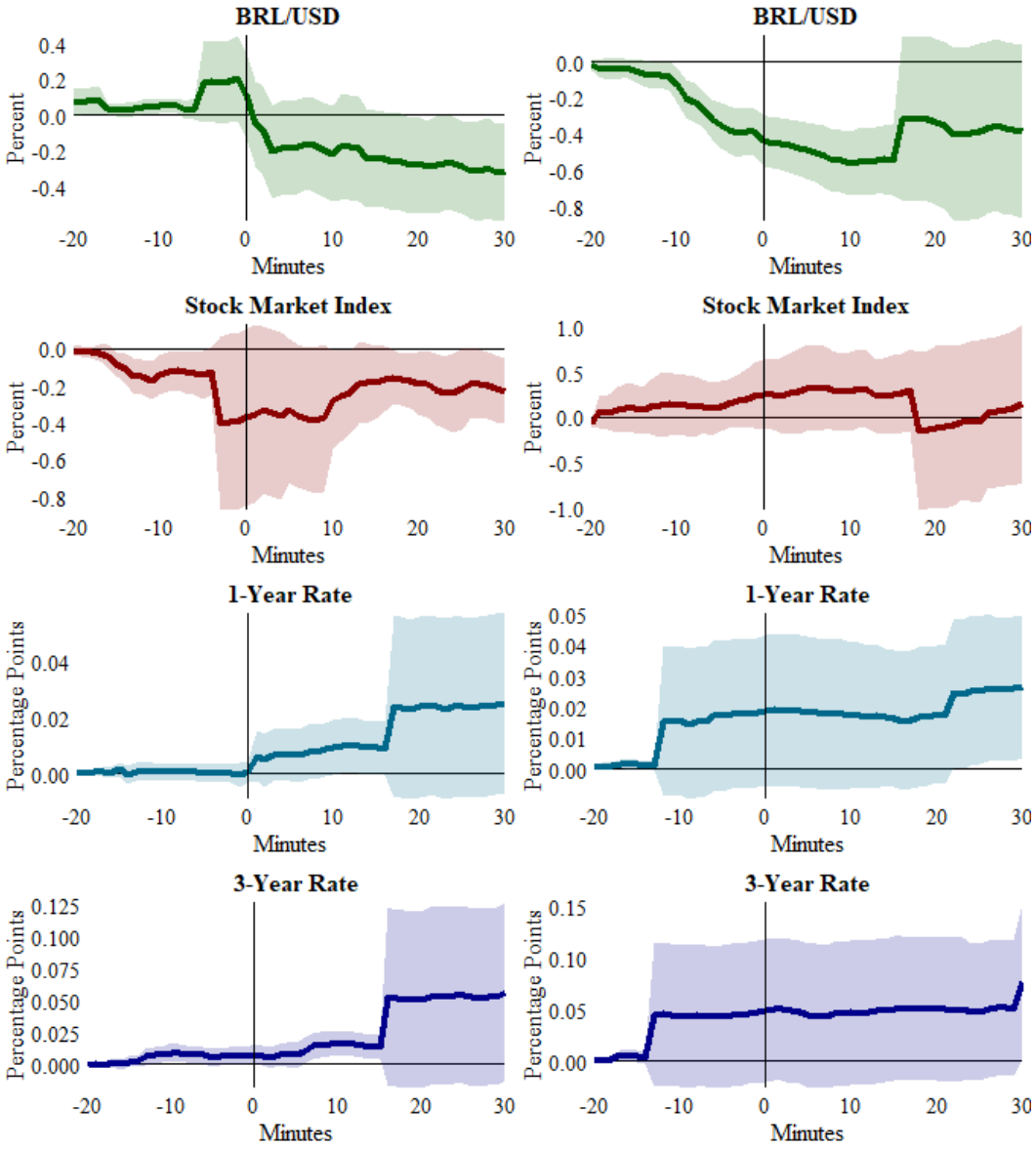
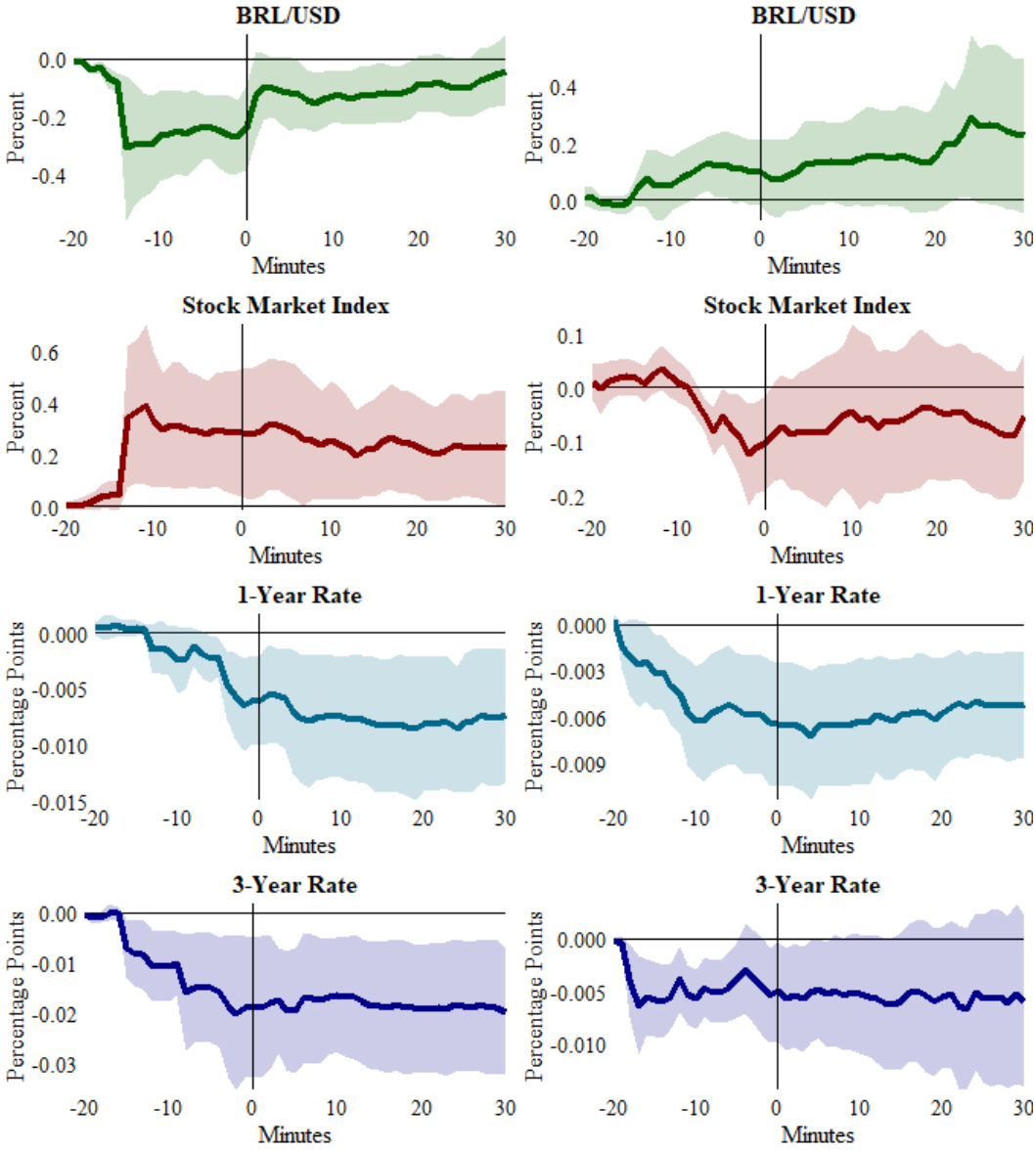


Figure 4.4 left exchange rate chart shows an analogous situation of the previous figure, i.e., a day in which the BRL was sharply appreciating and the information of the auction depreciates the currency by 0.2 percent. The intervention moment by itself is way less relevant, except for the positive effect on the stock market. Nevertheless, as in the previous figure, the announcement increases futures rates (or at least prevents further downward pressure as in prior communication minutes).

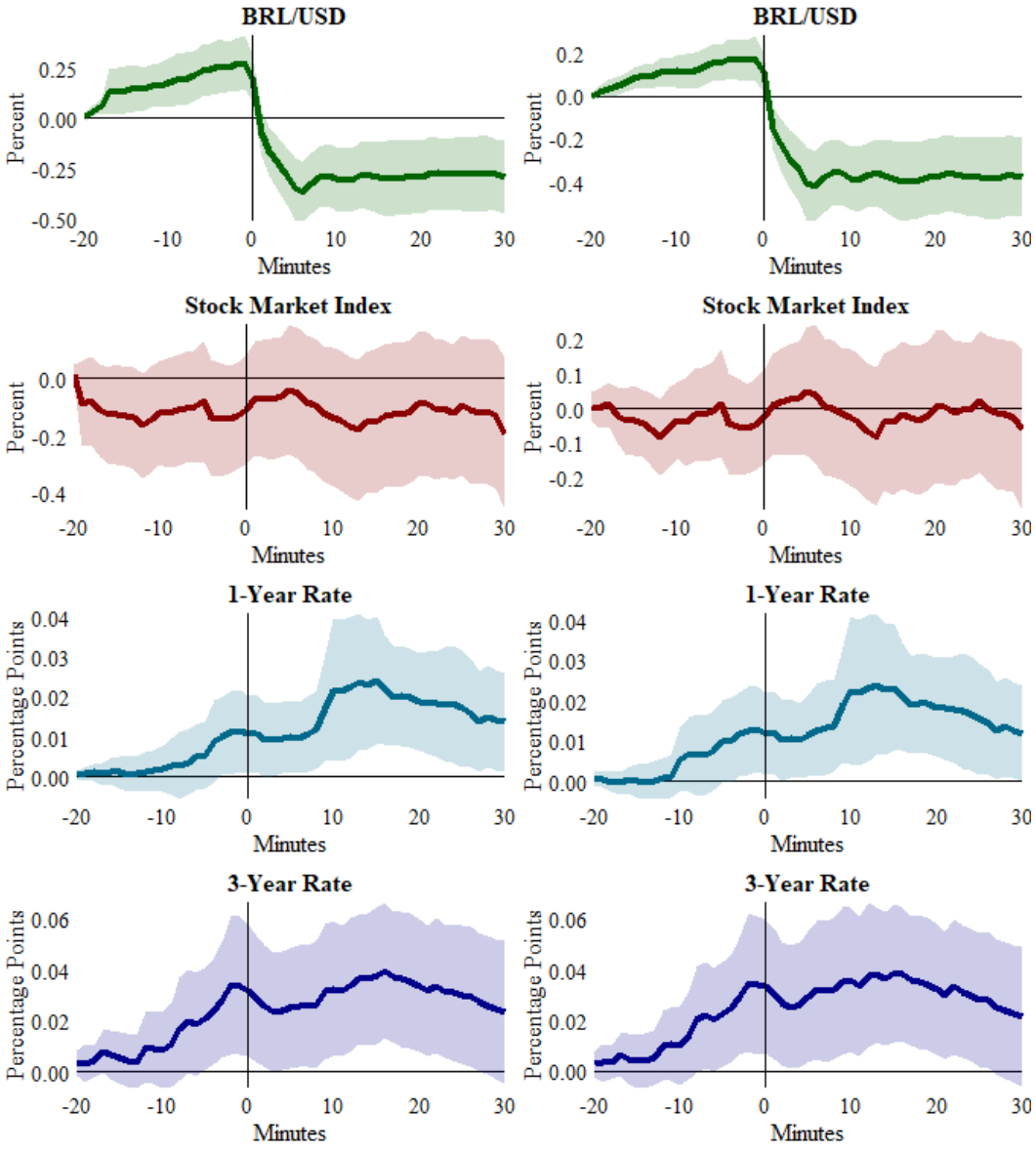
Figure 4.4: Intraday Reverse Swap Shock (Announcement Moment;LHS) and Intraday Reverse Swap Shock (Intervention Moment;RHS)



Now we change from derivatives to spot operations. We are grasping ourselves in the Intraday spot sales shock, represented in Figure 4.5. The first thing to be noted is the equivalence of LHS and RHS column charts, as the announcement-auction interval merely does not exist, as mentioned earlier. About the BRL/USD, the swap pattern repeats, but more heavily: BRL quickly losing value minutes before (while the BCB believes the exchange rate market is malfunctioning, recall that would always be the alleged reason to intervene); however, it gains value instantaneously after the event- around 0.5 percent, with clear significance. Like other intervention types, the stock market is less correlated with the FX interventions than the interest rates one,

and there is no apparent impact here. Despite already being in an upwards trend day (Figures 2.6 and 2.7), the futures rates still seem to present some upward movement (around 0.02 percentage points) after the intervention event, at least in the 1-year yield.

Figure 4.5: Intraday Spot Sales Shock (Announcement Moment;LHS) and Intraday Spot Sales Shock (Intervention Moment;RHS)



All in all, the new unknown information that an intervention will happen impacts way more the assets than the auction itself. In theoretical terms[2], that

[2]The two main channels that interventions impact exchange rates are the portfolio balance and signalling ones. The former believes that different currency assets are imperfect substitutes, then agents demand a higher return of the asset whose supply increased (decreased) by the intervention, which calls for a depreciation (appreciation) in the asset's currency. The latter says that the central banks have more information about the fundamentals

means signalling effects prevails over the balance sheet effects. Another trend in the results is that Day Before type is less potent in moving asset prices than the Intraday type[3]. Furthermore, the 3-year yield tends to have more significant responses to the shocks than the 1-year yield.

In the matter of direction, the BRL/USD reacts as expected: USD sales (or swap issuance) inducing an appreciation, and USD purchase (or reverse swap issuance) a depreciation. Still, in the matter of direction, it is interesting that either the stock market index and the futures interest rate have quite the same reaction for the two different directions; however, the stock market tends to respond in a less statistically significant way. The reactions are an increase in the stock market index and the futures interest rates.

The futures of ibovespa and futures of rates responses direction uniformity intrigues us for two reasons: first, usually, the co-movement of those assets are stock market up and rates down (or vice versa for both asset classes). Second, in both directions and asset classes, we have situations in which the intervention changes the "natural" course of the asset for a typical intervention day for that direction, which could be seen in Figures 2.3, 2.6 and 2.7.

4.2 9 Hours Horizon

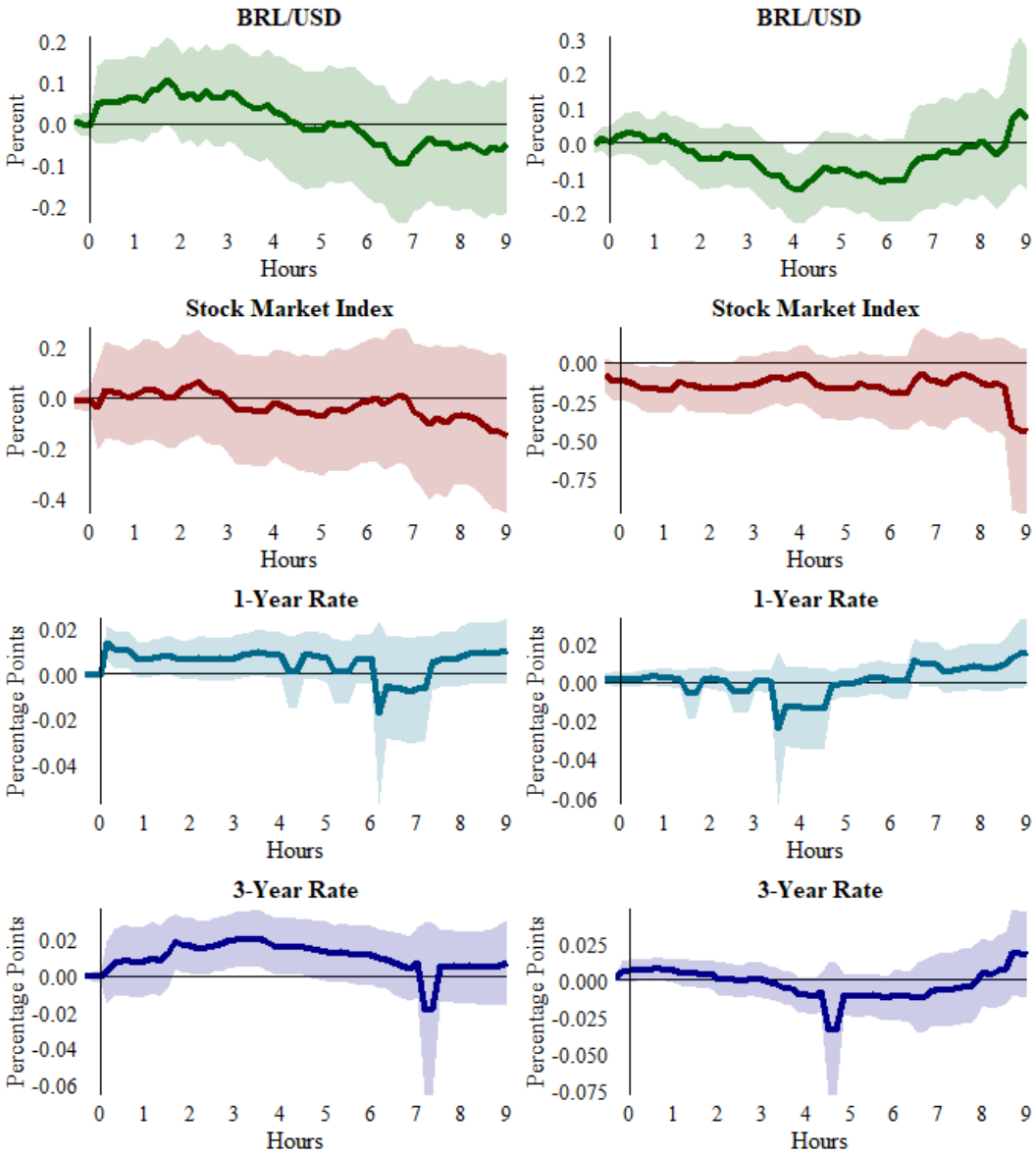
The 9 hours (equivalent of a trading day) window allows us to discuss two specific dimensions: (i) if the impact direction or magnitude changes from the short to the medium term estimation, and (ii) if the persistence of the shocks varies between intervention types. We follow the same exposition order of the shorter horizon.

Figure 4.6 illustrates that the narrative might change when considering the post-intervention hours. The non-relevant impact on the BRL/USD becomes a mild depreciation effect, followed by a mild appreciation one. The positive dynamic reaction on the futures of ibovespa, turns from positive to negative. However, both yield maturities maintain the increase associated with the Day Before swap issuance.

of the economy- which supposedly affect the exchange rate- and can use the intervention to signal that (Chamon & Magud (2019)).

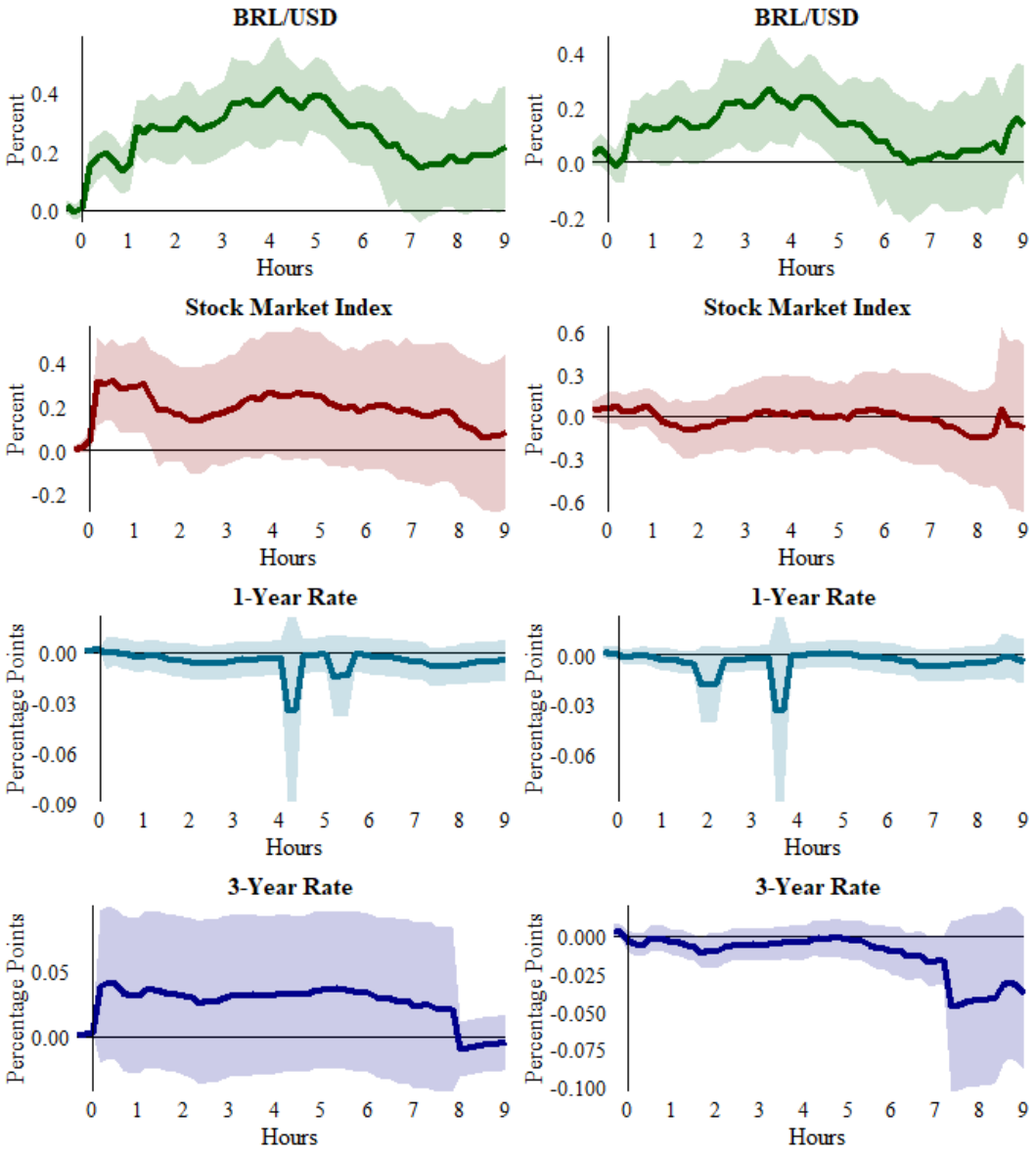
[3]Program type, in its turn, is less potent than the Day Before, as shown in the Appendix. Hence, the more surprised, the powerful the shock.

Figure 4.6: Day Before Swap Shock (Announcement Moment;LHS) and Day Before Swap Shock (Intervention Moment;RHS)



Day Before reverse swap situation, illustrated in Figure 4.7, portrays a shock whose impact increases over some hours (in the same 30 minutes direction) and then diminishes considerably.

Figure 4.7: Day Before Reverse Swap Shock (Announcement Moment;LHS) and Day Before Reverse Swap Shock (Intervention Moment;RHS)



Moving to the Intraday types, the swap shock (Figure 4.8)- except the BRL/USD- increase by some hours and then sustain a certain delta: 0.5 percent, 0.2 percentage points, 0.3 percentage points for the ibovespa futures, 1-year rate, 3-year rate, respectively. Specifically, on the BRL/USD, the impact increases continually over the trading day period, letting the BRL/USD appreciation achieve around 1.5 percent. Observe that the responses' directions are the same as in the shorter window estimation and that only the exchange rate significantly changes the direction of the expected movement in a typical USD sales day (Figures 2.3, 2.4, 2.6, and 2.7).

Figure 4.8: Intraday Swap Shock (Announcement Moment;LHS) and Intraday Swap Shock (Intervention Moment;RHS)

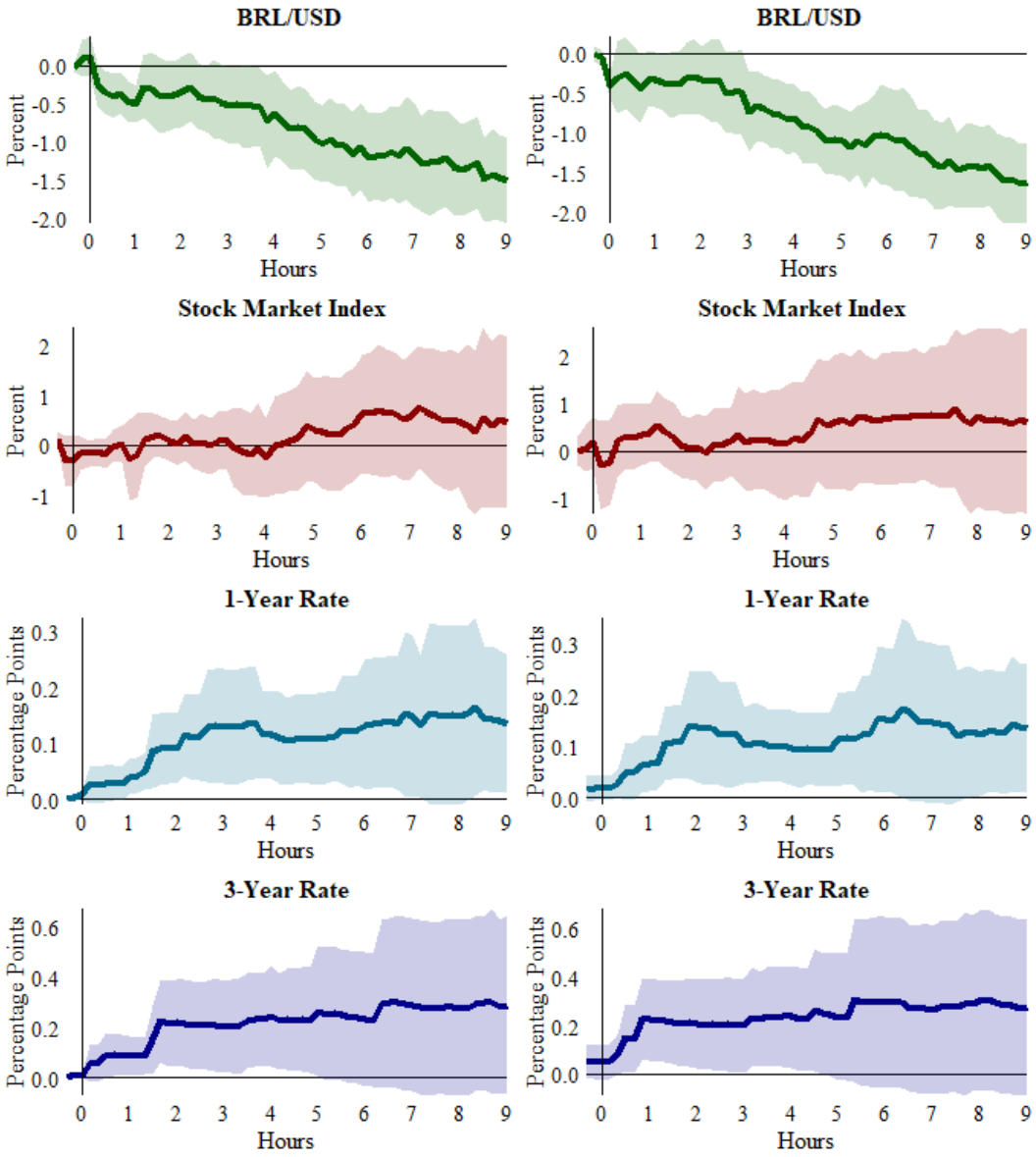
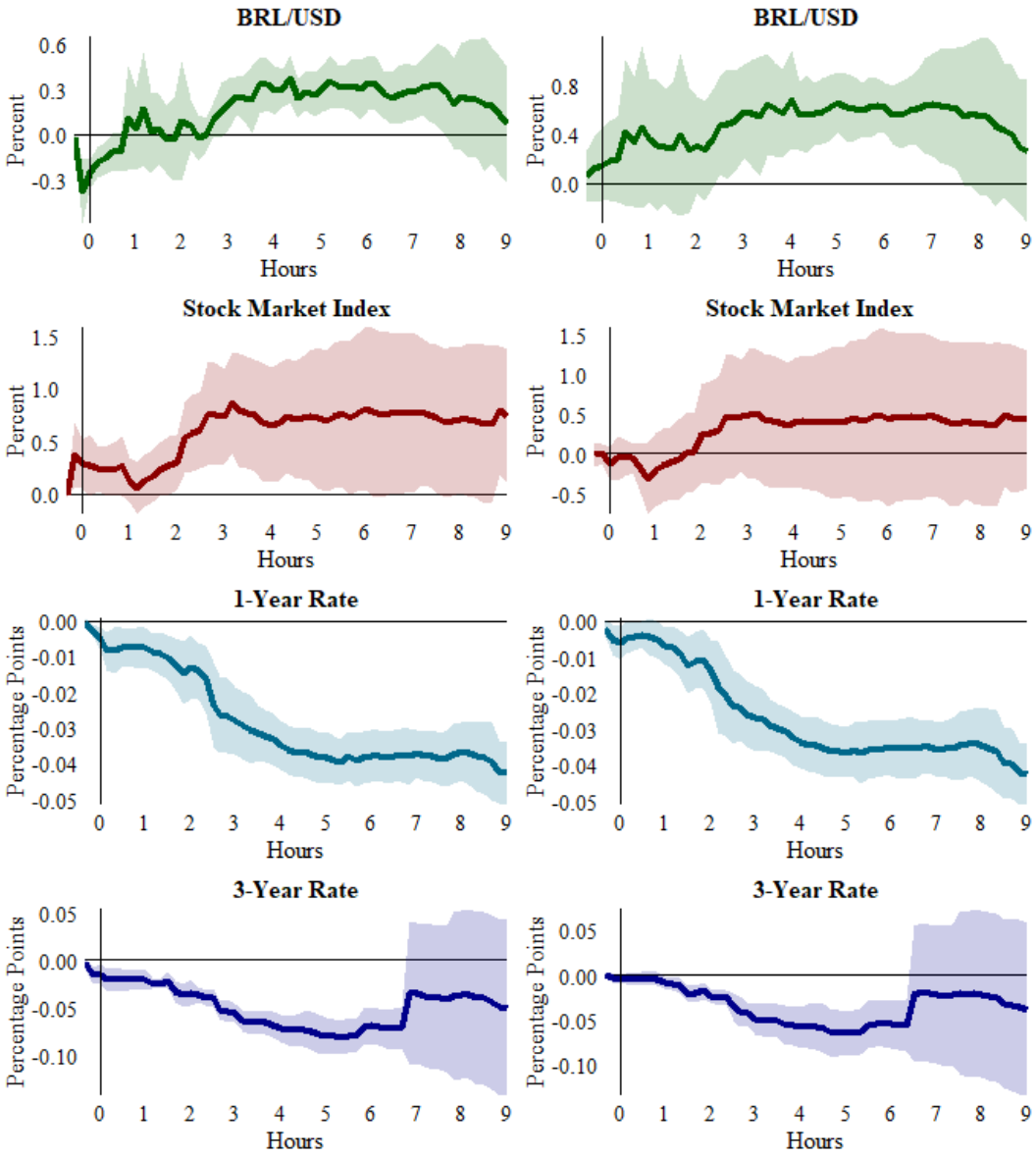


Figure 4.9 shows the Intraday reverse swap auction shock. The exchange rate charts express that the intervention leads to almost 0.6 percent depreciation but fades away after a trading day. The other assets present other behaviour, sustaining a specific variation degree. The stock market index increases around 0.8 percent, and either 1-year or 3-year rates achieve 0.04 percentage points lessen. The main point here would be that the intervention could- for some hours- change the "natural" course of the asset prices (Figures 2.3, 2.4, 2.6, and 2.7).

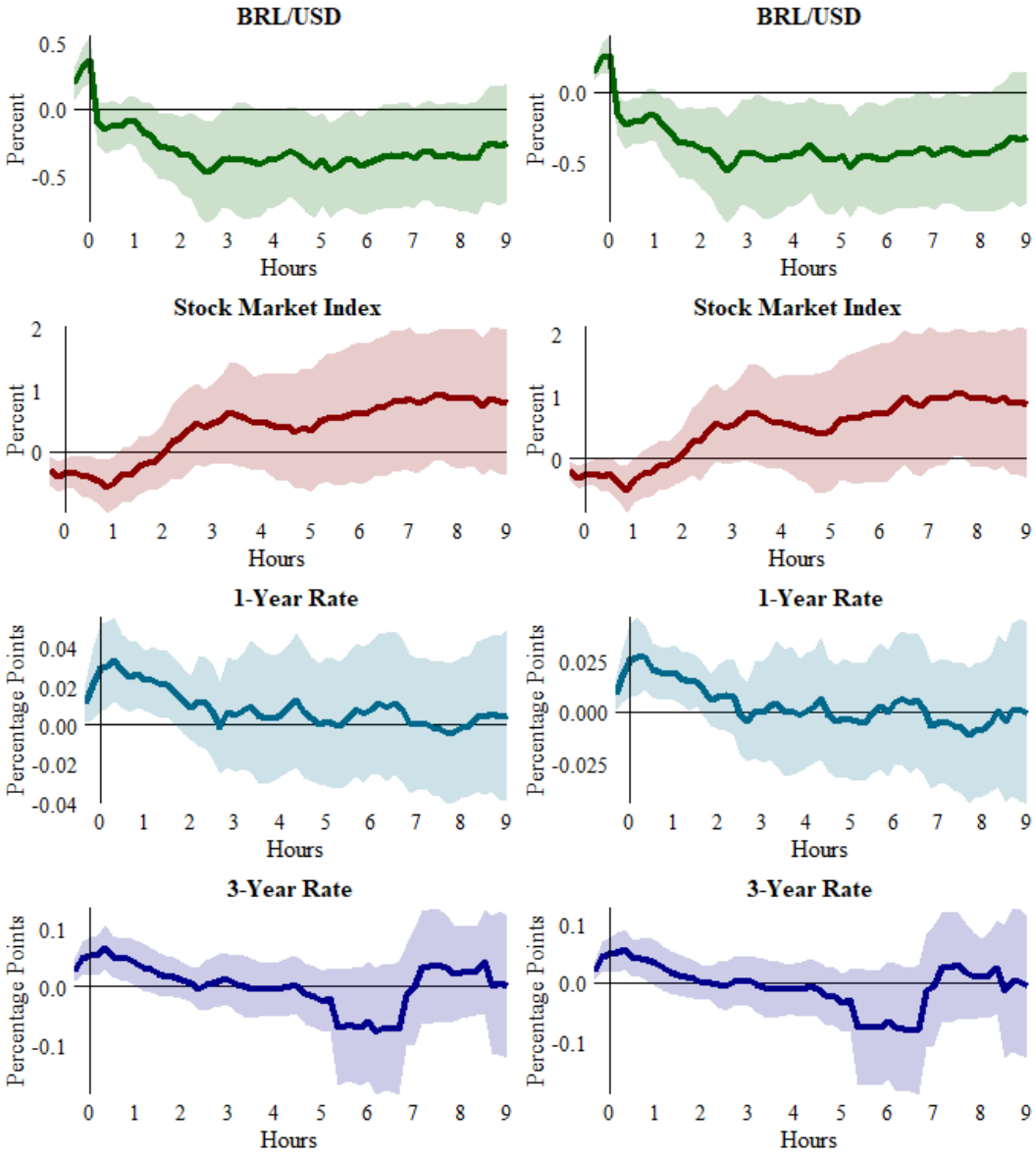
Figure 4.9: Intraday Reverse Swap Shock (Announcement Moment;LHS) and Intraday Reverse Swap Shock (Intervention Moment;RHS)



Lastly, Intraday spot sales also present a unique effect across the assets (Figure 4.10). The BRL/USD reaches nearly 1.0 percent (from 0.5 in the first 30 minutes) appreciation after 2 hours and then keep stable. The futures of ibovespa, who kept unchanged in the shorter window, present an almost 1.0 percent increase, however with dubious statistical significance. The futures of interest rates gave back all the increase to have a final no impact balance. This case shows that the intervention is associated with a change of the "natural" course of asset prices path across all the asset classes (Figures 2.3, 2.4, 2.6, and 2.7). Moreover, it is the only case in which the intervention shock changes asset direction in terms of natural responses *and* the asset classes have the

expected co-movement.

Figure 4.10: Intraday Spot Sales Shock (Announcement Moment;LHS) and Intraday Spot Sales Shock (Intervention Moment;RHS)



Summing up, it is remarkable that the three Intraday varieties have different styles of persistence across the asset classes. Regarding the BRL/USD, the response to the swap shock keeps increasing, the response to the reverse swap shock fades away, and the reaction to the spot shock stabilized at a certain level. Concerning the stock market index, all the three Intraday varieties tend to increase the index, nonetheless in the absence of clear statistical significance. Finally, the impact on rates varies as in the exchange rate case. The swap shock is associated with a constant increase in the rates, contrary to the reverse swap

associated with a rapid increase that does not prevent a final day decline, and, at last, the spot sales shock impact on rates dies out completely.

4.3 Additional Discussion

In this section we discuss the results and comment additional estimations we made to try to explain that. The first thing that intrigues us is the fact that the stock market index has a positive reaction (when significantly) and the interest rates a negative reaction (rates go up), independently of the intervention direction. It seems one of the markets interprets the event as positive, perhaps in terms of financial stability, and the other as a stress moment, maybe signaling additional risk-premium.

As the closest paper compared to ours is Menkhoff et al. (2021) we brought their guess for the fact their estimations show that for a USD purchase, the Yen depreciated, the rates go down and the stock market up. Regarding interest rates, an explanation might be that the market can interpret that as monetary policy would support the intervention weakening of the Yen by rather loosening than tightening. Concerning the stock market index, a depreciation of the Yen would improve competitiveness of exports, which are significant in the index. Having said that, we tried to compare the reaction of specifically Brazilian stocks to FX interventions. Contrasting export-oriented stocks versus import-oriented, we found no relevant differences. Therefore, the channel suggested by Menkhoff et al. (2021) does not seem valid for Brazil.

The second result we want to discuss is the fact that Intraday swap shocks (Figure 4.8) and Intraday spot sales shocks (Figure 4.10) have different persistence impact on the BRL/USD, in a 9 hours horizon. The response to the swap shock keeps increasing, while the response to the spot shock stabilized at a certain level. To investigate if the finding is related to a possible size variance of interventions, we ran the regressions using dummies- actually this investigation is valid for all the research- and nothing really changed (all dissertations results included). Moreover, we removed the episodes in which happened more than one intervention per day (existed two for both types) and ran the regressions. Once more, the results were pretty the same (again, all estimations included). Finally, we tried to restrict Intraday swap events to the 2019-2021 period, when the Intraday spot events happened, and, one more time, estimations did not really change.

That being said, we do the same as in the first result that intrigued us, which is suggest an explanation, and here conversations with financial market participants helped us. We believe that the spot exchange rate market can not

absorb the intervention as a whole, but the derivatives exchange rate market can. Ours possible explanation is supported by the fact that the trading volume in the FX derivatives market is four times larger than in the spot one (Chamon et al. (2019))[4].

[4]In fact, according to Garcia & Urban (2005) or more recently to Garcia et al. (2014) the futures market even dominates the Brazilian FX price discovery.

5
Conclusion

This dissertation investigates if Brazilian FX interventions have spillovers effects on asset prices, such as futures USD contracts, futures stock market index contracts and futures interest rates contracts. We do that by classifying the interventions into three types, according to the degree of surprise, and by using minute-by-minute data.

The results show that the exchange rate reacts as expected, working as a sanity test of our empirical approach. Our main contribution on the BRL/USD was to display the remarkable diversity, across interventions types, on interventions' impact within 30 minutes and effect persistence within a 9 hours horizon. Therefore we do not recommend treating all swap or spot interventions as one, as many of the area's papers.

The results for the stock market and rates are novelties per se since ours is the first paper to analyze an emerging country and the first to use a high-frequency approach. We see that stock market index and futures interest rates increase either in USD sales or purchases.

Furthermore, we contribute by highlighting the following findings: (i) the announcement impacts much more than the intervention itself (signalling channel triumphs over the portfolio channel), (ii) the least expected the intervention type shock, the greater the impact on asset prices, (iii) longer-dated rates yields tend to present greater responses to the interventions than shorter-term yields, (iv) stock market results have less statistical significance than the other assets.

6
Appendix

6.1
Didactic Identification Discussion

Here we are going to let the Cholesky step absolutely clear, didactically recalling what is behind of an identification process. Taking $\boldsymbol{z}_t = (z_{1t}, \ldots, z_{mt})' \in \mathbb{R}^m$ as a vector with our variables, consider the following structural model (SVAR):

$$\begin{aligned}
\boldsymbol{B}\boldsymbol{z}_t &= \boldsymbol{A}_0 + \boldsymbol{A}_1\boldsymbol{z}_{t-1} + \ldots + \boldsymbol{A}_p\boldsymbol{z}_{t-p} + \boldsymbol{u}_t \\
\boldsymbol{B}\boldsymbol{z}_t &= \boldsymbol{A}_0 + \boldsymbol{A}(L)\boldsymbol{z}_t + \boldsymbol{u}_t
\end{aligned}$$

Where: $\boldsymbol{B} \sim (m \times m), \boldsymbol{A}_0 \sim (m \times 1), \boldsymbol{A}_1 \sim (m \times m), \ldots, \boldsymbol{A}_p \sim (m \times m)$ are parameters; $\boldsymbol{u}_t = (u_{1,t}, \ldots, u_{m,t})'$ is a vector with the structural shocks; $\boldsymbol{A}(L) = \boldsymbol{A}_1 L + \boldsymbol{A}_2 L^2 + \cdots + \boldsymbol{A}_p L^p$; elements of the main diagonal of $\boldsymbol{B}$ are all 1.

On the one hand, the parameters $\boldsymbol{B}, \boldsymbol{A}_0, \boldsymbol{A}_1, \ldots, \boldsymbol{A}_p$ can not be estimated by OLS, because of the simultaneity bias. On the other hand, the reduced form parameters can:

$$\begin{aligned}
\boldsymbol{z}_t &= \boldsymbol{B}^{-1}\boldsymbol{A}_0 + \boldsymbol{B}^{-1}\boldsymbol{A}_1\boldsymbol{z}_{t-1} + \ldots + \boldsymbol{B}^{-1}\boldsymbol{A}_p\boldsymbol{z}_{t-p} + \boldsymbol{B}^{-1}\boldsymbol{u}_t \\
\boldsymbol{z}_t &= \boldsymbol{C}_0 + \boldsymbol{C}_1\boldsymbol{z}_{t-1} + \ldots + \boldsymbol{C}_p\boldsymbol{z}_{t-p} + \boldsymbol{v}_t \\
\boldsymbol{z}_t &= \boldsymbol{C}_0 + \boldsymbol{C}(L)\boldsymbol{z}_t + \boldsymbol{v}_t
\end{aligned}$$

Since we know that:

$$\begin{aligned}
\boldsymbol{C}_0 &= \boldsymbol{B}^{-1}\boldsymbol{A}_0 \\
\boldsymbol{C}_1 &= \boldsymbol{B}^{-1}\boldsymbol{A}_1 \\
&\vdots \\
\boldsymbol{C}_p &= \boldsymbol{B}^{-1}\boldsymbol{A}_p, \text{e} \\
\boldsymbol{\Sigma}_v &= \boldsymbol{B}^{-1}\boldsymbol{\Sigma}_u\left(\boldsymbol{B}^{-1}\right)'
\end{aligned}$$

To get (identify) the structural parameters from the reduced form parameters, we just need to find $\mathbf{B}$. As the number of parameters in the reduced

form is $m(1+pm)+\frac{m(m+1)}{2}$ and in the structural is $m(m-1)+m(1+pm)+m$, then, the latter has $\frac{m(m-1)}{2}$ additional parameters.

Hence, we need to impose $\frac{m(m-1)}{2}$ restrictions. The alternative we chose to do that is to assume $\mathbf{B}$ is a lower triangular matrix, by the Cholesky decomposition, having recursive identification.

Recall that the Cholesky decomposition says that for all symmetric and positive-definite matrix $\boldsymbol{\Omega}$, there is only one triangular matrix $\mathbf{P}$, such that $\boldsymbol{\Omega} = \boldsymbol{PP'}$. The elements of the main diagonal of $\boldsymbol{P}$ are all positives.

By the decomposition, $\boldsymbol{\Sigma}_u = \boldsymbol{PP'}$. However, we can write $\boldsymbol{P = AD^{1/2}}$, where $\boldsymbol{A}$ is a triangular matrix with all main diagonal elements equal to 1 and $\boldsymbol{D}$ is a diagonal matrix with positive elements. Therefore, $\boldsymbol{\Sigma}_u = \boldsymbol{ADA'}$.

Since $\boldsymbol{\Sigma}_v = \boldsymbol{B}^{-1}\boldsymbol{\Sigma}_u\left(\boldsymbol{B}^{-1}\right)'$, we can write $\boldsymbol{A} \equiv \boldsymbol{B}^{-1}$ and $\boldsymbol{\Sigma}_u \equiv \boldsymbol{D}$. Note that $\mathbf{B}$ also is going to be a triangular matrix (i.e. the inverse of a triangular is triangular). Finally, we imposed $\frac{m(m-1)}{2}$ restrictions and our system is uniquely identified. That's the process behind our identification in the dissertation.

6.2
Main Group of Assets

6.2.1
30 Minutes Horizon

Figure 6.1: Swap Shock

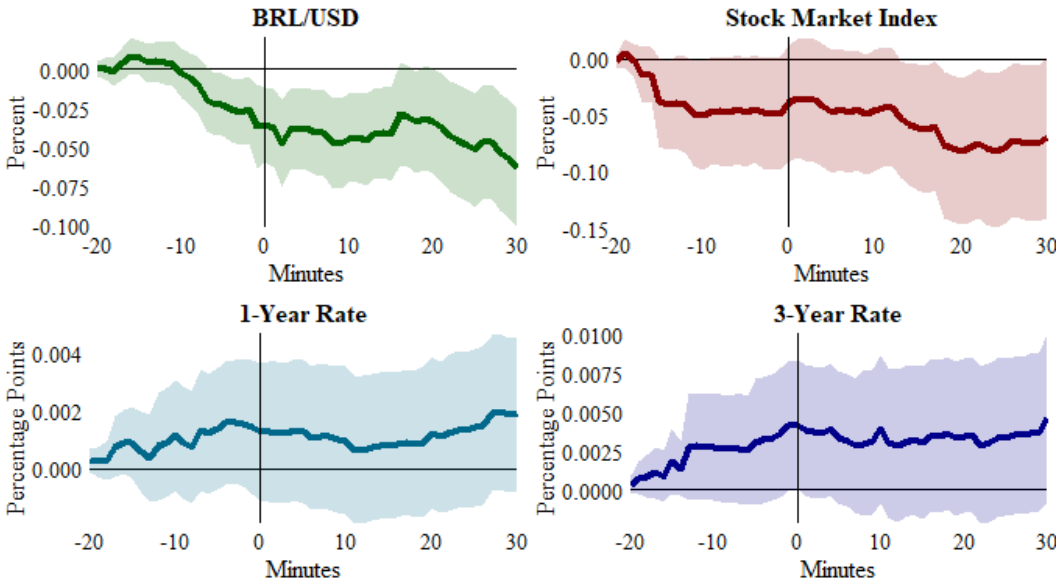


Figure 6.2: Reverse Swap Shock

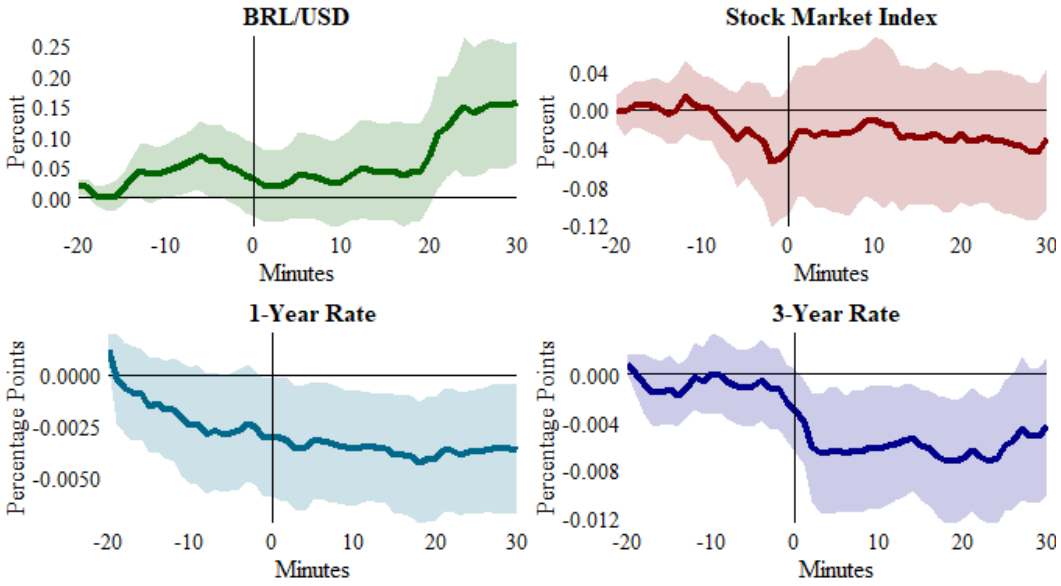


Figure 6.3: Program Swap Shock

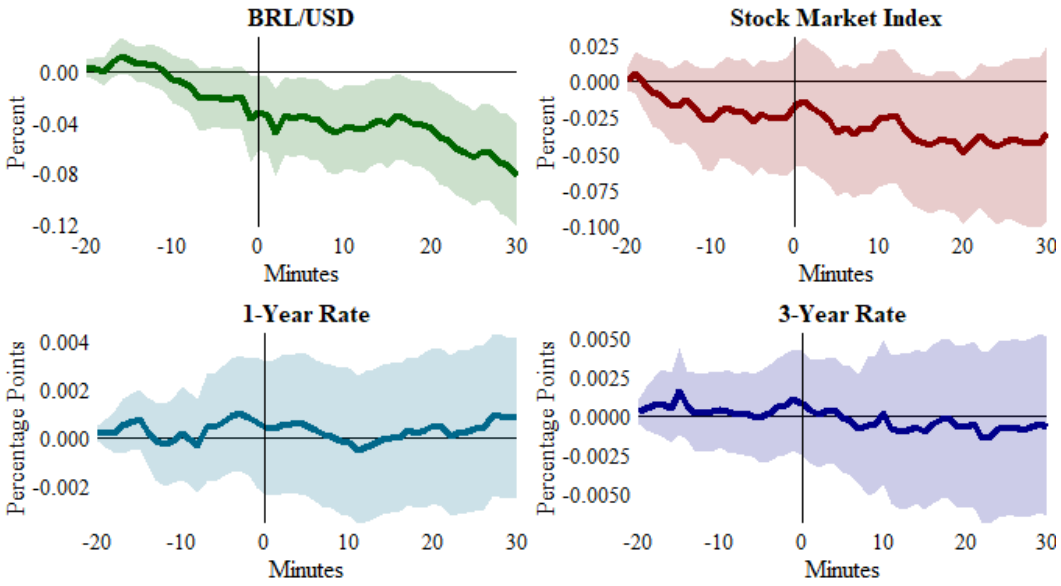


Figure 6.4: Spot Sales Shock

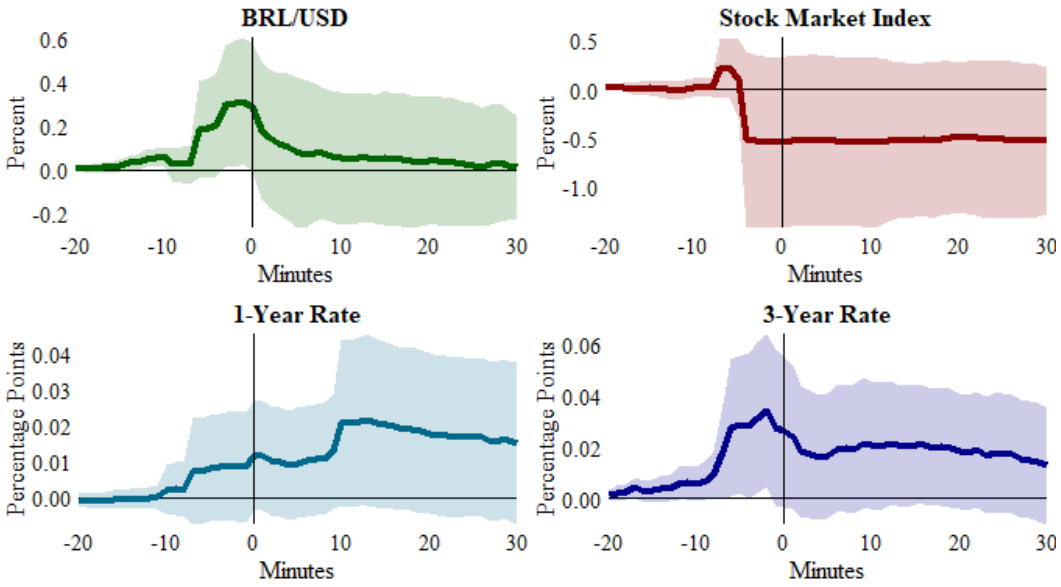
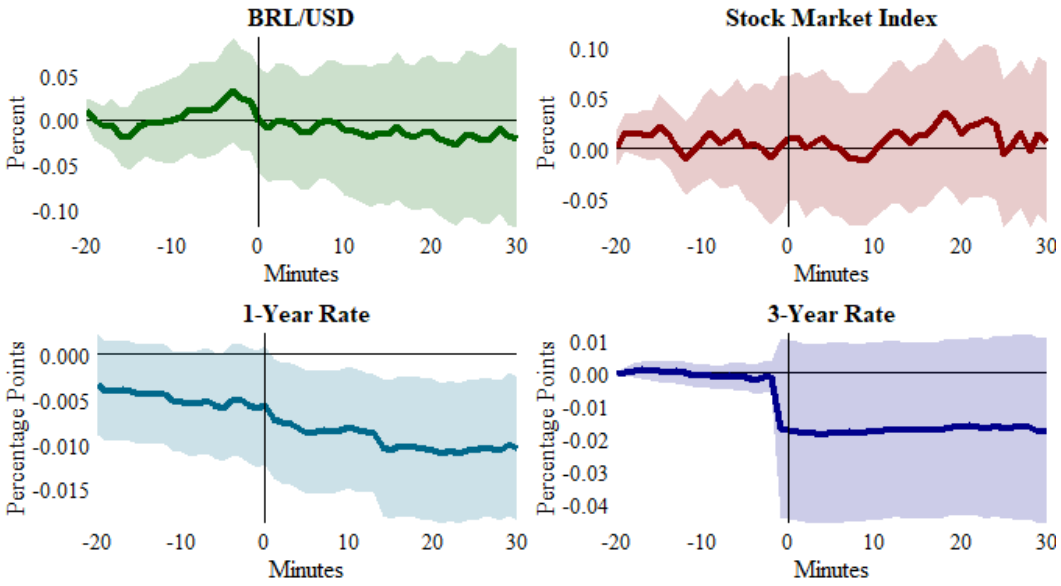


Figure 6.5: Program Spot Sales Shock



6.2.2
9 Hours Horizon

Figure 6.6: Swap Shock

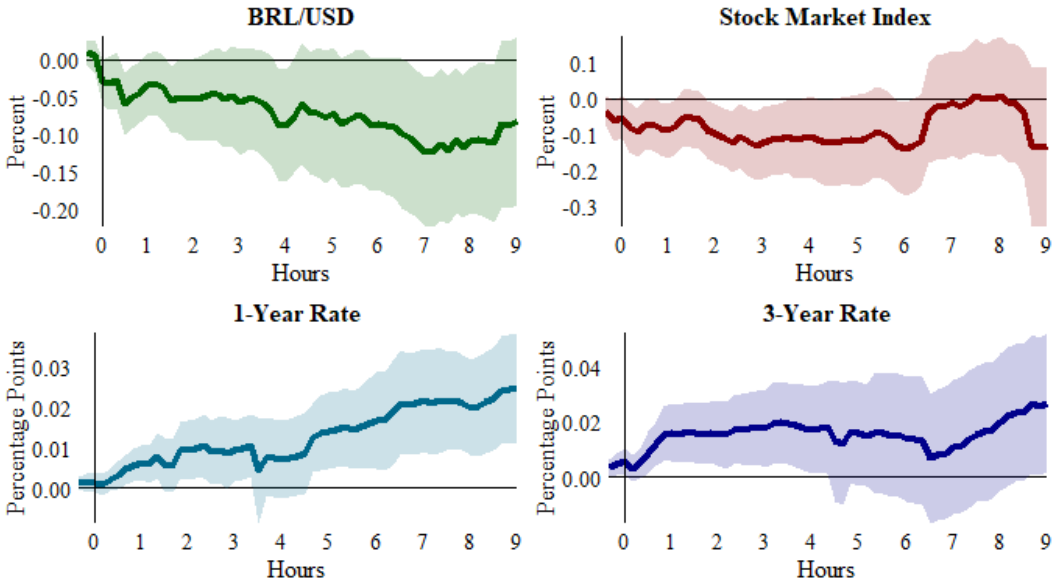


Figure 6.7: Reverse Swap Shock

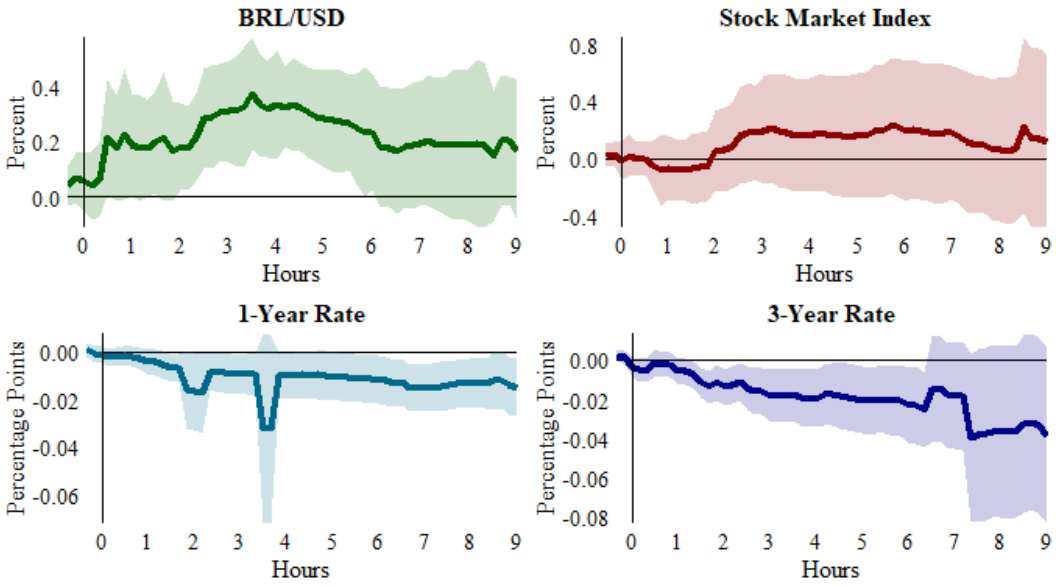


Figure 6.8: Program Swap Shock

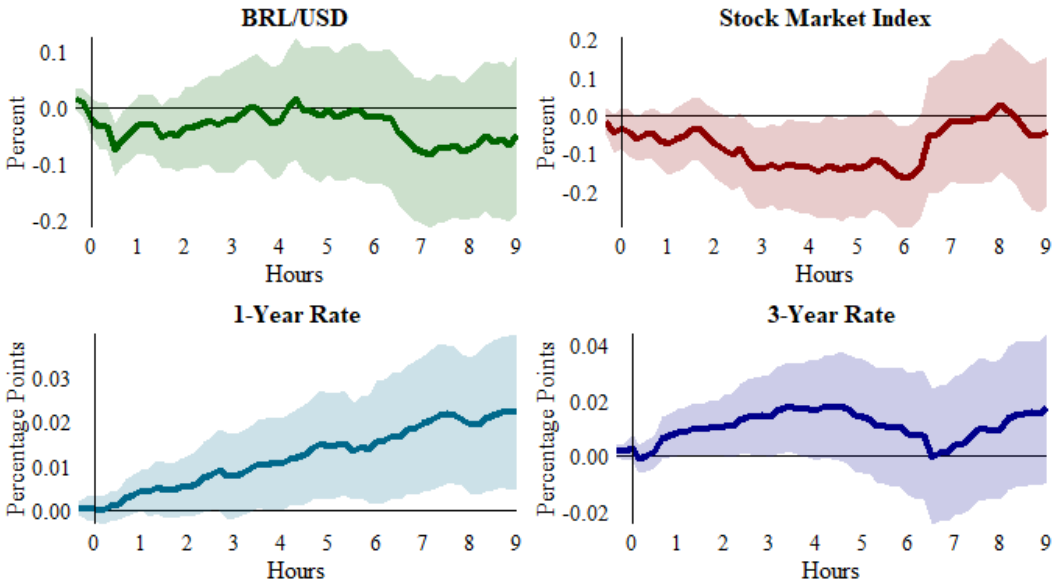


Figure 6.9: Spot Sales Shock

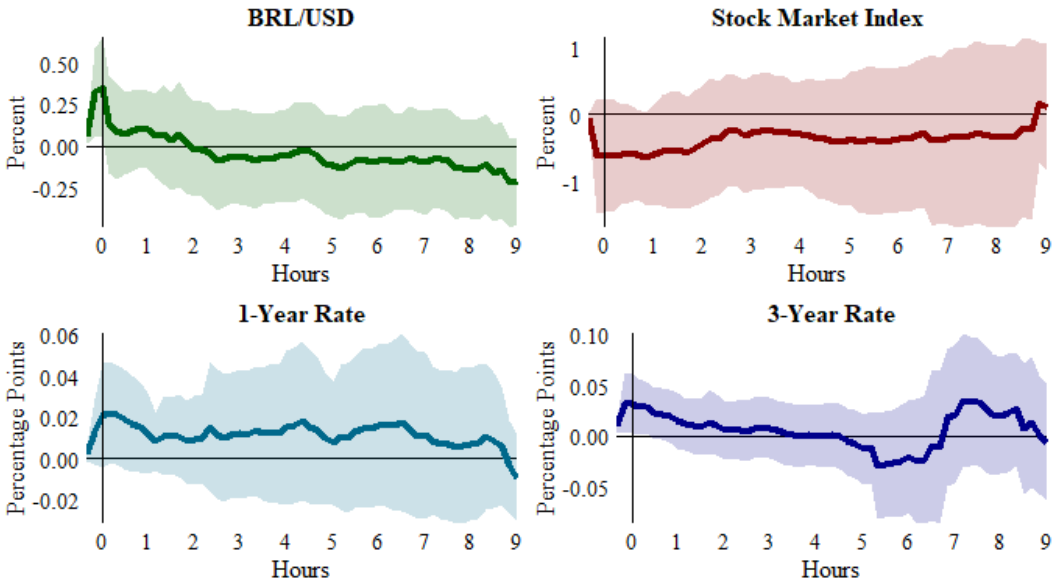
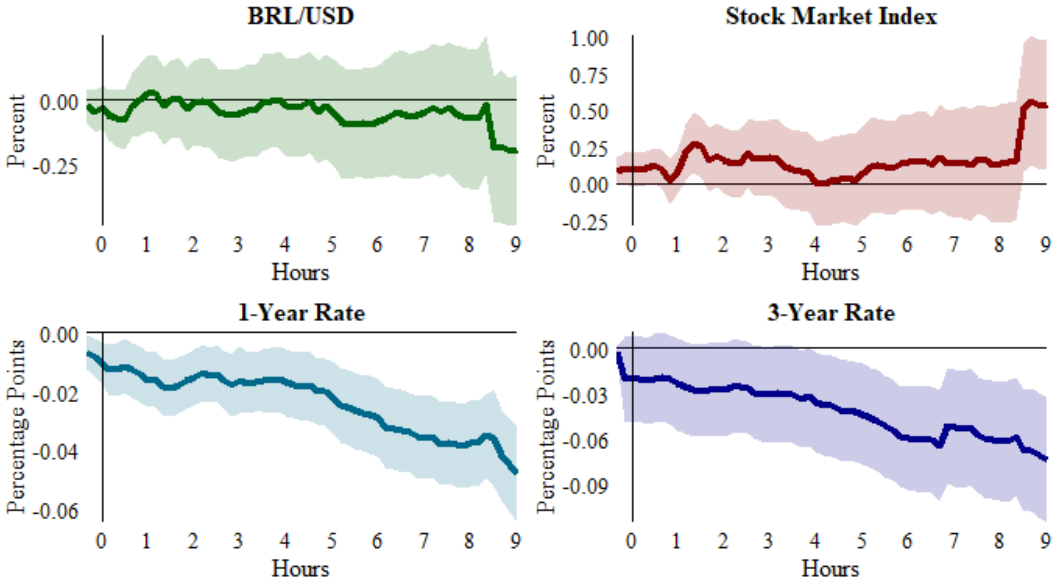


Figure 6.10: Program Spot Sales Shock



6.3
6-Month and 5-Year Rates

6.3.1
30 Minutes Horizon

Figure 6.11: Swap Shock

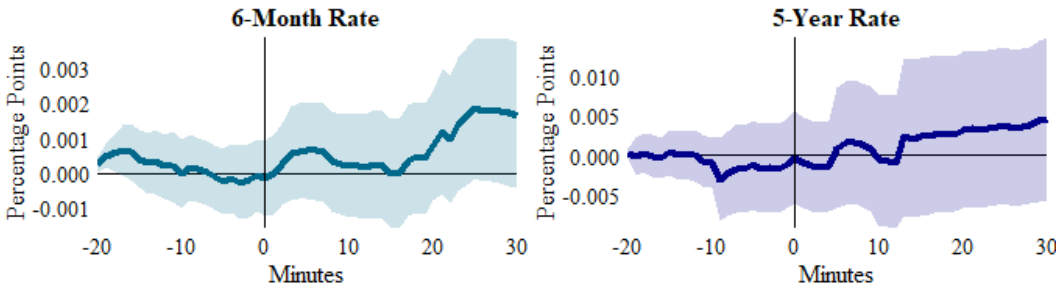


Figure 6.12: Reverse Swap Shock

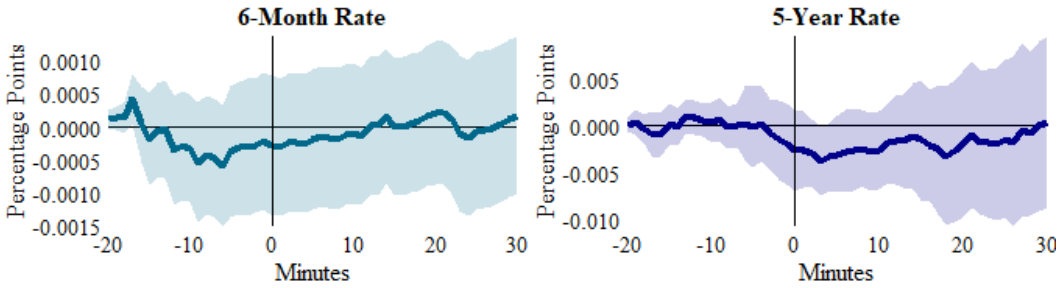


Figure 6.13: Program Swap Shock

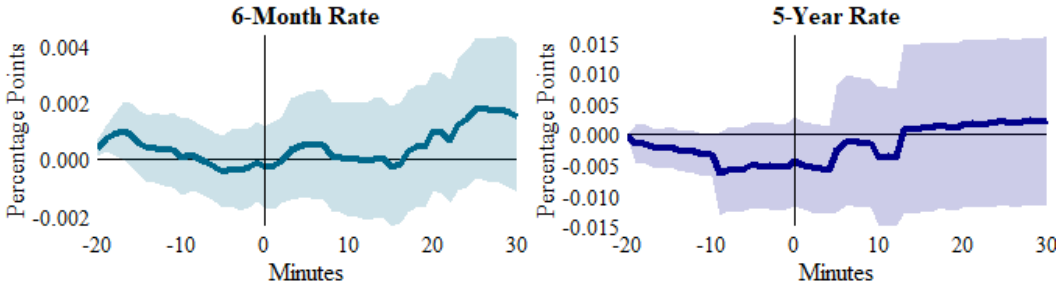


Figure 6.14: Day Before Swap Shock (Announcement Moment;LHS) and Day Before Swap Shock (Intervention Moment;RHS)

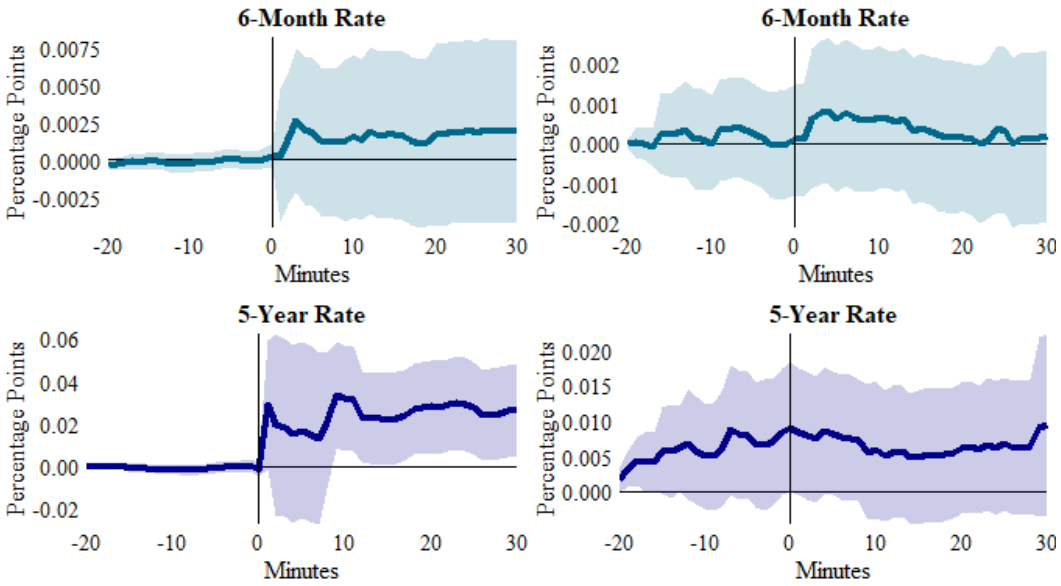


Figure 6.15: Day Before Reverse Swap Shock (Announcement Moment;LHS) and Day Before Reverse Swap Shock (Intervention Moment;RHS)

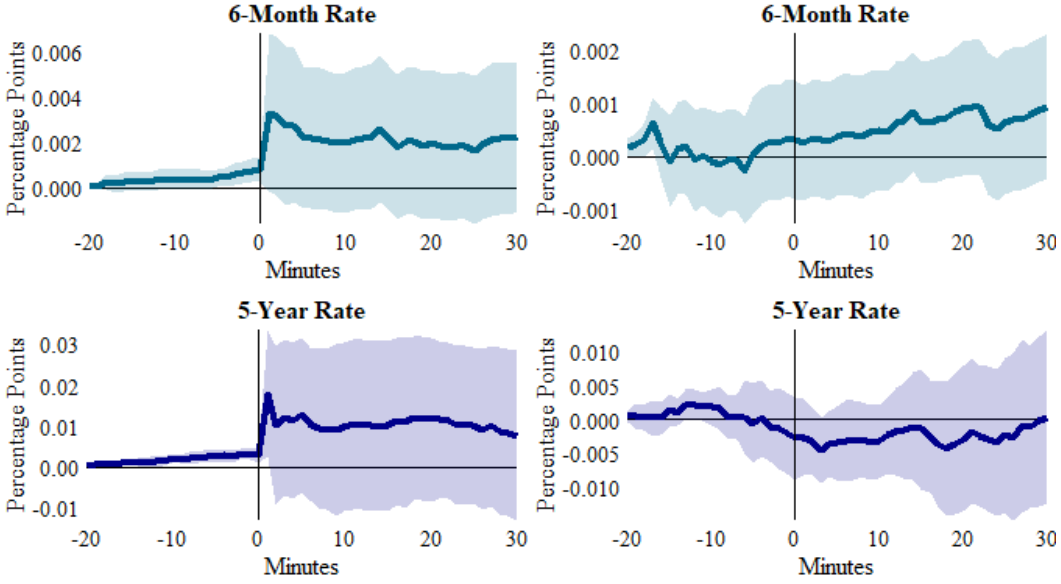


Figure 6.16: Intraday Swap Shock (Announcement Moment;LHS) and Intraday Swap Shock (Intervention Moment;RHS)

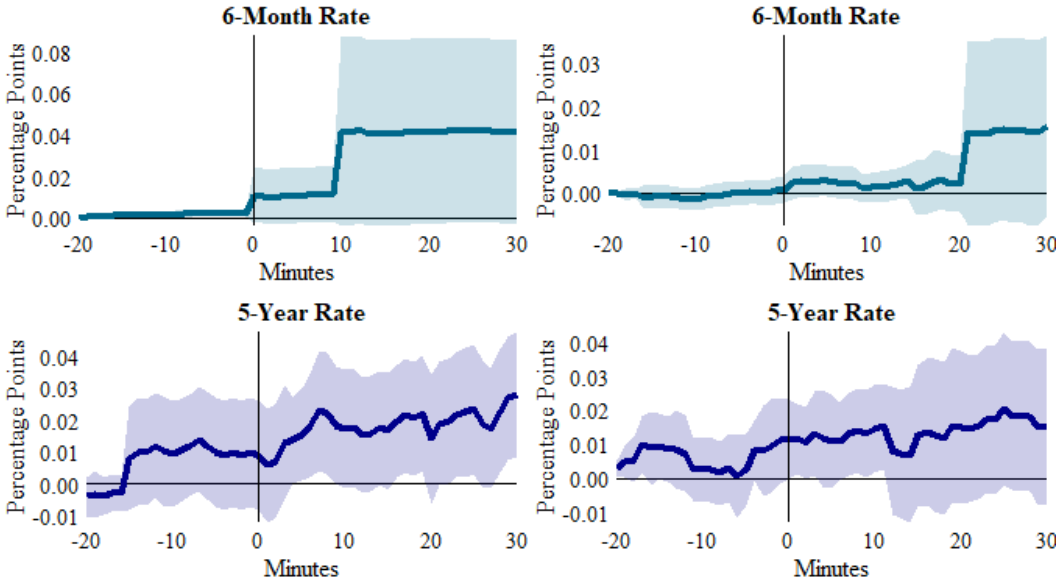


Figure 6.17: Intraday Reverse Swap Shock (Announcement Moment;LHS) and Intraday Reverse Swap Shock (Intervention Moment;RHS)

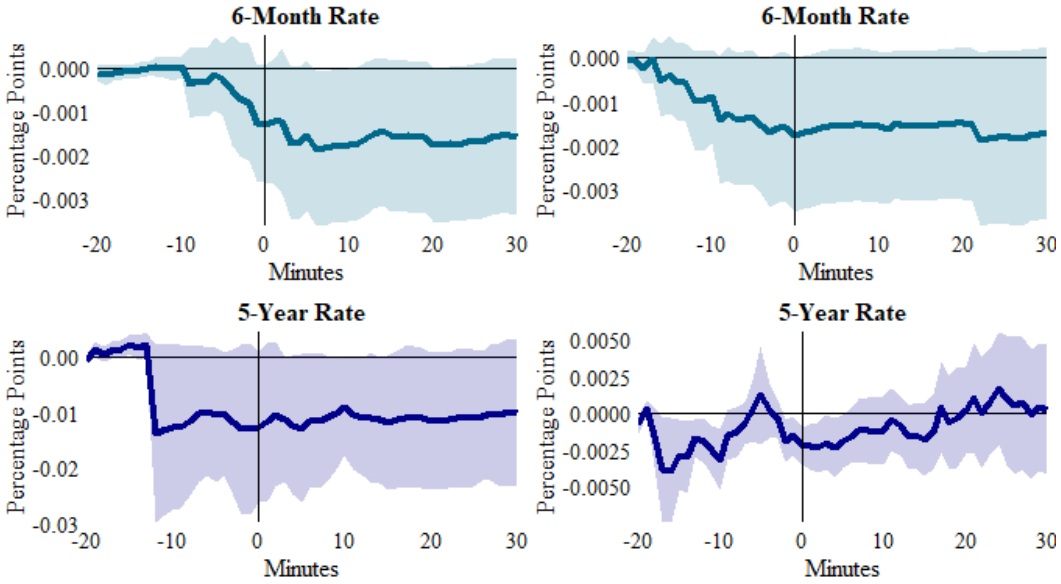


Figure 6.18: Spot Sales Shock

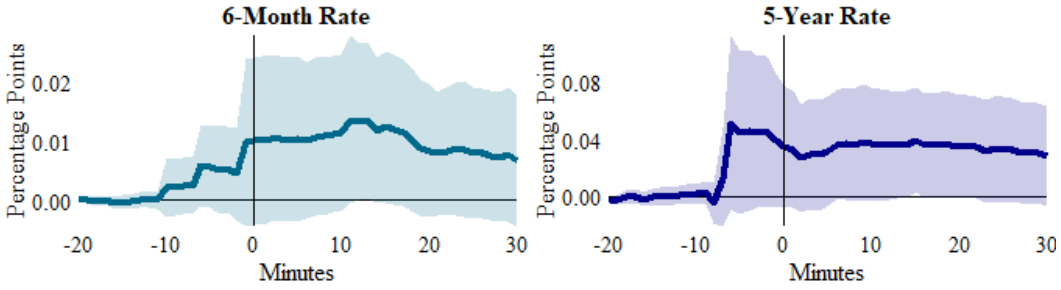


Figure 6.19: Program Spot Sales Shock

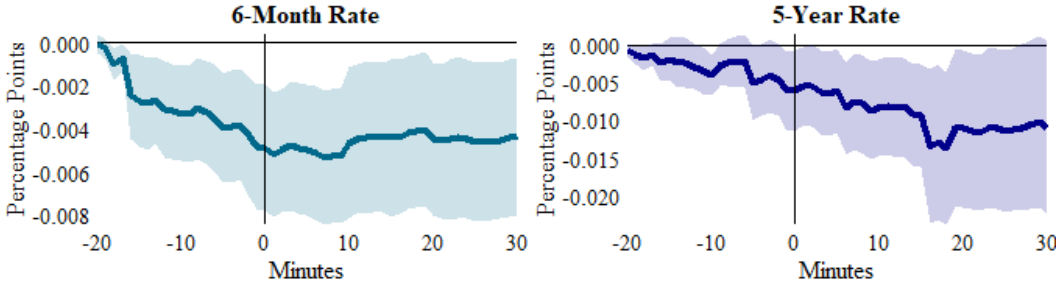
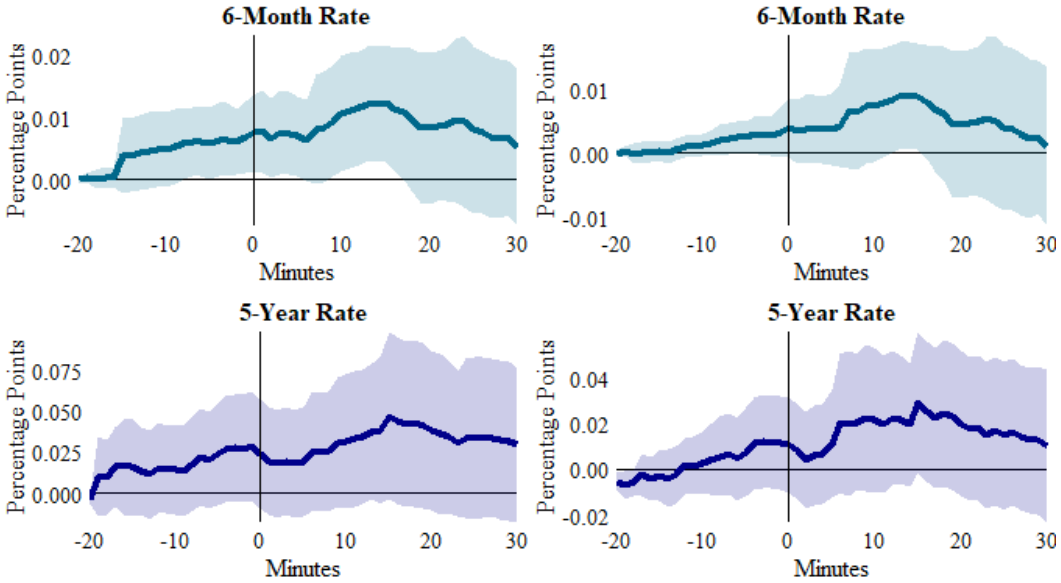


Figure 6.20: Intraday Spot Sales Shock (Announcement Moment;LHS) and Intraday Spot Sales Shock (Intervention Moment;RHS)



6.3.2
9 Hours Horizon

Figure 6.21: Swap Shock

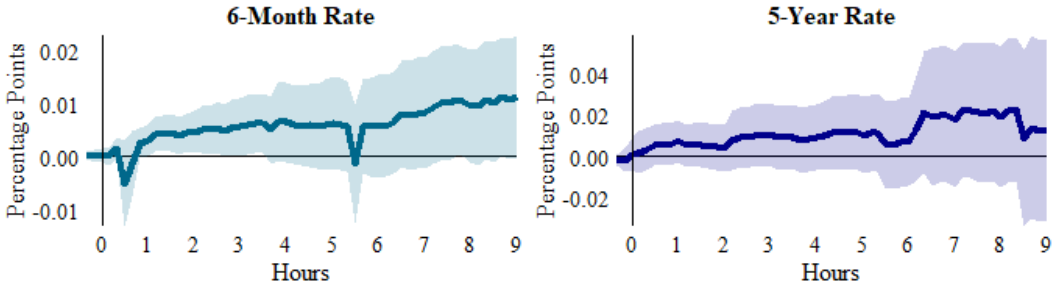


Figure 6.22: Reverse Swap Shock

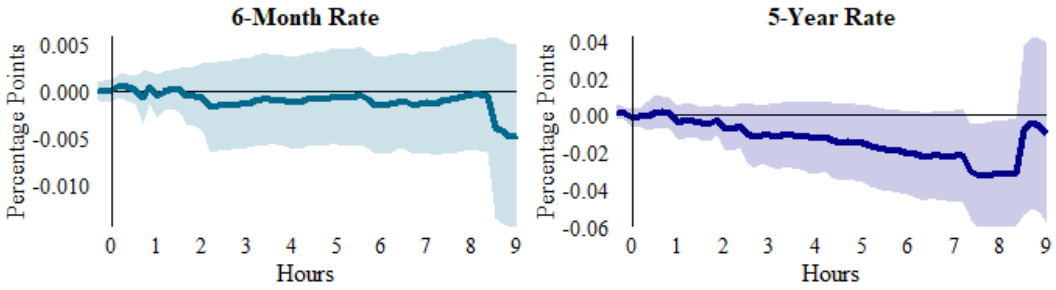


Figure 6.23: Program Swap Shock

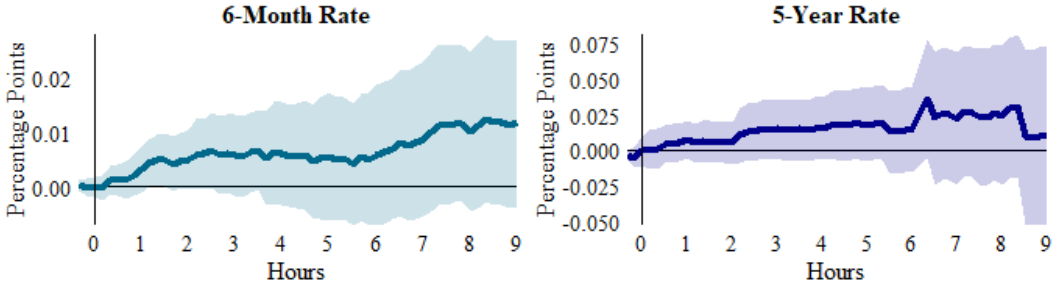


Figure 6.24: Day Before Swap Shock (Announcement Moment;LHS) and Day Before Swap Shock (Intervention Moment;RHS)

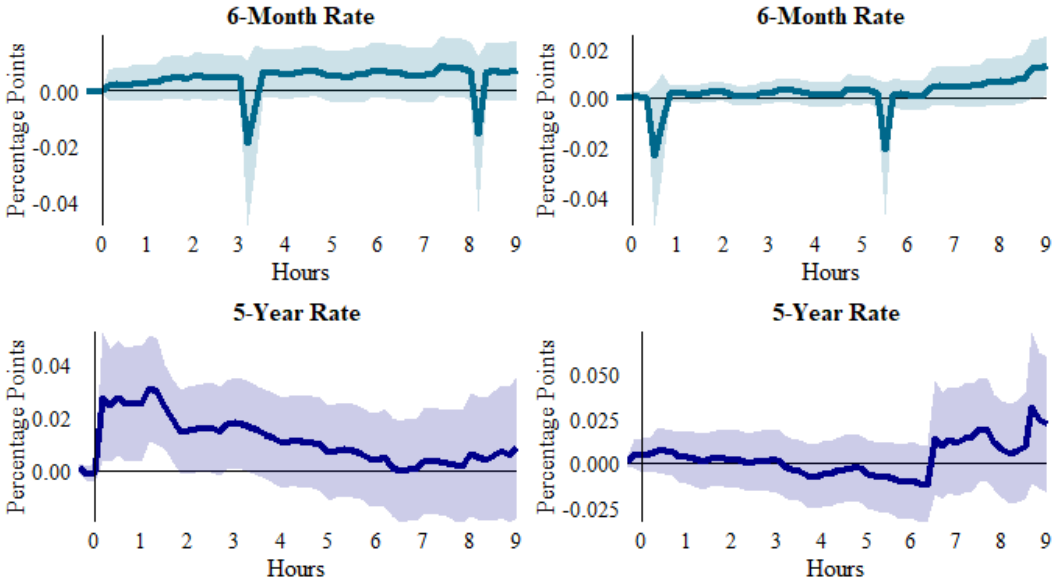


Figure 6.25: Day Before Reverse Swap Shock (Announcement Moment;LHS) and Day Before Reverse Swap Shock (Intervention Moment;RHS)

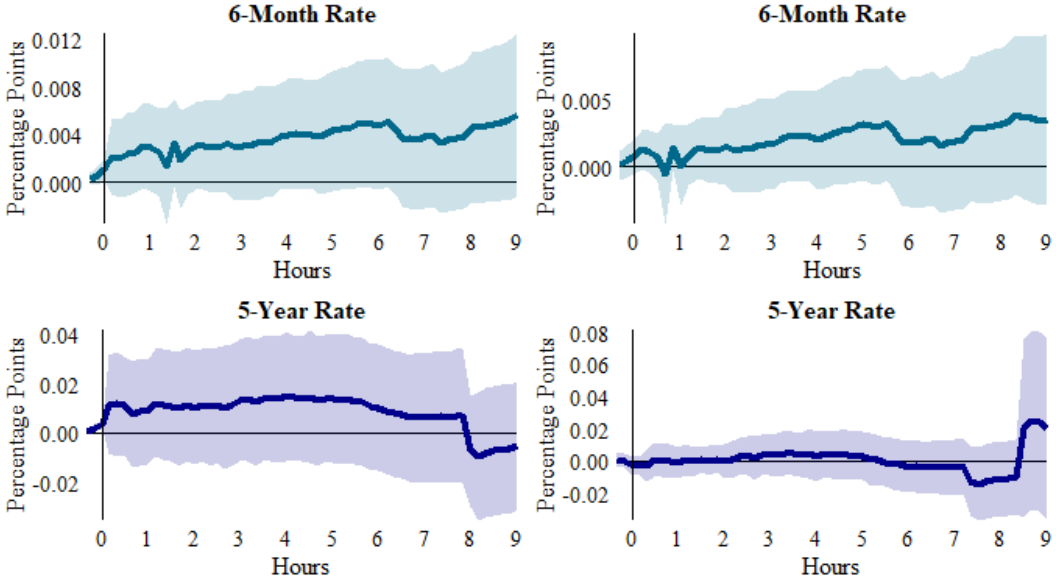


Figure 6.26: Intraday Swap Shock (Announcement Moment;LHS) and Intraday Swap Shock (Intervention Moment;RHS)

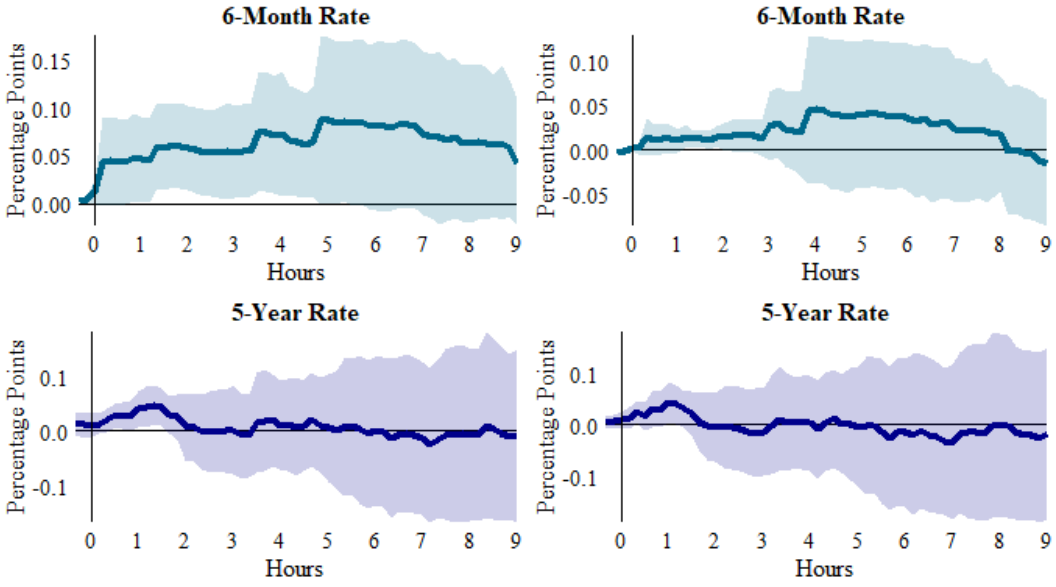


Figure 6.27: Intraday Reverse Swap Shock (Announcement Moment;LHS) and Intraday Reverse Swap Shock (Intervention Moment;RHS)

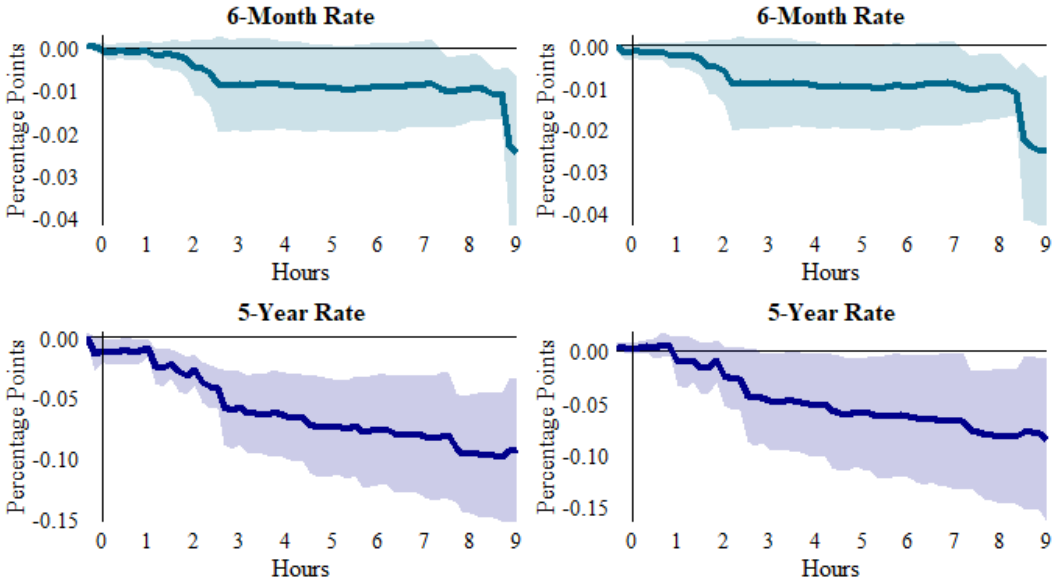


Figure 6.28: Spot Sales Shock

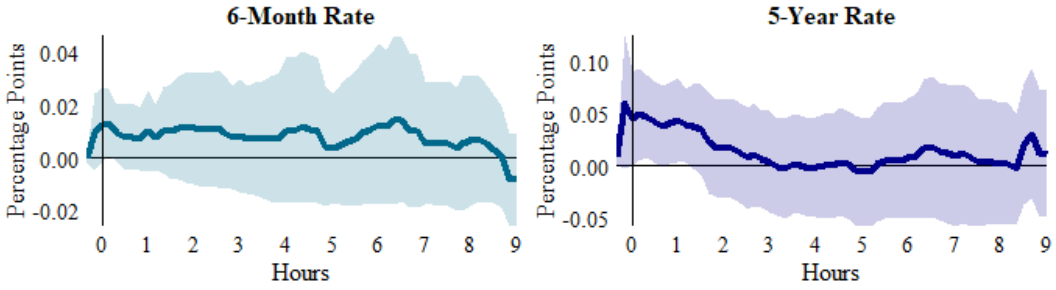


Figure 6.29: Program Spot Sales Shock

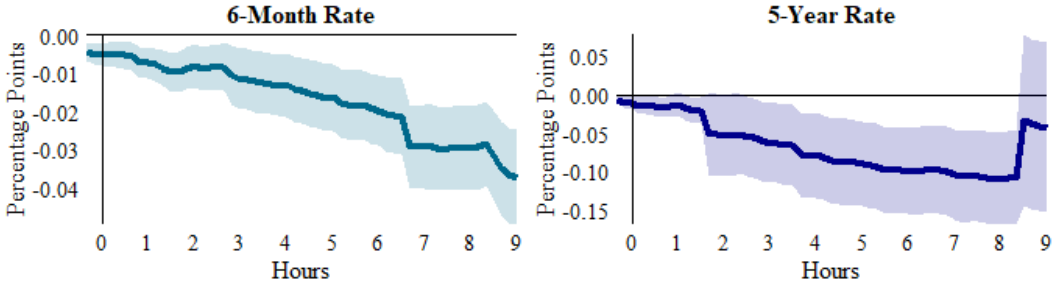
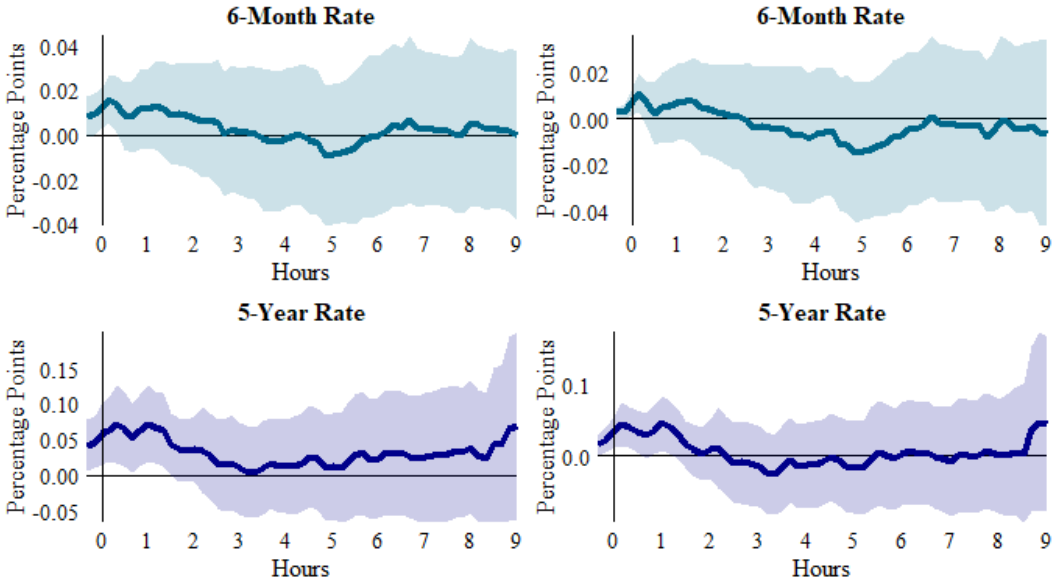


Figure 6.30: Intraday Spot Sales Shock (Announcement Moment;LHS) and Intraday Spot Sales Shock (Intervention Moment;RHS)



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