FX interventions in Brazil: a synthetic control approach*

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Abstract

In the aftermath of the Taper Tantrum episode, the Central Bank of Brazil announced a major program of intervention in foreign exchange markets on August 2013, with daily sales of FX futures settling in domestic currency swaps that provided insurance against a depreciation of the real. We analyze the effect of that program on the level and volatility of the exchange rate using a synthetic control approach. Our counterfactual results suggest that program led to an appreciation of the Brazilian in excess of 10 percent. Some of our estimates also point to a decline in the option-implied volatility. A second announcement extending the program had a more muted effect on the exchange rate. Subsequent extensions had little or no impact, likely because they were already expected and priced-in by the market.

JEL classification codes: F31, G14.

Keywords: FX interventions; synthetic control.

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1 Introduction

The Fed's taper announcement on May 2013 led to a major repricing of risk, adding pressure on several emerging market currencies. The Brazilian real (BRL) depreciated about 15 percent during the following three months, despite sizable interventions by the Central Bank of Brazil (BCB in the Portuguese acronym) in the foreign exchange market. On August 22, 2013, the BCB announced a major program of intervention through FX swaps, with the aim of satisfying the excess demand for hedging and providing liquidity to the FX market. The program consisted of daily sales of US$ 500 million worth of currency forwards (US dollar swaps) in the Brazilian markets, that provided investors insurance against a depreciation of the real. These swaps settle in domestic currency and provide investors the very same hedging they would obtain by buying spot dollars and holding them until the maturity of the swap.[1] The program also indicated that on Fridays, the central bank would offer US$1 billion on the spot market through repurchase agreements (short term credit lines in USD). The program announcement stated it would last until at least December 31, 2013. On December 18, 2013, the BCB announced that it would extend the program until at least mid-2014, although the daily interventions were reduced to US$ 200 million. On June 24, 2013, that program was extended until at least end-2014, and eventually extended until March 31, 2015.[2]

Figure 1 shows the behavior of the BRL exchange rate (an increase in the exchange rate denotes a depreciation of the BRL) and the magnitude of these interventions. The BRL was depreciating at a rapid pace prior to the announcement. That trend is immediately reversed, with the BRL appreciating 10 percent in the month following the announcement. All in all, the announcement implied a cumulative intervention of about US$ 50 billion through 2013-end. The program was eventually extended, as discussed above, and the total amount of currency forwards stood at about US$ 110 billion as of the time of writing. This amounts to roughly a third of total FX reserves, making the program one of the largest episodes of reserve deployment in countries with a floating exchange rate regime. Another unique aspect of the program is that intervention took place through swaps, which is a temporary form of intervention since the additional FX liquidity provided is eventually removed once the swap expires. The program and its extensions spanned a year and a half,

[1] Because they settle in real, they involve convertibility risk. For a detailed discussion of these contracts, please refer to Garcia and Volpon (2014).

[2] For a detailed discussion of the program, please refer to Kang and Saborowski (2015).

so much of the maturing swaps were rolled-over. Nevertheless, it still provides an example of large scale temporary intervention (albeit over a long horizon), which stands in contrast to many other country experiences (and studies) where intervention occurs mainly in the direction of accumulating reserves.

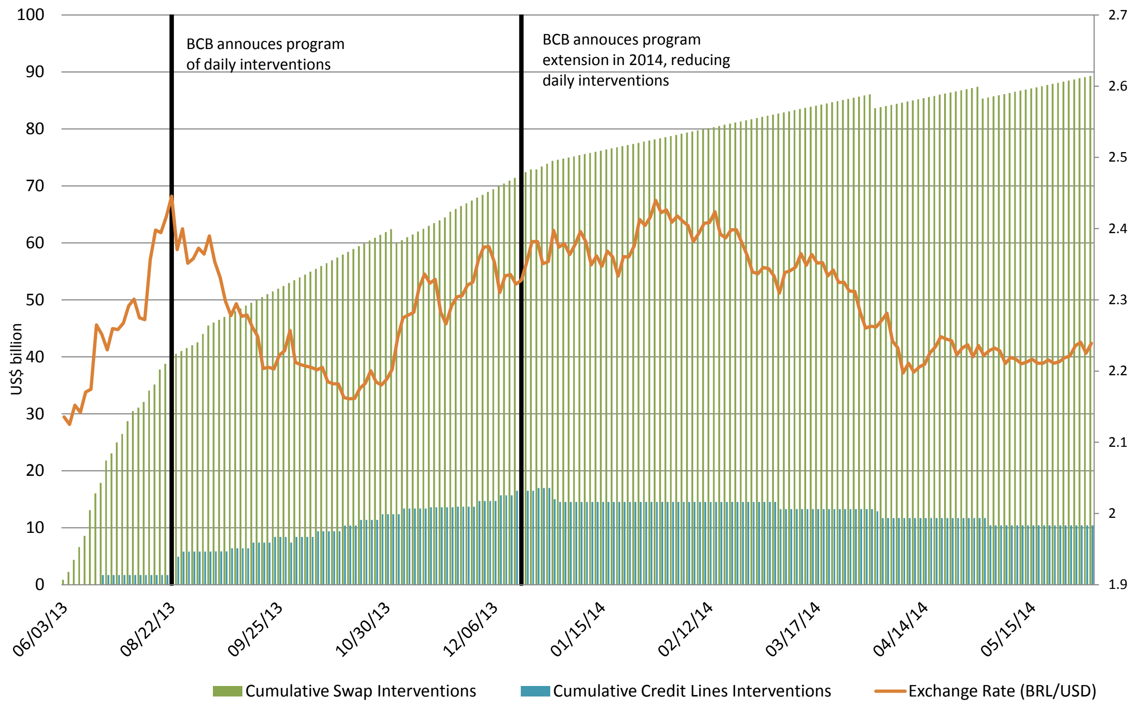


Figure 1: Cumulative Swap Interventions, Cumulative Credit Lines Interventions and Exchange Rate (BRL). Source: BCB and AC Pastore.

Most modern open economy models, assume uncovered interest parity holds, which leaves no scope for FX intervention to affect the exchange rate (some noteworthy exceptions include Benes et al. 2012, and Ghosh et al. 2015). Nevertheless, there is a very large empirical literature analyzing the effectiveness of central bank interventions. Sarno and Taylor (2001) survey the early literature, which typically focused on Advanced Economies and generally concluded that sterilized intervention was not very effective (with the possible exception of signaling future monetary policy). That is not surprising, since the amount of FX intervention pursued in advanced economies was a tiny fraction of the size of their bond markets. But in the case of Emerging Markets (EMEs), FX intervention has a non-trivial effect on the relative supply of local currency bonds. For example, in the case of Brazil, the stock of reserves corresponds to about a quarter of the stock of government bonds. So it seems reasonable to expect that a change in the relative supply of assets of that magnitude to have some effect on the exchange rate. A number of more recent papers focusing on emerging markets tends to find more supportive evidence for an effect, but the evidence remains somewhat mixed. Menkhoff (2013) provides an excellent survey of that literature.

In the Brazilian context, a number of papers have shown that FX intervention, including through swaps, can affect the exchange rate. For example, Andrade and Kohlscheen (2014) show that the Brazilian real moved about 0.33 bps following the announcement of a currency swap auction. Barroso (2014) estimates that a purchase or sale of US$ 1 billion lead to a 0.51 percent depreciation or appreciation of the Brazilian real. Werther (2010) found that the effects of sterilized interventions are very small on its magnitude (between 0.10 and 1.14 percent for each US$ 1 billion) and of low duration. More generally, estimates for the effect of a US$ 1 billion dollar intervention on the exchange rate typically range from 0.10 to 0.50 percent.

Studies on FX intervention face a substantial, perhaps insurmountable, endogeneity problem, since a central bank tends to purchase FX when it wants to slow down an appreciation, and vice-versa. That can bias regression estimates (perhaps even to the point of flipping the sign of the effect). Different strategies have been used to address this problem, including VARs, IV strategies, and relying on high-frequency data. All of these strategies have some drawbacks, including the extent to which they truly tackle this endogeneity.

In this paper we use a synthetic control approach to estimate the effects of the Brazilian swap program. To our knowledge, we are the first paper to use this technique to study the effects of FX interventions.[3] We follow Abadie et al. (2010), which in a nutshell, consists of constructing a synthetic control group that provides a counterfactual exchange rate against which we can compare the evolution of the Brazilian real after that announcement. This methodology is not appropriate for studying the effect of frequent interventions, but it is well suited for an event-study setting where a large change in intervention policy is announced, as in the case of Brazil. Our counterfactual uses data from other countries, with weights that are based on the pre-announcement co-movement with Brazil. As a result, whatever noise and error is involved in this type of analysis, it will be orthogonal to the endogeneity problem that plagues the literature on FX intervention. Our findings point

[3] Jinjarak et al. (2013) use the synthetic control method to analyze the effects of the adoption and removal of capital controls in Brazil on capital flows and the exchange rate. Their results show that capital controls had no effect on capital flows and small effects on the the exchange rate.

to an appreciation of the BRL in the first few weeks following the announcement of the program in excess of 10 percentage points. This is consistent with a surprise effect on the market, which by all accounts was not expecting the program. This result is particularly striking, once we take into account that the BCB was already intervening substantially in the market prior to the program, albeit in a discretionary fashion. In fact, the pace of intervention declined after the program (as shown in Figure 1). We also construct synthetic control groups using the methodology proposed by Carvalho et al. (2015), which allows us to make inference of the results. That approach points to a similar effect on the BRL (if anything stronger) following the announcement of the FX swap program, and that effect is statistically significant. Our results on the option-implied volatility are more mixed, with some of our estimates pointing to a tangible decline while others do not. A similar analysis of the follow-up announcements (extending the program) point to a more muted effect, which is not surprising since by most accounts the market was expecting the program to be extended in some form (so the surprise element was much smaller than in the previous announcements). Finally, as a robustness check, we also perform a more standard event-study analysis, which confirms a large effect on the exchange rate following the August announcement, but not for the latter announcements.

The remainder of the paper is organized as follows. Section 2 outlines the methodologies used, section 3 presents data description and section 4 shows our results. Finally, section 5 concludes.

2 Methodology

In this section, we present the synthetic control approach proposed by Abadie et al. (2010) and by Carvalho et al. (2015). Then, we use these methodologies to evaluate the effects of the BCB intervention programs on the Brazilian exchange rate.

2.1 Abadie et al. (2010)

Let Y_{it}^I denote the exchange rate in a country i in period t for a country that adopts a policy (e.g. an FX intervention program) at time T_0, and Y_{it}^N denote non-observed exchange rate that would have occurred had the country not adopted the FX interventions program.

We assume that there is no effect of the intervention program in the period preceding the policy change ($t < T_0$), i.e., $Y_{it}^N = Y_{it}^I$. Hence, the effect of the intervention program is given by $\alpha_{it} = Y_{it}^I - Y_{it}^N$ from period T_{0+1} to T. Without loss of generality, suppose the policy change occurred on country $i = 1$ (Brazil in our case). We assume that Y_{it}^N follows a factor model given by:

$$Y_{it}^N = \delta_t + \theta_t Z_i + \lambda_t \mu_i + \varepsilon_{it} \tag{1}$$

where λ_t is an unknown common factor that depends on time, Z_i is a vector of observable variables, θ_t is a vector of parameters and μ_i is a vector of factor loadings. At last, ε_{it} is a mean zero iid shock.

In addition, consider $W = (\omega_2, ..., \omega_{j+1})'$ as a vector of weights such that $\omega_i \geq 0$ and $\sum_{i=2}^{j+1} \omega_i = 1$. Suppose that there is an optimal weight vector $\hat{W}$ that can accurately replicate pre-treatment observations in Brazil. Abadie et al. (2010) show that under regular conditions $Y_{it}^N = \sum_{i=2}^{j+1} \hat{\omega}_i Y_{it}$. Thus, we can calculate $\hat{\alpha_{1t}} = Y_{it} - \sum_{i=2}^{j+1} \hat{\omega}_i Y_{it}$ for $t \geq T_0$.

Define X_1 as a vector of pre-treatment characteristics of the Brazilian exchange rate that contains Y and Z, and similarly X_0 for the control countries. Hence, the optimal weight vector $\hat{W}$ is chosen through the minimization of the following equation

$$\sqrt{(X_1 - X_0\hat{W})'V(X_1 - X_0\hat{W})} \tag{2}$$

where V is a $k \times k$ symmetric and positive semi-definite matrix (k is the number of explanatory variables). Also V is chosen to minimize the mean square prediction error in the period prior to the policy change. We use the STATA *synth* routine to obtain V.

Finally, we use permutations tests to examine the significance of our results, due to the fact that the usual statistical inference is not available. For each control country in our sample, we assume that it implemented a FX intervention program in T_0. We then produce counterfactual synthetic control for each "placebo control" and calculate the effect α_{it}^P for $t \geq T_0$. Therefore, we can check if the effect found for Brazilian exchange rate is different from the effects on the control currencies.

2.2 Carvalho et al. (2015)

Consider n countries for T periods indexed by $i \in \{1, ..., n\}$. As in Abadie et al. (2010), assume that one country implemented a policy change in T_0. Furthermore, consider that we observe q variables for each country i and that they all follow jointly a covariance-stationary process. We can then stack all the n countries in a vector $y_t = (y_{1t}, ..., y_{nt})'$ and use the Wold decomposition to write the following equation for $1 \leq t \leq T$

$$\mathbf{y_t} - \mu_\mathbf{t} = \sum_{j=0}^{\infty} \phi_{t-j}\varepsilon_{t-j} \tag{3}$$

where each ϕ_{t-j} is a $(nq \times nq)$ matrix and the constraint $\sum_{j=0}^{\infty} \phi_{t-j}^2 < \infty$ must be satisfied for $1 \leq t \leq T$. Also, ε_t is a nq-dimensional serially uncorrelated white noise with covariance matrix Σ_t.

Moreover, consider that Brazil is indexed by 1 and define the direct effect in our variable of interest y_{1t} as

$$\delta_\mathbf{1t} = \mathbf{y_{1t}} - \mathbf{y_{1t}^*} \tag{4}$$

where $\mathbf{y_{1t}^*}$ is our variable of interest without the FX intervention program. But, $\mathbf{y_{1t}^*}$ is not observed, therefore, we have to estimate $\mathbf{y_{1t}^*}$ before estimate $\delta_\mathbf{1t}$. For this reason, we consider the best linear predictor as $(\mathbb{E}(y_{1t}^*|1, y_{-1t}^*))$

$$\mathbf{y_{1t}} = \mathbf{y_{1t}^*} = \mathbf{w_0} + \mathbf{w_1}\mathbf{y_{-1t}} + \mathbf{v_{1t}}, 1 \leq t \leq T_0. \tag{5}$$

where $\mathbf{y_{-1t}}$ is a matrix with all q variables for all $n-1$ countries (not including Brazil), $\mathbf{w_1}$ is a $(q \times (n-1)q)$ matrix and $\mathbf{w_0}$ is $(q \times 1)$ vector.

We estimate w by OLS for all the q equations.[4] While Abadie et al. (2010) constraint the weights to be non-negative and to add up to one, Carvalho et al. (2015) allow for negative weights which can capture information that would otherwise be missed, and also relaxes the assumption on their sum.For example, consider an extreme case where there is a perfectly negatively correlated country with Brazil. Under the restrictions adopted by Abadie et al. (2010), this peer would be disregarded despite the fact that using it would result in an almost perfect synthetic counterfactual. The opposite case is also problematic, consider that all the peers are uncorrelated to Brazil. Due to the restriction to sum to one, the estimator automatically assign weights to countries that have no contribution in explaining the counterfactual trajectory.

Differently from Abadie et al. (2010), Carvalho et al. (2015) presents the statistical inference for the average direct effect between period T_{0+1} and T. Hence, we can test if the effect of the intervention programs on the Brazilian exchange rate is statistically significant. In addition, another moments can be tested. In our case, we are also interested

[4]As stressed by Carvalho et al. (2015), it is one of the possible ways to estimate equation (4).

to analyze if the FX swap program had an effect on the variance of the exchange rate. We consider the same linear specification as in (5) and our dependent and independent variables becomes $\ddot{\mathbf{y}}_{\mathbf{1t}} = (\mathbf{y}_{\mathbf{1t}} - \bar{\mathbf{y}}_{\mathbf{1t}})^2$ and $\ddot{\mathbf{y}}_{-\mathbf{1t}} = (\mathbf{y}_{-\mathbf{1t}} - \bar{\mathbf{y}}_{-\mathbf{1t}})^2$, respectively. Therefore, the average effect is also estimated and all the hypothesis testing can be carried on (see Carvalho et al. (2015) for more details.).

3 Data

Our analysis consider three outcome variables of interest: the exchange rate (bilateral exchange rate with respect to the USD), its 3-month option-implied volatility, and risk reversal. The latter measures the difference between the volatility implied by an out-of-the-money put option (25 delta) and an equivalent out-of-the-money call option, which is a measure of the insurance premium investors are willing to pay to insure against a risk-off episode. Figure2 plots the evolution of the option-implied volatility over time. There was a rapid increase in volatility following the "tapering" speech. Volatility declines substantially after the program announcement, eventually settling at a lower level (although still higher than the volatility prior to the tapering speech). Volatility does not respond much in the immediate aftermath of the program extension announcements. Figure 3 is analogous to Figure 2 but plots the evolution of the option-implied risk reversal. There is a marked reduction following the program and the first extension.

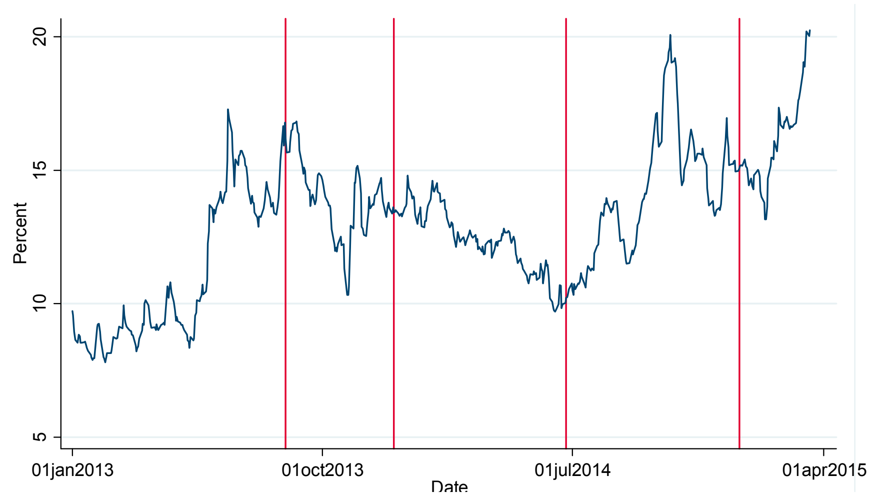


Figure 2: Brazilian Real Option-Implied Volatility. Notes: Vertical bars indicate the program announcement and extensions. Source: Bloomberg.

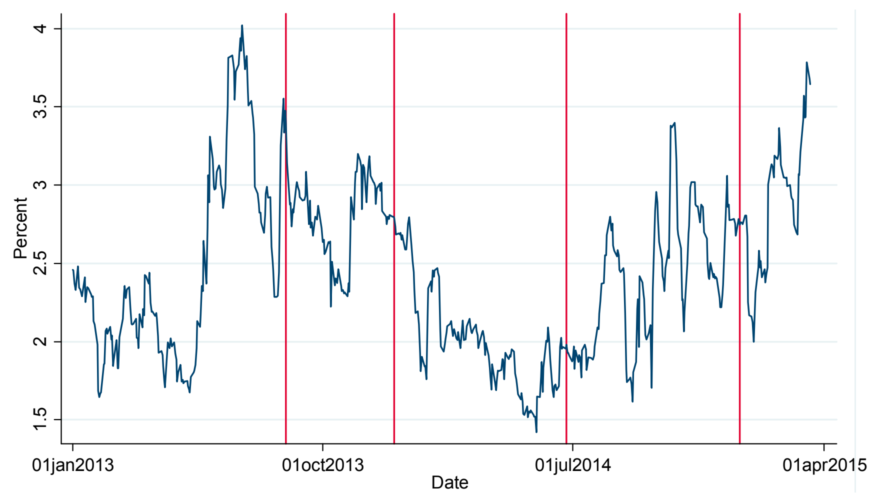


Figure 3: Brazilian Real Option-Implied Risk Reversal. Notes: Vertical bars indicate the program announcement and extensions. Risk Reversal measures the difference between implied volatility of out-of-the-money put and out-of-the-money call (25 delta). Source: Bloomberg.

In addition to these outcome variables, explanatory variables include capital flows, and stock and bond market indices. The source of all data is Bloomberg, except for the capital flow series which comes from the Emerging Portfolio Fund Research (EPFR) database.

We use weekly data in our synthetic estimates (the highest frequency at which the capital flows series is available). For each event, we consider a window consisting of the 12 weeks prior to the announcement, the week of the announcement, and the 12 weeks afterwards.

We consider a sample of 16 countries when estimating the synthetic for Brazil, which includes: Australia, Brazil, Chile, Colombia, India, Indonesia, Korea, Malaysia, Mexico, New Zealand, Peru, Philippines, Poland, Russia, South Africa, Thailand, and Turkey. We included all the emerging market countries with EPFR data plus Korea, and Australia and New Zealand (the latter two because they are major carry trade currencies).

For the implementation of both methodologies, the series used should be stationary. For this reason, we use the log difference of the exchange rate, equity and bond indices, and the difference of the option-implied volatility and risk-reversal in our analysis. Capital flows to each country are scaled by the 2012 GDP in US dollars for each country.

4 Results

In this section, we use the approaches presented on the methodology section to analyze the FX intervention programs in Brazil. In addition, we present an event study to check the robustness of our results.

4.1 Program Announcement

4.1.1 Level effect

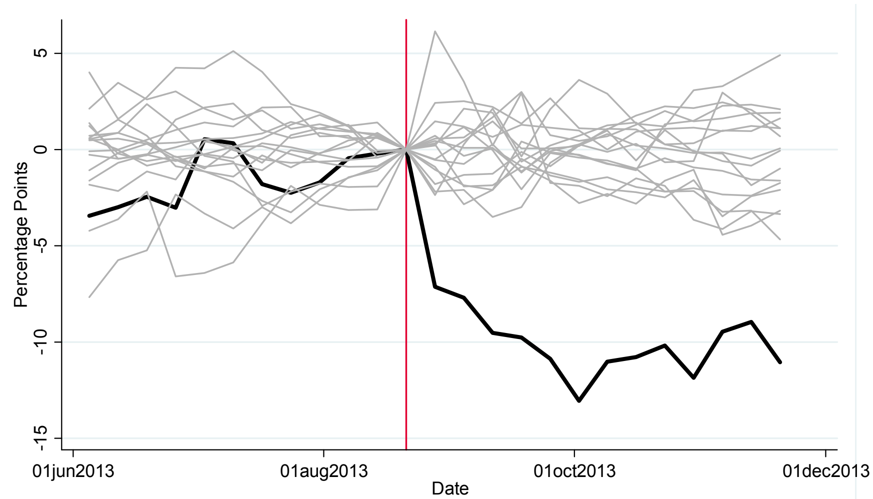
Figure 4 presents our estimates for the effect of the program announcement on the exchange rate. As mentioned above, the estimation uses the log change in the exchange rate as the dependent variable. But in order to more easily illustrate the resulting effect on the level, we accumulate the weekly log differences for the actual and for the synthetic exchange rates, and report the gap between the two. That gap is set to zero on the last observation prior to the announcement (so the level at any date t corresponds to the gap in the accumulated log differences from t to the announcement, and vice-versa). Figure 4(a) shows the estimates using Abadie et al. (2010) approach. In addition to the log change in the exchange rate, the explanatory variables considered include capital flows, the change in volatility, and the log change in the equity and bond indices. The thick dark line indicates the gap between the actual BRL and its synthetic (a negative value indicates that the BRL was more appreciated than its synthetic), while light gray lines indicate the gap for the other countries, which is used as a placebo test. The gap for the BRL is slightly negative and broadly stable during most of the pre-announcement period. But the gap declines sharply after the announcement, remaining at a substantially negative level. The bulk of the change takes place in the first week (about 10 percentage points). But the trend persists with the gap peaking at close to 15 percentage points before narrowing slightly. These results imply that the BRL was over 10 percentage points stronger than what its synthetic would suggest weeks after the announcement. Moreover, please note that the gap for the BRL is a major outlier vis-a-vis the placebos in the post-announcement period, with none of the placebos experiencing nearly as large a shift (in the pre-announcement period, both the BRL and placebos should hover around zero by construction). The weights and countries used for the construction of the synthetic control group do not have an economic interpretation, a point that is stressed in the literature (e.g. Abadie et al. 2010).[5,6] The means for Brazil and for its synthetic are reported in Table A.1.

The effect of this program is also estimated using a univariate approach that considers only the exchange rate, following the methodology proposed in Carvalho et al. (2015). Under this approach, we cannot consider all peers and control variables (otherwise there would be more parameters being estimated than the data available). We choose 3 peers that maximize the fit of the exchange rate regression: South Africa, Thailand and Peru. The counterfactual is estimated through a regression of the BRL on the others peers' change in log of exchange rate and a constant.[7] The gap between the actual and synthetic BRL is reported in Figure 4(b). The results point to a cumulative effect that is even stronger, peaking at around 20 percentage points. This approach provides a statistical inference for the average effect, which is statistically significant (with a p-value below 2 percent at four lags). The effect is smaller when the counterfactual is estimated without a constant (around five percentage points).

[5]With that caveat in mind, the synthetic draws from India, Indonesia and Malaysia, with weights of 14, 76, and 9 percent, respectively.

[6]Results are similar when we consider only Inflation Targeting countries.

[7]The R^2 of a regression of BRL in these currencies is equal to 0.8.



(a) Gap Between Actual and Synthetic

(b) Gap Between Actual and Univariate Synthetic

Figure 4: Effect of the Program Announcement on the Level of the Exchange Rate and Placebo Tests. Notes: Figures plot gap between the cumulative change in the log of the actual exchange rate and that implied by the synthetic estimates. Thick dark line indicates the gap for Brazil, and light gray lines indicate the gap for estimates from other countries (placebos). For ease of illustration, gaps are set to zero on the last observation prior to the announcement, which is indicated by the vertical line. Panel A based on the methodology in Abadie et al. (2010) and Panel B based on Carvalho et al. (2015).

4.1.2 Volatility effect

The approach in Carvalho et al. (2015) allows us to estimate other moments of the exchange rate. We can estimate an effect on volatility by using the squared change in the log of the exchange rate as the dependent variable (and the corresponding variable for other countries as the explanatory variable). The estimates suggest the average effect on the variance is close to zero and not statistically significant.

We can also assess the impact of the program on volatility using the option-implied exchange rate volatility. This readily available series provides a forward-looking measure of volatility (since it is based on option prices) that can quickly respond to the program (unlike say, measures of volatility constructed from past exchange rate data). Figure 5 reports the results for the change in the volatility. In Figure 5(a) we use the changes in the exchange rate, equity and bond indices, and capital flows as explanatory variables. For ease of illustration, we accumulate all the changes so as to report the resulting level of effect (setting the level at the last observation prior to the announcement to zero). Again, the thick dark line corresponds to the BRL while the thin gray lines to the placebo tests. There is a sharp decline in the gap in volatility after the announcement, by 5 percentage points, which is driven mainly by an increase in volatility among the countries in the synthetic control (India in particular) rather than an absolute decline in volatility for Brazil).[8] If we drop India from the pool of potential countries for the synthetic control, the results continue to point to a decline in volatility, but of only 2 percentage points.[9] That would still be a sizable decline (to put magnitudes in perspective, the volatility of the BRL was about 17 percent in the last observation prior to the announcement, so a 2 percentage point decline amounts to over 10 percent of the original volatility). The placebo tests point to the BRL being an outlier after the announcement. But the discrepancy between the BRL and the placebos is much smaller than in Figure 5(a).

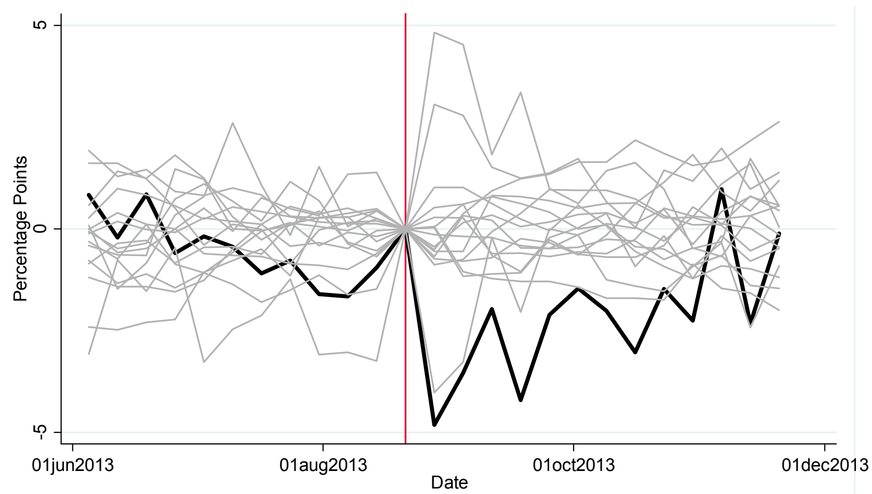
Figure 5(b) reports the results using the univariate approach, drawing on Peru and India. The results are more muted, and not statistically significant.

Finally, Figure 6 is analogous to Figure 5(a) but reports results for the risk-reversal measure. There is a sharp decline following the announcement (driven mainly by a decline in that variable for Brazil, which goes from 3.5 to 2.7 in the two observations before and after the announcement). A comparison with the placebos suggests the behavior of the

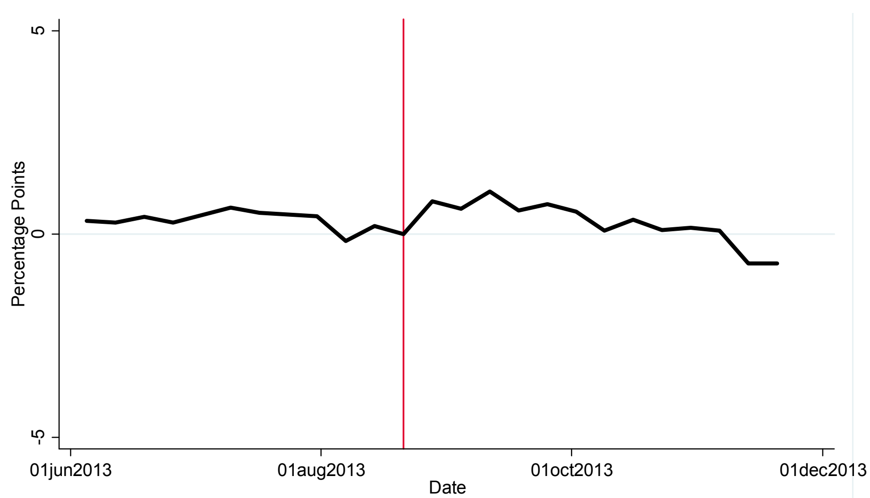
[8]The synthetic draws on Australia and India, with weights of 31 and 69 percent, respectively.

[9]The synthetic would draw on Australia and Indonesia, with weights of 64 and 36 percent, respectively.

BRL was an outlier in the two weeks following the announcement, but not afterwards.



(a) Gap Between Actual and Synthetic



(b) Gap Between Actual and Univariate Synthetic

Figure 5: Effect of the Program Announcement on the Option-Implied Volatility of the Exchange Rate and Placebo Tests. Notes: Figures plot gap between the cumulative change in the option-implied volatility and that implied by the synthetic estimates. Thick dark line indicates the gap for Brazil, and light gray lines indicate the gap for estimates from other countries (placebos). For ease of illustration, gaps are set to zero on the last observation prior to the announcement, which is indicated by the vertical line. Panel A based on the methodology in Abadie et al. (2010) and Panel B based on Carvalho et al. (2015).

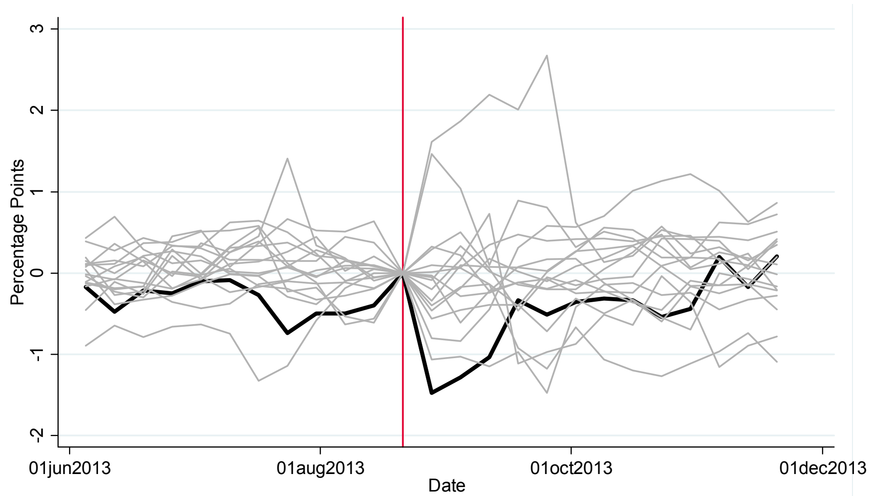


Figure 6: Effect of the Program Announcement on the Option-Implied Risk Reversal of the Exchange Rate and Placebo Tests. Notes: Figures plot gap between the cumulative change in the risk reversal and that implied by the synthetic estimates. Thick dark line indicates the gap for Brazil, and light gray lines indicate the gap for estimates from other countries (placebos). For ease of illustration, gaps are set to zero on the last observation prior to the announcement, which is indicated by the vertical line. Based on the methodology in Abadie et al. (2010).

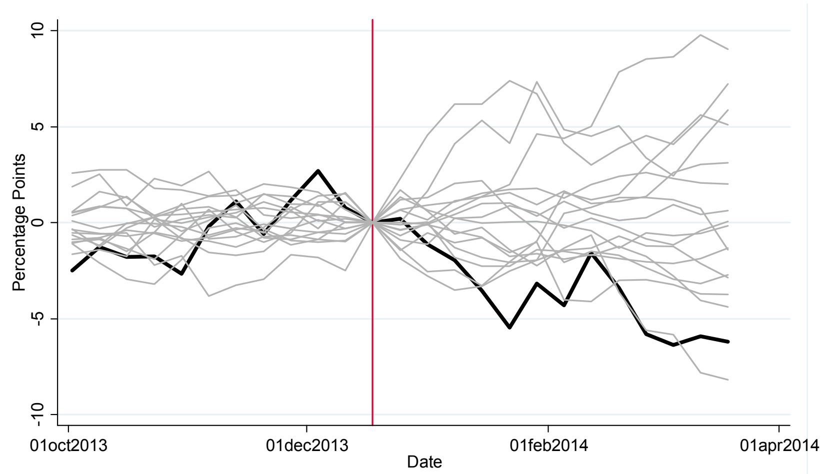
4.2 Program Extension Announcement

4.2.1 Level effect

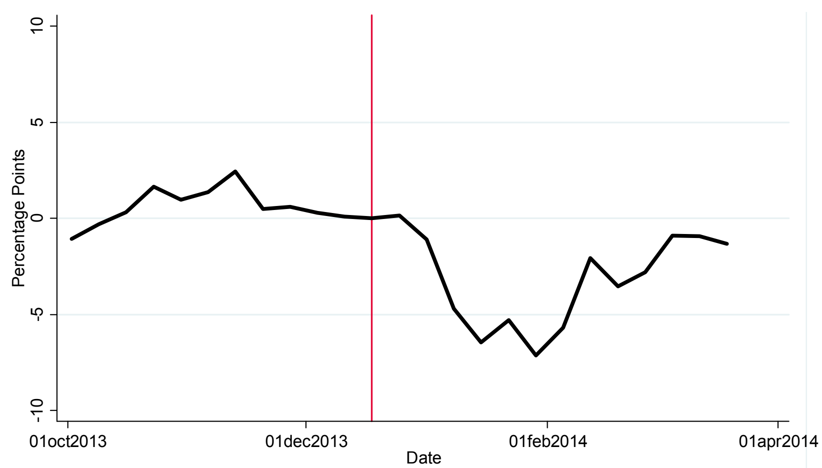
On December 18, 2013, the intervention program was extended until mid-2014, but with reduced daily interventions. There were expectations that the swap sales would continue (i.e. the market did not expect it to end abruptly at the end of 2013), but the announcement removed that uncertainty and clarified the scope of the program going forward. Therefore, the announcement could still impact the exchange rate, but that impact should be less dramatic than the one following the first announcement.

Figure 7 is analogous to Figure 4, but reports the results for the cumulative changes in the exchange rate around this second announcement. Figure 7(a) points to a gradual appreciation of the BRL vis-a-vis its synthetic, with that gap reaching about 5 percentage points, and remaining close to that level. A comparison with the gaps for the placebos suggest that the BRL was clearly on the stronger side, but was not nearly as much of an outlier as in Figure 4(a).[10]

Figure 7(b) reports the result under the univariate approach. The results also point to a decline of around 5 percentage points over the first four weeks, but that is gradually reversed over time. The effect is not statistically significant under any lag structure.



(a) Gap Between Actual and Synthetic



(b) Gap Between Actual and Univariate Synthetic

Figure 7: Effect of the December 2013 Announcement on the Level of the Exchange Rate and Placebo Tests. Notes: See notes to Figure 4.

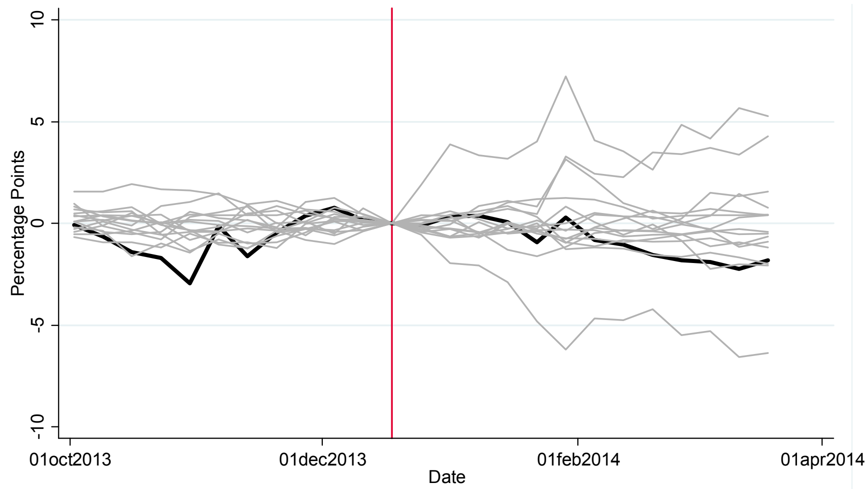
[10]The synthetic draws on Australia, Indonesia, Peru and Turkey, with weights of 19, 9, 5 and 67 percent, respectively.

4.2.2 Volatility effect

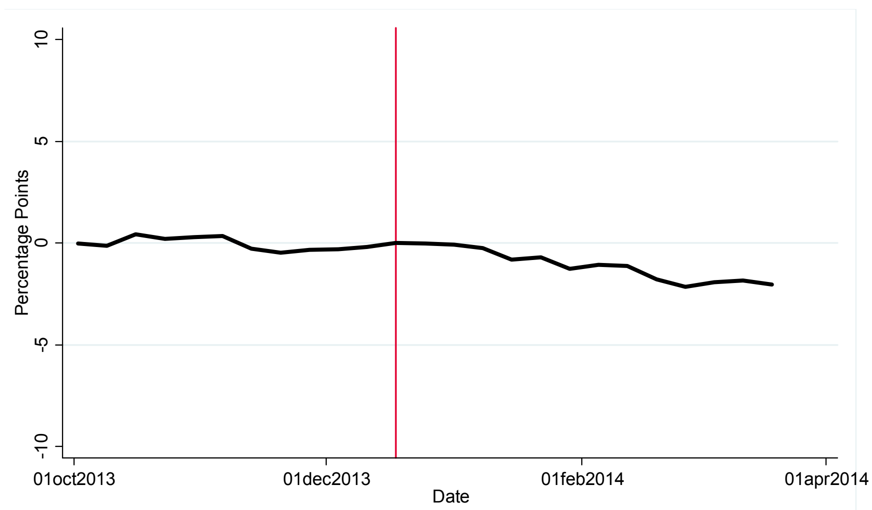
Figure 8 is analogous to Figure 5, but reports the effect on the option-implied volatility following the second announcement. There is virtually no change in volatility under neither of the methodologies considered. We also do not find any statistically significant effect of the second announcement when we estimate the synthetic for the squared log change in the exchange rate, using the univariate approach. There is also virtually no effect on the risk reversal following the second announcement (Figure 9). While there is a sharp decline in risk reversal for Brazil following the second announcement, as shown in Figure 3, the same was true for its synthetic (which draws heavily from Peru, where a sizable decline also took place around that time).

4.3 Addition Program Extensions

There were two additional announcements. One on June 24, 2014 extending the program until at least 2014-end, and a final announcement on December 30, 2014 extending the program until March 31, 2015. Figures 10 and 11 reports the results for the level of the exchange rate. The estimates suggest virtually no effect on the BRL exchange rate following the June 2014 announcement. The results point to a larger gap following the December 2014 announcement, which peaks at an appreciation of around 5 percent before quickly reversing. But overall, the results for the BRL are broadly in line with the placebos during most of the post-announcement period, suggesting no significant effect. The results for the volatility and risk reversal also point to little or no effect, and are not reported for the sake of conciseness.



(a) Gap Between Actual and Synthetic



(b) Gap Between Actual and Univariate Synthetic

Figure 8: Effect of the December 2013 Announcement on the Option-Implied Volatility of the Exchange Rate and Placebo Tests. Notes: See notes to Figure 5.

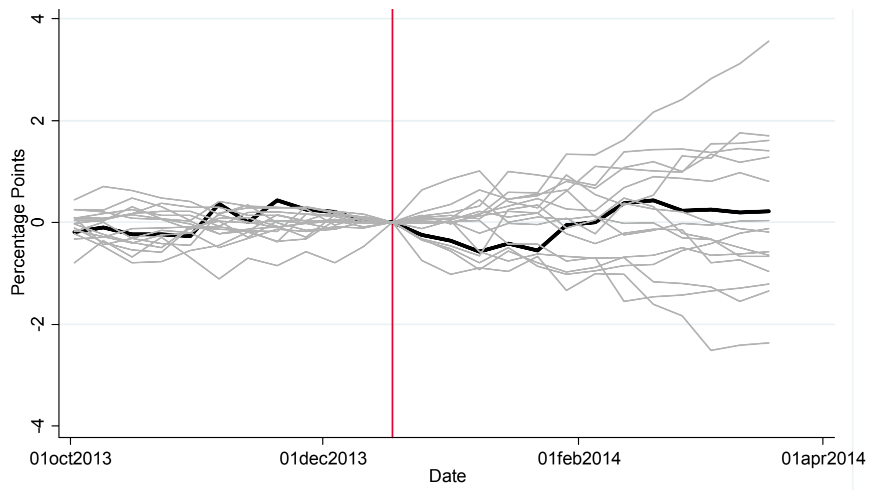


Figure 9: Effect of the December 2013 Announcement on the Option-Implied Risk Reversal of the Exchange Rate and Placebo Tests. Notes: See notes to Figure 6.

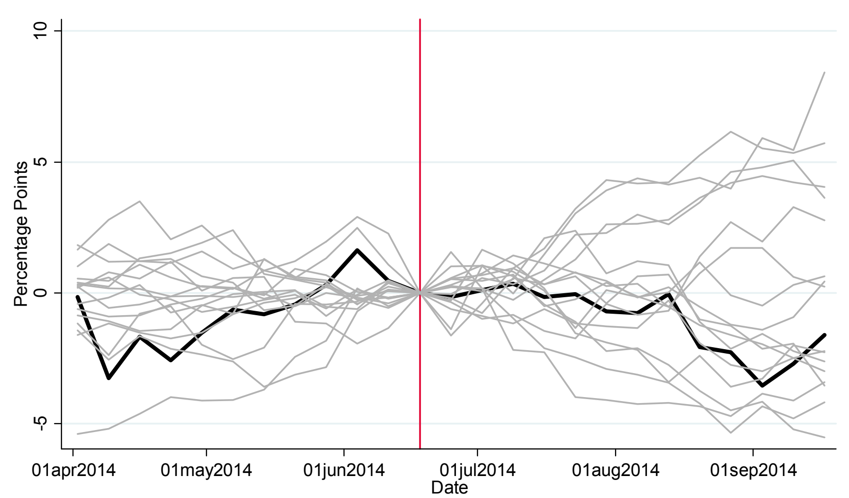


Figure 10: Effects of the June 2014 Announcement on the Level of the Exchange Rate and Placebo Tests. Notes: See notes to Figure 4.

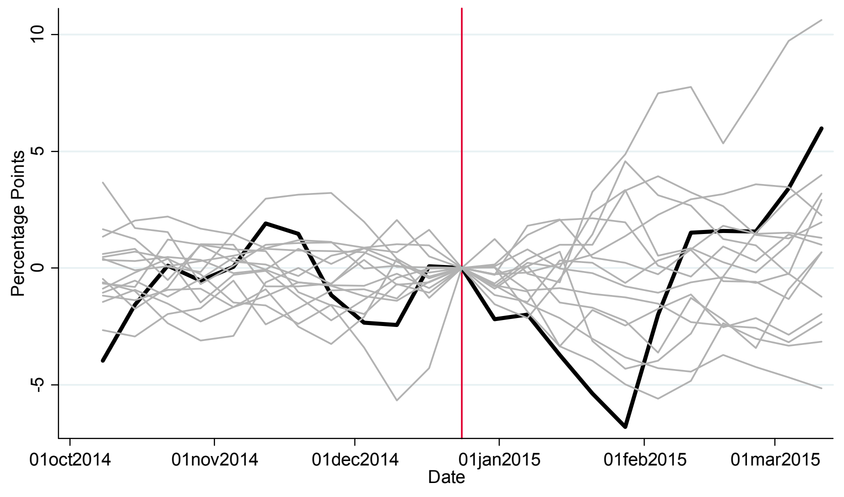


Figure 11: Effects of the December 2014 Announcement on the Level of the Exchange Rate and Placebo Tests. Notes: See notes to Figure 4.

4.4 Event Study

As a robustness check, we complement our analysis with a standard event-study analysis around the announcement of the FX swap program.[11] Using daily data, we estimate:

$$\begin{aligned}\Delta log(e_t) = c + \gamma_1 \Delta(CDI_t - LIBOR_t) + \gamma_2 \Delta log(VIX_t) + \gamma_3 \Delta log(Commodities_t) \\ + \gamma_4 \Delta log(DollarIndex_t) + \gamma_5 \Delta(Dollar - AsiaIndex_t) + \gamma_6 FXInt_t + \varepsilon_t \qquad (6)\end{aligned}$$

Where e is the dollar-real bilateral exchange rate, and explanatory variables include the change in the spread between the one-month CDI (Brazil's interbank rate) and the one-month $LIBOR$, the change in the log of the VIX, the change in the log of the CRB commodity price index, the change in the log of an index constructed by the Federal Reserve for the value of the dollar relative to major currencies of advanced economies weighted by US trade shares, the change in the log of the Bloomberg JP Morgan Asia and Latin America currency indices (we recomputed the latter, based on published weights, to exclude the BRL), and the Foreign Exchange Intervention by the central bank (based on announced swaps, netting out maturing ones).[12]

[11] Please refer to Campbell, Lo and MacKinlay (1996) for a description of the event study approach.

[12] The data sources are: Central Bank of Brazil for the exchange rate; Federal Reserve Economic Data for the dollar index, and Bloomberg for the remaining series.

We estimate this regression using data for January 2013 until 20 days prior to the August 22 announcement. We then compute the change in the log of the exchange rate beyond what would have been implied by that fitted model (analogous to the Cumulative Abnormal Returns in a standard finance event study) and the corresponding error bands around that estimate. We consider a +/- 20 working day window around the two announcements. Figure 12 reports the results, which point to a statistically significant cumulative appreciation of about 10 percent after the August 22 announcement, in line with our synthetic cohort estimates. In contrast, there is virtually no response following the December 18 announcement.

We estimate a similar regression but using the change in the option-implied volatility and risk reversal as the dependent variables. Figure 13(a) reports the results for volatility. While there is a decline following both announcements, it is not statistically significant (the error bands are too wide and span a zero effect). Figure 13(b) reports the results for the risk reversal. It declines following both announcements. That cumulative decline is statistically significant in the immediate aftermath for the first announcement, but over time the error bands become wider and that is no longer the case. In the case of the second program, the error bands initially span zero, but that is no longer the case towards the end of the post-announcement window the cumulative effect. The cumulative effect points to a 1.4 percentage point decline, which is sizable (the risk reversal stood at 2.8 prior to the announcement).

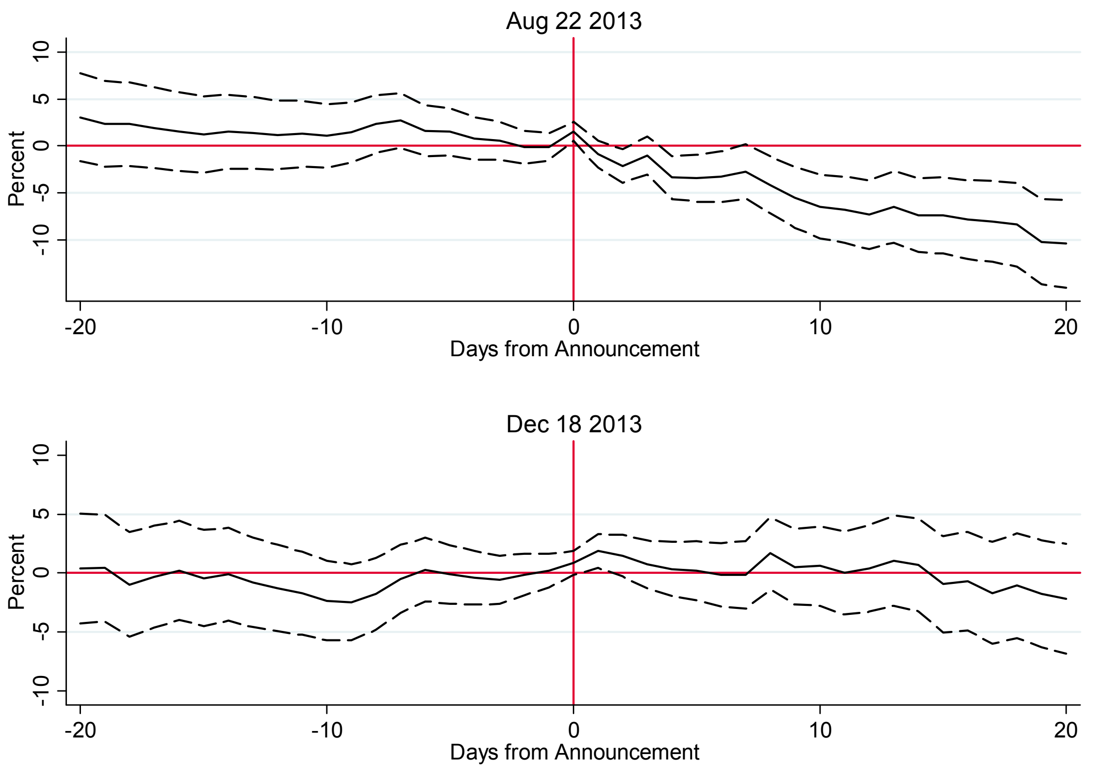
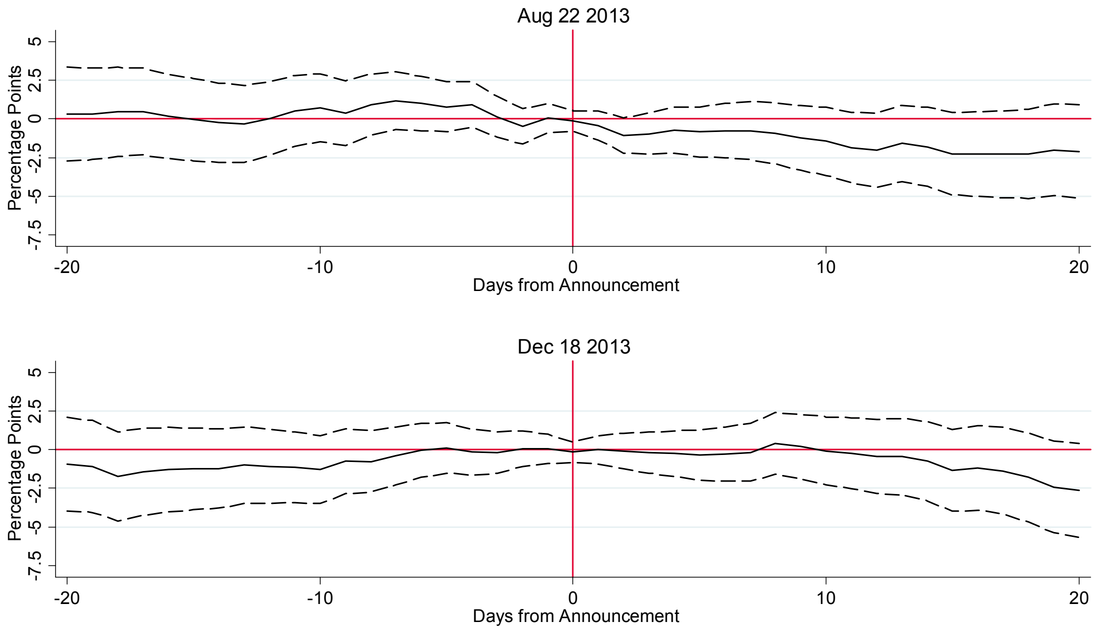
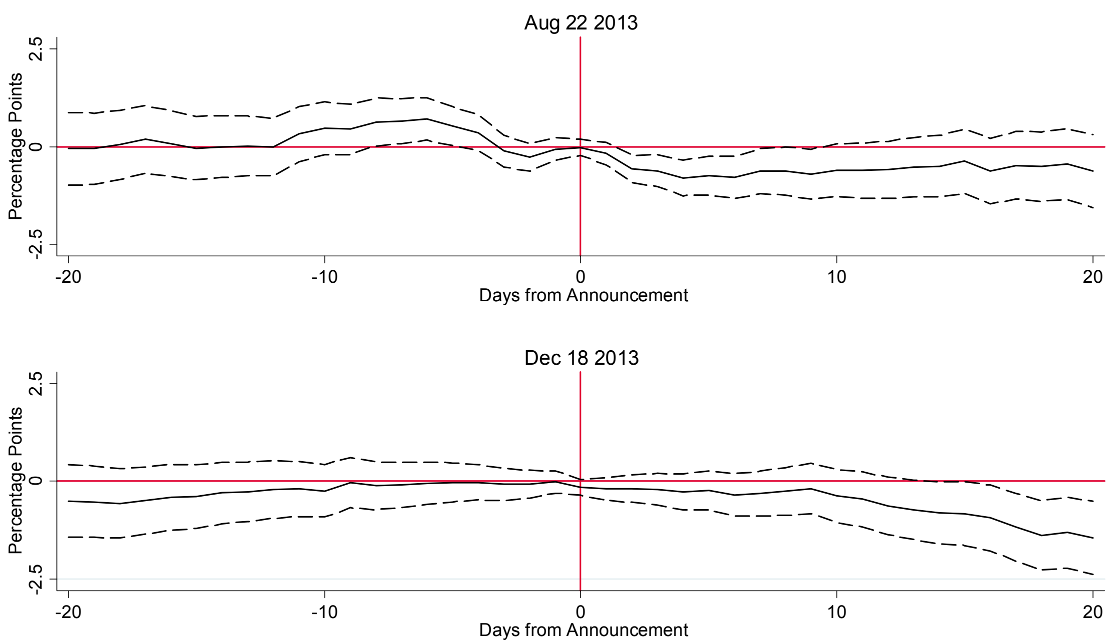


Figure 12: Cumulative Changes in the Exchange Rate Around Program Announcement and Extension. Notes: Dashed lines correspond to +/- 2 Standard Deviations. Cumulative changes start at 0 for both and after period.



(a) Option-Implied Volatility



(b) Risk Reversal

Figure 13: Cumulative Changes in the Option-Implied Volatility and Risk Reversal of the Exchange Rate Around Program Announcement and Extension. Notes: Dashed lines correspond to +/- 2 Standard Deviations. Cumulative changes start at 0 for both and after period.

5 Conclusion

The gyrations in international capital markets have brought renewed interest in tools to manage capital flows, with intervention in FX markets being one of the most commonly used tools. This paper has analyzed the effect of the large scale program of FX swaps that the BCB has embarked following the market's "taper tantrum" of 2013. This program was fairly unique because of its large scale (amounting to about a quarter of reserves) and the fact that the intervention took place through swaps (which makes the intervention temporary in nature, despite the long horizon of the program).

Immediately after announcement of the program, on August 22 2013, the Brazilian real reverted its depreciation trend, and eventually stabilized at a significantly more appreciated level. Our synthetic estimates point to an eventual appreciation relative to the synthetic in the range of 10-19 percentage points. The event-study analysis in the previous section also points to an appreciation of around 10 percent. If we compare this effect with the total volume of intervention mobilized during that program, it would be broadly in line with the point estimates for the effectiveness of FX intervention in Brazil from previous studies. Despite this large effect on the level of the exchange rate following the first announcement, the results on the volatility are more mixed. Some estimates point to a sizable decline, but overall the estimates are less robust than those for the level. Our estimates for the announcement of the extension of the program on December of 2013 had smaller effect on the exchange rate, ranging from no effect to 5 percent, and does not seem to have had an effect on its volatility. This smaller response may be the result of that extension being already expected and priced-in by the market. The third and fourth extensions had a fairly muted effect, likely for the same reason.

Our results are consistent with the view that FX interventions can be effective in deterring exchange rate overshooting in times of market turmoil. The large size of the program, and the market surprise following its announcements facilitate the identification of an effect, which would be more challenging in the context of small and frequent interventions that have come to be expected by the market.

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A Appendix

Variable	Figure 4(a) Treated	Figure 4(a) Synthetic	Figure 5(a) Treated	Figure 5(a) Synthetic	Figure 6 Treated	Figure 6 Synthetic	Figure 7(a) Treated	Figure 7(a) Synthetic
$\Delta log(BRL)$	1.257	0.913	1.1257	0.938	1.257	0.528	0.364	0.252
$\Delta log(Volatility)$	0.379	0.737	0.379	0.371	0.379	0.364	-0.066	-0.171
$\Delta(RiskReversal)$					0.034	0.040		
$\Delta log(EquityIndex)$	-0.671	-1.687	-0.671	-0.747	-0.671	-0.692	-0.587	-0.587
$\Delta log(BondIndex)$	-0.993	-0.986	-0.993	-0.399	-0.993	-0.562	-0.268	-0.030
$CapitalFlows/GDP$	-0.002	-0.002	-0.002	-0.001	-0.002	-0.002	-0.002	-0.001

Variable	Figure 8(a) Treated	Figure 8(a) Synthetic	Figure 9 Treated	Figure 9 Synthetic	Figure 10 Treated	Figure 10 Synthetic	Figure 11 Treated	Figure 11 Synthetic
$\Delta log(BRL)$	0.364	0.364	0.364	0.095	-0.277	-0.266	0.692	0.686
$\Delta log(Volatility)$	-0.066	-0.066	-0.066	-0.028	-0.096	-0.181	-0.152	0.301
$\Delta(RiskReversal)$			0.001	-0.003				
$\Delta log(EquityIndex)$	-0.587	-0.586	-0.587	-0.280	1.171	0.884	-0.019	-0.019
$\Delta log(BondIndex)$	-0.268	0.026	-0.268	-0.175	0.393	0.411	0.260	0.259
$CapitalFlows/GDP$	-0.002	-0.001	-0.002	-0.001	0.001	0.001	-0.001	-0.001

Table A.1: Predictor Means for the Synthetic Estimates. Notes: Treatment corresponds to the means for Brazil, and Synthetic to the means for its synthetic estimates in the Figure indicated by the different columns. For example, the results under the Figure 4(a) heading correspond to the means and synthetic for the log change in the exchange rate in the sample around the program announcement. For ease of illustration, variables are scaled to 100 times the log change in the exchange rate, equity and bond indices, and volatility, risk reversal and capital flows are measured in percentage terms.