Journal of International Money and Finance 47 (2014) 202–216

Contents lists available at ScienceDirect

Journal of International Money and Finance

journal homepage: www.elsevier.com/locate/jimf

Official FX interventions through derivatives

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JEL code:
F30

Keywords:
Intervention
Exchange rate
Derivatives
Brazil

A B S T R A C T

We use high-frequency data to study the effects of currency swap auctions carried out by the Brazilian Central Bank on the USDBRL exchange rate. We find that official currency swap auctions impact the exchange rate in a significant way, even though they do not directly alter the supply of foreign currency in the market. We show that during our sample period auctions of contracts in which the Central Bank took a short position in USD had larger effects than those in which the Central Bank took a long position. The supply of currency swaps to the market provides an alternative for traders that demand foreign currency for financial (speculative or hedging) rather than transactional reasons, and thus affects the demand for foreign currency and its price. This mechanism is likely to be particularly relevant when forecasters extrapolate exchange rate trends at short-term horizons.

1. Introduction

A recent survey article by Lukas Menkhoff (2012) has noted that, to the extent that interventions in emerging markets tend to occur regularly and central banks in these countries have considerable leverage, interventions in emerging markets are significantly different from those that have occurred in

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[1] We thank Paulo Berger, João Henrique Simão and Thiago Said Vieira for valuable help in obtaining the data, as well as Michael Moore, an anonymous referee and participants of the BIS CCA Research Conference in Santiago and of the Central Bank Workshop on the Microstructure of Financial Markets at the ECB for useful suggestions. The views expressed in this work are those of the authors and do not necessarily reflect those of Banco Central do Brasil or its members.

http://dx.doi.org/10.1016/j.jimonfin.2014.05.023
0261-5606/

advanced economies. Nevertheless, interventions in these markets have not received their fair share of attention in the academic literature. Menkhoff notes that "*when it comes to empirical studies on foreign exchange interventions, established surveys indicate a severe lack of consideration [for emerging economies]. For example, Sarno and Taylor (2001) do not cover a single study which would specifically address emerging markets and Neely's (2005) comprehensive survey about empirical work has a share of 2 out of 41 studies which are based on evidence from emerging markets.*" (p.3). His study concludes that much more research on interventions in emerging markets is needed. Indeed, he goes as far as stating that "*when we talk about foreign exchange interventions today we should talk about emerging markets.*"

Once an observer has established that most emerging economies do engage in direct or indirect interventions in the foreign exchange market, an important question that ensues is which policy tools should optimally be used by a monetary authority if it decides to intervene. As a matter of fact, the instruments that have been used to conduct exchange rate policy, and to ensure the smooth functioning of the exchange rate market, have typically developed in sync with the increasing sophistication of exchange rate markets. Indeed, in some countries derivative contracts have come to the forefront of the exchange rate policy toolkit of Central Banks. In the case of Brazil, for instance, *Banco Central do Brasil* carried out a total of 12 currency swap auctions in the second half of 2012 — at the same time that it did not resort to any plain vanilla spot market auctions. Yet, somewhat surprisingly, the use of such instruments has not received the appropriate attention in the economic literature.

A well known advantage of issuing such contingent liabilities as currency swaps is that authorities become able to intervene in the exchange market indirectly, without varying the stock of foreign exchange reserves. Alternatively, a Central Bank might also want to engage in derivative operations to deepen the market for instruments for risk management or to act as an automatic stabilizer of the foreign exchange market (Blejer and Schumacher (2000)). The caveat, of course, is that the use of such instruments requires much more careful risk assessments than traditional instruments. In the case that we analyze in this paper, however, it is important to bear in mind that the notional amount of the net BCB exposure in the currency swap market — that was below US$ 2 bn at the end of the period that we investigate[2]- was dwarfed by international reserve holdings that fluctuated between US$ 346 bn and US$ 379 bn. In other words, to some extent, the large holdings of international reserves provided an insurance, as well as the means to fight eventual adverse movements for the Central Bank.[3]

This study shows that currency swap contracts, that trade the exchange rate variation (plus a local onshore US$ interest rate) for the cumulative domestic interest rate, can have a significant impact on the level of the exchange rate without altering the supply of foreign currency in the market in any direct way. The rationale for such effect is that the supply of currency swaps to the market provides an alternative for traders that are demanding currency for speculative or hedging reasons. In other words, altering the supply of these contracts will ultimately affect the relative demand for foreign currency and therefore, also its price. This mechanism is particularly potent if, as Frankel and Froot (1990) and Taylor and Allen (1992) already confirmed, forecasters tend to extrapolate the exchange rate trends at short-term horizons. More recently, also Menkhoff and Taylor's (2007) survey established the widespread use of technical analysis in the foreign exchange market. They argue that such practice informs traders on non-fundamental forces. Using high-frequency data, we find that the currency swap auctions that were carried out by the Brazilian Central Bank between January 2011 and March 2013 indeed had significant effects on the USDBRL exchange rate. Furthermore, we find that auctions of contracts in which the Central Bank offered to go short in foreign currency had larger effects than those in which the Central Bank went long. As we show, our findings are robust to a number of alternative econometric specifications. More specifically, we find very similar effects when we model the high-frequency exchange rate variation using GARCH models, least squares regressions or a parsimonious VAR specification. Importantly, our study properly controls for intraday variation in macroeconomic variables as well as for time-stamped news effects.

[2] That is, from January 1st, 2011 to March 31st, 2013.

[3] Conversely, when it is receiving exchange rate variation, a Central Bank could issue more domestic currency to cause a depreciation of the currency.

The present article adds to the existent literature in at least two ways. First, our study represents a contribution to the small set of studies on the effects of interventions in emerging markets that is based on high-frequency data. Most existing studies on the subject were not able to make use of intraday data. Second, our contribution represents an important innovation in that we analyze the effects of indirect interventions in the foreign exchange market, *i.e.* interventions via currency swaps. To the best of our knowledge, the official use of such exchange rate derivatives to attain exchange rate policy objectives had not been the subject of a systematic analysis in the academic literature before. We find that, even though these operations do not involve direct exchanges of foreign currency, they clearly do have a significant impact on the exchange rate on their own.

1.1. Relation to the literature

A few papers of the existing intervention literature can be related to the present article. For comprehensive surveys of the literature, we refer the reader to the studies of Sarno and Taylor (2001), Neely (2005) and Menkhoff (2012). In terms of the empirical strategy that we follow, a paper that lies close to ours is Dominguez et al. (2013).[4]

Within the group of emerging economies, Disyatat and Galati (2007) have pointed out that if emerging markets can be characterized by lower asset substitutability and greater size of interventions relative to market turnover, (direct) interventions should be more likely to be successful due to the portfolio balance channel or to the microstructure/order flow channel. Nevertheless, they find that intervention in the Czech Republic had only small and weakly significant impacts on the spot rate and on the risk reversal. Earlier, however, Tapia and Tokman (2004) had found that interventions via direct spot market transactions and via US Dollar denominated papers did not have significant effects in the case of Chile. Our results, however, indicate that even indirect interventions – *i.e.* those that do not involve direct transactions of foreign exchange – can have significant effects on the exchange rate. To some extent then, our findings resonate with those of Guimarães and Karacadag (2004), that found that direct interventions had an impact on the value of the Mexican Peso. Also Adler and Tovar (2011) report evidence of significant effects of direct interventions. The analysis of these two studies, however, was based respectively on daily and weekly data. Using intraday data, we are able to demonstrate a much faster response of indirect interventions – with maximum impact occurring in the minutes that follow the announcement of currency swap auctions.

1.2. Outline

The paper proceeds as follows. Section 2 briefly presents some background information on the recent Brazilian policy framework and on the use of currency swap auctions. Section 3 presents the intraday data that is used in the analysis. Section 4 then outlines the baseline econometric specification that was employed for estimation. The following section presents the GARCH model based estimation results. Section 6 shows that the estimated impacts are very similar when the effects of swap auctions are estimated using a VAR model, that takes better care of the possibility of intraday endogeneity. Section 7 discusses the main robustness checks that were performed. The paper closes with some concluding remarks.

2. Currency swap auctions in Brazil

After the abandonment of the currency peg against the US Dollar, in January 1999, the Brazilian Central Bank started to operate under a floating exchange rate regime. Since mid 1999, the main objective of the monetary authority has been to meet the explicit inflation target that is set in advance by the *Conselho Monetário Nacional* (CMN).[5] The Central Bank also acts in foreign exchange markets in

[4] This study concludes that reserve sales by the *Czech National Bank* had a significant impact on the exchange rate.

[5] Indeed, consumer price inflation has stayed within the allowed ± 2% deviation from the target in every year between 2004 and 2013.

order to curb excessive exchange rate volatility. It is important to note that even though interventions in the foreign exchange market have been common – as in other emerging economies – the volatility of the Brazilian Real has typically been larger or comparable to the volatility of G-3 currencies in both, bilateral and effective terms.[6]

Since March 2002, the Brazilian Central Bank has used public currency swap auctions as an instrument that is aimed at ensuring the smooth functioning of the foreign exchange market, as well as to ensure that there is a proper supply of hedging instruments in the market. These swap contracts, to some extent, replaced domestic government bonds that were linked to the exchange rate. Bevilaqua and Azevedo (2005) provide a detailed discussion about the (re-)introduction of this type of contracts, as well as the replacement of US$ linked Treasury Notes (NTN-Ds).

Swap contracts are registered at the *BM&FBovespa exchange as "SCC – Contrato de Swap Cambial com Ajuste Periódico"*.[7] Auctions are always announced through the Central Bank's communication system, establishing the exact time of the auction – typically a few minutes after the announcement, the quantity of contracts that the Central Bank is offering to buy or sell, as well as the maturities that are on offer. Each participating institution is allowed to place up to five bids, specifying the quantity and price (i.e. the implicit interest rate) for each. After bids are placed, the Central Bank has the discretion to accept any volume of contracts up to the maximum amount that is on offer. If the Central Bank is offering to buy these derivative contracts the financial institution receives the equivalent of the exchange rate variation over the time of the contract plus a local onshore US$ interest rate, *all paid in Brazilian Reais*. At the same time, the Central Bank receives the cumulative interbank interest rate.

The BCB carried out 61 currency swap auctions between January 1st, 2011 and March 31st, 2013. During this period, the timing and the volumes on offer did not follow any pre-announced rule.[8] The local market convention has been to label auctions as *traditional swaps* when the Central Bank is buying contracts (which may have the effect of limiting the depreciation of the Brazilian Real), and as *reverse swaps* when the Central Bank is selling these contracts. Even though there is no exchange of foreign currency involved and the Central Bank does not alter the supply of foreign exchange, market participants typically see *traditional swaps* as being the financial equivalent to a sale of USD Dollars in the futures market by the BCB. Table 1 shows the exact timing and magnitude of these operations.

To the extent that a change in the supply of *SCC* derivatives alters the supply of hedging instruments that are available in the market, such auctions will have an affect on the relative demand for USD dollars in the marketplace and, as a consequence, the prevailing USDBRL exchange rate. To illustrate this point, Fig. 1 shows the daily evolution of the USDBRL rate between September 1st, 2011 and October 15th – a period in which the Central Bank did not perform any direct USD auctions. Between September 1st and the 21st, the USDBRL exchange rate moved from 1.62 to 1.88. This rapid movement prompted the Central Bank to announce a traditional swap auction on the morning of September 22nd, offering the exchange rate variation to market participants in exchange for an agreed interest rate. As the auction provided an alternative for traders and trend extrapolators that were acquiring USD for speculative reasons (as well as those that needed to hedge their position), the speculative demand for USD dropped and the Brazilian Real recovered some ground. The figure shows that similar developments prompted new BCB action in the beginning of October.

Of course one could always argue that, while the anecdotal evidence presented above is very suggestive, other conditions that affect the USDBRL market may also have varied during the time period in question. This would make it more difficult to infer which part of the variation is directly attributable to the swap auctions. In what follows, we aim to establish whether a thorough analysis that is based on intraday variation, and that includes the proper control variables at high-frequency,

[6] Indeed, during the sample period of this study, the realized volatility of the exchange rate of the Brazilian Real (against the USD) exceeded that of the Mexican and the Chilean Peso, as well as that of the Canadian Dollar, the Euro and the Japanese Yen, for instance. It was below that of the South African Rand.

[7] The contract can be found at http://www.bmfbovespa.com.br.

[8] A rule for the auctioning of traditional swaps was announced later, after our sample period, on the evening of August 22nd, 2013. On the following day the Real appreciated strongly.

Table 1
Currency swap operations of the BCB.

Auction Nr.	Date	Bidding time	Type	Contracts on offer
1	1/17/2011	12:00–12:30	Reverse	20000
2	1/21/2011	12:00–12:30	Reverse	20000
3	1/24/2011	12:00–12:30	Reverse	20000
4	1/27/2011	11:30–12:00	Reverse	20000
5	2/4/2011	12:30–13:00	Reverse	20000
6	2/10/2011	11:30–12:00	Reverse	20000
7	2/18/2011	11:30–12:00	Reverse	30000
8	2/22/2011	14:30–15:00	Reverse	20000
9	2/25/2011	11:45–12:15	Reverse	20000
10	2/28/2011	10:30–11:00	Reverse	30000
11	3/28/2011	12:15–12:45	Reverse	16500
12	3/30/2011	14:00–14:30	Reverse	30000
13	3/31/2011	11:15–11:45	Reverse	30000
14	3/31/2011	12:30–13:00	Reverse	30000
15	4/1/2011	11:30–12:00	Reverse	30000
16	4/29/2011	12:00–12:15	Reverse	30000
17	4/29/2011	12:45–13:00	Reverse	30000
18	5/31/2011	12:45–13:00	Reverse	34000
19	5/31/2011	14:30–14:45	Reverse	34000
20	6/28/2011	11:00–11:15	Reverse	34000
21	7/8/2011	11:15–11:30	Reverse	30000
22	7/13/2011	14:30–14:45	Reverse	30000
23	7/27/2011	12:15–12:30	Reverse	26000
24	8/30/2011	10:45–11:00	Reverse	37400
25	8/31/2011	11:30–11:45	Reverse	24400
26	9/22/2011	10:45–11:00	Traditional	112290
27	10/3/2011	15:45–16:00	Traditional	106975
28	10/4/2011	11:15–11:30	Traditional	90525
29	10/28/2011	11:15–11:30	Traditional	30000
30	2/23/2012	12:15–12:30	Reverse	40000
31	2/29/2012	10:15–10:30	Reverse	40000
32	3/27/2012	11:15–11:30	Reverse	41200
33	5/18/2012	15:45–16:00	Traditional	13000
34	5/22/2012	11:30–11:45	Traditional	49400
35	5/22/2012	12:30–12:45	Traditional	19100
36	5/23/2012	12:15–12:30	Traditional	80000
37	5/24/2012	12:00–12:15	Traditional	40000
38	5/25/2012	10:00–10:15	Traditional	40000
39	6/5/2012	10:15–10:30	Traditional	40000
40	6/8/2012	12:30–12:45	Traditional	30000
41	6/11/2012	12:45–13:00	Traditional	20000
42	6/27/2012	11:15–11:30	Traditional	60000
43	6/28/2012	10:15–10:30	Traditional	60000
44	6/29/2012	10:15–10:30	Traditional	60000
45	8/21/2012	11:30–11:40	Reverse	50000
46	9/12/2012	10:20–10:30	Reverse	36000
47	9/14/2012	10:20–10:30	Reverse	36000
48	9/14/2012	14:30–14:40	Reverse	70000
49	9/17/2012	09:40–09:50	Reverse	70000
50	10/5/2012	10:45–10:55	Reverse	50000
51	10/23/2012	09:40–09:50	Reverse	60000
52	10/25/2012	09:30–09:40	Reverse	30000
53	11/23/2012	11:45–11:55	Traditional	62800
54	12/3/2012	09:40–09:50	Traditional	40000
55	12/26/2012	10:40–10:50	Traditional	40000
56	12/26/2012	11:40–11:50	Traditional	40000
57	1/28/2013	11:30–11:40	Traditional	37000
58	2/8/2013	11:35–11:45	Reverse	37000
59	2/15/2013	9:40–9:50	Reverse	27000
60	3/11/2013	10:35–10:45	Reverse	30000
61	3/27/2013	11:30–11:40	Traditional	20000

Note: The notional amount of each contract is the equivalent of USD 50,000.

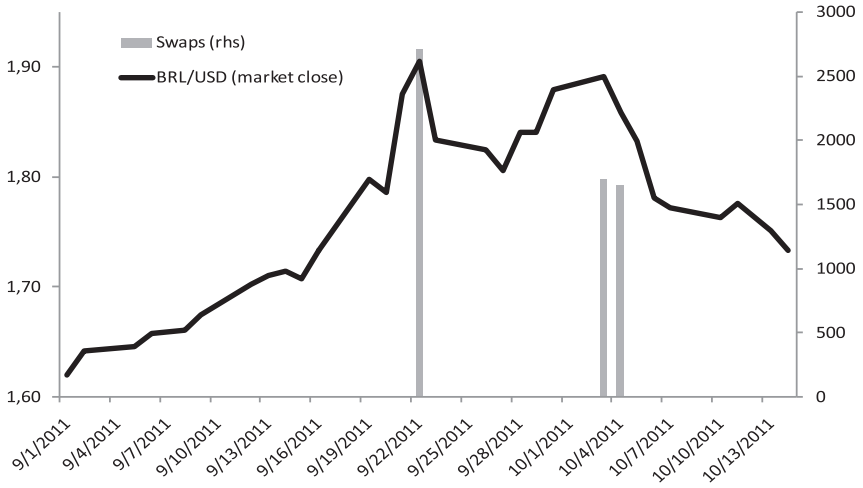

Fig. 1. Swap Auctions and the exchange rate.

supports the view that BCB currency swap operations indeed had a significant and systematic price effect.

3. Data

To compute the systematic impact of currency swap auctions on the spot USDBRL exchange rate we use high-frequency data from two sources: the local futures exchange BM&FBovespa and Bloomberg. The spot exchange rate at 15 min intervals, our main variable of interest, is derived from data obtained from the first source. We restrict our analysis to cover trading times between 9:00 a.m. to 5:00 p.m. local time, so that we are left with a sample of 17,044 observations that cover the 27 month period between January 2011 and March 2013 - after excluding weekends and holidays.

Our aim is to establish the effect of an *event* of a currency swap auction on the exchange rate and on its conditional volatility. To identify the effects with precision, we control for intraday commodity price variations (as measured by the variations of the *Commodity Research Bureau*'s index) and changes in the VIX rate, as reported by *Bloomberg*, as these variables have been shown to be important determinants of the value of the Brazilian Real (Kohlscheen (2014a, 2014b)). The high-frequency changes in these global control variables were obtained from *Bloomberg*. We also control for the reserve purchase operations (i.e. direct USD purchases) that were carried out by the BCB during this period.[10]

Finally, we control for time-stamped macroeconomic news announcements. More precisely, we control for official announcements of GDP and consumer price inflation figures in Brazil and the United States. We follow Andersen et al. (2003, 2007) in that we define each news surprise variable as the difference between the announced figure and prior survey expectations (taken from *Agência Estado Broadcast*), divided by the sample standard deviation of the variable in question.

4. Econometric specification

In order to allow for the possibility of volatility clustering, we estimate the effects of interventions using a GARCH(1,1) model as the baseline specification. More specifically, we estimate

[10] The exact timing of BCB operations was obtained through *BC Correio*.

$$\Delta s_t = \alpha + \sum_{i=1}^{I} \beta_i \Delta s_{t-i} + \sum_{j=0}^{T} \gamma_j S_{t-j} + \sum_{k=0}^{T} \delta_k P_{t-k} + \sum_{l=0}^{T} \eta_l R_{t-l} + \sum_{m=0}^{M} \theta_m Macro_{t-m} + \sum_{n=0}^{N} \lambda_n News_{t-n} + \varepsilon_t \quad (1)$$

and

$$\sigma_t^2 = \phi + \xi \varepsilon_{t-1}^2 + \rho \sigma_{t-1}^2 \quad (2)$$

where s_t represents the log of the spot USDBRL exchange rate and α a constant that may capture any eventual long-run trend. S_t is a scaled variable that indicates the announcement of a traditional currency swap operation, P_t is the equivalent variable for reverse swap operations and R_t flags reserve purchase auctions. $Macro_t$ stands for a vector of macroeconomic control variables, $News_t$ is a vector of standardized macro news announcements and ε_t represents the residual. Note that the specification allows the announcements of interventions, macroeconomic control variables, as well as official announcements of macroeconomic indicators to impact the exchange rate with a lag. In our baseline specification, the scaled intervention variables are defined as the ratio between the volume on offer in a given auction and the sample mean of that number. Therefore, the coefficients can be interpreted as the effects of an average auction.[11] As we show in the robustness section, when we replace these variables by simple announcement dummy variables we obtain coefficients of very similar magnitudes.

We assess whether swap auctions that are carried out by the BCB impact the exchange rate in a systematic way by evaluating the sequence of estimated γs and δs. In particular, if traditional currency swaps are effective, we would expect to find negative γs, as *traditional swaps* should reduce the USDBRL rate (i.e. lead to an appreciation of the Brazilian Real). Conversely, if reverse swaps are effective, we would expect to find positive δ coefficients. As the largest significant lag of a swap dummy that we ever found to be of statistical significance is 6, we set $T = 6$ as a benchmark throughout. In the robustness Section we show that the results are similar when we increase T to 12. This means that we effectively evaluate the intraday exchange rate impacts of swap operations using a time window that goes up to 90 min after the event. The conditional volatility equation includes an ARCH and a GARCH term. This allows for the possibility that the previous period volatility news (ε_{t-1}^2), as well as the past forecast variance (σ_{t-1}^2), affect the current volatility forecast.

5. GARCH estimation results

5.1. The conditional mean equation

Table 2 reports the estimation results for equation (1) for four alternative GARCH (1,1) models. The models were estimated by maximum likelihood assuming a Gaussian distribution for the error terms. The first two columns include six lags of each intervention variable, whereas columns III and IV include only the lags that were found to be statistically significant at 5%. Throughout, standard errors were computed using the robust method of Bollerslev and Wooldridge.

The $Q^2(24)$ statistic at the bottom of the Table represents the Ljung–Box Q-statistic (with 24 lags) for the squared residuals of the model, which is never found to be significant. This indicates that the chosen GARCH specification has properly dealt with the autocorrelation in the squared residuals. In contrast, when we use ordinary least squares, this statistic reaches 2372.8 (p-value <0.001).

The models included also control for macroeconomic conditions that were found to be relevant in previous studies. Furthermore, models II and IV add (current and lagged) macro news variables. Note that the adjusted R2 statistic and the log-likelihood increase somewhat when the news variables are

[11] The number of contracts on offer, which is made public at the time of announcement, is highly correlated with the number of contracts that are eventually sold. For our sample, the mean offer was of 38,900 contracts.

Table 2
Impact of swap operations on USDBRL returns.

D.V.: log change in USDBRL rate				
	I	II	III	IV
d (log BRL/USD rate) t-1	−0.060 E2**	−0.061 E2**	−0.060 E2**	−0.060 E2**
	6.57	6.64	6.57	6.48
d (log commodity price index)	−0.088 E2**	−0.089 E2**	−0.088 E2**	−0.088 E2**
	5.28	5.35	5.28	5.30
d (VIX)	0.078**	0.078**	0.079**	0.079**
	7.28	7.27	7.29	7.31
Traditional swap t	−0.507**	−0.508**	−0.507**	−0.508**
	6.62	6.68	6.60	6.67
Traditional swap t-1	−0.128**	−0.129**	−0.126**	−0.126**
	3.31	3.34	3.25	3.26
Traditional swap t-2	−0.063	−0.063	–	–
	1.88	1.88	–	–
Traditional swap t-3	0.017	0.017	–	–
	0.50	0.50	–	–
Traditional swap t-4	0.031	0.031	–	–
	1.03	1.03	–	–
Traditional swap t-5	−0.069*	−0.069*	−0.075*	−0.075*
	2.06	2.09	2.27	2.30
Traditional swap t-6	−0.042	−0.043	–	–
	0.77	0.78	–	–
Reverse swap t	0.155**	0.155**	0.155**	0.155**
	5.20	5.21	5.19	5.20
Reverse swap t-1	0.042**	0.043**	0.043**	0.042**
	2.87	2.87	2.91	2.86
Reverse swap t-2	0.016	0.017	–	–
	0.92	0.92	–	–
Reverse swap t-3	−0.001	−0.001	–	–
	0.07	0.07	–	–
Reverse swap t-4	−0.026	−0.026	–	–
	1.83	1.81	–	–
Reverse swap t-5	−0.018	−0.017	–	–
	1.02	1.02	–	–
Reverse swap t-6	0.020	0.020	–	–
	1.24	1.25	–	–
Constant	Yes	Yes	Yes	Yes
Control for current and lagged reserve purchases	Yes	Yes	Yes	Yes
Lagged macro controls	Yes	Yes	Yes	Yes
Current and lagged news variables	No	Yes	No	Yes
No. of observations	17,044	17,044	17,044	17,044
Sum of traditional swap coefficients	−0.707	−0.706	−0.708	−0.710
Wald stat – traditional	58.92**	59.72**	58.91**	59.93**
Sum of reverse swap coefficients	0.197	0.198	0.197	0.197
Wald stat – reverse	34.06**	35.89**	35.82**	35.70**
Sum of reserve purchase coefficients	0.033	0.033	0.033	0.033
Wald stat – spot	9.08**	9.67**	9.48**	9.42**
Adjusted R2	0.0849	0.0861	0.0848	0.0860
Log-likelihood	90669.40	90686.8	90664.26	90681.3
Q2 (24)	16.898	17.083	16.396	16.617

Note: * and ** denote statistical significance at the 5% and 1% confidence levels, respectively. All coefficients were multiplied by 100. The sample covers data from 01/01/2011 to 03/31/2013.

included. The table also shows that the return lag is significant at 1%, and negatively signed, indicating a mean-reverting pattern for exchange rate variations.[12] The intraday market volatility index VIX and the intraday CRB commodity price index are also significant determinants of the value of the Real at intraday frequencies. Higher commodity prices and lower risk lead to a stronger Brazilian Real. This is

[12] Further lags of the dependent variable, if included, attain insignificant coefficient values and lead to worse AIC and BIC statistics.

in line with earlier findings that were based on lower frequency (Kohlscheen (2014a)). Note that these are global control variables, so that reverse causality here is highly unlikely.[13]

In all four specifications the negative coefficients of the S (sale) variables are all found to be significant at 5% for times t, $t-1$ as well as for $t-5$. The maximum impact clearly occurs in the first half-hour that follows the announcement of a traditional currency swap. According to Model II (which is our benchmark), about 90% of the total effect occurs within this short time frame.[14] The (small) additional blip that is detected between 1 h and 1 h and half after the announcement is likely to be related to the publication of the auction results, that typically occurs about 1 h after the initial announcement. Importantly, the hypothesis that the significant γ_j coefficients in Table 2 add up to zero is clearly rejected by the appropriate Wald tests. The χ^2 statistic for the null of a zero cumulative effect attains values between 58.9 and 59.7 (which are associated with *p-values* below 10^{-4}). The total effect of an average size traditional swap is estimated to be of 71 bp.

For the reverse swaps, we found smaller (but clearly significant) positive coefficients for the P (purchase) variables. Also here, the effect of interventions comes very fast and the hypothesis that the cumulative effect is zero is easily rejected – although χ^2 statistics are lower (between 34.1 and 35.9). Even so, the sum of the reverse swap coefficients clearly exceeds the sum of the reserve purchase coefficients, as shown in the lower part of the Table. Note however that we are not able to compare the effects of traditional swaps with direct USD reserve sales, as our sample period contains no instance of plain USD sales in the spot market.[15] The larger effects of purchase interventions via derivatives is hardly surprising if we consider the fact that the average intervention volume for swaps was four times that of the typical spot market auction during our sample period. Furthermore, the relative importance of future exchange rate markets in Brazil is well documented.[16,17]

The effects of traditional and reverse swaps are clearly asymmetric. The null that the (absolute value) of the sum of the γ coefficients is equal to that of the δ coefficients is rejected with a $\chi^2(1)$ statistic of 27.31 (*p-value* below 10^{-4}). Alternatively, the *t–statistic* for the difference in the absolute value of sum of significant coefficients is 5.23. These asymmetric effects might be explained by the larger leverage that a monetary authority attains by holding a large stock of foreign reserves.

Table 3 shows the estimated conditional volatility equations. The coefficients in equation (2) are always found to be significant at 1%. Previous interval volatility news does affect the conditional variance, as larger (absolute) residuals increase the estimated volatility.

5.2. Effects of macroeconomic news

The results of Model II in Table I, and in the remainder of this paper, control for the time-stamped effects of macroeconomic news announcements. As Andersen et al. (2003, 2007), we define each news surprise variable as the difference between the announced figure and prior survey expectations (taken from *Agência Estado Broadcast*), divided by the sample standard deviation of the variable in question. The coefficients for the news variables that were obtained from the estimation of equation (1) of the GARCH(1,1) model can be seen in Table A1 in the Appendix. We find that both, Brazilian and U.S. GDP Surprises have significant effects on the exchange rate at the 1% confidence level. While positive activity news for Brazil lead to an appreciation of the Brazilian Real, unexpected increases in output in the U.S. strengthen the U.S. Dollar. In quantitative terms, the effects of these two shocks are of similar magnitude. The Wald test does not reject the null of equal (absolute) effects ($\chi^2(1)$=0.07, which corresponds to a p-value of 0.797). On the other hand, the

[13] An analysis based on daily data found that local stock market variation, as well as U.S. and local short-term interest rate variations, did not have a significant effect on the USDBRL over the period of this study. Insensitivity of the exchange rate to local rates had been found earlier, in a study of monetary policy events (Kohlscheen (2014b).

[14] Considering the coefficients that are significant.

[15] For an analysis of the effects of spot market interventions, with a sample that includes sales of USD, the reader is referred to the study of Barroso (2014).

[16] A snapshot from April 2013 shows that the average daily turnover for outright forwards was 3 times larger than the turnover for spot BRL transactions (Triennal Central Bank Survey 2013, *Bank of International Settlements*). Ventura and Garcia (2012) and Garcia et al. (2014) also point to evidence that highlights the relative importance of the futures FX market in Brazil.

[17] Another difference is that in the case of direct USD auctions only banks can place bids.

Table 3
Conditional volatility equations.

	I	II	III	IV
Constant	2.30 E−09	2.28 E−09	2.26 E−09	2.48 E−09
	1.26	1.35	1.23	1.14
Sigma2 t-1	0.9864**	0.9863**	0.9864**	0.9857**
	546.1	535.2	546.8	513.5
Residual2 t-1	0.0125**	0.0125**	0.0125**	0.0132**
	7.63	7.52	7.63	7.78

Note: ML estimation with Gaussian distribution of error terms. * and ** denote statistical significance at the 5% and 1% confidence levels, respectively.

effects of CPI announcement surprises on the exchange rate are not found to be significant. Dominguez, Fatum and Vacek (2013) also found that this was the case in their study of the Czech Republic, for the full sample estimates.[18]

6. Estimation with a VAR model

The fact that we are working with high-frequency data would normally tend to diminish the risk of simultaneity bias considerably. In principle, however, there is the possibility that, in discretionary intervention regimes as the one that was practiced by the BCB during the period under study, currency swap auctions are a consequence rather than the cause of intraday exchange rate movements. To allow for this possibility, and as a robustness check, we explicitly allow for the possibility that currency swaps react to exchange rate movements. For this, we specify a parsimonious VAR model.[19]

Our (3,1) vector of endogenous variables contains the traditional and the reverse swap announcement variables, as well as the (log) change in the exchange rate. We also include a vector of control variables in the VAR, in order to take intraday commodity price and risk variations into account, as well as reserve purchase operations. We estimated the model with 9 lags for the endogenous variables, as this choice gave the minimum value for the Akaike criterion. The results are based on a standard Cholesky factorization with the ordering traditional swap, reverse swap, exchange rate change. In other words, given that we are working with high-frequency data, we impose that traditional and reverse swap operations do not respond to simultaneous exchange rate movements. The nominal exchange rate, on the other hand, may react to traditional and reverse swap contemporaneously. The ordering also imposes the short-run condition that traditional swaps do not react to reverse swaps contemporaneously.[20] Standard errors were obtained through non-parametric bootstrapping.

The impulse responses following a swap resemble the reactions that were obtained with the GARCH specifications quite closely. In particular, we find that the bulk of the effect of traditional swaps on the exchange rate occurs within the first half hour after the announcement of an auction. We also find the small additional effect, that is again statistically significant, between 1 h and 1 h and half after the announcement, which is likely to be related to the publication of the results. Fig. 2 plots the accumulated orthogonalized impulse responses after a one standard deviation innovation in each of the endogenous variables, with the associated 95% confidence intervals that were obtained via bootstrapping (with 1000 replications). It is interesting to note that the effects of swaps on the exchange rate are found to persist. The estimates suggest that an (unexpected) average traditional swap would lead to a total impact of 79 bps on the exchange rate after 16

[18] These authors use Czech and Euro area inflation announcements.
[19] We thank an anonymous referee for making this suggestion.
[20] We also estimated a Structural VAR in which we imposed the additional short-run condition that reverse swaps do not react to traditional swaps contemporaneously. The LR test clearly does not reject the restrictions in the SVAR. For all practical purposes we obtain the same results as in the VAR, as the estimated correlation between the residuals of the traditional and the residual swap equations is negligible (−0.00062).

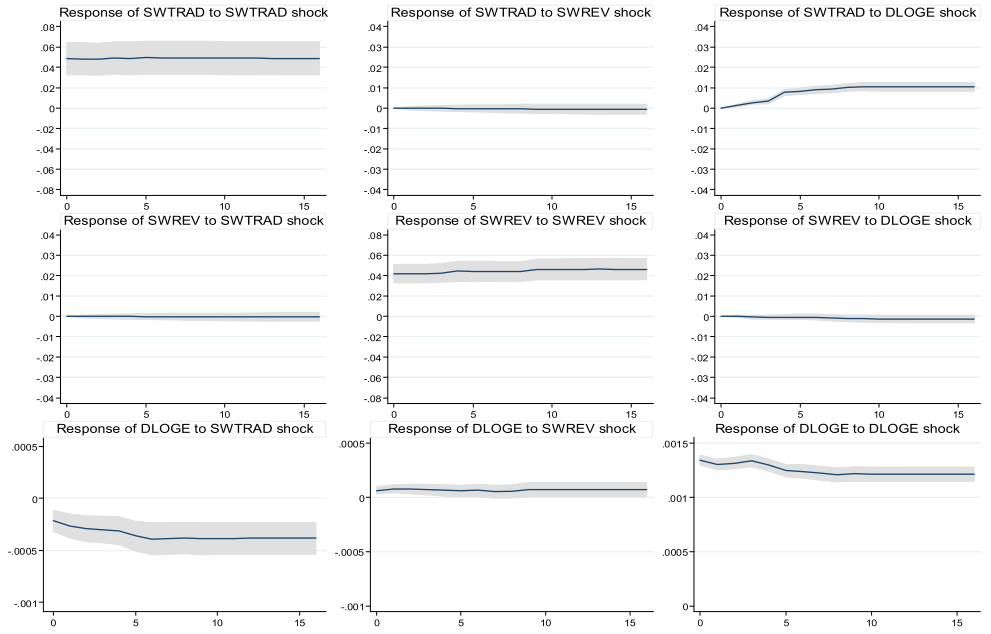

Fig. 2. Accumulated orthogonalized impulse responses after 1 S.D. innovation.

periods. The *t*-statistics for the cumulative effects are −4.83 and 2.15, respectively, for the traditional and the reverse swaps, indicating that the effects are also significant from a statistical viewpoint.

All in all, the agnostic VAR specification that is described above suggests effects of interventions via derivatives that are similar to those found with GARCH models.

7. Robustness

We proceed to report on further checks that were performed to establish whether the results of the two previous Sections are indeed robust. More specifically, we checked whether non-significant variables affect the results in any substantive way, when we use alternative econometric specifications, when we impose alternative error distributions, when we allow for lead intervention variables, when we re-estimate the GARCH model using a less parsimonious specification, when we estimate the model with a much larger number of lags for the intervention variables, when we check for time variation in the coefficients, and when we use only intervention dummy variables.[21]

First, we re-estimated the baseline model using ordinary least squares, ignoring time variations in exchange rate volatility. The results are reported in Table A2. The pattern resembles that found with the GARCH (1,1) specification very closely. The total effects of interventions are found to be marginally smaller, when compared to the ones found with the baseline GARCH model. The Ljung–Box Q statistic however indicates clear autocorrelation in the squared residuals of the model. Note that the *t*-statistics – which are based on Newey–West HAC standard errors – are considerably smaller than under the GARCH specification. This could be an indication that precluding time variations in volatility might lead to inefficient estimates.

[21] Results from this section that are not reported can be obtained upon request.

Second, we re-estimated the GARCH model using alternative error distributions. When we assumed that errors followed a t-student distribution, we found that the pattern of the coefficients resembled the one reported in Table 2. However, the overall fit became much worse: the standard error of the regression and the sum of squared residuals increased, whereas the plain and the adjusted R2 dropped significantly (the latter from 0.0861 to 0.0493). A similar picture also emerged when we imposed a generalized error distribution (GED) instead.[22] Given the much better fit, we decided to keep the Gaussian distribution as our baseline.

Third, we added a lead intervention variable for each type of intervention to the specification of equation (1), to capture possible anticipation effects. This led to insignificant estimates for the $t+1$ variables, with no material changes for the other coefficients.

Fourth, we tested less parsimonious GARCH specifications. More precisely, we checked alternative GARCH(p,q) models, varying p and q up to four. What we found is that increasing the order of the GARCH model did not change the results in any significant way. Since the Bayesian Information Criterion decreased only very marginally when we used the GARCH(2,1) model, and the other coefficients were barely affected, we decided to maintain the more parsimonious GARCH(1,1) model as our baseline.

Fifth, we increased the number of lags of the intervention variables from 6 to 12. None of the added lags was found to be significant and the main findings were unaffected.

Sixth, in order to analyze how coefficients evolved over time, we split the sample in two halves. We then re-estimated the GARCH(1,1) model for each subsample. Of course, the caveat of this exercise is that, by doing so, we obtain estimates that are based on a smaller number of interventions. In particular, the estimated coefficients for the traditional swap auctions during the first period rely on only four events. In qualitative terms, the results for the subsamples resemble the pattern that we find for the complete sample. The effects of reverse purchase auctions and of reverse swaps are larger in the second half of the sample, while the effect of traditional swaps is somewhat smaller. The effect of traditional swaps continues to be the largest among the three by a wide margin.

Finally, we replaced all swap intervention variables by dummies, ignoring the information on volumes. By doing this, the sum of significant traditional swap coefficients reduced from 70.7 bps in our baseline specification to 68.7 bps. On the other hand, for reverse swaps, it increased from 19.8 bps to 20.1 bps. The hypothesis of symmetry continued to be easily rejected with a χ^2 statistic of 26.41.

8. Concluding remarks

This study analyzed the effect of currency swap auctions on the exchange rate. We did so by properly controlling for intraday variations in commodity prices and global risk, as well as for the release of macroeconomic news. Using high-frequency data and information on time-stamped official currency swap auctions in Brazil, we have shown that public auctions of derivatives in Brazil did indeed have a significant effect on the USDBRL rate. Traditional swaps led to systematic appreciations of the local currency whereas reverse swaps led to depreciations. The effects however were clearly asymmetric, as traditional swap auctions (when the Central Bank offers to go short in USD) were found to have a larger impact on the exchange rate. Our results were confirmed separately by GARCH, VAR and OLS models. Invariably, we have found that the bulk of the exchange rate effect occurs within the first 30 min that follow the announcement of an operation.

Future research could aim to investigate whether currency swap auctions in emerging economies also have a systematic effect on variables such as the risk reversal or on onshore USD interest rates. Another extension might consider how the effects change when intervention follows a pre-specified rule.

[22] In this case the adjusted R2 dropped to 0.0378, while the standard error of the regression and the sum of squared residuals increased.

Table A1
Impact of Macroeconomic News on USDBRL Returns.

D.V.: log change in USDBRL rate	
Brazilian GDP Surprise t	−0.1278**
	2.00
Brazilian GDP Surprise t-1	−0.0715**
	3.62
Brazilian GDP Surprise t-2	0.0448
	0.46
Brazilian GDP Surprise t-3	0.0341
	0.65
Brazilian CPI Surprise t	−0.0125
	1.19
Brazilian CPI Surprise t-1	−0.0005
	0.01
Brazilian CPI Surprise t-2	0.0194
	0.53
Brazilian CPI Surprise t-3	−0.0044
	0.15
U.S. GDP Surprise t	−0.0541
	1.39
U.S. GDP Surprise t-1	0.1806**
	2.63
U.S. GDP Surprise t-2	0.0466
	0.30
U.S. GDP Surprise t-3	−0.0031
	0.01
U.S. CPI Surprise t	0.0434
	0.26
U.S. CPI Surprise t-1	0.0471
	0.40
U.S. CPI Surprise t-2	−0.0526
	1.94
U.S. CPI Surprise t-3	−0.0192
	0.06

Note: * and ** denote statistical significance at the 5% and 1% confidence levels, respectively.
All coefficients were multiplied by 100. The sample covers data from 01/01/2011 to 03/31/2013.

Table A2
Impact of swap operations on USDBRL returns – least squares.

D.V.: log change in USDBRL rate	
d (log BRL/USD rate) t-1	−0.034 E2**
	2.60
d (log commodity price index)	−0.133 E2**
	4.74
d (VIX)	0.079**
	4.46
Traditional swap t	−0.445**
	5.90
Traditional swap t-1	−0.122**
	2.08
Traditional swap t-2	−0.069**
	3.32
Traditional swap t-3	−0.017
	0.89
Traditional swap t-4	0.024
	0.88
Traditional swap t-5	−0.094*
	2.11

Table A2 (*continued*)

D.V.: log change in USDBRL rate	
Traditional swap t-6	−0.066
	1.23
Reverse swap t	0.151**
	4.15
Reverse swap t-1	0.039*
	2.56
Reverse swap t-2	−0.016
	0.80
Reverse swap t-3	−0.024
	1.20
Reverse swap t-4	−0.017
	0.81
Reverse swap t-5	−0.016
	0.78
Reverse swap t-6	0.030
	1.58
Constant	Yes
Control for current and lagged reserve purchases	Yes
Lagged macro controls	Yes
Current and lagged news variables	Yes
Significant news variables (at 5%)	GDP
	US GDP
	US CPI
No. of observations	17,044
Sum of traditional swap coefficients	−0.661
Wald stat – traditional	39.84**
Sum of reverse swap coefficients	0.190
Wald stat – reverse	23.20**
Sum of reserve purchase coefficients	0.029
Wald stat – spot	4.35**
Durbin–Watson	1.998
Adjusted R2	0.0907
Log-likelihood	88544.47
Q2 (24)	2372.8**

Note: t-statistics based on HAC standard errors are reported below the coefficients. * and ** denote statistical significance at the 5% and 1% confidence levels, respectively. All coefficients were multiplied by 100.

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