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The Relative Effectiveness of Spot and Derivatives Based Intervention: The Case of Brazil[1]

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Abstract

This paper studies the relative effectiveness of foreign exchange intervention in spot and derivatives markets. We make use of Brazilian data where spot and non-deliverable futures based intervention have been used in tandem for more than a decade. The analysis finds evidence in favor of a significant link between both modes of intervention and the first two moments of the real/dollar exchange rate. As predicted by theory for the case of negligible convertibility risk, the impact of spot market intervention in our baseline sample is strikingly similar to that achieved through futures based intervention worth an equivalent amount in notional principal.

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I. INTRODUCTION

Unconventional monetary policies in advanced economies and volatile capital flows in and out of emerging markets have brought foreign exchange intervention (FXI) back to the forefront of the policy debate. Following the global financial crisis, policymakers argued that unconventional policies in developed economies were causing lending booms in developing economies and threatened their competitiveness.[2] More recently, net capital flows to emerging markets have slowed and turned negative in some instances amid uncertainty about the pace of policy tightening in major advanced economies (IMF, 2016). While flexible exchange rate regimes have facilitated more orderly currency adjustments than during past slowdowns, intervention has been an important part of the policy response, aimed at smoothing the adjustment, avoiding disorderly market conditions or defending against a perceived overshooting.

The effectiveness of sterilized FXI in moving exchange rates has long been under debate. Sterilized intervention should affect neither prices nor interest rates but can drive exchange rates through signaling (Mussa, 1981; Vitale, 1999) and coordination (Taylor, 1995; Taylor and Sarno, 2001) channels as well as when frictions cause agents not to be indifferent between holding assets denominated in different currencies (Branson and Henderson, 1985; Kumhoff, 2010; Gabaix and Maggiori, 2015).[3] Economic theory would thus suggest FXI to be less effective in instances where reserve currency assets are perfect, or at least near-perfect, substitutes for domestic assets. The reason is that sterilized changes in reserves will be offset by an equal and opposite flow of private money. By contrast, in a country with imperfect asset substitutability the offsetting flow may only partially take place or not at all, thus rendering FXI more effective. In countries in which capital mobility is restricted, in turn, FXI could be effective even in the absence of imperfect substitutability (Bayoumi and Saborowski, 2014; Bayoumi et al, 2015).

The earlier empirical literature on the effectiveness of spot intervention focused on developed economies (Dominguez and Frankel, 1993; Humpage, 1999) and provided only limited evidence in favor of a potential relationship between FXI and the exchange rate in all but the very short term (or when interventions were coordinated between major central banks).[4] The findings of more recent cross country studies (Adler et al 2015; Blanchard et al 2015; Fratzscher et al, 2015) that include a large number of emerging economies, in turn, are more supportive of such a link. Similarly, several recent studies of emerging economies confirm that spot FXI may not only impact the exchange rate but also its volatility (Scalia, 2008; Broto,

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[2] See http://www.bbc.com/news/business-11424864.

[3] In addition, the market microstructure literature shows that new information released through FXI can also lead market participants to revise their beliefs in the presence of different types of frictions at the micro level (Lyons, 2006).

[4] The literature on market microstructure in turn finds more supportive evidence for the effectiveness of FXI (Dominguez, 2003; Payne and Vitale, 2003). For a comprehensive survey of the literature see Sarno and Taylor (2001), Neely (2005), Lyons (2006) and Menkhoff (2013).

2013; Fry and Wanaguru, 2013). Nevertheless, it appears that these findings cannot be generalized to all countries and sample periods. (Disyatat and Galati, 2007; Broto, 2013; Catalan-Herrera, 2016).

A less well researched question regards the effectiveness of FXI in derivatives markets. In the 1990s, several Latin American countries (e.g., Brazil, Chile, Mexico and Peru) intervened in foreign exchange markets by issuing debt denominated in, or indexed to, foreign currencies. Since then, intervention in markets for swaps, options and forwards has become part of the policy toolkit in a number of countries amid the development of increasingly liquid markets (e.g. in Brazil, Colombia, India, Indonesia, Mexico, South Africa and Thailand).[5] The relatively scarce empirical literature on the topic finds that derivatives based intervention, similar to spot intervention, can indeed be effective. It includes Kohlscheen and Andrade (2014) who find that auctions of Brazilian non-deliverable FX futures settled in local currency had a significant effect on intra-day exchange rate changes. Chamon et al (2015) show that a program of pre-announced interventions using the same instruments was effective although it appeared not to affect exchange rate volatility. Relatedly, Keefe and Rengifo (2015) show in an event study that FX options based intervention conducted by the Central Bank of Colombia was effective in reducing daily exchange rate volatility. While the literature on derivatives based intervention thus finds evidence supporting the effectiveness of such policies, to our knowledge, there is no study that directly compares the effectiveness of spot and non-spot FXI.

In this paper, we aim to fill this gap by investigating the effectiveness of spot and non-spot FXI in a common empirical framework. In particular, we compare the Brazilian Central Bank's (BCB) FXI in spot markets to its intervention using non-deliverable futures contracts (commonly referred to as FX swaps and Reverse FX swaps). The particular context in Brazil is crucial in allowing a comparison of the two modes of intervention: the Brazilian authorities have used futures based interventions over a long period of time and, importantly, often alongside intervention in spot markets. This variation in the choice of FXI instrument should minimize the learning bias in our data that may arise when agents adapt their actions to the prevailing mode of intervention. In addition, the BCB provides detailed data not only on both modes of intervention but also on instruments that are key to identifying distinct reaction functions for each policy. Finally, the non-deliverable futures contracts the BCB employs settle in local currency and thus offer an interesting opportunity to determine whether the effectiveness of this mode of FXI may be conditional on the absence of convertibility risk (e.g. the risk that capital controls are introduced).

The empirical approach we take in this paper is straightforward. We estimate instrumental variables regressions using daily data to explain changes in the R$-US$ exchange rate as well as its implied volatility. The baseline sample period of 2008–13 reflects data availability, but we also experiment with samples starting as early as 2002 by limiting the set of instruments included in the baseline specification. Our explanatory variables of interest are spot intervention—in billions of U.S. dollars—and futures intervention—in billions of U.S. dollar equivalent of notional principal—defined such that positive values imply that the BCB takes a

[5] See BIS Quarterly Reviews of December 2010, March 2011, and December 2013.

long dollar position. We control for the presence of conditional heteroscedasticity in the data using the continuously updated GMM estimator (CUE, Hansen et al, 1996).

The analysis finds strong evidence in favor of a significant link between intervention through both spot and derivatives markets and changes in the real/dollar exchange rate. Both spot intervention and futures intervention enter the regression significantly and with the expected signs. What is more, the impact of US$1 billion in net spot market intervention changes the real/dollar exchange rate by about 1 percent, an impact that is statistically indistinguishable from the 0.7 percent change achieved through auctions of non-deliverable futures worth US$1 billion in notional principal. This main result of the paper is in line with the theoretical work of Eaton and Turnovsky (1984) who show that spot and forward market intervention have equivalent effects on the spot exchange rate in the absence of convertibility risk (e.g. through capital controls). In contrast, when convertibility risk rises, hedging local positions through futures contracts becomes incomplete, giving rise to a wedge between covered foreign and domestic interest rates and implying that intervention in the forward market no longer equally impacts the spot exchange rate. Our results would thus suggest that convertibility risk has been too limited in our baseline sample to drive a significant wedge between the relative effectiveness of spot and futures market intervention, perhaps in part due to the confluence of other factors (e.g. differences in relative market liquidity, financial intermediary capital constraints, institutional frictions and global shocks) that could generate persistent deviations from covered interest rate parity of either sign. However, in an extended sample we find some evidence suggesting that futures intervention is ineffective in the presence of non-negligible convertibility risk, in line with the contingent local currency claim character of the underlying instrument.

We find that the same result holds when using the change in the implied exchange rate volatility as the dependent variable. Once again, both modes of intervention are statistically significant and enter the regression with the expected coefficient sign. The results imply that US$1 billion in spot dollar sales (or a comparable amount of futures intervention) reduces volatility by some 2.5 percent. We also distinguish interventions in which the BCB takes a short dollar position from those in which it takes a long dollar position. The findings provide tentative evidence suggesting that auctions of futures in which the BCB takes a long dollar position are less effective in depreciating the exchange rate than spot dollar purchases. Finally, there is evidence suggesting that futures intervention is ineffective in the presence of non-negligible convertibility risk, in line with the contingent local currency claim character of the underlying instrument.

The analysis also detects significant differences in the reaction function estimates of the two instruments. The BCB appears to use spot FXI, more so than futures based intervention, in reaction to daily movements in the exchange rate and to resist capital flow pressures. Conversely, it is more likely to use futures based intervention to smooth trend movements in the exchange rate and to react to changes in risk aversion in global financial markets. Finally, we also find that spot rather than derivatives based intervention tends to be used to offset the exchange rate effects of tighter/looser monetary policy.

Our results contribute to the literature in at least two important ways. First, to our knowledge this is the first study analyzing empirically the relative effectiveness of spot and derivatives based intervention in a common framework. By providing evidence suggesting that intervention in derivatives markets can be no less effective than intervention in spot markets, it highlights the advantages of a broader policy toolkit. Second, our study allows comparing central bank reaction functions for spot and derivatives based intervention, allowing us to understand which factors incentivize FXI more generally and one mode of intervention versus the other.

The remainder of this paper is organized as follows: Section II briefly discusses the data and the features of Brazilian foreign exchange interventions, before laying out our empirical specification. Section III outlines the results of the empirical analysis, and Section IV concludes.

II. CONTEXT AND EMPIRICAL SPECIFICATION

FX Intervention in Brazil

Since the adoption of its floating exchange rate regime in January 1999, the BCB has intervened frequently in foreign exchange markets, including through the use of derivatives instruments. Brazil's derivatives markets have developed to rank among the largest in the world amid demand for hedging instruments to cover interest and exchange rate risk given Brazil's history of high inflation, devaluations and high nominal interest rates. Trading volumes in Brazil's derivatives markets are around four times larger than those in its spot market for foreign exchange (Kang and Saborowski, 2014); relatedly, it appears that derivatives markets lead the spot market in price discovery (Garcia et al, 2014).[6] Importantly, the Brazilian exchange regime prohibits financial instruments traded in Brazilian markets from settling in foreign currency with a few exceptions.[7] As a result, policymakers can make use of a highly liquid market for FX derivatives that settle in local currency.

The derivatives instruments most frequently used by policymakers are the so-called Brazilian FX Swaps and Reverse FX Swaps.[8] The instruments were first used in March 2002 and soon replaced dollar linked treasury notes as the preferred mode of non-spot intervention (Bevilaqua

[6] Access to Brazil's spot market is restricted to chartered banks, laws preclude trading the *real* offshore, and domestic bank accounts denominated in foreign currency are forbidden by law.

[7] Brazilian law (Decree-Law No. 857) states that every contract, security, document or obligation, in order to be fulfilled in Brazil, can't stipulate payment in gold or foreign currency, or, in any form, restrict or refuse fulfillment in the Brazilian currency. The exceptions to that law are: currency exchange operations, import/export contracts, export financing (when a Brazilian bank buys, paying in reais, in advance, the amount of foreign currency to be received by an exporter in an export operation) or loans or any obligations in which the creditor or debtor is domiciled outside Brazil.

[8] Brazilian FX Swaps and Reverse FX Swaps are typically auctioned. The BCB announces detailed information prior to each auction, such as the exact time of the auction, the maximum quantity of contracts that the BCB offers, and the maturity. Bidders are allowed to place up to five bids, specifying the quantity and price quotation for the bids. However, every bid-winner pays the same SELIC rate and receives the same cupom cambial and exchange rate variation. The BCB has its discretion to accept any volume of contracts up to the maximum that is on offer.

and Azevedo, 2005). Formally, Brazilian FX swap contracts are structured such that, at maturity, the BCB pays its counterparts the observed exchange rate variation against the dollar plus the ex-ante Cupom Cambial and receives the ex-ante SELIC rate in return.[9] In other words, it makes a positive return if the observed exchange rate depreciation falls short of initial expectations and makes a loss otherwise. By offering a quantity of FX swaps, the BCB thus takes a short dollar position in the markets and expands the availability of hedge to investors with open *real* positions, potentially bidding down the forward exchange rate.[10] The Brazilian Reverse FX swap is structured in the same way except that the BCB takes the long dollar position.

The discussion highlights that the name Brazilian FX swap is somewhat misleading since the instruments are more similar to non-deliverable futures; unlike conventional cross-currency swaps, they do not involve an exchange of notional principal; the crucial difference to conventional non-deliverable futures is that they settle in local currency.[11] One major advantage of intervening via these instruments is thus that the operation does not directly impact the BCB's stock of foreign exchange reserves. From the BCB's counterparts' perspective, however, the fact that the instrument settles in local currency represents a risk to the extent that immediate conversion to hard currency at maturity is less than certain. As a result, using auctions of FX swaps in place of spot dollar sales is likely to be ineffective if convertibility risk is non-negligible. The reason is that investors are unlikely to purchase the derivative contract if they cannot be sure that its proceeds can be converted into dollars at maturity as needed (Kang and Saborowski, 2014). In what follows we frequently refer to FX swaps and Reverse FX swaps as futures based intervention for simplicity.

For the purpose of comparing the effectiveness of the two modes of intervention empirically, two conditions are key: first, developments triggering spot intervention as opposed to futures intervention need to be sufficiently distinct in order to allow for identification when included jointly in a regression; second, the two modes of intervention need to have been used during broadly the same time period in order to minimize the possibility that agents adapt their actions to the prevailing mode of intervention Figure 1 illustrates that these conditions are generally in place in our sample. The chart shows, for instance, that the BCB used both spot purchases and auctions of Reverse FX swaps during the period of 2005–11, presumably to tame appreciation pressures and accumulate reserves; in turn, both spot sales of dollars and auctions of FX swaps were used to stabilize markets during the crisis episodes of 2002/03 and 2008/09.

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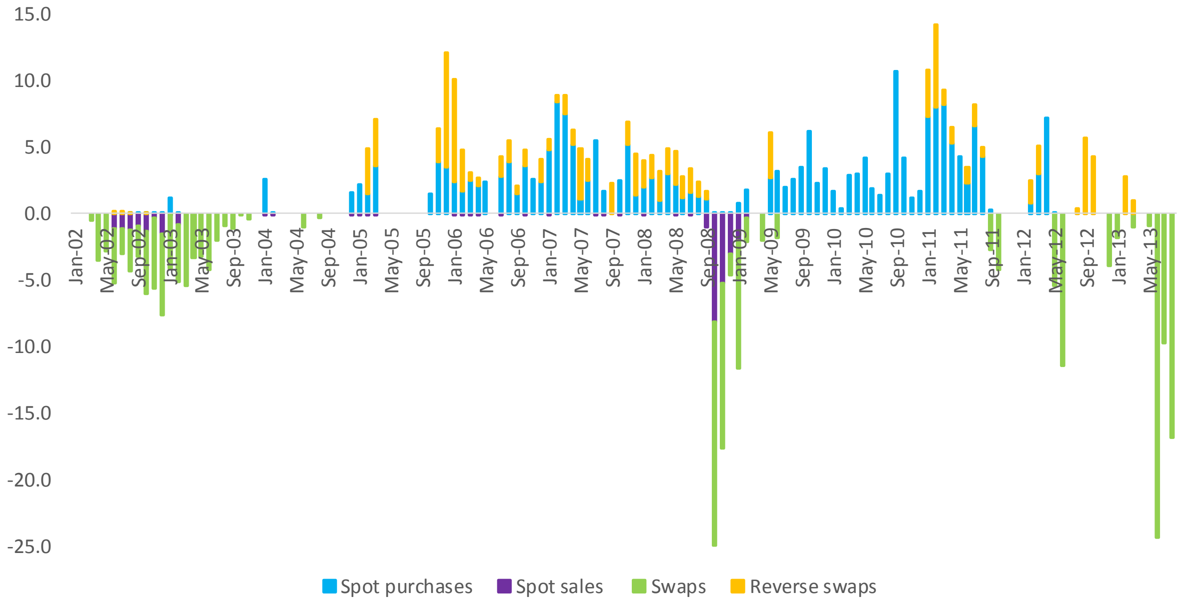
[9] The Selic rate is the BCB overnight rate; the Cupom Cambial is a highly liquid instrument that serves as the onshore dollar interest rate and is priced in basis points equal to the spread between the overnight interbank deposit rate and the expected exchange rate variation.

[10] In addition, the instruments not only transmit price signals but also fill a market gap as futures contracts tend to have shorter maturities and OTC markets offering derivative products with longer maturities are not sufficiently liquid (Kang and Saborowski, 2014).

[11] Another frequently used instrument is the Brazilian FX repo which is akin to a conventional FX swap, resembling a dollar credit line. It has traditionally been used to provide FX liquidity to the market during periods of seasonal shortages.

Only during the market turmoil following the taper tantrum in May 2013 did the central bank use FX swaps alone.

Figure 1. Spot and Brazilian (Reverse) Futures based intervention in Billions of US$ or Notional Principal Equivalent



Notes: The chart shows the evolution of spot and futures based FX intervention. The variables shown are Spot market purchases (*Spot purchases*), spot market sales (*Spot sales*), Short-dollar futures intervention (*Swaps*) and Long-dollar futures intervention (*Reverse swaps*) in billions of U.S. dollars and aggregated at monthly frequency. The futures based intervention variables exclude auctions for roll-over.

Data and Empirical Approach

The sample period used for our baseline regression ranges from September 3rd 2008 to August 21st, 2013. The beginning of the period is determined by data availability. The end point is chosen to be one day before the announcement of the central bank's 2013/14 intervention program. We exclude this most recent episode because the heavy interventions conducted at the time were largely pre-announced months in advance (with rollover rates as the only discretionary factor). Including the episode would have required a distinct empirical approach compared to the one taken in this paper as auctions were likely priced in at the time they occurred (Chamon et al, 2015).

We estimate different variants of a standard intervention model:

$$\Delta y_t = \alpha_i + \sum_{i=1}^{p} \phi_i \Delta y_{t-i} + \sum_{i=0}^{q} \delta_i SWI_{t-i} + \sum_{i=0}^{l} \beta_i SPI_{t-i} + X_t'\gamma + \varepsilon_t \tag{1}$$

$$INT_t = \alpha_i + \sum_{i=1}^{p} \phi_i \Delta y_{t-i} + X_t'\varphi + Z_t'\theta + u_t \tag{2}$$

where Δy_t is the dependent variable defined as the daily percentage change in the nominal R$/US$ exchange rate in the first set of regressions and as the daily percentage change in the implied R$/US$ volatility in the second set of regressions. The exchange rate is defined in units of local currency such that higher values imply a depreciation of the *real* and rising volatility respectively. The specification includes lagged values of the dependent variable, a measure of futures intervention, SWI_{t-i}, a measure of spot intervention, SPI_{t-i}, and a vector of control variables, including year dummies, X_t. All of these variables are defined in Table A1 in the Appendix.

For the remainder of the paper, spot intervention is defined as spot dollar purchases minus spot dollar sales in billions of U.S. dollars. The BCB publishes data on spot sales and purchases at a daily frequency since May 2009 and at a monthly frequency since 2000. In order to allow extending our daily sample back to include earlier episodes of heavy interventions, we construct an estimate of both variables based on daily data the BCB publishes under the heading "Factors conditioning the Monetary Base—External Sector Operations" in combination with the monthly data on spot intervention. In particular, we set the daily spot intervention variable to zero in months during which no intervention took place according to the monthly data; in months during which spot intervention was non-zero, we set the variable equal to the composite of external sector operations, namely the sum of spot, forward, FX repo and FX loan operations. While the variable is thus not a fully clean proxy for spot intervention in the earlier data, it would provide the best possible option for extending the sample.[12]

Detailed data on FX swap and FX Reverse swap auctions is available from the BCB at a daily frequency since 2002. We define the futures intervention term as the notional principal entailed in auctions of Reverse FX swaps minus that entailed in announcements of FX swap auctions in billions of U.S. dollars.[13,14] In other words, in line with the spot intervention term, futures intervention takes positive values when the BCB takes long dollar positions and negative values when it takes short dollar positions. Importantly, the magnitudes of the two variables are comparable in the following sense: US$1 of negative spot intervention (spot sales) takes US$1 of Brazilian *real* exposure off of investors' books; similarly, US$1 of futures intervention takes US$1 of Brazilian *real* exposure off of investors' books, although only temporarily and conditional on the absence of convertibility risk.

The main empirical challenge in studying the effectiveness of FXI is the endogeneity of the intervention terms to the contemporaneous movements in the exchange rate. To identify exogenous variation in both types of intervention we rely on the continuously updated generalized method of moments estimator (CUE). The method uses a vector of instruments Z_t

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[12] When aggregating our spot intervention proxy at monthly frequency, it has a correlation of 97 percent with the monthly spot market intervention data available from the BCB in the baseline sample period. In the extended sample (going back to 2001), the correlation is 86 percent.

[13] Auctions tend to be announced a day in advance and settled several days later.

[14] We exclude FX swaps and reverse FX swaps auctioned to roll over existing swap contracts. The reason is that these could drive the exchange rate in either direction, depending on whether the roll-over rate surprised the market on the up- or the downside.

for the vector of endogeneous variables given in Equation 2, where INT_t is a two-dimensional vector of the two modes of intervention. CUE estimates are robust to conditional heteroscedasticity and tend to perform better than the standard two-stage least squares (2SLS) estimator in finite samples and in the presence of weak instruments (Hahn et al., 2004). Nevertheless, we also estimate Equations (1–2) using a 2SLS estimator for robustness.

Finding appropriate instruments for the two FXI terms is particularly challenging in our setup as candidate terms not only need to fulfill standard requirements for instruments; it is also essential that they allow identifying separate reaction functions that are sufficiently distinct to permit including the two modes of intervention jointly in our regressions. In part following the literature on spot interventions (see, inter alia, Ito and Yabu, 2007, Fatum and Hutchison, 2010), we include the following terms in our vector of instruments: (i) lagged trend exchange rate volatility, (ii) lagged exchange rate deviations from trend, (iii) lagged one year moving average of the exchange rate, (iv) the change in the monetary policy rate, (v) trend spot and futures intervention, and (vi) lagged trend FX flows.[15]

The first three terms capture the hypothesis that central banks react to exchange rate developments in various forms. The change in the local policy rate, in turn, captures potential linkages between monetary and foreign exchange intervention policies (Gnabo et al, 2010). The two trend intervention terms account for persistence in intervention, for instance during periods of trend appreciation. Finally, the trend FX flows variable captures net foreign exchange flows into Brazil. The intuition here is similar to that of the 'exchange rate deviation from trend' term. However, including the FX flows term separately aims to better distinguish flow pressures on the exchange rate from pure price pressures based on the hypothesis that the BCB may have a higher propensity to react to what it perceives as flow pressures using spot rather than derivatives based intervention. The term indeed turns out to be particularly important in distinguishing the reaction functions for spot and futures intervention. Our instruments pass a battery of validity and weak exogeneity tests.[16]

In selecting the vector of control variables X_t we follow the literature while trying to keep the specification parsimonious. In particular, our benchmark choice of controls includes: (i) the daily percent change in the Thomson Reuters Core Commodity (CRB) price index (both current and lagged), (ii) the daily percent change in the Chicago Board Options Exchange Market Volatility Index (VIX, both current and lagged), (iii) the lagged average change in the expected exchange rate depreciation over the coming 3 months (based on spot and forward rate differentials) and (iv) the lagged daily percentage change in the five year sovereign CDS spread for Brazil. The first two controls capture the importance of commodity prices (see also Kohlscheen and Andrade, 2014) and global risk aversion (Forbes and Warnock, 2012; Rey, 2013). The latter two control for the impact of changes in depreciation expectations and changes in investor perceptions of country risk (Della Corte et al, 2015); they enter only in lags to avoid potential endogeneity concerns. In the robustness section, we add several alternative

[15] All trend variables reflect short-term trends and are defined over a two-week window.

[16] In the robustness checks we include several alternative instruments and vary the moving average window for our benchmark instruments with no significant impact on the results.

controls (day of the week effects, local macroeconomic news surprises, regional and EM news sentiment, actual interest rate differential) with no impact on our results.

III. ESTIMATION RESULTS

The estimation section is divided into three parts: the first shows estimates of reaction functions for both types of intervention; the second presents estimates for regressions that use changes in the real/dollar exchange rate as the dependent variable; the third runs a similar set of regressions but uses the implied volatility in the exchange rate as the dependent variable. In the two latter sections, we ask whether or not one or both of the two modes of intervention are effective in the sense that we can establish a causal link to the dependent variable. Assuming that this first question can be answered with the affirmative, we ask whether one mode is more effective than the other.

III.1 REACTION FUNCTION ESTIMATES

We begin our analysis by estimating central bank reaction function for both types of intervention. The instruments and control variables are those discussed in the previous section and defined in Table A1. The estimates of the reaction functions are reported in Table 1. All estimations report White's (1980) heteroscedasticity-consistent (robust) standard errors. The first two columns show the estimated reaction functions for the spot and futures based interventions using the CUE estimator. The following two columns report the 2SLS results, which, as expected, differ only marginally. The first six explanatory variables in the table are the second stage control variables included in X while the bottom six variables are the instruments.[17]

Estimated coefficients for the instruments generally carry the expected signs throughout the regressions in Table 1 and are statistically significant for at least one of the two modes of intervention. Moreover, the model diagnostics at the bottom of Table 1 suggest that the instruments are valid. Kleibergen and Paap's (2006) rank LM statistic strongly rejects the null hypothesis that the model is unidentified. In addition, the instruments pass weak identification tests. Kleibergen and Paap's (2006) Wald F statistic significantly exceeds the Stock and Yogo (2005) threshold of maximum size distortions.[18] We also compute Sanderson and Windmeijer's (2016) conditional F-test which additionally controls for cross-effects of multiple endogenous regressors. The results from the test strongly reject the weak instrument hypothesis.

We now move to discussing the first-stage coefficient estimates in detail. The estimates in Table 1 would suggest that the two modes of intervention react to short-term trends in the nominal exchange rate and excessive FX volatility in the expected direction: the BCB would take short dollar positions when the *real* is depreciating or when volatility is elevated and long

[17] Estimated coefficients for further lags of the control variables were not statistically significant in the joint estimation and are dropped from the analysis.

[18] The Wald F statistic results may not be fully accurate as the critical values are tabulated under the assumption of conditional homoscedasticity in the regression errors. Nevertheless, the strong rejection of the null hypothesis as well as the results from the Sanderson and Windmeijer (2015) conditional F-test imply that these concerns should be small.

dollar positions in the opposite case. In contrast, the response to the remaining variables differs notably between the two modes of intervention.

Table 1. First-Stage Regressions

	Spot	Futures	Spot	Futures	Spot	Futures
Lagged daily pct change in FX	-0.019*	0.012	-0.019*	0.012	-0.003	-0.005
	(0.01)	(0.02)	(0.01)	(0.01)	(0.07)	(0.05)
CRB index, percent change	0.027	0.018	0.027	0.018	-0.16	0.133
	(0.02)	(0.02)	(0.02)	(0.02)	(0.12)	(0.13)
CRB index, lagged percent change	-0.025	-0.029	-0.025	-0.029	-0.06	0.007
	(0.03)	(0.02)	(0.03)	(0.03)	(0.14)	(0.11)
VIX, percent change	0	-0.004**	0	-0.004**	-0.002	-0.017*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
VIX, lagged percent change	0.002	0	0.002	0	0.001	-0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
Trend spot forward differential	-0.047***	0.008	-0.047**	0.008	-0.413**	0.089
	(0.02)	(0.01)	(0.02)	(0.01)	(0.20)	(0.06)
5Y sovereign CDS return, lagged	-0.002	-0.016***	-0.002	-0.016**	-0.019	-0.053***
	(0.00)	(0.01)	(0.00)	(0.01)	(0.02)	(0.02)
Lagged pct FX deviation from trend	-1.115*	-2.741***	-1.115**	-2.741***	-11.689**	-16.992***
	(0.64)	(0.89)	(0.53)	(0.87)	(5.30)	(3.27)
Medium-run FX trend	-0.253	-0.758**	-0.253	-0.758**	-0.254	-2.872***
	(0.20)	(0.32)	(0.32)	(0.36)	(0.57)	(1.01)
Lagged trend FX volatility	-0.009***	-0.014***	-0.009***	-0.014***	0.018	-0.034***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
Lagged trend FX transactions	0.000***	0	0.000***	0	0.000***	0
	0.00	0.00	0.00	0.00	0.00	0.00
Policy rate change	0.616***	-0.012	0.616***	-0.012	3.665***	-0.906
	(0.16)	(0.33)	(0.18)	(0.30)	(0.99)	(1.47)
Trend spot intervention, lagged	0.168**	-0.126*	0.168	-0.126**	2.476***	0.453***
	(0.08)	(0.07)	(0.11)	(0.06)	(0.16)	(0.14)
Trend futures intervention, lagged	-0.022	0.399***	-0.022	0.399***	0.271	2.372***
	(0.04)	(0.12)	(0.04)	(0.13)	(0.34)	(0.34)
Constant	0.291*	0.500**	0.291	0.500**		
	(0.15)	(0.22)	(0.23)	(0.25)		
N	1,100	1,100	1,100	1,100	1,100	1,100
F test	12.6 (0.00)	8.6 (0.00)	11.7 (0.00)	8.5 (0.00)	-	-
Kleibergen-Paap rk Wald F	12.6	8.6	11.7	8.5	-	-
Sanderson-Windmeijer F test	7.4 (0.00)	13.1 (0.00)	6.5 (0.00)	11.3 (0.00)	-	-
Kleibergen-Paap rk LM	71.1 (0.00)	47.3 (0.00)	17.8 (0.01)	24.7 (0.00)	-	-
Mc Fadden's R^2					0.485	0.407

Notes: The dependent variable in columns 1 and 3 is *spot intervention* - in billions of U.S. dollars – while the dependent variable in columns 2 and 4 is *futures intervention* - in billions of U.S. dollar equivalent of notional principal – defined such that positive values imply that the BCB takes a long dollar position. The dependent variable in columns 5 (spot) and 6 (futures) takes the value +1 when the BCB takes a long dollar position, -1 for when it takes a short dollar position; and 0 in the absence of intervention. Explanatory variables are defined in Table A1. The first two columns report estimates using CUE, column three and four report estimates using 2SLS, the last two columns report estimates from an ordered probit. Heteroscedasticity robust standard errors in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level. For test statistics p-values are reported in parentheses.

First, the lagged change in the monetary policy rate is significantly positively associated only with spot intervention, suggesting that spot rather than futures intervention tends to be used to offset the exchange rate effects of tighter/looser monetary policy. Second, spot intervention appears to be used more in response to short-term movements in the exchange rate, as suggested by the signs and the significance of the coefficients on the daily change in the exchange rate and the expected depreciation term; futures intervention, in turn, appears to be used to smooth medium-term exchange rate trends (see one year moving average term). Third, the BCB responds to changes in country risk and global risk aversion through futures based intervention (the reaction of spot intervention has the expected sign but is not statistically significant). Fourth, the lagged trend FX transactions variable enters the spot regressions significantly with a positive coefficient while its coefficient is not significant in the futures regressions. This suggests that spot intervention is the mode of choice when responding to actual currency outflows rather than purely price based pressures on the exchange rate. Finally, there is evidence that both spot and futures intervention tend to cluster as illustrated by the positive and significant coefficient on their lagged moving averages. Conversely, the relationship between spot (futures) intervention and lagged futures (spot) intervention is, if anything, negative, although rarely significantly so.

In sum, the BCB appears to react to daily movements in the foreign exchange market and perceived flow pressures using spot interventions. On the other hand, futures interventions appear to be primarily used in reaction to trend movements in the exchange rate as well as to changes in country and global risk perceptions.

We perform several robustness checks of the reaction function results. Table A2 in the Appendix presents the estimates of the reaction functions when additional instruments are included and when the window over which the short term trend variables are calculated varies. Although some of the additional instruments are significant in the first stage regressions, this does not change the significance or the magnitudes of the coefficients of the baseline regressors.[19] In addition, Table A3 shows that changes in the instrument set do not impact the second stage results. Another potential concern is that the multiple zeros in the dependent variables in the reaction function regressions may bias the linear regression estimates. To assess the importance of this potential bias, Columns 5 and 6 of Table 1 report estimates from an Ordered Probit model (Ito and Yabu, 2007).[20] While the magnitudes of the estimated coefficients are not directly comparable to the linear regression estimates, we confirm that neither the significance of the key variables nor their signs change much.[21]

[19] For space considerations Table A2 and A3 do not report results from regressions using local macroeconomic news as instruments as the results remain the same as in the baseline.

[20] Ito and Yabu (2007) show that the ordered probit specification can be interpreted as a linearized version of the general friction model of central bank intervention (Almekinders and Eijffinger, 1996).

[21] The only relevant difference is that the Ordered Probit model reduces the importance of the daily change in the exchange rate and FX volatility in the spot intervention regressions.

III.2 INTERVENTION AND EXCHANGE RATE CHANGES

The second stage results of our baseline regressions for the exchange rate changes equation (1) are summarized in Table 2. Columns 1 to 3 use the CUE estimator, Columns 4 to 6 use the 2SLS estimator and Column 7 uses simple OLS. In order to allow for delayed impacts of our control variables, we include them either as moving averages or with both their contemporaneous and lagged values.[22]

Table 2. Second-Stage Regressions

	1	2	3	4	5	6	7
Lagged daily pct change in FX	-0.053	-0.121*	-0.141**	-0.148*	-0.171**	-0.158**	-0.167**
	(0.06)	(0.07)	(0.07)	(0.08)	(0.08)	(0.07)	(0.07)
CRB index, percent change	-0.161*	-0.1	-0.138	-0.112	-0.097	-0.119	-0.064
	(0.10)	(0.10)	(0.10)	(0.08)	(0.11)	(0.11)	(0.10)
CRB index, lagged percent change	-0.406***	-0.435***	-0.420***	-0.413***	-0.421***	-0.415***	-0.423***
	(0.08)	(0.08)	(0.08)	(0.10)	(0.08)	(0.08)	(0.08)
VIX, percent change	0.012**	0.016***	0.012**	0.012*	0.015**	0.014**	0.013**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
VIX, lagged percent change	-0.009	-0.006	-0.009	-0.009*	-0.008	-0.009*	-0.006
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Trend FX forward differential	0.147***	0.087**	0.164***	0.146***	0.073*	0.130***	0.047
	(0.05)	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)	(0.04)
5Y sovereign CDS return, lagged	0.112***	0.118***	0.111***	0.106***	0.118***	0.116***	0.104***
	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)
Spot intervention	1.026**		1.009**	1.294***		0.748*	0.248
	(0.49)		(0.49)	(0.43)		(0.42)	(0.21)
Futures intervention		0.973**	0.729**		0.876**	0.680*	-0.127**
		(0.39)	(0.37)		(0.38)	(0.37)	(0.06)
Constant	-0.024	0.227**	0.148	-0.016	0.256**	0.171	0.082
	(0.05)	(0.11)	(0.11)	(0.05)	(0.12)	(0.12)	(0.31)
R^2	0.23	0.11	0.15	0.23	0.14	0.18	0.28
N	1,100	1,100	1,100	1,100	1,100	1,100	1,100
Hansen’s J stat.	8.4 (0.21)	8.8 (0.19)	5.2 (0.40)	8.5 (0.20)	12.1 (0.06)	9.3 (0.10)	
Kl.-Paap rk Wald F stat	12.6	8.6	7.8	11.7	8.5	6.1	
Kl.-Paap rk LM stat	71.1 (0.00)	47.3 (0.00)	49.2 (0.00)	17.8 (0.01)	24.7 (0.00)	22.7 (0.00)	
Stock-Wright LM S stat	21.4 (0.00)	21.4 (0.00)	21.4 (0.00)	21.0 (0.00)	22.4 (0.00)	23.5 (0.00)	
C test for endogeneity	15.0 (0.04)	15.0 (0.04)	15.0 (0.04)	23.4 (0.00)	21.4 (0.00)	24.1 (0.00)	
Wald statistic			0.17 (0.67)			0.01 (0.92)	

Notes: The dependent variables is the percent daily change in the R$/US$ rate. Explanatory variables are defined in Table A1. Regressions 1-3 report estimates using CUE, regressions 4-6 report estimates using 2SLS, regression 7 reports OLS estimates. Heteroscedasticity robust standard errors in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level. For test statistics p-values are reported in parentheses. Wald statistic tests the null hypothesis of equality of the spot and futures intervention coefficients.

[22] Estimated coefficients for further lags of the control variables were not statistically significant in the joint estimation and are dropped from the analysis.

We begin by including the intervention terms separately in the regressions. The first regression in Table 2 shows that the spot intervention term is highly significant and carries the expected positive coefficient. Taken at face value, the coefficient of 1.03 suggests that US$1 billion of spot purchases (sells) would depreciate (appreciate) the exchange rate by 1.03 percent. Similarly, Regression 2 would suggest that futures intervention is a highly significant determinant of the real/dollar exchange rate, with futures intervention worth US$1 billion in notional equivalent moving the exchange rate by some 0.97 percent. Interestingly, these results not only suggest that both modes of intervention are highly significant determinants of the exchange rate, but their impacts on average are also very similar. The third regression in Table 2 includes both intervention terms in the regression simultaneously. Of crucial importance at this point is the fact that our instruments identify central bank reaction functions that are sufficiently distinct to permit including the two variables jointly in a single regression. The results in Column 3 confirm those from the first two regressions: while both coefficients are now somewhat smaller, they are still strikingly similar at 1 and 0.7 respectively, and the two variables remain highly significant. Indeed, the Wald-test cannot reject the null hypothesis the two coefficients are equal.

The estimated coefficients on the control variables are in line with theory, and they are frequently significant at conventional levels. Across Table 2, we find that the lagged dependent variable is significant with a negative coefficient. The commodity price index and its lag both carry the expected negative coefficient, indicating that rising commodity prices are associated with an appreciating *real*, but only the lagged term is consistently significant. The VIX term carries a positive coefficient and is highly significant as we would expect, suggesting that risk aversion in global financial markets is associated with depreciating exchange rates in emerging markets and the effect appears to be contemporaneous. Similarly, lagged depreciation expectations and a rise in the country risk are associated with *real* depreciation.

The bottom five columns of Table 2 show that the baseline specification passes the J-test of overidentifying restrictions as well as the underidentification and weak identification tests. The Stock and Wright LM statistic, in addition, confirms that the impact of the interventions is significant even if we allow for the case of weak instruments. Finally, the C-test for endogeneity confirms that both types of interventions are endogenous to contemporaneous movements in the exchange rate. To assess the sensitivity of the results to our choice of estimator, Regressions 4 to 6 present the same regressions as in Columns 1 to 3 except that we now use the 2SLS estimator in place of our preferred CUE estimator. The results are barely affected by this specification change except that the magnitudes of the estimated coefficients for the intervention variables are slightly smaller when included jointly. Finally, in Column 7, we run the same regression as in Columns 3 and 6 except that we depart from the use of instruments and run a simple OLS regression of the percentage change in the exchange rate on the two intervention terms and controls. The coefficients on both terms become substantially smaller and turn negative in the case of futures intervention. This is in line with the results from the endogeneity test since theory would predict that the OLS regression without instruments would likely introduce a negative bias in the estimated coefficients.[23]

We extend our baseline specification in several directions. The results are presented in Table 3. *First*, we extend the sample to 2002, the first year for which the futures intervention data is available. As we move the start date back to 2002 we lose the FX transactions instrument (which plays an important role in ensuring that the reaction function for the two modes of intervention are sufficiently distinct) as well as the implied volatility term due to lack of data availability. In place of lagged trend exchange rate volatility we now include an alternative forward-looking proxy of uncertainty in the FX market, namely the lagged trend difference between the onshore and offshore forward rate. The data for this variable is available from 2002, and is highly correlated with the volatility series (sample correlation 0.47 over the period).[24] The first two columns in Table 3 show that our main findings continue to hold in that both modes of intervention appear to be significant drivers of the exchange rate with only somewhat lower coefficients than before (0.83–0.92 for spot intervention and 0.55–0.58 for futures intervention).[25] The results in the first column, however, indicate that the specification does not pass the J-test. The second column shows that excluding the potentially problematic instrument (the long-run trend in the exchange rate—as suggested by the J-test) does not change the results.

Second, an important advantage of extending the sample period back to 2002 is that it allows us to test whether futures intervention loses its effectiveness in the presence of non-negligible convertibility risk. As discussed earlier, FX swap contracts settle in local currency. As such, they only provide effective hedge against currency movements to the extent that their holder is able to convert the proceeds at the time of maturity. In other words, we would expect futures intervention to be ineffective in the presence of non-negligible convertibility risk. In order to test this prediction, we define a dummy variable denoted "Convertibility Risk" that takes the value 1 on days on which the three-month onshore dollar interest rate (cupom cambial) was 1.5 standard deviations above its sample mean.[26,27] Including this variable alongside its interaction with futures intervention in Regression 3–4, we indeed find tentative evidence for our hypothesis: the interaction term is highly significant with a negative coefficient, indicating

[23] A negative bias would result if the BCB responds to a depreciating (appreciating) exchange rate by taking short (long) dollar positions.

[24] The variable also passes the instrument redundancy test.

[25] The results from individual intervention regressions are also in line with the findings in the baseline regressions.

[26] It is important to note that changes in the cupom cambial do not necessarily reflect convertibility risk, although large shifts relative to offshore dollar interest rates are likely attributable to it.

[27] The results do not change if we use a higher or lower threshold (2 instead of 1 standard deviation) or if we use the spread between the cupom cambial and the three month US$ Libor rate in place of the cupom cambial. Figure A1 in the Appendix shows that the period of heightened convertibility risk broadly matches the crisis episode of 2002/03.

that futures intervention becomes less significant when convertibility risk is high.[28] In fact, the combined coefficient of futures intervention and the interaction term turns negative, suggesting that futures intervention moves the exchange rate *with the wind* in such an environment.

Third, our baseline specification implicitly assumes that the impact of both types of interventions is symmetric. To allow for asymmetric effects we interact our intervention variables with a dummy variable denoted “Spot (Futures) Positive” that takes the value one on days when the BCB takes long dollar positions. Column five of Table 3 presents the estimates of regressions in which we use the interaction of “Spot (Futures) Positive” with lagged trend exchange rate volatility and trend intervention as additional instruments for the interaction terms.[29] The coefficient for the spot intervention interaction term is negative, but not statistically significant indicating that spot FXI has a broadly symmetric impact on exchange rate changes. The coefficient for the futures intervention interaction term, on the other hand, is negative and statistically significant, suggesting that derivatives based interventions are more effective when the BCB takes short dollar positions. The tentative evidence of asymmetries in the effects of futures interventions corroborates the findings of Kohlscheen and Andrade (2014) who show that FX swap auctions (“Futures negative”) have much stronger impacts relative to Reverse FX swaps (“Futures positive”) in their high frequency setting. The result may reflect the fact that the Brazilian foreign exchange market, as is the case in most other EMs, lacks sufficient depth in FX hedging instruments with long maturities. Futures based intervention may thus fill a market gap by providing hedging opportunities that would otherwise not exist in sufficient quantity. The resulting impact on exchange rates may be higher than the one that would materialize if the central bank simply took a position in an already existing market. Since in Brazil private foreign liabilities in local currency grossly exceed private domestic assets in foreign currency (such that downside risks for private investors are more likely to arise in the form of depreciations), this effect may be more relevant for private market participants when the central bank takes a short dollar position.

The final regression of Table 3 allows for a dynamic impact of the interventions. In addition to the instrumented contemporaneous value of interventions we add the first five lags of each intervention to the specification, however only the coefficients for the first lag of the futures intervention term and the first two lags of the spot intervention term turn out to be significant. Column 6 in Table 3 reports the cumulative impact of both types of intervention together with the Wald test of the null hypothesis of no difference in the cumulative effects. The results again suggest that both modes of intervention have significant and quite similar impacts on exchange rate changes.

[28] We interact the instruments with the convertibility risk dummy to obtain instruments for the interaction term.

[29] Both additional instruments enter the first stage regressions of the interaction terms significantly and pass the instrument validity tests.

Table 3. Second-Stage Regressions: Additional Results

	1	2	3	4	5	6
Lagged daily pct change in FX	-0.082*	-0.077*	-0.079*	-0.066	-0.120**	-0.197**
	(0.05)	(0.05)	(0.04)	(0.04)	(0.06)	(0.08)
CRB index, percent change	-0.177**	-0.166**	-0.179***	-0.182***	-0.142	-0.111
	(0.07)	(0.07)	(0.07)	(0.07)	(0.09)	(0.11)
CRB index, lagged percent change	-0.353***	-0.356***	-0.362***	-0.358***	-0.402***	-0.449***
	(0.06)	(0.06)	(0.06)	(0.06)	(0.09)	(0.08)
VIX, percent change	0.006	0.007	0.006	0.007*	0.011*	0.015**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
VIX, lagged percent change	-0.001	-0.002	0.001	0	-0.008	-0.008
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Trend spot forward differential	0.164***	0.180***	0.163***	0.175***	0.159***	0.093
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)
5Y sovereign CDS return, lagged	0.091***	0.096***	0.090***	0.093***	0.103***	0.121***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Spot intervention	0.927*	0.831*	0.892*	0.781*	2.140**	0.839**
	(0.48)	(0.48)	(0.46)	(0.46)	(1.01)	(0.35)
Futures intervention	0.582*	0.556*	0.651**	0.512*	0.693*	0.926**
	(0.34)	(0.34)	(0.32)	(0.32)	(0.36)	(0.46)
Conv. Risk * Futures intervention			-2.179*	-2.269*		
			(1.29)	(1.34)		
Convertibility Risk			0.066	0.032		
			(0.66)	(0.65)		
Spot positive * Spot intervention					-1.188	
					(1.11)	
Swap positive * Futures intervention					-0.936**	
					(0.38)	
Constant	0.136	0.105	0.153	0.094	0.166	0.186
	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.12)
R^2	0.14	0.15	0.14	0.17	0.16	-0.03
N	2,202	2,202	2,202	2,202	1,100	1,068
Hansen's J stat.	13.9 (0.01)	4.4 (0.23)	17.3 (0.04)	7.7 (0.36)	8.0 (0.33)	4.6 (0.47)
Kl.-Paap rk Wald F stat	9.6	11.4	5.7	6.7	7.3	3.7
Kl.-Paap rk LM stat	54.9 (0.00)	53.7 (0.00)	64.2 (0.00)	63.0 (0.00)	72.0 (0.000)	24.5 (0.000)
Stock-Wright LM S stat	26.0 (0.00)	17.8 (0.00)	32.0 (0.00)	23.0 (0.01)	31.0 (0.00)	24.1 (0.00)
C test for endogeneity	23.1 (0.00)	11.5 (0.04)	29.5 (0.00)	16.1 (0.10)	26.4 (0.01)	15.4 (0.03)
Wald statistic	0.20(0.66)	0.30 (0.58)				0.04(0.85)
Wald statistic – short USD					1.80 (0.17)	
Wald statistic – long USD					6.01 (0.01)	

Notes: The dependent variables is the percent daily change in the R$/US$ rate. The *Convertibility Risk* variable takes the value one on days on which the three month local interest rate (cupom cambial) was 1.5 standard deviations above its sample mean. The *Spot* (*Swap*) *positive* dummy takes the value one on days when the BCB takes a long dollar position via the respective mode of intervention. Other explanatory variables are defined in Table A1. All regressions report estimates using CUE. Regressions 2 and 4 exclude the medium-run FX trend from the instrument set. The coefficients for *spot* and *futures intervention* in Regression 6 are cumulative effects. Heteroscedasticity robust standard errors in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level. For test statistics p-values are reported in parentheses. Wald statistic tests the null hypothesis of the equality of the spot and futures intervention coefficients. Wald statistic – short USD tests the null hypothesis of equality of the spot and futures intervention coefficients. Wald statistic – long USD tests the null hypothesis of equality of the sum of the level and interaction term coefficients for spot and futures interventions.

Table 4 includes a battery of robustness checks of our baseline specification, including one additional regressor at a time. Regression 1 repeats our baseline specification. Regression 2 includes Brazilian macroeconomic announcement surprises (for inflation, unemployment and industrial production). Regressions 3 and 4 include the Citi EM Economic Surprise Index and the Citi Latin America Economic Surprise Index, respectively, in the specification alongside their respective lags. Neither variable appears to add much to the regressions' explanatory power and neither variable changes our results in a notable way. The same is the case when we add additional lags of the dependent variable (Regression 5).[30] Regression 6 adds the actual interest rate differential and once again our results are unchanged. Finally, Regression 7 drops all remaining insignificant variables from the regression without affecting our findings.

In sum, we find that spot and futures based interventions have very similar impacts on the exchange rate. This main result of the paper is in line with the theoretical work of Eaton and Turnovsky (1984) who show that spot and forward market intervention have equivalent effects on the spot exchange rate in the absence of convertibility risk (e.g. through capital controls). Our finding suggests that episodes of non-negligible convertibility risk are rare and have thus only a limited impact on the regression coefficients (Figure A1). Similarly, the finite nature of the futures contracts does not seem to weaken the relative effectiveness of futures based intervention in Brazil significantly, suggesting that the maturities are sufficiently long to limit the associated roll-over risk for FX investors.

III.3 INTERVENTION AND IMPLIED EXCHANGE RATE VOLATILITY

The final part of the empirical analysis examines a potential role for the two modes of FXI in reducing exchange rate volatility. Indeed, containing FX volatility was named a prime motive for FXI in a recent BIS survey of EM central banks (Mohanty and Berger, 2013). Short of targeting a specific exchange rate level or range, a role for FXI in limiting volatility in foreign exchange markets may arise in the form of limiting private sector exposure to FX risk. When private foreign liabilities in local currency grossly exceed private domestic assets in foreign currency (as is the case in Brazil), downside risks for private investors are more likely to arise in the form of depreciations rather than appreciations. It is thus through reducing its own net long position in foreign exchange that the central bank can limit private sector FX risk during periods of high volatility. Testing the relevance of this link and comparing the relative effectiveness of the two modes of intervention is the focus of this sub-section.

[30] We report coefficient only for the second lag but the regression includes up to four lags which were all insignificant. We also included day-of-the-week dummies (not reported), with no effect on our results.

Table 4. Robustness Checks

	1	2	3	4	5	6	7
Lagged daily pct change in FX	-0.141**	-0.140**	-0.139**	-0.138**	-0.152**	-0.163**	-0.142**
	(0.07)	(0.07)	(0.07)	(0.06)	(0.06)	(0.06)	(0.06)
CRB index, percent change	(0.14)	(0.14)	(0.15)	(0.16)	(0.12)	(0.12)	
	(0.10)	(0.10)	(0.10)	(0.10)	(0.09)	(0.10)	
CRB index, lagged percent change	-0.420***	-0.423***	-0.432***	-0.418***	-0.415***	-0.424***	-0.416***
	(0.08)	(0.08)	(0.09)	(0.09)	(0.08)	(0.09)	(0.08)
VIX, percent change	0.012**	0.012**	0.012**	0.011*	0.01	0.012*	0.017***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
VIX, lagged percent change	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	
Trend spot forward differential	0.164***	0.163***	0.166***	0.184***	0.177***	0.137***	0.161***
	(0.05)	(0.05)	(0.06)	(0.06)	(0.06)	(0.05)	(0.05)
5Y sov. CDS return, lagged	0.111***	0.111***	0.109***	0.109***	0.107***	0.114***	0.103***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)
Spot intervention	1.009**	1.005**	1.090**	1.223**	1.072**	0.900*	0.934*
	(0.49)	(0.49)	(0.52)	(0.56)	(0.49)	(0.51)	(0.48)
Futures intervention	0.729**	0.729*	0.711*	0.670*	0.733**	0.944***	0.660*
	(0.37)	(0.37)	(0.39)	(0.38)	(0.35)	(0.36)	(0.37)
Inflation surprise		0.46					
		(2.03)					
Unemployment surprise		(0.13)					
		(0.41)					
Industrial production surprise		(0.08)					
		(0.09)					
Citi EM surprise index			(0.71)				
			(0.72)				
Citi EM surprise index, lagged			0.54				
			(0.71)				
Citi LATAM surprise index				1.75			
				(1.50)			
Citi LATAM surprise index, lagged				(1.88)			
				(1.51)			
Lag 2 of daily change in FX					0.01		
					(0.05)		
Interest rate differential, change						(0.34)	
						(0.43)	
Interest rate differential, lagged change						(0.18)	
						(0.42)	
Constant	(0.02)	0.15	0.02	0.09	0.15	0.197*	0.14
	(0.05)	(0.11)	(0.10)	(0.11)	(0.10)	(0.11)	(0.11)
R^2	0.23	0.15	0.16	0.15	0.14	0.10	0.17
N	1100.00	1100.00	1086.00	1088.00	1100.00	1058.00	1101.00
Hansen's J stat.	8.4 (0.21)	5.1 (0.41)	5.1 (0.41)	4.8 (0.44)	4.2 (0.53)	5.0 (0.42)	5.1 (0.41)
Kl.-Paap rk Wald F stat	12.60	7.80	7.90	8.30	7.90	7.80	7.80
Kl.-Paap rk LM stat	71.1 (0.00)	49.1 (0.00)	49.3 (0.00)	51.5 (0.00)	48.2 (0.00)	49.0 (0.00)	49.0 (0.00)
Stock-Wright LM S stat	21.4 (0.00)	21.3 (0.00)	22.4 (0.00)	21.7 (0.00)	21.5 (0.00)	23.0 (0.00)	19.7 (0.01)
C test for endogeneity	15.0 (0.04)	17.2 (0.02)	17.2 (0.02)	17.2 (0.02)	17.2 (0.02)	17.2 (0.02)	17.2 (0.02)

Notes: The dependent variables is the percent daily change in the R$/US$ rate. Explanatory variables are defined in Table A1. All regressions report estimates using CUE. Heteroscedasticity robust standard errors in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level. For test statistics p-values are reported in parentheses.

The dependent variable throughout this sub-section is the implied volatility in the real/dollar exchange rate. We use the same set of instruments and the same control variables as before, allowing us to focus our discussion here only on the second stage results. The first three regressions in Table 5 present the results from estimating our baseline specification using the CUE and including the two intervention terms individually and jointly. Regression 4 shows the results from estimating the same specification as in Regression 3 using OLS in place of the CUE. Regression 5 extends the sample period back to 2003 (when the volatility data starts), Regression 6 tests for asymmetric effects of interventions. Regression 1 in Table 5b allows for dynamic impact of interventions and the remainder of the regressions add additional control variables for robustness. Table A4 in Appendix reports results from additional robustness checks, including estimating the coefficients via 2SLS.

As in the previous sub-section, we find that the control variables in Table 5 generally carry the expected signs and are often significant. The lagged dependent variable is significant with a positive coefficient in most regressions, indicating some (small) persistency in volatility movements. Higher commodity prices are significantly negatively associated with volatility in the real/dollar exchange rate as expected, and the impact is primarily contemporaneous. The VIX, in turn, enters the regression with a positive coefficient in all regressions and is always highly significant. Intuitively, higher risk aversion in global financial markets implies higher volatility in emerging market exchange rates.[31]

Regressions 1 and 2 in Table 5a contain the results from estimating the baseline specification when including one intervention term at a time. We note that both intervention terms enter the regression with the expected positive coefficient and are significant. Analogously to the exchange rate regressions, the coefficient estimates are strikingly similar, ranging between 4.2 and 4.6. When including the two terms jointly in Regression 3, the coefficients fall notably but remain in a close range between 2.3 and 3. The Wald test once again fails to reject the null hypothesis of coefficient equality. Taken at face value, these findings imply that US$1 billion in short dollar spot intervention or short dollar futures intervention reduces implied volatility in the real/dollar exchange rate by some 2.5 percent. Regression 4, in turn, shows that the coefficient on the intervention term drops significantly in the absence of instruments, signaling that these were important in attenuating a likely negative bias. In line with this finding, a battery of tests confirms the validity of our instruments and documents the endogeneity of the two intervention variables.

The remainder of Table 5 conducts a number of robustness checks. Regression 5 extends the sample period to 2003–13 by dropping the FX transactions term from our set of instruments. Compared to the baseline specification in Regression 3, we find that the coefficient on spot intervention increases somewhat while futures intervention loses its significance and carries a somewhat lower coefficient than before. Regression 6 tests for asymmetric effects by adding interaction terms between the intervention variables and a dummy variable indicating positive

[31] The coefficients for the lagged forward exchange rate differential and the CDS spread change are not statistically significant at any lags and are excluded from the later baseline analysis.

Table 5a. Second-Stage Regressions: Implied Volatility

	1	2	3	4	5	6
Lagged daily pct change in IV	0.070*	0.107**	0.090**	0.070*	-0.087**	0.102**
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)
CRB index, % change	-2.119***	-2.037***	-2.100***	-1.685***	-1.672***	-1.929***
	(0.34)	(0.35)	(0.34)	(0.37)	(0.36)	(0.33)
CRB index, lag % change	-0.169	-0.202	-0.217	-0.449	-0.533*	-0.396
	(0.37)	(0.36)	(0.37)	(0.36)	(0.28)	(0.36)
VIX, percent change	0.260***	0.280***	0.274***	0.287***	0.257***	0.284***
	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)
VIX, lagged % change	0.056*	0.053	0.051	0.057	0.085***	0.068**
	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)
Trend spot forward differential	0.161	-0.215	0.083	-0.31	0.106	
	(0.26)	(0.19)	(0.26)	(0.19)	(0.25)	
5Y sov. CDS return, lagged	0.047	0.087	0.079	0.06	0.197***	
	(0.07)	(0.08)	(0.08)	(0.07)	(0.06)	
Spot intervention	5.887***		3.849*	1.003*	4.262**	5.115*
	(1.85)		(2.07)	(0.55)	(1.98)	(2.87)
Futures intervention		3.975***	2.421*	-0.281	1.847	2.304*
		(1.23)	(1.25)	(0.39)	(1.23)	(1.38)
Spot positive * Spot interv.						-2.623
						(3.44)
Swap positive * Futures interv.						-1.291
						(1.57)
Constant	0.193	1.358***	0.86	0.728	0.798	0.980*
	(0.43)	(0.51)	(0.55)	(1.05)	(0.54)	(0.54)
R^2	0.24	0.18	0.23	0.3	0.15	0.24
N	1,097	1,097	1,097	1,097	1,935	1,097
Hansen's J stat.	6.9 (0.33)	6.2 (0.40)	3.2 (0.67)		1.1 (0.89)	10.2 (0.18)
Kl.-Paap rk Wald F stat	12	8.9	7.4		7.4	7.4
Kl.-Paap rk LM stat	67.5 (0.00)	50.3 (0.00)	46.8 (0.00)		54.9 (0.00)	51.3 (0.00)
Stock-Wright LM S stat	20.7 (0.00)	20.7 (0.00)	20.7 (0.00)		15.7 (0.02)	32.1 (0.00)
C test for endogeneity	20.2 (0.01)	20.2 (0.01)	20.2 (0.01)		12.9 (0.04)	53.6 (0.00)
Wald statistic			0.25 (0.61)		0.82(0.36)	
Wald statistic – short USD						0.59 (0.44)
Wald statistic – long USD						0.61 (0.43)

Notes: The dependent variables is the percent daily change in R$/US$ implied volatility. The Spot (Swap) positive dummy takes the value one on days when the BCB takes a long dollar position via the respective mode of intervention. Other explanatory variables are defined in Table A1. Regression 4 reports OLS estimates, all other regressions report estimates using CUE. The coefficients for the spot and futures intervention in regression 7 are cumulative effects. Heteroscedasticity robust standard errors in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level. For test statistics p-values are reported in parentheses. Wald statistic tests the null hypothesis of the equality of the spot and futures intervention coefficients. Wald statistic – short USD tests the null hypothesis of the equality of the spot and futures intervention coefficients. Wald statistic – long USD tests the null hypothesis of the equality of the sum of the level and interaction term coefficients for spot and futures interventions.

Table 5b. Second-Stage Regressions: Implied Volatility

	1	2	3	4	5
Lagged daily pct change in IV	0.118**	0.101**	0.100**	0.103**	0.094**
	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)
CRB index, % change	-2.133***	-2.110***	-2.253***	-2.209***	-2.125***
	(0.36)	(0.34)	(0.34)	(0.34)	(0.34)
CRB index, lag % change	-0.396	-0.361	-0.323	-0.412	-0.346
	(0.39)	(0.38)	(0.38)	(0.38)	(0.37)
VIX, percent change	0.286***	0.274***	0.271***	0.273***	0.273***
	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)
VIX, lagged % change	0.069**	0.069***	0.071***	0.067**	0.071***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Spot intervention	3.276*	3.699**	3.716**	3.697**	3.765**
	(1.81)	(1.64)	(1.89)	(1.78)	(1.66)
Futures intervention	2.706*	2.274*	2.445*	2.558*	2.206*
	(1.46)	(1.26)	(1.31)	(1.33)	(1.28)
Inflation surprise		-3.158			
		(7.34)			
Unemployment surprise		0.412			
		(1.83)			
IP surprise		-0.135			
		(0.30)			
Citi LATAM surprise index			2.144		
			(4.45)		
Citi LATAM surprise index, lag			-2.487		
			(4.42)		
Citi EM surprise index				-4.653	
				-2.896	
Citi EM surprise index, lagged				3.954	
				-2.877	
Lag 2 of daily pct change in IV					0.04
					-0.04
Constant	0.883	0.913*	0.861	0.446	0.890*
	-0.539	-0.512	-0.546	-0.591	-0.514
R^2	0.16	0.23	0.23	0.23	0.24
N	1,065	1,097	1,085	1,083	1,095
Hansen's J stat.	3.4 (0.63)	3.1 (0.69)	3.5 (0.63)	2.8 (0.72)	3.1 (0.69)
Kl.-Paap rk Wald F stat	3.5	3.5	3.5	3.5	3.5
Kl.-Paap rk LM stat	22.3 (0.001)	38.5 (0.00)	37.5 (0.00)	37.5 (0.00)	36.9 (0.00)
Stock-Wright LM S stat	27.6 (0.00)	23.7 (0.00)	24.4 (0.00)	24.4 (0.00)	22.8 (0.00)
C test for endogeneity	28.2 (0.00)	24.4 (0.00)	23.6 (0.00)	25.0 (0.00)	24.0 (0.00)
Wald statistic	0.04 (0.84)				

Notes: The dependent variables is the percent daily change in R$/US$ implied volatility. The Spot (Swap) positive variable takes the value one on days when the BCB takes long dollar position via the respective mode of intervention. Other explanatory variables are defined in Table A1. All regressions report estimates using CUE. The coefficients for spot and futures intervention in regression 1 are cumulative effects. Heteroscedasticity robust standard errors in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level. For test statistics p-values are reported in parentheses.

interventions.[32] The estimated coefficients for both interaction terms carry negative signs but are not statistically significant, suggesting that both modes of intervention havesymmetric impacts on volatility Regression 1 in Table 5a allows for dynamic effects of the interventions by including the first five lags of each intervention term in the specification. Only the coefficient for the first lag of futures intervention, however, is found to be significant, in line with previous findings in the literature. The estimated (quasi) cumulative impacts—shown in the table instead of the individual coefficients—are again very similar for the two modes of intervention. Finally, Regression 2 adds the three announcement surprise terms to the regression while Regressions 3 and 4 add the Citi Latin America and EM Economic Surprise Indexes and Regression 5 adds additional lags of the dependent variable.[33] The results remain robust to all these additions.

In sum, the results of this section suggest that both spot and futures intervention have important impacts on implied exchange rate volatility. As in the previous section, we also find that these impacts are strikingly similar for spot and futures interventions of a comparable magnitude. While the channels through which FXI affects volatility are the same for the two modes of intervention, spot intervention would be more effective to the extent that the finite maturity of futures contracts or the prevalence of convertibility risk limit the ability of futures intervention to reduce private sector FX risk. As in the previous section, the similarity in the effectiveness of the two modes of intervention thus suggests that convertibility risk is generally negligible and that the maturities of the futures contracts are sufficiently long not to give rise to significant convertibility risk.

IV. Conclusions

This paper studies the relative effectiveness of foreign exchange intervention in spot and derivatives markets. We focus on the case of Brazil where spot and non-deliverable futures based intervention have been used alongside each other since the early 2000s.

In particular, we compare the Brazilian Central Banks's purchases and sales of spot dollars to its auctions of non-deliverable futures settled in local currency (futures intervention) via instrumental variable regressions that seek to explain changes in the real/dollar exchange rate and its implied volatility. Our set of instruments for the two intervention terms makes use of a rich data set and succeeds at identifying distinct reaction functions that permit including the two modes of intervention jointly in our regressions.

The analysis also detects significant differences in the reaction function estimates of the two instruments. The BCB appears to use spot intervention more so than derivatives based intervention in reaction to daily movements in the exchange rate and to capital flow pressures. Conversely, it is more likely to use futures based intervention to smooth trend movements in the exchange rate and when price pressures dominate. Finally, we also find that spot rather

[32] As in the previous section we use interaction terms between "Positive" and lagged trend exchange rate volatility as well as trend intervention as additional instruments for the interaction terms.

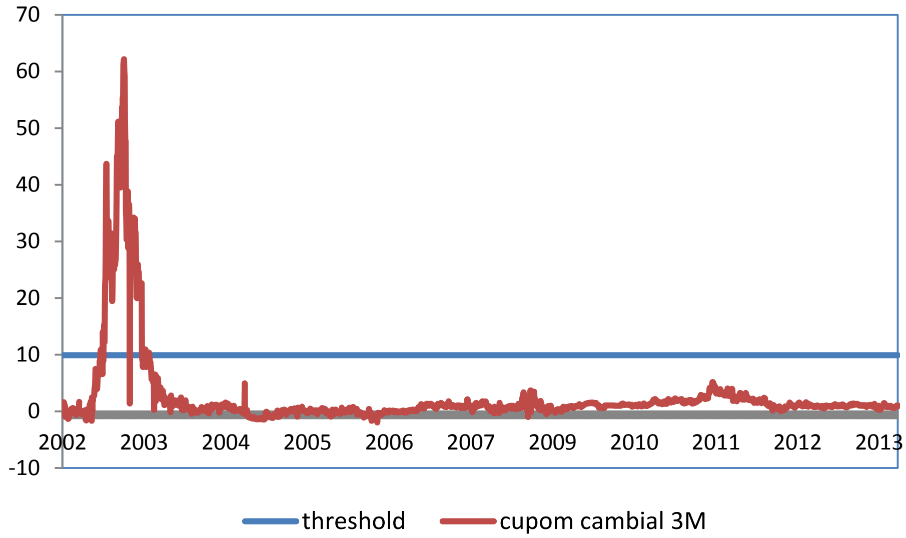
[33] We report only the coefficient for the second lag but regression includes up to four lags whose coefficients are not statistically significant.

than derivatives based intervention tends to be used to offset the exchange rate effects of tighter/looser monetary policy.

Our results contribute to the scarce literature on derivatives based intervention in at least two important ways. First, to our knowledge this is the first study that analyzes empirically the relative effectiveness of spot and derivatives based intervention in a common framework. By providing evidence suggesting that intervention in derivatives markets can be no less effective than intervention in spot markets, it highlights the usefulness of a broader central bank toolkit. Second, our study allows comparing central bank reaction functions for spot and derivatives based intervention, allowing us to understand which factors incentivize both intervention more generally and one mode of intervention versus the other in particular.

APPENDIX

Figure A1: Convertibility Risk



Notes: The graph shows the evolution of *Convertibility Risk* proxied by the three month Cupom Cambial rate. The threshold is equal to one sample standard deviation above the sample mean. The cupom cambial is priced in basis points equal to the spread between the overnight interbank deposit rate and the expected exchange rate variation and serves as the onshore dollar interest rate.

Table A1. Variable Definitions and Sources

Variable Name	Definition	Source
Dependent Variables		
Exchange rate	Percent Daily Change in R$/US$	Bloomberg; authors' calculations
Volatility	Percent Daily Change in implied R$/US$ volatility	Bloomberg; authors' calculations
Intervention Terms		
Spot intervention	Spot purchases net of Spot sales	BCB and authors' calculations
Futures intervention	Reverse FX swaps net of FX swaps	BCB and authors' calculations
Spot purchases	In billions US$	BCB and authors' calculations
Spot sales	In billions US$	BCB and authors' calculations
Reverse swaps	In billions of notional outstanding principal in US$	BCB and authors' calculations
Swaps	In billions of notional outstanding principal in US$	BCB and authors' calculations
Instruments		
FX deviation from trend	The difference between the exchange rate and the two week moving average of the exchange rate in log terms.	Bloomberg; authors' calculations
Trend FX volatility	Two week moving average of implied volatility	Bloomberg; authors' calculations
Medium-run FX trend	One year moving average of the log of the exchange rate	Bloomberg; authors' calculations
Trend FX transactions	One-week average FX transactions In billions US$	BCB and authors' calculations
Trend spot intervention	One week moving average of the spot interventions	BCB and authors' calculations
Trend futures intervention	One week moving average of the futures interventions	BCB and authors' calculations
Policy rate change	One week change in the Selic target rate	Bloomberg; authors' calculations
Difference between the onshore and offshore forward rate	One-week moving average percent difference between offshore and onshore NDF	Bloomberg; authors' calculations
Control Variables		
5Y sovereign CDS return	Percent daily change in 5Y sovereign CDS spread	Bloomberg; authors' calculations
CRB index	Thomson Reuters Core Commodity (CRB) price index	Haver; authors' calculations
VIX	Chicago Board Options Exchange Market Volatility Index	Haver; authors' calculations
Trend FX forward differential	One-week average percent difference between spot and forward rate	Bloomberg; authors' calculations
Inflation surprise	The difference between actual announcement and Bloomberg expectations	Bloomberg; authors' calculations
Unemployment surprise	The difference between actual announcement and Bloomberg expectations	Bloomberg; authors' calculations
Industrial production surprise	The difference between actual announcement and Bloomberg expectations	Bloomberg; authors' calculations
Citi EM surprise	Citi EM surprise Index	Haver; authors' calculations
Citi LATAM surprise	Citi Latam surprise Index	Haver; authors' calculations
Interest rate differential	Difference between Selic and Fed Funds rate	Bloomberg and Haver.
Other		
Convertibility Risk	Value 1 on days when cupom cambial is 1.5 std above sample mean	Bloomberg; authors' calculations
Cupom cambial	Three-month onshore dollar interest rate	Bloomberg; authors' calculations

Table A2. First-Stage Regressions, Alternative Instruments

	Spot	Futures	Spot	Futures	Spot	Futures
Lagged daily change in FX	-0.018*	0.011	-0.026**	0.008	-0.019*	0.011
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)
CRB index, percent change	0.03	0.017	0.029	0.017	0.029	0.02
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
CRB index, lagged percent change	-0.024	-0.03	-0.022	-0.029	-0.022	-0.024
	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)	(0.02)
VIX, percent change	0	-0.004**	0	-0.004**	0	-0.004**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
VIX, lagged percent change	0.001	0.001	0.002	0.001	0.002	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Trend FX forward differential	-0.048***	0.008	-0.055***	0.011	-0.049***	0.002
	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)
5Y sovereign CDS return, lagged	-0.002	-0.016***	-0.002	-0.016***	-0.002	-0.016**
	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)
Lagged FX deviation from trend (2W)	-1.067*	-2.740***			-1.057	-2.529***
	(0.65)	(0.89)			(0.67)	(0.90)
Medium-run FX trend	-0.335	-0.808**	-0.216	-0.699**	-0.202	-0.572*
	(0.21)	(0.34)	(0.20)	(0.32)	(0.21)	(0.33)
Policy rate change	0.506***	-0.017	0.610***	-0.03	0.647***	0.053
	(0.14)	(0.34)	(0.16)	(0.33)	(0.16)	(0.33)
Lagged trend FX volatility (2W)	-0.009***	-0.014***	-0.009***	-0.012***		
	(0.00)	(0.00)	(0.00)	(0.00)		
Lagged trend FX transactions	0.000***	0	0.000***	0	0.000***	0
	0.00	0.00	0.00	0.00	0.00	0.00
Trend spot intervention, lagged	0.161**	-0.129*	0.163**	-0.115*	0.189**	-0.074
	(0.08)	(0.07)	(0.08)	(0.07)	(0.08)	(0.07)
Trend swap intervention, lagged	-0.023	0.396***	-0.011	0.377***	0.006	0.453***
	(0.04)	(0.12)	(0.03)	(0.12)	(0.04)	(0.12)
Citi LATAM surprise index	0.042*	0.01				
	(0.02)	(0.03)				
Lagged FX deviation from trend (1M)			-0.123	-2.421***		
			(0.40)	(0.62)		
Lagged trend FX volatility (1M)					-0.007**	-0.008***
					(0.00)	(0.00)
Constant	0.355**	0.539**	0.262*	0.444**	0.24	0.327
	(0.16)	(0.24)	(0.15)	(0.22)	(0.16)	(0.23)
N	1,094	1,094	1,100	1,100	1,100	1,100
F test	11.3 (0.00)	7.6 (0.00)	12.6 (0.00)	8.7 (0.00)	12.2 (0.00)	6.2 (0.00)
Kleibergen-Paap rk Wald F	11.3	7.6	12.6	8.7	12.2	6.2
Sanderson-Windmeijer F test	6.5 (0.00)	11.2 (0.00)	8.8 (0.00)	13.8 (0.00)	6.1 (0.00)	13.1 (0.00)
Kleibergen-Paap rk LM	74.2 (0.00)	47.7 (0.00)	71.3 (0.00)	48.9 (0.00)	70.3 (0.00)	37.9 (0.00)

Notes: The dependent variables in all columns are spot intervention - in billions of U.S. dollars - and futures intervention - in billions of U.S. dollar equivalent of notional principal—defined such that positive values imply that the BCB takes a long dollar position. All columns report CUE estimates. Columns 1–2 add the regional news index (*Citi LATAM*) to the list of instruments. Columns 3–4 use the one month moving average of the exchange rate to approximate short-term trends. Columns 5–6 use one month moving average of the implied volatility to approximate short-term trends in volatility. Heteroscedasticity robust standard errors in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level. For test statistics p-values are reported in parentheses.

Table A3. Second-Stage Regressions, Alternative Instruments

	1	2	3	4
Lagged daily change in FX	-0.138**	-0.129**	-0.143**	-0.142**
	(0.06)	(0.06)	(0.07)	(0.06)
CRB index, percent change	-0.129	-0.138	-0.138	-0.141
	(0.09)	(0.10)	(0.10)	(0.10)
CRB index, lagged percent change	-0.423***	-0.422***	-0.425***	-0.417***
	(0.08)	(0.08)	(0.08)	(0.08)
VIX, percent change	0.012**	0.013**	0.013**	0.012**
	(0.01)	(0.01)	(0.01)	(0.01)
VIX, lagged percent change	-0.009	-0.008	-0.008	-0.008
	(0.01)	(0.01)	(0.01)	(0.01)
Trend FX forward differential	0.162***	0.165***	0.154***	0.161***
	(0.05)	(0.06)	(0.06)	(0.05)
5Y sovereign CDS return, lagged	0.112***	0.113***	0.114***	0.110***
	(0.02)	(0.02)	(0.02)	(0.02)
Spot intervention	0.961**	0.983**	0.789*	1.000**
	(0.48)	(0.50)	(0.48)	(0.49)
Futures intervention	0.707*	0.642*	0.907**	0.666*
	(0.36)	(0.36)	(0.38)	(0.36)
Constant	0.143	0.124	0.183	0.139
	(0.11)	(0.11)	(0.11)	(0.11)
R^2	0.16	0.17	0.12	0.16
N	1,100	1,094	1,100	1,100
Hansen J	5.9 (0.65)	5.2 (0.51)	5.5 (0.36)	5.0 (0.42)
Kl.-Paap rk Wald F	5.5	7	9.6	7.4
Kl.-Paap rk LM	49.7 (0.00)	50.4 (0.00)	60.2 (0.00)	46.1 (0.00)
Stock-Wright LM S	22.2 (0.01)	21.6 (0.01)	22.4 (0.00)	20.0 (0.01)
C test for endogeneity	16.0 (0.10)	15.1 (0.06)	14.8 (0.04)	14.4 (0.04)

Notes: The dependent variables is the percent daily change in R$/US$. Explanatory variables are defined in Table A1. Regression 1 reports the second-stage results when macro-surprise news are added to the instrument set. Regression 2 adds the regional news index (*Citi LATAM*) to the instruments. Regression 3 uses one month moving average of the exchange rate to approximate short-term trends. Regression 4 uses one month moving average of implied volatility to approximate short-term trends in volatility. Heteroscedasticity robust standard errors in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level. For test statistics p-values are reported in parentheses.

Table A4. Second-Stage Regressions: Implied Volatility, Additional Regressions

	1	2	3	4
Lagged daily change in IV	0.157***	0.061**	0.104***	0.086***
	(0.04)	(0.03)	(0.03)	(0.03)
CRB index, percent change	-2.221***	-1.924***	-1.808***	-1.935***
	(0.34)	(0.40)	(0.37)	(0.41)
VIX, percent change	0.253***	0.282***	0.294***	0.288***
	(0.03)	(0.03)	(0.03)	(0.03)
Spot intervention	3.793**	6.426***		4.200**
	(1.63)	(1.94)		(2.09)
Futures intervention	2.080*		3.647**	2.502**
	(1.25)		(1.54)	(1.21)
CRB index, lagged percent change		-0.409	-0.396	-0.386
		(0.46)	(0.47)	(0.45)
VIX, lagged percent change		0.044	0.045	0.04
		(0.03)	(0.04)	(0.04)
Trend FX forward differential		0.198	-0.206*	0.12
		(0.22)	(0.11)	(0.20)
5Y sovereign CDS return, lagged		0.074	0.106*	0.1
		(0.07)	(0.06)	(0.07)
Constant	0.814	0.285	1.457**	0.976*
	(0.52)	(0.30)	(0.69)	(0.52)
R^2	0.22	0.23	0.2	0.22
N	1,105	1,097	1,097	1,097
Hansen J	3.5 (0.62)	7.7 (0.26)	7.8 (0.26)	4.2 (0.52)
Kl.-Paap rk Wald F	6.3	10.6	8.4	6
Kl.-Paap rk LM	38.2 (0.00)	19.2 (0.01)	12.4 (0.09)	16.7 (0.01)
Stock-Wright LM S	22.1 (0.00)	17.0 (0.02)	15.8 (0.03)	16.7 (0.02)
Endogeneity test	24.2 (0.00)	26.4 (0.00)	30.6 (0.00)	25.0 (0.00)

Notes: The dependent variables is the percent daily change in R$/US$ implied volatility. All explanatory variables are defined in Table A1. Regression 1 reports CUE estimates when all insignificant variables are excluded from the baseline specification. Regressions 2–4 report estimates of the baseline specification using 2SLS. Heteroscedasticity robust standard errors in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level. For test statistics p-values are reported in parentheses.

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