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The Impact of Foreign Exchange Intervention in Colombia. An Event Study Approach[1]

El impacto de las intervenciones cambiarias en Colombia. Un estudio de eventos

Juan José Echavarría
Luis Fernando Melo
Mauricio Villamizar

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Abstract

To date, there is still great controversy as to which exchange rate model should be used or which monetary channel should be considered, when measuring the effects of monetary policy. Since most of the literature relies on structural models to address identification problems, the validity of results largely turn on how accurate these assumptions are in describing the full extent of the economy. In this paper we compare the effects of different types of central bank intervention for the Colombian case during 2000-2012, without imposing restrictive parametric assumptions or without the need to adopt a structural model. Using an event study approach, we find that all types of interventions (international reserve accumulation options, volatility options and discretionary) have been successful according to the smoothing criterion. In particular, volatility options had the strongest effect. Results are robust when using different windows sizes and counterfactuals.

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1 Authors' email: jechavso@banrep.gov.co, lmelovel@banrep.gov.co, mvillavi@banrep.gov.co.
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Key words: Central bank intervention, foreign exchange intervention mechanisms, event study.

JEL classification: E52, E58, F31.

Resumen

Hasta la fecha, hay gran controversia sobre el modelo de tipo de cambio que se debe utilizar o el mecanismo de transmisión que debe ser considerado para medir los efectos de la política monetaria. Dado que la mayoría de la literatura se basa en modelos estructurales como estrategia de identificación, la validez de los resultados depende, en gran medida, de la validez de sus supuestos. Este artículo compara los efectos de diferentes tipos de intervenciones para el caso colombiano durante el período 2000-2012, sin imponer supuestos paramétricos restrictivos y sin la necesidad de adoptar un modelo estructural. Nuestros resultados muestran que todos los tipos de intervención cambiaria (opciones de acumulación de reservas, opciones de volatilidad e intervenciones discrecionales) han tenido éxito según el criterio de suavización en el estudio de eventos. En particular, las opciones de volatilidad parecen haber tenido el mayor efecto. Los resultados son robustos cuando se utilizan ventanas de diferentes tamaños y diferentes escenarios.

Palabras clave: intervenciones de bancos centrales, intervenciones cambiarias, estudio de eventos.

Clasificación JEL: E52, E58, F31.

Introduction

In context of discretionary central bank intervention, monetary authorities systematically react to informative variables when setting their policy decisions, i.e. the timing and magnitude of interventions are driven by market behavior in order to meet explicit or implicit policy objectives. As such, researchers usually assume functional forms of both the policy rule and the process determining the economy in order to estimate causal effects. However, since most of these studies purely rely on structural models to address identification problems (see Christiano, Trabandt and Walentin, 2011) then the validity

of results largely depends on how accurate the assumptions are in describing the full extent of the underlying economy.

To date, there is still great controversy as to which exchange rate model should be used (stock, monetary, microstructure-based, etc.) or which monetary channel should be considered (signaling, portfolio, or expectations), when measuring the effects of policy. Moreover, the Colombian case poses additional methodological challenges since there have been multiple mechanisms of foreign exchange rate intervention. These consist of: international reserve accumulation and volatility options in the first part of the 2000s, discretionary (dirty) interventions during 2004-2007 and day-to-day constant and preannounced interventions during 2008-2012. A better understanding of these mechanisms and their effects is hence warranted, without imposing restrictive parametric assumptions or without the need to adopt a full-blown structural model.

While several other countries (e.g. Mexico, Turkey, Japan or the Czech Republic) have also conducted policy with multiple intervention mechanisms, few of them have intervened in a systematic way. For instance, countries like Japan exhibited large-scale but sporadic foreign exchange interventions (i.e. they purchased 24 billion dollars in September 2010). Also, countries like Mexico have held pre-established dates to accumulate reserves with the adoption of volatility options (1996-2001). The Colombian experience is thus an interesting case study because its policy framework has consisted of explicit interventions which systematically reacted to either past movements in the exchange rate (volatility options) or the behavior of monetary authorities (discretionary).

In this paper we compare the effects of international reserve accumulation, volatility options and discretionary interventions,[2] using an event study approach. This paper is complementary to the work of Echavarría, Melo and Villamizar (2013) which focuses on preannounced interventions. Following the methodology presented in Fatum and Hutchison (2001), we define four criteria to evaluate a successful intervention: 1) Direction (Frankel, 1994); 2) Reversal (Fatum and Hutchison, 2001); 3) Smoothing (Humpage, 1996); and 4) Matching. Results show that all types of interventions were successful according to the smoothing criterion. In particular, volatility options had the strongest

2 Preannounced interventions were not used given the few events available.

effect according to several criteria. Results are robust when using different windows sizes and counterfactuals.

This paper is organized as follows: Section I provides a general overview of the Colombian foreign exchange rate intervention. Parts of this section (*in italics*) are taken directly from Echavarría et al. (2013). Section II describes the event study methodology and Section III presents the results. Finally, section IV concludes.

I. Foreign Exchange Interventions

Foreign exchange interventions for the Colombian case during the period 2000-2012 are summarized in Graph 1. *Average yearly purchases were close to US$ 2,200 million, much larger than average sales (US$ 571 millions). Purchases were especially high in 2005 and 2007, and also during 2010-2012[3]. Yearly purchases represented 0.12% of (yearly) market transactions in and 4.06% in 2005, with an average of 1.70% in 2000-2012. They represented 1.0% of the average stock of international reserves in 2003 and 33% in 2005, with an average of 11.86% in 2000-2012[4].*

Table 1 shows the relative importance of the different mechanisms of intervention: options for reserve accumulation, options for volatility control, discretionary interventions, and fixed (close to) US$ 20 million per day interventions.[5] Put options for reserve accumulation, partially implemented to replenish the strong reduction of international reserves observed in 1997-2000, accounted for all purchases in 2000-2003, while discretional interventions explained a large part of purchases in 2004-2007. The amounts and periods of interventions were initially announced, but that practice changed when periods and amounts became indefinite.

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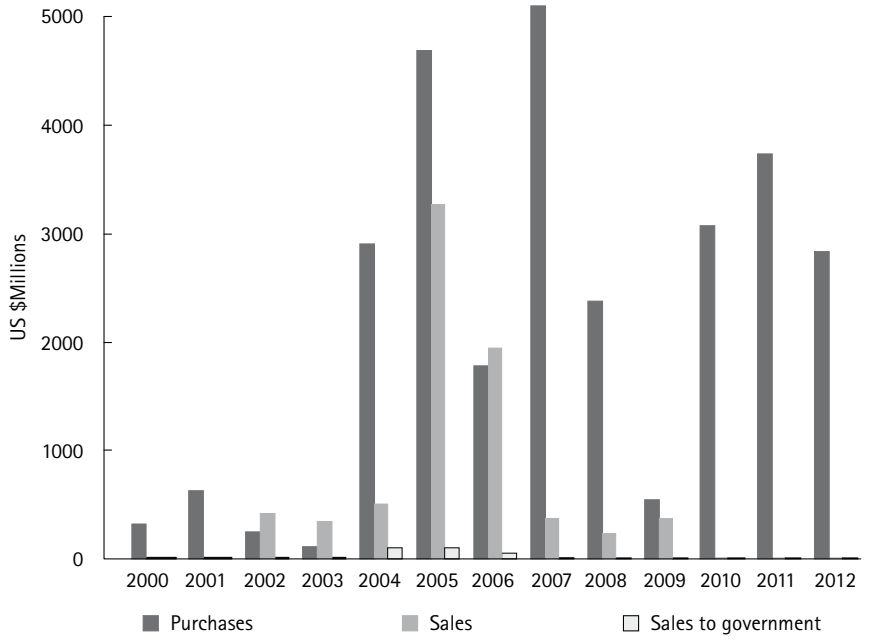
3 There were some sales of US$ dollars to the government in 2004-2006, intended to repay external debt.

4 Daily transactions in the market were close to US$ 1000 million at the end of the sample, and to US$ 320 million in 2001-2004 (average). The stock of international reserves was close to US$ 33,000 million at the end of the sample and to US$ 10,611 in 2001-2004 (average).

5 Next day purchases accumulate when there is a holiday in the United States or when t-1 auctions are not fully exercised.

Graph 1. Colombian Central Bank Interventions



Source: Banco de la República and authors' calculations. The year 2012 includes January - August.

Volatility options were used to buy and (mainly) sell foreign currency in some days in 2004, 2006, 2007, 2008 and 2009. Options were auctioned automatically whenever the difference between the exchange rate of the previous day (the TRM) and the moving average of the last twenty days was higher or lower than 5%. This percentage changed to 4% in December 2001; to 2% in February 6, 2006; to 5% in June 24, 2008; and to 4% in October 13, 2011. However, volatility options have not been used during the last years, partially because there are doubts about their impact, and partially because they could conflict with the effect of the US$ 20 million purchases (the central bank could be selling and buying dollars during the same day).

Put/call options for reserve accumulation were auctioned monthly and agents had the right to exert them (totally or partially) during the next month, as long as the exchange rate was lower than the average of the last 20 days. This meant that international reserves were bought at a "low" price (opposite for sales). The Board of the Central Bank could announce a new auction during the month even if the previous auction had not yet expired.

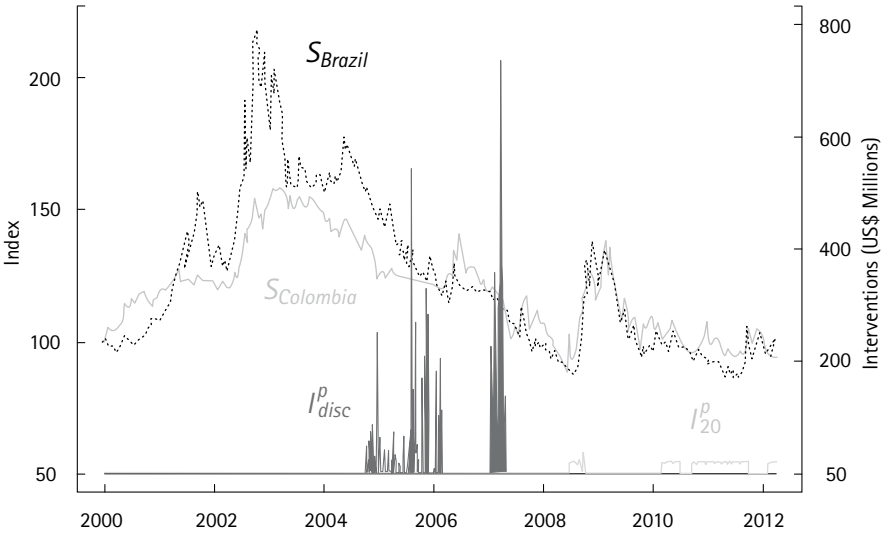
Table 1. Colombian Central Bank Interventions, 2000-2012

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012*
PURCHASES (US $)	319	629	252	106	2905	4658	1781	5082	2381	539	3060	3720	2840
Participation(%)													
Options Put	100	100	100	100	54	0	33	11	41	100	0	0	0
International Reserve Accumulation	100	100	100	100	48	0	0	0	19	0	0	0	0
Volatility Options	0	0	0	0	6	0	33	11	22	100	0	0	0
$20 million/day aprox.	0	0	0	0	0	0	0	0	59	0	100	100	100
Discretional Intervention	0	0	0	0	46	100	67	89	0	0	0	0	0
SALES (US $)	0	0	414	345	500	3250	1944	369	235	369	0	0	0
Participation (%)													
Options Call	0	0	100	100	0	0	49	100	100	100	0	0	0
International Reserve Reduction	0	0	0	100	0	0	0	0	0	0	0	0	0
Volatility Options	0	0	100	0	0	0	49	100	100	100	0	0	0
Sales to National Government	0	0	0	0	100	100	51	0	0	0	0	0	0
NET PURCHASES	319	629	-163	-238	2405	1408	-164	4713	2147	171	3060	3720	2840

Source: Author's calculations. * The year 2012 includes January - August.

Graphs 2 and 3 show the evolution of the different types of foreign exchange intervention and the nominal exchange rate (S_t), for both Colombia and Brazil during 2000-2012. Discretional interventions I^p_{disc} and preannounced interventions of US$ 20 million I^p_{20} are shown in Graph 2 and reserve accumulation $I^p_{res\_opt}$ and volatility options $I^p_{vol\_opt}$ in Graph 3. In total, there were 723 days of discretionary purchases, with an average of US$ 20 million and a maximum of US$ 723 million (on March 390, 2007); 437 days of US$ 20 million interventions distributed in four episodes; 80 days of reserve accumulation (purchases) with an average of US$ 41 million and a maximum of US$ 200 million; and 41 days of volatility option purchases with an average of US$ 51 million and a maximum of US$ 170 million.

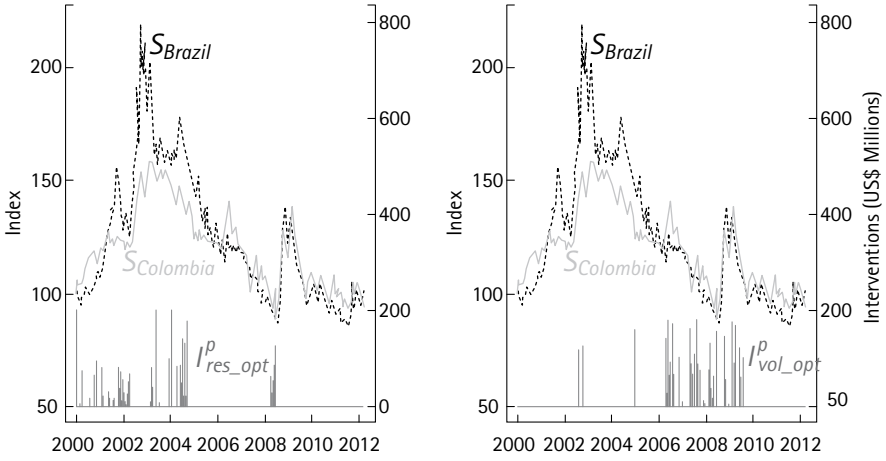
Graph 2. Different Types of Intervention and the Nominal Exchange Rate in Colombia and Brazil



Source: Central Bank of Colombia and Authors' Calculations.

Overall, exchange rate interventions in Colombia have been relatively transparent (See Ramírez, 2005). Options are announced on the same day that they are exercised (the name of the firm remains secret) and the amount of intervention is announced each week. Very often the Board of Directors pre-announced the total amount of dollars to be purchased/sold during the next months. For example, the Board announced an intervention of US$ 1 billion during the

Graph 3. Different Types of Intervention and the Nominal Exchange Rate in Colombia and Brazil



Source: Central Bank of Colombia and Authors' Calculations.

last three months of 2004,[6] and in June 20, 2008 the Board announced the new US$ 20 million daily interventions, with an amount of US$ 2.4 billion to be bought between July and December.

To date, there is still a general lack of consensus within the literature regarding the effectiveness of Central Bank intervention. This, in part, is the result of the different methodologies employed. Studies that have used a GARCH methodology in Colombia include Toro and Julio (2005), Kamil (2008), Echavarria, Vasquez and Villamizar (2009b), Rincon and Toro (2010). On the other hand, studies that have used structural Vector Autoregressions (SVARs) or General Equilibrium models (DSGEs) include Echavarria, Lopez and Misas (2009a) and Vargas, Gonzales and Rodriguez (2013).

Results of these studies vary in terms of both significance and duration of policy effects. And, since most studies purely rely on parametric assumptions to model the behavior of monetary authorities, then the validity of estimations largely turn on how accurate these assumptions are in describing the full extent of the underlying economy. Hence, this paper will help shed some

6 But in December 2004 the Board announced additional undefined interventions and periods.

light on the effects of foreign exchange intervention using an event study approach, without imposing restrictive parametric assumptions.

II. Methodology: An Event Study Approach

Event studies were originally applied in the area of finance (MacKinlay, 1997), but in recent years they have also been used in areas as diverse as: the impact of different local factors on financial crisis (IMF, 2007, pp.124-132), the relationship between the development of capital markets and the environment in emerging countries (Dasgupta, Laplante and Mamingi, 1997), the effects of fiscal policy in the process of disinflation (Celasum, Gelos and Pratti, 2004), and even the impact of the merits of the Central Bank Governor on financial markets (Kuttner and Posen, 2007).

There are some limitations when using a non-parametric approach to estimate the effects of policy. One of these drawbacks consists of a certain degree of subjectivity when choosing the window size of the event window, event and post-event. While we refer to standard cross-validation techniques and allow for multiple window sizes for robustness, it is usually the case that large windows over-smooth the density of the underlying data structure. On the other hand, small bandwidths might reduce the bias but at the expense of obtaining a larger variance in the estimates. Also, the longer the event window is defined, the fewer events are found within the sample. Finally, long pre and post estimation windows increase the likelihood of exogenous shocks (foreign and domestic) that might affect the exchange rate (always expressed as Pesos per Dollar). Bearing these limitations in mind, we believe that our event study approach holds clear advantages over the bulk of the literature that uses restrictive parametric assumptions.

In the related literature, Humpage (1996), Fatum and Hutchison (2001), Fatum and Hutchison (2008) and Fratzscher (2012) used event studies to analyze the effect of interventions on the exchange rate. All of them conclude that interventions produce the desired results, even when considering a 15 day window (the longest period considered by most of them). For Fratzscher (2012, pp. 739) "overall, there is overwhelming evidence that both actual and oral intervention events for the G3 economies have been successful", and the success rate remains relatively stable when extending the time window to 40 days.

In this section we compare the cumulative effect of the different types of foreign exchange intervention. We exclude day-to-day constant and preannounced interventions from our analysis given the few events available. The methodology starts with the definition of the event window comprised by: a) the pre-event window, b) purchases and sales of foreign exchange (the event); and c) the post-event window.

Following Fatum and Hutchison (2001), Hutchison (2002) and Fratzscher (2012), we consider a sensitivity analysis for pre and post events of 2, 5, 10 and 15 days. Additionally, we define the event as the cluster of foreign exchange intervention in which the Central Bank did not stop intervening for 2, 5, 10 or 15 days. In other words, the event begins when the central bank first conducts purchases or sales in the foreign exchange market and ends when 2, 5, 10 or 15 consecutive days have elapsed without interventions. We then define four criteria to evaluate a successful intervention: 1) Direction (Frankel, 1994); 2) reversal (Fatum and Hutchison, 2001); smoothing (Humpage, 1996); and 4) Matching. They can be summarized as follows:

- The Direction criterion considers a successful event when the exchange rate depreciates (appreciates) after USD purchases (USD sales), without any regard about the trend of the exchange rate before intervention. As Frankel (1994) argues, a successful intervention means that the exchange rate moves in the direction wanted by the central bank. In this sense, the Direction criterion does not take into account the behavior of the exchange rate before interventions take place. The central bank could simply be following a *leaning-with-the-wind* policy, with the behavior of the exchange rate probably dictated by market conditions.
- The Reversal criterion is more demanding, and success requires that the exchange rate depreciates (appreciates) after USD purchases (USD sales). The difference with the direction criterion is that it now requires the exchange rate to be appreciating (depreciating) before an intervention episode.
- The Smoothing criterion also considers the pre-intervention period, but it is less demanding. This criterion defines success when exchange rate appreciations (depreciations) are lesser in magnitude after USD purchases (USD sales).

- The Matching criterion is similar to the smoothing criterion but considers the magnitude of exchange rate changes as opposed to comparing the number of successful events. Hence, the matched sample test consists of verifying whether the behavior of the exchange rate experienced a significant variation between the pre and post-event windows.

The statistical analysis for the first three criteria (Direction, Reversal and Smoothing) consists of counting the number of successful events and comparing it with the total number of events. Specifically, we use a sign *t-test*, based on a binomial distribution, to check if the probability of a successful event *(p)* is greater or equal than *0.5* (or a given probability value). As for the Matched criterion, the analysis consisted of computing the difference between the corresponding pre and post event exchange rate values. And, by assuming that the variation of the exchange rate of both sub-samples is normally distributed, we use a *t-test* with *n-1* degrees of freedom ("n" being the number of matched pairs).

Formally, the four criteria can be expressed as shown in Graph 4 for the case of purchases (vice versa for sales).

Graph 4. Definitions of Criteria for Successful Interventions

Criteria	Pre-event	Event	Pos-event
Direction		USD Purchases	$\Delta^{+}S_t > 0$
Reversal	$\Delta^{-}S_t < 0$	USD Purchases	$\Delta^{+}S_t > 0$
Smoothing	$\Delta^{-}S_t < 0$	USD Purchases	$\Delta^{+}S_t > \Delta^{-}S_t$
Matching (magnitude)		USD Purchases	$\Delta^{+}S_t > \Delta^{-}S_t$

Overall, reversal is a more demanding criterion than direction since it does not consider the behavior of the exchange rate in the pre-event window. It is also more demanding than the smoothing criterion since it does not require the exchange rate to depreciate (appreciate) after USD purchases (USD sales).

III. Results

Table 2 presents the results when the estimation window, the pre, and the post-event periods correspond to five days. Column (1) presents the different types of intervention which include A) discretionary, B) options for reserve accumulation, C) options for volatility control, D) the combination t_2 which considers interventions that were set by the board of directors (A+B), and E) the combination t_3 which considers all types of interventions (A+B+C). We recognize that different types of foreign exchange intervention could have been motivated by different covariates and policy objectives. However, it might be of interest to know if the combined effect (t_2 or t_3) had an impact on the exchange rate. That is, regardless of trying to depreciate/appreciate domestic currency or stem exchange rate volatility (or affect any central moment for that matter), it is crucial to see if interventions had an effect on the exchange rate (and specifically, over the smoothing, direction and reversal criteria).

Column (2) distinguishes sales from purchases, and columns (4) - (6) present the total and the successful number of cases. Columns (7) – (10) consider the p-value associated with the sign test for different values (probability of success): 0.5, 0.6, 0.7 and 0.8. Highlighted values correspond to p-values less than 0.10.[7]

The results confirm that all types of intervention are successful, when considering $H_0 : p \leq 0.5$ (column 7) meaning that an exchange rate appreciation is less intense after purchases of foreign currency by the central bank (vice-versa for sales). However, only the volatility options are successful when considering a more rigorous null hypothesis $H_0 : \ p \leq 0.6, 0.7$ or 0.8 (and t_3 in some cases).

Results of Table 3 suggest that t_3 and volatility options were successful according to the direction criterion $\left(H_0 : \ p \leq 0.5\right)$. The former, with p-values of 0.02 for sales, and 0.11 for purchases. The combined effect of volatility options, "purchases + sales" is also significant at the 10% level (not reported). The stronger effect of volatility options also appears in Table 4 for reversals (t_3 is not significant in this last case) and in Table 5 for matching. We also report in the next section the results of the same tests, controlling for two alternative scenarios. Scenario (a) considers the evolution of the exchange rate in Brazil;

7 Tables 2 – 5 only considered event, pre and post periods of five days, but results for the other combinations yield similar results. We report in the Appendix the case of 10 days.

Table 2. Sign Test, Smoothing

Type of Intervention	Purchases/ sales	window	Total Cases	Favorable Cases	% Success	H_0: $p \leq 0.5$	H_0: $p \leq 0.6$	H_0: $p \leq 0.7$	H_0: $p \leq 0.8$
						P-value	P-value	P-value	P-value
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
A. Discretionary	Purchases	5	11	8	72.7	0.03	0.12	0.31	0.62
	Sales	5	0	-	-	-	-	-	-
B. Options reserve accumulation	Purchases	5	19	12	63.2	0.08	0.31	0.67	0.93
	Sales	5	1	1	100.0	.	.	.	.
C. Options volatility	Purchases	5	11	10	90.9	0.00	0.00	0.02	0.09
	Sales	5	9	9	100.0	0.00	0.00	0.00	0.00
t_2=(A)+(B)	Purchases	5	30	20	66.7	0.02	0.18	0.59	0.94
	Sales	5	1	1	100.0	.	.	.	.
t_3=(A)+(B)+(C)	Purchases	5	38	28	73.7	0.00	0.03	0.26	0.78
	Sales	5	8	8	100.0	0.00	0.00	0.00	0.00

Source: Authors' calculations. Pre, post, and event-windows correspond to 5 days. The statistical analysis consisted of counting the number of successful events and comparing it with the total number of events. We use a sign t-test, based on a binomial distribution, to check if the probability of a successful event (p) is greater or equal than a given probability value.

and Scenario (b) considers what happened in those cases in which volatility options should have been applied if the rule were in place.

Table 3. Sign Test, Direction

Type of Intervention	Purchases/ sales	Window	Total Cases	Favorable Cases	% Success	H_0: $p \leq 0.5$ p-value
(1)	(2)	(3)	(4)	(5)	(6)	(7)
A. Discretionary	Purchases	5	11	6	54.5	0.27
	Sales	5	0	0	.	.
B. Options reserve accumulation	Purchases	5	19	11	57.9	0.18
	Sales	5	1	1	100.0	
C. Options volatility	Purchases	5	11	7	63.6	0.11
	Sales	5	9	7	77.8	0.02
t_2=(A)+(B)	Purchases	5	30	17	56.7	0.18
	Sales	5	1	0	-	-
t_3=(A)+(B)+(C)	Purchases	5	38	23	60.5	0.07
	Sales	5	10	8	80.0	0.01

Source: Authors' calculations. Pre, post, and event-windows correspond to 5 days. The statistical analysis consisted of counting the number of successful events and comparing it with the total number of events. We use a sign t-test, based on a binomial distribution, to check if the probability of a successful event (p) is greater or equal than a given probability value.

Table 4. Sign Test, Reversal

Type of Intervention	Purchases/ sales	Window	Total Cases	Favorable Cases	% Success	H_0: $p \leq 0.5$ p-value
(1)	(2)	(3)	(4)	(5)	(6)	(7)
A. Discretionary	Purchases	5	11	5	45.5	0.50
	Sales	5	0	0	.	.
B. Options reserve accumulation	Purchases	5	19	6	31.6	0.92
	Sales	5	1	0	-	.
C. Options volatility	Purchases	5	11	7	63.6	0.11
	Sales	5	9	7	77.8	0.02
t_2=(A)+(B)	Purchases	5	30	11	36.7	0.90
	Sales	5	1	0	-	.
t_3=(A)+(B)+(C)	Purchases	5	38	17	44.7	0.69
	Sales	5	10	8	80.0	0.01

Source: Authors' calculations. Pre, post, and event-windows correspond to 5 days. The statistical analysis consisted of counting the number of successful events and comparing it with the total number of events. We use a sign t-test, based on a binomial distribution, to check if the probability of a successful event (p) is greater or equal than a given probability value.

Table 5. Matching Test

Type of Intervention	Purchases/ sales	Window	Total Cases	Average Difference	P-value H_0: $D \leq 0$ or H_0: $D \geq 0$*
(1)	(2)	(3)	(4)	(5)	(6)
A. Discretionary	Purchases	5	11	0.06	0.42
	Sales	5	0	.	.
B. Options reserve accumulation	Purchases	5	19	0.05	0.39
	Sales	5	1	-0.16	.
C. Options volatility	Purchases	5	11	1.08	0.11
	Sales	5	9	-0.72	0.02
t_2 = (A)+(B)	Purchases	5	30	0.05	0.41
	Sales	5	1	-0.10	.
t_3 = (A)+(B)+(C)	Purchases	5	38	0.30	0.32
	Sales	5	10	-0.67	0.04

* $D \leq 0$ for purchases and $D \geq 0$ for sales.
Source: Authors' calculations. Pre, post, and event-windows correspond to 5 days. The statistical analysis consisted of computing the difference between the corresponding pre and post event exchange rate values. We assume that the variation of the exchange rate of both sub-samples is normally distributed, so we use a t-test with n-1 degrees of freedom ("n" being the number of matched pairs) to draw inference.

A. Counterfactuals

The Colombian exchange rate could have increased after an intervention episode for a variety of reasons, including the effects of other countries like Brazil (See Section I). For this reason, Tables 6a-6c present the same exercise of Tables 2-5 but for the case of Brazil. In other words, we consider the evolution of the exchange rate in Brazil in periods corresponding to pre and post Colombian volatility interventions. This provides a counterfactual experiment that allows us to test for possible bias that might have been introduced by predetermined variables.

Results for volatility options are presented in Table 6a which suggests that interventions under this counterfactual were not successful according to the direction, reversal and the matched criteria. However, the case of Brazil casts some doubts when considering the impact of intervention on the smoothing criterion (it is also significant in Brazil with the associated null hypothesis of

Ho: $p \leq 0.5$).[8] This result no longer holds when considering the null hypothesis of *Ho:* $p \leq 0.8$, which is significant for the Colombian case (see Table 2) but not significant for the case of Brazil.

Results for discretionary interventions and reserve accumulation are presented in Tables 6b and 6c, respectively. While discretionary interventions in Brazil exhibited no significant effects, options for reserve accumulation were significant under the smoothing and direction criteria for the null hypothesis of *Ho:* $p \leq 0.5$. In sum, out of the 12 counterfactual exercises presented in Tables 6a-6c, only 3 were significant, two of which correspond to the weakest criteria (smoothing with a null of *Ho:* $p \leq 0.5$).

Table 6a. Control I: Sign Tests for Volatility Options Using Brazil As Counterfactual

Criterion	Window	Total Cases (Purchases + Sales)	Favorable Cases	% Success	*Ho*: $p \leq 0.5$,	*Ho:* $p \leq 0.8$,	*Ho: D* ≤ 0,
					p-value	p-value	p-value
Smoothing	5	20	17	85	0.00	0.21	-
Direction	5	20	12	60	0.13	-	-
Reversal	5	20	9	45	0.58	-	-
Matched	5	20	-	-	-	-	0.26

Source: Authors' calculations. Refer to Tables 2-5 for the statistical analysis of each criterion.

Table 6b. Control I: Sign Tests for Discretionary Interventions Using Brazil As Counterfactual

Criterion	Window	Total Cases (Purchases + Sales)	Favorable Cases	% Success	*Ho*: $p \leq 0.5$,	*Ho:* $p \leq 0.8$,	*Ho: D* ≤ 0,
					p-value	p-value	p-value
Smoothing	5	11	7	64	0.11	0.84	-
Direction	5	11	3	27	0.89	-	-
Reversal	5	11	3	27	0.89	-	-
Matched	5	11	-	-	-	-	0.44

Source: Authors' calculations. Refer to Tables 2-5 for the statistical analysis of each criterion.

8 We are assuming that Brazil was not intervening in those same periods, or that the pattern of intervention during the whole period was different.

Table 6c. Control I: Sign Tests for Reserve Accumulation Options Using Brazil As Counterfactual

Criterion	Window	Total Cases (Purchases + Sales)	Favorable Cases	% Success	*Ho: p* ≤ 0.5, p-value	*Ho: p* ≤ 0.8, p-value	*Ho: D* ≤ 0, p-value
Smoothing	5	20	14	70	0.02	0.80	-
Direction	5	20	14	70	0.02	-	-
Reversal	5	20	10	50	0.41	-	-
Matched	5	20	-	-	-	-	0.33

Source: Authors' calculations. Refer to Tables 2-5 for the statistical analysis of each criterion.

The second counterfactual considered was related to the behavior of the Colombian exchange rate in periods in which rule-based volatility options should have been triggered if the rule were in place, but was not, simply because the board of the Central Bank decided to suspend interventions. In principle, monetary authorities may have chosen to suspend this particular intervention mechanism for reasons related to exchange rate movements, leading to an endogenous relationship. However, we consider a period of over 3 years (2010-2012) in which the rule was no longer in place. And, while exchange rate movements in 2009 might have influenced the decision to permanently terminate this type of interventions, it is very unlikely that this relationship persisted for more than a few months (certainly not for years after the decision was taken). Given the small number of events available, we only considered the case of a 2-day event window, pre and post event.

Table 7 shows, once again, that our results are not biased by pre-existing differences. Tables 6 and 7 thus suggest that the counterfactual experiments for volatility options are robust for direction, reversal and for the matched test, but not for smoothing.

Table 7. Control II: Sign Test for Volatility Options in Brazil Using Different Conditions As Counterfactual

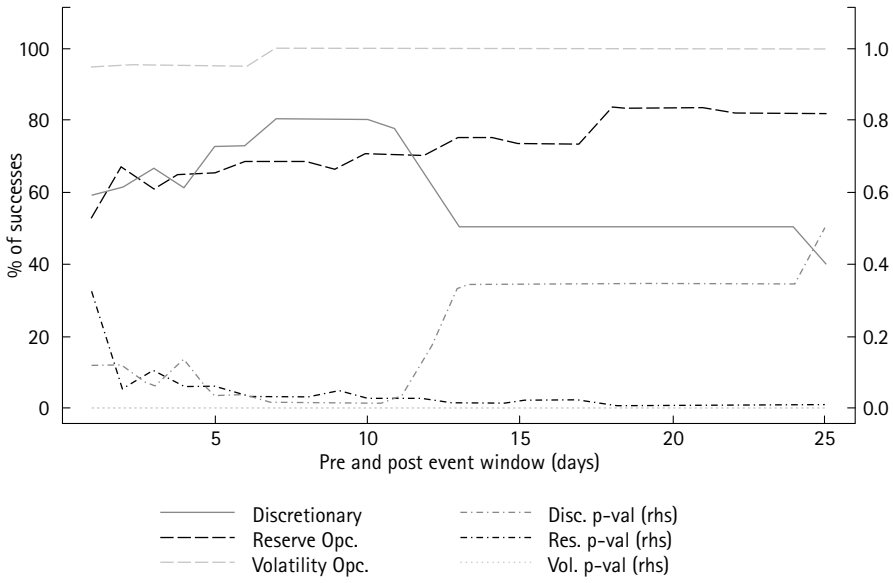
Criterion	Window	Total Cases (Purchases+ Sales)	Favorable Cases	%Success	H_0: $p \leq 0.5$, p-value	H_0: $D \leq 0$, p-value
Smoothing	2	10	7	70	0.05	-
Direction	2	10	7	70	0.58	-
Reversal	2	10	6	60	0.17	-
Matched	2	10	-	-	-	0.40

Source: Authors' calculations. Refer to Tables 2-5 for the statistical analysis of each criterion.

B. Robustness Checks

Graphs 5-8 show additional robustness checks for our proposed criteria: Smoothing (Figure 5), Direction (Figure 6), Reversal (Figure 7) and Matching (Figure 8). For each type of intervention, we computed the percentage of successes and p-values of the evaluation test[9] for different window sizes. Two main results can be seen: 1) volatility options are successful according to the four criteria and for all window sizes considered, and 2) all intervention mechanisms are successful when considering only the smoothing criteria and for window sizes that are less than 12 days.

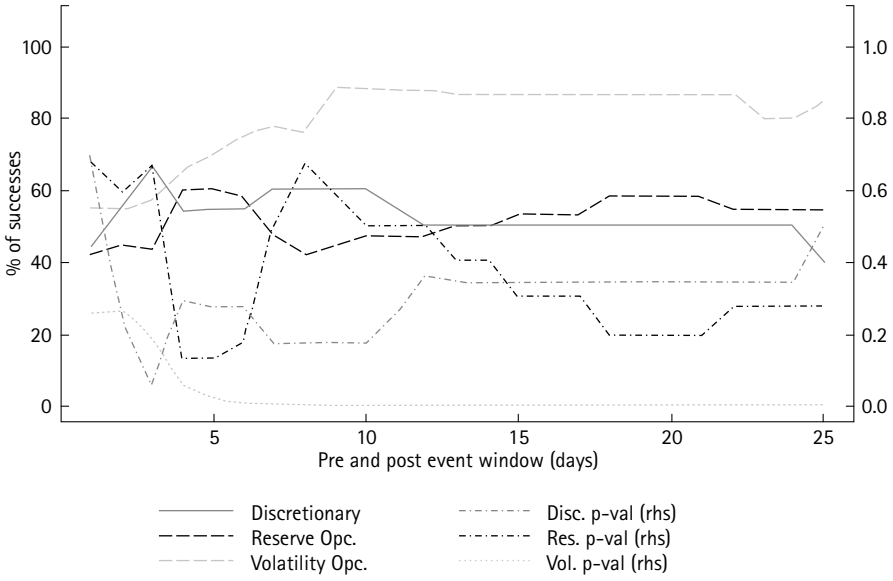
Graph 5. Robust Exercise-Smoothing Criteria



Source: Authors' calculations. Refer to Tables 2-5 for the statistical analysis of each criterion.

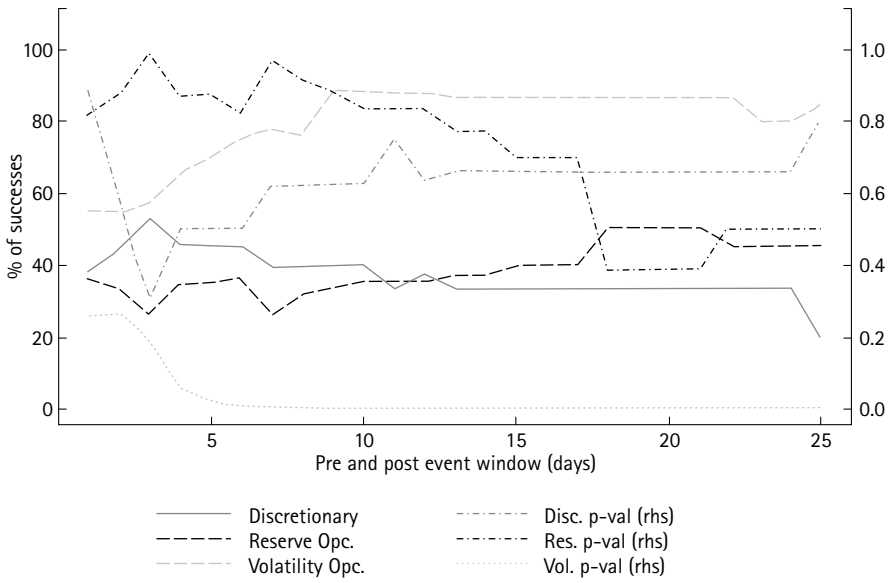
9 For the match test only the p-value is presented.

Graph 6. Robust Exercise Direction Criteria



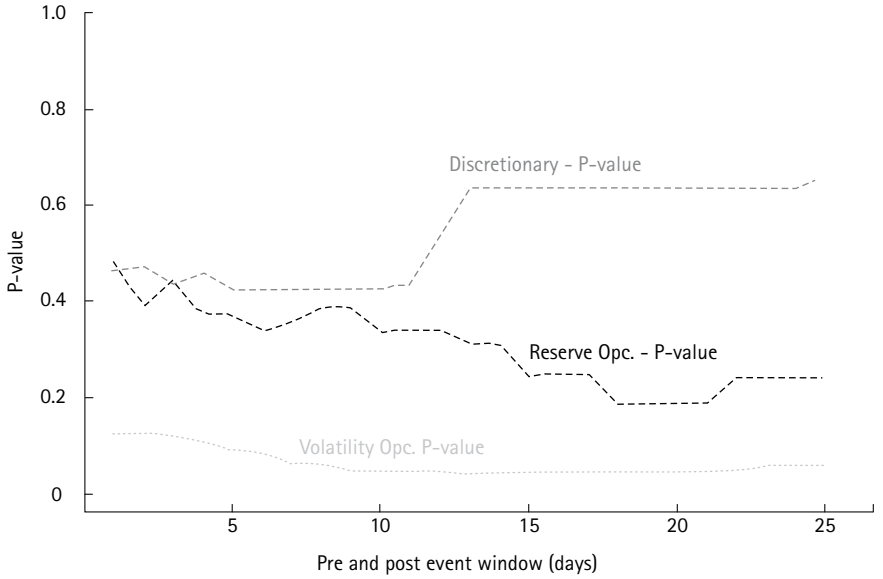
Source: Authors' calculations. Refer to Tables 2-5 for the statistical analysis of each criterion.

Graph 7. Robust Exercise – Reversal Criteria



Source: Authors' calculations. Refer to Tables 2-5 for the statistical analysis of each criterion.

Graph 8. Robust Exercise – Matched Test



Source: Authors' calculations. Refer to Tables 2-5 for the statistical analysis of each criterion.

IV. Conclusions

We compare the effects of international reserve accumulation options, volatility options and discretionary interventions for the Colombian case during 2000-2012, using an event study approach. Following Fatum and Hutchison (2001), we define four different criteria to evaluate a successful intervention: 1) Direction, 2) Reversal, 3) Smoothing, and 4) Matching.

We also conduct two counterfactual exercises: 1) we consider the evolution of the Brazilian exchange rate in periods corresponding to pre and post Colombian volatility interventions and 2) we consider periods in which volatility options should have been conducted if the intervention rule was in place, but was not, because the board of the Central Bank decided to suspend interventions. Finally, we conduct robustness checks by allowing for various event window sizes.

Results show that all types of interventions were successful according to the smoothing criterion when considering the null hypothesis of $H_0 : p \leq 0.5$.

Also, volatility options were successful when considering a more rigorous null hypothesis of $H_0: p \leq 0.6, 0.7$ or 0.8. Moreover, volatility options were also successful according to the direction, reversal and matching criteria.

We also find that volatility options, using Brazil as a counterfactual exercise, were not successful according to the direction, reversal and matched criteria. The case of Brazil casts some doubts when considering the smoothing criterion (it is also significant in Brazil under the null hypothesis of $H_0 : p \leq 0.5$). However, this result no longer holds when considering the null hypothesis of H_0: $p \leq 0.5$, which is significant for Colombia but not significant for Brazil. Also, while discretionary interventions in Brazil exhibited no significant effects, options for reserve accumulation were significant under the smoothing and direction criteria under the null of $H_0 : p \leq 0.5$.

As a result, our findings indicate that: 1) volatility options were successful according to the four criteria and for all window sizes considered, and 2) all intervention mechanisms were successful under the smoothing criteria and for window sizes of less than 12 days. Finally, most of our counterfactual exercises suggest that our results are not biased by pre-existing differences. However, this is not the case for the options for reserve accumulation. Success for this mechanism should be further analyzed and results should be cautiously interpreted.

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Appendix

Table A.1. Sign Test, Smoothing (10 days)

Type of Intervention	Purchases/ sales	Window	Total Cases	Favorable Cases	% Success	$H_0: p \leq 0.5$ p-value
(1)	(2)	(3)	(4)	(5)	(6)	(7)
A. Discretionary	Purchases	10	6	4	67	0.11
	Sales	10	0	0	.	.
B. Options int. reserves	Purchases	10	14	10	71	0.03
	Sales	10	1	1	100	.
C. Options volatility	Purchases	10	10	10	100	0.00
	Sales	10	5	5	100	0.00
t_2=(A)+(B)	Purchases	10	18	12	67	0.05
	Sales	10	1	1	100	.
t_3=(A)+(B)+(C)	Purchases	10	24	19	79	0.00
	Sales	10	6	6	100	0.00

Source: Authors' calculations. Refer to Tables 2-5 for the statistical analysis of each criterion.

Table A.2. Sign Test, Direction (10 days)

Type of Intervention	Purchases/ sales	Window	Total Cases	Favorable Cases	% Success	$H_0: p \leq 0.5$ p-value
(1)	(2)	(3)	(4)	(5)	(6)	(7)
A. Discretionary	Purchases	10	6	3	50	0.34
	Sales	10	0	0	.	.
B. Options int. reserves	Purchases	10	14	9	64	0.09
	Sales	10	1	1	100	.
C. Options volatility	Purchases	10	10	8	80	0.01
	Sales	10	5	4	80	0.03
t_2 = (A)+(B)	Purchases	10	18	11	61	0.12
	Sales	10	1	1	100	.
t_3 = (A)+(B)+(C)	Purchases	10	24	18	75	0.00
	Sales	10	6	5	83	0.02

Source: Authors' calculations. Refer to Tables 2-5 for the statistical analysis of each criterion.

Table A.3. Sign Test, Reversal (10 days)

Type of Intervention	Purchases/ sales	Window	Total Cases	Favorable Cases	% Success	H_0: $p \leq 0.5$ p-value
(1)	(2)	(3)	(4)	(5)	(6)	(7)
A. Discretionary	Purchases	10	6	2	33	0.66
	Sales	10	0	0	.	.
B. Options int. reserves	Purchases	10	14	7	50	0.40
	Sales	10	1	0	0	.
C. Options volatility	Purchases	10	10	8	80	0.01
	Sales	10	5	4	80	0.03
t_2 = (A)+(B)	Purchases	10	18	9	50	0.41
	Sales	10	1	0	0	.
t_3 = (A)+(B)+(C)	Purchases	10	24	16	67	0.03
	Sales	10	6	4	67	0.11

Source: Authors' calculations. Refer to Tables 2-5 for the statistical analysis of each criterion.

Table A.4. Matching Test (10 days)

Type of Intervention	Purchases/ sales	Window	Total Cases	Average Difference	*P-value* H_0: $D \leq 0$ or H_0: $D \geq 0$*
(1)	(2)	(3)	(4)	(5)	(6)
A. Discretionary	Purchases	10	6	-0.05	0.58
	Sales	10	0	.	.
B. Options int. reserves	Purchases	10	14	0.06	0.30
	Sales	10	1	-0.01	.
C. Options volatility	Purchases	10	10	0.62	0.07
	Sales	10	5	-0.63	0.05
t_2 = (A)+(B)	Purchases	10	18	0.04	0.41
	Sales	10	1	-0.01	.
t_3 = (A)+(B)+(C)	Purchases	10	24	0.28	0.24
	Sales	10	6	-0.53	0.11

* $D \leq 0$ for purchases and $D \geq 0$ for sales.
Source: Authors' calculations. Refer to Tables 2-5 for the statistical analysis of each criterion.