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Abstract

The adoption of a managed regime assumes that interventions are relatively successful. However, while some authors consider that foreign exchange interventions are ineffective, arguing that domestic and foreign assets are close substitutes, others advocate their use and maintain that their effects can even last for months. There is also a lack of consensus on the related question of how to intervene. Are dirty interventions more powerful than pre-announced ones? This paper compares the effects of day-to-day interventions with discretionary interventions by combining a Tobit-GARCH reaction function with an asymmetric power PGARCH(1,1) impact function. Our results show that the impact of pre-announced and transparent US$ 20 million daily interventions, adopted by Colombia in 2008–20–12, has been much larger than the impact of dirty interventions adopted in 2004–2007.We find that the impact of a change in daily interventions (from US$ 20 million to US$ 40 million) raises the exchange rate by approximately Col $2, implying that actual interventions of US$ 1,000 million increase the exchange rate in one day by 5.50%. We also find that capital controls have a positive effect.

Key words: Central bank intervention, reaction function, Tobit-GARCH, foreign exchange intervention mechanisms, capital controls, dirty interventions .

JEL Cclassification: E52, E58, F31.

[1] The views expressed in this working paper are those of the authors, and do not necessarily represent those of the Colombian Central Bank. We want to thank Kathryn Dominguez, Rasmus Fatum, Hernán Rincón, Hernando Vargas, and Juan Pablo Zárate for their comments.

Contents

I. Introduction

Each of the major international capital market-related crises since 1994 has involved a fixed or pegged exchange rate regime (Fischer, 2001), and authors such as Kamil (2012) argue that currency missmatches are much marked under pegs. Supporters of free floating in Colombia contrast the deep crisis of 1999, under an exchange band regime, with the relatively successful recent experience under flexible rates.[2] More generally, countries that adopted inflation targeting, and floated, handled the recent international crisis much better (Carvalho, 2010).

But Razin and Rubinstein (2006) find a tension between the pro-GDP growth and the pro-crisis effects produced by pegged exchange rates[3] to be one of the reasons why the number of countries with managed exchange rates has increased during the last decade,[4] and why many of those considered free floaters by the IMF do not really float (Calvo and Reinhart, 2002). The *corners hypothesis*, that countries are (or should be) moving away from the intermediary regimes, in favor of either the hard peg corner or a floating corner, began to lose popularity after the failure of Argentina' s quasi-currency board in 2001.[5] In the literature, Frankel (2012) mentions five advantages of floating, but also five advantages of fixing.

International reserves accumulation (as a percentage of the monetary base) has been much larger in countries like Singapuore, Korea, Thailand and Taiwan than in China, a country whose international reserves represent more than 45% of GDP, and Brazil's finance minister, Guido Mantega, considers that "we are in the midst of an international currency war between the North and the South". On September 15, 2010, Japan purchased US$ 24 billion, an amount larger than the total of all interventions conducted by the US Federal Reserve since 1990 and more than six times larger than the entire US intervention in 1985 (Fratzscher, 2012). Finally, on September 6, of 2011, the Swiss National Bank decreed set an exchange rate target of SFr1.20 to the euro, by "being prepared to purchase foreign exchange in unlimited quantities".

Some recent literature finds that FX interventions have important effects. Thus, for Fratzscher (2012) "countries with high reserve ratios are those that tend to have undervalued exchange rates" (pp. 722–723); and, based on GARCH regressions and event studies for the G3 countries, the same author concludes that "FX intervention policies can indeed exert a sizeable influence on overall exchange rate developments in the

[2] See Gómez, Uribe, and Vargas (2002), Zárate, Cobo, and Gómez (2012) and Echavarría, et al .(2012).

[3] Hausmann, Pritchett, and Rodrik (2004) find that rapid growth accelerations that are sustained for a period of several years are related with to real exchange depreciations, and Rodrik (2008) shows that higher growth in emerging economies occurs, on average, after 10 years of strong devaluations.

[4] Eichengreen, et al. (2011), Figure 1 presents the share of different exchange rate regimes when considering world GDP and world exports.

[5] For Frankel (2012), the corners hypothesis did not have a good theoretical foundation. Thus, for example, a target zone is entirely compatible with the uncovered interest parity condition (Krugman, 1991).

medium term" (p .737).

To our knowledge, however, there is scant evidence on the related question on how to intervene.[6] Is it better for monetary authorities to proceed with secret *dirty interventions* or with open, pre-announced and transparent interventions? Many central banks have adopted inflation targeting during the last decade convinced that they affect the economy as much through their influence on expectations as through any direct, mechanical effects of central bank trading in the market for overnight cash (Woodford, 2005). They try to be transparent, teach the market about their most likely behavior and try to affect expectations. Why shouldn't these principles also apply to the management of the exchange rate? Why is it, then, generally assumed (but not proven), that the impact of dirty interventions and "surprises" is stronger?

Colombia offers an ideal case study because of the various modalities of intervention that the central bank has conducted in the past.[7] These consist of international reserve accumulation and volatility options in the first part of the decade of 2000s, discretionary (dirty) interventions during 2004–2007 and day-to-day (close to) constant and preannounced interventions during 2008–2012.

Section II describes the evolution of foreign exchange intervention and capital controls in Colombia, Section III considers a relatively standard simultaneous equations model for the determinants of the exchange rate and Section IV presents the estimation results. When comparing the effects of day-to-day interventions with discretionary interventions, we combine a Tobit-Garch reaction function with an asymmetric power PGARCH(1,1) impact function. Section V concludes after a preliminary discussion on possible channels through which foreign exchange intervention affects the exchange rate.

II. Foreign exchange intervention and capital controls in Colombia, 2000–2012

The US Federal Reserve describes four different reasons to intervene in foreign exchange markets: to influence trend movements in exchange rates, to calm disorderly markets, to rebalance its foreign exchange reserve holdings, and to support fellow central banks in their exchange rate operations (Dominguez, 1999). Echavarría, Vásquez, and Villamizar (2009) present a review of the different arguments given by the central bank's Board of Directors to rationalize interventions in Colombia. Volatility and excessive trends can bring

[6] Mandeng (2003) considers the impact of option interventions in Colombia, and Dominguez, Fatum, and Vacek (2013) analiyzse the impact of discretionary and day-to-day sales of reserves by the Czech National Bank between 2004 and 2007.

[7] Colombia adopted a "passive" crawling peg between 1967 and 1991, and an exchange rate band between 1991 and 1999. The country suffered the strongest crisis of the century (and one of the strongest in Latin America) in 1999, and moved into an inflation targeting regime at the end of 1999. It has then moved in the direction of further exchange rate flexibility, but exchange rate interventions have been important. There has always been a local debate about the optimum amount (and modality) of intervention.

a reduction in international trade, increase pressures towards protectionism, increase inflation persistence and delay the development of the financial sector (Rigobón, 2008). The costs of exchange rate "missalignments" of the exchange rate could be higher in emerging countries where volatility is larger (partially due to shallow financial markets) and where the real exchange rate could have a higher impact on trade and the real economy.[8] Many emerging markets are relatively open to trade, with high levels of pass-through and higher levels of dollarized liabilities.[9] The fear of floating (both upwards and downwards) could then be higher in emerging markets than in developed economies.[10]

The central bank's Board of Directors is in charge of monetary and exchange rate policy in Colombia. The Minister of Finance sits in the Board with one vote (among seven), which means that the government has a moderate role in the design of exchange rate policy, albeit less than in other countries such as Brazil or Mexico (Junguito and Vargas, 1996). Most discussions by the members of the Board have been centered on the level and the volatility of the exchange rate, partially because Colombia (together with Mexico and Poland) obtained has a flexible credit line with the IMF, a "cheap" mechanism to partially safeguard the country against international shocks.[11] The level of reserves has been "moderate" when compared to other countries in the region**,**[12] and the available studies on the optimal level of international reserves produce a very wide range of estimations, in which results are extremely sensitive to the specific parameters of the underlying model.[13]

Graph 1 summarizes the history of interventions in Colombia during the period 2000–2012. 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 in 2010–2012.[14] Yearly purchases represented 0.12% of (yearly) transactions in the market in 2003, and 4.06% in 2005, with an average of 1.70% in 2000–

[8] This and other paragraphs of the paper are taken from Echavarría, Vásquez, and Villamizar (2009).
[9] See Calvo (1999) and Domac and Mendoza (2004).
[10] See Calvo and Reinhart (2002) and Levy-Yeyati and Sturzenegger (2007).
[11] The amounts involved were US$ 23,668 (45% of the stock of international reserves) in 2009, US$ 3,674 (13.9%) in 2010, and US$ 5,909 (19.1%) in 2012. IMF funds are disbursed in anticipation to a balance of payments crisis and the country pays interests only when it uses the credit line. See Junta Directiva (2009), June, p.101.
[12] The ratio of reserves to M2 or M3 proposed by Obstfeld, Shambaugh, and Taylor (2008) is high in Colombia (it is only higher only in Peru) and higher than the desirable figure of 5%–10% suggested by Wjinholds and Kapteyn (2001) for flexible exchange regimes (also higher than the figure of 20% suggested by the authors for fixed exchange regimes). The relation to short term debt is average in the region and higher than the desired value of one (1). Mejía (2012) shows that international reserves in Colombia are relatively low when compared to GDP. The relation between reserves and M3 has been decreasing since 2003, while the relation between reserves and short term debt increased between 2000–2006 and 2007–2012.
[13] For a discussion on the optimal level of reserves in Colombia see Mejía (2012), Calvo, Izquierdo, and Loo-Kung (2012) and Banco de la República (2012). The calculation made by the technical staff of the Bank in 2003 concluded that the observed level of US$ 10.000 millions was close to the optimum.
[14] There were some sales of US$ dollars to the government in 2004–2006, intended to pay external debt.

2012; they represented 1% of the average stock of international reserves in 2003, 33% in 2005, with an average of 11.86% in 2000–2012.[15]

Graph 1
Colombian central bank interventions

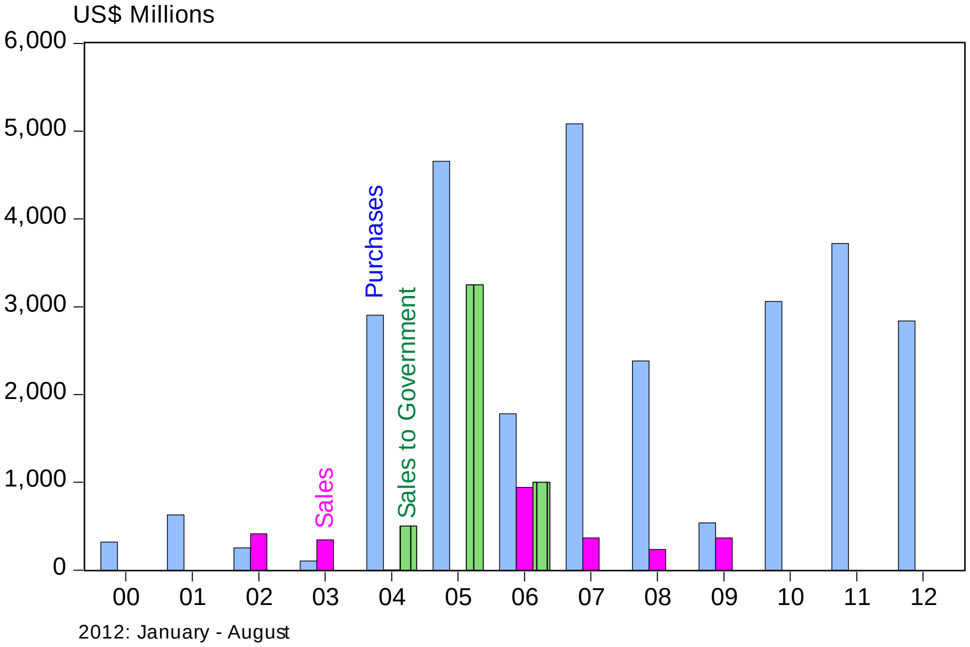


Table 1 shows the relative importance of different types of intervention: options for reserve accumulation, options for the control of volatility, discretionary interventions and fixed (close to) US$ 20 million per day interventions.[16] Put options for reserve accumulation, partially implemented to 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 the intervention were initially announced, but that practice changed later on when periods and amounts became indefinite.

Following the example of Chile and Israel, the central bank decided to buy (close to) US$ 20 million per day, during two months in 2008, five months in 2010, six months in 2011, and every month since February 6, of 2012. The amount of US$ 20 million was obtained as an "average" of the daily purchases in

[15] Daily transactions in the market are close to US$ 1,000 million today, and to US$ 320 million in 2001–2004 (average). The stock of international reserves is close to US$ 33,000 million today, and to US$ 10,611 in 2001–2004 (average).

[16] Next day purchases accumulate when there is a holiday in the United States or when t-1 auctions are not fully exercised. For a good description of the evolution of Colombian interventions, see Junta Directiva del Banco de la República (2007), pp.68-85 and Junta Directiva del Banco de la República (2011), pp.111-114.

those two countries. In 2008 Chile purchased US$ 50 million in a market with daily transactions of US$ 2,036 million, while Israel purchased US$ 25 million in a market with daily transactions of US$ 3,543 million. Colombia (with a market of US$ 1,290 million), should buy daily amounts of US$ 31.8 and US$ 9.1 million in order to emulate Chile and Israel, respectively. The amount of US$ 20 million also took into account the sterilization capabilities of the central bank during those years. It was considered at the time that this was a good mechanism for accumulating reserves without promoting the "speculative attacks" observed in the past with dirty interventions.

Finally, volatility options were used to buy and (mainly) sell foreign currency in some days in 2004, 2006, 2007, 2008 and 2009. Volatility options have not been used during the recent years, partially because there are doubts about their impact, and partially because they might interfere 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 exercise them totally or partially during the following 30 days, as long as the exchange rate was lower than the average of the last 20 days. This means that international reserves were purchased at a "low" price (or "high" in the case of sell orders). The bank could announce a new auction during the same month even if the previous action had not expired.

Volatility options were auctioned automatically whenever the difference between the exchange rate of the previous day (the so called TRM) and the moving average of the last twenty days was higher (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.

Ramírez (2005) considers that exchange rate interventions in Colombia were relatively transparent. Options were announced the same day that they were exercised (the name of the firm remained confidential), and the amount of intervention was announced each week. Very often the Board of Directors pre-announced the total amount of dollars to be bought/sold during the next months. For example, the Board announced an intervention of US$ 1000 millions during the last three months of 2004,[17] and on June 20, of 2008 the Board announced the new US$ 20 millions interventions, with an amount of US$ 2,400 million to be bought between July and December (US$ 3,500 million over the whole year).

As will be seen in Sections III and IV, some interventions have been related to misalignments of the *real* exchange rate. As a proxy for the long-run equilibrium exchange rate ($\bar{s}_t$) we consider the mean of seven in house "structural" models estimated at the Colombian central bank: models (1) and (2) are based on

[17] But in December 2004, the Board announced additional undefined interventions in terms of amounts and periods.

purchasing power parity; model (3) uses a Hodrick-Prescott filter; models (4) and (5) are based on VEC and structural VEC methodologies; and models (6) and (7) on equilibrium theories of the current account. This *equilibrium* exchange rate is presented monthly to the Board of Directors to feed the discussion on potential misalignments.

What were the reasons that moved the monetary authority to change discretionary (dirty) interventions in 2004–2007 for clean, transparent, and pre-announced US$ 20 million per day purchases? Part of the answer has to do with the speculative attacks from banks and other private agents. As can be seen in Graph 3, discretionary interventions stopped after March 1, 2006, and *devaluations* were very strong the following days, stronger than in Brazil (something similar happened after April 30, 2007).[18] Also, because some members of the Board were convinced that oral interventions (i.e. vocal or mediatic) were important, a result that we discuss in Section IV.C.

Table 1
Colombian interventions, 2000–2012

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012*
Purchases (US$)	319	629	252	106	2,905	4,658	1,781	5,082	2,381	539	3,060	3,720	2,840
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	3,250	1,944	369	235	369	0	0	0
Participation (%)													
Options Call			100	100	0	0	49	100	100	100			
International Reserve Reduction			0	100	0	0	0	0	0	0			
Volatility Options			100	0	0	0	49	100	100	100			
Sales to National Government			0	0	100	100	51	0	0	0			
Net Purchases	319	629	-163	-238	2,405	1,408	-164	4,713	2,147	171	3,060	3,720	2,840

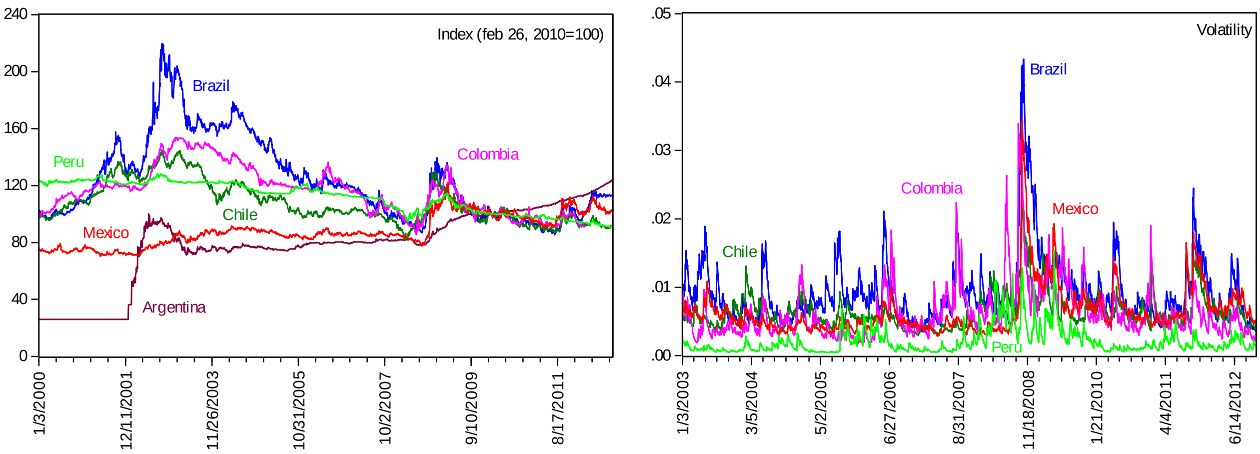
*: january - august

Graph 2 shows the level and the volatility of the daily nominal exchange rate for a group of Latin American countries. Exchange rates are defined as the amount of local currency per US$, so an increase corresponds to a depreciation of the Colombian peso. The level of the different *nominal* exchange rates is not very different at the beginning and the end of the period in Colombia (index of 91.7 in November 6, 2012 and 97 in March 3, 2000), Brazil (113.0 vs. 101.2) and Chile (91.3 vs. 100.6), but it is lower today in Peru (91.3 vs. 123.7). This implies a strong *real* revaluation for the four countries. On the other hand there were strong nominal devaluations in Argentina (mainly, 123.7 vs. 25.9), and Mexico (101.8 vs. 74.7).

[18] Causality could also run in the opposite direction, with purchases being abandoned when the exchange rate started to rise.

The right part of the graph shows the volatility of the exchange rate, calculated from a GARCH model. Averages for the whole period indicate that it has been especially high in Brazil, followed by Chile, Colombia and Mexico (similar levels) and it has been much lower in Peru. Volatility was especially marked in all countries at the end of 2008 (Lehman Brothers), in some episodes at the beginning of 2012, and at in the middle of 2005, 2006 and 2010, but it does not seem to be higher today than in the past. The correlation between volatility in Colombia and Brazil has been especially high but it has also been high between Colombia and Chile (0.47), Mexico (0.45) and even Peru (0.45). Loaiza and Melo (2012) find a strong relation between the exchange rates in Colombia and Brazil (see also Section IV).

Graph 2
The exchange rate in some Latin American countries. Level and volatility



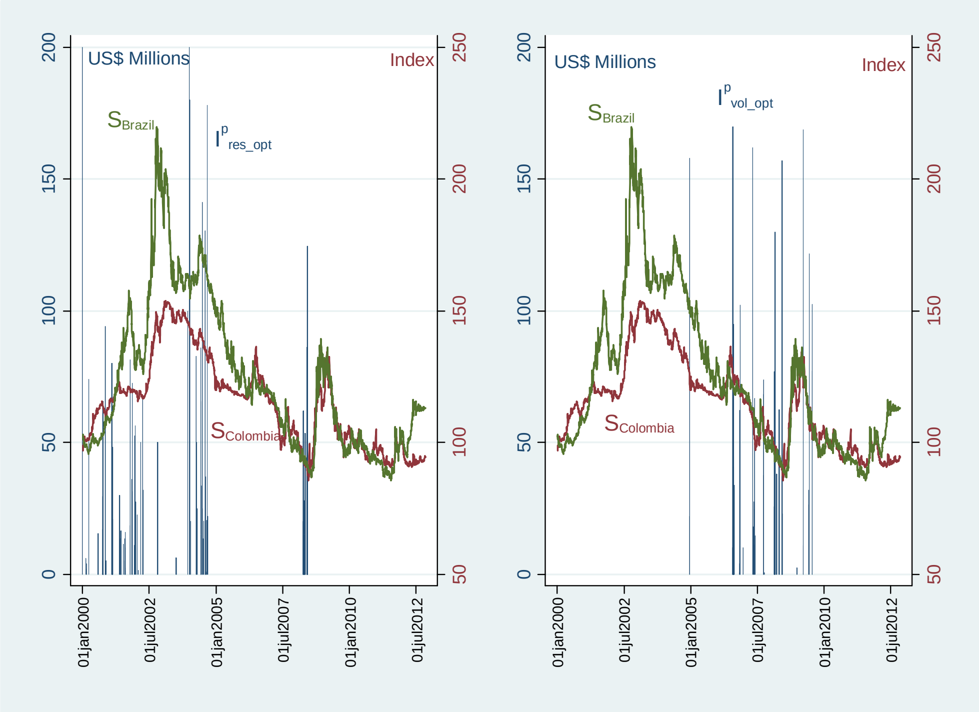
The level of the exchange rate in Colombia, although similar at the beginning and end of the sample, underwent severe revaluation and devaluation episodes. Exchange rate devaluations were particularly pronounced between the end of 1999 and January 2003 (56%, international panic with Lula); during the first semester of 2006 (14%) and during the Lehman Brother's crisis (51%, July, 2008 – February, 2009). The pattern is relatively similar in Brazil, with higher volatility between 2000 and 2006, and a different level at the end of the sample. On the other hand, revaluations were marked in Colombia between January 2003 and June 2008 (-42.5%) and between February 2009 and February 2012. Most foreign exchange purchases were conducted during periods of strong revaluation of the exchange rate.

Graphs 3 and 4 show the evolution of the different types of intervention, and the nominal exchange rate (S_t) in Colombia and Brazil, during 2000–2012. Discretional intervention I^p_{disc} and US$ 20 million options I^p_{20} are shown in Graph 3; and reserve accumulation $I^p_{res\_opt}$ and volatility options $I^p_{vol\_opt}$ in Graph 4. 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 options (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 3
Different types of intervention and the nominal exchange rate in Colombia and Brazil

Graph 4
Different types of intervention and the nominal exchange rate in Colombia and Brazil

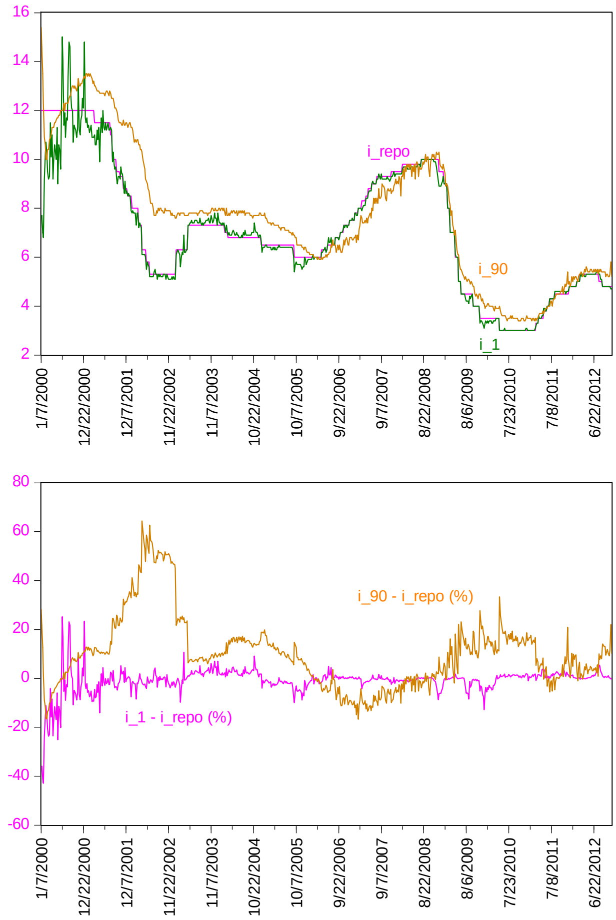


With some sporadic exceptions,[19] the Board always made clear that interventions would be sterilized, which meant that the one-day market interest rate was very close to the Board's repo rate, both before and after intervention. Large government-remunerated deposits at the central bank eased the job. Average deposits in 2008–2011 doubled the amount of total interventions, and represented one fifth of the average stock of international reserves. The first panel of Graph 5 presents the evolution of the one-day repo rate (i_t^{repo}), the interbank one-day rate (i_t^1) and the 90-days rate (i_t^{90}), while the second panel shows the percentage differences between them. The value of $\frac{i_t^1 - i_t^{repo}}{i_t^{repo}}$ (%) was high in 2000–2001, but small in the following years. In fact, the difference has been smaller during periods of intervention of any type, with an average of 1.51% for periods of intervention in 2002–2012 and 1.76% for the whole period. This does not mean, however, that other effects were not present. Thus, for example, interventions could have affected the

[19] As in March, 2004, when the Board announced that sterilized purchases would correspond to up to 50% of total purchases. See Banco de la República, *Informe de la Junta Directiva al Congreso*, March, 2004, p.46.

value of $\frac{i_t^{90} - i_t^{repo}}{i_t^{repo}}$ (%) and produce some additional *liquidity effects* on the exchange rate (Neely, 2006).[20] We will argue in Section IV.B that sterilized interventions can partially explain the insignificant impact of the one-day interest rate differential on the explanation of the nominal exchange rate.

Graph 5
Are interventions sterilized?



Capital controls were implemented between May 7, 2007 and October 8, 2008. Panel (a) of Graph 6 shows the two indices calculated by Rincón and Toro (2011). Both series, tax^1 and tax^2 indicate the equivalent tax (%) imposed on capital inflows, using the *ex post* maturity period for the different types of inflows; tax^1 distinguishes the deposits denominated in US$ dollars from those denominated in domestic

[20] The system of reserve requirements was modified when the day-to-day interventions were introduced. See Junta Directiva del Banco de la República (2008), July, Chapter IV.

currency, and tax^2 treats them all as denominated in domestic currency, the main difference between both being the devaluation/revaluation expectations.[21] Market participants had to deposit 40% of the inflow (debt and portfolio)[22] at the central bank during six months without interest payments. The variation in each series is then due to changes in the maturity of the different capital inflows. Both indices show that controls in 2007 –2008 were much less severe than in 1993–1996, and not very different from those imposed in 1997–2000.

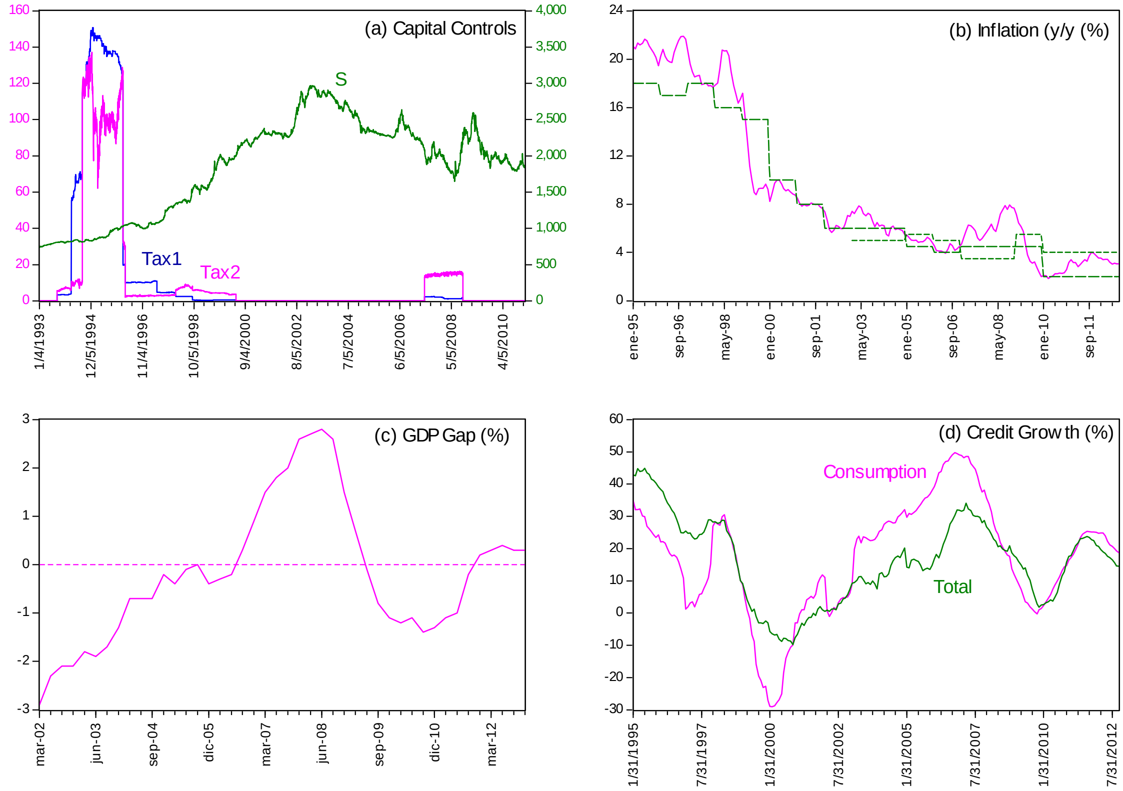
Macro prudentials were the main drivers of capital controls in 2007–2008, although there was also a strong revaluation of the exchange rate between the peak reached in June 29, 2006 (Col $ 2620/US$) and June 10, 2008 (Col $1670/US$). Inflation was rising and was already situated above the central bank target range in 2006–2009; the output gap calculated by the staff of the central bank had been growing almost exponentially after March 2002, and was close to 3% of GDP in the first part of 2008; consumption credit was growing at nominal rates close to 50% per year and total credit at rates close to 30% during the second part of 2007. Foreign direct investment explains the large bulk of total capital inflows during the period 2000–2012, but short-term capital inflows were relatively important during the second semester of 2006 and the first few early months of 2007.[23]

[21] The first one tax^1 uses the methodology propossed by Ocampo and Tovar (2003) and complemented by Rincón (2000), while the second one tax^2 uses the methodology propossed by Cárdenas and Barrera (1997) for Colombia and by Edwards and Rigobón (2005) for Chile.

[22] The first (debt) imposed by the Board of the central bank, and the second (portfolio), some weeks later, by the government. The Board also imposed a limit of 500% for the relation between purchases plus sales of foreign exchange derivatives (mainly forwards) and capital. See Junta Directiva del Banco de la República (2007), p.75; (2008), March, 2008, pp.40-43 and (2011), p.113.

[23] See Junta Directiva del Banco de la República (2011), Marzo, pp.120-125. The evolution of FDI in 2000–2011 appears in Junta Directiva del Banco de la República (2011), July, pp.77.

Graph 6
Capital controls as macro-prudential regulation, 2007–2008



III. The Model

- Actual interventions

The econometric model we use comprises two equations: the reaction function of the Board of Directors and the impact equation. The first one explains the dynamics of discretionary interventions,[24] and the second describes the behavior of exchange rate percent changes $\Delta s_t = s_t - s_{t-1}$ (s_t the log of the nominal exchange rate.[25])

$$I_t^{disc} = \gamma_0 + \gamma_1 I_{t-1}^{disc} + \gamma_2 \sum_{j=1}^{20} \Delta s_{t-j} + \gamma_3 \left(s_{t-1} - \overline{s}_{t-1}\right) + \gamma_4 D_t^{net} + \gamma_5 \left(\pi_t - \pi^*\right) + u_{1t} \qquad (1)$$

[24] It closely follows Echavarría, Vásquez, and Villamizar (2009) and Kamil (2008)

[25] We use daily information on the so called TRM, where $S_t = TRM_{t+1}$. Thus allows us to compare daily exchange rates among different countries.

$$\Delta s_t = \delta_0 + \delta_1 I_t^{disc} + \delta_2 I_{t-1}^{20} + \delta_3 \Delta\rho_{CDS,t} + \delta_4 (i_t - i_t^{\star}) + \delta_5 \Delta s_{t-1} + \boldsymbol{\delta}' \mathbf{x}_t + u_{2t} \qquad (2)$$

Given the high frequency (daily) of the data, the shocks of both equations can be described by the following GARCH processes: [26]

$$u_{1t} = \sigma_{1t}\varepsilon_{1t};\ \sigma_{1t}^2 = \alpha_{1,0} + \alpha_{1,1} u_{1t-1}^2 + \beta_1 \sigma_{1t-1}^2 \qquad (3)$$

$$u_{2t} = \sigma_{2t}\varepsilon_{2t};\ \sigma_{2t}^{\lambda} = \alpha_{2,0} + \alpha_{2,1}\left(\left|u_{2,t-1}\right| - \eta u_{2,t-1}\right)^{\lambda} + \beta_2 \sigma_{2,t-1}^{\lambda}, \text{ for } \lambda > 0 \text{ and } \left|\eta\right| \leq 1 \qquad (4)$$

With $\varepsilon_{1t} \overset{iid}{\sim} N(0,1), \varepsilon_{2t} \overset{iid}{\sim} N(0,1)$, $\mathbf{x}_t = \left(\Delta q_t, \Delta tax_t, \Delta s_{t-1}^{bra}\right)'$

I_t^{disc} corresponds to the discretionary *purchases* shown in Table 1 and in Graph 3, $\sum_{j=1}^{20} \Delta s_{t-j}$ to the variation of the nominal exchange rate during the last 20 market days,[27] $s_{t-1} - \bar{s}_{t-1}$ to the percentage difference between the observed exchange rate and the equilibrium level reported by the staff of the central bank (see Section II), D_t^{net} to a dummy variable equal to 1 when the central bank was a net debtor[28], and $\pi_t - \pi^*$ to the difference between monthly inflation and the (yearly) target of the central bank.[29]

In equation (2) we assume that the daily devaluation/revaluation of the exchange rate Δs_t depends on I_t^{disc} (instrumented), on the US$ 20 million purchases I_{t-1}^{20}, on risk (ρ_{CDS}, measured as the five-year credit default swaps for Colombia), on $i_t - i_t^*$ (the difference between the one-day interest rates in the United

[26] See Bollerslev, Chou, and Kroner (1992). An asymmetric power GARCH PGARCH(1,1) (Ding, Granger, and Engle, 1993), was estimated for the errors of equation (2). However, a simple GARCH(1,1) was estimated in the case of equation (1) given the nonlinear Tobit specification of the disturbances.

[27] This is the period considered by Kamil (2007) and by Echavarría, Vásquez, and Villamizar (2009), and corresponds to the period contemplated for the volatility options. Other periods were tried with similar results.

[28] According to some, the Board should be worried (and intervene less) when the central bank is a net debtor, because in this case there is a lot of liquidity in the market. Banks do not have to come to the central bank to obtain resources and that weakens some of the channels of monetary policy. See Echavarría, Vásquez, and Villamizar (2009) and the citations quoted there.

[29] We also considered the alternative variable $\pi_t - \pi^{\text{expected}}$, where inflation expectations come from the monthly expectations survey conducted by the central bank. Results are very similar for both variables. Given that this variable is observed on a monthly basis, we repeated the corresponding value for the days of a given month. This issue can be addressed in several ways such as Kalman Filter or other econometric methodologies. However, these techniques are not free from statistical errors due to the estimation of unobserved components. Moreover, the economic authorities only observe the monthly values of this series.

States and Colombia[30]), on the nominal exchange rate in Brazil S_t^{brazil}, and on capital controls tax_t (tax_t^1 in Graph 6, tax_t^2 was also tried with similar results). The positive statistical association between the exchange rate in Colombia and Brazil (see Graph 2) is considered in Loaiza and Melo (2012) .

The relevance of real shocks is discussed in Krugman and Obstfeld (2002), ch.15, and is captured by the evolution of the real exchange rate q_t. Rincón and Toro (2011) include some real variables such as the terms of trade and the missalignment of the real exchange rate in their estimation of the nominal exchange rate in Colombia, and Engel, Mark, and West (2007) suggest to include productivity and the current account in the right side. Chinn (2012) proposses the relative price of tradables and non-tradables as another relevant real shock. The 151 traders interviewed by Murcia and Rojas (2012), assign a role to some real variables such as the behavior of GDP, and unemployment in Colombia and, even more, to unemployment and fiscal results in the United States, and to growth in China. Dominguez (1999) assigns a prominent role to news on US GDP in the determination of the US exchange rate.

We use daily information for I_t^{disc}, I_{t-1}^{20}, Δs_t, Δs_t^{brazil}, $\Delta\rho_{CDS}$, $i_t - i_t^*$, Δtax and D_{pos}^{net}; monthly information for π_t, Δq_t and $\bar{s}_t$, and yearly information for π^*. The estimation of the parameters of equations (1) and (2) is carried out according to the multistep methodology proposed by Iglesias and Phillips (2012) for the case of simultaneous equations under GARCH disturbances. The first step consists of applying a traditional 2SLS, the second step estimates the conditional variance $\sigma_{2,t}^2$ associated with the GARCH model in equation (4), and the last step estimates the parameters of expression (2), obtained from the following standardized version of the equation:

$$\frac{\Delta s_t}{\hat{\sigma}_{2,t}} = \delta_0^* + \delta_1 \frac{\hat{I}_t^{disc}}{\hat{\sigma}_{2,t}} + \delta_2 \frac{I_{t-1}^{20}}{\hat{\sigma}_{2,t}} + \delta_3 \frac{\Delta\rho_{CDS,t}}{\hat{\sigma}_{2,t}} + \delta_4 \frac{i_t - i_t^\star}{\hat{\sigma}_{2,t}} + \delta_5 \frac{\Delta s_{t-1}}{\hat{\sigma}_{2,t}} + \boldsymbol{\delta}' \frac{\mathbf{x}_t}{\hat{\sigma}_{2,t}} + \frac{u_{2t}}{\hat{\sigma}_{2,t}}$$

This procedure corrects for endogeneity of the discretionary interventions I_t^{disc}. The degree of endogeneity for I_t^{20} is much lower since there were only few decisions taken by the authorities in the first case. Moreover, the inclusion of I_{t-1}^{20} instead of I_t^{20} eliminates the possibility of endogeneity.

The step related with the estimation of equation (1) uses the methodology suggested by Calzolari and

[30] We used the one-day annualized interest rate for the treasury bills in Colombia and in the United States.

Fiorentini (1998) for Tobit models with GARCH errors.[31] This estimation is based on the standard likelihood function of the Tobit model with time-varying conditional variance to account for the GARCH effect:

$$\ln L = \sum_{I_t^{disc}>0} -\frac{1}{2}\left[\log(2\pi) + \ln\sigma_{1t}^2 + \frac{(I_t^{disc} - \mathbf{x}_t'\boldsymbol{\beta})^2}{\sigma_{1t}^2}\right] + \sum_{I_t^{disc}=0} \ln\left[1 - \Phi\left(\frac{\mathbf{x}_t'\boldsymbol{\beta}}{\sigma_{1t}}\right)\right]$$

Where $\mathbf{x}_t{}' = \left(1, I_{t-1}^{disc}, \sum_{j=1}^{20}\Delta s_{t-j}, s_{t-1} - \overline{s}_{t-1}, D_t^{net}, \pi_t - \pi^*\right)$ and σ_{1t}^2 is computed from the GARCH model (3) with $u_{1t}^2 = \begin{cases} \left(I_t^{disc} - \mathbf{x}_t'\beta\right)^2 & \text{if } I_t^{disc} > 0 \\ \sigma_{1t}^2 + \mathbf{x}_t'\beta \dfrac{\sigma_{1t}\phi\left(\frac{\mathbf{x}_t'\beta}{\sigma_{1t}}\right)}{1 - \Phi\left(\frac{\mathbf{x}_t'\beta}{\sigma_{1t}}\right)} & \text{if } I_t^{disc} = 0 \end{cases}$

- Surprises

Macroeconomic surprises (or shocks) could be the relevant variables in an environment of flexible prices.[32] As such, Dominguez, Fatum, and Vacek (2013) evaluate the impact of *both the observed and the unexpected change* in international reserves on the exchange rate.[33] The comparison between the impact of both the actual and the unexpected interventions could shed some additional light on the relevant transmission channels.

In order to account for the unexpected component of the reaction function, we also estimated the censured residual of equation (1). This alternative estimation method allows us to capture the unexpected component of policy and, in theory, should capture all policy influences that are not determined by systematic responses to relevant economic variables. These surprises can be interpreted as exogenous shocks to how central bankers value their targets, to how their views are aggregated, changes in beliefs, or even strategic considerations affecting a private agent's expectations. It also has the advantage of removing potential endogeneity when estimating equation (2) since the resulting residuals are now uncorrelated with variables that affect the policy decision process. We calculated these shocks as follows:

$$\varepsilon_t = I_t^{disc} - E\left[I_t^{disc} \mid X_t\right]$$

[31] Ignoring heteroskedasticity results in estimates that are not consistent (Maddala and Nelson, 1975). Chen, Chang, and Yu (2012) estimate a Tobit-GARCH model to the reaction function of the Japanese authorities.
[32] See Barro (1976), Christiano, Eichenbaum, and Evans (1998) and Romer and Romer (1989), among others. See also Dornbusch (1980).
[33] The authors also consider *surprises* (instead of observed values) for the other right-hand variables, but they do not appear to be significant.

Where the last term can be characterized (for the Tobit model with GARCH errors) as:

$$E\left[I_t^{disc} \mid X_t\right] = \int_{I_t^{disc}>0} \left(I_t^{disc}\right) dF\left(I_t^{disc} \mid X_t\right)$$

$$= \Pr\left(I_t^{disc} > 0 \mid X_t\right) E\left(I_t^{disc} \mid X_t, I_t^{disc} > 0\right)$$

$$= \Phi\left(\frac{x_i'\beta}{\sigma_{1t}}\right)\left[x_t'\beta + \sigma_{1t}\frac{\phi\left(\frac{x_i'\beta}{\sigma_{1t}}\right)}{\Phi\left(\frac{x_i'\beta}{\sigma_{1t}}\right)}\right]$$

And $\Phi(\cdot)$ and $\phi(\cdot)$ correspond to the CDF and PDF of a standard normal distribution.

IV. Estimation of the model

IV.A. Actual interventions

Column (1) of Table 2 presents the results of estimating a traditional Tobit regression. Column (2) considers only those variables statistically significant in column (1), and column (3) presents the results for the alternative Tobit-GARCH estimation. The period considered starts in September 2, 2003, the first day we for which we have information on inflation expectations (see footnote 27), and ends on December 21, 2007, the last day of discretionary interventions. Results are very similar when we start at the beginning of the sample (January 3, 2000).

The (preferred) results on column (3) show that the lagged value of the intervention, the misalignment of the exchange rate and the inflation gap are significant at the 1% level, but neither the cumulative variation of the exchange rate (*p value* of 13%) nor the central bank net position are significant at the 10% level. Significance levels are very similar for the traditional Tobit regression in column (1), though the coefficients differ, and the results in column (2) are similar to those in column (1). We obtained $\hat{I}_t^{disc}$ from column (3) – Tobit-GARCH- and used it in the estimation of equation (2) for the determinants of Δs_t.

Table 2

The reaction function of the central bank ($\hat{I}_t^{disc}$), September 2, 2003 – December 21, 2007

Method	Tobit		Tobit - GARCH
Dep. Var:	I_t^{disc}	I_t^{disc}	I_t^{disc}
	(1)	(2)	(3)
Constant	-0.1675	2.75	32.8118
	(9.269)	(9.808)	(6.612)***
I_{t-1}^{disc}	0.6144	0.6152	0.7136
	(0.192)***	(0.070)***	(0.100)***
$\sum_{j=1}^{20} \Delta s_{t-j}$	-1.4358		-0.3958
	(1.263)		(1.719)
$s_{t-1} - \bar{s}_{t-1}$	-955.2364	-990.6376	-833.8378
	(170.411)***	(136.030)***	(108.395)***
D_{net_pos}	-1.0938		-23.5185
	(27.637)		(-27.520)
$\pi_t - \pi^*$	-35.9156	-34.8412	-62.8904
	(10.663)***	(7.935)***	(-8.705)***
Observations	1000	1000	1000

Numbers in parenthesis correspond to the standard deviation
***, **, *: significant at 1%, 5% and 10%

Table 3 presents the main results for the estimation of equation (2), according to the methodology proposed by Iglesias and Phillips (2012). The number of observations in Table 2 for the reaction function (1000) is different from the number in Table 3 (2010). As mentioned above, we only considered the period September 23, 2004–April 30, 2007 in the first case, while in Tables 3 and 4 we considered the period September 23, 2004–March 29, 2012, when one or the other modality of intervention I_p^{disc} and I_t^{20} took place. At the bottom of the Table we also present a Wald Test contrasting the coefficients of I_t^{20} with those of I_t^{disc}. The diagnostic tests on the residuals (autocorrelation, remaining GARCH effects) and stability of coefficients, suggest that there is no evidence of miss specification.[34]

All variables, except $i_t - i_t^*$ are significant (at least) at the 10% level and have the expected sign. Also, the coefficients are very similar for the four specifications employed. Of particular interest is the coefficient of I_{t-1}^{20} which is more than three times that of I_t^{disc} (instrumented); significance is also higher.[35] The coefficient of I_{t-1}^{20} is statistically different from that of I_t^{disc} at 10% in column (3) and at 14% in the other three columns. Results are very similar when we consider the relationship between the amount of both types of interventions and the amount traded each day in the market as covariates.

We also divided the sample in two to account for any significant change that might have arisen from considering that discretionary and pre-announced interventions did not occur simultaneously. We ran two regressions with different samples, with one type of intervention at a time. The intervention coefficients remained significant, with very similar values to the previous estimations.

Our results are strikingly similar to those of Dominguez, Fatum, and Vacek (2013) when comparing the impact of reserve *sales* by the Czech National Bank in the period 2004–2007. The authors find little evidence that reserve sales influence the exchange rate when sales are carried out on a discretionary and relatively infrequent basis, but they find a statistically and economically significant appreciation of the domestic currency when sales are carried out in daily constant amounts.

Besides, contrary to Rincón and Toro (2011), we find that both types of intervention are statistically significant, with or without capital controls. Most day-to-day interventions were implemented when capital controls were not in place, and I_t^{disc} is statistically significant in regressions similar to those in Table 3, (removing I_{t-1}^{20}) for the period previous to the implementation of capital controls.

Also, contrary to the literature that suggests that capital controls only change the maturity of capital flows (Cárdenas and Barrera, 1997), our results suggest that capital controls also depreciate the nominal exchange rate. A similar positive impact of capital controls on the exchange rate is obtained by Edwards and Rigobón (2005) for the case of Chile, and some central bankers interviewed by Mihalkej (2005) also consider that interventions are more effective when there are capital controls or limits to leverage (in dollars) imposed on the financial institutions. We also considered the cross impact of the interaction term $\Delta tax_t.(i_t - i_t^*)$. The

[34] Results are available on request.

[35] This last result contrasts with the surveys reported by Murcia and Rojas (2012), Graph 14, according to which the impact of discretionary – dirty interventions should be higher than the impact of other types of intervention, like I_{t-1}^{20}.

coefficients are positive and statistically significant, which means that capital controls allow the authorities to increase interest rates without causing additional revaluation of the exchange rate.[36] However, results were not robust when considering the impact of the interaction between Δtax_t and $\hat{I}_t^{disc}$. Capital controls have other additional effects, of course. As mentioned by Magud, Reinhart, and Rogoff (2011) "While the effectiveness of controls varies across time, country, and type of measures used, limiting private external borrowing in the "good times" plays an important prudential role, because more often than not countries are "debt intolerant". Indeed, often the critical problem in good times is that countries borrow too much".

Table A.1 (in the Appendix) considers the traditional Tobit estimation of $\hat{I}_t^{disc}$ (derived from column 1 in Table 2), with results relatively similar to those in Table 3 (Tobit-GARCH). The coefficients of most variables, except $i_t - i_t^*$ and Δs_t^{brazil} are statistically significant at the 1% level, and the coefficient of I_{t-1}^{20} is again larger than the one for discretionary interventions. The coefficients are statistically larger at 10% in columns (2) and (3), and at 11% in columns (1) and (4). We observe lower standard deviations, and the R^2 coefficient is close to 0.15 in all regressions.

Table 4 is similar to Table 3, but considering Δi_t and Δi_t^* separately. Results are very similar across both Tables for variables different from interest rates and, again, the coefficient of I_{t-1}^{20} is three to four times bigger than that of I_t^{disc}. The short-term interest rate in the United States Δi_t^* is highly significant, contrary to the effects of the short-term interest rate in Colombia. This result is similar to the one found in the survey conducted by Murcia and Rojas (2012).[37] The coefficient of I_{t-1}^{20} is statistically different from that of I_t^{disc} at 10% in columns (1) and (3), and at 14% in columns (2) and (4).

The coefficients obtained in Table 3 suggest that a one-day change from US$ 20 million to US$ 40 million raises the Colombian exchange rate by approximately Col $ 2. This means (all caveats considered) that *actual interventions* of US$ 1000 million, the amount mentioned by Fratzscher (2012) for the G3 countries, increase the exchange rate in one day by approximately 5.50% (using an exchange rate of $ 1,817

[36] See Villar and Rincón (2000) and Klein and Shambaugh (2006).

[37] Echavarría, Vásquez, and Villamizar (2009) do not find a significant impact for $i_t - i_t^*$ when they consider $s_{t+k} - s_t$ as the dependent variable, but find a significant impact for $s_{t+k}^e - s_t$, with s_{t+k}^e taken from the Colombian central bank surveys. As shown by Echavarría and Villamizar (2012), there are important differences between S_{t+k} and S_{t+k}^e. The last two authors also show that there is a variable risk premium which could explain the result. For a recent discussion on the validity of the uncovered interest parity see Chinn (2012).

per dollar), much higher than the 1.54% found by Fratzscher (2012) for actual interventions in the German–euro area, or the 0.06% for the US$-Yen (no statistical relationship is found for the relation between the German mark and the US dollar).

As mentioned by Fratzscher (2012), we are not only interested on the *impact*, but also on the *permanence* of interventions. This question is not directly addressed in the paper since the impact of intervention is linear in the model and we cannot capture the assumed (and expected) impact reduction through time. However, based on calculations similar to those suggested by equations (1) and (2) *for different maturities*, Echavarría, Vásquez, and Villamizar (2009) suggest that the impact of interventions could last as long as six months, and the traders interviewed in Colombia by Murcia and Rojas (2012) think that, for most types of interventions, the impact within one year is not very different from the impact in one day. Finally, the event study conducted by Echavarría, et al.(2013) suggests that the impact of discretionary, volatility and reserve accumulation interventions lasts at least 25 market days.

However, the periods mentioned in the previous paragraph are much larger than those suggested by interviews with traders and central bankers (Neely, 2006), by related empirical work for the United States and by recent experiences in the developed countries. For the United States, for example, Dominguez (1999) finds reversion towards the mean during the same day of the intervention. On September 15, 2010 the Japanese authorities purchased US$ 24 billion, an amount larger than the total of all interventions conducted by the US Federal Reserve since 1990 and more than six times larger than US intervention in the entire year of 1985, when the United States, Europe and Japan conducted concerted interventions to weaken the dollar. The devaluation of the yen against the dollar was 3% (from 83 to 85 yen/dollar) but the exchange rate returned to the pre-intervention level *four weeks* after the intervention (Fratzscher, 2012).

Table 3

Determinants of Δs_t (with $i_t - i_t^*$) and observed interventions

Method:	Simultaneous Equations - PGARCH(1,1)			
Dep. Var:	Δs_t	Δs_t	Δs_t	Δs_t
	(1)	(2)	(3)	(4)
Constant	-0.0628	-0.0589	-0.0650	-0.0604
	(0,035)*	(0,035)*	(0,035)*	(0,035)*
$\hat{I}_t^{disc}$	0.0013	0.0013	0.0013	0.0013
	(0,001)*	(0,001)*	(0,001)*	(0,001)*
I_{t-1}^{20}	0.0044	0.0042	0.0046	0.0042
	(0,002)**	(0,002)**	(0,002)**	(0,002)**
$\Delta \rho_{CDS}$	0.0211	0.0202	0.0203	0.0204
	(0,001)***	(0,001)***	(0,001)***	(0,001)***
$i_t - i_t^*$	0.0004	-0.0003	-0.0003	0.0001
	(-0.008)	(-0.008)	(-0.008)	(-0.008)
Δq	0.1126	0.1151		0.1148
	(0,024)***	(0,024)***		(0,024)***
Δs_t^{brasil}		0.0697	0.0653	0.0678
		(0,016)***	(0,016)***	(0,016)***
Δtax			0.0064	0.0058
			(0,002)***	(0,002)**
Wald test (p value):				
$H_0: I_t^{20} = \hat{I}_t^{disc}$	0.13	0.13	0.08	0.13
Observations:	2010	2010	2010	2010

Only intervention purchases were considered. Numbers in parenthesis correspond to standar deviations; ***, **, *: significant at 1%, 5% and 10%, with heteroscedasticity consistent covariance; an AR(1) term was included in all cases (see equation 2)

$\hat{I}_t^{disc}$ is derived from column (3) in Table 1.

Table 4

Determinants of Δs_t (with Δi_t and Δi_t^*) and observed interventions

Method:	Simultaneous Equations - PGARCH(1,1)			
Dep. Var:	Δs_t	Δs_t	Δs_t	Δs_t
	(1)	(2)	(3)	(4)
Constant	-0.0610	-0.0607	-0.0670	-0.0605
	(0,019)***	(0,019)***	(0,019)***	(0,019)***
$\hat{I}_t^{disc}$	0.0012	0.0013	0.0013	0.0013
	(0,001)*	(0,001)*	(0,001)*	(0,001)*
I_{t-1}^{20}	0.0044	0.0042	0.0046	0.0042
	(0,002)**	(0,002)**	(0,002)**	(0,002)**
$\Delta\rho_{CDS_t}$	0.0208	0.0200	0.0201	0.0202
	(0,001)***	(0,001)***	(0,001)***	(0,001)***
Δi_t	-9.705E-05	1.6309E-05	-9.727E-05	2.021E-05
	(-0.001)	(-0.001)	(-0.001)	(-0.001)
Δi_t^*	0.0025	0.0024	0.0020	0.0021
	(0,001)***	(0,001)***	(0,001)**	(0,001)**
Δq	0.1124	0.1152		0.1149
	(0,024)***	(0,024)***		(0,024)***
Δs_t^{brasil}		0.0684	0.0644	0.0670
		(0,016)***	(0,016)***	(0,016)***
Δtax_t			0.0060	0.0054
			(0,002)**	(0,002)**
Wald test (p value):				
$H_0: I_t^{20} = \hat{I}_t^{disc}$	0.10	0.13	0.08	0.13
Observations:	2010	2010	2010	2010

Only intervention purchases were considered. Numbers in parenthesis correspond to standar deviations; ***, **, *: significant at 1%, 5% and 10%, with heteroscedasticity consistent covariance; an AR(1) term was included in all cases (see equation 2)

IV.B. Surprises

Table 5 is similar to Table 3, except for the fact that we now consider the *unexpected* component of interventions ε_t instead of observed interventions I_t^{disc}. We notice that, again, the coefficients of I_{t-1}^{20}, $\Delta\rho_{CDS}$, Δq and Δs_t^{brasil} are significant at the 1% –5% level, but some results differ: intervention *surprises* and capital controls are not significant, but $i_t - i_t^*$ is significant. The central result of this paper holds again, namely that the effectiveness of day-to-day interventions is much stronger than that of discretionary interventions (not significant in this case; the Wald Test included in Tables 3 and 4 is not needed).

Table 5

Determinants of Δs_t (with $i_t - i_t^*$) and unexpected interventions

Method:	Simultaneous Equations - PGARCH(1,1)			
Dep. Var:	Δs_t	Δs_t	Δs_t	Δs_t
	(1)	(2)	(3)	(4)
Constant	0.0056	0.0101	0.0085	0.0099
	(-0.011)	(-0.011)	(-0.011)	(-0.011)
$I_t^{disc} - E\left[I_t^{disc} \mid X_t\right]$	-0.0001	-0.0001	0.0000	-0.0001
	(-0.0001)	(-0.0001)	(-0.0001)	(-0.0001)
I_{t-1}^{20}	0.0025	0.0025	0.0028	0.0025
	(0,001)**	(0,001)*	(0,001)**	(0,001)*
$\Delta\rho_{CDS}$	0.0138	0.0132	0.0130	0.0132
	(0,001)***	(0,001)***	(0,001)***	(0,001)***
$i_t - i_t^*$	-0.0090	-0.0099	-0.0107	-0.0099
	(0.004)**	(0.003)***	(0.004)***	(0.003)***
Δq	0.0960	0.0969		0.0969
	(0,019)***	(0,019)***		(0,019)***
Δs_t^{brasil}		0.0419	0.0420	0.0417
		(0.009)***	(0.009)***	(0.009)***
Δtax			0.0011	0.0008
			(-0.002)	(-0.001)
Observations:	2010	2010	2010	2010

Only intervention purchases were considered. Numbers in parenthesis correspond to standar deviations; ***, **, *: significant at 1%, 5% and 10%, with heteroscedasticity consistent covariance; an AR(1) term was included in all cases (see equation 2)

$\hat{I}_t^{disc}$ is derived from column (3) in Table 1.

The variable $i - i^*$ is not statistically significant in Table 3 (our preferred results), nor is Δi in Table 4. The impact of $i - i^*$ on Δs is subject to much debate since there is a lack of consensus in the literature regarding the validity of uncovered interest rates when rational expectations are assumed (Chinn, 2012). Dominguez, Fatum, and Vacek (2013) do not find a significant relation between those two variables, either, and attribute the result to the fact that interventions are sterilized (short-run interest rates are constant after the intervention). On the other hand, “successful” increments in the repo rate reduce longer-term interest rates and affect the yield curve,[38] short-term expectations do not seem to be rational and there is a variable risk premium.[39] Some recent literature haves shown that transitory and permanent interest rate shocks are not perceived correctly by the market,[40] and Calvo and Reinhart (2002) present a simple model where lack of credibitlity by the authorities could explain the *positive* correlation they find between interest rates and exchange rates in a panel data for different countries. As can be observed in Graph 7 the exchange rate clearly moves in the same direction as country risk (ρ_{CDS}), but we do not observe the negative expected negative correlation with interest rate differentials. In fact, there are some periods like 2003–2006 and 2008–2010 when they exhibit similar comovements.[41]

Other factors could be involved in the determination of the nominal exchange rate. The 151 traders interviewed by Murcia and Rojas (2012), Graph 2 consider that fundamentals explain close to 82% of the one-month and one-year variations of the exchange rate, but only 50.3% of the one-day variations. The literature suggests that the impact of interventions is higher when they are announced, coordinated among countries, and consistent with the rest of the macroeconomic policy. In the very short run, order flow affects exchange rate behavior. Evans (2010) provides evidence that order flow gives information to the market on the slowly evolving state of the macroeconomy. Also, Chinn and Moore (2011) find significant results for a model that combines order flows and macroeconomic fundamentals.

Long-horizon forecasts might be more successful than in short-horizon ones, since the amount of "news" that is not captured in typical macroeconomic variables is very large (Mark, 1995). Finally, some additional variables could be relevant in the explanation of intervention and impact functions. Adler, Castro, and Tovar (2012), for example, argue that the central bank capital (i.e net worth) has been relevant in the explanation of monetary and exchange rate policy in Latin America. Kamil (2007) and Neely (2006) suggest that the impact of interventions is higher when there is a misalignments of the exchange rate, and the literature suggests that large and not very frequent interventions are more effective, as well as first-time interventions after periods of no intervention.

[38] See Chen and Tsang (2011). Echavarría, Vásquez, and Villamizar (2009) find positive evidence of uncovered interest parity in Colombia for periods longer than one year. The evidence for shorter periods is more doubtful.

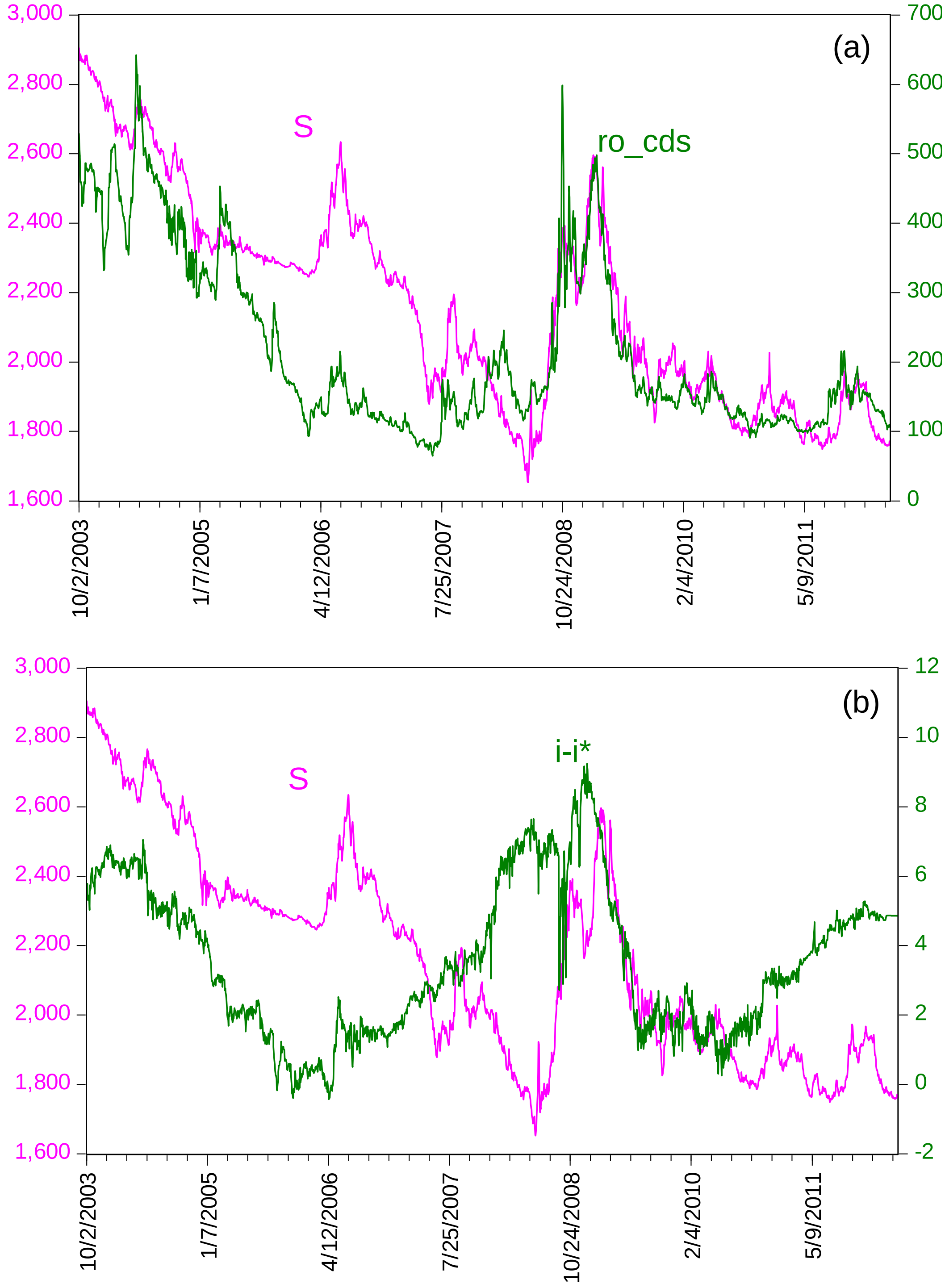
[39] See Echavarría and Villamizar (2012) for the case of Colombia. The authors find that the forward rate is generally different from the future spot rate, mainly because forecast errors are on average different from zero, which suggests that exchange rate expectations are not rational. The role of the risk premium is also important, albeit statistically significant only for the one-year ahead forecasts (not for one month).

[40] See Gourinchas and Tornell (2002) and Molodtsova and Papell (2009).

[41] Something similar happens when considering the evolution of S_t and i_t . See also Uribe (2010) and Uribe and Toro (2004).

Graph 7

The nominal exchange rate (S), risk (ρ_{cds}), and interest rates in Colombia (i_t) and abroad (i_t^*)



IV.C. Channels

Based on the uncovered interest parity condition Kearns and Rigobón (2005) obtain the expression

$S_t = E_t \left\{ \sum_{j=0}^{T-1} \left[i^*_{t+j} - (i_{t+j} - \rho_{t+j}) \right] \left| I_t \right. \right\} + E_t \left\{ S_{t+T} \left| I_t \right. \right\}$, where ρ_t correspond to a variable risk premium, and I_t represents the history of intervention, assuming that it represents a central part of the whole information set Ω_t. The inclusion of variable risk ρ_t assumes that bonds represent wealth (assuming no Ricardian Equivalence) and that bonds denominated in pesos and dollars are imperfect substitutes. The spot exchange rate (S_t) thus depends on the future path of interest rates and risk in Colombia and abroad, and of the expected exchange rate in *t+T*. The positive effect of expansionary future monetary policy (i.e. lower $i_{t+j} - i^*_{t+j}$) on the exchange rate is generally accepted in the literature, and Echavarría, López, and Misas (2008) find some evidence for the importance of this channel for Colombia.[42] Much more controversy exists on the impact of sterilized intervention through the portfolio $E_t \left\{ \sum_{j=0}^{T-1} \rho_{t+j} \left| I_t \right. \right\}$ and the signaling channel $E_t \left\{ s_{t+T} \left| I_t \right. \right\}$.[43] While studies conducted in the 1980s indicate that interventions during that period may in part have functioned through a portfolio balance channel, evidence on from recent intervention episodes suggests that the signaling channel may have become more relevant. The portfolio channel could be more important in an emerging market like Colombia, when compared to an industrialized country, given the still precarious development of the financial markets and, for the same reason, could be less important today than in the past. On the relative importance of the signaling channel see Disyatat and Galati (2007), Lecourt and Raymond (2006), Dominguez and Frankel (1993b) and Fratzscher (2012).

The average amount of daily discretionary interventions (I_t^{disc}) was also close to US$ 20 million (Section II) but their effectiveness seems to have been much lower than that of the pre-announced day-to-day and (almost) constant interventions (I^{20}). Consistent with the previous result, we also find that discretionary intervention *surprises* did not affect the exchange rate. We argue, then, that the channel related to $E_t \left\{ S_{t+T} \left| I_t \right. \right\}$ seems to be much more relevant than the other two channels mentioned by the literature. In other words, vocal (oral) interventions mentioning an undesired exchange rate level could be more important

[42] The central bankers interviewed by Neely (2006) also assign an important role to the amount of additional liquidity provided by the exchange rate intervention. Lewis (1995), Dominguez and Frankel (1993b) and Kim (2003) show that the level of intervention is a good predictor of future short-run interest rates in Japan and in the United States, but results are less conclusive in other works. Thus, Fatum and Hutchison (2001) do not find such evidence for the United States, Kaminsky and Lewis (1993) and Humpage (1991) find a relation, but very often in the opposite expected direction; Flood and Garber (1991) obtain mixed results.

[43] See Dominguez and Frankel (1990) and Dominguez and Frankel (1993a).

than other channels such as the portfolio balance or the signaling of future monetary policy. The authorities could consider that the expected future exchange rate in the last term of the previous equation is "incorrect" due to a strong overshooting effect, or because of movements of the exchange rate driven by *chartists* towards the wrong level. This assumes that the central bank has privileged information not available to the private sector (Schwartz, 2000). Moreover, intervention is not required in this case, with an important role for credibility and good communication strategies by the central bank.

Signaling was an important "intervention mechanism" in Chile during 2001–2002 (Tapia and Tokman, 2004). Also, many advanced economies such as the United States, the euro area and the United Kingdom have moved away from using actual interventions, to using communication as their primary policy tool. Mediatic-oral intervention and signaling have been used in a few occassions in Colombia. Thus, for example, in June of 2008 the Board announced that there was an important missalingment of the exchange rate when compared to fundamentals. Also, in October of 2009 the Board announced that it would increase permanent liquidity by $ 3 billions, buying either pesos or dollars. Following the announcement, the Board only purchased Colombian pesos, but the impact on the exchange rate was marked. Fratzscher (2012) finds an important impact of *oral interventions*: 0.12% – 0.20% for the US$–euro ratio (depending on which country intervenes) and 0.15% for the US$–Yen ratio. The author suggests that the effect of actual and oral intervention has become smaller over time (but it is still statistically significant in the 2000s).

The impact of signaling appears to be especially marked in those periods in which the variance of expectations (uncertainty in general) is particularly high in the market (Fratzscher, 2012), since in those periods the announcements by the central bank could play an imporant coordination role. Echavarría and Villamizar (2012) show that this was the case for Colombia in 2009, and in some months of 2005, 2006 and 2007. On the other hand, Evans and Lyons (2002) argue that interventions may have a stronger effect when market participants are positioned strongly in one particular direction of the exchange rate. Finally, Fratzscher (2012) finds that oral interventions are more effective if they are *leaning with the wind* (when leaning against the wind, interventions do not appear to be statistically significant).

Also, the uncovered interest parity could have been invalid in the very short run, yielding other possible explanations: 1) day-to-day interventions could have not induced attacks by private banks,[44] partially because they do not give any no signals for the search targeting of a specific level of the exchange rate; 2) infrequent reserve purchases could have been seen as transitory, 3) day-to-day interventions could have taken place when market conditions were both either favorable or unfavorable.

[44] Lebaron (1999) finds that central bank interventions may be the source of unusual profits for traders using technical analysis; profits go to zero when interventions days are excluded from the analisysis.

V. Conclusions

The adoption of a managed regime assumes that interventions are relatively successful, a highly controversial issue. While some authors consider interventions ineffective, arguing that assets are very close substitutes, others advocate their use and maintain that their effects can even last for months. We know even less about the optimal modality of intervention. Are dirty interventions more powerful than clean, transparent, pre announced constant ones?

Our results show that the impact of pre-announced and transparent US$ 20 million daily interventions, adopted by Colombia in 2008–2012, was much larger than the impact of dirty interventions adopted in 2004–2007. Our empirical results are surprisingly similar to those of Dominguez, Fatum, and Vacek (2013) when comparing the impact of reserve *sales* by the Czech National Bank. Dirty interventions in Colombia probably created incentives for speculative attacks against the central bank, and the impact of oral interventions has probably been much larger than the impact of actual interventions. Many central banks have adopted inflation targeting during the last decade, convinced that they affected the economy as much through their influence on expectations as through any direct, mechanical effects. Why shouldn't these principles also apply to the management of the exchange rate?

We find that the impact of a change in daily interventions (from US$ 20 million to US$ 40 million) raises the Colombian exchange rate by approximately Col $ 2. This means (all caveats considered) that *actual interventions* of US$ 1,000 million, increase the exchange rate in one day by 5.50%, much higher more than the 1.54% found by Fratzscher (2012) for actual interventions in the German–euro area, or the 0.06% for the US$–Yen (no statistical relationship is found for the relation between the German mark and the dollar). We also find an important positive impact of capital controls on the exchange rate.

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VII. Appendix

Table A. 1

Determinants of Δs_t (with $i_t - i_t^*$) and observed interventions

Method:	Simultaneous Equations - PGARCH(1,1)			
Dep. Var:	Δs_t	Δs_t	Δs_t	Δs_t
	(1)	(2)	(3)	(4)
Constant	-0.0396	-0.0409	-0.0428	-0.0413
	(0.016)**	(0.016)***	(0.016)***	(0.016)***
$\hat{I}^{disc}_{tobit,t}$	0.0015	0.0015	0.0015	0.0015
	(0.000)***	(0.000)***	(0.000)***	(0.000)***
I^{20}_{t-1}	0.0036	0.0036	0.0040	0.0036
	(0.001)***	(0.001)***	(0.001)***	(0.001)***
$\Delta\rho_{CDS}$	0.0139	0.0138	0.0136	0.0139
	(0.001)***	(0.001)***	(0.001)***	(0.001)***
$i_t - i_t^*$	-0.0033	-0.0030	-0.0039	-0.0031
	(-0.004)	(-0.004)	(-0.004)	(-0.004)
Δq	9.0541	9.0578		8.9720
	(1.757)***	(1.757)***		(1.777)***
Δs_t^{brasil}		-0.0062	-0.0053	-0.0059
		(-0.008)	(-0.008)	(-0.008)
Δtax			0.6242	0.6039
			(0.316)**	(0.313)*
Wald test (p value):				
$H_0: I_t^{20} = \hat{I}_t^{disc}$	0.11	0.10	0.06	0.11
Observations:	2010	2010	2010	2010
R-squared	0.15	0.15	0.15	0.16

Only intervention purchases were considered. Numbers in parenthesis correspond to standar deviations; ***, **, *: significant at 1%, 5% and 10%, with heteroscedasticity consistent covariance; an AR(1) term was included in all cases (see equation 2)

$\hat{I}^{disc}_{tobit,t}$ is derived from column (1) in Table 1.