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Do Actions Speak Louder than Words? A Foreign Exchange Intervention Analysis*

Freddy A. Pinzón-Puerto† Mauricio Villamizar-Villegas‡

Abstract

We revisit an old question but with a new identification strategy, namely the difference in exchange rate effects between announced ("vocal") and secret ("dirty") foreign exchange intervention. Using a Regression Discontinuity Design, we exploit a rule-based intervention mechanism enacted by the Central Bank of Colombia that, under observable and deterministic conditions, triggered either the issuance of FX options or the ability to exercise them. We take the former (issuance) as central bank announcements under a sharp setting, since the rule and information that triggered the issuance of options was public, and we take the latter (exercise) as secret trades under a fuzzy setting, since traders could have chosen (but were not required) to exercise their options in the following days after issuance. Our results indicate that, unconditionally, both announcements and secret trades carry similar effects. However, the effects of announcements are considerably amplified conditional on: (i) higher central bank credibility, (ii) less frequent announcements, and (iii) episodes of higher FX volatility.

JEL Classification: E58, F31, C22

Keywords: Foreign Exchange Intervention effectiveness; Regression Discontinuity Design; Announced Intervention; Secret Intervention

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¿Acciones o Palabras?
Un Análisis de Intervención Cambiaria

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Resumen

Revisitamos una antigua pregunta, pero con una nueva estrategia de identificación, concretamente, la diferencia entre los efectos de las intervenciones cambiarias anunciadas ("vocales") y secretas ("sucias"). Para esto estudiamos un mecanismo de intervención basado en reglas del Banco de la República que, bajo condiciones observables y deterministas, activó la emisión de opciones (*call* y *put*) o la capacidad de ejercerlas. Interpretamos la primera (emisión) como anuncios del Banco bajo un diseño de regresión discontinua *sharp*, ya que la regla y la información cambiaria que la activó eran públicas, e interpretamos los ejercicios de las opciones como operaciones secretas bajo un diseño de regresión discontinua *fuzzy*, ya que los agentes del mercado podían haber elegido (pero no estaban obligados) a ejercerlas en los días siguientes a su emisión. Nuestros resultados indican que, de forma no condicional, tanto los anuncios como la intervención secreta tienen efectos similares. Sin embargo, el impacto de los anuncios se amplifica cuando se condicionan a: (i) una alta credibilidad del banco central, (ii) anuncios menos frecuentes y (iii) episodios de mayor volatilidad cambiaria.

Códigos JEL: E58; F31; C22

Palabras clave: Intervención cambiaria; Regresión discontinua; Intervención con anuncios; Intervención secreta

1 Introduction

The literature on foreign exchange intervention (FXI) effectiveness tends to move in synchronous motion to major currency episodes, starting from the demise of the Bretton Woods system (1970s), concentrating during the crises of the European Monetary System (1992) and East Asia (1997-1999), and arguably peaking in the 2000s, when many emerging market economies adopted flexible exchange rate regimes.[1] More recently, the World Financial Crisis (2007-2009), the Great Lockdown (2020-2021), and the Inflation Surge (2021-2022) have brought a renewed interest among policymakers, only this time viewed as part of an integrated policy framework (Itskhoki and Moll, 2019; Basu et al., 2020; Adrian et al., 2020).

To date, valuable progress has been made in synthesizing several of the lessons learned and establishing a pecking order of policy guidelines with sufficient external validity. However, one issue has eluded most of the empirical literature: the difference –in exchange rate effects– between announcements ("vocal") and secret ("dirty") interventions. The main challenge, besides the many confounding factors in FXI studies, is constructing a credible counterfactual scenario e.g., an announced episode of intervention had the central bank not announced it. Among the handful of papers that have attempted this endeavor are: Adler and Tovar (2014); Echavarría et al. (2014, 2018); and Luna Santos (2021), all of which compare discretionary with pre-announced (and mostly constant) intervention.

However, a potential concern is that these two types of intervention differ in ways that can also affect the exchange rate, so treatment can ultimately reflect operational (and transactional) differences rather than the information contained in the announcements and which is conveyed to the market. For example, pre-announced intervention is generally conducted in clusters and during longer periods of time, while discretionary intervention often carries larger but more sporadic trades. Moreover, this literature employs different methodologies for each type of intervention, making the comparison of the effects much less straightforward.

In this paper, we contribute to this debate (announcement versus secret intervention effectiveness) by analyzing the exact FXI mechanism with the same clear-cut identification strategy, all conducted in the same context (time period and country) except for one key difference: some interventions were announced and made public to market participants while others were unannounced and unknown. Specifically, using a Regression Discontinuity Design

[1] This was especially the case for Latin America, kicked off with Argentina's *Corralito* crisis in 2001.

(RDD), we exploit a rule-based intervention mechanism enacted by the Central Bank of Colombia (CBoC) during 2002-2012 that, under observable and deterministic conditions, triggered either the issuance of FX options or the ability to exercise these options. We take the former (issuance) as central bank announcements under a sharp setting, since the rule and information that triggered the issuance of options was public, and we take the latter (exercise) as the effective transaction –purchases or sales of foreign currency (USD)– under a fuzzy setting, since traders could have chosen (but were not required) to exercise the option in the following days after issuance. Also, while the central bank made an official announcement on the day of issuance, it did not disclose information on when traders decided to exercise each of their options.

This setting is ideal for at least four reasons. First, the design matches our research evaluation, namely the difference between public announcements and secret intervention, with the added benefit that the rule was exactly the same for both. To illustrate, the mechanism operated as follows: at the close of business day, traders gained information on whether the exchange rate would trigger the rule. If triggered, put or call options (intended to purchase and sell foreign currency, respectively) were auctioned at the start of the following day, in an amount equivalent to 20% of the daily FX market turnover. Hence, we observe the exact amount of foreign currency to be traded via option sales, embedded in the announcement, regardless of these being exercised on subsequent days. After the auction, option-holders had up to one calendar month to exercise before expiration. During that time, the rule could not issue new options; instead, it allowed traders to exercise their outstanding options, if triggered.

Second, the discontinuity in the rule creates a localized quasi-experiment; we argue that treatment assignment within the vicinity of the triggering threshold is *as good as randomly assigned*. This allows us to identify the effect of intervention, both the issuance (announcement) and exercising (transaction) of options, by comparing days in which the cutoff was barely met or missed. Thus, the advantage of our RDD is that exogeneity follows from traders' uncertainty on *when* the rule would be triggered, not on *what* the rule was. This strategy pays dividends over the related literature, since we sidestep the need to estimate FX policy reaction functions. Further, we argue that locally, within the vicinity of the rule-based triggering threshold, the exchange rate becomes uncoupled from macroeconomic and financial variables.

Third, all FXI conducted in Colombia were sterilized i.e., designed to leave the domestic money supply (and thus the domestic interest rate) unchanged. This is useful since it avoids the concern that accompanying interest rate changes over- or underplay exchange rate effects. And fourth, we observe high-frequency data (tick-by-tick transactions carried out by the market and the central bank), which allows us to pin down effects to the minute of interventions. Hence, not only do we gain precision in the timing (and exchange rate responses) of the policy change, but we also omit a measurement error that is common in the literature; for example, some studies use proxies of FXI (e.g. changes in international reserves) since official FXI intervention data is scarce and mostly proprietary.

In theory, our question relates to the relative importance of FXI under the signaling versus portfolio channels. The portfolio balance channel operates under the assumption that different currency denominated assets are imperfect substitutes. It follows that portfolio recompositions (in our case induced by the actual purchases or sales of foreign currency when FX options are exercised) are only optimally admissible as long as the exchange rate absorbs the changes in expected returns. In this sense, risk-averse investors require a price compensation ("risk premium") for holding positions that they would otherwise not hold. Alternatively, the signaling channel (which in our case applies to FX announcements) conveys information about the future stance of monetary policy, so forward-looking markets have an immediate effect on the exchange rate. Taken to an extreme and under perfect credibility, the sole announcement of an intervention can lead to a desired exchange rate level without actually buying or selling foreign currency (Basu, 2012).[2]

To our knowledge, there is no other paper besides ours that evaluates the same type of intervention (with and without announcement) and, further, which employs the same methodology.[3] In fact, the only other two studies that employ RDD in the context of FXI are Kuersteiner et al. (2018) and Vargas-Herrera and Villamizar-Villegas (2020). However, these studies center only on the announcement of FXI and are hence mute about the effects of secret interventions.

[2]Pioneers on the portfolio channel include Kouri (1981) and Henderson and Rogoff (1981), while pioneers on the signaling channel include Dornbusch (1976) and Mussa (1976).

[3]Also, in the RDD literature, studies that simultaneously include fuzzy and sharp designs under the same setting are very rare, and even more so in the field of macroeconomics (Villamizar-Villegas et al., 2022). This may be somewhat explained by the inherent difficulty of finding institutional settings at the level of national economies where these methods can be applied.

Our results indicate that, unconditionally, both announcements and secret trades carry similar effects, which is somewhat surprising given that most of the literature hints towards a stronger signaling channel.[4] Of course, part of the literature, when referring to the signaling channel, actually reports a combined effect of central bank announcements plus actual trades, and not just the isolated "pure expectation" effect of the announcement. But even studies that attempt to untwine each channel find stronger effects coming from central bank signaling. Such is the case of Dominguez and Panthaki (2007) who use interventions that the market expected but that did not materialize, or Menkhoff et al. (2021) who compare a Proxy-SVAR-approach that captures the two combined channels with a Cholesky-approach that only captures the portfolio channel (the authors also use actual announcements). However, a major hurdle of studies that use FXI announcements is that they generally do not specify the amount of foreign currency to be traded, since this information is either rarely available –even in the minutes of central bank's board meetings– or in some cases published weeks or months after the facts.

For same-day effects, we find a 0.9% and 1.0% exchange rate depreciation for the issuance (announcement) and exercise (secret trades) of put options, respectively (recall that put options denote central bank purchases of foreign currency). In terms of FX volatility, the issuance and exercise of put options are able to curb volatility by 0.9 percentage points (pp) and 1.2pp, respectively. For longer horizons (1-month), the issuance and exercise of put options depreciate the exchange rate by up to 2% and 4%, respectively, and the effects persist for up to 20 working days. For the case of call options (i.e., central bank sales of foreign currency), the issuance leads to an exchange rate appreciation of 4% (10 days after issuance), while the exercise shows an overall null effect. In terms of FX volatility, both the issuance and exercise (for call and put options) show a similar result, namely a reduction of 3pp. In sum, we note that while the magnitude of our findings is in line with most of the emerging market literature, we find larger effects for FX volatility.

However, conditional on (i) central bank credibility –measured by *leaning with the wind* policies as well as by the anchoring of expectations–, (ii) episodes of high FX volatility, and (iii) riskier FX factors, we find that the effects of announcements are amplified considerably, more so than the effects of secret trades. The motivation for interacting variables in (ii) and (iii) rests on the work of Vargas-Herrera and Villamizar-Villegas (2020) who argue that FXI effectiveness increases with higher FX uncertainty, given that the central bank faces

[4] See Kaminsky and Lewis (1996); Fratzscher (2008); Ghosh (1992); and Bauer and Rudebusch (2014).

less speculative attacks from traders and arbitragers. In our exercises, we find that, for put options, high central bank credibility increases FXI effectiveness –of announcements– by up to 1.4pp, while it has a null effect on the effects of secret trades. In turn, episodes of high FX volatility increase the effectiveness of announcements by 2pp compared to a 1.4pp gain for the case of secret trades. Regarding risk factors, all measures have amplifying effects –for both the issuance and exercise of options– of above 2pp, but again more pronounced for announcements.

In a similar vein, we also find larger effects for announcements when conducted less frequently. For this, we conduct exercises that cover various other FX mechanisms, so while richer in external validity, we are unable to conduct our localized approach (only applicable to the rule-based mechanism), so our identification strategy at this stage is weaker. With this caveat in mind, our results (using a propensity score matching technique) suggest an effectiveness gain in favor of central bank announcements of up to 0.7pp. Moreover, this gain in effectiveness increases to 2pp in cases when the central bank announces longer intervention episodes and when conducting FXI during *leaning with the wind* episodes.

Our results are backed up by several robustness tests and exercises. For example, in Section 5.4.1, we confirm that the amounts in FXI announcements and exercising days are comparable, so that they do not overplay the signaling channel (since announcements contain larger amounts). In Sections 6.1 - 6.5, we confirm that interventions were in fact sterilized, and perform a series of tests that validate our identification strategy, including: rule-manipulation tests, test of locally balanced covariates, placebo tests against lagged outcomes, and alternative versions of our fuzzy RDD specification. We also check for potential contamination of effects based on the days that options were exercised. Finally, in Appendix B, we control for other sporadic (yet concurrent) FXI mechanisms.

Our investigation has relevant policy implications for FXI practitioners. In essence, it provides guidelines to optimize effectiveness based on the type of intervention. We also provide insights on ways to enhance effectiveness based on specific economic conditions, such as in episodes of exchange rate uncertainty and central bank credibility. These guidelines are not limited to countries with fixed or heavily controlled exchange rate regimes; in fact they can be applied to –all but fully floaters–.[5] Even fully-fledged inflation targeters (such as

[5]According Ilzetzki et al. (2019), in 2016 there were 96 countries with either hard pegs, bands, or currency boards, 45 with narrow crawling pegs or bands, 32 with managed floating or flexible bands, 6 with freely floating, and 12 with freely falling regimes.

Colombia, our case study) can benefit from this analysis since most central banks are not bounded by the *monetary trilemma*: episodes when central banks simultaneously allow for free capital flows, maintain autonomy in their policy rate decisions, and manage the exchange rate.[6] Also, the signaling channel is always operative, where credibility plays a crucial role in allowing for central bank signals to fully permeate into the rest of the economy.

This paper is organized as follows: Section 2 surveys the empirical literature on FXI effectiveness and highlights the most common pitfalls in identification. Section 3 describes the FXI policy carried out by the CBoC, and more generally, the exchange rate regime, objectives, and types of intervention. It also describes our data and data sources. Section 4 details our identification strategy. Sections 5 and 6 present our main results and validate our main RDD assumptions, respectively. Finally, Section 7 concludes.

2 FXI literature review

Central banks intervene in exchange rate markets for a variety of reasons. According to Kuersteiner et al. (2018), central banks often try to limit short-run fluctuations in the exchange rate and smooth excessive trends to attract investment opportunities and avoid currency crises. Patel and Cavallino (2019) show that higher exchange rate volatility may spur financial instability and derail the transmission from monetary policy to inflation. Hofmann et al. (2019) show that FXI can dampen the flow of domestic corporate loans, especially for borrowers with larger currency mismatches and for banks with thinner capital buffers. In other cases, central banks simply build-up international reserves as a precautionary measure against potential sudden-stops and other destabilizing external shocks.

However, the ample literature in the field of FXI effectiveness is mixed, although arguably tilted towards those that find significance in the short term (1-3 months). In fact, according to the largest meta-analysis found in Arango-Lozano et al. (2020), which covers 279 effects from 74 studies, central bank purchases (sales) in the amount of $1 billion USD are able to depreciate (appreciate) domestic currency by 1 percentage point (pp) and also reduce exchange rate volatility by 0.6pp. The authors find that effects are magnified with greater financial openness, when banking crises are mild, and when interventions are large in size and announced, among others. In terms of duration, they find that effects remain significant for an average of 21 and 56 working days –when targeting the exchange rate level and volatility,

[6] In theory, departures from the uncovered interest rate parity are sufficient to break free from the *trilemma*.

respectively. Other narrative surveys such as Menkhoff (2013) and Villamizar-Villegas and Perez-Reyna (2017) also show that a little over half of the surveyed studies find significant effects.

To give some examples, authors such as Dominguez and Frankel (1993), Fatum and Hutchison (2006), and Fatum and Hutchison (2010) find evidence in favor of FXI effectiveness when conducted infrequently and in large amounts. Fratzscher et al. (2019) find that FXI is an effective policy tool, with a success rate of over 80% for 33 countries, under some criteria. Other advocates of FXI include the works of: Domaç and Mendoza (2004); Guimarães and Karacadag (2004); Echavarría et al. (2010); Echavarría et al. (2014); and Chamon et al. (2017). On the flip side, critics that do not find significant effects include: Sarno and Taylor (2001); Hillebrand and Schnabl (2003); Galati et al. (2005); Moura et al. (2013); Adler and Tovar (2014); and Marins et al. (2017).

The absence of a general consensus is not surprising given the considerable country heterogeneity and the numerous objectives to intervene (e.g., build-up reserves, target different moments of the exchange rate, etc.), but also because assessing FXI effectiveness is empirically challenging. This is because of an inherent endogeneity problem well recognized in the literature. In particular, endogeneity in FX markets arises because of three reasons mainly:

1. Self-selection bias: since FXI does not occur at random; instead, central banks choose specific moments to intervene, mostly related to exchange rate turmoil. The main issue is that all relevant information that monetary authorities use when deciding to intervene is unknown.

2. Measurement error: since data on intervention is scarce (and mostly proprietary) and is why numerous studies approximate FXI with changes in international reserves, often reflecting valuation effects instead of actual sales or purchases of foreign currency.

3. Simultaneity bias: since FXI responds to economic conditions, and concurrently, the economy responds to central bank actions.

In our case, and in relation to the first point (self-selection), we argue that local treatment assignment is exogenous, in essence because the exchange rate has the same probability of being closely above or below the cutoff. Regarding the second point (measurement error), we fortunately observe tick-by-tick transactions carried out by the market and the central bank, which allows us to pin down effects to the minute of interventions. Regarding the third point (simultaneity bias), the combination of high-frequency data coupled with a clear timing profile of interventions mitigates potential problems of reverse causality.

Given that Colombia (our case study) is one of the countries that gathers most of the FXI studies in the literature (second after Japan, according to Arango-Lozano et al.), in Appendix A we present a summary of the findings specific to Colombia which will later allow us to compare the magnitude of our results. On average, studies conducted in Colombia find that purchases (sales) in the amount of $1 billion USD depreciate (appreciate) domestic currency by 3-5pp, so nearly three-to-five fold over the average effect of the literature.

3 Institutional setting and data sources

In this section, we briefly describe the FXI policy undertaken by the CBoC in two dimensions: the exchange rate regime and the rule-based mechanism. We also describe the data sources used in our empirical analysis.

3.1 Exchange rate regime

In 1999 the CBoC adopted an inflation targeting regime with a flexible exchange rate, intended to maintain a low and stable inflation and gear output levels close to its potential. As noted by Cardozo (2019), exchange rate flexibility is fundamental for preserving the stability of the financial and payment systems for three main reasons. First, the exchange rate works as an adjustment variable against economic shocks, hence lessening the volatility of economic activity. Second, exchange rate flexibility allows for the autonomous use of the policy rate as an instrument to bring inflation and output closer to their targets. Third, exchange rate flexibility diminishes agents' incentives for excessive risk-taking.

Consequently, FXI carried out by the CBoC did not intend to conflict with the inflation targeting regime. Instead, it was designed to correct excessive fluctuations in the exchange rate that could compromise its objectives. To guarantee the compatibility of FXI and inflation targeting scheme, purchases and sales of USD were always sterilized.

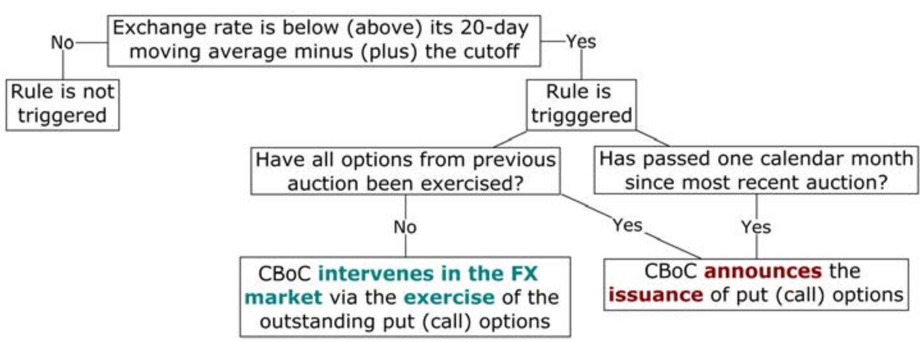
3.2 Rule-based intervention mechanism

In November 1999, right after the CBoC adopted an inflation targeting regime, it introduced a rule-based intervention mechanism to stem exchange rate volatility. Since the market of FX options and forwards was considerably thin at the time, this type of intervention also provided coverage mechanisms to market participants against extreme exchange rate movements.[7]

The mechanism operated as follows: at the close of business day, traders gained information on whether the exchange rate would trigger the rule, which was whenever the exchange rate crossed below (above) its 20-day moving average minus (plus) a given threshold.[8] If triggered, put (call) options were auctioned at the start of the following day using a uniform clearing-price format. The offered amount was almost always 180 million USD (roughly 20% of the daily FX market turnover), and the strike price was the average exchange rate of the previous day. After the auction, option-holders had up to one calendar month to exercise before expiration. During that time, the rule could not issue new options; instead, it allowed traders to exercise their outstanding options, if triggered.

To further illustrate, Figure 1 details, as a flow chart, how this intervention operated. As shown, the rule needed to be triggered (necessary condition) for either the issuance or exercise of FX options. If one month had elapsed after the last auction or if all options had been exercised, then the rule triggered a new auction (sufficient condition). However, if the rule was triggered while options were still outstanding, then the rule simply allowed option-holders to exercise.

Figure 1: The rule-based FXI mechanism



[7]Other FXI mechanisms were later enacted, mostly intended to build up reserves. A review of these mechanisms can be found in Vargas et al. (2013).

[8]The rule started with a threshold set at ±4%. It was then modified to ±2% from December 19, 2005 to June 24, 2008, and to ±5% from October 7, 2008 to October 27, 2009. Interventions were temporarily stopped from June 26, 2008 to October 6, 2008, and from October 28, 2009 to October 30, 2011. The mechanism was permanently stopped on February 6, 2012.

This setting is ideal since the same rule triggered either the issuance of FX options or the ability to exercise them. We take the former (issuance) as central bank announcements under a sharp setting, since the rule and information that triggered the issuance of options was public, and we take the latter (exercise) as the effective transaction –purchases or sales of foreign currency (USD)– under a fuzzy setting, since traders could have chosen (but were not required) to exercise the option in the following days after issuance. Also, while the central bank made an official announcement on the day of issuance, it did not disclose information on when traders decided to exercise each of their options.

Descriptive statistics for the rule-based mechanism are shown in Table 1 and Figure 2. In particular, the COP/USD exchange rate underwent severe appreciation and depreciation winds. Peak values ranged from 2,969 in February 2003 to 1,652 in June 2008.

Between December 2001 and February 2012, the rule was triggered 231 times (91 times for call options and 140 times for put options). In terms of FX announcements, there were 38 auctions: 17 for the issuance of call options and 21 for the issuance of put options. In terms of FX trades, options were exercised on 75 occasions: 34 times for call and 41 times for put. Regarding dollar amounts, the CBoC issued a cumulative sum of USD 3,059 million through call options and USD 3,760 million through put options. Effective purchases (option exercises) via put options totaled USD 2,373 million, and sales through call options totaled USD 2,330 million.

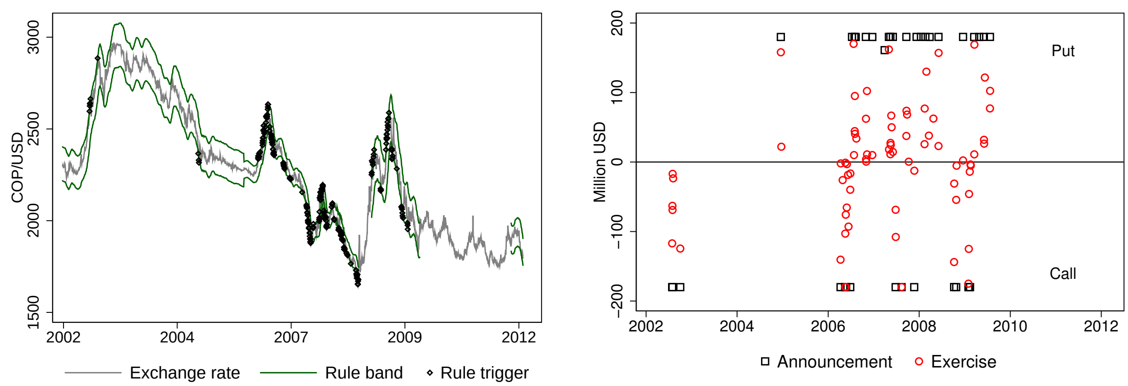
We note that while the issuance amounts were almost always USD 180 million per auction (both for call and put options), the average exercise (per day) totaled USD 68.5 million and USD 57.9 million for call and put options, respectively. Hence, issuance days carry a nearly 3-fold difference over exercising days. Given the non-linearities in the effects of FXI on the exchange rate, in Section 5.4.1 we confirm that the amounts in FXI announcements and exercising days are fairly comparable, so that they do not overplay the signaling channel vis-a-vis the portfolio channel.

Table 1: Summary Statistics

Variable	Mean	Cumulative Sum	St. Deviation	Min.	Median	Max.	Obs. (frequency)
COP/USD Exchange rate	2,257	-	348	1,652.41	2269.4	2,968.9	2,433
Put options issued	179.1	3,760.4	4.1	161	180	180	21
Call options issued	180	3,059.3	0.1	179.8	180	180	17
Put options exercised	57.9	2,373.1	51.9	0.5	38	170	41
Call options exercised	68.5	2,330.3	59.7	1.0	58.7	179.9	34
Rule triggered (put)	-	-	-	-	-	-	140
Rule triggered (call)	-	-	-	-	-	-	91

Note: Author's calculations using daily data from December 24, 2001, to February 3, 2012. The table reports the frequency and amount issued and exercised of FX options. The last six rows present calculations for non-zero observations.

Figure 2: Mechanics of the rule-based FXI



(a) Triggering rule

(b) Announcement vs Exercise

3.3 Data

We rely on records from two main sources, SET-ICAP FX S.A. and the CBoC. First, SET-ICAP FX S.A. is the authority in charge of managing the largest electronic FX platform in the country, which reports over 90% of the total COP/USD market volume worldwide.[9] Data from this source include minute-by-minute FX operations between December 2001 and February 2012. Second, the CBoC (Market Operations and Development Department) reports information on FXI, including the timing and amount of every FX auction issued by the CBoC, as well as those exercised by each market participant.

[9]The offshore FX market for COP/USD is small and restricted by regulation (*Resolución Externa* 2018).

To explore whether central bank credibility and risk factors amplify exchange rate effects, we gather additional data obtained or constructed from either the CBoC or Bloomberg. These measures include: the domestic policy rate, global volatility "*VIX*" index, the emerging market risk index "*MXEFOCXO*", the Colombian "*EMBI*" index, departures from the Uncovered Interest Parity (UIP) condition, and the degree of anchoring in inflation expectations, i.e., the closeness of 1-month and 1-year expectations to the target. We also use the *CBoC Expectations Survey* to obtain the dispersion in exchange rate forecasts. Finally, we obtain official press releases and minutes following the Board of Directors' meetings in order to extract all FXI announcements (relevant for our analysis on large and sporadic announcements of Section 5.4.3).

4 Identification strategy

Our identification strategy is based on the discontinuity in the policy rule, which in essence creates a localized quasi-experiment, i.e., treatment assignment within the vicinity of the triggering threshold is *as good as randomly assigned*. This allows us to identify the effect of intervention, both the issuance (announcement) and exercising (secret trades) of options, by comparing days in which the cutoff was barely met or missed.

We argue that locally, within the vicinity of the triggering threshold, the exchange rate becomes uncoupled from macroeconomic and financial variables. Put differently, small variations in the error term (e.g., exchange rate surprises), which are reflected in small variations in the exchange rate, in turn, lead to large and discontinuous jumps in the probability of intervention, which is what we exploit in our investigation. Conceptually, this happens because the exchange rate has equal probability of being closely above or below the cutoff. To our advantage, the RDD approach relies on the somewhat weak assumption that observable and unobservable factors may vary smoothly around the cutoff (Hahn et al., 2001; Imbens and Lemieux, 2008).

We begin by formalizing the FXI rule, which was whenever the COP/USD exchange rate (e_t) crossed below (above) its 20-day moving average ($\bar{e}_t$) minus (plus) a given threshold (r_t). Hence, we denote our running variable (X_t) as:

$$X_t = \frac{1}{r_t}\frac{e_t - \bar{e}_t}{\bar{e}_t} \tag{1}$$

For ease in notation, in this section we only describe the case for call options (issuance and exercise). This way, the rule is triggered whenever $X_t \geq 1$. Nonetheless, without loss of generality, the case for put options follows the exact mirror analysis, where the rule is triggered whenever $X_t \leq -1$. To illustrate our identification strategy, consider a linear setting of the form:

$$y_t = \alpha + \beta \mathbb{1}\{X_t \geq 1\} + \epsilon_t \tag{2}$$

Where $\mathbb{1}\{\cdot\}$ is an indicator function. It follows that,

$$\begin{aligned} &\mathbb{E}\left[y_{1t} - y_{0t} | X_t = x\right] \\ =& \lim_{x \downarrow 1} \mathbb{E}\left[y_t | X_t = x\right] - \lim_{x \uparrow 1} \mathbb{E}\left[y_t | X_t = x\right] \\ =& \left(\alpha + \beta + \lim_{x \downarrow 1} \mathbb{E}\left[\varepsilon_t | X_t = x\right]\right) - \left(\alpha + \lim_{x \uparrow 1} \mathbb{E}\left[\varepsilon_t | X_t = x\right]\right) = \beta \end{aligned} \tag{3}$$

where y_{1t}, y_{0t} are the pair of potential outcomes: y_{1t} if exposed to treatment (FXI) and y_{0t} if not exposed. Note that the underlying assumption for equation (3) to hold is for the right and left limits of the conditional means of the error term to be the same. This follows from the continuity of potential outcomes.[10] And, while this assumption cannot be directly tested, it does have some testable implications, which we conduct in Section 6. In essence, this notion has a theoretical justification supported by Lee (2008), who shows that one need not assume the RDD isolates treatment variation that is *as good as randomized*; instead, such randomized variation is a consequence of agents' inability to precisely manipulate the running variable just around the threshold. In our case, identification holds because, despite market agents knowing the policy rule, they are not able to predict with certainty whether or not the rule will be triggered until the end of trading day.

4.1 FXI Announcements under a sharp design

We interpret the issuance of options as central bank announcements under a sharp setting (we use the terms "issuance" and "announcement" interchangeably), since the rule and information that triggered the rule were public and because the probability of treatment jumps discontinuously at the cutoff from 0 to 1. Formally, expressing $D_t = \mathbb{1}(X_t \geq 1)$ as the

[10] This assumption captures the idea that observations slightly below and above the cutoff would show the same average response if their treatment status had not changed. Thus, any difference between the average response of treated and control observations at the cutoff can be interpreted as a causal effect of FXI.

intervention dummy variable switched on whenever the rule was triggered, then:

$$1 = \lim_{x \downarrow 1} Pr\left(D_t\right) > \lim_{x \uparrow 1} Pr\left(D_t\right) = 0. \tag{4}$$

Notice that our running variable (X_t) in this case is the same as in equation (1), only now excluding days in which there were still outstanding options from a previous auction (since in those days the rule only allowed the exercise of options, see Section 3.2).

In our estimations, we use the bias-corrected, robust, local linear estimators developed in Calonico et al. (2014). Also, we construct local average impulse response functions following Jordá (2005) method of local projections, in up to 20 working days (1-month) ahead of intervention. Specifically, we estimate the policy effect by solving the following:

$$\arg\min_{\boldsymbol{\gamma^j}} \sum_{t=2}^{T-j} \left(y_{t+j} - \gamma_0^j + \gamma_1^j D_t + \gamma_2^j (X_t - 1) + \gamma_3^j (X_t - 1) \times D_t\right)^2 K\left(\frac{X_t - 1}{h^j}\right) \text{ for } j\text{=1-20} \tag{5}$$

where y_{t+j} denotes the various outcome variables of interest (exchange rate changes, FX volatility, etc.) j periods ahead of intervention and $K(\cdot)$ is a triangular kernel with bandwidth h. Under this sharp design, $\hat{\gamma}_1$ is our parameter of interest. Note that the term $(X_t - 1)$ represents the "centered" running variable. We also allow for the slopes of this term to vary at either side of the cutoff by including the interaction term $(X_t - 1) \times D_t$. We estimate equation (5) for call and put auctions separately.

4.2 Exercising of options under a fuzzy design

The exercise of options can be interpreted as the operative (effective transaction) of FXI. The fuzziness of our design comes from the fact that traders could have chosen (but were not required) to exercise the option in the following days after issuance. Importantly, the CBoC did not disclose information on when traders decided to exercise their options, so we treat this type of trades as secret.

While this case also exhibits a discontinuous jump in the probability of treatment (similar to equation (4)), it does not jump from 0 to 1, as is the case with a sharp design. In other words, the running variable does not perfectly predict FXI, meaning strong but imperfect compliance with the rule. As such, we proceed with the following two-stage approach based on local non-parametric linear regressions:

$$\arg\min_{\boldsymbol{\theta^j}} \sum_{t=2}^{T-j} \left(D_{t+j}^{FXI} - \theta_0^j + \theta_1^j D_t + \theta_2^j (X_t - 1) + \theta_3^j (X_t - 1) \times D_t\right)^2 K\left(\frac{X_t - 1}{h^j}\right) \tag{6}$$

$$\arg\min_{\boldsymbol{\delta^j}} \sum_{t=2}^{T-j} \left(y_{t+j} - \delta_0^j + \delta_1^j \hat{D}_t^{FXI} + \delta_2^j (X_t - 1) + \delta_3^j (X_t - 1) \times \hat{D}_t^{FXI}\right)^2 K\left(\frac{X_t - 1}{h^j}\right) \tag{7}$$

also for j=1-20. Notice that D_t^{FXI} is a dummy variable denoting the *actual* exercise of options, as opposed to $D_t = \mathbb{1}(X_t \geq 1)$ which denotes the predicted rule-based exercise. Intuitively, in the first stage (equation 6) we estimate the predicted probability of exercising options, –intent-to-treat–, and use it to instrument compliant observations in the second stage (equation 7). Consequently, the fuzzy RD estimand is:

$$\delta_1^j = \frac{\lim_{x \downarrow 1} E[y_{t+j}|X_t = x] - \lim_{x \uparrow 1} E[y_{t+j}|X_t = x]}{\lim_{x \downarrow 1} E[D_t|X_t = x] - \lim_{x \uparrow 1} E[D_t|X_t = x]} \tag{8}$$

which essentially represents the ratio between the jump in the outcome variable and the share of compliant observations (those that are triggered by the rule and receive treatment). As shown in Hahn et al. (2001), equation (8) can be construed as a Wald-type Instrumental Variable estimator derived from the above mentioned two-stage procedure.[11]

5 Results

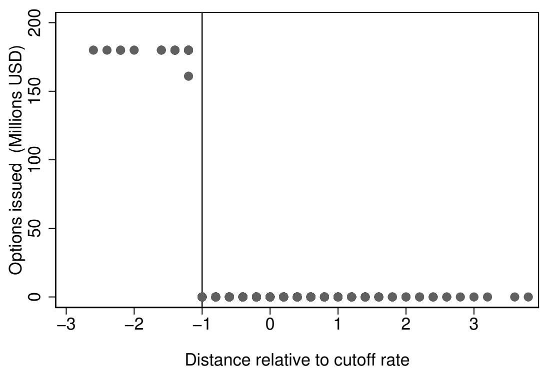
5.1 Enforcement

We begin by examining the treatment policy and its enforcement effects. That is, we first test whether the rule actually triggered the issuance and exercise of FX options. Figure 3 confirms this for the case of FX issuance (announcement). Consistent with Table 1, whenever the assignment variable was below the cutoff, $X_t \leq -1$, and no outstanding options remained from the previous auction, then the CBoC would auction put options (i.e. purchases of foreign currency) in an amount close to \$180 million USD (roughly 20% of the daily FX market turnover). Similarly, sales of foreign currency were announced through the issuance of call options when $X_t \geq 1$.

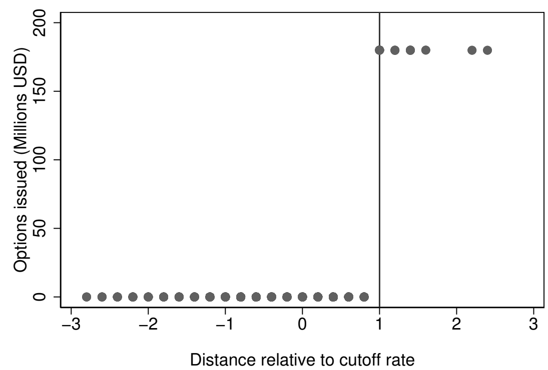
[11] For expositional purposes, in our empirical exercises we also report the reduced-form estimate "ρ_1". This estimate is computed by re-scaling the discontinuity in the outcome variable y_t by the probability of intervention, essentially, $\rho_1 = \theta_1 \delta_1$ (see equations 6 and 7).

Alternatively, when options were still outstanding, then the rule did not trigger new options, instead, it allowed traders to exercise their options. This is seen in Figure 4, where the conditions $X_t \leq -1$ and $X_t \geq 1$ triggered the exercise of put and call options, respectively. Since traders could choose not to exercise an option on a given day (hence the fuzziness), we observe several zero-value observations below (above) the cutoff for put (call) options.

Figure 3: Issuance of FX Options (Announcement)

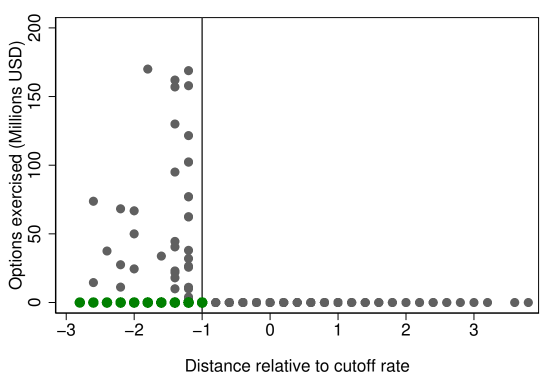


(a) Put options

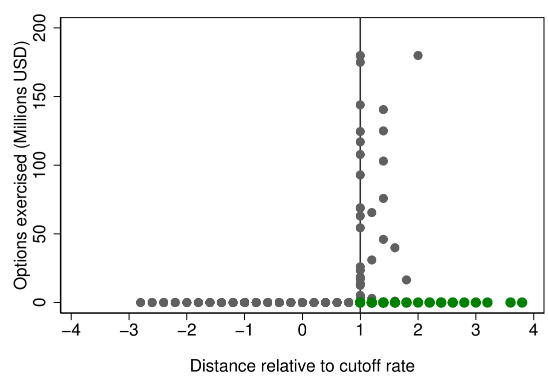


(b) Call options

Figure 4: Exercise of FX Options (Secret Intervention)



(a) Put options



(b) Call options

5.2 Intra-day and same-day effects

We next quantify the short-term –intra-day and same-day effects– of FXI on both the COP/USD exchange rate and FX volatility. Given the numerous ways of measuring FX volatility, we present (as our baseline choice) the leads of our assignment variable X_{t+j} that triggered the rule, as described in equation (1). For robustness, we nonetheless consider other measures of FX volatility, such as the estimated residuals from a GARCH(1,1) model.[12] Formally, FXI announcements correspond to the point estimate of the sharp design (γ_1^j), while secret FXI trades correspond to the second stage estimate of the fuzzy design (δ_1^j), as shown in equations (5) - (7).

Figure 5 shows the implied impulse response functions (IRFs), measured in 15-minute intervals from the beginning of trading day (8:00 a.m.) previous to intervention until the close of trading day (1:00 p.m.) of the day of intervention. To clarify, we include one day prior to intervention as an indirect test of identification (i.e., similar to testing for the parallel trends assumption in a difference in difference strategy). Hence, a null effect previous to treatment confirms the inability of agents to precisely predict when the rule would be triggered. Locally, exchange rate days that eventually receive FXI (treatment group) cannot be systematically different from exchange rate days that later miss the cutoff (control group).

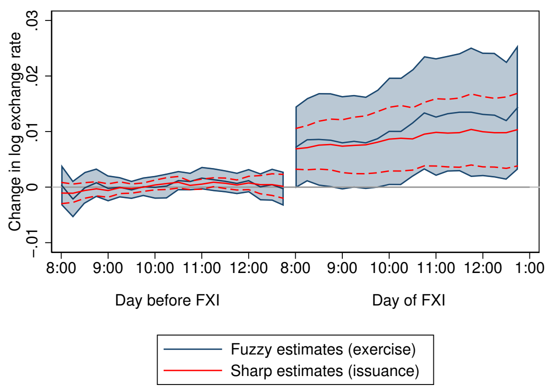
Panels 5(a) and 5(b) show the effects of the issuance (sharp estimates) and exercise (fuzzy estimates) of FX options on the exchange rate (log difference), between the listed time and the average rate from the previous day. As observed, put options lead to an immediate 1% exchange rate depreciation. Notably, the estimates are very similar for both the issuance and exercise of put options. In comparison, the effects of call options exhibit either a null (exercise) or unexpected (issuance) effect, since the exchange rate should, in principle, appreciate following sales of foreign currency by the CBoC. As will be examined in Appendix B, this is mostly explained by some sporadic but simultaneous purchases conducted through other intervention mechanisms.

Panels 5(c) and 5(d) show the impact on FX volatility and similarly indicate a reduction of close to 1pp for the case of put options (issuance and exercise). For call options, only the sharp estimates (announcement) exhibit significant effects, although the fuzzy estimates follow a similar pattern. Finally, we note that FXI does not affect the previous day's spot rate, as expected.

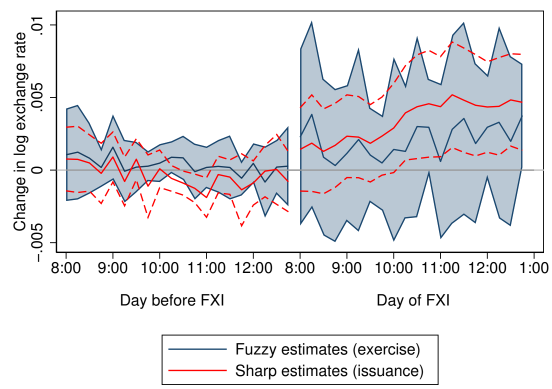
[12]Often, the empirical literature employs a GARCH(1,1) specification to capture the main features of financial series, as long as the unconditional variance is constant.

Figure 6 visually examines the same effect but now as a function of the running variable. Panels 6(a) and 6(b) confirm our intra-day results, namely that the exchange rate depreciates when the rule is triggered crossing the (-1) threshold to the left, and exhibits either a null or small but unexpected depreciation when the rule is triggered crossing the (+1) threshold to the right. Results for FX volatility (panels 6(c) and 6(d)) support FXI effectiveness in curbing exchange rate volatility via put options (call options do not show a significant jump in volatility).

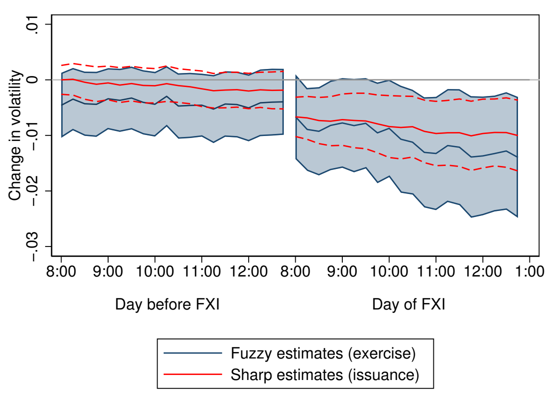
Figure 5: Intra-day effects on the exchange rate and FX volatility



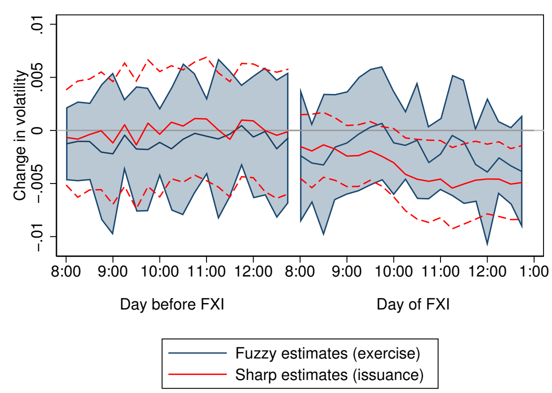
(a) Put options on FX level



(b) Call options on FX level



(c) Put options on FX volatility

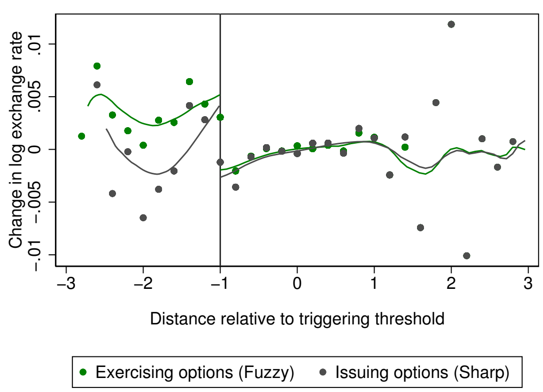


(d) Call options on FX volatility

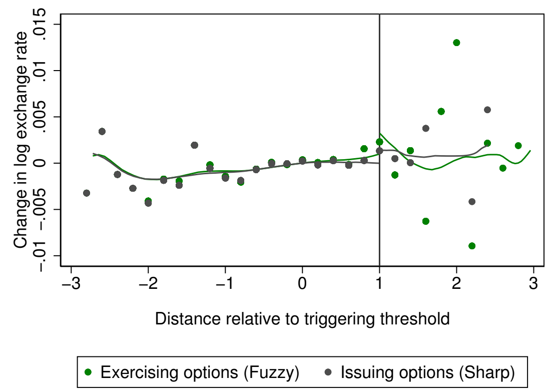
Note: For panels (a) and (b), the outcome variable is the log exchange rate difference between the listed time and the average spot rate from the previous day. For panels (c) and (d), the outcome variable is FX Volatility as defined in equation (1), also from the listed time compared to the previous day. The solid curves present a series of RD estimates. The bands display 90% confidence intervals.

To summarize, we report all the aforementioned results in Table 2. Column 1 reports the effect on the exchange rate, namely a 0.9% and 1.0% depreciation for the issuance and exercise of put options, and a 0.3% depreciation for the issuance of call options (exercise of call options is non-significant). In terms of FX volatility (as proxied by the assignment variable in column 2), the issuance and exercise of put options are able to curb volatility by 0.9pp and 1.2pp. Another measure of volatility, such as the estimated residuals from a GARCH(1,1) model yields similar albeit smaller results. Finally, columns 4-5 show *placebo* effects for lagged outcome variables. As observed, coefficients are non-significant which suggest a lack of confounding factors affecting the exchange rate around the triggering cutoff.

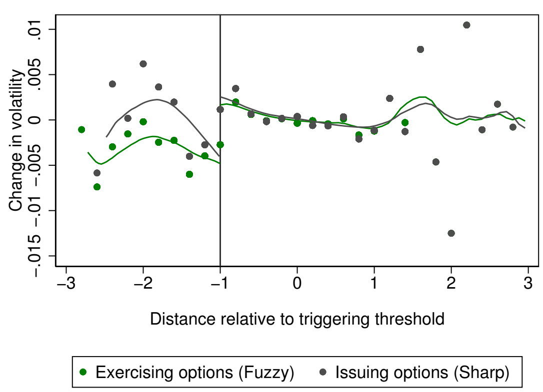
Figure 6: Same day effects on the exchange rate and FX volatility



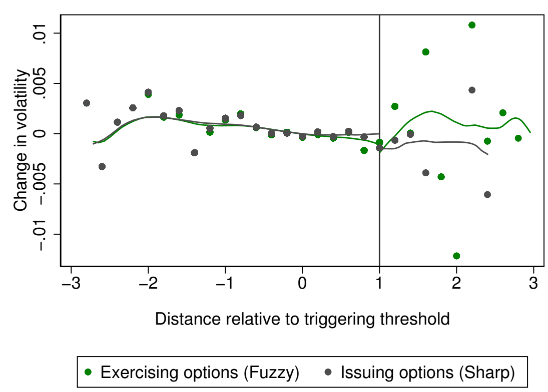
(a) Put options on FX level



(b) Call options on FX level



(c) Put options on FX Volatility



(d) Call options on FX Volatility

Note: The outcome is the difference between the log average spot rate (panels a-b) and assignment variable (panels c-d) from 8:00 a.m. to 8:15 a.m. on the day the rule was triggered and the log average rate from the previous day. The plotted points show averages of the dependent variable for 0.2 width bins. Fitted curves result from local linear regression of the outcome variable on the running variable.

Table 2: Same day effects: sharp and fuzzy RDD estimates

	Main outcomes			Placebos (lagged outcome variables)	
	(1)	(2)	(3)	(4)	(5)
	$\log(e_t/e_{t-1})$	$\text{Vol}_t - \text{Vol}_{t-1}$	GARCH(1,1)	$\log(e_{t-1}) - \log(e_{t-2})$	$\text{Vol}_{t-1} - \text{Vol}_{t-2}$
Put options (USD Purchases)					
Issuance					
	0.00860***	-0.00877***	-0.00215*	-0.00107	-0.00179
	(0.00316)	(0.00317)	-0.0012	(0.00185)	(0.00184)
Exercise					
Second stage estimates	0.0101*	-0.0115**	-0.00899*	0.00413	0.00327
	(0.00538)	(0.00542)	(0.00531)	(0.00351)	(0.00315)
First stage estimates	-0.388***	-0.346***	-0.362***	-0.348***	-0.383***
	(0.0761)	(0.0507)	(0.0547)	(0.0512)	(0.0772)
Reduced-form estimates	-0.00393**	0.00399**	0.00325*	-0.00144	-0.00125
	(0.00169)	(0.00162)	(0.00197)	(0.00116)	(0.00112)
Call options (USD Sales)					
Issuance					
	0.00326*	0.00260	-0.00270	6.90e-05	-0.000283
	(0.00173)	(0.00185)	(0.00216)	(0.00318)	(0.00314)
Exercise					
Second stage estimates	0.00252	0.000928	0.00570	0.000188	-0.000807
	(0.00272)	(0.00304)	(0.00629)	(0.00316)	(0.00424)
First stage estimates	0.650***	0.577***	0.535***	0.650***	0.493***
	(0.0904)	(0.0756)	(0.0678)	(0.0906)	(0.0615)
Reduced-form estimates	0.00164	0.000536	0.00305	0.000122	-0.000398
	(0.00184)	(0.00177)	(0.00327)	(0.00205)	(0.00209)
Bandwidth-put (issuance)	0.8379	0.7766	0.6975	0.6991	0.743
Bandwidth-call (issuance)	1.13065	1.1013	0.8812	0.91505	0.8891
Bandwidth-put (exercise)	0.7754	0.7783	0.5827	0.7499	0.7433
Bandwidth-put (exercise)	0.9521	0.949	1.1416	0.9424	0.9484
Observations	1,866	1,866	1870	1,866	1,866

Method: Local linear regression. Robust standard errors in parentheses. Bandwidth is chosen optimally following Imbens and Kalyanaraman (2012). *** p<0.01, ** p<0.05, * p<0.1 .

Dependent variables: Column 1 shows the effects on the difference between the log average daily exchange rate on the day of the intervention and the day before. Column 2 measures the effects on the difference between the exchange rate volatility on the day of the intervention and the day before. Column 3 shows the effects on the estimated residuals from a GARCH(1,1) model. Column 4 shows the effects on the difference between log average daily exchange rate the day before the intervention and two days before. Finally, column 5 presents the effects on the difference between exchange rate volatility the day before intervention and two days before the intervention.

Running variable: The forcing variable is described by equation (1).

Sample: Daily data from the period when the rule-based intervention mechanism was in place in Colombia: December 24, 2001 to February 3, 2012.

These first findings are in line with what most of the literature has found for emerging markets. For case studies conducted in Colombia, Echavarría et al. (2014); Kamil (2008); Echavarría et al. (2018); Kuersteiner et al. (2018) find that purchases of 100 million USD (through different mechanisms of FXI) depreciate the exchange rate by 0.55%, 0.76%, 0.40%, and 1.7%, respectively. In Mexico and Peru, Domaç and Mendoza (2004) and Lahura and Vega (2013) find that sales of 100 million USD appreciate the exchange rate by 0.9% and 0.4%.

Regarding effects on FX volatility, we note that our findings are larger compared to the existing literature. For example, in Colombia, Kamil (2008) and Villamizar-Villegas (2016) show a reduction in volatility of 0.02% and 0.5% after 100 million USD purchases. In meta-analyses such as Arango-Lozano et al. (2020), studies report average effects of 0.1% and 0.06% for the case of FX level and volatility, respectively, in response to 100 million USD dollar interventions.

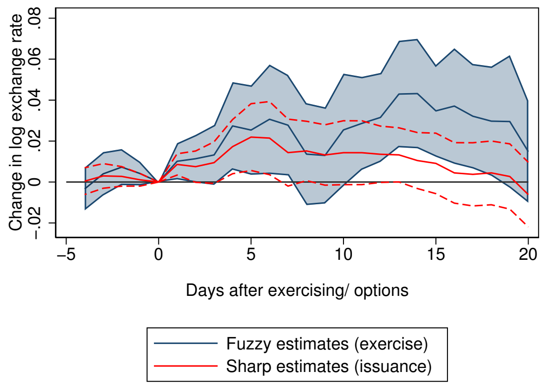
5.3 One-month effects

We extend the results in the previous subsections to a one-month (20-working days) horizon. Figure 7 presents IRFs for the effects on the exchange rate and FX volatility. In particular, panel 7(a) shows that after the issuance (exercise) of put options, the exchange rate depreciates by up to 2% (4%) and the effects persist for up to 13 (20) days before subsiding towards their pre-intervention level. For the case of call options, panel 7(b) shows a maximum exchange rate appreciation of 4% almost 10 days after issuance, but an overall null effect for the fuzzy estimates (exercise). For FX volatility, panels 7(c) and 7(d) show a significant reduction of close to 3pp for call and put options (similar for both issuance and exercise).

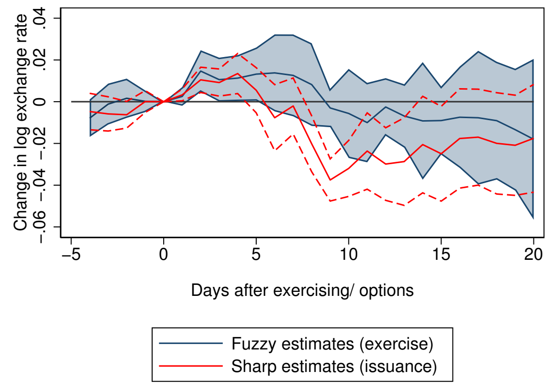
We conclude that, unconditionally, both announcements and secret interventions carry similar effects, which is somewhat surprising given that most of the literature hints towards a stronger signaling channel (Obstfeld, 1988; Kaminsky and Lewis, 1996; Fratzscher, 2008; Ghosh, 1992; Bauer and Rudebusch, 2014) and in many cases questions the effects of secret and sterilized FXI. To be fair, advocates of the signaling channel generally refer to the combined effect of a central bank announcement plus the subsequent trades, not just the isolated effect of the announcement.

While similar, there are nonetheless some differences in the effects of announcements versus secret trades. For example, for put options, the effects are practically identical for the first 10 days after FXI, but stronger and marginally longer for the case of secret trades (exercise) after day 10. For call options, the effects of announcements predominate.

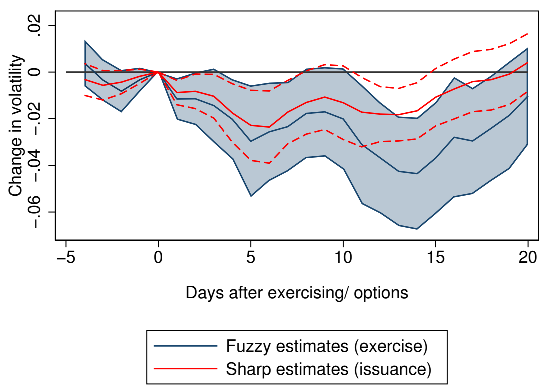
Figure 7: One-month effects on exchange rate level and volatility



(a) Put options on FX level



(b) Call options on FX level



(c) Put options on FX volatility

(d) Call options on FX volatility

Note: Impulse Response Function: Exchange rate effects 20 working days after intervention. For panels (a)-(b), the dependent variable is the log difference of the daily average spot rate $t+j$ days after FXI and the log average rate the day before the FXI. For panels (c)-(d), the dependent variable is the difference between FX volatility $t+j$ days after the FXI and the day before the FXI. The central solid curves present the fuzzy/sharp regression discontinuity estimates. The upper and lower lines display 90% confidence intervals.

5.4 Differential effects

5.4.1 Intervention Amount

Up to this point, we have compared intervention announcements, almost always of USD 180 million per auction-day, with secret trades, which carried an average amount (per day) of close to USD 60 million (see Section 3.2). Hence, issuance days carry a nearly 3-fold difference over exercising days. In principle, this difference could be overplaying the signaling channel vis-a-vis the portfolio channel.

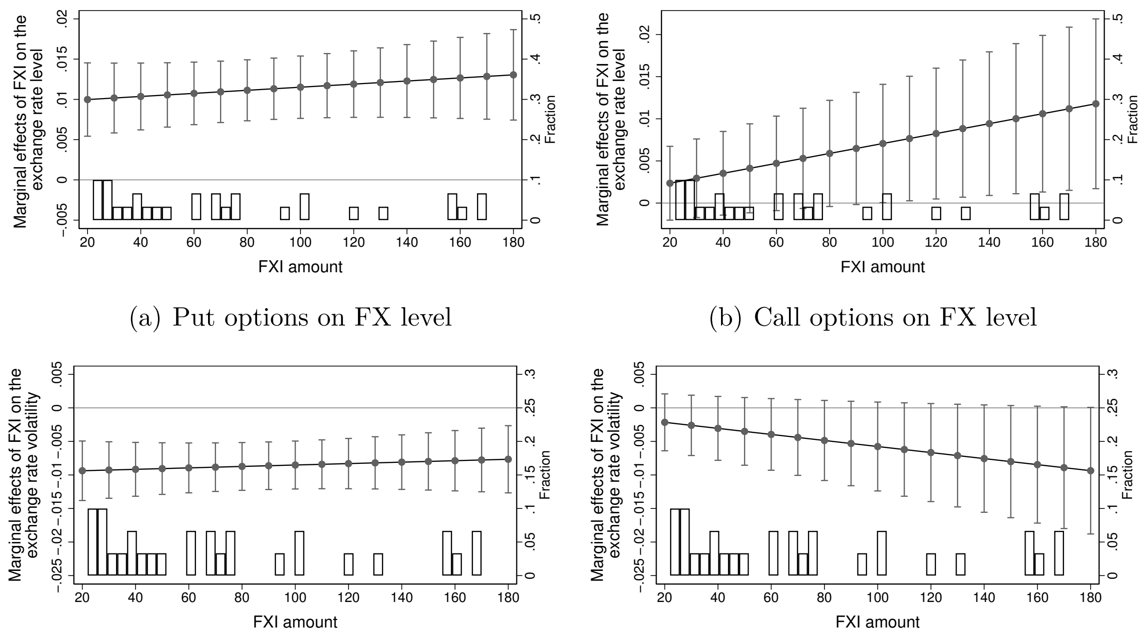
To address this concern, we evaluate the incremental effect of an additional "intervention dollar". To do so, we interact our fuzzy specifications (equations 6 - 7) with a continuous *exercised amount* variable. Our results, shown in Figure 8, report the marginal effect of intervention (y-axis) evaluated at each intervention amount (x-axis). For illustrational purposes, on the right axis we plot the observed distribution of exercised amounts (depicted in bars), so as to show the variability in intervention amount.

For put options, the effect of an additional dollar is small.[13] For example, a 60 million USD intervention produces an exchange rate depreciation of 1.1% while a 180 million USD intervention produces an exchange rate depreciation of 1.3%, so only a 0.2pp gain. Similarly, the effects on FX volatility are of -0.9pp and -0.8pp for intervention amounts of 60 and 180 million USD, respectively. For call options, the effects vary slightly more: 0.6% versus 1.1% for FX depreciation, and -0.5pp versus -0.8pp, for FX volatility in response to intervention amounts of 60 and 180 million USD. However, these last results (call options) are, for the most part, non-significant and with ample confidence bands.

In general, we note that this adjustment does not substantially alter our previous findings. That is, even after adjusting for FX amounts, our results still convey that, unconditionally, both announcements and secret interventions carry similar effects. If anything, these adjustments further narrow their initial differences, especially for the case of call options.

[13]We acknowledge, however, a discontinuous jump –from 0 to 20 million USD– on the exchange rate (y-intercept). Once this amount has been exercised, the marginal effect of an additional dollar is small.

Figure 8: Same day effects based on intervention amounts



(a) Put options on FX level

(b) Call options on FX level

(c) Put options on FX volatility

(d) Call options on FX volatility

Note: This graph shows the incremental effects of FXI amounts on exchange rate levels (panels a-b) and volatility (panels c-d). 90% confidence intervals are displayed. On the right axis, the distribution of the intervention amount (in bars) is depicted.

5.4.2 Amplifying covariates

We now extend the analysis to a more general evaluation; on whether FXI effectiveness is magnified in periods of: (i) central bank credibility, (ii) FX volatility, and (iii) other FX risk factors. To do so, we again interact our sharp and fuzzy specifications (equations 5 - 7) with a set of control variables.

For central bank credibility, we employ two measures. The first is a dummy variable switched on whenever the central bank carried out *leaning with the wind policies* i.e., episodes in which monetary tightening was accompanied by USD sales, or when monetary easing was accompanied by USD purchases.[14] The second measure captures the degree of anchoring in inflation expectations (i.e., closeness to the inflation target) and is motivated by the work of Bems et al., 2021.

For FX volatility, we employ three measures. The first is simply a 20-day moving

[14]According to Kamil (2008), most *leaning against the wind* policies (except if inflation is rising due to a supply shock) make FXI ineffective.

average volatility (i.e., monthly squared returns). The other two measures, taken from the CBoC survey, are the dispersion of the 1-month-ahead and 12-months-ahead exchange rate forecasts by market participants (i.e., forecast disagreements about the future exchange rate). The choice of these variables is motivated by Lahiri and Sheng (2010), who state an explicit association between forecast disagreements and market volatility.

In turn, FX risk factors include: departures from the Uncovered Interest rate Parity (UIP) condition, the VIX index, the emerging market risk "MXEFOCXO" index, and the Colombian EMBI. The motivation for introducing these variables rests on the work of Vargas-Herrera and Villamizar-Villegas (2020) who argue that FXI effectiveness increases with higher FX uncertainty, given that the central bank faces less speculative attacks from traders and arbitragers. Also, as a country opens itself financially, global shocks become more relevant (Schoenmaker, 2013; Rey, 2015; Kalemli-Ozcan, 2019; Devereux et al., 2020). To further rationalize these expected findings, in Appendix C we provide some relevant implications of the model used in Vargas-Herrera and Villamizar-Villegas.

Results are reported in Table 3. For comparability purposes, all control variables are normalized, so that impulse shocks correspond to one standard deviation. For put options, we note that high central bank credibility increases FXI effectiveness –of announcements– by up to 1.4pp (day 10 for leaning with the wind policy and days 15 and 20 for inflation anchoring), while it has a lower or null amplifying effect for secret trades (0.9pp for leaning with the wind policy and for 1-month inflation anchoring).

Regarding FX volatility and risk factors, all measures have considerable amplifying effects for the case of announcements, and instead exhibit a lower or null incremental effect for secret trades. For example, a higher emerging market risk index increases the effectiveness of announcements by 3.8pp (day 20) compared to 1.9pp for secret trades. Similarly, UIP departures increase the effectiveness of announcements by up to 2.0pp (day 10) compared to a null incremental effect for secret trades. Also, a higher VIX index increases the effectiveness of announcements by 1.8pp (day 10) compared to a null effect for secret trades. Similarly, FX volatility, for example, measured by the 1-month dispersion in surveyed forecasts increases the effectiveness of announcements by 2.0pp (day 10) compared to a 1.4pp gain for the case of secret trades. Finally, the EMBI shows a similar effect on the issuance and exercise of options, with an incremental effect of close to 2.0pp.

Effects are similar albeit less clear for call options, which show stronger (more negative) amplifying effects for the case of announcements when there is a higher forecast dispersion and a higher EMBI.[15] The same applies to our results on FX volatility, presented in Table D2 of Appendix D.

Table 3: Incremental effects of FXI - level

	Day 1	Day 5	Day 10	Day 15	Day 20	Day 1	Day 5	Day 10	Day 15	Day 20
	Issuance - Sharp RDD					**Exercise - Fuzzy RDD**				
Put options (USD Purchases)										
CB Credibility										
Leaning with the wind	0.009**	0.011**	0.014**	0.010*	0.010*	0.001	0.005	0.009**	0.009**	0.008*
	(0.0045)	(0.0051)	(0.006)	(0.0056)	(0.0057)	(0.002)	(0.004)	(0.004)	(0.004)	(0.004)
Inflation anchoring (1 month)	0.008*	0.010*	0.013*	0.012*	0.014**	0.001	0.003	0.009*	0.011*	0.009
	(0.0049)	(0.0058)	(0.0072)	(0.0068)	(0.0067)	(0.003)	(0.004)	(0.005)	(0.006)	(0.007)
Inflation anchoring (12 months)	0.001	0.004	0.011*	0.014***	0.013***	0.001	0.001	0.002	0.004	0.009
	(0.0048)	(0.0053)	(0.0064)	(0.0052)	(0.0043)	(0.002)	(0.003)	(0.004)	(0.006)	(0.006)
FX Volatility										
FX Volatility (1 month)	0.008***	0.010***	0.012***	0.007*	0.004	-0.001	0.003	0.009**	0.007	0.003
	(0.002)	(0.003)	(0.004)	(0.004)	(0.004)	(0.002)	(0.003)	(0.004)	(0.004)	(0.005)
FX Dispersion (1 month)	0.012***	0.015***	0.020***	0.016***	0.016***	0.003	0.007**	0.014***	0.012***	0.010***
	(0.0036)	(0.0043)	(0.0051)	(0.0048)	(0.0049)	(0.002)	(0.003)	(0.004)	(0.003)	(0.003)
FX Dispersion (12 months)	0.006*	0.007**	0.009**	0.007*	0.007*	0.000	0.003	0.007*	0.007*	0.005
	(0.0032)	(0.0038)	(0.0043)	(0.0036)	(0.0036)	(0.002)	(0.003)	(0.004)	(0.004)	(0.003)
Other FX Risks										
EMBI	0.014*	0.017**	0.021**	0.014	0.012	0.003	0.016***	0.023***	0.015	0.010
	(0.0076)	(0.0083)	(0.0101)	(0.0103)	(0.0109)	(0.003)	(0.005)	(0.007)	(0.01)	(0.012)
VIX index	0.010***	0.013***	0.018***	0.015***	0.013**	0.002	0.008***	0.013***	0.010***	0.008**
	(0.0035)	(0.0039)	(0.0048)	(0.005)	(0.0055)	(0.002)	(0.003)	(0.003)	(0.004)	(0.004)
EM risk index	0.004	0.011	0.026*	0.036***	0.038***	0.002	0.002	0.007	0.014	0.019*
	(0.0096)	(0.0108)	(0.0137)	(0.0138)	(0.0136)	(0.005)	(0.006)	(0.008)	(0.01)	(0.011)
UIP departure	0.011**	0.014***	0.020***	0.017**	0.016*	-0.001	0.006	0.009	0.006	0.006
	(0.0045)	(0.0049)	(0.0065)	(0.0075)	(0.0087)	(0.003)	(0.004)	(0.006)	(0.008)	(0.009)
Call options (USD Sales)										
CB Credibility										
Leaning with the wind	0.000	0.001	-0.001	-0.004	-0.004	0.005	0.006	0.006	0.003	0.003
	(0.004)	(0.0052)	(0.0084)	(0.0108)	(0.0127)	(0.004)	(0.005)	(0.007)	(0.009)	(0.010)
Inflation anchoring (1 month)	-0.050	-0.053	-0.138	-0.157	-0.123	-0.010	0.015	0.061	0.132	0.174
	(0.0756)	(0.1223)	(0.2144)	(0.249)	(0.2656)	(0.059)	(0.071)	(0.114)	(0.131)	(0.132)
Inflation anchoring (12 months)	-0.010	-0.024	-0.066	-0.069	-0.051	0.001	0.001	-0.015	-0.024	-0.019
	(0.0245)	(0.0358)	(0.0573)	(0.0676)	(0.0765)	(0.013)	(0.019)	(0.03)	(0.041)	(0.049)
FX Volatility										
FX Volatility (1 month)	-0.003	-0.002	0.003	0.012	0.015	-0.009**	-0.008	-0.009	-0.009	-0.011
	(0.007)	(0.011)	(0.018)	(0.021)	(0.023)	(0.004)	(0.005)	(0.008)	(0.009)	(0.01)
FX Dispersion (1 month)	-0.022***	-0.034***	-0.051**	-0.061**	-0.074***	-0.019**	-0.027**	-0.035**	-0.043**	-0.052***
	(0.0084)	(0.0123)	(0.0246)	(0.0279)	(0.026)	(0.009)	(0.011)	(0.015)	(0.017)	(0.017)
FX Dispersion (12 months)	-0.003	-0.005	-0.006	-0.009	-0.015	-0.004	-0.006*	-0.008*	-0.013**	-0.018***
	(0.0049)	(0.0073)	(0.0122)	(0.0138)	(0.0143)	(0.004)	(0.004)	(0.004)	(0.005)	(0.006)
Other FX Risks										
EMBI	-0.019***	-0.021***	-0.042***	-0.064***	-0.077***	-0.002	-0.004	-0.007	-0.006	-0.005
	(0.0005)	(0.0009)	(0.0018)	(0.0024)	(0.0027)	(0.002)	(0.002)	(0.004)	(0.006)	(0.006)
VIX index	0.000	-0.002	-0.006	-0.002	0.002	-0.006*	-0.007**	-0.013***	-0.017***	-0.018***
	(0.0096)	(0.0126)	(0.0225)	(0.0264)	(0.0284)	(0.003)	(0.004)	(0.004)	(0.005)	(0.006)
EM risk index	0.004	0.003	0.002	0.000	-0.001	0.009*	0.011*	0.017*	0.02*	0.022*
	(0.0058)	(0.0081)	(0.0145)	(0.0171)	(0.0183)	(0.005)	(0.006)	(0.01)	(0.012)	(0.013)
UIP departure	-0.003	-0.006	-0.013	-0.003	0.01	0.002	0.004	0.002	0.006	0.013
	(0.0097)	(0.0149)	(0.0249)	(0.0287)	(0.0307)	(0.005)	(0.006)	(0.009)	(0.011)	(0.013)

Method: Local linear regression. Robust standard errors in parentheses. Bandwidth chosen following Imbens and Kalyanaraman (2012). *** p<0.01, ** p<0.05, * p<0.1.
Dependent variable: Difference between the log average daily exchange rate on the day of the intervention and the day before.
Variable of interest: We interact sharp and fuzzy specifications (equations 5 - 7) with a set of control variables, pertaining to (i) central bank credibility, (ii) foreign exchange uncertainty, and (iii) and risk factors.
Running variable: The forcing variable is described by equation (1).
Sample: Daily data from the period when the rule-based intervention mechanism was in place in Colombia: December 24, 2001 to February 3, 2012.

[15] Note that call options present less statistical power given fewer observations and degrees of freedom.

5.4.3 Sporadic Announcements

We acknowledge that larger and more sporadic announcements could potentially exert pressure on the exchange rate, that is, "*more bang for the buck*". After all, the rule-based mechanism that we study was originally designed at the beginning of the 2000's, and its original presentation to the public could have carried a stronger effect than its subsequent (and multiple) triggered announcements; the latter perhaps seen only as a small part of a decade-long intervention regime.

To this end, in this section we depart from our baseline framework and compare the largest FX announcements by the CBoC (stated in official press releases and minutes following the Board of Directors' meetings) with unannounced and discretionary FXI conducted in the largest and centralized FX trading platform (*SET-ICAP FX*). A caveat, however, is that since both FXI announcements and trades are derived from discretionary –and not rule based– mechanisms, then our localized approach does not apply, and hence our identification strategy at this stage is weaker.

To give some context, throughout our sample the CBoC made 57 large intervention announcements: 47 corresponding to dollar purchases and 10 to dollar sales.[16] Given the few sale announcements, we only consider the case for purchases. Among these, the CBoC announced that interventions would be conducted via the following mechanisms:

- FX options to accumulate reserves → 23 cases,
- Pre-announced FX auctions for USD purchases → 21 cases,
- Discretionary purchases in the centralized FX trading platform → 3 cases

On average, the announcement length (central bank commitment-length to purchase dollars) was 3.6 months, and the amount was USD 410 million.

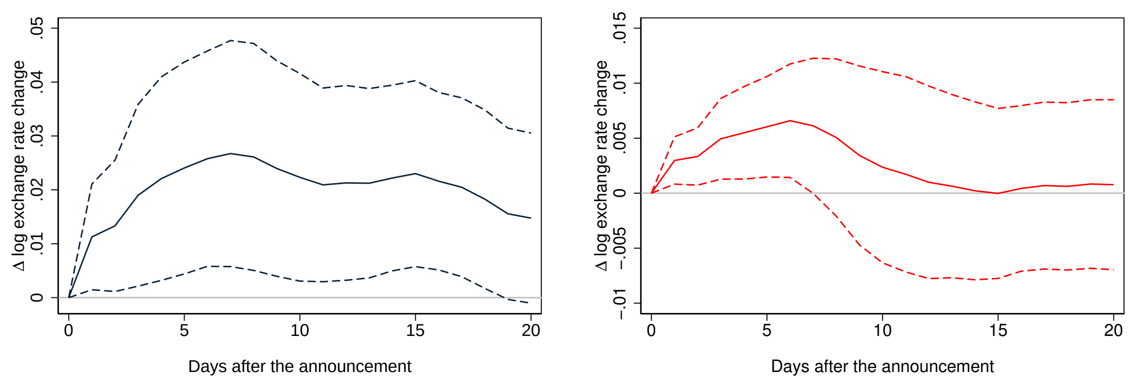
To evaluate the difference between these announcements and unannounced FXI trades, we employ a Propensity Score Matching technique -PSM (Rosenbaum and Rubin, 1983). Specifically, we match on variables such as the FXI amount and type of intervention mechanism (basic specification). For robustness, we also include a larger set of matching covariates such as: the difference between the inflation rate and the CBoC's target, the difference between the policy rate and overnight market rate, the Emerging Markets Bonds Index, and the lagged 1-day, 20-day, and 1-year exchange rate depreciation.

[16] In Appendix E we provide a detailed report of all announcements.

The PSM methodology first estimates a propensity score (i.e., the conditional probability of a FXI announcement, $\check{D}_t$). We do this by using a Probit model, so that $Pr(\check{D}_t = 1|W_t) = \Phi\left(W_t'\delta\right)$, where $\Phi(\cdot)$ is the cumulative normal distribution. We then use a nearest neighbor matching: each announcement is matched with an unannounced FXI with similar characteristics.[17]

Our results are reported in Figure 9 and denote the incremental effect of FXI announcements (treatment) over unannounced FXI trades (control). Our basic specification (panel 9(e)) suggests a large effectiveness gain in favor of central bank announcements, by up to 2.5pp, significant over the entire month. However, when including more matching covariates, the effect is reduced to a gain of 0.7 percentage points over 7 working days (panel 9(f)).

Figure 9: Announcement vs. Unannounced intervention



(e) Basic specification

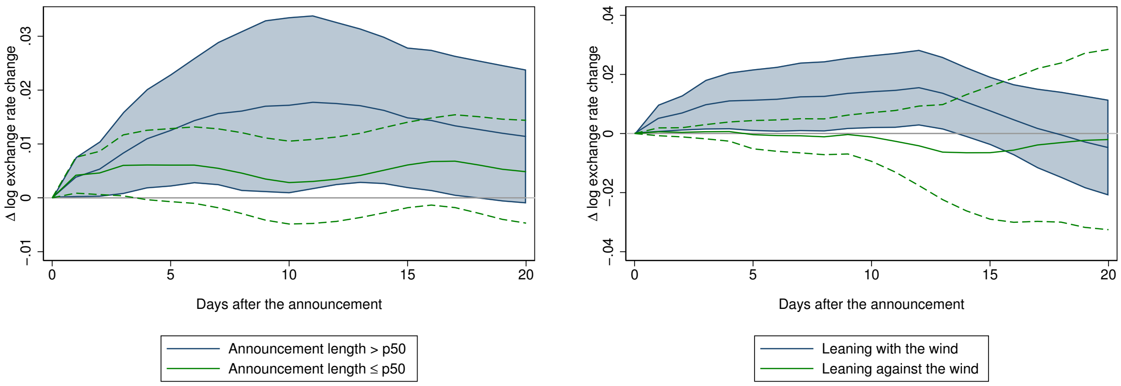
(f) Including more covariates

Note: The solid line present the PSM estimates of the intervention announcement vis-a-vis the unannounced intervention. The short-dash lines display 90% confidence intervals.

Nonetheless, announcements carry larger effects when the FXI episode length is longer (hinting towards a more systematic regime) and when the central bank has higher credibility (measured as when conducting *leaning with the wind* policies). This is observed in Figure 10 where, using our specification with more covariates, we split announcement days in either episode lengths that are higher or lower than the median, as shown in panel 10(a), and episodes of high and low central bank credibility, as shown in panel 10(b). In both cases, larger announcements and higher credibility, report a 2pp lead versus secret trades.

[17]We also test for balanced covariates (not reported but available upon request).

Figure 10: Longer FXI episodes and higher central bank credibility



(a) FXI episode length

(b) CB credibility

Note: The graphs show the PSM estimates (specification with additional covariates) of the intervention announcement vis-a-vis unannounced intervention on the exchange rate, distinguishing for different announcement lengths and periods of high versus low central bank credibility. The upper and lower lines display the 90% confidence intervals.

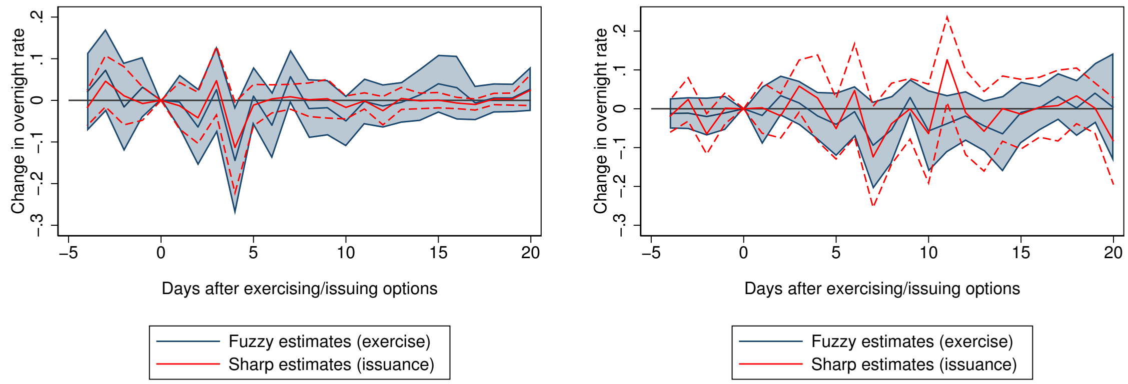
6 Validity of RDD assumptions

6.1 Sterilized interventions

In Section 3, we described how all FXI conducted in Colombia were sterilized i.e., designed to leave the domestic money supply (and thus the domestic interest rate) unchanged. This is useful since it avoids the concern that accompanying interest rate changes potentially over- or underplay exchange rate effects.

To corroborate this empirically, in Figure 11 we present 1-month effect estimates, similar to those in Section 5.3 –only now setting the overnight market interest rate as dependent variable. The Figure depicts a non-significant effect in response to FXI via both put and call options, thus corroborating that interventions were, in fact, sterilized.

Figure 11: One-month effects on the overnight rate



(a) Put options

(b) Call options

Note: Effects on the overnight rate 20 calendar days after intervention. The dependent variable is the difference between the overnight rate t days after the intervention and the day before the auction. The central solid curves present the fuzzy/sharp RD estimates. The upper and lower lines display the 90% confidence intervals.

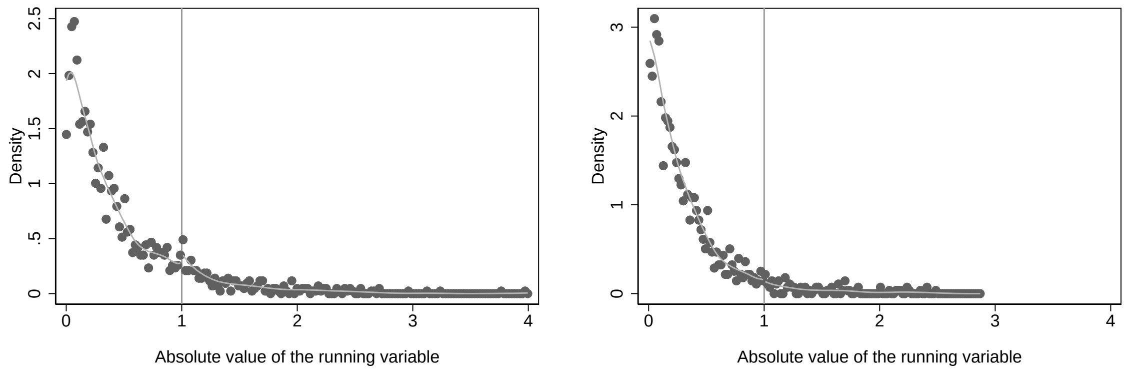
6.2 Rule manipulation tests

A fundamental assumption for RDDs is that assignment nearby the cutoff, which determines the treatment exposition (i.e., issuing/exercising options), be locally random. This assumption may be violated if market intermediaries can accurately predict and/or manipulate the assignment variable to surpass the threshold that triggers the rule. Nevertheless, despite traders knowing the policy rule, in this section we provide evidence that random factors make the exchange rate locally unpredictable.

We test the validity of this assumption in two ways. First, the local randomness condition implies no manipulation near the threshold. In Figure 12 we present a density test of the running variable at either side of the cutoff, following McCrary (2008), where the null hypothesis implies continuity at the threshold (and therefore a lack of manipulation). Intuitively, a discontinuity would indicate an unbalanced number of days when the rule was barely triggered and when the rule was barely missed. As observed, results for issuing (sharp RDD) and exercising (fuzzy RDD) of options, displayed in panels 12(c) and 12(d), indicate no evidence of manipulation, with p-values of 0.83 and 0.72, respectively.[18]

[18] We stack call and put options together by taking the running variables in absolute value. Hence, the rule is triggered whenever $X_t \geq 1$, for both call and put options (see equation 1).

Figure 12: Density test around the triggering threshold



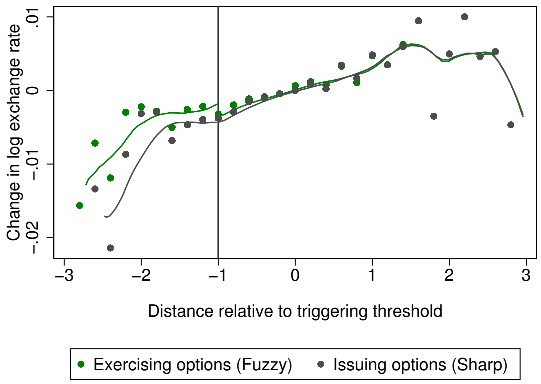
(c) Exercising options - fuzzy

(d) Issuing options - sharp

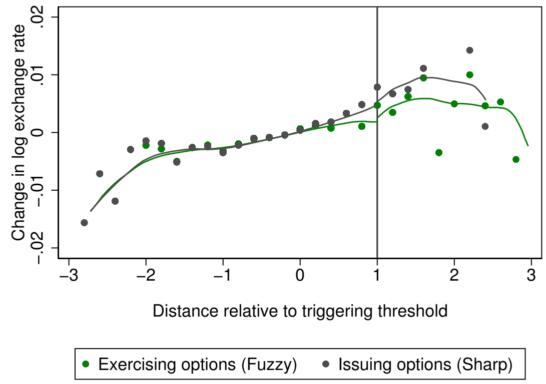
Note: The plotted points show the frequency of the running variable for exercising and issuing options in bins of width 0.02. The solid curve is a local linear fit of the density of the absolute value of the running variable on either side of the cutoff.

A second test consists of a placebo test on lagged outcomes, i.e., examining whether the lagged exchange rate level and volatility measures respond to the contemporaneous policy. A formal version of this test was already presented in columns 4 and 5 of Table 2. For illustrational purposes, we now present these results graphically in Figure 13, which show no clear jump around the threshold for put or call options.

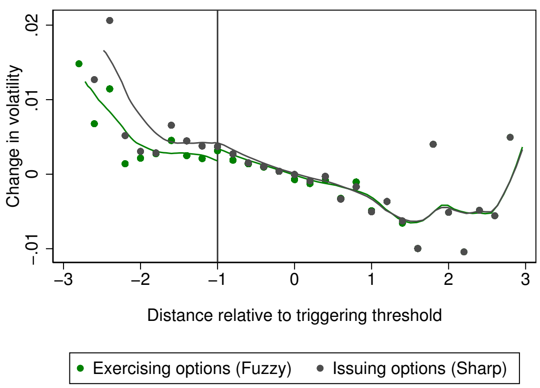
Figure 13: Placebo test: lagged FX level and volatility in response to contemporaneous FXI



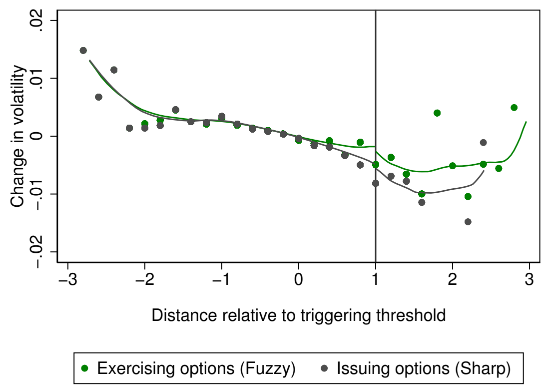
(a) Put options on FX level



(b) Call options on FX level



(c) Put options on FX volatility



(d) Call options on FX volatility

Note: the outcome is the lag difference spot rate and FX volatility. The plotted points show averages of the dependent variable for 0.2 width bins. Fitted curves result from local linear regression of the outcome variable on the running variable.

6.3 Balanced covariates

We proceed by testing for the correlation between some underlying fundamentals and the probability of exercising/issuing options. Specifically, we regress a dummy treatment variable (switched on whenever options are issued/exercised) on lagged macroeconomic fundamentals, including: the daily exchange rate depreciation, FX forwards, interbank interest rate, and EMBI spread. Intuitively, this *falsification test* examines detectable baseline differences between intervention and non-intervention days. Conditional on the running variable, if fundamentals are correlated with treatment near the cutoff, then these baseline differences can exert some influence (i.e., bias) on our estimates.

Results for this test are presented in Table 4. Notice that when using the entire sample (non-localized approach), FXI is correlated with fundamentals: exchange rate depreciation, FX forwards, and interbank interest for put options, and FX forwards, interbank interest rate, and EMBI spread for call options (columns 1 and 3). However, when the sample is restricted to observations in the vicinity of the triggering threshold (bandwidth of 0.5), the correlation between FXI and fundamentals disappears (columns 2 and 4). In fact, the only significant variable (besides the constant) is the running variable, as expected. Moreover, the test does not reject the null hypothesis that fundamentals are jointly statistically different from zero.[19] Thus, this exercise suggests that macroeconomic factors behave smoothly (i.e., are balanced) around the cutoff point.

[19]We note that the low predictive power of fundamentals is not solely explained because of the restricted sample. In fact, the running variable itself remains a strong predictor of intervention, as seen by the significance of its coefficients and F-tests.

Table 4: Correlation of intervention on fundamentals

	(1) All	(2) BW = 0.5	(4) All	(5) BW = 0.5
	Purchases of US dollars		Sales of US dollars	
Exercising options - Fuzzy RDD				
Lag log change in spot rate	-3.608*	1.707	-1.284	3.229
	(1.847)	(4.404)	(2.514)	(4.612)
Lag exercised forward rate	-607.8***	-491.3	-270.2***	583.7
	(137.0)	(707.8)	(66.71)	(487.0)
Lag interbank rate	0.0573***	0.0401	0.0483***	0.0158
	(0.00982)	(0.0392)	(0.00967)	(0.0266)
Lag EMBI spread	6.16e-05	0.000200	-8.98e-05*	-0.000184
	(5.28e-05)	(0.000265)	(5.32e-05)	(0.000143)
Running var.	-0.237***	-1.420***	0.207***	1.271***
	(0.0245)	(0.0902)	(0.0230)	(0.102)
Constant	-0.0497	0.205	-0.00469	0.405*
	(0.0735)	(0.320)	(0.0753)	(0.228)
Observations	553	74	553	72
Fundamentals, F test	11.76	0.341	11.62	1.746
Fundamentals, Prob > F	3.58e-09	0.849	4.61e-09	0.150
Running var., F test	93.38	247.8	81.08	155.4
Running var., Prob > F	0	0	0	0
Issuing options - Sharp RDD				
Lag log change in spot rate	-1.852	0.392	-1.971*	-7.408
	(1.424)	(7.487)	(1.063)	(6.323)
Lag exercised forward rate	-189.9**	748.2	-102.5**	259.6
	(76.65)	(590.2)	(45.32)	(545.6)
Lag interbank rate	0.0275***	0.000521	0.0121**	0.0137
	(0.00688)	(0.0754)	(0.00591)	(0.0261)
Lag EMBI spread	2.73e-05	-9.44e-05	-5.78e-05*	-0.000128
	(3.08e-05)	(0.000374)	(3.42e-05)	(0.000152)
Running var.	-0.143***	-1.205***	0.0897***	1.059***
	(0.0300)	(0.205)	(0.0263)	(0.149)
Constant	-0.00424	0.393	0.0653	0.324
	(0.0433)	(0.683)	(0.0438)	(0.232)
Observations	553	32	553	46
Fundamentals, F test	4.529	1.529	1.906	0.818
Fundamentals, Prob > F	0.00132	0.223	0.108	0.521
Running var., F test	22.55	34.64	11.66	50.44
Running var., Prob > F	2.62e-06	3.31e-06	0.000686	1.35e-08

Note: Using daily data, each column presents an OLS regression of macroeconomic fundamentals and the running variable on a treatment dummy (i.e., exercising/issuing options). The first F-statistic and p-value provide a joint test of the null that coefficients on the macroeconomic fundamentals are zero. The second F-statistic and p-value do the same for the running variable. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

6.4 Potential contamination of effects

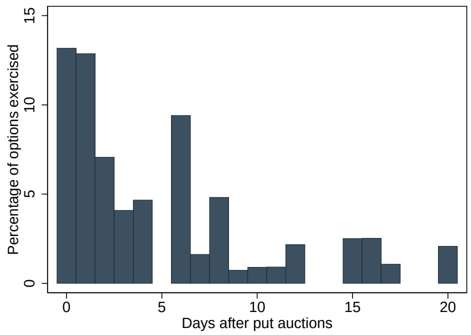
The exercise of FX options, as described in Section 3.2, required: (i) the rule to be triggered and (ii) for there to be outstanding options. Recall that these were necessary *but not sufficient* conditions, since traders could have chosen not to exercise their options (most likely weighing a more profitable rate in the future). By these criteria, the day of the auction was also viable for exercise. In principle, this can magnify the effects of FXI announcements as well as secret trades. For example, if some traders exercised their options on the day of the auction, then our sharp RDD estimates would be capturing the combined effect of announcements and a fraction of secret trades. Similarly, fuzzy estimates would be capturing –for the fraction of trades conducted on the day of the auction– the combined effect of trades and announcements.

In Figure 14, we depict the share of options that were exercised t-days after intervention announcements. As observed, traders usually exercised their options earlier on (first 5 days), at the risk of waiting too long and not being able to exercise their options at all. Additionally, the figure shows that 13% of put options and close to 30% of call options were exercised on the day of the auction.

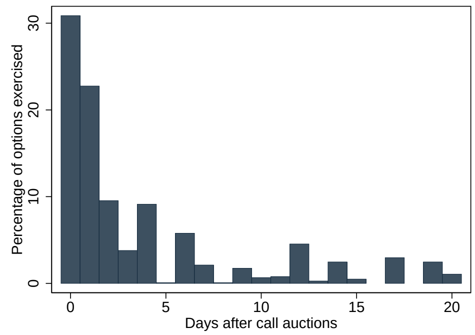
To address this concern, we first exclude the issuance day from our fuzzy estimates. Technically, this entails adding an additional restriction to our running variable, one which restricts the rule to be triggered only *after* the auction. This way, no trade is accompanied by an announcement, and the portfolio channel is left to operate separately from the signaling channel. We present these results in Figure 15, where we also report our baseline results from Section 5.3. As shown, fuzzy RDD estimates –excluding announcement days– are practically identical to our previous results, which suggests a negligible contamination from the fraction of options exercised during the auction day.

Second, we conduct sharp RDD regressions (for announcements) but now excluding days in which there were large and concurrent option exercises. Specifically, we exclude days in which traders exercised amounts above the median (see Table 1). Results, presented in Figure 16, again show very similar responses to our baseline findings.

Figure 14: Amount exercised t days after the announcement



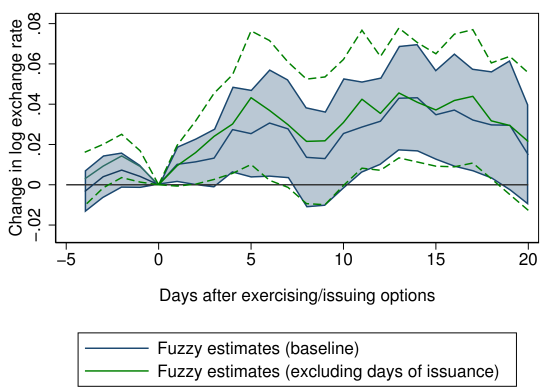
(a) Put options



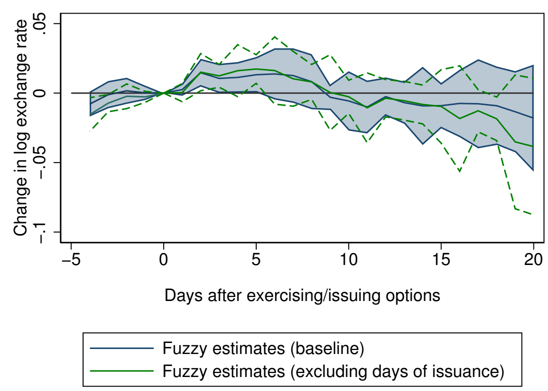
(b) Call options

Note: The Figure displays the share of options exercised t days after the announcement.

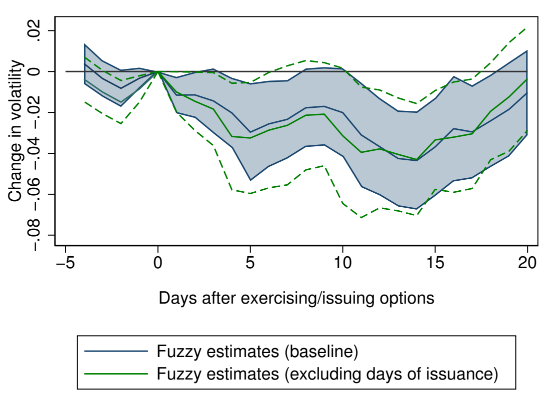
Figure 15: Fuzzy baseline vs. Fuzzy excluding days of issuance



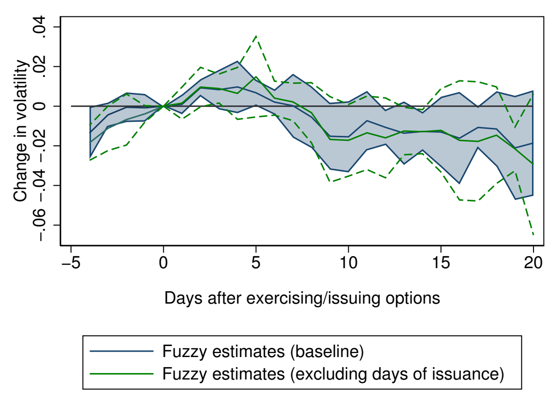
(a) Put options on FX level



(b) Call options on FX level



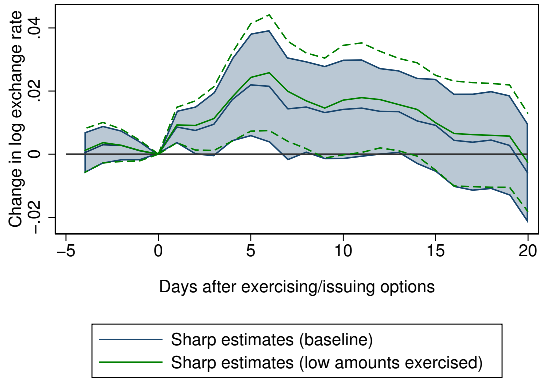
(c) Put options on FX volatility



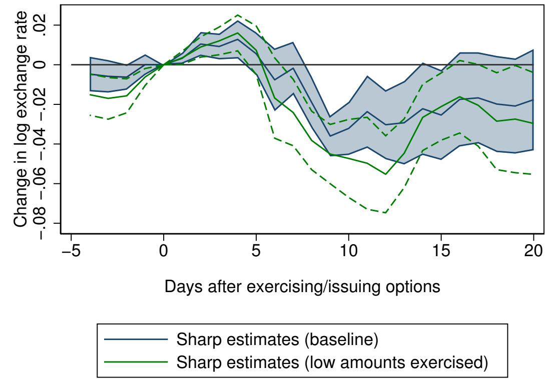
(d) Call options on FX volatility

Note: IRFs: Exchange rate effects 20 working days after intervention. The dependent variables are the log difference of the daily average spot rate (panels a-b) or FX volatility (panels c-d) $t + j$ days after intervention and the day before intervention. The central solid curves present the fuzzy/sharp RDD estimates. The upper and lower lines display 90% confidence intervals.

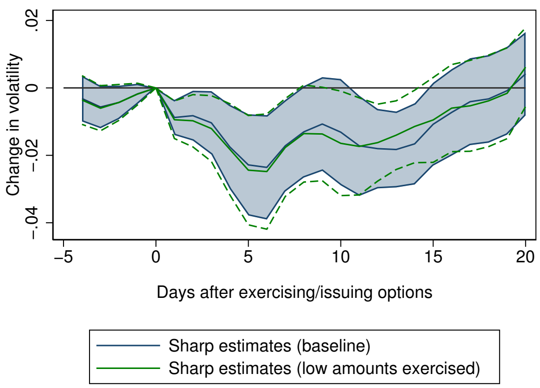
Figure 16: Sharp baseline vs. Sharp when low amounts were exercised



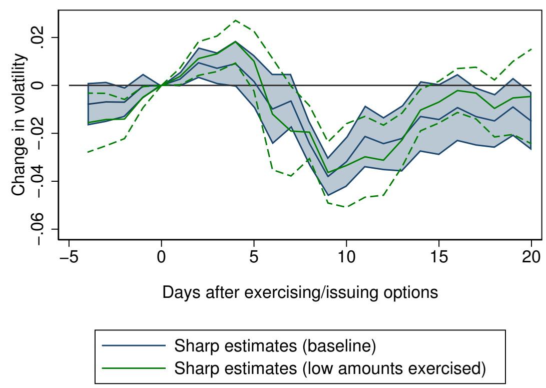
(a) Put options on FX level



(b) Call options on FX level



(c) Put options on FX volatility



(d) Call options on FX volatility

Note: IRFs: Exchange rate effects 20 working days after intervention. The dependent variables are the log difference of the daily average spot rate (panels a-b) or FX volatility (panels c-d) $t+j$ days after intervention and the day before intervention. The central solid curves present the fuzzy/sharp RDD estimates. The upper and lower lines display 90% confidence intervals.

6.5 Option Greeks in fuzzy specification

In this section, we control for weighted time value measures (the auction's *Greeks*) to capture potential behavioral differences, especially when *out-of-the-money* options get closer to the expiration day.

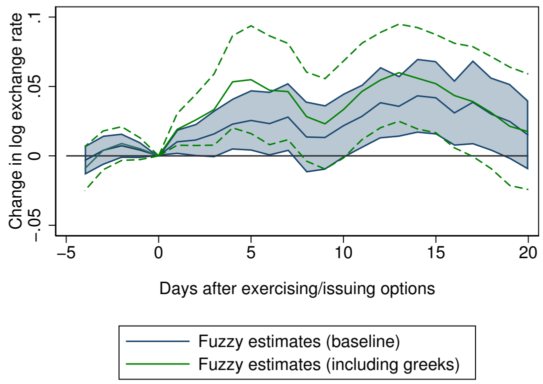
To give some context, the options' Greeks (i.e., Delta, Gamma, and Vega) collectively characterize the option's sensitivity to various quantifiable risk factors. In such manner, Greeks give agents a theoretical valuation approach that highlights several risks of their positions at each point in time.

As such, we take the following Greeks from Rojas-Bernal and Villamizar-Villegas (2021), who provide a parametric estimation of the same uniform clearing price auction undertaken by the CBoC:

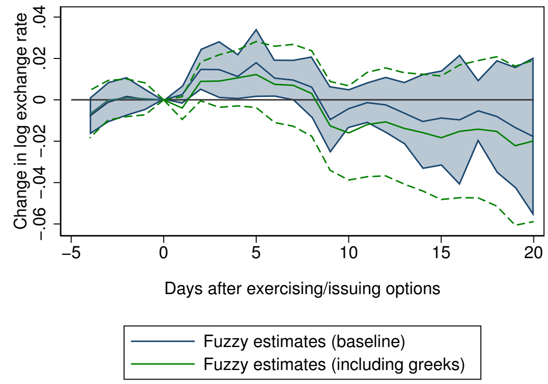
1. *Delta*: measures the sensitivity of an option's premium to a change in the underlying security price.
2. *Gamma*: measures the rate of change of Delta (e.g., highest when at-the-money and close to expiration).
3. *Vega*: measures the option's rate of volatility (e.g., higher if long-dated).

Figure 17 shows results when including the option's Greeks. While estimates appear slightly larger (in absolute terms), they are not statistically different from our baseline results. Hence, we take these findings as another robustness check that confirms our baseline findings.

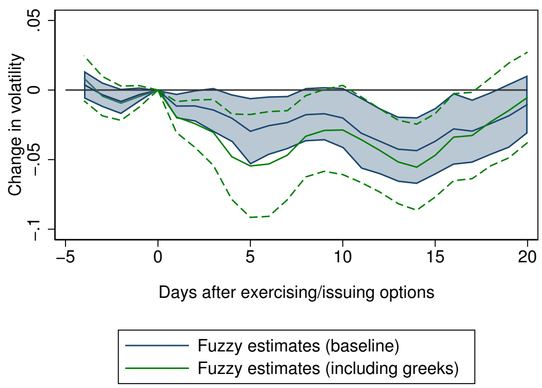
Figure 17: Fuzzy estimates including the option's Greeks



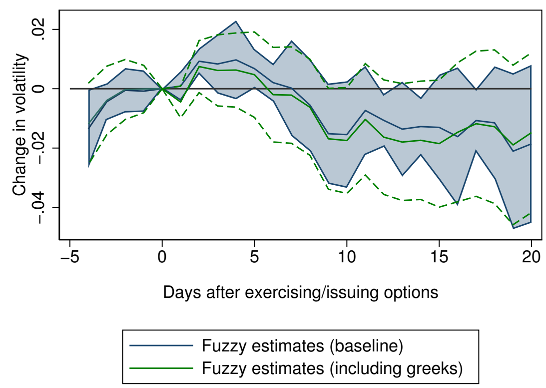
(a) Put options on FX level



(b) Call options on FX level



(c) Put options on FX volatility



(d) Call options on FX volatility

Note: IRFs: Exchange rate effects 20 working days after intervention. The dependent variables are the log difference of the daily average spot rate (panels a-b) or FX volatility (panels c-d) $t + j$ days after intervention and the day before intervention. The central solid curves present the fuzzy/sharp RDD estimates. The upper and lower lines display 90% confidence intervals.

7 Concluding remarks

Foreign Exchange Intervention (FXI) remains the standard instrument available to central banks to manage FX markets. In some cases, central banks try to limit short-run fluctuations in the exchange rate and smooth excessive trends to attract investment opportunities, mitigate currency crises, stem financial stability risks, and avoid the derailment of monetary policy to inflation. All these issues have been studied extensively, and the literature that exists today has made significant progress in synthesizing the lessons learned and establishing a pecking order of policy guidelines. However, one issue has eluded most of the empirical work: the difference –in effectiveness– between announcements ("vocal") and secret ("dirty") interventions.

To shed light on this issue, we exploit a Colombian FX scheme in which some interventions were announced and made public to market participants while others were unannounced and unknown. We argue that our methodology, based on a rule discontinuity, pays dividends over the related literature, in part because we sidestep the need to estimate a FX policy reaction function. Additionally, we argue that our results for announcements and secret trades are comparable since we use the same identification, sample, and context. This represents a gain in identification since the related literature usually evaluates different FXI mechanisms, making the comparison of the effects much less straightforward.

Our main findings indicate that, unconditionally, both announcements and secret trades carry similar effects, which is somewhat surprising given that most of the literature hints towards a stronger signaling channel. On average, announcements by the central bank move the exchange rate in the expected direction, by up to 2% and reduce volatility by up to 3pp. Secret trades exert a very similar effect. However, announcements are considerably amplified conditional on: (i) central bank credibility, (ii) episodes of high FX volatility, and (iii) riskier FX factors. In those cases, the effects of announcements are amplified by roughly 1pp - 2pp, while the incremental effects of secret trades have either a smaller or null effect. In a similar vein, we also find larger effects for announcements when conducted less frequently.

We believe that our investigation has relevant policy implications. In essence, it provides guidelines to improve FXI effectiveness based on the type of intervention and market conditions. These guidelines are not limited to countries with fixed exchange rates; in fact, they can be applied to –all but fully floaters–. Our paper also sheds light on theoretical work that distinguishes between the portfolio and signaling channels. Namely, we provide empirical evidence that the portfolio channel, on average, performs at least as well as the signaling channel, and only in certain cases does the signaling channel outperforms the portfolio channel.

8 Bibliography

Adler, G. and C. E. Tovar (2014): "Foreign exchange interventions and their impact on exchange rate levels," *Monetaria*, 0, 1–48.

Adrian, T., C. J. Erceg, J. Lindé, P. Zabczyk, and M. J. Zhou (2020): "A quantitative model for the integrated policy framework," IMF Working Papers 2020/122, International Monetary Fund.

Arango-Lozano, L., L. Menkhoff, D. Rodríguez-Novoa, and M. Villamizar-Villegas (2020): "The effectiveness of FX interventions: A meta-analysis," *Journal of Financial Stability*, 100794.

Basu, K. (2012): "How to devalue exchange rates, without building up reserves: Strategic theory for central banking," *Economics Letters*, 117, 758–761.

Basu, S. S., E. Boz, G. Gopinat, F. Roch, and F. D. Unsal (2020): "A conceptual model for the integrated policy framework," IMF Working Papers 2020/121, International Monetary Fund.

Bauer, M. and G. Rudebusch (2014): "The signaling channel for Federal Reserve bond purchases," *International Journal of Central Banking*, 10, 233–289.

Bems, R., F. Caselli, F. Grigoli, and B. Gruss (2021): "Expectations' anchoring and inflation persistence," *Journal of International Economics*, 132, 103516.

Calonico, S., M. D. Cattaneo, and R. Titiunik (2014): "Robust nonparametric confidence intervals for regression-discontinuity designs," *Econometrica*, 82, 2295–2326.

Cardozo, P. (2019): "Learning from experience in Colombia," *Foreign exchange intervention in inflation targeters in Latin America*, 137.

Chamon, M., M. Garcia, and L. Souza (2017): "FX interventions in Brazil: a synthetic control approach," *Journal of International Economics*, 108, 157–168.

Devereux, M. B., C. Engel, and G. Lombardo (2020): "Implementable rules for international monetary policy coordination," *IMF Economic Review*, 68, 108–162.

Domaç, I. and A. Mendoza (2004): *Is there room for foreign exchange interventions under an inflation targeting framework?: Evidence from Mexico and Turkey*, vol. 3288, World Bank Publications.

Dominguez, K. M. and J. A. Frankel (1993): "Does foreign-exchange intervention matter? The portfolio effect," *The American Economic Review*, 83, 1356–1369.

Dominguez, K. M. E. and F. Panthaki (2007): "The influence of actual and unrequited interventions," *International Journal of Finance & Economics*, 12, 171–200.

Dornbusch, R. (1976): "Expectations and Exchange Rate Dynamics," *Journal of Political Economy*, 84, 1161–76.

Durán-Vanegas, J. D. (2015): "Do foreign exchange interventions work as coordinating signals in Colombia?" *Ensayos Sobre Politica Economica*, 33, 169–175.

Echavarría, J. J. (2009): "Intervenciones cambiarias y política monetaria en Colombia: un análisis de VAR estructural," *Borradores de Economía; No. 580.*

Echavarría, J. J., D. Vásquez, and M. Villamizar (2010): "Impacto de las intervenciones cambiarias sobre el nivel y la volatilidad de la tasa de cambio en Colombia," *Ensayos Sobre Política Económica.*

Echavarría, J. J., L. F. Melo-Velandia, and M. Villamizar-Villegas (2014): "The impact of foreign exchange intervention in Colombia. An event study approach," *Revista Desarrollo y Sociedad*, 1, 7–31.

——— (2018): "The impact of pre-announced day-to-day interventions on the Colombian exchange rate," *Empirical Economics*, 55, 1319–1336.

Fatum, R. and M. Hutchison (2006): "Effectiveness of official daily foreign exchange market intervention operations in Japan," *Journal of International Money and Finance*, 25, 199–219.

Fatum, R. and M. M. Hutchison (2010): "Evaluating foreign exchange market intervention: Self-selection, counterfactuals and average treatment effects," *Journal of International Money and Finance*, 29, 570–584.

Fratzscher, M. (2008): "Communication and exchange rate policy," *Journal of Macroeconomics*, 30, 1651–1672.

Fratzscher, M., O. Gloede, L. Menkhoff, L. Sarno, and T. Stöhr (2019): "When is foreign exchange intervention effective? Evidence from 33 countries," *American Economic Journal: Macroeconomics*, 11, 132–156.

Galati, G., W. Melick, and M. Micu (2005): "Foreign exchange market intervention and expectations: the yen/dollar exchange rate," *Journal of International Money and Finance*, 24, 982–1011.

Ghosh, A. R. (1992): "Is it signalling? Exchange intervention and the dollar-Deutschemark rate," *Journal of International Economics*, 32, 201–220.

Guimarães, R. P. and M. C. Karacadag (2004): *The empirics of foreign exchange intervention in emerging markets: the cases of Mexico and Turkey*, International Monetary Fund.

Hahn, J., P. Todd, and W. Van der Klaauw (2001): "Identification and estimation of treatment effects with a regression-discontinuity design," *Econometrica*, 69, 201–209.

Henderson, D. W. and K. Rogoff (1981): "New foreign asset positions and stability in a world portfolio balance model," International Finance Discussion Papers 178, Board of Governors of the Federal Reserve System (U.S.).

Hillebrand, E. T. and G. Schnabl (2003): "The effects of Japanese foreign exchange intervention GARCH estimation and change point detection," *Japan Bank for International Corporation Institute Working Paper*.

Hofmann, B., H. S. Shin, and M. Villamizar-Villegas (2019): "FX intervention and domestic credit: Evidence from high-frequency micro data," BIS Working Papers 774, Bank for International Settlements.

Ilzetzki, E., C. M. Reinhart, and K. S. Rogoff (2019): "Exchange arrangements entering the twenty-first century: Which anchor will hold?" *The Quarterly Journal of Economics*, 134, 599–646.

Imbens, G. and K. Kalyanaraman (2012): "Optimal bandwidth choice for the regression discontinuity estimator," *Review of Economic Studies*, 79, 933–959.

Imbens, G. W. and T. Lemieux (2008): "Regression discontinuity designs: A guide to practice," *Journal of Econometrics*, 142, 615–635, the regression discontinuity design: Theory and applications.

Itskhoki, O. and B. Moll (2019): "Optimal development policies with financial frictions," *Econometrica*, 87, 139–173.

Jordá, Ó. (2005): "Estimation and inference of impulse responses by local projections," *American Economic Review*, 95, 161–182.

Kalemli-Ozcan, S. (2019): "U.S. monetary policy and international risk spillovers," NBER Working Papers 26297, National Bureau of Economic Research, Inc.

Kamil, H. (2008): "Is central bank intervention effective under inflation targeting regimes? The case of Colombia," IMF Working Papers 08/88, International Monetary Fund.

Kaminsky, G. L. and K. K. Lewis (1996): "Does foreign exchange intervention signal future monetary policy?" *Journal of Monetary Economics*, 37, 285–312.

Kouri, P. J. (1981): "Balance of Payments and the Foreign Exchange Market: A Dynamic Partial Equilibrium Model," Working Papers 81-09, C.V. Starr Center for Applied Economics, New York University.

Kuersteiner, G. M., D. C. Phillips, and M. Villamizar-Villegas (2018): "Effective sterilized foreign exchange intervention? Evidence from a rule-based policy," *Journal of International Economics*, 113, 118–138.

Lahiri, K. and X. Sheng (2010): "Measuring forecast uncertainty by disagreement: The missing link," *Journal of Applied Econometrics*, 25, 514–538.

Lahura, E. and M. Vega (2013): "Asymmetric effects of FOREX intervention using intraday data: evidence from Peru," BIS Working Papers 430, Bank for International Settlements.

Lee, D. S. (2008): "Randomized experiments from non-random selection in U.S. House elections," *Journal of Econometrics*, 142, 675–697.

Luna Santos, F. (2021): "Comparing the impact of discretionary and pre-announced central bank interventions," *Journal of International Money and Finance*, 110.

Mandeng, M. O. (2003): *Central bank foreign exchange market intervention and option contract specification: the case of Colombia*, International Monetary Fund.

Marins, J. T. M., G. S. Araujo, and J. V. M. Vicente (2017): "Do central bank foreign exchange interventions affect market expectations?" *Applied Economics*, 49, 3017–3031.

McCrary, J. (2008): "Manipulation of the running variable in the regression discontinuity design: A density test," *Journal of Econometrics*, 142, 698–714.

Menkhoff, L. (2013): "Foreign exchange intervention in emerging markets: A survey of empirical studies," *The World Economy*, 36, 1187–1208.

Menkhoff, L., M. Rieth, and T. Stöhr (2021): "The dynamic impact of FX interventions on financial markets," *The Review of Economics and Statistics*, 103, 939–953.

Moura, M. L., F. R. Pereira, and G. de Moraes Attuy (2013): "Currency wars in action: How foreign exchange interventions work in an emerging economy," Tech. rep., Insper Working Paper, Insper Instituto de Ensino e Pesquisa.

Mussa, M. (1976): " The Exchange Rate, the Balance of Payments and Monetary and Fiscal Policy under a Regime of Controlled Floating," *Scandinavian Journal of Economics*, 78, 229–48.

Obstfeld, M. (1988): "The effectiveness of foreign-exchange intervention: recent experience," Working Paper 2796, National Bureau of Economic Research.

Patel, N. and P. Cavallino (2019): "FX intervention: goals, strategies and tactics," *BIS Paper*.

Rey, H. (2015): "Dilemma not Trilemma: The Global Financial Cycle and Monetary Policy Independence," NBER Working Papers 21162, National Bureau of Economic Research, Inc.

Rincón, H. and J. Toro (2010): “Are capital controls and central bank intervention effective?” Borradores de Economia 625, Banco de la Republica de Colombia.

Rojas-Bernal, A. and M. Villamizar-Villegas (2021): “Pricing the exotic: Path-dependent American options with stochastic barriers,” *Latin American Journal of Central Banking*, 2, 100025.

Rosenbaum, P. R. and D. B. Rubin (1983): “The central role of the propensity score in observational studies for causal effects,” *Biometrika*, 70, 41–55.

Sarno, L. and M. P. Taylor (2001): “Official intervention in the foreign exchange market: is it effective and, if so, how does it work?” *journal of Economic Literature*, 39, 839–868.

Schoenmaker, D. (2013): *Governance of international banking: The financial trilemma*, no. 9780199971596 in OUP Catalogue, Oxford University Press.

Uribe, J. D. and J. Toro (2005): “Foreign exchange market intervention in Colombia,” in *Foreign exchange market intervention in emerging markets: motives, techniques and implications*, ed. by B. for International Settlements, Bank for International Settlements, vol. 24 of *BIS Papers chapters*, 139–49.

Vargas, H., A. González, and D. Rodríguez (2013): “Foreign exchange intervention in Colombia,” *BIS Paper*.

Vargas-Herrera, H. and M. Villamizar-Villegas (2020): “Effectiveness of FX intervention and the flimsiness of exchange rate expectations,” *Journal of Financial Stability*, 100813.

Villamizar-Villegas, M. (2016): “Identifying the effects of simultaneous monetary policy shocks,” *Contemporary Economic Policy*, 34, 268–296.

Villamizar-Villegas, M. and D. Perez-Reyna (2017): “A theoretical approach to sterilized foreign exchange intervention,” *Journal of Economic Surveys*, 31, 343–365.

Villamizar-Villegas, M., F. A. Pinzon-Puerto, and M. A. Ruiz-Sanchez (2022): “A comprehensive history of regression discontinuity designs: An empirical survey of the last 60 years,” *Journal of Economic Surveys*, 36, 1130–1178.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