23 April 2013
Draft to be completed
Not cleared for publication.
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The effects of intraday foreign exchange market operations in Latin America: Results for Chile, Colombia, Mexico and Peru[1]

Miguel Fuentes and Pablo Pincheira[2] , Hernan Rincon and Juan Manuel Julio[3], Santiago Garcia-Verdu and Miguel Zerecero[4], Marco Vega and Erick Lahura[5] and Ramon Moreno[6]

Introduction

An ongoing issue in Latin America and other emerging market economies (EMEs) is how to cope with cycles in capital inflows and outflows and the resulting pressures on the exchange rate. Extended periods of capital inflows have related currency appreciation pressures, raise well known concerns including the risk of adverse effects on the tradable goods sector, deterioration of current account balances, the formation of asset price bubbles, excessive foreign indebtedness and increasing financial fragility. Episodes in which capital inflows reverse also raise concerns.

In this setting, Latin American authorities have had to choose between the possible costs of allowing the exchange rate to fluctuate freely, or trying to dampen exchange rate volatility or mitigate its effects through operations – or intervention -

[1] The opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the central banks that contributed to this project or of the Bank for International Settlements (BIS). This joint paper was prepared under the auspices of the BIS Consultative Council for the Americas, a group of central bank governors from the Americas region. The authors thank Kathryn Dominguez, who advised on project design and implementation, and Rasmus Fatum and Carlos Montoro for comments. Alan Villegas (BIS) created the dataset on US announcements and with Diego Urbina (BIS) provided research assistance in preparing various versions of this paper. This project was coordinated by Ramon Moreno, with the assistance of Carlos Montoro (BIS).

[2] Central Bank of Chile.

[3] Bank of the Republic (Colombia).

[4] Bank of Mexico,

[5] Central Reserve Bank of Peru.

[6] Bank for International Settlements

in the foreign exchange market.[7] Latin American central banks have chosen to intervene in foreign exchange market operations for extended periods. One motive is *to accumulate foreign reserves for precautionary reasons* during periods of foreign currency inflows or exchange rate appreciation, in order to then deploy these reserves during episodes of financial stress when the supply of foreign currency suddenly declines. Episodes of stress may be associated with a "sudden stops" in cross border financing, and sharp depreciation pressures, which can damage the financial and the real sectors, particularly in the presence of currency mismatches. Even in less extreme situations, the availability of foreign currency liquidity may be lower and related costs of foreign currency financing may be higher during periods of depreciation pressures.

Another motive is *to influence the exchange rate*, specifically to dampen exchange rate volatility or to reduce deviations from some perceived or estimated equilibrium exchange rate. Policymakers in the region who have adopted inflation targeting regimes stress that they do not seek to target the exchange rate level.

Foreign exchange market intervention raises important issues including possible incompatibility with the monetary framework (eg the exchange rate could compete with the inflation rate as a primary target), significant quasi-fiscal costs, and effectiveness in achieving its goals (eg financial stability or reduced exchange rate volatility).

The present paper focuses largely on the issue of effectiveness, by addressing the following questions: (i) what are the effects of intervention on the exchange rate (ii) are the effects persistent or transitory? (iii) are any effects more apparent on the foreign exchange returns or its volatility? (iv) do the effects of intervention differ when goals (to buy or sell fixed amounts of foreign currency or to influence the exchange rate) or intervention approaches; (eg discretionary vs nondiscretionary) are not the same? (iv) what are the implications of intervention for market turnover? In order to shed light on these questions, this paper uses intraday data on exchange rate returns or turnover in foreign exchange markets, macroeconomic announcements and foreign exchange operations by central banks in four Latin American countries, Chile, Colombia, Mexico and Peru. As some of the data are confidential, and also reflecting individual central bank knowledge of their own markets, the results are estimated for each foreign exchange market by central bank authors using a common methodology based on the work of Kathryn Dominguez (1999, 2003 and 2006).

The analysis involves the following elements.

- We describe *the distributional properties of the intraday exchange rate data*, and compare the first four moments of the distribution of exchange rates during intervention and no-intervention days. We run *event study regressions* to estimate *the impact of intervention (and macro surprises) on*

[7] In this paper we will use the terms foreign exchange market intervention and operations interchangeably. Some use the term intervention to apply only to those foreign exchange market operations whose objective is explicitly to influence the exchange rate. However all the goals of foreign exchange operations are not always made public, and even operations that are not intended to influence the exchange rate may do so, As a result, it is not always obviously where to draw the line. For a discussion of these terms and issues, see Moreno (2005).

*exchange rate returns and exchange rate volatilit*y (only intervention days are included in regressions).

- Event study regressions are implemented to estimate the impact of intervention (and macro surprises) on exchange rate market turnover. (Results are available for Colombia.)

There are several advantages to the use of intraday data and the methodology highlighted above. First, as the timing of intervention can be precisely identified relative to returns, identification problems that arise in lower frequency data can be avoided.

Second, the factors – such as macroeconomic announcements - that influence returns and consequently the timing and amount of intervention appear to be largely revealed by intraday news, and less so by data at daily or lower frequencies.

Third, the methods used in this paper are also useful for understanding whether the differing goals of intervention, or in operating procedures or instruments appear to influence the effects of intervention. As discussed below, in Latin America, the goals of intervention have varied over time and across central banks. In some cases studied in this paper, the goal has been to dampen exchange rate volatility under an inflation targeting regime (Peru), and in others the goal has been to adjust foreign reserves for precautionary motives (accumulation in Chile and Colombia, provision of foreign currency in Mexico). As for operating procedures, in three out of four cases (Chile, Colombia and Mexico) intervention was not discretionary, and auctions offered to purchase or sell predetermined amounts of foreign currency (see below). In the last case (Peru), however, intervention was discretionary and the amounts were not known until after the fact.

Nevertheless, at least two caveats may be highlighted. One is that because interventions in the samples studied in this paper occur over extended periods, intervention days may reflect particular economic or institutional circumstances. This can make it difficult to compare exchange rate behaviour across intervention and no-intervention days, and to consider interventions as events and estimate event study regressions. This is in contrast to G-3 interventions, where the methods used in this paper were first applied, where interventions are far more sporadic, and intervention and no-intervention days are arguably "similar" (with the main difference being the intervention). In this study this issue is addressed in part by introducing some controls in the event study regressions (eg for US or domestic macroeconomic surprises) and in some cases an indicator of investor sentiment – the Vix) that would capture some factors that could introduce dissimilarity between intervention and no-intervention days. A more extensive analysis could shed further light on this issue, but is outside the scope of this paper. In Mexico, as discussed below, in one of the cases analysed intervention and no-intervention samples were selected to help make them more similar.[8]

[8] In particular, the full sample was defined as days in which a USD sales auction triggered (ie Mexican peso depreciated by more than 2%). Intervention days are those in which there was a non-zero allocation, while no-intervention days are those in which there was no allocation even if the auction was triggered.

Another caveat is that this method will not necessarily shed light on the effects of intervention over the medium-term. However, this topic has been widely studied using daily or quarterly data. The use of confidential intraday data, which is far less common, can shed valuable light on the effectiveness of intervention.

II. Data coverage and properties

A. Data description and sources

The analysis in this paper involves three types of high-frequency data: (i) Intraday price data for the foreign exchange market from Bloomberg (Chile, Mexico and Peru) or national sources (Colombia). For Colombia, market turnover data are also analysed; (ii) time stamped US or country (for Colombia and Peru) macro announcements compiled from Bloomberg and (iii) volume of intervention in the foreign exchange market (see Annex Tables A1 to A3).

Intraday price or transactions volume data.

The data used in empirical analysis are time-stamped (transactions) prices in the wholesale spot foreign exchange interbank markets of Chile, Colombia, Mexico and Peru.[9] For Colombia time-stamped data on quantities traded are also available. In *Chile*, all the operations of the central bank are conducted through centralized trading platforms. In *Colombia* the dataset reflects wholesale spot interbank trades of US currency performed through SET-FX, the centralized interbank foreign exchange electronic market service, which belongs to the Colombian Stock Exchange (BVC). In *Mexico,* transactions are those reported by Reuters for the Mexican market, but does not include trading of the peso outside Mexico. The Mexican market data are taken as representative because of the size and depth of the peso[10] exchange market and on the assumption that the peso market is globally integrated so no arbitrage opportunities remain. In Peru, foreign exchange trading in the market is done through Datatec and Reuter platforms.

B. Data transformations and sample size

Construction of the samples involves data transformation and the selection of windows that vary from country to country (see also Annex Table A1).

In *Chile,* the sample covers the episodes of intervention in 2008 and 2011, where the goal was to increase foreign reserves held by the central bank.

In *Colombia*, the full sample is from 2 May 2007 to 23 November 2011. Trade prices are marked with the real transaction time to the last second. From these prices, the price on each time mark is calculated as follows. If transactions occur on the time mark, the price at the mark is the average price of these trades. If there are no transactions on the time mark, the price at the mark is the average of the two

[9] In some cases, descriptive statistics are based on bid-ask spreads.

[10] For more details, see discussion in García and Zerecero (2013).

nearest prices, before and after the time mark, weighted by their corresponding distances to the mark. Data transformations were implemented so as to ensure the most "data gain" (in terms of minimizing the interval width in such a way that the upper and lower interval limits reflect actual market activity) while ensuring good quality in the reported data. In particular the optimal interval width and data loss at the beginning of the trading day were studied carefully.[11] The preceding analysis for the Colombian FX market resulted in a sample of 1,025 trading days, with 43 prices per trading day (reflecting precise price measurements for each 7 minute time mark from 8:06 to 1:00 pm for each trading day), for a total of 44,705 prices.

In Mexico, five minute price data were used. Following Dominguez (1999) a weighted average of the exchange rate prices closest to the time considered is estimated. For data points for which there are no contemporaneous bid and ask prices the equidistant bid and ask are first estimated separately and then an average is taken.

The FX returns are estimated using the returns from 7:10 to 14:55 for the specification where macroeconomic announcements are considered (estimates are from 9:10 am to 13:20 pm when no macroeconomic announcements are considered, but this is not reported here). There are 215,424 observations in the estimation sample.

In Peru, the sample period (reflecting the span of intervention data available), was from January 5, 2009 to 27 April 2011. Five minute price data were used. The FX market in Peru is local, it lasts about 4½ hours from 9:00 AM to 1:30 PM. Transactions between 9 AM and 9:15 are scarce so the price dataset starts at five minute intervals at 9:15-9:20. In the 5 minute time series the time index starts at 9:20 and ends at 13:30 for the business day. When calculating the 5-minute return series, the returns for 9:20 are left out.

Time stamped US or country macroeconomic announcements

The empirical analysis reported in this paper includes data on macroeconomic announcements. These are used to construct a set of control variables, and also to compare the relative impact of intervention to the effects of external macroeconomic announcements compiled from Bloomberg, which are represented by the following US macroeconomic announcements (recorded as surprises, see below): US Consumer Confidence, CPI, Durable Good, Fed Funds Rate, Unemployment, Housing, Industrial Production, PPI, NAPM, Retail Sales, GDP, Trade Balance.[12] In some cases, data on domestic macroeconomic announcements (eg Colombia) have also been included as control variables. For more details, see Annex Table A2.

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[11] For Colombia it was found that: (i) The first 6 minutes of the trading day should not be taken into account: this reduces to a minimum the need to carry back the first trading price and conveniently completes the 5 trading hours so that no data is lost at the end of the trading day; (ii) The optimal interval width is 7 minutes, after that the data gain from increasing the width of the time interval decreases; (iii) Days containing too few trades should be deleted. Few trades within a day arise because the market is particularly slow (30-Dec of any year, for instance) or because of poor record keeping (price information for whole days or important parts of particular trading days is missing). For consistency, however, the information included was cross checked with Bid/Offer quotes and the TRM (Tasa Representativa del Mercado), the official daily exchange rate of the forex market.

[12] These variables have been found to be relevant in influencing the US dollar exchange rate against some major currencies (see Andersen et al (2003).

Volume of intervention in the foreign exchange market. The explanatory variable for intervention is constructed by recording the amount of intervention (purchase or sale of foreign currency) at the time it takes place. For the empirical analysis described below, the amounts are expressed in US dollars except in Peru, where they are expressed as a proportion of daily market turnover. For Colombia the impact of intervention on market turnover is also analysed. The samples for intervention are identified in the next section.

C. Intervention and factors that could influence its impact

What effects might be anticipated from intervention in Latin America in practice? The literature identifies a number of channels through which foreign exchange market intervention could influence the exchange rate, and the effects depend on the way intervention is implemented. The first point to be borne in mind is that FX operations *were sterilised*, as all four central banks contributing to this paper adjusted liquidity to meet an interest rate operating target within the framework of inflation targeting regimes.[13] However, foreign exchange market intervention could still have an effect through at least three channels described below.

To illustrate, consider how central bank (sterilised) purchases of foreign currency could lead to domestic currency depreciation. Under the *portfolio balance* channel (sterilised) intervention increases the share of domestic securities in investor portfolios and (assuming domestic and foreign assets are not perfect substitutes). A depreciation eliminates the resulting excess supply of such securities. The portfolio balance channel could be strengthened if frictions (eg capital controls, transactions taxes, low domestic market liquidity) reduce the substitutability of domestic and foreign assets. In markets with some frictions, the effects of intervention may also be more apparent at very short horizons if the central bank appears to be committed to an exchange rate target, or if intervention is *large* and is *unexpected*, which may increase the costs associated with rebalancing portfolios.

Under the *signalling* channel, central bank foreign currency purchases cause an expected easing in future monetary policy, which by lowering the relative returns on domestic assets would cause the currency to depreciate. This signalling channel could be particularly relevant in emerging market economies where intervention is costly (eg by imposing quasi-fiscal costs on the central bank when the returns on foreign reserve holdings are below the costs of financing such holdings) and its sustainability may therefore be in doubt unless monetary policy is loosened. However, the relevance of the signalling channel is not always clear: some research has found that rather than signalling a change in monetary policy, intervention can become ineffective if it appears incompatible with monetary policy. In Colombia in the mid-2000s, central bank purchases of foreign exchange tended to dampen exchange rate appreciation when monetary policy was easing, but ceased to be effective when monetary policy tightened, becoming incompatible with the direction of intervention. Part of the problem is that the central bank (which had become a net debtor to the financial system) would find it increasingly costly to drain the liquidity associated with intervention, thus reducing the credibility of such

measures (see Kamil, Vargas et al. For other evidence on the signalling channel in Colombia see Toro and Julio (2005)).

Still another channel is the *coordination channel.* (Taylor, 1994; Sarno and Taylor, 2001; Reitz and Taylor, 2008). Exchange rates are often thought to be driven by non-fundamental factors which may lead to large and persistent misalignments. In this setting, official foreign exchange market intervention may act as a coordinating signal, encouraging stabilising speculators to re-enter the market at the same time. In Colombia, the coordination channel may have operated around June 2008 when the COP had appreciated the most relative to June 1999. This situation was an opportunity for the central bank to bring about a depreciation of the peso through forex intervention. Rincon and Toro (2010) find that this was the only period where intervention statistically affected (positively) the exchange rate mean return. Foreign exchange market intervention that tends to "lean against the wind" (seeking to counter the direction of the exchange rate or dampen its volatility) may operate in part through the coordination channel. This channel is likely to be more relevant if central banks target the level of an exchange rate to reduce misalignment.

Our review of the channels of transmission of the effects of intervention thus suggests that the effects on the exchange rate would tend to be larger if intervention:

- Targeted the exchange rate level or limited volatility to very narrow bands;
- Were large relative to market turnover (due to portfolio balance effects), or foreign reserves (possibly also influencing perceptions about monetary policy, due to quasi-fiscal costs);
- Surprised markets.

Targets In principle intervention could have a larger impact in the short run if the goal of intervention is to target the level of the exchange rate. This, however was not the stated objective of the central banks for the periods studied in this paper[14] Instead, three of the four central banks explicitly targeted predetermined foreign currency *quantities.* Thus Central Bank of Chile over the periods 14 April 2008 – 29 September 2008 and 03 January 2011-16 December 2011 and Bank of the Republic (Colombia) over three uninterrupted rounds between 24 June 2008 and 30 Sep 2011 purchased foreign currency to *meet preannounced foreign reserve accumulation targets* ($50 million a day in Chile in 2011 and $20 million a day in Colombia). Except for the periods September-December 2011, these were for the most part periods of capital inflows in Latin American foreign exchange markets.[15] In contrast, over the period 9 October 2008-9 April 2010[16],

Mexico *sold* foreign currency (implementing auctions of dollars with a minimum price), in order to provide the necessary liquidity to meet the conditions of

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[14] In addition, exchange rates may not have served as a signal of future changes in monetary policy but rather an effort to dampen its effects. For example, one explanation for intervention in Mexico over certain periods (outside the sample studied in this paper) in which the exchange rate faced appreciation pressures related to carry trades, is that the central bank could not lower the policy rate to discourage such carry trades because of still high inflation. See Sidaoui (2012).

[15] However, intraday exchange rate returns show depreciation over certain time intervals.

[16] Mexico also sold foreign currency during the period after 30 November 2011 but this is not included because the time of the auctions changes.

uncertainty and lack of liquidity in the foreign exchange market. The daily amount offered for sale was initially $400 million (later $300 million) whenever an auction was triggered by a sufficiently large depreciation of the peso (2%). The total amount auctioned between 2008 and 2011 was USD 351.06 billion. The intervention sample is 9 October 2008 to April 2010 on days in which there was a positive allocation of US dollars. There are two no-intervention (control) samples. The first comprises days between April 12, 2010 and November 29, 2011 that had no intervention whatsoever (No-intervention 1 sample)[17]. The second comprises days within 9 October 2008 to April 2010 in which the intervention rule was triggered (ie the Mexican peso depreciated more than 2%) but no US dollars were actually allocated during the auctions (No intervention 2). Some of the observations of the No-intervention 2 sample are selected from days in which US dollars are not allocated in at least one auction. For example, if at 9:30 US dollars are allocated, and at 11:30 no dollars are allocated, the 9:30 observation is part of the intervention sample and the 11:30 observation is part of the No intervention sample 2. In Mexico there are 288 observations in the intervention sample, 10,125 in the No intervention 1 sample and 9,295 in the no-intervention 2 sample. See García and Zerecero (2013) for further discussion.

In contrast, foreign exchange market intervention by the Central Reserve Bank of Peru - which was operated by a committee that implements open market operations on a daily basis - was aimed at reducing excess volatility as perceived by policymakers that implement the intervention. Intervention was fully discretionary in amounts and in timing, with markets always aware of the possibility of intervention. Markets only learned the total intervention amount at the end of the day because this figure is made public. Nevertheless, the central bank sought to avoid signalling an exchange rate path (Rossini and others, 2011) while seeking to dampen exchange rate volatility. Over the sample period 5 January 2009-27 April 2011, there were 7384 intervention transactions (1847 in 2009, 5050 in 2010 and 487 in 2011) and 720 5-minute interval observations (181, 502 and 37 respectively in the same years).

Size of intervention. The intervention studied in this paper occurred in the spot market and was *large by some metrics* (eg compared to intervention in advanced economies prior to the global financial crisis, or compared to foreign reserves) over the sample periods covered in this paper. In Chile, the goal was to increase foreign reserves in 2008 by $8 billion (in effect, however, the operation was suspended on 29 September 2008, shortly after the Lehman bankruptcy, having reached US$5.75 billion). In 2011 the goal was to increase foreign reserves by $ 12 billion through daily purchases of $50 million. These totals may be compared to foreign reserves of US$28 billion at the end of 2010, and intervention of $2 billion in 2001. In Colombia[18], the preannounced interventions were $20 million a day in its third round of intervention between September 2010 and September 2011. Over that period, the Bank of the Republic (Colombia) accumulated nearly $5.2 billion (compared to foreign reserves of $32.4 billion at the end of September 2011). In

[17] In Mexico, the period from November 30 to December 31, 2011 is excluded as the type of intervention considered in this paper (with minimum price (type 3), see García and Zerecero (2013)) took place at a different time of the day. Notice these are less than 30 days.

[18] The Bank of the Republic accumulated $1.4 billion in the first round of intervention ending in October 2008 and $1.6 billion in the March-June 2010 round of intervention.

Mexico, between 9 October 2008 and 9 April 2010 the central bank offered a total of $351.1 billion, compared to foreign reserves totalling US$98.28 billion at the end of April 2010.[19] Using another metric, with the exception of Peru, where (discretionary) intervention as a percentage of daily turnover averaged 31% over the sample period, the amount of daily (nondiscretionary) intervention compared to market turnover was relatively small, averaging 1.4% in Chile (2011), 2.4% in Colombia (2011) and 0.02% in Mexico.

Market "surprises" and discretion. The scope for "market surprises" from intervention was limited in three of the four countries studied in this paper – Chile, Colombia and Mexico - in the sense that the target daily amounts of foreign currency to be purchased or sold over well-defined intervention periods were preannounced. While there was therefore little or no uncertainty about the amounts of foreign currency available for purchase or sale, the actual transaction amounts would depend on the auction procedures. In Colombia the Bank of the Republic used a 3-minute Dutch auction procedure, under which prices could adjust until most if not all the foreign currency amount targeted was purchased.[20] In contrast in Mexico, the minimum price procedure implied that the target amount of foreign currency was not sold once the minimum price threshold was reached. In line with this there were days when no amounts were allocated even if an auction was triggered (by an overnight depreciation of 2%).[21]

A possibly important source of "surprises" which could strengthen the impact of intervention on exchange rate returns was *uncertainty about the timing of intervention during the day*. Other than in Mexico, the timing of auctions was not preannounced: for example, in Colombia, sales were announced 2 minutes in advance. In the case of Peru, intervention could occur on a daily basis at any time during trading hours and contingent on the state of the market (eg a substantial drop in the spot price early in the trading day relative to the closing price the day before). The time of intervention during the day (as well as the amount of intervention) was at the discretion of the authorities.

In line with the preceding, the frequency of intervention as well as the target amounts of foreign currency purchased or offered for sale varied in the course of the day in Chile, Colombia and Peru, and to a lesser extent in Mexico.

Graph 1 plots the frequency of intervention and the amount of intervention relative to daily market turnover (intervention in US dollars in the case of Chile) in the course of the trading day.[22] It shows that in Chile most of the foreign exchange

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[19] For a fuller description of this type of foreign exchange market operations in Mexico, see García and Zerecero (forthcoming). These sales of foreign currency may at least partly offset large accumulation in foreign reserves from direct foreign currency sales (to meet tax obligations) to the Bank Mexico by Mexican government institutions, notably the state oil company Pemex. However, as noted by García and Zerecero, while the goal of US dollar sales has sometimes been to offset such foreign reserve accumulation, this was not the stated objective during the period considered in this paper.

[20] In Colombia, whenever there was any (usually small) residual amount not allotted in the daily auction, it would be carried forward to the next day. Therefore, a slight variation around the USD 20 million target would sometimes be observed during some days of an intervention round.

[21] This outcome is used to define a "no intervention" sample in which the auction is triggered by a sufficiently large depreciation but no foreign currency is allocated.

[22] In Colombia, the number of days in which there was intervention in each M minute interval as a percentage of 387 is reported. In Peru, frequency is computed using the formula $freq_j = \frac{N_j}{\Sigma_1^J N_j}$ the

operations took place before 12 pm. In Colombia, 76% of the interventions (293 days) occurred between 9:23 and 11:57, of which 46% (179 days) occurred between 9:23 and 10:40.[23] There was much less intervention (5.7% of the sample or 22 days) earlier in the morning (8:48-8:55) or after noon (12:39-12:46). Moreover, interventions at the end of the trading day tend to be more frequent than at the beginning.

In contrast, in Mexico foreign currency was offered for sale three times a day, at predetermined times (9:30 am, 11:30 am and 1:00 pm, lasting 5 minutes each). [24] There were two elements of uncertainty. One is how much would be allocated out of the amount offered in each of the three auctions. As illustrated in the graph, the amounts actually allocated on average fell significantly below the amount offered.[25] Another was precisely how much would be offered during each of the three auctions in the day, as the amount would depend on how much was allocated in the earlier auctions. In particular, the amount would be adjusted to ensure that the target daily amount was offered. As illustrated in the graph, on average on intervention days, the amount of foreign currency allocated at auctions as a percentage of market turnover at 9:30 am, 11:30 am and 1:00 pm was respectively, 0.033%, 0.139% and 0.135%.

In Peru, about 66 per cent of interventions occur in the last hour of a typical trading day (between 12:25 and 13:30), of which about 63% occur in the last half hour, and 15 per cent occur in the last 5 minutes.[26]

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number of days that have interventions in each M-minute interval of the day (the variable N_j is set to 1 when there is at least one intervention during the jth M-minute interval, and J is the total number of intervals (eg 51 in Peru)), scaled by the total number of interventions summed over all the intervals. The width of the each interval M varied across countries, with M=7 minutes in Colombia, and M=5 minutes in Peru).

[23] In Colombia the distributions of (intervention and control samples) are based on the returns for non-overlapping intervals. The distributions for returns on wider intervals are not shown because whole trading days are missing, which may affect the effective width and thus the returns on these intervals.

[24] In a second episode of similar interventions in Mexico starting November 30, 2011, these schedules were changed to 9:00 am, 12:00 pm and 3:00 pm, respectively. This episode is not included in the analysis.

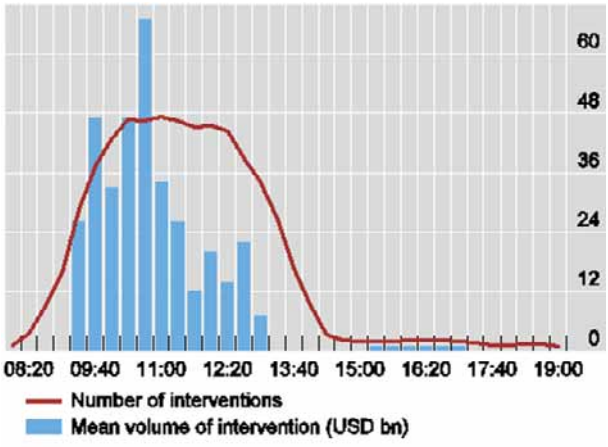
[25] In contrast, the amounts offered in the auctions without minimum price (which sometimes were offered on the same days as auctions with minimum price) were always fully allocated. See Garcia and Zerecero (2013).

[26] Over 124 days, for Peru, two alternative ways of computing the frequency of intervention during trading hours yield different results. The first approach (extensive margin) counts the number of intervention transactions within each 5-minute interval across all intervention days. According to this measure (not shown) 53% of all intervention transactions are made in the last 15 minutes of the trading day, of which more than 35% are in the last 5 minutes. The second approach (intensive margin) divides the sum of intervention volumes at that interval along the whole sample by the number of days that registered interventions at that interval. For example, over the 9:25-9:30 interval, the sum of the interventions is USD 23 million which divided by the two days in which intervention *occurred, it gives an average of USD 11 million. This measure indicates that the highest intensity of intervention is during the last 5-minute interval, and that apart from some peaks (around 10:00, 11:00 and 12*:00) the intensity of intervention is more or less uniformly distributed for the remaining intervals.

Distribution of intervention during the day[1]

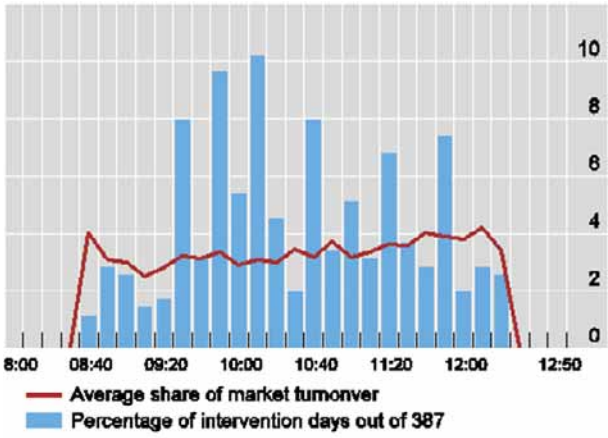
Graph 1

Chile



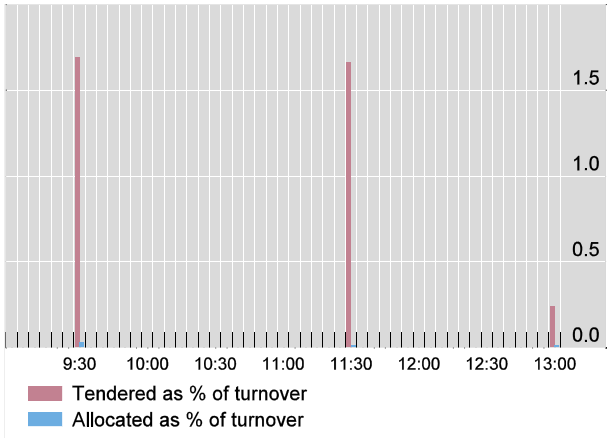
Colombia[2]

Per cent



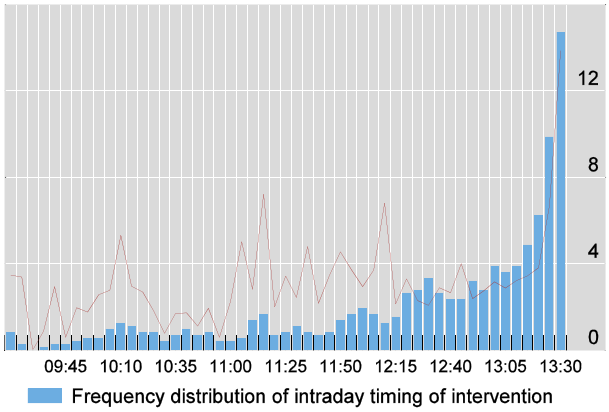
Mexico

Per cent



Peru

Scaled by daily turnover; per cent



[1] Based on actual transactions. In Mexico foreign currency was offered for sale three times a day to total a fixed daily amount. The actual amounts offered in each of the three auctions would vary (subject to their summing to the daily target). The amount allocated also varied. [2] Relative frequency, number of days as a percentage of 387

Source: Central banks.

D. Descriptive statistics: intraday foreign exchange distribution for whole, intervention and no-intervention samples

A question of interest is whether the differences in approaches to intervention reported above (notably the reliance on discretionary surprise intervention in Peru versus the use of preannounced quantity targets over certain periods in Chile, Colombia and Mexico) are reflected in differences in the impact of intervention on foreign exchange returns and the volatility of such returns.
In order to gain insights on the various effects of intervention, we first explore the distribution of foreign exchange returns over the full, intervention and no-intervention samples.
An important issue is the selection of the no-intervention sample so that it resembles the intervention sample as closely as possible (with the main difference being the intervention). To achieve this, no-intervention samples were chosen spanning periods that were close or adjacent to the intervention periods (See Table A3 for dates selected or criteria used). In the case of Mexico, the no-intervention sample was defined in two ways: (i) days in which a minimum price auction was not triggered; (ii) days in which a minimum price auction was triggered but no US dollars were allocated. In the regression analysis an attempt to account for remaining differences was made by including control variables.

As shown in Annex Table A4 the distribution of returns over the full sample in Chile, Colombia, Mexico and Peru, show the following characteristics

- *Mean values of returns* differ across countries and over time intervals. For example, the exchange rate tends to depreciate (ie changes are positive) in Colombia and in Mexico, while tending to appreciate in Chile and Peru.
- *Mean and variance of returns* increase in absolute value as the time interval increases in Chile, Colombia and Mexico. [27] In contrast, in Peru the mean is the same at the 5 minute and 24 hour intervals, and the variance declines as the time interval rises. It may be noted that the size of the variance of returns is much smaller in Peru than in the other three countries studied here.
- *Skewness of returns* is negative at short horizons in Chile, Colombia, Mexico and Peru but turns positive at longer horizons (ie at longer horizons the tail of the distribution shifts from the left to the right of the distribution).
- *Kurtosis* (ie evidence of heavy tails) shows large declines as the time interval increases in all four countries.

The preceding data suggest possible deviations from normality in the behaviour of intraday exchange returns, with skewness away from zero and generally large kurtosis. The Bai and Ng (2005) test was implemented to test whether deviations from normality are statistically significant, with mixed results. In Colombia, Mexico

[27] One interpretation is that a higher return is on average associated with higher risk.

and Peru, the symmetry of FX returns could not be rejected, with the sample skewness is not significantly different from zero. However, for the full sample, the null hypothesis that kurtosis=3 (implying normality) is generally rejected.

Bai and Ng test for skewness and kurtosis

Table 1

Statistic	No pre-whitening nor degrees of freedom correction				With pre-whitening and degrees of freedom correction			
	Whole sample	Intervention	No-intervention		Whole sample	Intervention	No-intervention	
Chile								
Skewness	–1.51	0.88	–1.87		–1.70	0.88	–2.13	
Kurtosis	3.72**	4.83**	3.36**		2.73**	4.81**	2.42	
Colombia								
Skewness	–0.06	–0.06	–0.55		–0.54	–0.06	–0.53	
Kurtosis	6.54**	2.67**	6.24**		5.91**	2.47**	5.80**	
Mexico[1]								
Sample			1	2			1	2
Skewness	–1.16	0.93	1.47	–0.24	–1.16	8.24	1.47	–0.27
Kurtosis	2.08*	1.15	2.57**	1.82*	2.02*	1.48	2.07*	1.67*
Peru[2]								
Skewness	–0.11	0.34	–0.15		–0.77	0.87	–0.99	
Kurtosis	2.72**	3.58**	2.44**		11.15**	0.62	15.06**	

** = reject kurtosis=3 at 1%; * = reject kurtosis=3 at 5%.

[1] Quote statistics. For whole sample, estimation sample. [2] Bartlett Kernel. For 5-minute returns.

Source: Central bank authors.

Comparison of intervention and no-intervention days

Further insights may be gained from an informal comparison of intervention and no-intervention days, which suggests the following properties:

- *Mean return.* This tends to depreciate during intervention days. During no intervention days, it tends to depreciate by less or appreciate in Chile, Colombia, Mexico, and Peru.[28]
- *Volatility of returns*. This is higher during intervention days in Chile, Colombia, Mexico and Peru (only at the highest – 5 minute – frequency).

[28] While the very high frequency data show no trend in Peru, when the central bank intervened, the exchange rate tended to appreciate and when the central bank did not intervene, the exchange rate tended to depreciate.

- *Deviations from normality (skewness and kurtosis).* As the Bai and Ng tests suggest that skewness does not deviate from normality[29], we focus on kurtosis which tends to be higher on intervention days in Colombia, and lower in Chile and Peru. However, in Peru and Mexico, the Bai and Ng test for kurtosis on 5-minute returns (with prewhitening and degrees of freedom correction) does not reject normality during intervention days but does so on no-intervention days. One interpretation is that discretionary intervention in Peru (and somewhat less precisely, non-discretionary intervention in Mexico) limits the incidence of extreme values.[30] However, normality is still rejected in Chile and Colombia during intervention days, suggesting that such (non-discretionary) intervention does not eliminate tail risks.

Why are deviations from normality a concern? An important reason is that they could be associated with risks of very sharp movements in the value of portfolios, which in turn can pose financial stability risks. Focusing on heavy tails, a traditional explanation is that they are the result of "irrational behaviour", such as trend-following. However, recent research also highlights the potential importance of leverage in explaining heavy tails, with possible financial stability implications. For example, Thurner, Farmer and Geanakopolos (2012) develop a model of leveraged asset purchases with margin calls, with "value investors" and noise traders. Using a line of reasoning that can apply to foreign exchange markets, they show that when funds are not allowed to borrow, asset price fluctuations are approximately normally distributed and uncorrelated across time. However, when leverage is permitted, so that funds can borrow to increase their investments, funds have higher profits during good times, but a downward shock to prices when funds are fully leveraged can lead to margin calls and to sales into already falling markets. This amplifies the downward movement in the asset price and can lead to large losses. This can lead to clustered volatility, in which volatility is low before a crash because value investors are able to dampen volatility, but rises sharply after the crash when they suffer severe losses. Another implication is heavy tails, due to leverage-induced crashes, and due to clustered volatility.[31]

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[29] Skewness generally becomes negative for intervention days in Colombia, Mexico and Peru. In Mexico, skewness on intervention days is mixed (positive at 5 min and 24 hr intervals, negative in between). It is positive on no-intervention days 1, and negative on no intervention days 2. In Peru skewness is positive at most frequencies on intervention days, while the sign switches on no-intervention days.

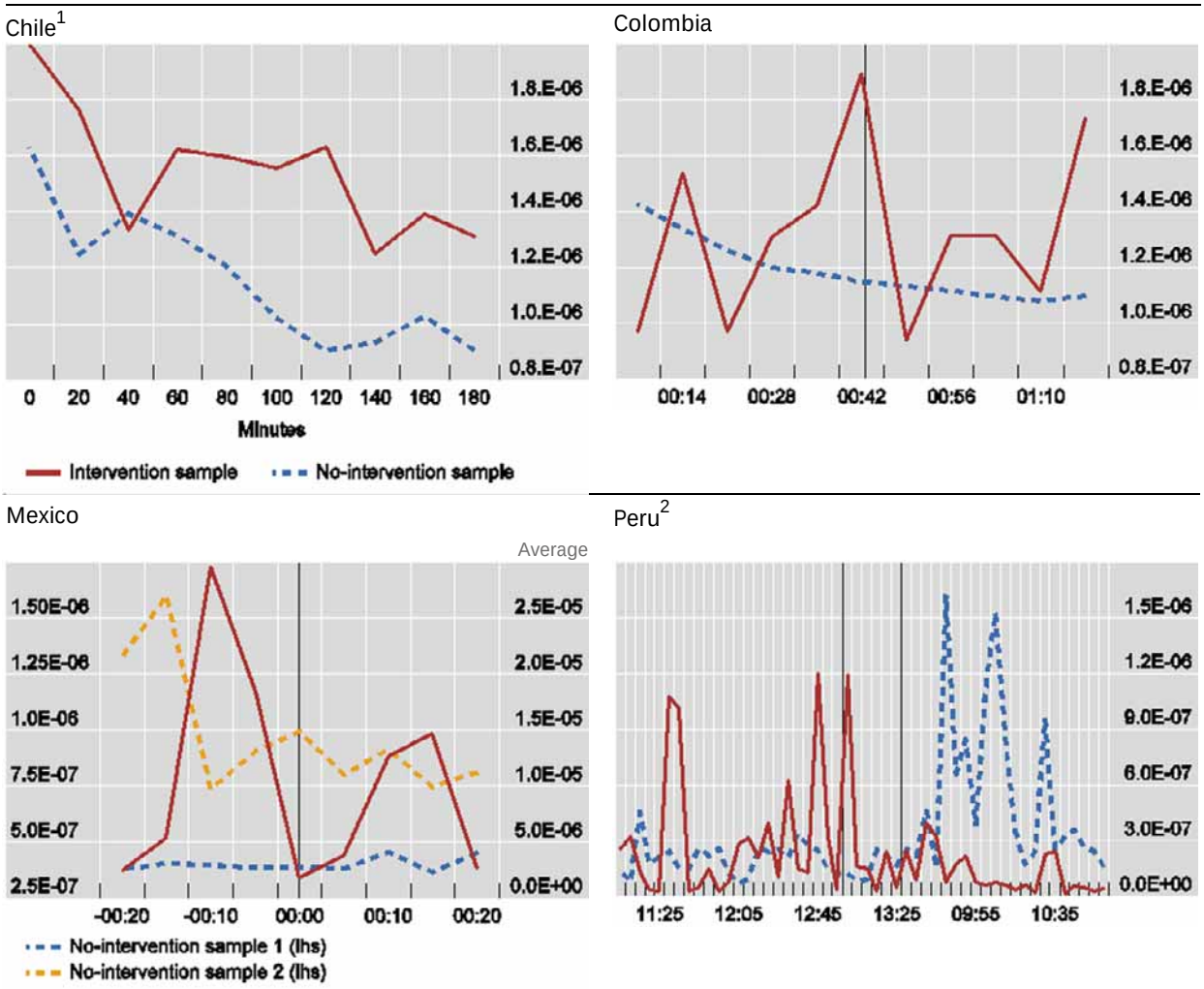
[30] To put it differently, this might mean that during no-intervention days relatively more extreme exchange rate movements have been allowed, for example sharp (extreme) depreciation on no-intervention day t following a series of high (but not extreme) appreciations on intervention day t-1.

[31] As for (negative) skewness, it is potentially a concern because it could also indicate crash risks. In an empirical study of eight major currencies' exchange rates relative to the US dollar, Brunnermeier, Nagel and Pedersen (2009) find that countries with high interest rate differentials (ie destination or investment currencies) tend to have negative skewness, implying that carry trade returns have crash risks. The reverse would be true for funding currencies. As a possible explanation, Brunnermeier and Pedersen (2009) show – in a setting where agents are liquidity constrained - that securities that speculators invest in have a positive average return (a reward for providing liquidity) and a negative skewness (because shocks that lead to speculator losses are amplified when speculators hit funding constraints and unwind their positions, while shocks that lead to speculator gains are not amplified.

E. Average return volatility for intervention and no-intervention days

Following Dominguez (2003), samples of intervention and no-intervention time windows were matched according to the time of intervention and the day of the week. The idea is to control for volatility seasonality by day of the week as well as intraday.

Comparison of the return volatility for intervention and no-intervention samples — Graph 2



Note: Vertical line denotes time of intervention. For Peru, vertical lines delineate the "intervention cluster".

[1] Standard deviation of 20 minutes return. [2] Volatility comparison around intervention cluster.

Source: Central banks.

For Chile, Graph 2 (Panel A) shows the standard deviations of returns for the 2011 and 2008 interventions, with the red line for the intervention sample and the blue line for the counterfactual. Volatility declines during the day but more steeply during no-intervention days.

In Colombia, the volatility tends to increase slightly 7 to 14 minutes before the intervention, and the duration of this increase lasts until impact, to return very fast

to the volatility of the control sample. However, a slight volatility spike may be observed 35 minutes after the intervention.[32]

For Mexico, average return volatility for intervention and no-intervention days were examined at 9:30 am, 11:30 am and 1:00 pm using transactions data. It was found that (i) average return volatility on intervention days is on average greater than on no-intervention days; (ii) the average return volatility for intervention days is much higher at 9:30 am than at 11:30 am and 1:00 pm spiking approximately 15 minutes after intervention), as illustrated in Graph 2.

In Peru, the distribution of intervention during the day has a bearing on the volatility comparisons. As noted, intervention tends to cluster late in the trading day: in 48 out of 124 days with intervention operations, interventions clustered in last ½ hour (ie with no intervention in the 2 hours prior to the cluster 11 am to 13:00, or during the early hours of the next trading day 9:25 AM to 11 AM. **)**
A question of interest (see Dominguez (2003)) is whether volatility shows any effects from intervention before or after the intervention event, for which non-overlapping intervention episodes need to be identified. This is particularly challenging in the case of Peru, because intervention occurs at all times during the trading day and most notably in the last half hour of trading. To deal with this, an effort was made to isolate intervention clusters during the last half hour by (1) isolating intervention clusters during the last half hour of trading; (2) assuming that the FX market has no interruptions between 13:30 and 9:25 on the following day. The variance of returns (as measured by squared returns) can then be measured before, during and after the intervention cluster.
As shown in Graph 2, variances show a peak in volatility at 13:00, just when the intervention cluster starts. Volatility falls after the peak and during central bank intervention and remains low during the first two trading hours of the next day. Volatility also tends to be higher before the intervention cluster as compared to the control sample, which includes matched (by time of day and day of week) 5 minute volatility observations during no-intervention days. A striking outcome of this analysis is that it shows that volatility in the early hours of the day following intervention remains low compared to the volatility of no-intervention days.
Intervention and no-intervention samples can be compared assuming that news, shocks and policy events that appear after the market closes at 13:30 are not related to intervention that took place in the morning. For example, the central bank announces its interest rate policy decision in the evening of a given Thursday each month. The assumption here is that the policy rate decision is orthogonal to the intervention decision.

[32] For Colombia, a disaggregated comparison of mean square returns between the control and intervention matched samples is available from the Juan Manuel Julio and Hernan Rincon. It suggests that the response of mean square returns to intervention is not homogenous, varying with the time and day of the week of the intervention. However, on average, the mean square of seven minutes returns tends to increase slightly 7 to 14 minutes before the intervention and spikes on impact to return very fast to the level of volatility of the control sample. However, this type of analysis does not rule out longer term effects on volatility. Aggregate results for Colombia are shown in Graph 2. Assuming there is no intraday seasonality, all the intervention and no-intervention samples may be pooled to observe the average relationship between the volatility of returns and intervention over the sample.

F. The Brown and Forsythe Homoskedasticity Test[33]

To test for homoscedasticity, the Brown and Forsythe test was implemented. Mexico and Peru implemented tests of homoscedasticity during the day. In the case of Mexico, the test is whether variances were equal in a symmetric way around the time of the 3 interventions for all samples (the window is 20 minutes before and 20 minutes after intervention). As shown in Table 2, the null hypothesis of equal variances is not rejected. However, given the reduced size of the intervention sample, the test does not have enough power to be conclusive.]

In the case of Peru, given the presence of intervention clusters, the first test was to check whether the volatility of returns differs before after after the intervention cluster, for both the intervention and no-intervention (control) samples at the 5-minute interval. The null hypothesis of equal variances (that the sample variances are homoscedastic) before and after 11:00 is rejected for both the intervention (F-statistic 4.59, p-value 4%) and the no-intervention (F-statistic 13.48, p-value 0.06%) samples. Similar results were obtained with a second exercise was performed with volatilities around isolated intervention events (not preceded by any intervention event 2 hours before or after) that occur within 5-minute intervals during the day. This type of event is relatively rare in the Peruvian market (only 28 cases are documented) but is closest in spirit to the one performed in Dominguez (2003) because it focuses on event time and not clock time.[34]

Brown Forsythe test for equality of return variances within samples

Transactions data, F-statistic — Table 2

	Hour	Intervention sample	No-intervention sample	
Mexico[1]			Sample 1	Sample 2
	9:30 am	0.34	0.16	2.57
	11:30 am	0.09	1.40	0.25
	1:00 pm	0.08	0.73	0.02
Peru[2]	11:00 am[3]	4.59**	13.48***	
	Isolated intervention events[4]	3.68*	6.30**	

*** = reject homoscedastic sample variances at 1%; ** = reject homoscedastic sample variances at 5%;* = reject homoscedastic sample variances at 10%.

[1] ± 20-minute window. [2] Sample variances at 5-minute intervals. [3] Intervention cluster window. [4] Events such that they are not preceded by any intervention event 2 hours before or after; ± 2-hour window.

Source: Central bank authors.

[33] Detailed results for Chile and Peru were still not available from this section to the end of this paper.

[34] Homoskedasticity at different times of day was also tested using Colombian data. The findings suggest that for particular times of intervention – but not for others - there is strong evidence of heteroskedasticity.

The Brown Forsythe test was in some cases also implemented to test for homoskedasticity between the pooled intervention and no-intervention samples. In Chile and Colombia the value of the statistic is 30.08 and 27.06, respectively, so homoskedasticity is rejected at the 1% significance level. While volatility of returns (7 minutes in the case of Colombia) thus differs between the intervention and no-intervention samples, this result might not hold for all intervention times in the sample.[35]

G. Volatility seasonal

Following Dominguez (2006), the intraday seasonal component of the volatility of returns was estimated for Chile, Colombia, Mexico, and Peru.

In the case of Colombia, an ARCH(2) model with T distributed residuals was fitted to the 1,025 average daily returns. From this model the daily volatility factor σ_t was estimated for each day t in the sample.[36] By estimating $E[R_{t,n}]$ with the sample mean return over the sample, the estimate of $x_{t,n}$ in Dominguez (2006, equation 6, page 1057), was computed for each intraday sub-interval n and day t, where $N = 42$ is the number of intraday intervals in the trading day. A tuning parameter p=5 was selected after comparing estimated volatility seasonals for tuning parameters between 4 and 9 (evidence of over fitting at the end of the trading was found for $p > 6$, and of underfitting for $p < 4$, with the results basically the same for p between 4 and 6).

In Mexico, the seasonal component was estimated first by using no-intervention days, and then by considering the whole sample, the underlying assumption being that the seasonal component does not change through the sample. A GARCH model (instead of a FIGARCH) was used, with parameter p=6.

In Peru, the average of squared returns for each 5-minute interval over the whole, intervention and the no-intervention samples. To estimate the smooth seasonal component (see Dominguez (2006)) we fit an MA(1)=FIGARCH(1,d,1) model for daily returns in the sample 5 January 2009 to 27 April 2011. This allows estimation of the daily volatility factor σ_t, which is then used in the flexible Fourier form (FFF) regression (Dominguez, 2006, page 1057). The tuning parameter for estimating the volatility seasonal is p=7.

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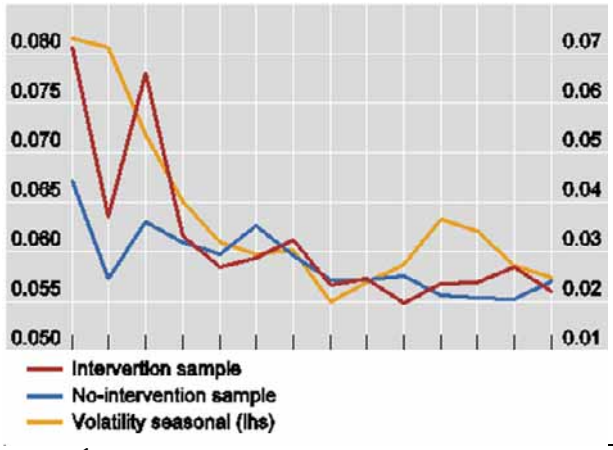
[35] For Colombia, the p-value of the test for homoscedasticity between the pooled intervention and no-intervention samples at the most frequent times of intervention were also obtained and suggest that at the time of intervention – but not at other times – there is strong evidence of heteroskedasticity. The results are available from Juan Manuel Julio and Hernan Rincon.

[36] Alternative ARCH and GARCH specifications were tried and GARCH terms did not significantly affect the volatility of mean daily returns.

Volatility seasonal

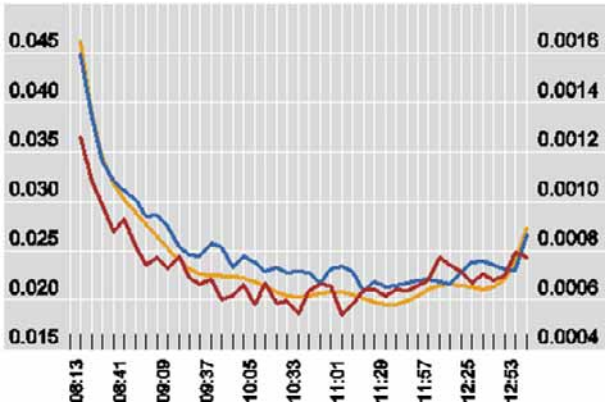
Graph 3

Chile



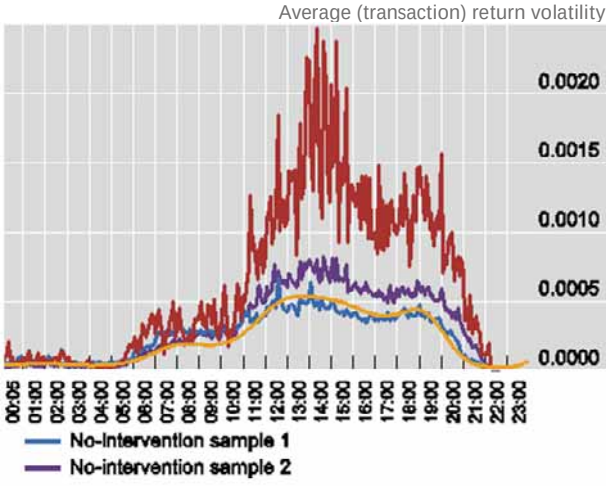
Colombia

Average absolute returns

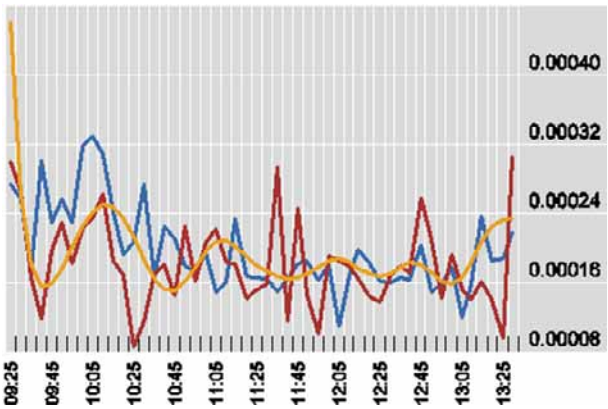


Mexico[1]

Average (transaction) return volatility



Peru



[1] 40-minute windows around 9:30, 11:30 and 13:30 interventions.

Source: Central banks.

Graph 3 shows the volatility estimates on the pooled intervention and no-intervention samples, as well as the volatility seasonal calculated as in Dominguez (2006).[37] In Chile and Colombia, except for a normalization constant, the volatility seasonal picks up the features of intra-daily volatility. On an average trading day the volatility of returns starts high and falls slowly. A similar pattern is observed in Peru,

[37] Dominguez (2006, equation (8), page 1058) and Andersen and Bollerslev, 1997.

where in both intervention and no-intervention samples, volatilities tend to be higher during the early hours of a trading day. The estimated volatility seasonal is high around 10:10 am, 11 am and at the close of the trading day. From 10:30 am to 1 pm the volatility for intervention days is higher than the volatility during the no-intervention days. After 13:00 both volatilities tend to be the same. The pattern is quite different in Mexico, where trading in the peso occurs over a 24-hour period. The volatility seasonal rises until about 13:00, is relatively stable until about 19:00 and then declines.

One interpretation of the preceding results is that the volatility seasonal declines as the market agrees on the effect of exogenous information on prices. However, in Colombia and Peru the explanation for higher volatility at the end of the trading day is less clear because trades are less frequent in Colombia, but more frequent in Peru (see Graph 1).

III. Empirical analysis

A. Event Study style regression

Following Dominguez (2003 and 2006) a set of regressions was estimated to study the effect of foreign exchange market intervention on the mean return, return volatility, and (for Colombia) market turnover.[38] Further details are available from the respective central bank coauthors.

The following specifications are reported in this paper:

- Regression of mean return on dummy variables for intervention and control variables (typically macroeconomic surprises).
- Regression of the volatility of returns on intervention and control variables.
- Regression of market turnover on intervention and control variables and intraday seasonals (Colombia only).

The general specification of these equations may be described as follows[39]:

Event style regression with macroeconomic/announcements control variables Table 3

38 For Colombia, The general equation specification for the effect of the intervention on the mean return and turnover follows Dominguez (2003, equation (1), page 34), and the equation to study the effect of intervention on the mean volatility of returns follows Dominguez (2006, equation 9, page 1059).

39 As a reference, see Dominguez (2003, 2006), who implements similar regressions using US data.

Returns regression

$$R_{t,i+l} = \beta_0 + \sum_{l=-m^I}^{m^I} \beta_{1,i+l} I_{t,i+l} + \sum_{j=1}^{n} \sum_{l=-m^K}^{m^K} \beta_{2,i+l}^{j} K_{t,i+l}^{j} + \sum_{k=1}^{p^R} \beta_{3,i+l-k} R_{t,i+l-k} + \varepsilon_{t,i+l}$$

Volatility regression

$$V_{t,i+l} = \gamma_0 + \sum_{l=-m^I}^{m^I} \gamma_{1,i+l} I_{t,i+l} + \sum_{j=1}^{n} \sum_{l=-m^K}^{m^K} \gamma_{2,i+l}^{j} K_{t,i+l}^{j} + \sum_{k=1}^{p^V} \gamma_{3,i+l-k} V_{t,i+l-k} + \gamma_4 S_{t,i+l} + \vartheta_{t,i+l}$$

Turnover regression (Colombia)

$$T_{t,i+l} = \delta_0 + \sum_{l=-m^I}^{m^I} \delta_{1,i+l} I_{t,i+l} + \sum_{j=1}^{n} \sum_{l=-m^K}^{m^K} \delta_{2,i+l}^{j} K_{t,i+l}^{j} + \sum_{k=1}^{p^T} \delta_{3,i+l-k} T_{t,i+l-k} + \delta_4 S_{t,i+l} + \in_{t,i+l}$$

R exchange rate returns

V volatility of returns (absolute value of returns in Colombia and Peru, standard deviation in Mexico)

I intervention in US dollars (in Peru as a proportion of market turnover).

K control variables indexed by $\mathrm{j} = 1 \text{ to } \mathrm{n}$. The baseline specification includes 12 US macroeconomic surprises (defined below), expressed in absolute values in the volatility and turnover regressions.

S intraday seasonal

T market turnover

t intervention date

i time of intervention

j types of announcements (1 to n)

l leads and lags (ranging from -m to m) for intervention and announcements.

k lags on the dependent variable (1 to p). The number of lags was selected by information criteria (eg in Colombia p=3 by the Schwartz criterion and in Peru p=6 by the Akaike criterion). The superscripts for the total number of lags, n, m or p refer to the corresponding regression they apply to.

Estimation was implemented using alternative methods, ie GMM for Colombia and Mexico or HAC (Newey-West robust standard errors Peru).

In the above specifications

- Intraday returns data are only those recorded on the days in which the central bank intervened.

- Significant lead coefficients on intervention would suggest market participants know about the interventions before it took place
- It is possible to test for intraday persistence or mean reversion by checking whether the lag coefficients sum to zero

Variable specification

Before reporting the regression results, it is useful to describe how the variables are specified, and the window around which estimation was performed.

Intervention leads and lags

In general, if an intervention takes place on day t at time i the lag and lead with respect to the intervention time is set at l. Then the intervention amount $I_{t,i+l}$ is entered at the time of intervention[40] and for a symmetric time window of a prespecified length (from $-m^I$ to m^I) before and after the intervention. The intervention amount is set to zero if there was no intervention on day t. The coefficients $\beta_{1,i+l}$ are thus associated to the time before, at and after the intervention. These are the coefficients that are plotted in Graph 4, along with the associated 2 standard error bands. .

In *Colombia*, after fitting several models with windows as wide as two hours before and after the intervention for the leads and lags of the intervention and news indicators, a symmetric window of 70 minutes that contains each intervention, was chosen. In line with this choice, the intervention occurs sometime between 00:35 and 00:42 time marks and its effect on any of the three variables is estimated on a time window consisting of 35 minutes before and 35 after the intervention (in Colombia, the value of m^I = 35.).

Moreover, an analysis of the frequency of occurrence of news releases in windows around interventions reveals that there are just 23 news releases (observations) in a 70 minute window around interventions, only 15 in a 42 minutes widow, and only one on impact (in a 7 minutes interval). A closer look at these releases shows, also, that there is no concentration of interventions near to announcements of any particular macro indicator. Therefore, for Colombia, *there does not seem to be enough sample information to study the effect of the interaction between intervention and the macro announcements of particular variables*.

In the case of *Mexico*, intervention in the sample occurs only three times a day, rather than continuously throughout the day. The intervention variables are specified by setting a symmetric time window of 40 minutes on intervention day t at time of intervention (ie either 9:30 am, 11:30 am or 1:00 pm), (in Mexico, the value of m^I=20).

In Peru, leads and lags were chosen to maximise the p-value of the Wald statistic for the null hypothesis that all coefficients are jointly equal to zero.

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[40] In earlier versions of this paper, intervention dummies were used as explanatory variables instead of intervention amounts. For some countries with a fixed amount of daily intervention (eg Colombia) the results using intervention dummies were similar to those using intervention quantities. However, in countries where the amount of intervention was discretionary during the sample period (Peru) or depended on auction results (Mexico) the results would differ.

Control variables

External surprises and indicators. The regressions also include control variables, notably a set of macroeconomic news announcements, which are recorded in the form of surprises (for more details on the series included see Annex Table A2). Surprises are defined as the difference between the macroeconomic announcement and the median expectations (as indicated by survey forecasts taken from Bloomberg), standardised by the standard deviation of the survey. In Mexico and Peru, however, the standard deviation is approximated by the difference of the maximum minus the minimum divided by six.[41]

$$K_{jt} \equiv \frac{A_{jt} - \bar{A}_{jt}}{\sigma_{A_{jt}-\bar{A}_t}}$$

In the regressions for Colombia, Mexico and Peru, twelve types of US macroeconomic announcements listed earlier were included, denoted by j=1,...., 12. However, the results for only some of the macroeconomic announcements are reported in Mexico, in the cases in which the return are the dependent variable, for the estimation of the partial sums (and not for the regressions) only the variables for which the effect on the exchange rate was not ambiguous in the short run was included. In particular, news announcements that lead to an appreciation in the exchange rate were included, while coefficients for unemployment, federal funds rate, or trade balance are not included in so far their interpretation is not totally unambiguous.

Absolute macroeconomic surprise announcements were used on the right hand side in the volatility (Colombia, Mexico and Peru) and turnover (Colombia) equations. In addition the daily VIX was included.

Other controls. In addition to these controls, in the specifications for Colombia 3-domestic surprises are included as well as a daily implied tax on capital flows. For Mexico, a dummy variable is included as a control when auctions with no minimum price were implemented during the same days as auctions without a minimum price (the focus of the present paper). For, Peru a dummy variable is included that controls for the first interval within an hour.

Span of intraday data. In Mexico, since many news announcements' time stamps are earlier than 9:10 am, the intervals of the days were extended accordingly For example, if there is a news announcement at 7:30 am, data starting at 7:10 am is considered. In fact, data can go from 7:10 am to 2:35 pm, as 7:30 am is the earliest time and 2:15 pm is the latest time news announcements take place in the Mexican database.

For the intervention and announcement series, observations outside the windows on intervention days are not included. No-intervention days are also excluded (these data are considered uninformative).

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[41] In Mexico, positive news announcements are defined as realized values for the variable in question above the median plus the standard deviation. Negative news announcements are defined as a realized value for the variable in question below the median minus the standard deviation. See Garcia and Zerecero (2013).

Lag selection for control variables. In Peru the span of the leads and lags on surprises was selected to minimise an information criterion (AIC) and test the joint significance of the coefficients using Wald tests. For intervention, leads and lags ranged from -6 to 6 (ie m=6). For the dummy variable controlling the first interval in the hour the lead and lag ranged from -1 to 1.

C. Impact of intervention on mean returns and volatility

1. The effect of the intervention on mean returns

Graph 4, left column, shows the estimated coefficients of leading, contemporary and lagged intervention.

For Chile, the first row of Graph 4 shows that 2 periods before the intervention, returns show a significant appreciation. However the point estimates shift to depreciation and become insignificant closer to the time of intervention and after it.

In the case of Colombia, the second row of Graph 4 illustrates the impact of USD 1 million intervention – measured in basis points - on 7-minutes mean returns of the COP/USD exchange rate. Turning to the left hand panel, the solid line corresponds to the coefficient estimates, while the dashed lines show two standard deviation confidence intervals derived from a GMM estimation procedure. The graph shows a small (0.14 basis points), significant increase in mean returns on impact. After reversing (with some overshooting) the effect is zero 1:03-00:42 minutes after the intervention. However, the cumulative effect of intervention (column 2) is not significant.

In Mexico, the effects on returns of intervention in the form of minimum price auctions are not significant.[42]

In the case of Peru, the right hand panel shows the cumulative response of returns when a purchase intervention equivalent to 10 per cent of turnover (approximately 1 standard deviation of historical intervention amounts relative to turnover), in a regression that takes into account controls in the form of US macroeconomic surprises. The effect on cumulative returns is close to 0.03 per cent for about 30 minutes (by way of comparison, the effect in a regression with no controls is about 0.01 per cent). For example, if the initial spot price is 2.700 soles, it increases up to about 2.7008 soles within the first minutes after the intervention (ie about 8 pips[43]). However, there is no long-run effect of intervention on returns.

[42] This result holds for a number of specifications the Bank of Mexico authors tried except a specification that included Intervention Dummies, Macroeconomic Dummies and the VIX. In this specification, intervention has a significant effect on returns minutes after the intervention.

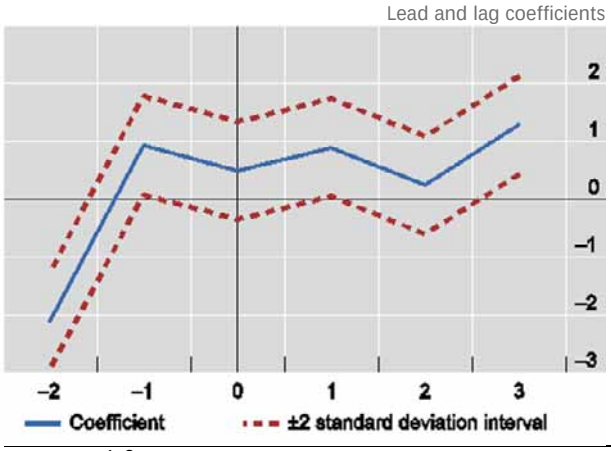
[43] Compared to 0.04 pips in a regression with no controls A pip is the smallest unit of price for any foreign currency. The USD-PEN currency is quoted with 4 decimal points.

The effects of intervention on mean returns (lead and lag coefficients within intervention window)

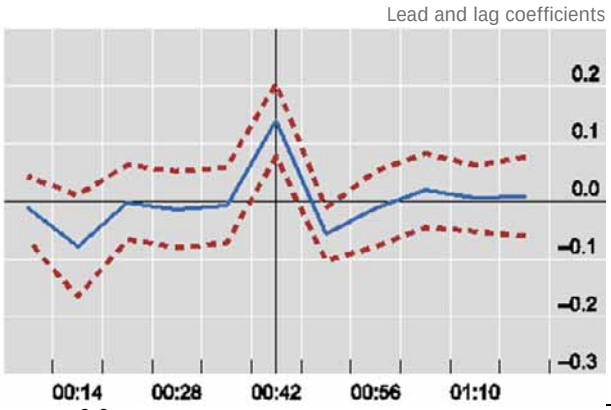
In basis points

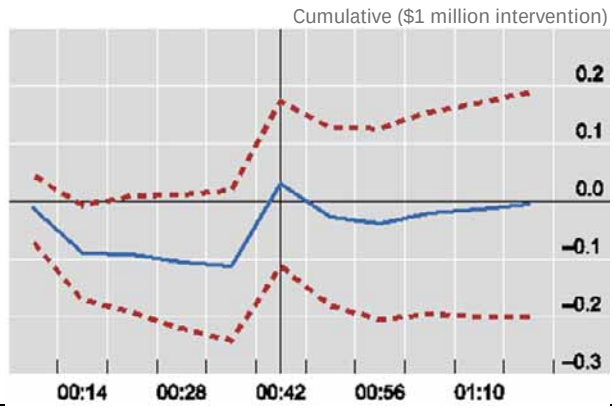
Graph 4

Chile

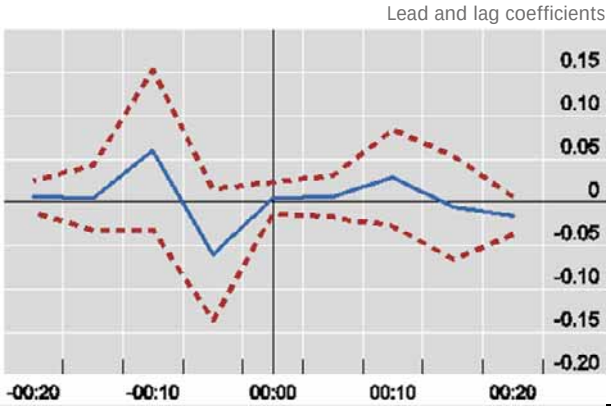


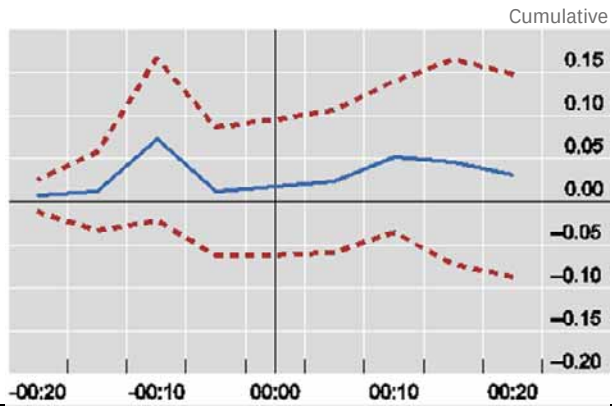
Colombia[1, 3]



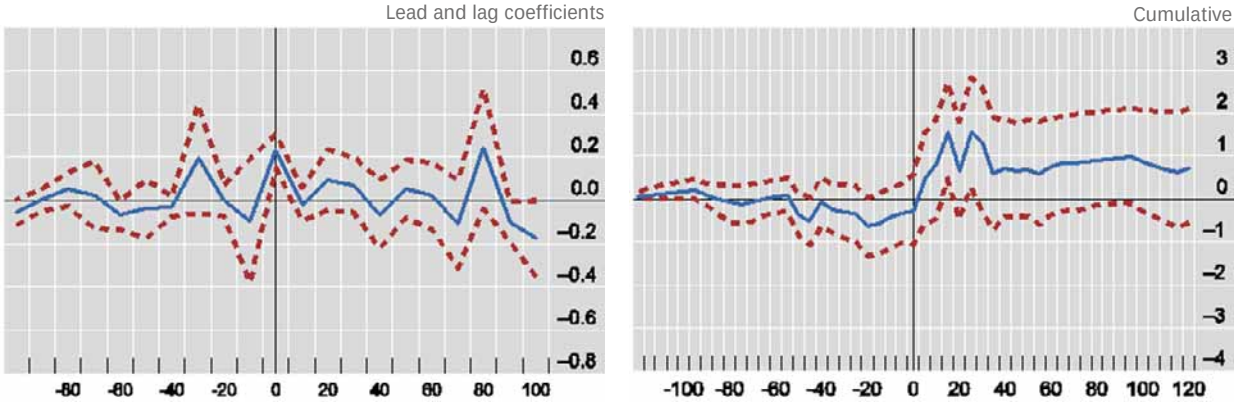


Mexico[2, 3]





Peru[3, 4, 5,]



Vertical line indicates intervention time.

[1] (As indicated in the text) the intervention window is between 00:35 and 00:42. [2] In the regression, on the right hand side are (i) the actual amounts allocated in the intervention; (ii) standardised macroeconomic surprises; (iii) a dummy variable controlling for days in which an auction with no minimum price was also implemented. [3] Regression coefficients are estimated using OLS with HAC standard errors. Sample goes from 1/05/2009 to 4/29/2011. It excludes first observation in any day and holidays. There are 14950 observations. [4] No controls. [5] For Peru left hand side panel data is the value of coefficients not in basis points. [6] Cumulative is the sum of the coefficients.

Source: Central banks.

2. The effects of surprise US announcements on mean returns

As noted earlier, US macroeconomic surprises were added as controls. A question of interest is whether the effect of such announcements are large compared to the effects of intervention, If they are, policymakers may see a need to intervene more actively, or to accumulate larger amounts of foreign reserves in order to respond to external shocks.

In the case of Colombia, the market reacted in anticipation and with a lag to a positive surprise to US consumer confidence. This shock lowers the 7-minutes mean return around 8 bps on impact. Moreover, the confidence bands suggest that there are also borderline significant leading effects, and also significant lagged effects on average returns.[44] The cumulative effect of a standard deviation surprise US macroeconomic announcement (represented by US consumer confidence in Colombia) has a significant negative effect on mean returns after the impact, lasting around 15 minutes. However the effect reverts to zero afterwards. The effects of other US macro surprises showed similar characteristics.[45]

In the case of Mexico, news announcements have, in absolute magnitude, a much greater effect than intervention. However, there is a clear “regress to the mean” effect on the return after the news announcements.

[44] The estimated effect of any other macroeconomic surprise may be requested from Hernan Rincon and Juan Manuel Julio, Bank of the Republic (Colombia).

[45] The estimation of the effect of Colombian macroeconomic announcements is more involved as these interventions tend to be off market hours, and were therefore carried forward to the 8:06 minutes time mark of the following trading day. The coefficient estimates related to these announcements may be biased and thus are not shown here.

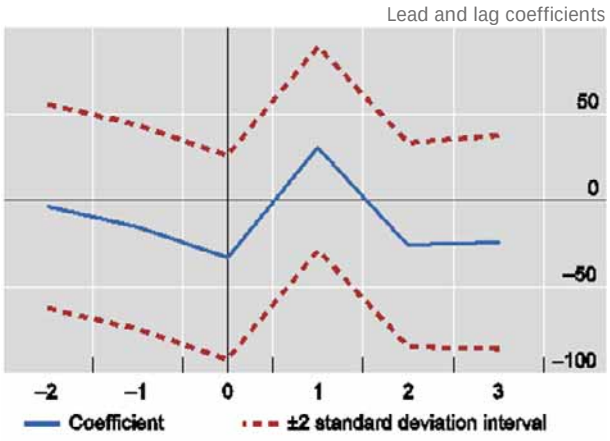
In the case of Peru, a positive US macro surprise reduces returns. The effect is permanent in the case of surprises to either GDP or retail sales.

On average, the responses of the mean returns to a positive average US surprises (eg US consumer confidence in Colombia) are much larger than the effect of the intervention, particularly on impact in Colombia, Mexico and Peru (almost twice the effect of the approximately 1 standard deviation shock of intervention to turnover). One explanation is that macroeconomic surprises – unlike intervention - are usually related to fundamentals.

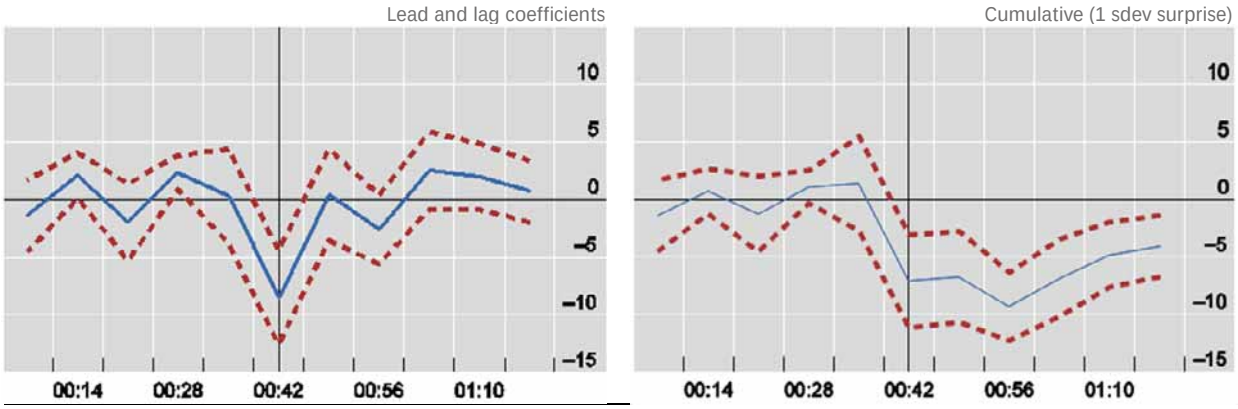
The effects of US announcement surprises on mean returns (lead and lag coefficients within intervention window)

In basis points — Graph 5

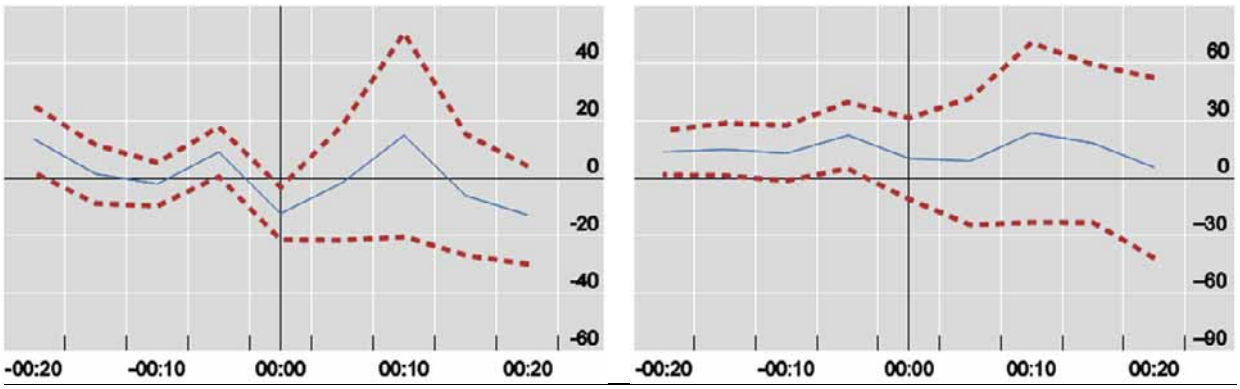
Chile



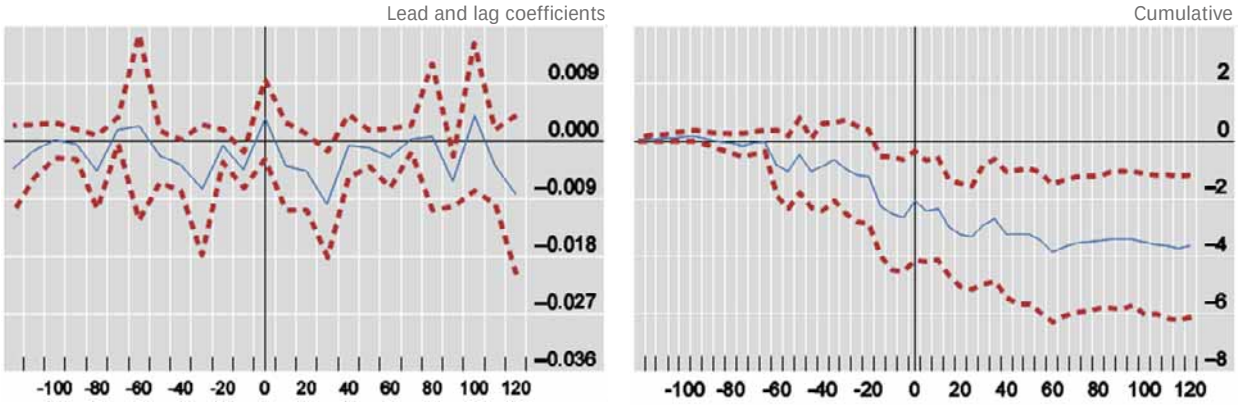
Colombia (US consumer confidence)[1, 4]



Mexico[2, 4]



Peru[3, 4]



Vertical line indicates intervention time.

[1] The announcement window is between 00:35 and 00:42. [2] Coefficients are the partial sums of the ones associated to the macroeconomic variables. In the regression, on the right hand side are (i) the actual amounts allocated in the intervention; (ii) standardised macroeconomic surprises; (iii) a dummy variable controlling for days in which an auction with no minimum price was also implemented. [3] For Peru left hand side panel data is the value of coefficients not in basis points. [4] Cumulative is the sum of the coefficients.

Source: Central banks.

3. The effects of intervention and macro announcements on the volatility of returns

In this section the effects of intervention and macro announcements on the intraday volatility of returns are discussed. Following the specification shown in Table 3, the endogenous variable is the absolute value of returns. Intervention volumes (in Peru as a fraction of daily turnover). and macroeconomic surprises are entered as explanatory variables, as is the intraday seasonal corresponding to the period of time within the day (for Colombia the intraday seasonal was also added to the turnover equation). Graph 6 shows the estimated coefficients on intervention (left column) and on macroeconomic surprises.

a. The effects of intervention on the volatility of returns

In Chile and Mexico, intervention appears to have no significant effect on volatility along the window considered. In Colombia the (7-minute) volatility of returns falls 25 and 21 minutes before the intervention auction is announced. Beyond this, the

intervention does not seem to modify the volatility during or after the intervention, except perhaps for a slight reduction 7 minutes after the intervention.

In Mexico, when using intervention quantities, there seems to be an increase in volatility minutes after the intervention takes place, and in some specifications a positive statistically significant effect 20 minutes after the intervention. However, the effects do not appear to be economically significant.[46] On the other hand, when dummies are used for interventions and macroeconomic announcements (not shown) the effects are economically significant. One reason may be that dummies mitigate simultaneity that arises because there is a trigger mechanism for the auction, which depends on the exchange rate. Thus there is some indication that the volatility might be increase after the intervention. Also, the Bank of Mexico authors performed GMM-SUR estimations separating the actual time of the intervention and found that at 9:00 am. the effects tend to be much stronger.

In Peru, the response to an intervention equivalent to 10 per cent turnover is shown. Volatility, measured as absolute value of returns, increases contemporaneously and 5 minutes after the intervention, falling 10 minutes after the intervention. However, these effects are not statistically significant. Nevertheless a correlation may not be apparent if the large presence of the central bank in the foreign exchange market (30% of market turnover on average) successfully reduces volatility to very low levels by deterring market participants from taking positions that are counter to the central bank's. Volatility in Peru's foreign exchange returns is much lower than in the other countries studied in this paper (Annex Table A4).

b. The effects of US macroeconomic announcements on the volatility of returns

In Chile and Mexico, surprise US news announcements have, in absolute magnitude, a much greater effect on volatility than does intervention. The effects are significant at some points in time. In Colombia, a surprise to US consumer confidence has no effect on the volatility of returns on impact, but reduces the 7-minutes returns volatility 7 and 28 minutes later. Moreover, the volatility increases significantly 21 minutes prior to the intervention. However, the volatility before the announcement tends to be higher than the volatility immediately after the announcement. In Mexico, the reverse appears to be true.

For Peru, the effects of US announcements are large, statistically significant, and persistent.

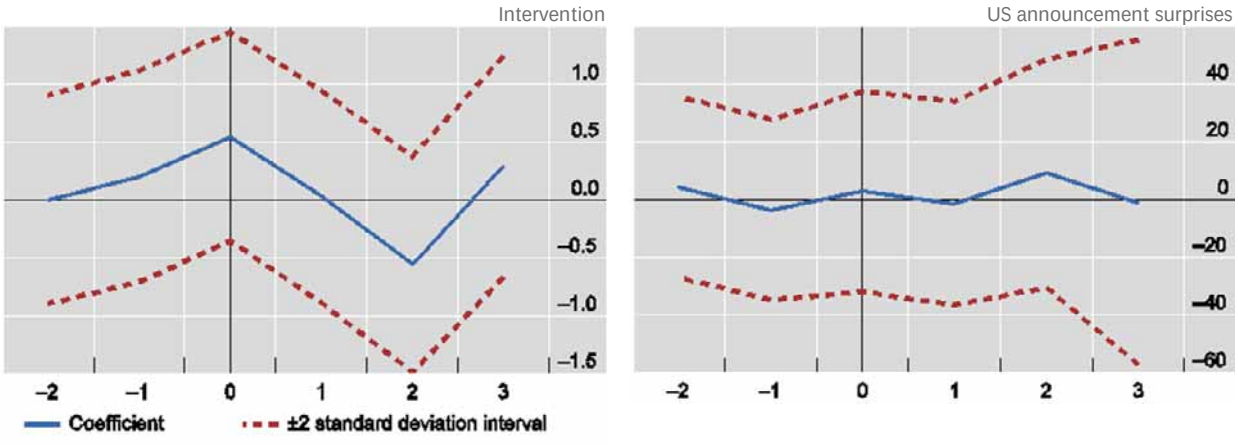
[46] For example the average transaction variance for the intervention sample is 1.202E-05, while the maximum estimate of the coefficients associated to the intervention in the regressions when using the quantities for the interventions and standardized announcement is below 1E-5, i.e. a 0.0043 relative effect.

The effects of intervention and US announcement surprises on the volatility of returns (lead and lag coefficients)

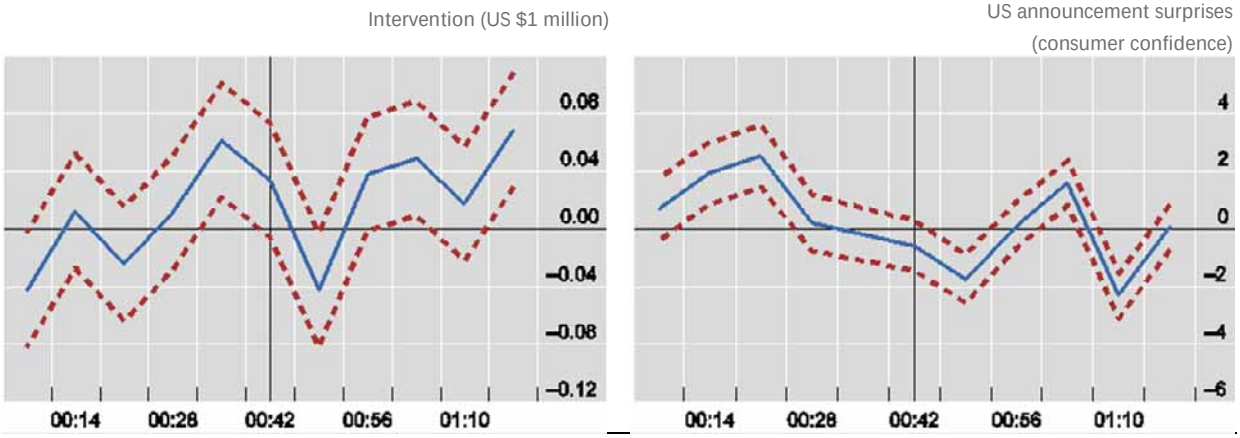
In basis points

Graph 6

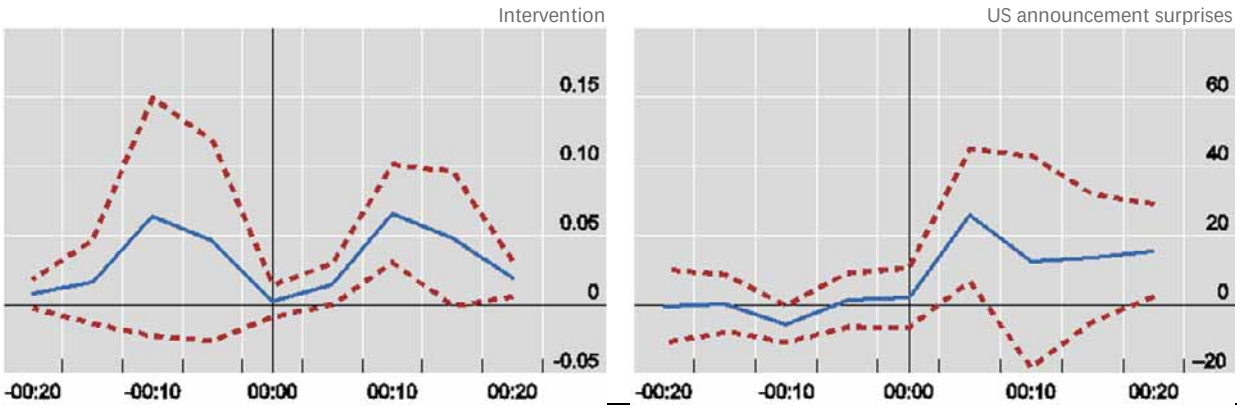
Chile



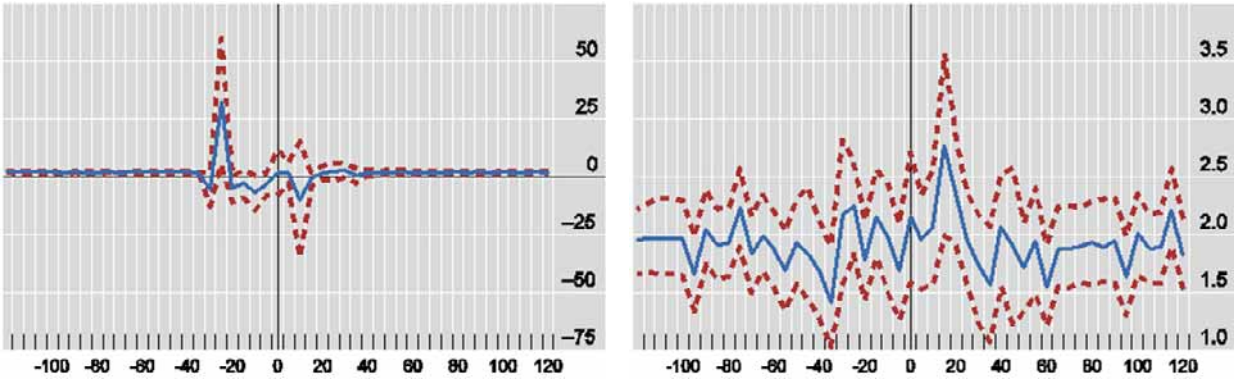
Colombia[1]



Mexico



Peru[2]



Vertical line indicates intervention time.

[1] (As indicated in the text) the intervention window is between 00:35 and 00:42. 2. 90 per cent confidence interval is included. The horizontal axis is measured in minutes. The vertical axis measures FX volatility measured as absolute value of returns.

Source: Central banks.

5. Effects of intervention and US announcements on market turnover (Colombia)

A novel feature of the Colombian dataset is that the volume of each trade is recorded, which allows computation of the market turnover on any set of intraday intervals of time. Therefore, the effect of the intervention on the market turnover may be assessed through an event study regression as in Dominguez (1999, 2003 and 2006).

What effect would we expect intervention to have on market turnover? The literature suggests that if intervention results in more market agreement on the exchange rate, market turnover should fall (Jorion (1996), Tauchen and Pitts (1983)). Furthermore, volatility should also fall, as a large body of evidence suggests that (detrended) volume is positively related to volatility.

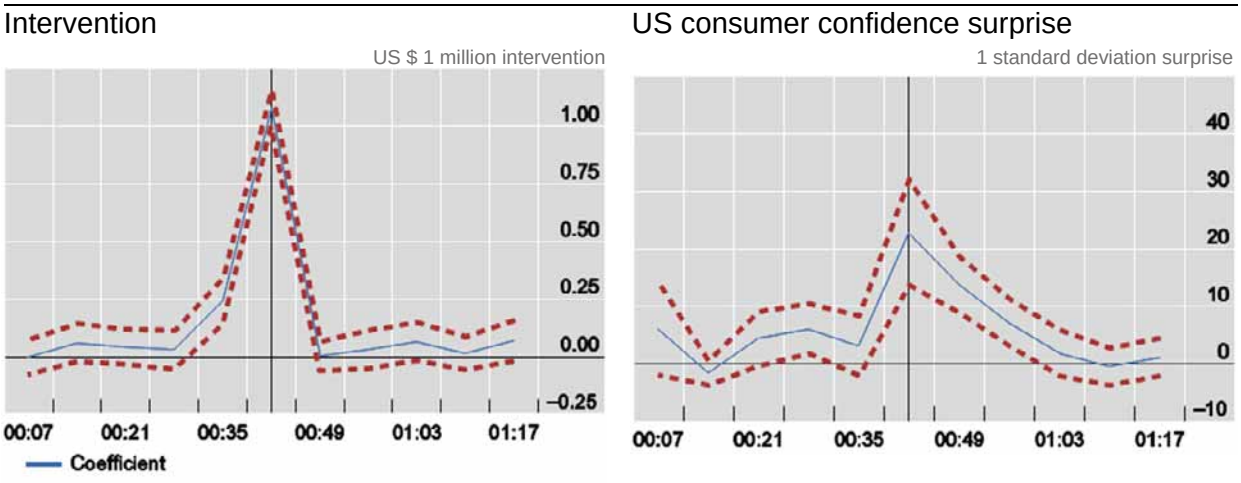
However, Colombia was not targeting the exchange rate over the sample period, so it is not clear ex ante whether more agreement on the exchange rate and lower market turnover should be expected. On the one hand, the regular purchases of foreign currency might have increased agreement that appreciation pressures would be dampened, reducing market turnover and volatility. In line with this, the regression results reported earlier indicate that a 20 million USD intervention significantly increases mean returns by 2.8 bp on impact, and reduces mean returns by 1.17 bp 7 minutes after the intervention. The exchange rate thus increases permanently by 1.63 bp after the intervention.

On the other hand, by improving resilience to external shocks, foreign currency purchases could also contribute to sharper appreciation and one-sided behaviour. In a setting in which appreciation pressures were already significant, market turnover and volatility could increase further.

Colombia: Effects of intervention and US announcement surprises on market turnover (coefficient values)

Millions of US dollars

Graph 7



Vertical line indicates intervention time.

Source: Central banks.

In Colombia during the sample period, Graph 7 shows that market turnover increases USD 4 million 7 minutes before intervention and USD 20 million on impact. It then falls sharply. One interpretation is that disagreement rises prior to intervention and falls after it. In line with this interpretation, the coefficients of volatility in exchange rate returns rise before the intervention, also peaking 7 minutes before the intervention and then fall at the time of intervention and some period later (volatility rises again sometime after the intervention, see Graph 7.) The implication is that intervention might increase agreement about exchange rates in the market, at least temporarily.

Further insights on the drivers of market turnovers are provided by the responses to the other explanatory variables.

- A 1 standard deviation US consumer confidence surprise is associated with a sharp increase in turnover on impact, with a much larger effect on turnover than the daily intervention. The increase in turnover effect is later partly reversed.
- The effect of VIX on market turnover is small, negative and very significant, much like the effect of the implied tax of capital controls.
- The coefficients related to lags of turnover reveal moderate turnover persistence. High persistence in turnover arises then from the persistence of the intraday market turnover seasonal.

Conclusions

Central banks have intervened for extended periods in fx markets in Latin American for significant amounts (from less than 2.5% of market turnover in Chile, Colombia and Mexico to over 30% of market turnover in Peru). Intervention may pose challenges for monetary policy implementation, impose quasi-fiscal costs (purchases of foreign assets generally yield lower returns than the debt sold to finance such purchases). They also raise questions about effectiveness.

The analysis of intervention using intraday data in (four) Latin American countries yields the following results.

First, high frequency intraday exchange returns are characterised by deviations from normality. In particular, returns exhibit heavy tails (high kurtosis) on no-intervention days but in a number of cases do not deviate from normality on intervention days. A possible interpretation is that intervention limits tail risks. As heavy tails could reflect is the risk of sudden crashes due to leverage, the implications of intervention for financial stability and possible channels of transmission (eg intervention might work by building buffers) warrant further examination.

Second, the evidence from Chile, Colombia and Mexico on sterilised, rule-based intervention that targets purchases/sales of preannounced quantities of foreign reserves has at most small and transitory effects on foreign exchange returns. The effects of such intervention on exchange rate volatility appear to be larger, but are also transitory. Also for rules-based interventions, the effects of intervention on exchange rate returns and volatility appear to be much smaller than the effects of US macroeconomic policy announcements, but such announcements also appear to have transitory effects. One implication is that sterilised, rule-based intervention intended to accumulate foreign reserves or to increase liquidity does not distort the price discovery mechanism in the foreign exchange market.

Third, the evidence from Peru suggests that sterilised, discretionary and unannounced intervention has significant effects on foreign exchange returns, although these are transitory. The evidence on the effect of intervention on the volatility of returns is mixed. On the one hand, an analysis of return volatilities indicates that volatility tends to fall after intervention on intervention days (while it rises on no-intervention days). On the other hand, the effects of intervention on volatility are not significant in event study regressions. However, given the much larger size of intervention (relative to market turnover) and lower volatility of returns in Peru, one explanation is that that success at stabilising exchange rate volatility (possibly by influencing expectations) masks the relationship between intervention and volatility in a regression. [47]

Fourth, an analysis of Colombian data suggests that intervention appears to increase market turnover before it takes place and on impact but the effect later declines. This could imply more market disagreement about the direction of the exchange rate before intervention, and greater agreement after it. The effects of intervention in this case are uncertain ex ante, given that the goal of the

[47] A structural VAR analysis that distinguishes between central bank purchases and sales of foreign currency also suggests that intervention in Peru is effective. See Lahura and Vega (2013).

intervention during the period under review was to accumulate foreign reserves for precautionary reasons, not to influence the exchange rate level or its volatility

To conclude, the preceding results suggest that while serving the goals of foreign reserve accumulation or of supplying foreign currency liquidity to the foreign exchange market, non-discretionary (rule-based) FX operations in Latin America have had very limited effects on the exchange rate, thus posing little or no risk of distorting pricing in FX markets. This is consistent with intervention being relatively small as a percentage of market turnover, and with the use of preannounced non-discretionary rules for intervention in Chile, Colombia and Mexico. In Peru, where intervention was much larger, and intervention was discretionary and not preannounced, the effects of intervention on returns appear to have been much larger. Also, intervention tends to (temporarily) lower exchange rate volatility and market turnover.

ANNEX

FX market data description and sources

Table A1

	Chile (tbc)	Colombia	Mexico	Peru
Sample period (estimation)		2 May 2007 to 23 Nov 2011	Whole sample: Jan 2003-Dec 2011 (June and Dec 2003 are not available). The estimation sample goes from October 9, 2008 to November 29, 2011. The period from November 30 to December 31, 2011 is excluded as (Type 3) interventions took place time at different times of the day. Notice that these took place in a period of less than 30 days.	5 January 2009 to 27 April 2011.
Days covered and Time span wihin day		(M-F except Colombian and US holidays). 8:00 am to 1 pm (5 hours long)[1]	Time span during a day: available data goes from 00:00 hrs.-23:55 hrs. Naturally one sees fewer observations in the very early or late parts of the day. Even so, for estimation we use the observations contained in the time windows surrounding either an intervention or a macro announcement. Thus, we use observations from 9:10 hrs.-13:20 hrs. in the no macro announcements case and from 7:10 hrs.–14:35 hrs. If macro announcements take place. This depends on the time stamps of each event.	(M-F except for Holidays) From 9:25 am to 1:30 pm.

Time stamped measurements	Time-stamped transactions prices (COP/USD) and quantities. traded in the electronic spot market (about 70% of the wholesale spot market in Colombia)	Time-stamped transactions prices (MXN/USD)	Time-stamped intervention transactions prices (PEN/USD) and volumes.

Source: Central bank authors.

FX market data description and sources (cont.)

Table A1

	Chile (tbc)	Colombia	Mexico	Peru
Data transformations			Following Dominguez (1999) we estimate a weighted average of the exchange rate prices closest to the time considered. For data points for which there are no contemporaneous bid and ask prices we first estimate the equidistant bid and ask separately, and then take the average.	5-minute FX transaction prices from Bloomberg. 5-minute aggregates of intervention transaction volumes.
Sampling frequency		7 minute intervals, 8:06 am-1 pm (ie drop first 6 minutes of trading day). Implies 43 price records per day, of which 42 used (overnight returns deleted)	Frequency changes in the sample. It depends on the bid, ask or transactions set by market participants. Thus to obtain the equidistant 5 minute interval we transform the data.	Equidistant 5-minute intervals.
Sample size (transformed data used in estimation): Prices		44705 prices including overnight returns (however overnight returns were deleted, as were days containing too few trades). These are over 1025 days (out of 1114 initial sample) taking into account optimal interval and data loss at beginning of trading day	Total sample: 622,367. Estimation sample: 215,424. Intervention: 288. No-intervention 1: 10,125. No-intervention 2: 9,297.	Excluding first observation in a day and holidays: 28650.
Sample size market turnover		44705 market turnover observations (one for each 7 minute interval)		Excluding holidays: 753 (daily data).

[1] "Next-day" trades are excluded from the dataset because this market is too shallow and represents less than 5% of the Forex market.

Source: Central bank authors.

FX market data description and sources (cont.) Table A1

	Chile (tbc)	Colombia	Mexico	Peru
Coverage intervention				
Coverage macroeconomic announcements				
Sources		SET-FX (centralized interbank FX electronic market service of Colombian Stock Exchange, BVC), Bloomberg	Reuters. The peso is a worldwide traded currency, so Reuters does not incorporate all of the information associated with the peso trading transactions worldwide. Yet, considering the size and depth of the peso exchange market (e.g. see BIS Triennial Survey (2010)) and barring arbitrage opportunities, we take the Reuters data as representative.	Time stamped spot intervention transaction is from DATATEC (centralized interbank FX electronic platform. Blind system in which bidders are known only to those involved in the transactions and after the transaction is closed). Macro announcements are obtained from Bloomberg.

Source: Central bank authors.

Control variables: macroeconomic surprises[1] and other controls

Table A2

Countries	International	Domestic	Source / Comments
Colombia, Mexico, Peru	US Consumer Confidence, CPI, Durable Good, Fed Funds Rate, Unemployment, Housing, Industrial Production, PPI, NAPM, Retail Sales, GDP, Trade Balance		Bloomberg. Motivation for these variables: A study by Andersen et al (2003) found that these variables affected the US dollar exchange rate against major currencies. They are selected on the expectation that they could also affect the value of the US dollar against Latin American currencies
Colombia		Monthly CPI inflation releases (usually in the evening), year-to-year GDP growth (usually during forex spot market trading hours), Bank of the Republic monetary intervention interest rate (usually after 1 pm). Time stamp of these releases is rounded to the minute of the release (no apparent prespecified schedule followed). Other controls: Daily implied tax	Bank of the Republic (Colombia)
Mexico		None included.	
Peru		None included	

1. In regression analysis use standardized surprise with respect to current expectation for the variable. See main text for details.

Source: Bloomberg and central bank authors.

Intervention operations

Table A3

	Chile (tbc)	Colombia	Mexico	Peru
Type of intervention and description		The Bank of the Republic (the central bank) announces a round of daily intervention lasting several months for USD 20 million through a 3 minute Dutch auction, in which the central bank purchases US dollars	Auction of dollars at a minimum price (Type 3). This mechanism sought to provide the necessary liquidity to address uncertainty and lack of liquidity in the foreign exchange market.	Intervention is mostly done via trading in the spot market through DATATEC (platform of FX interbank transactions). Intervention is performed in a discretionary way.
Timing of intervention within day		Timing discretionary, announced to market participants 2 minutes before the start of auction	This type of interventions took place on 9:30 am, 11:30 am and 1:00 pm.	Timing is discretionary within a day. Overall amount of intervention is announced to the participants once markets close.
Treatment (intervention) sample		387 days. From 24-Jun-2008 to 30-Sep-2011 three rounds of intervention: (i) 24-Jun-08 to 06-Oct-08, (ii) 03-Mar-10 to 30-Jun-10, and (iii) 15-Sep-10 to 30-Sep-11. In all rounds, the Bank of the Republic bought USD. The sample starts right after a period of fully discretionary intervention which ended on 1-May-2007	October 9, 2008 to April, 2010 and there be a positive allocation of dollars.	124 intervention days out of 568 days in sample.
Control (no-intervention) sample		638 days. Four no-intervention periods in the sample: (i) 2-May-2007 to 23-Jun-2007, (ii) 07-Oct-2008 to 02-Mar-2010, (iii) 1-Jul-2010 to 14-Sep-2010, and (iv) 3-Oct-2011 to 23-Nov-2011	Sample 1: days between April 12, 2010 and November 29, 2011 with no interventions. Sample 2: days between October 9, 2008 and April, 2010 where no dollars were allocated during the auctions. Again, this could be because the auction did not take place or it did take place but no dollars were allocated.	

[1] "Next-day" trades are excluded from the dataset because this market is too shallow and represents less than 5% of the Forex market.

Source: Central bank authors.

Intervention operations (cont.)

Table A3

	Chile (tbc)	Colombia	Mexico	Peru
Other considerations		Whenever there is a (usually small) residual amount not allotted in the auction, it is carried forward to the next day. Therefore, a slight variation around the USD 20 million target may be observed between the days of an intervention round. An intervention round may be extended or finished any time after a public announcement by the CCB	In the context of treatment sample and control sample 2, while we have defined these in terms of days, the key unit is the time window surrounding an event. For instance, if at 9:30 hrs. a positive quantity of dollars is allocated and at 11:30 hrs. no dollars are allocated, the former is part of the treatment sample and the latter is part of the control sample 2	
Data source / comments		Bank of the Republic (Colombia)	Reuters.	

Source: Central bank authors.

Intraday foreign exchange returns, whole sample (transactions data)[1]

Table A4

Rate	Time interval	Mean	Median	Variance	Skewness	Kurtosis
CLP/USD	5 min	0.00E+00		8.70E-02	–1.70E-01	12.60
	20 min	0.00E+00		1.49E-01	–1.31E-01	19.38
	1 h	–1.00E-03		2.57E-01	4.59E-01	18.33
	6 h	-5.00E-03		5.16E-01	3.29E-01	9.84
	24 h	–1.00E-02		7.62E-01	1.37E-01	5.83
COP/USD	7 min	6.00E-06	2.86E-06	1.22E-03	-0.08	16.21
	1 h	3.51E-05	4.97E-05	3.22E-03	-0.15	8.17
	5 h	2.52E-04	2.07E-05	7.32E-03	0.11	4.52
MXP/USD[2]	5 min	4.25E-07	0.00E+00	4.18E-07	–3.06	496.53
	1 h	5.10E-06	0.00E+00	5.01E-06	–0.67	60.41
	6 h	3.62E-05	–7.76E-05	2.92E-05	0.53	24.91
	24 h	1.00E-04	–4.45E-04	1.19E-04	0.61	17.19
PEN/USD	5 min	–2.50E–06	0.00E+00	3.51E–07	–0.16	209.50
	1 h	–9.54E–07	0.00E+00	2.30E–08	1.78	73.68
	6 h	–2.12E–06	–8.77E–07	4.06E–09	0.13	11.21
	24 h	–2.50E–06	–3.08E–06	2.28E–09	0.56	11.74

[1] For Chile average bid-ask. [2] Estimation sample. Using returns from the whole day (ie 24 hours).

Source: Central bank authors.

Intraday foreign exchange returns, intervention sample (transactions data)[1]

Table A5

Rate	Time interval	Mean	Median	Variance	Skewness	Kurtosis
CLP/USD	5 min	1.00E-03		9.00E-02	1.07E-01	8.01
	20 min	3.00E-03		1.57E-01	-1.20E-02	11.38
	1 h	7.00E-03		2.89E-01	1.70E-02	14.40
	6 h	3.80E-02		5.87E-01	2.14E-01	6.67
	24 h	7.10E-02		8.91E-01	1.76E-01	4.26
COP/USD	7 min	1.05E-05	9.47E-07	1.25E-03	-0.09	26.42
	1 h	7.06E-05	8.67E-05	3.28E-03	-0.53	14.10
	5 h	4.39E-04	5.39E-04	7.84E-03	-0.12	7.90
MXP/USD[1]	5 min	1.27E-04	9.09E-05	1.20E-05	1.47	41.34
	1 h	9.03E-04	1.65E-03	6.28E-05	–2.78	15.18
	6 h	7.39E-03	8.33E-03	1.07E-04	–1.45	7.69
	24 h	2.39E-02	2.04E-02	1.29E-04	2.45	11.39
PEN/USD	5 min	1.62E–06	0.00E+00	3.83E–07	0.23	90.91
	1 h	3.24E–06	0.00E+00	1.54E–08	–0.24	46.05
	6 h	3.34E–06	–8.77E–7	2.15E–09	3.30	29.87
	24 h	1.62E–06	–2.14E–6	7.76E–10	2.41	17.25

[1] For Chile, average bid-ask. [2] Considering returns only from the windows around the interventions.

Source: Central bank authors.

Intraday foreign exchange returns, no-intervention sample (transactions data)[1]

Table A5

Rate	Time interval	Mean	Median	Variance	Skewness	Kurtosis
CLP/USD	5 min	0		8.60E-02	-2.50E-01	13.94
	20 min	-1.00E-03		1.47E-01	-1.68E-01	21.90
	1 h	-3.00E-03		2.49E-01	6.09E-01	19.60
	6 h	-1.40E-02		4.99E-01	3.46E-01	10.92
	24 h	-2.70E-02		7.30E-01	8.60E-02	6.33
COP/USD	7 min	3.29E-06	4.60E-06	1.20E-03	-0.08	8.82
	1 h	1.36E-05	1.75E-05	3.18E-03	0.09	4.14
	5 h	1.38E-04	-3.61E-04	7.65E-03	0.25	2.35
MXP/USD[2]			No-intervention sample 1			
	5 min	1.35E-05	7.46E-06	4.02E-07	0.66	17.64
	1 h	8.76E-05	–1.66E-05	4.48E-06	0.66	9.32
	6 h	1.83E-04	–6.11E-05	2.40E-05	0.44	5.37
	24 h	4.52E-04	–1.81E-04	5.91E-05	0.43	6.22
			No-intervention sample 2			
	5 min	1.21E-05	1.61E-05	9.02E-07	–0.20	37.42
	1 h	1.19E-04	5.14E-05	1.19E-05	0.66	20.98
	6 h	–5.32E-04	–2.48E-04	6.08E-05	–0.68	9.29
	24 h	–8.78E-04	–9.52E-04	1.18E-04	–0.67	9.94
PEN/USD	5 min	–3.64E–06	0.00E+00	3.42E–07	–0.29	250.31
	1 h	–2.12E–06	0.00E+00	2.51E–08	2.04	74.28
	6 h	–3.64E–06	–1.88E–6	4.58E–09	–0.12	9.31
	24 h	–3.64E–06	–3.46E–6	2.69E–09	0.50	10.37

[1] For Chile, average bid-ask. [2] Considering returns only from the windows around the interventions.

Source: Central bank authors

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