On central bank interventions in the Mexican peso/dollar foreign exchange market[1,2]

Santiago García-Verdú[3]
Bank of Mexico

Miguel Zerecero[4]
Bank of Mexico

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Abstract

In recent years the Bank of Mexico has made a series of rules-based interventions in the peso/dollar foreign exchange market. We assess the effectiveness of two specific interventions that occurred in periods of great stress for the Mexican economy. The aim of these two interventions was, respectively, to provide liquidity and to promote orderly conditions in the foreign exchange market. For our analysis, we use the framework implemented by Dominguez (2003) and Dominguez (2006), an event-style microstructure approach based on bid-ask spreads as a measure of liquidity and of orderly conditions. In general, our results show no indication of an effect in the opposite direction from the one intended for the first intervention and are fairly conclusive regarding a significant reduction on the bid-ask spread for the second intervention.

Keywords: foreign exchange rate, central bank interventions, microstructure.
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[3] Adviser to the Board, contacting author: sgarciav@banxico.org.mx
[4] Economist, Directorate of Economic Studies, General Directorate of Economic Research.

Introduction

This paper has a twofold objective. First, we seek to outline the peso/dollar market's organisation, as well as the behaviour of the intraday peso/dollar exchange rate and, in particular, the dynamics of its bid-ask spread. Second, we assess two specific types of intervention that were intended, respectively, to provide liquidity and to promote orderly conditions in the foreign exchange market. To measure liquidity and the degree of orderliness in the foreign exchange market, we use the exchange rate bid-ask spread. Where the bid-ask spread diminishes, we interpret this as an increase in liquidity and/or more orderly conditions, other things being equal, and vice versa. There are, of course, several challenges when it comes to measuring an intervention's effectiveness. Of particular concern are the construction of the control sample and the selection of a set of control variables.

To this end, we follow the approach proposed by Dominguez (2003) and Dominguez (2006). Specifically, we use a study-event microstructure approach to interventions. In the same way as Dominguez, we use intraday data and control for a selected set of macroeconomic variables with a view to accounting for differences in the macroeconomic scenario when comparing the dynamics of the exchange rate both during an intervention and at other times.

In recent years, Mexico has implemented several types of intervention. Instead of attempting to assess every intervention, we focus for the following reasons on two specific types. First, these two interventions took place in the same time period and had similar aims and characteristics. This allows us to use bid-ask spreads to measure the effectiveness of both interventions. The first type of intervention was by far the most important one in terms of dollars tendered.[5] We leave the analysis of other types of intervention to be undertaken by future researchers.

It has been established in the literature that some short-run aspects of the exchange rates cannot be explained by conventional asset pricing models (Sarno and Taylor (2002)). It is the microstructure approach that often sheds light on our understanding of the short-run behaviour of the exchange rates and, in particular, on the effectiveness of central bank interventions in the foreign exchange market.

The effectiveness of intervention has been a matter of much debate in the literature (Sarno and Taylor (2002)). In fact, Dominguez and Frankel (1993) challenged the conventional wisdom of the time, which was that interventions were essentially

[5] Note that we refer to the amount tendered, not to the amount allocated.

ineffective. But improved data availability during the past several years has helped to change the perception of their effectiveness.

Our main results can be summarised as follows. For the first intervention, there is no indication of an effect in the opposite direction from the one intended and, for the second, there is fairly conclusive evidence for a significant reduction in the bid-ask spread. These results hold even though we have considered several specifications. We explore some of the reasons why this might be the case. Further research is thus warranted.

The rest of the paper is divided into seven sections. In the first, we present a brief literature review. The second describes the organisation of the peso foreign exchange market, highlighting certain characteristics that might have implications for our results. The third section outlines the different types of intervention implemented by the Bank of Mexico in the recent years, particularly the ones we analyse in this paper. The next section examines several key aspects of the data, including some statistics. The fifth considers the use of the bid-ask spread to measure liquidity and orderly conditions in the foreign exchange market. The sixth assesses the effectiveness of a specific type of intervention, using the bid-ask spread as a yardstick. The last section concludes.

Literature review

We divide our literature review into two parts. In the first part, we recap several topics in the interventions literature. Our survey is based on Lyons (2001), Sarno and Taylor (2002), and Vitale (2005). We include this overview to make our paper as self-contained as possible. In the second part, we summarise what we believe is the most relevant research on interventions on the Mexican peso/dollar exchange rate.

A key issue is the rationale for interventions. A long strand of literature explores this issue. For example, one theme is the so-called wrong rate argument. On this view, the authority believes that the exchange rate does not reflect the prevailing fundamentals of the economy. This rationale hinges upon the assumption that the authority has an informational advantage with respect to market participants. In effect, one can presume that a central bank knows more about future monetary policy than market participants. Nonetheless, there are some drawbacks. For example, authorities may not be in a position to determine the equilibrium exchange rate based on economic fundamentals. If that is the case, an intervention might have unintended side effects.

Second, an intervention's effects depend crucially on whether or not it is sterilised. When it is unsterilised, the effects of an intervention are similar to those of an open market operation, as the monetary base is changed. The key difference is that, in an unsterilised

intervention, the bank uses mainly foreign assets, while in an open market operation it uses domestic assets.

In the case of a sterilised intervention, by contrast, the literature has focused mainly on two possible channels through which it might take effect, namely, the portfolio balance and the expectations or signalling channel. We look at each in turn.

In the portfolio balance channel as an intervention takes place, financial institutions (eg) buy dollars directly from the central bank. In the sterilisation process, the central bank buys domestic bonds from the public. Thus, the relative supply of domestic to foreign bonds decreases. If domestic and foreign bonds are imperfect substitutes, then their relative prices would change, lifting the exchange rate.

In the Mexican-US case, it is reasonable to assume that domestic and foreign bonds are imperfect substitutes.[6] Frankel (1982) and Obstfeld (1983) find that, in the Deutsche mark/dollar foreign exchange market, the portfolio balance effects are small. For their part, Dominguez and Frankel (1993) make the case for the importance of this channel using the deviations from the UIP as a measurement of risk premium in the foreign exchange market.

An underlying assumption in the portfolio channel argument is whether Ricardian equivalence holds. To see this, suppose that the foreign and domestic bonds are perfect substitutes. Now, say, that financial institutions buy dollars from the central bank and that the sterilisation process involves the central bank buying domestic bonds from the public, leading to a reduction in the relative supply of domestic bonds. If these bonds were perfect substitutes, the argument goes, their relative prices would stay put. Nonetheless, suppose that they are perfect substitutes *but* also that Ricardian equivalence holds. Accordingly, as agents know that the domestic government will eventually need to obtain additional revenues from other sources, they would then increase their savings, which would partially offset the intervention effect. In sum, the perfect substitutability of bonds is not a sufficient condition for the portfolio channel effect to be present.

Second, the expectations or signalling channel will have an effect if participants perceive the intervention as signalling the central bank's intentions with regards to its future monetary stance (Mussa (1981)). In this case, it is irrelevant whether domestic and foreign bonds are substitutes or not. Dominguez (1987) studies the central authority's capability to signal its monetary policy intentions.

[6] One might argue that the substitutability has increased in recent years.

In our case, an effect through the expectations channel is most probably weak insofar as the interventions considered are rules-based. Nonetheless, the actual policy variable of the period in which the intervention is active or some variations as to their implementation might play some role in this respect, presumably at a low frequency. It is worth pointing out that the central bank's aims of providing liquidity or promoting orderly conditions do not preclude these channels from playing a part. Yet, we do not intend to quantify these effects.

Third, a closely related issue is whether an intervention should be public, rules-based, and transparent, or whether it should be discretionary and private. On the one hand, to rephrase Kenen (1988), the rules of the foreign exchange market need to be as transparent as possible to maintain credibility. Thus, the authorities have an incentive to clearly convey their intentions for the expectations channel to be more effective. On the other hand, Dominguez and Frankel (1993) have considered whether the authorities might have an incentive to keep the effects of an intervention to a minimum under some circumstances and, in such cases, to make it private and discretionary. Cuckierman and Meltzer (1986) argue that a public intervention under an adverse macroeconomic environment, for example if the authority lacks a high degree of credibility, might be unfavourable. Another case might be when a central bank wishes only to readjust its reserves portfolio and, thus, chooses a stealth intervention.

Fourth, there is the question of whether coordinated interventions by authorities in two countries are more effective than an intervention implemented by just one country on its own. The main rationale for such an approach is the potential for policy spillovers. Thus, for instance, if two interventions are intended to have opposite effects, it is in the authorities' interests at least to share some information. In this matter, Kenen (1995) has found that coordinated interventions have tended to be more effective than unilateral ones. In the case of an unsterilised coordinated intervention, the effect on the exchange rate would be affected by the relative monetary policy stance.

Coordinated interventions between sovereign entities can be studied under the framework of non-cooperative repetitive games. They entail governmental strategies. For example, Buiter and Eaton (1986) study optimal monetary policies in interdependent economies. In general, the literature recognises that important gains can ensue from cooperation, although an equally important issue is to understand when governments have the incentive to cooperate and, thus, when they are more likely to reach a cooperative equilibrium.

Sixth, a key point is whether the model at hand assumes rational expectations. In such a case, as is well known, there is a joint hypothesis problem. In assuming rational expectations and rejecting a model, one never knows whether the rejection is due to a violation of rational expectations or to the model. In this respect, Dominguez and Frankel (1993) have as a relative advantage that they do not assume rational expectations, and are capable of jointly measuring the effects of both channels. They find strong evidence that a sterilised intervention affects the exchange rate through both channels. In addition, they find that the effect is augmented if the intervention is publicly announced, which is consistent with Kenen (1988).

Seventh, an important thread of the literature is the study of the central bank's reaction function. It is challenging both to posit and estimate a reaction function because central banks take into consideration several elements when making a decision to intervene. We conjecture that formulating a reaction function is less of challenge when the interventions being considered are rules-based.

Moving on to the research on the Mexican peso exchange rate literature, we would like to highlight the following papers. In addition, it is worth mentioning that this part of the literature is at an exploratory stage.

First, Sidaoui (2005) provides an excellent overview of the Bank of Mexico's interventions between 1995 and 2004. The start of this period was marked by three key events: the Mexican crisis, the depletion of Mexico's international reserves, and the peso's flotation.

Second, Archer (1995) provides a description of the intervention methods used in different countries. He analyses how the methods implemented by the authorities depend on the aims and the macroeconomic environment. Also, he highlights the design of interventions in the Mexican case, particularly the preannounced quantities and rules that triggered the intervention with a view to ensuring transparency.

Third, Isshi et al (2006) present an extensive study of foreign exchange interventions, using Mexico and Turkey as case studies. Interestingly enough, these authors point to some of the possible reasons why interventions in developing economies might be more effective than those in advanced economies. In particular, they argue that "many [emerging market] countries intervene in amounts that are large relative to market turnover. They also use a variety of foreign exchange, monetary, and banking regulations that effectively constrict the size of the market, increasing the central bank's size in it".

Fourth, Broto (2012) compares the effects of intervention in four Latin American countries, namely, Chile, Colombia, Mexico, and Peru. She finds that the effect is differentiated according to whether foreign currency is bought or sold. She also finds that,

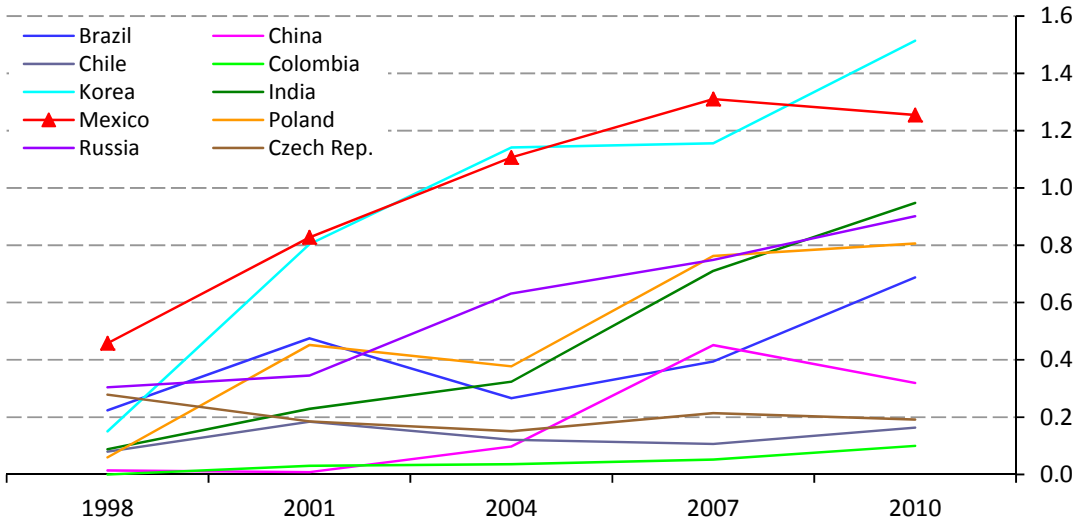
in general, volatility is reduced by the interventions and that the intervention's size plays a minor role.

Fifth, Domaç and Mendoza (2004) argue that in Mexico central bank foreign exchange sales were generally effective in influencing the exchange rate. Moreover, Guimarães and Karacadag (2004) find only weak supportive evidence for an effect of one intervention on the level of the exchange rate in Mexico. Furthermore, Guimarães and Karacadag (2004) do not find that the interventions had a significant impact on exchange rate volatility.

Description of the peso/dollar foreign exchange market

The Mexican peso is the world's 13th most transacted currency according to the BIS *Triennial Central Bank Survey of Foreign Exchange and Derivatives* (2010).[7] As shown in Figure 1, which presents the average daily turnover volumes in the global foreign exchange market for a group of selected currencies, turnover in the Mexican peso has exceeded those of the Brazilian real, the Russian rouble, the Indian rupee, and the Chinese renminbi in recent years. And these volumes increased significantly during the years considered in this study.

Figure 1
Turnover in the global FX market for selected currencies[1,2]
(% daily average transaction volume)



1. As all transactions involve two currencies, the totals add up to 200%.
2. Each datum is with respect to April of each year.
Source: BIS *Triennial Central Bank Survey of Foreign Exchange and Derivatives* (2010).

[7] Other related surveys are those made by the Federal Reserve Bank of New York and the Bank of England. Their results are for the most part consistent with the data presented in this section.

The peso foreign exchange market has several significant characteristics. First, Table 1 presents the average daily turnover in the spot, forwards and swaps markets. As shown, the swaps market accounts for the bulk of these transactions. Second, since May 2008, the peso's window of operation has been extended to 24 hours. In that month, the Mexican peso joined the Continuous Linked Settlement (CLS), the largest multi-currency cash settlement system in the world. Besides extending its hours of operations, this development has helped to reduce the peso's settlement risk. Thus, the currency's CLS accession has undoubtedly been very significant, as we explain in more detail below.

Table 1
Average daily turnover
(in millions of US dollars)

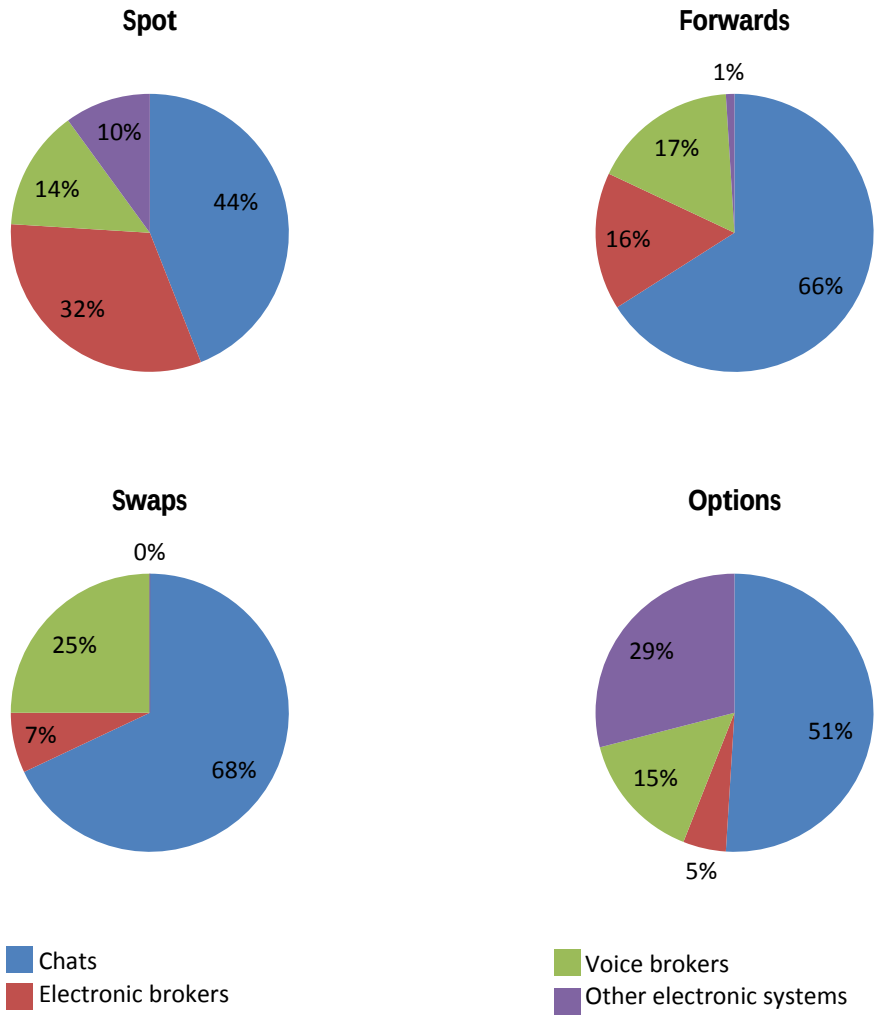
	Spot	Forwards	Swaps
Banks and stock exchange	4,770	644	14,683

Source: Bank of Mexico.

Third, the platforms on which the exchange takes place may play a role in the currency's dynamics. As is apparent in Figure 2, the most common means of transacting the Mexican peso in the spot market is through chats, followed by electronic and voice brokers. The most common transaction methods for forwards and swaps are through chats, followed by electronic and voice brokers. Currency options are for the most part over the counter (OTC), and are mainly transacted via chats, followed by other electronic systems. As is apparent, chat systems have gained in popularity thanks to their convenience, low cost, and reliability. London is the most important market for derivatives on the Mexican peso, followed by the US markets.

All in all, the Mexican peso market has made significant progress in recent years in terms of its depth, liquidity, and settlement risk. In fact, turnover in the spot and associated markets is now comparable to that of currencies belonging to the most financially developed countries.

Figure 2
Comparing different platforms in the peso foreign exchange markets (2010).



Source: Bank of Mexico.

Interventions in the peso/dollar foreign exchange market

The central bank's interventions in the peso/dollar foreign exchange market are a relevant topic for many reasons. To begin with, the exchange rate is an important channel of monetary policy, so that any variation in monetary policy stance might affect, albeit indirectly, the exchange rate. Second, the peso foreign exchange market has grown vigorously, together with its options and futures offshoots. Third, the exchange rate is probably one of the Mexican economy's most important prices, given the condition of an open economy in terms of both capital flows and trade. Also of relevance is the sheer

volume of remittances sent to Mexico from the United States. Fourth, and perhaps most importantly, interventions are one of the key macroeconomic policy tools at the disposal of governments. Thus, understanding their effects should be of fundamental interest to policymakers.

In the Mexican case, the entity responsible for deciding on interventions and on matters relating to the structure of the foreign exchange market is the Foreign Exchange Commission (*Comisión de Cambios*). This body comprises the Secretary and a Deputy Secretary of the Secretariat of Treasury and Public Credit (*Secretaría de Hacienda y Crédito Público (SHCP)*, a second Deputy Secretary of the SHCP, the Governor of the Bank of Mexico, and two members of its Board of Governors. Operationally the central bank is responsible for implementing interventions.

In recent years, the Bank of Mexico has usually intervened according to a rules-based approach. Typically, the aims have been to provide liquidity, to promote orderly market conditions, to reduce volatility in the foreign exchange market and to change the rate of reserves accumulation.

While we will focus on two specific interventions, in what follows we provide a brief overview of all interventions undertaken in recent years. The main characteristics of other interventions are of significance for this study as they took place during one of the periods we have used for our control sample.

1. *Auction sales of dollars to reduce the rate of reserves accumulation*. This mechanism is intended to reduce the rate of accumulation of international reserves, as its name suggests. The implementation was announced on 7 March 2003. The intervention was then active from 2 May 2003 to 1 August 2008. The amount tendered was USD 30,082 million. The intervention's timestamp was 09:30., lasting for two minutes. This type of intervention was on four occasions followed by a second auction on the same day: on 26 June 2003; 12 November 2004; 23 March 2005; and 22 April 2005.
2. *Extraordinary auction sales of dollars.* This intervention was intended to provide the liquidity needed to improve the conditions in an environment of uncertainty and lack of liquidity in the foreign exchange market. It was implemented on five days only: 8, 9, 10, 16 and 23 October 2008. The amount tendered was USD 12,502 million.
3. *Auction of dollars with a minimum price.* This was one of the two interventions that we focus on in this paper.

   As in the case of the Type 2 intervention, the aim was to provide the funds needed to combat uncertainty and lack of liquidity in the foreign exchange market. This intervention was initially active from 9 October 2008 to 9 April 2010. The total

amount tendered between 2008 and 2011 was USD 351,058 million. The auctions took place three times a day: at 09:30, 11:30 and 13:00, lasting for five minutes on each occasion. We refer to this period as the first episode. The intervention was repeated on 30 November 2011. Starting on that date, the intervention times were changed to 09:00, 12:00 and 15:00. We refer to this period as the second episode. In this paper we focus on the first episode, for the reasons explained below.

It is worth mentioning that several changes were made to the maximum allocated daily amount. On 8 October 2008, the commission announced that, as of the next day, this type of auction would take place with a maximum allocated daily amount of USD 400 million. On 5 March 2009 the commission announced that, as of 9 March, the maximum allocated daily amount would be USD 300 million. On 29 May 2009, the commission announced that as of 9 June the maximum allocated daily amount would be USD 250 million.

In what follows, we explain some of the auction's logistics in more detail. The auction's minimum price was set at the previous working day's exchange rate plus 2%. More precisely, $\text{min\_price}_t = p_{t-1} \times 1.02$ where p_{t-1} is equal to the FIX exchange rate of day T–1 if no auction took place the day before, or the average price of the auction of day T–1, if an auction took place. The minimum price is the same for each auction on the same day.

Auctions are convened some minutes before they actually take place.[8]

The participants place each bid as a function of a price (p_i) and a quantity (q_i). The time that a bid is placed is also relevant (t_i) in case of draws. Thus, in order for any participant to obtain an allocation, a necessary condition is to have his bid be $p_i \geq \text{min\_price}_t$. As mentioned, auctions last five minutes.

Denote the maximum possible allocated daily amount by M. The maximum possible allocated amount in *each* auction depends on M and the amount actually sold in the previous auction on the same day.

Thus, M_9, M_{11}, M_{13} denote, respectively, the maximum possible allocated amount in the 09:30, 11:30 and 13:00 auctions. In addition, n denotes the number of participants in the auctions. To clarify this matter, suppose that $p_1 \geq p_2 \geq p_3 \geq \ldots \geq p_n$.

For the 9:30 auction, M_9 always equals M. Once bids are in, if $\Sigma p_i q_i \leq M_9$ then the central bank starts allocating the dollars to the highest bidder, then to the next

[8] The FIX exchange rate is an average of wholesale market quotes obtained from electronic trade platforms and other electronic sources that are representative of the foreign exchange market. These quotes are collected three times a day, between 09:00 and 12:00, and the resulting average is the exchange rate known as the FIX.

highest bidder, and so forth, until all bids are satisfied. Being a multiple price auction, each participant obtains the price they bid at.

If $\Sigma^n p_i q_i > M_9$, then the participants are notified of the minimum price at which they must rebid if they are to have a chance of getting some dollars assigned, the so-called marginal price.

If the new round of bids is such that $\Sigma^n p_i q_i \leq M_9$, then the dollars are assigned and the auction is over. If, however, the bids are such that $\Sigma^n p_i q_i > M_9$ before the time is up, the participants are notified of the new marginal price, and so forth.

If $\Sigma^n p_i q_i > M_9$ by the time is up, the auction is over and the dollars are allocated until $\Sigma^m p_i q_i \geq M_9$, where $m \leq n$. It might be the case that the m^{th} participant might not get his full amount assigned, q_m. If that is the case, participants $m+1^{th}$, $m+2^{th}$, … , n get no allocation.

For the 11:30 auction, let M_{11} equal to $\max\{M_9 - \Sigma^n p_i q_i, 0\}$, where the $\{(p_i,q_i)\}^n$ are the prices and quantities assigned in the 09:30 auction. If $M_{11} = 0$ then there is no 11:30 auction. Otherwise the auction is implemented as the 09:30 auction, except for the fact that M_{11} is the new maximum amount.

For the 13:00 auction, likewise, let M_{15} equal to $\max\{M_{12} - \Sigma^n p'_i q'_i, 0\}$, where $\{(p'_i,q'_i)\}^n$ are the prices and quantities associated with the 11:30 auction. If M_{12} is 0 then there is no 15:00 auction. Again, the auction is otherwise implemented as the 13:00 auction except that M_{13} is the new maximum amount to be auctioned.

If, in any auction, there is a draw in terms of the bid price, the participant that sent its bid first has preference over the other. At the end of each auction, the bids are made known to the participants, but the institutions' names associated with them are not revealed.

4. *Auction of dollars without minimum price.* This is the second intervention that we study here. It is intended to promote orderly conditions in the foreign exchange market and was established as a mechanism for selling a significant portion of the projected accumulation of international reserves in the exchange market. The auctions took place from 9 March 2009 to 30 September 2009 with a tender amount of USD 10,250 million. The timestamp for this intervention was 09:10, lasting for five minutes. This was followed on three occasions by a second intervention on the same day: 25 March 2009; 1 April 2009; and 3 April 2009 at 10:00, lasting five minutes each.

   The nature of the auction for the Type 4 intervention differs from the Type 3 intervention by having no minimum price and no triggering rule. In effect, the auction is convened every working day. There is a daily maximum amount.

The auctions are interactive, ie participants know the bids during the auction and could improve their bid. More specifically, participants present their bids with a continuous knowledge of the marginal price.

This new intervention policy remained current until 8 June 2009. On 29 May 2009, the Exchange Rate Commission announced modified terms and conditions for the ensuing months, reducing the maximum amount of auction sales from USD 100 million to 50 million per day starting from 9 June until 8 September 2009. On 1 September, it was announced that the auctions would be continued until 30 September and suspended on 1 October 2009.

5. *Dollar credit auction.* The resources for this auction came from the swap line negotiated with the Federal Reserve. These were used to conduct auctions of dollar credits among domestically based corporations.[9] The first and only auction took place on Tuesday 21 April 2009, in which USD 4,000 million was tendered. The auction started at 12:30, lasting for 30 minutes.
6. *Auction sales of dollars (put) options.* This mechanism was intended to support the accumulation of international reserves. The auctions took place at 12:30, lasting 30 minutes on each final working day of the month between 26 February 2010 and 31 October 2011. In this auction, the central bank sold put options on dollars. The holder had, for a month, the option but not the obligation of buying a given amount of dollars to the central bank provided that the prevailing exchange rate was below a moving average of the exchange rate.[10]
   In our case, this intervention was implemented on the dates surrounding one of our non-intervention samples. In this regard, although the options can be exercised at any time during the one-month horizon, they are specifically designed not to affect the foreign exchange market in the period, as the option holders are able to exercise them only when there is a relative excess of dollars in the market.
7. *Direct sales (discretionary)*. This type of intervention was intended to attenuate the volatility of the foreign exchange market. The associated auctions took place on 4, 5, 6, 20, 23 and 27 February 2009. The Foreign Exchange Commission established the tendered amounts and exact timing.

[9] According to the Bank of Mexico's press release of 29 October 2008, the swap lines were set between the Bank of Mexico, the Federal Reserve, the Central Bank of Brazil, Bank of Korea, and Monetary Authority of Singapore. These were intended to help improve liquidity conditions in global financial markets and to combat difficulties in obtaining US dollar financing in well managed economies with strong fundamentals.

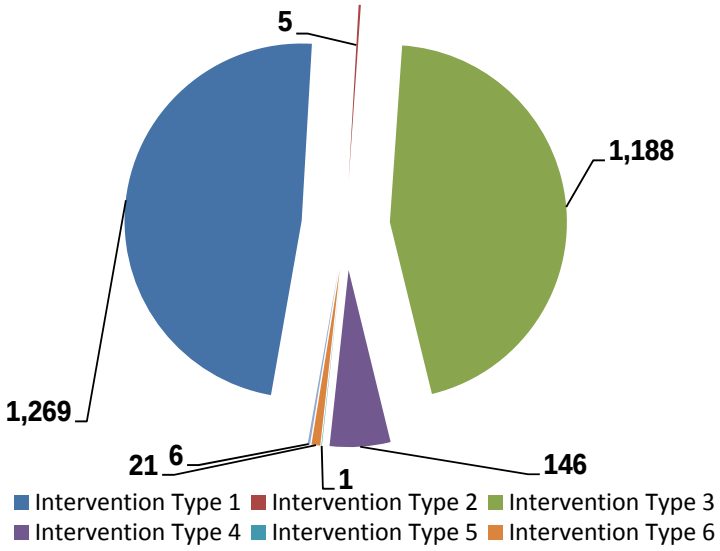
[10] In other words, this is an American put option with an expiration horizon of a month and a strike price that is a function of a moving average of the underlying.

All these interventions were sterilised. Essentially, as part of the daily operations of Bank of Mexico, the money market's liquidity requirements are estimated daily subject to the exigencies of the monetary policy stance. Thus, the results of each intervention auction are notified to the office that plans the daily liquidity requirements in the money market. This office then takes into account the auction's results, in effect, sterilising the intervention. As previously discussed, the effect of an intervention depends crucially on whether it is sterilised.

In this context, to give a sense of the relative importance of the different types of interventions, Figures 3 and 4 depict, respectively, the number of interventions and the tendered amounts of each type. Note that these data refer to the tendered amounts, not the actual allocated amount. By the number of interventions, Type 1 and Type 3 are clearly ahead of the pack. Yet, by the total amount tendered, the Type 3 intervention comes out on top, which speaks to its relative importance. Information on the Type 7 intervention is not included since it is not publicly available.

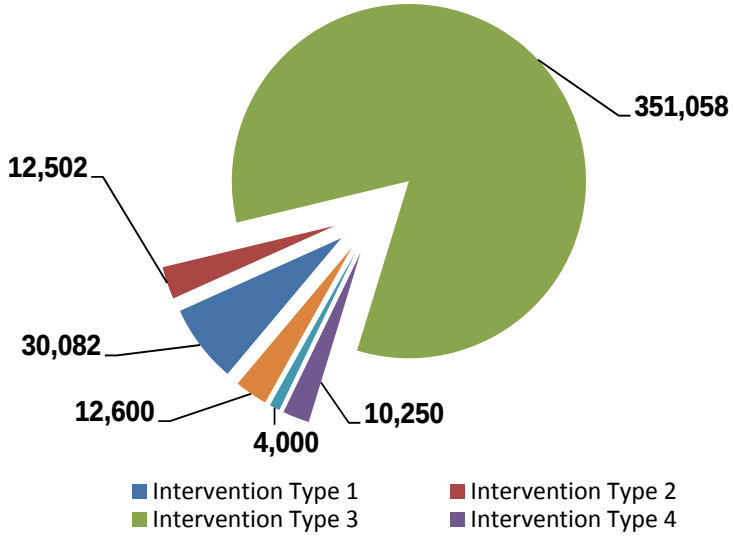
Figure 3

Number of interventions



This figure depicts the number of interventions of each type, regardless of the amount offered. Type 1 and Type 3 account for the bulk of these interventions.

Figure 4
Total amount tendered in each intervention type
(Millions of US dollars)

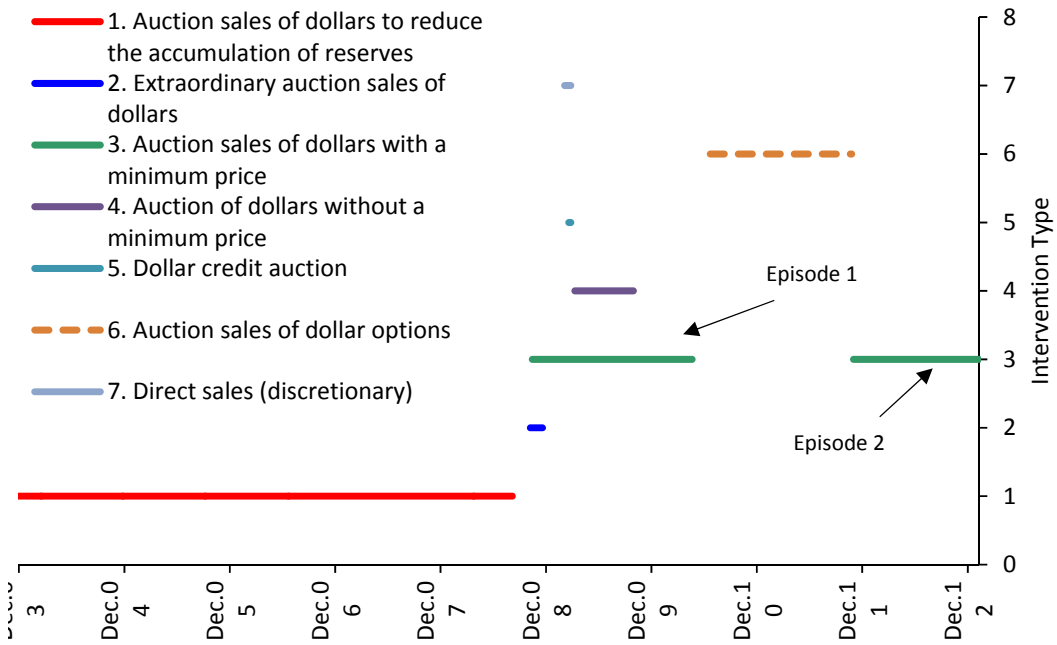


Total amount offered in each intervention type, in millions of US dollars. Type 3 interventions account for more than three quarters of the total amount tendered.

Figure 5 gives a broad picture of the time periods in which the interventions were implemented. Note that this is a snapshot of the actual intervention days, as auctions only take place on specific days. Also recall that the Type 6 intervention is implemented only on the last day of each month.

More concretely, the Type 3 intervention overlaps with Type 2 interventions (on 9, 10, 16 and 23 October 2008), Type 4 (during its entire duration), Type 5 (4 April 2009), Type 6 (on 26 February 2010 and 31 March 2010) and Type 7 (on 4, 5, 6, 20, 23 and 27 February 2009). The total number of days that interventions other than Type 3 were active was 152, (143 for Type 4, 1 for Type 5, 2 for Type 6, and 6 for Type 7). The different timestamps of these interventions are: Type 4 at 09:10, and Type 5 and 6 at 12:30. For Type 7, the timestamp was established by the Foreign Exchange Commission because this was a discretionary intervention. In sum, these events are deemed to comprise our control sample.

Figure 5
Intervention calendar



Source: Bank of Mexico.

By law, the National Oil Company (Pemex) sells to the central bank the dollars it obtains from its exports. Naturally, the central bank sterilises this operation. This is potentially important for the following reason. On the one hand, from a partial equilibrium perspective and being off-market, these transactions should not be a matter of great concern for our study. On the other, from a general equilibrium perspective, the quantity of dollars the central bank obtains from Pemex could have an impact on the bank's decisions. In addition, there is a data availability issue. The associated time series are only available on a weekly basis. Thus, we do not use these time series in our analysis.

Data

The exchange rate data are from Reuters. The Reuters system does not register all peso/dollar transactions worldwide. As is the case for the vast majority of foreign exchange markets, the peso/dollar market is rather decentralised. Thus, although there are systems that collect data on a significant portion of the transactions, inevitably some are not captured. The underlying assumption in the analysis is that the Reuters database is representative of all transactions taking place worldwide.

We have data for bids, asks and transactions. A natural question is to what extent a bid or an ask price reflects an actual price. In this respect, if a bid or an ask is submitted to the

trading platform, the party that sends it and the one that responds are obliged to follow through on the transaction.[11] Hence, to the extent that someone is either bidding or asking, their actions are binding. Thus, these data certainly convey some useful information from the exchange market. As used in this paper, the data can convey information somewhat different from the information contained in the actual transaction price. Given that the transaction data reflect actual prices, these are the most informative.[12]

There are some additional issues regarding the data. First, some observations were clearly outliers. Thus, when that was the case, they were excluded from the sample using the following criteria. We estimate a one-quarter moving average and standard deviation of the exchange rate level. Any datum beyond the plus/minus five standard deviations range is discarded. We restart this process after the September–October 2008 depreciation.

Second, the bid, ask and transaction data are not observed at equidistant intervals. Nonetheless, equidistant prices are needed to be able to apply standard econometric methodology. In this regard, we follow Dominguez (2003) in transforming the raw data into five-minute interval data. The key idea is to approximate the possible unobserved datum P_t, where t is one of the five-minute timestamps, as a function of the closest adjacent observed prices (be it a bid, ask or transaction price). The main difference between Dominguez's method and the one we use is that, in our case, the observed bid and ask data are separately set as equidistant prices. At a later stage, we estimate the average bid-ask returns and the bid-ask spread of the exchange rate. We proceed this way because the timestamps for the bid and ask prices in our database do not always coincide. Please refer to Dominguez (2003) for further details.[13]

[11] A possible variation is when the bid or ask is sent with a restriction. This is typically associated with a transaction that has a greater than average size. In this case, the amount transacted might vary, but the involved parties are both mutually obliged to complete it.

[12] There are several things we do not know, for instance, how every transaction was initiated, the amount involved in each transaction, the order flows, and whether it is a bid or an ask that is associated with a given transaction price. These data would certainly be informative, but we do not have them.

[13] One of our method's implications is that, to estimate the exchange rate at time t in an equidistant fashion, information after t is used. So, although the data might be used to measure an average effect, as in our case, it would be inadequate to use them for certain financial models for which using data strictly up to time t (including t) is important. A case in point is within the context of a financial derivative model. An alternative is to think of the exchange rate at time t only as a function of information available up to time t (including t). As for example, use the price at t when available, and use the price closest to but before t, when the price at t is not available. Still, the values obtained from these methods do not usually differ by more than 1 cent from each other.

Third, the statistical exchange rate returns are estimated using the returns from the entire day and from the timestamps surrounding the intervention hours. To clarify this point, consider the returns of the five-minute intervals at 08:30 and 08:35. We take these to be the log difference between the prices at 08:25 and 08:30 and 08:30 and 08:35, respectively. More generally, we have that $r_t = \log(P_t/P_{t-1})$, where t-1, t, t+1, … are equidistant.

The construction of the estimation sample is one of the key steps in an event study. We choose the following sample as we believe it is the most informative and, in tandem, it excludes some irrelevant observations that would probably only add noise to the estimation. The study sample includes those days where the Type 3 intervention mechanism was active (which also contains days where the Type 4 intervention was active). However, the estimation sample only includes the time windows surrounding the timestamp where the interventions occurred. This means that, from the entire study sample that includes the complete days, we took only specific intervals for each day.

The estimation sample can be divided into two: intervention and control samples. The control sample contains the observations of the timestamps where no dollars where allocated given an intervention associated with that window. This could have been the case for one of two reasons. First, there was no auction convened or, second, the auction was convened but the amount of dollars allocated was zero. The intervention sample contains the rest of the observations, meaning only observations that are inside a window which corresponds to an intervention time where dollars were allocated.

We think this sample provides good treatment and control samples because, during this period, agents know that an auction could be convened (for a Type 3 intervention) if the mechanism is triggered, and thus acts as a sort of barrier. It also takes into account that, when a Type 4 intervention was active, the mechanism of the Type 3 intervention was also active. Thus, it is likely that the days that could better play a role as a counterfactual to the Type 4 intervention are those days when a Type 3 intervention was active but the Type 4 intervention was not and no dollars were allocated for a Type 3 intervention. These days, as explained above, are contained in the control sample. We incorporate controls as well, as these might play an important role in determining the exchange rate.

It is worth mentioning that the sample only includes data after the peso's CLS accession, an event affecting the exchange rate, as we document below.

Going into a more detailed description of the sample, the estimation sample is from 9 October 2008 to 9 April 2010. The period from 30 November to 31 December 2011 is

excluded, as Type 3 interventions took place at different times of the day, associated with episode 2.

In effect, we do not use episode 2 of the Type 3 interventions for three reasons. First, there was a change in the times of the day this intervention was implemented, as mentioned above. Thus, attempting to measure its effect and accounting for this change might be problematic. Also, the second episode within our database accounts for a very small number of observations. In the same vein, incorporating data for 2012 should not make much of a difference as that type of intervention allocated dollars only on three days during the relevant year. Thus, we believe it is much more straightforward to concentrate on the first episode and, in terms of information, not much is lost if we do not use the data from the second episode and 2012. Finally, the Type 4 intervention was not active in the second episode of Type 3 intervention and the stress in the economy was significantly lower than in the period we consider.

The intervention sample is drawn from the windows surrounding the interventions from 9 October 2008 to 9 April 2010, when a positive amount of dollars was allocated.

The control sample is drawn from the windows surrounding the interventions from 9 October 2008 to 9 April 2010 *and* no dollars were allocated

Table 2 presents the number of observations in the total sample, as well as those for the study, the intervention, and the control samples.

Table 2
Set of samples

Samples	Observations
Total sample	622,368
Study sample	102,240
Intervention sample	1,439
Control sample	9,566

Table 3 presents basic statistics for various time intervals for the peso/dollar exchange rate returns for selected samples. The table presents key statistics on the behaviour of the exchange rate returns, namely, mean, variance, skewness, and kurtosis, at different time intervals and for various samples.

With respect to returns data statistics, first, in the study sample the means are negative and decrease as the horizon increases, while in the intervention sample they increase as the horizon lengthens. In the case of the control sample, the pattern is less clear, as it has a positive sign for the first two horizons and a negative one for the second two. The

behaviour of the means should be interpreted with care, as their estimation is subject to important significant standard errors.

Second, the variance increases with the time interval. This is in line with basic theory: a higher return is, on average, associated with greater risk.

Third, the skewness and kurtosis decrease in absolute value as the time interval increases. In other words, as the interval increases, the return distributions tend to a normal distribution. Nonetheless, for each time interval, the distributions are far from exhibiting a normal distribution. Although in some cases the skewness approaches zero, the kurtosis is in all cases relatively large, reflecting heavy tails in the distribution.

Third, in general, the intervention sample volatility is greater than the non-intervention sample volatility.

Skewness tends to be positive in the intervention sample and negative in the non-intervention sample. Thus, the mean tilts above (below) the median on intervention (non-intervention) sample. Fifth, the change in kurtosis between intervention and non-intervention days is very distinctive: on intervention days it is smaller.

In sum, these statistics provide an overview of the changes in the distribution of returns on intervention and non-intervention samples.

Yet, based on the samples, it is not possible to identify how far a given change in a statistic on intervention days is due to the intervention itself or due, for example, to the prevalent macroeconomic conditions. This question we explore more closely in the rest of the paper.

Table 3[1, 2]

Intraday FX return study sample						
Rate	**Time interval**	**Mean**	**Variance**	**Skewness**	**Kurtosis**	**Observations**
		Transaction				
MXP/USD	5 min	-1.48E-07	6.32E-07	-3.758	449.711	102,240
	1 h	-1.51E-06	7.37E-06	-0.886	54.986	102,240
	6 h	-2.06E-06	4.34E-05	0.540	22.251	102,240
	24 h	-5.50E-05	1.69E-04	0.782	14.922	102,240
Intraday FX return intervention sample						
Rate	**Time Interval**	**Mean**	**Variance**	**Skewness**	**Kurtosis**	**Observations**
		Transaction				
MXP/USD	5 min	3.53E-05	3.08E-06	2.234	127.313	1,439
	1 h	1.01E-04	2.14E-05	-2.653	25.217	1,439
	6 h	5.89E-04	5.68E-05	0.104	5.614	1,439
	24 h	3.78E-03	2.23E-04	0.479	6.322	1,439
Intraday FX return control sample						
Rate	**Time Interval**	**Mean**	**Variance**	**Skewness**	**Kurtosis**	**Observations**
		Transaction				
MXP/USD	5 min	6.45E-06	1.20E-06	-2.835	123.197	9,566
	1 h	1.21E-04	1.29E-05	-0.011	30.729	9,566
	6 h	-5.13E-04	6.22E-05	-0.793	9.499	9,566
	24 h	-7.26E-04	1.26E-04	-0.448	12.211	9,566

[1] We do not observe the convention of subtracting a 3 from the kurtosis.

[2] The study sample takes into account the observations for all days; the rest for the timestamps surrounding the intervention hours.

Source: Authors'estimations on Reuters data.

Measuring liquidity and orderly conditions in the foreign exchange market

In this section, first, we briefly explore the concepts of liquidity and orderly conditions. In particular, we discuss how far these can be measured by the bid-ask spread. Second, we consider whether there are other factors that might affect the bid-ask spread that are not directly related to the relevant concepts.

In this context, consider the following two descriptions of liquidity taken from Galati (2000). First, liquidity is the ability to sell something without discounting its price. Second, in a liquid market, large transactions have only a slight effect on prices. Evidently, both

definitions have a certain degree of ambiguity. In the first, it is unclear how one would determine the relevant price. In the second, it is unclear what is meant by slight. In effect, as Derman points out: "No one quite knows what liquidity really is, and so there is no good model of it. […] People define it by its proxies – bid-ask, average daily volume, market impact etc, which are features of but aren't actually liquidity itself."[14] Thus, we go along with Derman and think of the bid-ask spread as a proxy for liquidity.

There is probably no consensus on a common definition of orderly markets. Yet, one can argue that a small bid-ask spread is a sign of orderly markets. In contrast, a large bid-ask spread might involve an imbalance in orders or broad disagreements on the price of assets, both signs of disorderly markets. An orderly market has prices that reflect the fundamental value of assets. Thus, increasing a market's liquidity is a way of obtaining such prices.

We use the following definition for the bid-ask spread:

$$Spread_t \equiv ln\left(\frac{P_{ask,t}}{P_{bid,t}}\right)$$

where $P_{ask,t}$ and $P_{bid,t}$ are the equidistant ask and bid prices, respectively, of the peso/dollar exchange rate at time t. Thus, the bid-ask spread is the percentage difference between ask and bid prices. Note that we use the term bid-ask spread and spread interchangeability.

Table 4 presents basic statistics for the five-minute interval bid-ask spread. Several remarks are in order here. First, both the mean and the variance are greater in the intervention sample, as compared to the non-intervention sample. Likewise, the skewness and kurtosis are greater in the intervention sample in comparison with the non-intervention sample. Thus, in the intervention sample, the spread distribution has, on average, much heavier tails. In particular, its right tail is heavier. This shows the prevailing uncertainty in terms of liquidity on the days of the interventions.

[14] blogs.reuters.com/emanuelderman/.

Table 4[1, 2]

Intraday bid-ask spread five-minute interval

(percentage)

Samples	Mean	Variance	Skewness	Kurtosis	Observations
Total sample	1.17E-03	6.74E-06	12.88	347.22	622368
Study sample	1.80E-03	1.59E-05	10.62	162.73	102240
Intervention sample	4.58E-04	1.74E-07	3.97	25.21	1439
Control sample	4.81E-04	3.70E-07	15.25	422.83	9566

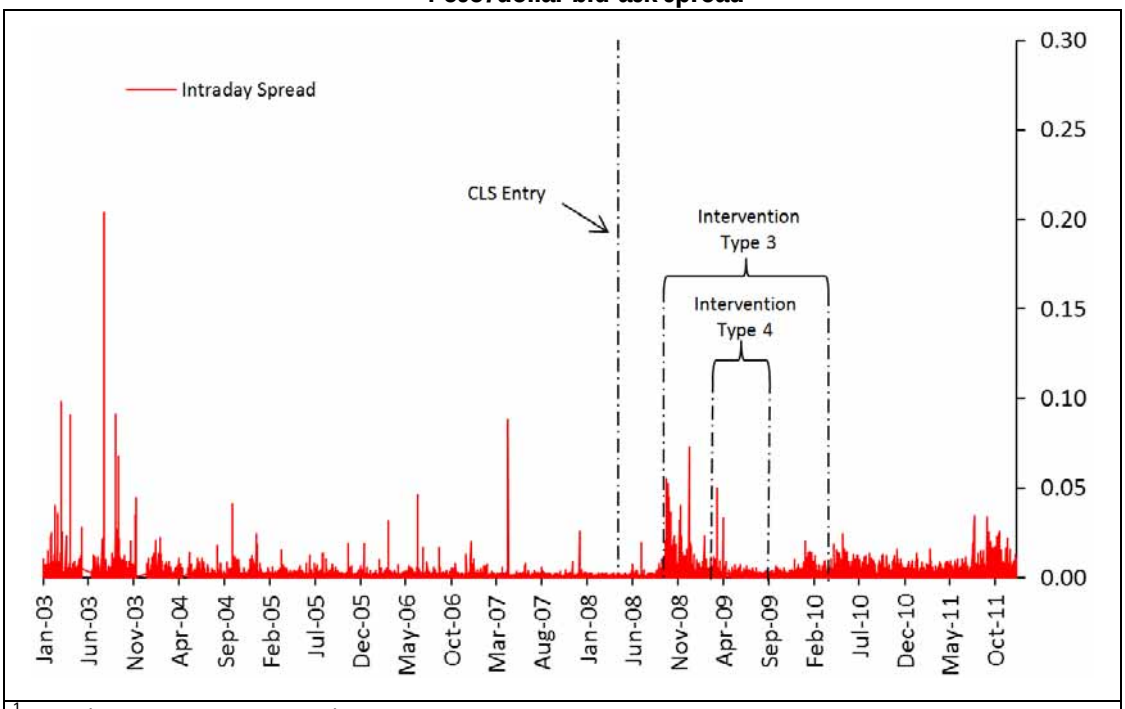
[1] The total and study samples take into account the observations for all days; the rest for the timestamps surrounding the intervention hours.
[2] We do not observe the convention of subtracting three from the kurtosis.
Source: Authors'estimations on Reuters data.

In what follows we analyse the time series of the peso/dollar bid-ask spread. In this respect, Figure 6 depicts its evolution in recent years. Three features clearly stand out.

(i) On average, an overall narrowing of the spread.
(ii) A narrowing of the spread immediately after May 2008.
(iii) An increase in the spread after September 2008.

Figure 6

Peso/dollar bid-ask spread[1]



[1] Period: January 2003–December 2011. Source: Reuters.

Next, we document some of the events associated with these features. As mentioned, in May 2008, the Mexican peso joined the CLS system and, consequently, the peso started to be traded on this platform 24 hours a day. We infer that the liquidity of the peso has

increased since then. Nevertheless, as is obvious, trading was adversely affected by the recent financial global crisis, starting in September 2008.

To assess whether these events statistically affected the bid-ask spread, we test to see if its means and variances have significantly changed in the relevant episodes. More concretely, for the means we perform a standard t-test, and for the variances we used the Brown-Forsythe test. To this end, we have divided the sample into three subsamples:

(i) Before May 2008;
(ii) After May 2008 (including May) and before September 2008; and
(iii) After September 2008 (including September).

The statistics in Table 5 present evidence for the changing market conditions due to the above-mentioned events.

Table 5
Statistics for the bid-ask spread in selected periods

	Mean	Standard deviation	Observations
Jan-03–Apr-08	1.01×10^{-3}	1.88×10^{-3}	363,744
May-08–Aug-08	4.54×10^{-4}	5.72×10^{-4}	23,904
Sep-08–Dec-11	1.50×10^{-3}	3.49×10^{-3}	234,720

Source: Authors' estimations on Reuters data.

By comparing the means for the first and second subsamples, one can see this statistic was greater – at least twice as great – before the peso's entry into CLS. However, by the time the financial crisis erupted, the average bid-ask spread had increased dramatically.

The results shown in Table 6 reject the null hypothesis of equality for both the mean and variance, at the usual confidence levels. These statistics support the view that market conditions have significantly changed since the peso's CLS accession and, as a separate incident, since the financial crisis started. In effect, most of the interventions of all types in the recent past have taken place after September 2008.

Table 6
Comparison of bid-ask spreads

Means (t-stats)	Jan-03–Apr-08	May-08–Aug -08	Sep-08–Dec-11
Jan-03–Apr-08	-	-	-
May-08–Aug -08	114.97	-	-
Sep-08–Dec-11	62.17	128.88	-
Variances (F-stats)	Jan-03–Apr-08	May-08–Aug -08	Sep-08–Dec-11
Jan-03–Apr-08	-	-	-
May-08–Aug-08	1504.02	-	-
Sep-08–Dec-11	5381.63	1841.36	-

To examine more closely the effects of the peso's CLS accession, we compare the same sample with an alternative control sample. Specifically, we consider the May 2007 to August 2007 period, covering the same period one year previously, as this could capture common seasonal components. Table 7 shows the statistics for both samples, while Table 8 presents the tests for the equality for the means and the variances.

Table 7
Spreads statistics

Basic statistics	**Mean**	**Std deviation**	**Observations**
May-07–Aug-07	4.89×10^{-4}	5.40×10^{-4}	25,056
May-08–Aug-08	4.54×10^{-4}	5.72×10^{-4}	23,904

Table 8
Comparing average spreads in selected periods

Tests	**Means (T-stat)**	**Variances (F-stat)**
May-07–Aug-07 vis-à-vis May-08–Aug-08	6.98	31.46

All in all, it is clear that the mean was reduced after the CLS accession; however the standard deviation is greater in the second sample. Both tests reject the null hypotheses of equality in mean and variances, at the usual levels of statistical significance. This adds to the evidence that the CLS accession changed the dynamics of the peso, effectively providing the foreign exchange market with more liquidity.

Moving on to the evolution of the bid-ask spread at an intraday basis, Figure 7 shows the average intraday bid-ask spread for different samples, namely, the intervention sample (days where there was an allocation of dollars), study sample (days where one of the

intervention mechanisms was active), and the total sample (from 2003 to 2011).[15] In this regard, several remarks are in order.

First, both the intervention sample and the study sample show, on average, higher levels of the bid-ask spread for any time of the day than the total sample. This reflects, in part, the stressful nature of this period for the Mexican economy, at the time when the interventions were made.

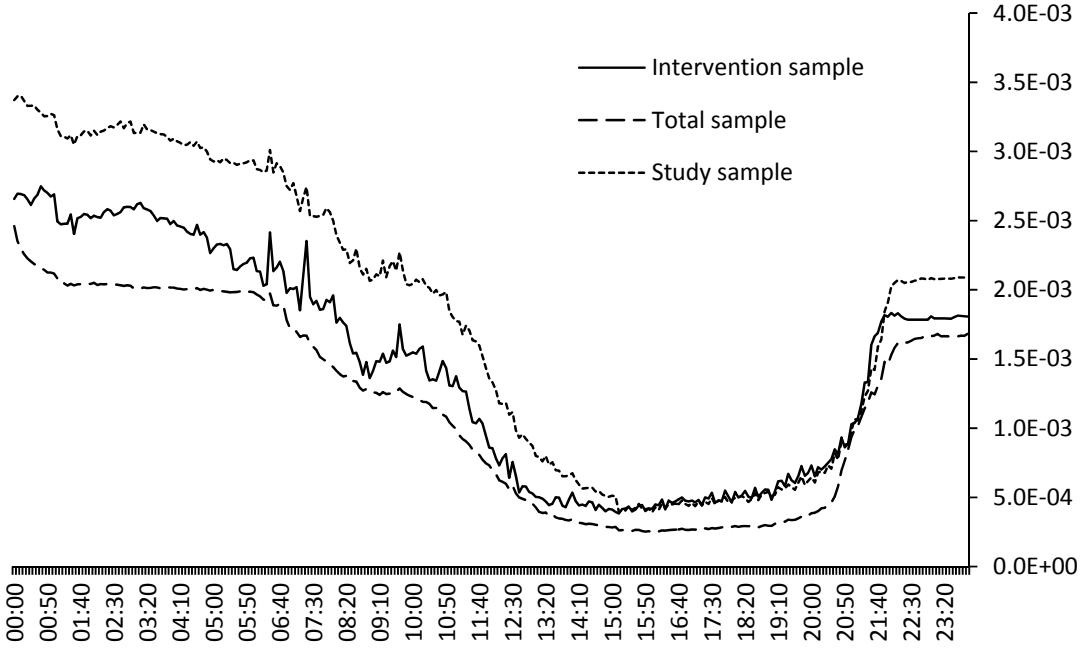
Second, for most parts of the day, the average spread in the intervention sample is usually lower than its counterpart in the study sample. This could be a sign of the interventions' effectiveness in reducing the bid-ask spread.

Third, some cyclical pattern is present in the intraday spread regardless of the specific sample considered. The bid-ask spread starts high in the early part of the day, coinciding with the Asian trading session. At that time of the day, some Asian financial markets have been open for some hours; eg by 00:00 (06:00 GMT) the Tokyo Stock Exchange has been open for four hours. Perhaps the plateau in the bid-ask spread, just past the 20:00 (2:00 GMT + next day) mark can be associated with the opening hours of the Asian trading session. Next, the European markets open, eg Germany and London are open by 02:00 (08:00 GMT). In this period, the average bid-ask spread starts to slowly narrow. As mentioned, the Mexican Stock Exchange opens at 08:30 (14:30 GMT) and closes at 15:00 (21:00 GMT), which coincides with the opening of the NYSE. By 05:30 (11:30 GMT) there is a clear increment in the rate at which the bid-ask spread narrows. Later in the day, at 12:00 (18:00 GMT), São Paulo opens, an event that does not seem to affect this rate.

Thus, the afternoon Asian trading session coincides with the morning European session, while the afternoon European session coincides with the Americas morning session. The bid-ask spread reaches, on average, its lowest level between 07:30 (13:30) and 13:00 (18:00), with marked relatively high levels at the end of the day.

[15] Note that the study sample contains the intervention sample.

Figure 7
Average peso/dollar intraday bid-ask spread for different samples



Notes: GMT.
Source: Authors' estimations on Reuters data.

First, regardless of intervention status, the average value of the bid-ask spread starts high in the early hours of the day, before narrowing and reaching a minimum around 07:30 (13:30 GMT). It stays at around the same level for approximately the next six hours. Then, towards the end of the day, at around 15:00 hours (21:00 GMT), it markedly increases. These dynamics are potentially affected by the opening and closing of financial markets around the world. Second, on average, the intervention mechanism was implemented on the days on which it was most needed, when liquidity was low, as measured by the higher average bid-ask spreads of the study and intervention samples. Third, it is worth noting the average magnitude of the spread during that part of the day.

Fourth, during the times when the interventions occur (ie between 09:00 (15:00) and 13:00 (18:00 GMT/Mexico City time), there does not seem to be a strong seasonal daily component, as the spread stays on average at the same level.[16] Thus, the use of a seasonal component in the regressions does not seem to be warranted. Fifth, although this analysis is relevant in its own right, what is pertinent to us is any possible implication that could affect the construction of the intervention samples and, in particular, the non-intervention samples. Thus, it is key to realise that the main two changes documented in

[16] In GMT time, the interventions occur between 14:00 and 20:00. The GMT time interval is larger than the Mexico City time interval because summer time is observed in Mexico.

this section, namely the peso's CLS accession and the global financial crisis, took place prior to the intervention and non-intervention samples.

General considerations

The canonical model is as follows:

$$S_{t,i} = c + X_t\beta + \Sigma_k \Sigma_m \beta_m^{(k)} D_{T,m}^{(k)} + \varepsilon_t$$

Where, abusing notation, $S_{t,T}$ stands for the bid-ask spread on time period t and on day T, m for the periods before, at or after the intervention. The variable *D* stands for the intervention variable, X_t stands for the control variables, which might be constructed as dummies or as standardised variables, which reflect the amount of dollars allocated in the auction.[17]

As previously discussed, in measuring the effect of the interventions on the spread, a key assumption is the construction of the control sample. In this context, the essential idea is to consider the most similar days possible, in which no dollars were allocated. This is, of course, challenging, as a similar period would most probably entail an actual intervention, just as a similar condition would probably trigger an auction and/or cause the participants to demand dollars. In addition, the control variables account for the unavoidable differences between the referred samples, and thus they should be carefully selected.

We also used the VIX, the so-called fear index, as a control variable in some of our specifications. In this, we seek to account for the macroeconomic uncertainty prevailing in the time period considered. Although this is an imperfect measure, it does to some extent capture the actual macroeconomic conditions.[18]

We use the GMM posited as a just-identify system and with the weighting matrix equal to the identity. This accounts for possible heteroscedasticity and autocorrelation in the error term. We assume that the autocorrelation has a lag of three periods

There are two econometric issues that are of concern, namely, simultaneity and endogeneity. As is well known, these can introduce biases in any of our estimates.

[17] We standardised a series by subtracting from each component the mean and dividing it by the standard deviation of the forecasted value. This could also be done with the historical mean and standard deviations. We prefer to use the former, as they should reflect more closely what is expected by the market participants compared to historical estimates.

[18] We use the VIX on a daily basis due to data availability. However we use a daily lag to avoid using future information contained in the contemporaneous daily VIX as this indicator might contain intraday information that became available after the time windows considered.

The presence of potential simultaneity can best be seen by recalling the triggering mechanism of the auction. If the exchange rate depreciated by more than 2% from one day to the next, then an auction is convened for a Type 3 intervention. Thus, if the bid-ask spread is correlated with such abrupt changes in the exchange rate, then simultaneity might be present. Also, there is potential simultaneity regarding a Type 4 intervention, because the activation of that mechanism was certainly a response to disorderly conditions in the market, as reflected in the bid-ask spread.

A possible way of dealing with simultaneity for a Type 3 intervention is to approximate a response function based on the triggering rule for the auction. This would alleviate the simultaneity issue.

On the effectiveness of interventions

An assessment of intervention effectiveness depends on the choice of framework. From the quantitative benchmark to the choice of the control sample and the control variables, every constituent influences the results. What is more, central banks provide no exact means of evaluating an intervention in the sense that their communiqués do not necessarily translate into a quantitative benchmark measurement.

A closely related issue is that the literature has differentiated between the stated and perceived aims of an intervention. For the purposes of this paper, we take as given that the perceived aim is the same as the stated one. In the specific case of the communiqué associated with a Type 3 intervention, it is stated that: *"the objective of this mechanism is to provide the necessary liquidity to meet the conditions of uncertainty and lack of liquidity in the foreign exchange market."* It has been our own choice to use the bid-ask spread as a yardstick.

A simple model

To begin with, we consider the following model, a regression that aims to characterise (perhaps in a simple manner) the behaviour of the bid-ask spread when an intervention takes place. The model is:

$$S_{t,i} = c + \Sigma_k \Sigma_m \beta_m^k D_{t,i,m}^k + \varepsilon_{t,i}$$

where:

- $S_{t,i}$ is the bid-ask spread on day t and at time *i*.
- $D_{t,i,m}^k$ is the intervention *k* variable, *k* could be intervention Type 3 or 4. As explained above, this can be a dummy or a standardised quantity. To detail the notation, suppose that this is a dummy. Thus, suppose an intervention takes place on day t at

time *i*. *m* determines the lag or lead with respect to the intervention time, ie m goes from –20 minutes to +20 minutes, in five-minute intervals. Then, $D^{k}_{t,i+m} = 1$ if there was an intervention k on day *t* and at time *i*, (on the time window of length 40 minutes surrounding the intervention time i). Or $D^{k}_{t,i+m} = 0$ if no dollars were allocated on day *t* at time *i.* This can also be constructed as the quantity of dollars allocated on day *t* at time *i*. The rest is defined analogously.

First, observations on interventions and control days outside the windows are excluded. We believe these data are uninformative. Second, three interventions take place on a Type 3 intervention day (or four in total if a Type 4 intervention is also active). Thus, this regression bundles them together since the β's coefficients account for the time before, at, and after the intervention and not the time of the day. Thus, for instance, β_{10} is only associated with the effect 10 minutes after the intervention, regardless of the actual time of the intervention. In short, the coefficients are relative to the time of the intervention, as opposed to absolute. However, the coefficients associated with a Type 4 intervention are reported separately since they cannot be bundled with the rest as their aim and active period are different.

We mentioned that it is simpler to use only the intervention variable, be it a dummy or the quantity of dollars allocated, since the intervention sample and the control sample would differ in many other aspects that are not captured by the intervention variable. The inclusion of control variables is warranted, or at the very least it is relevant to explore their effects on the coefficients' estimates associated with the intervention.

Controls

Our basic estimation uses 12 US macroeconomic indicators as control variables. These macroeconomic indicators are constructed in two different ways. First, as dummy variables defined in terms of surprises. These try to capture *unexpected* changes in the economy. Second, they are also constructed as standardised variables. This is very much in the spirit of the first exercise but, in addition, takes into consideration the size of the shock. They could affect the exchange rate, above and beyond the direct effects of the interventions themselves. If any change is expected, we assume it has been accounted for in the exchange rate.

Up to this point, we have decided not to use Mexican macroeconomic variables as controls for three reasons. First, anecdotal evidence from traders points to certain US macroeconomic variables as the most important determinants of the exchange rate. Second, casual observation and previous research has established the variables we use as

important determinants of the exchange rate. Third, their use is valuable in terms of allowing us to compare our results with other studies in the BIS CCA Research Working Group. At the same time, we certainly acknowledge that they might be relevant and plan to incorporate them in future research.

The macroeconomic variables considered are:

1. Consumer Confidence
2. Consumer Price Index (CPI)
3. Durable Goods
4. Housing
5. Industrial Production
6. Producer Price Index (PPI)
7. National Association of Purchasing Managers Index (NAPM)
8. Retail Sales
9. GDP
10. Unemployment
11. Trade Balance
12. Federal Funds Rate

Bloomberg, the source for these data, provides information about the market's expectations in the form of surveys. Each survey asks forecasting professionals for their prediction for the variable at hand. Using these data, we construct surprises as follows:

$$DN_{a,t} \equiv \begin{cases} 1 \;\; if \; SD_{a,t} < \left| Ind_{a,t} - Med_{Survey}{}_{a,t} \right| \\ 0 \; otherwise \end{cases}$$

where:

- $Surp_{a,t}$ is a variable that identifies a surprise event at time t. Since the spread typically increases regardless of the sign of the surprise, we use the absolute value.
- $Ind_{a,t}$ is the value of one of the macroeconomic variable at hand at the time of its release, denoted by t,
- $Med_{Survey}{}_{a,t}$ is the median value of the survey that referred to the announcement of one of the indicators at time t, and
- $SD_{a,t}$ is the standard deviation, which is approximated by taking the difference between the maximum value and the minimum value of the survey, divided by six. This approximation of the standard deviation was used because we could only

obtain the historical series of the maximum value, the minimum value, and the median of the forecasts.[19]

For each definition, the *a* denotes the type of announcement.

In the second case, we use the absolute value of the same macroeconomic variables but standardise them as follows.

$$DN_{a,t} \equiv \left| \frac{Ind_{a,t} - Med_{Survey}{}_{a,t}}{SD_{a,t}} \right|$$

In the third case, we use a dummy that controls for the Type 4 intervention. This is important for three reasons. First, this type was implemented while Type 3 was being deployed. Second, it is designed with a more flexible auction. The key difference is that its auction has no minimum price.

The model estimated in this case is:

$$S_{t,i+m} = c + \Sigma_k \Sigma_m \beta_m^k D_{t,i+m}^k + \Sigma_a \Sigma_m \beta_m D_{t,i+m} + \Sigma_a \Sigma_m \gamma_{a,m} DN_{a,t,i+m} + \varepsilon_{t,i+m}$$

Where:

- $S_{t,i+m}$ is the five-minute interval bid-ask spread on day *t* and at time *i*+*m*.
- $D_{t,i+m}^k$ is the intervention *k* variable, *k* could be a Type 3 or Type 4 intervention. The description is the same as in the simple model.[20]
- $DN_{a,t,i+m}$ is the news surprise announcement dummy. Say, a news announcement takes place on day *t* and at time *i* (thus, *i* can be 09:30, 11:30 or 13:00), *m* then determines the lag and lead with respect to the news announcement time. *m* goes from –20 minutes to +20 minutes, with five-minute intervals. Then, $DN_{a,t,i+m} = 1$ if it is a surprise news announcement on day *t* of kind *a* at time *i*+*m*, ie on the time window of 40 minutes duration surrounding the intervention. Finally, $DN_{a,t,i+m} = 0$ if there is no surprise news announcement on day or time t. As mentioned, the *a* denotes the type of announcement, ie *a* =1, 2, 3, ..., and 12.

Also, since the time of many news announcements is earlier than 09:10, we extend the intervals of the days considered accordingly. For example, if there is a news announcement at 07:30, we consider data starting from 07:10. In fact, data can start at

[19] An alternative was to estimate the standard deviation of the time series of the variable, yet we believe using the information in surveys is a more accurate description of the surprises.

[20] As mentioned before, observations on interventions and non-intervention days outside the windows are not included. We believe these data are uninformative.

any point from 07:10 to 14:35, as 07:30 is the earliest time and 14:15 is the latest time for a news announcement in our database.

In this respect, Figures 8 to 11 present, for each window, the coefficients $\beta_{1,m}$ associated with the intervention dummies and, $\sum_a \gamma_{a,m}$, as functions of m, related to the news announcements dummies for the macroeconomic announcements. For the estimation of the standard errors of these partial sums, the covariance between each pair coefficients needs to be taken into consideration.

Several remarks are in order.

First, the coefficients associated with the Type 3 intervention in the basic estimation for different specifications are significantly positive. However, the estimated coefficients of alternative models that use the VIX as a control are not significant. Thus, the significant coefficients of the basic estimation may be simply associated with the fact that the spread in the first part of the intervention sample was larger than in the control sample, as noted by Figure 6, just after the Lehman bankruptcy.

Second, the coefficients associated with the Type 4 intervention are, for the simple specifications, negative and significant, both statistically and economically. For example, in Figure 8, there is an average effect of -1.2×10^{-3}. Looking at the average value of the spread for the study sample, 1.8×10^{-3}, the effect of the intervention could account for a reduction of 6.66% of the average spread level for that period. Even more, the result seems robust even when we account for the VIX as a control variable.

Third, the partial sum of the announcements' coefficients is much greater in magnitude, compared to the intervention coefficients, as measured by the left axis. This should not come as a surprise as it is the aggregate effect of all 12 macroeconomic announcements. In fact, the coefficient value divided by 12, could be interpreted (in a very general way) as the average response of the spread to a macroeconomic surprise. So, after accounting for that issue, the effect on the spread of a *single* macroeconomic surprise is roughly the same in magnitude as the interventions' coefficients.[21] However, as it is shown in Figures 9 to 11, very few coefficients associated with the announcements are significant,

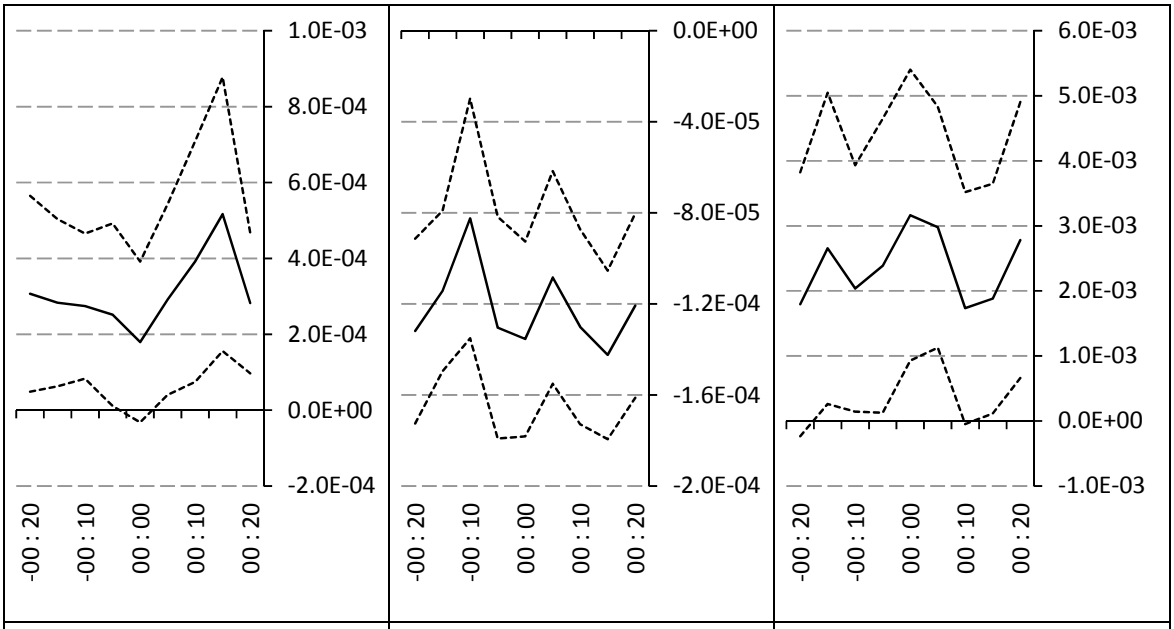
[21] These will only hold for some specifications, in particular the ones that use dummies both for the interventions and for the announcements, allowing the magnitude of the coefficients to be compared. In cases where the variables used are the intervention amounts and the standardised news, these equivalences are not so easily obtained. Also, this should be interpreted cautiously, as the exchange rate may be reacting to a particular announcement and this could be the main driver of the aggregate effect. A disaggregated comparison of the 12 indicators should be made to see the particular effect of a single announcement. We do not present such analysis here as it is outside the scope of this paper.

particularly after controlling for the VIX. The only particular robust effect is that at the time of the macroeconomic surprise, the spread is significantly larger.

In terms of the magnitude of the effect, the average of the bid-ask spread for intervention days is around 1.8 x $10^{-3}$and at the time of the intervention, the average effect of a single surprise in a macroeconomic indicator is around 2.5 x 10^{-4}. The size of the effect is then approximately 7.2% of the average bid-ask spread of the intervention days. Thus, these estimates are statistically and economically significant.

Figure 8

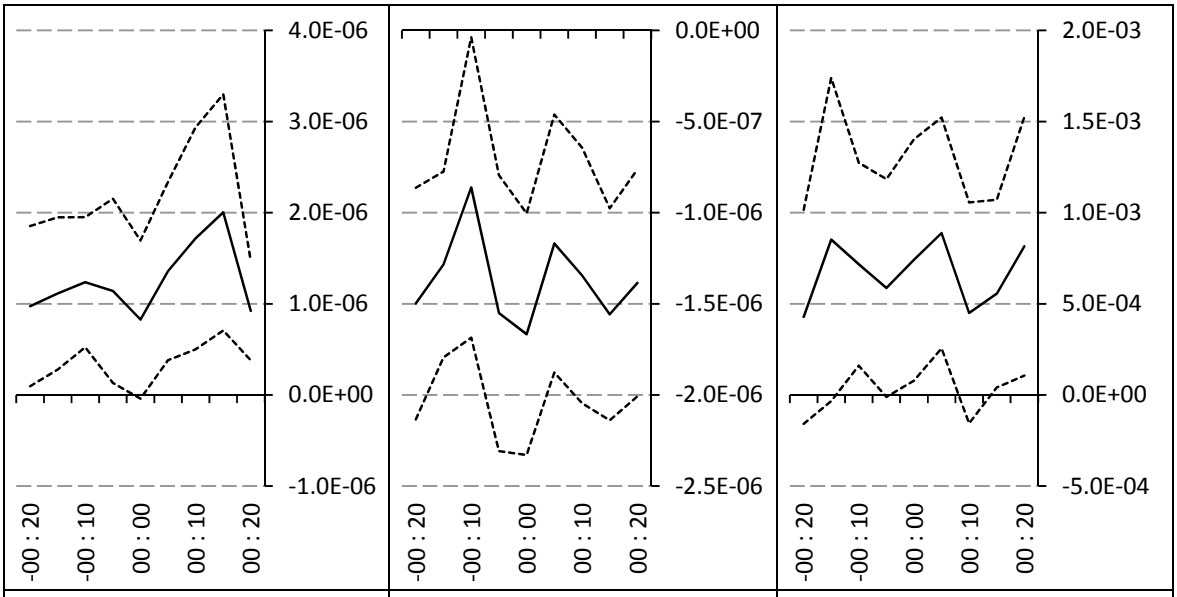
Before and after responses to interventions and macroeconomic announcements: Dummies



Type 3 intervention	Type 4 intervention	Macroeconomic announcements
Intervention dummies, macroeconomic dummies		

Figure 9

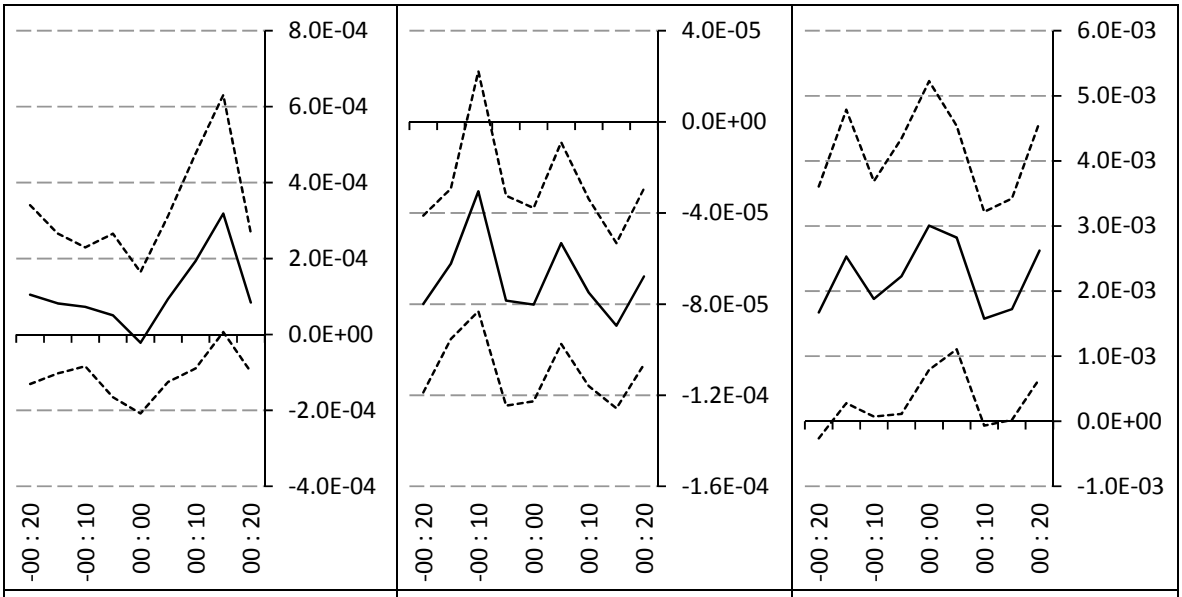
Before and after responses to interventions and macroeconomic announcements: Intervention amounts and standardised announcements



Type 3 intervention	Type 4 intervention	Macroeconomic announcements
Intervention amounts, macroeconomic standardised announcements		

Figure 10

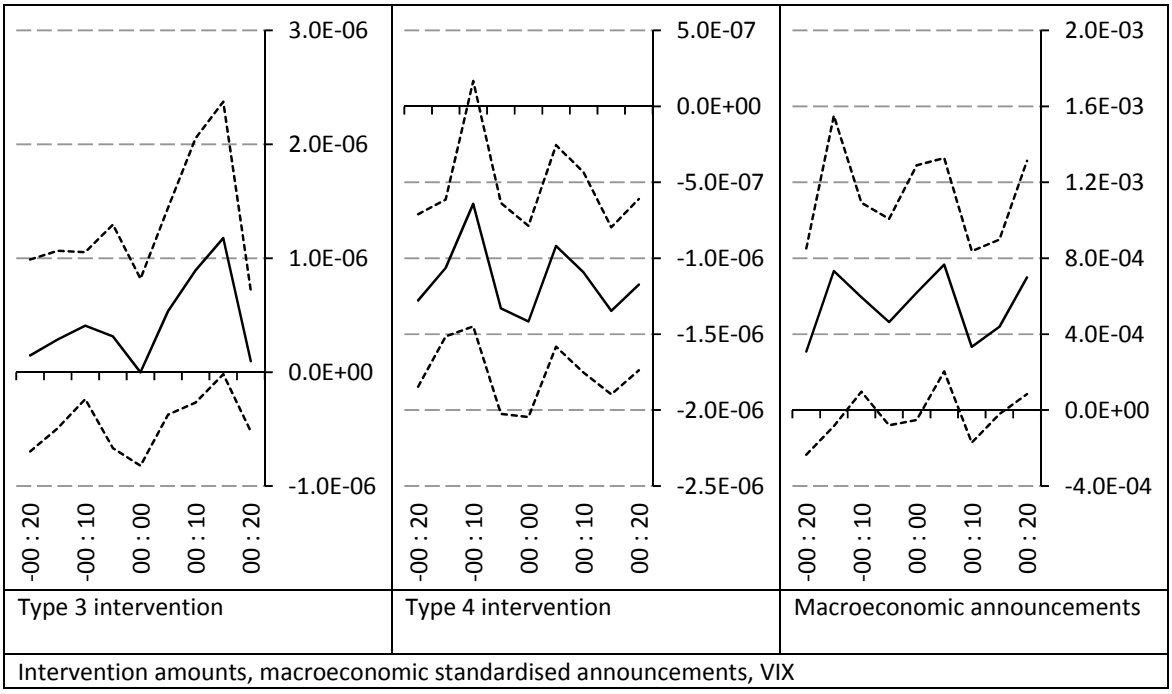
Before and after responses to interventions and macroeconomic announcements: Dummies; using the VIX as a control



Type 3 intervention	Type 4 intervention	Macroeconomic announcements
Intervention dummies, macroeconomic dummies, VIX		

Figure 11

Before and after responses to interventions and macroeconomic announcements: Intervention amounts and standardised announcements; using the VIX as a control



In sum, this evidence is not robust enough to suggest that a Type 3 intervention has an opposite effect to the one intended. We found some positive significant coefficients; however, their significance is not robust to different specifications. This does not allow us to make any conclusive argument regarding the effect of this intervention on the bid-ask spread. Second, the effect of a Type 4 intervention appears to be related to a significant reduction of the bid-ask spread. This result holds for different specifications.

The different results shown by the exercise for the two, rather similar, interventions, could reflect their small degree of difference from each other, and the difficulty of assessing them by means of the same type of exercise. For instance, the Type 4 intervention was triggered regardless of the condition of the market and did not have a minimum price. This could help to provide cleaner econometrical results. On the other hand, the Type 3 intervention had a minimum price and, even when the mechanism was active, the auction may not have been triggered. The rule that determined the triggering was known by the market participants; thus, they knew whether there was going to be an auction, and hence the surprise of the actual auction may not have been too large. However, it is easily conceivable that every market participant would have perfect information about *its own* future actions, but would ignore the positions of other

potential auctioneers. This could induce some kind of surprise for the Type 3 intervention. We acknowledge this issue and suggest that it should be addressed by future research.

Final remarks

To sum up, our results show no indication of an effect in the opposite direction from the one intended for the Type 3 intervention, but they do favour an interpretation that the Type 4 intervention was effective. This is in line with the growth in volume, depth and liquidity seen in the peso/dollar foreign exchange market in recent years. These mixed results suggest that the different designs of the various interventions could play an important part in explaining the effectiveness of each type. The recent growth of the peso/dollar market could account for the observation that the more passive interventions have a smaller effect than before.

Second, there is evidence to support the idea that macroeconomic surprises increase the bid-ask spread in an economically significant way. This is in line with the related literature.

Third, the timing of the interventions may have some important implications. As shown, there is a cyclical intraday pattern for the peso bid-ask spread, so that the timing of the intervention can affect the bid-ask spread in different ways. In other words, given two interventions of the same size, it would seem that their effectiveness might depend on the time of day they are implemented. This could partially explain the mixed results we found.

We make two key remarks regarding the simultaneity issue and the measurement of the intervention effects. One could conclude that the auction matters for the intervention's effectiveness. This might be the case. Yet it might also be the case that the difference is econometrical in nature. In essence, while the Type 3 intervention's triggering mechanism is a function of the exchange rate, this is not true of the Type 4 intervention. Thus, in this respect, the measurement of both interventions from the econometric point of view is crucial and this might well explain the different estimates.

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