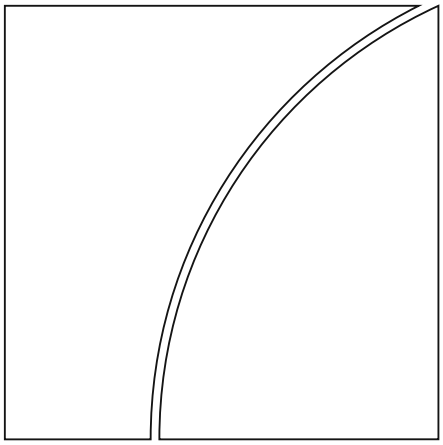

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Asymmetric effects of Forex intervention: evidence from Peruvian intraday data.[1]

Erick Lahura and Marco Vega*

Abstract

Asymmetric effects of Central Bank foreign exchange (forex) intervention have not been extensively studied in the literature, even though in practice Central Bank's motives for purchasing and for selling foreign currency may differ. This paper studies asymmetric effects of Central Bank interventions under the premise that policy authorities view depreciations and appreciations as having asymmetric implications. Using undisclosed intraday data for Peru from 2009 to 2011, this paper shows that Central Bank interventions in the foreign exchange market have a significant and asymmetric effect on interbank exchange rates. Specifically, central bank intervention is more effective in reducing the interbank exchange rate than in raising it.

Key Words : *exchange rate, foreign exchange market, intervention*
JEL Classification : F31, G14, G15.

1 Introduction

The Central Reserve Bank of Peru adopted a managed floating exchange rate regime in August 1990. Since then, the Central Bank has intervened frequently in the foreign exchange (forex) market. These interventions are discretionary, can occur at any time during trading hours and without any pre-announcement of either intervention times or volumes.

As recently documented in Armas and Grippa (2006), Rossini, Quispe and Rodriguez (2011) and Rossini, Quispe and Serrano (2013), forex intervention is an important element of monetary policy in Peru. Under the inflation targeting regime (in place since January 2002), monetary policy in Peru focuses on the achievement of the inflation target (currently 2.5 percent annually, plus or minus

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one percentage point) using the reference rate as the operational target. In addition, given the high degree of dollarization of financial assets (currently around 43% of total credit is denominated in foreign currency), monetary policy decisions also take into account the risks of financial dollarisation (liquidity and exchange rate risks), which can affect the normal evolution of credit and GDP. Thus, in order to deal with liquidity risks, the Central Bank controls reserve requirements on foreign currency liabilities and accumulates international reserves through interventions in the foreign exchange (forex) market. In addition, in order to deal with the exchange rate risk, the Central Bank performs sterilised forex interventions aimed at reducing exchange rate volatility and thus reducing the balance-sheet effect.

Over the last decade, Peru has been receiving sizeable capital inflows due to easy monetary conditions around the world and to the good economic fundamentals that the Peruvian economy has been building. This, in turn, has generated an appreciating trend in the domestic currency (Peruvian Nuevo Sol)[2] interrupted only by short depreciation spells linked to stress episodes of local or global origin. This pattern of exchange rate dynamics is shared by the currencies of similar emerging economies.

Peru's policy response to these developments in the nominal value of the currency has centered on active intervention operations to dampen the effects of capital inflows by purchasing foreign currency and accumulating foreign reserve buffers during periods of appreciation. Similarly, during the short spells of depreciation, the Central Bank has been selling the amount of US dollars required to calm markets and provide the necessary foreign currency liquidity. This process has been facilitated by the sizable foreign reserve buffers accumulated during capital flow bonanzas.

Thus, upward and downward pressures on the currency require different responses by the Central Bank and by market participants. This implies that Central Bank interventions may have asymmetric effects on the exchange rate. Few papers have tackled asymmetric effects of Central Bank intervention in emerging economies. in an environment like the one described here. Among the few papers that provide empirical evidence that foreign currency sales by the Central Bank are more successful than foreign currency purchases in affecting exchange rate returns Domac and Mendoza (2004) and Flores (2003). Therefore, the aim of this paper is to study the potential asymmetric effects of Central Bank interventions in the forex market.

For the empirical analysis, we measure the effectiveness of forex purchases and sales through their temporary impact on the exchange rate level. Although the objective of interventions is to reduce undesirable movements in the exchange rate on a daily basis, i.e. to reduce interday volatility, this goal cannot be achieved without

[2]Abbreviated as PEN.

having an impact on daily exchange rate levels. First, based a non-structural event-style regression commonly used in the literature, it is found that sale interventions have more impact than purchase interventions, in terms of both magnitude and significance. This is confirmed using a structural vector autoregression (SVAR) which is identified using long-run restrictions. In particular, under the view that the exchange rate is determined by its fundamentals in the long run, we use the identifying assumption that an exogenous change in forex intervention (either buying or selling) has no long-run effect on the level of the exchange rate. However, a shock to forex interventions may have transitory effects on the level of the exchange rate. As will be explained below, this allows us to analyse the response of the exchange rate to an exogenous change in forex intervention.

This paper contributes to the literature on foreign exchange intervention in emerging market economies in three dimensions. First, it is the first time undisclosed and comprehensive intraday intervention data - minute by minute data points for all trading days between January 2009 and April 2011 - have been used for Peru. Second, the paper shows that Central Bank interventions in the foreign exchange market have asymmetric effects on the spot exchange rate. In particular, sale interventions have a greater effect on exchange rate than purchase interventions. This result is robust to event study regressions and to a SVAR identification proposed in the paper. Lastly, the paper provides a simple signalling framework which formalises the asymmetric effect whereby sale interventions are more effective than purchase interventions.

The remainder of the paper is organised as follows. Section 2 presents a brief discussion of why asymmetric intervention effects may occur. In section 3 we outline a simple theoretical framework that provides a rationale for the occurrence of asymmetric intervention effects. Section 4 provides a description of the Peruvian forex market and of the data used in the empirical section. Section 5 describes the methodologies put forward for analyzing the effects of forex intervention, and section 6 sets forth our main conclusions.

2 Discussion on asymmetric intervention effects

Although there is a large literature on forex intervention, only few of them has focused on the asymmetric effects of Central Bank forex intervention. On the empirical side, Flores (2003), Domac and Mendoza (2004), Pasquariello (2007), Broto (2013), and Fatum et al. (2013) provide evidence that purchases and sales interventions may have asymmetric effects.

Domac and Mendoza (2004) analyse the Mexican and Turkish forex interventions using daily data and find that sales are more effective than purchases in affecting exchange rate returns. Broto (2013) studies asymmetric effects of purchases and sales on the conditional volatility of four Latin American Central Banks (Chile, Colombia, Mexico, and Peru) and finds that purchases are more effective

than sales in reducing conditional exchange rate return variances in Colombia, Mexico and Peru. Fatum et al. (2013) use intraday Danish intervention data and find that purchase and sale interventions both affect the exchange rate bid-ask spread, but in opposite directions, whereas Pasquariello (2007) shows that sales of the Swiss franc (CHF) exert a stronger influence on the CHF/USD spread than do purchases.

For the Peruvian case, Flores (2003) provides evidence of asymmetric intervention effects. Using daily data from January 1999 until June 2001, he finds that purchase interventions are more effective than sale interventions.[3] Furthermore, he finds that the amount of the intervention increases the effectiveness of sale interventions only, whereas this effect is negative for the case of purchases.

On the theoretical side, the literature has paid scant attention to asymmetric effects of purchase and sale interventions. Fatum et al. (2010) provide a theoretical background for asymmetric effects in the bid-ask spread which is tested empirically using the Danish data.[4]

Under a floating exchange rate regime with discretionary forex interventions, it is possible to establish two reasons for asymmetric effects to appear. First, the Central Bank may have an asymmetric loss function regarding the behaviour of the exchange rate, which implies an asymmetric reaction function in the face of depreciation or appreciation events. Second, asymmetric effects may turn up if purchases and sales interventions have different transmission channels. Evidently, in practice these two reasons operate simultaneously and interact with each other.

2.1 Asymmetric loss functions

For policy makers who participate in the forex market, the dangers of sharp exchange rate depreciations are markedly different from those of exchange rate appreciations. Exchange rate depreciations are linked to stress episodes associated with financial crises. Fear of floating, as defined by Calvo and Reinhart (2002) entails mostly a fear of depreciation. Large and abrupt depreciations trigger fears of financial distress. Such fears are particularly acute in emerging market economies whose financial markets are vulnerable - for example, as a result of financial dollarization (Rossini, Quispe and Rodriguez, 2011).

In contrast, exchange rate appreciations are not linked to short-run financial crises but to capital flow bonanzas. Thus, fear of appreciation is more related to fear of misallocation of resources between tradable and non-tradable sectors and

[3] In this paper, a purchase (sale) intervention is effective when the closing exchange rate is greater (less) than when the intervention began.

[4] The Danish kroner participates in the fixed exchange rate mechanism called ERM II by which the kroner fluctuates on a narrow horizontal band. The Danish forex intervention is based on unannounced interventions aimed at keeping the krone pegged to the euro within a horizontal band.

fear of excessive credit booms. These fears are justified: Kappler et al (2011), Levy-Yeyati et al (2012) and Bussiere et al. (2013) show that large real exchange rate appreciations may harm exports, the current account and economic growth.

Here, then, the asymmetry turns on the fact that large depreciations are avoided because they may imply financial crisis in the short run, while sharp or persistent appreciations are avoided because these may harm growth prospects. An asymmetric reaction function, in turn, implies that, for a given pressure of appreciation or depreciation, the central bank intervenes differently depending on whether it is purchasing or selling. This means that the features of purchase and sale interventions differ in terms of the volume of each transaction, daily aggregate volumes, dispersion of intervention transactions across market participants, intraday timing of intervention, and so on.

2.2 Asymmetric transmission mechanisms

There is no consensus on the main mechanism explaining the effectiveness of central bank interventions in altering exchange rates. Three main channels are put forward in the literature: the portfolio balance channel, the signalling channel and the coordination channel. The portfolio balance channel can be important in the context of emerging market economies where foreign currency reserves held by central banks are large relative to the amount of turnover in local foreign exchange markets (Galati and Melick, 2002). The effectiveness of the signalling channel depends on the credibility of the central bank performing the intervention (Disyatat and Galati, 2007). The coordination channel implies that intervention causes market views to move in a particular direction. This is achieved through the trading process in an environment where agents have heterogeneous information about fundamentals (Fratzscher, 2012).

Do any of these intervention transmission mechanisms imply asymmetric effects on spot exchange rate returns? To our knowledge, there is no theoretical literature on the subject. However, it is possible to establish some hypotheses. Through the portfolio channel, asymmetric effects may occur if the central bank is perceived to have quantitative constraints when intervening in the forex spot market either purchasing or selling. This could occur, for example, if the amount of foreign currency reserves the central bank holds is perceived to be too low. In that case, a sale intervention implies higher risk for domestic assets than does a purchase - which would lead to different exchange rate effects.

Through the signalling and coordination channels, asymmetric effects may occur because purchases and sales convey different information about the fundamentals that drive the spot exchange rate. This dynamic can come into play if agents perceive intervention purchases and sales differently. For example, during the appreciation trend that characterized most of the 2000-2010 decade in emerging economies, agents may have seen central banks as purchasing US dollars to accumulate reserve buffers, and attributed less credibility to the motive of smoothing

the domestic currency appreciation. On the other hand, during the sharp depreciation episodes observed in the sample, associated with sale interventions, more credibility may have been attributed to the motive of affecting exchange rates.

For the case of an emerging economy, an alternative view is that purchase interventions by Central Bank amount to increasing foreign currency reserves which consequently improve the country's insurance and fundamentals. But improved fundamentals attract even more capital flows that offset purchase interventions and thus weaken the final effect on exchange rates. Instead, in times of financial stress and depreciation pressures, sudden outflows of capitals are diminished precisely because the country is perceived to have high insurance due to its mounting foreign currency reserves. In this case, large depreciations are relatively easy to avoid through forex intervention. In this explanation, the amount of foreign currency that a central bank holds as a buffer is an important state variable that can empirically explain asymmetry.

3 A simple framework

In this section we provide a simple analytical framework for understanding asymmetric effects of central bank forex interventions. From the outset, we assume that forex interventions are discretionary in nature and are sterilized in the context of a managed floating exchange rate regime. We concentrate on the signalling channel[5] because asymmetric effects may appear due to the difference between the types of signals provided by forex sales and forex purchases. To see this, we start with an adjusted UIP given by

$$s_t = E^m \left[s_{t+T} | \Omega_t \right] - E^m \left[\sum_{j=0}^{T-1} (i_{t+j} - i^*_{t+j} - \rho_{t+j}) | \Omega_t \right] \tag{1}$$

where i_t is the domestic interest rate on short-term assets (and thus directly associated with monetary policy), i^*_t is the foreign currency interest rate, ρ_t is the risk premium on domestic assets, s_t is the log of the spot exchange rate measured as the PEN value of the US dollar and s_{t+T} is the log spot forex rate at some distant time. Equation (1) says that the spot exchange rate at date t is determined by expectations conditional on the information set available to market participants. Expectational terms are denoted by the operator $E^m[.|\Omega_t]$, where Ω_t stands for the information set available at time t. In what follows, we abstract from the portfolio balance channel so the risk premium values ρ_{t+j} are invariant to intervention[6].

[5]Since the Central Reserve Bank of Peru is perceived to have low quantitative constraints on purchasing or selling dollars, any asymmetric effect through the portfolio balance channel is likely to be small.

[6]The link between the portfolio balance channel and the variable ρ is described, for example, in Kearns and Rigobon (2005).

Also, since interventions are sterilized, the expected interest rate differentials are also invariant to intervention. We assume that the signalling effect does not operate by signalling future monetary policy actions but by conveying information about the long-run nominal exchange rate value.[7] Therefore, the only way the spot exchange rate can be affected by intervention is through signalling information about the long-run value of the exchange rate ($E^m[s_{t+T}|\Omega_t]$).

The process of signalling operates through participants in the forex market receiving signals about the fundamental value of the long-term exchange rate. This fundamental value, denoted by f_t, is unobservable in real time by market participants. Information about fundamentals continuously changes, and a central bank that intervenes discretionally may or may not intervene at every moment to pass its private information about fundamentals to the market. As pointed out in Rossini, Quispe and Rodriguez (2011) and Rossini, Quispe and Serrano (2013) intervention is not about signalling or committing to an invariant exchange rate level. Rather, the signalling hypothesis posits that each intervention by the central bank gives only information on current informed central bank knowledge about the direction of future exchange rate movements.

We assume that the market is composed of dealers and the central bank. All dealers are alike and receive the same signal f_t^d about the fundamental value f_t, while the central bank receives a signal f_t^c. Both signals contain noise, so we can write the expressions:

$$\begin{aligned} f_t^c &= f_t + \mu_t \quad ; \quad \mu_t \sim iid(0, \sigma_c^2) \\ f_t^d &= f_t + \eta_t \quad ; \quad \eta_t \sim iid(0, \sigma_d^2) \end{aligned}$$

The central bank receives the signal first, and it is less noisy than the one the dealers receive ($\sigma_d^2 > \sigma_c^2$). Upon receiving its signal, and given the state of the market, the central bank forms its own expectations $E^c\big[s_{t+T}|\Omega_t^c\big] = E^c\big[s_{t+T}|f_t^c\big] = f_t^c$ and decides to intervene or not. Dealers, on the other hand, either detect central bank intervention or perceive that the central bank is not intervening in the market. Thus, dealers first receive their signal independent of intervention, and then they observe or perceive a certain level of central bank intervention. So, $E^d\big[s_{t+T}|\Omega_t^d\big] = E^d\big[s_{t+T}|f_t^d\big] = f_t^d$, but with perceived information about the central bank intervening, dealers update their expectations: $E^d\big[s_{t+T}|f_t^d, I_t^p\big]$, where I_t^p is the perceived or detected level of central bank intervention.

A simple way to update expectations is to assume that perceived intervention operations and the true fundamental value of the exchange rate have a subjective joint probability density given by a bivariate normal. Under this assumption, the

[7] In modern monetary policy, central banks signal future movements in interest rates through what Woodford (2005) calls *forward guidance*, i.e. more transparent communication to signal future monetary policy intentions.

updated expectation is given by

$$E^d\left[s_{t+T}|f_t^d, I_t^p\right] = E^d\left[s_{t+T}|f_t^d\right] + \frac{cov(I_t^p, f_t|f_t^d)}{var(I_t^p|f_t^d)}\left[I_t^p - E[I_t^p|f_t^d]\right] \tag{2}$$

We argue that equation (2) sets the stage for asymmetric intervention effects. A purchase does not convey the same information as a sale. When the central bank purchases US dollars, the covariance between intervention and the fundamental value is weak because the central bank may be perceived as purchasing US dollars to accumulate buffer reserves, rather than because it believes the fundamental value of the exchange rate is high. So the appearance of another motive[8] on the buy side weakens the covariance term in (2). However, when the central bank sells US dollars, it is clearly doing so to forestall a sharp depreciation at a time of stress when it thinks the fundamental spot rate should not be depreciating as much as the markets believe. In such cases, dealers understand that foreign reserve decumulation is a by-product, not the aim, of intervention. Therefore dealers may think that the covariance between central bank intervention and the true fundamental value is larger.

Hence, with all else constant in (2) except for the size of the covariance, a sale intervention has more weight than a purchase intervention in terms of sending dealers an updated signal about the fundamental.

If we turn back to equation (1), the only term that affects the spot rate under sterilized intervention according to our signalling hypothesis is the market's expected value for the future spot rate, $E^m\left[s_{t+T}|\Omega_t\right]$, which is contingent on the information that the market has. This market expectation can be represented as the weighted average of the central bank's and dealers' expectations:

$$E^m\left[s_{t+T}|\Omega_t\right] = \alpha_t E^c\left[s_{t+T}|f_t^c\right] + (1-\alpha_t)E^d\left[s_{t+T}|f_t^d, I_t^p\right] \tag{3}$$

where α_t stands for the relative magnitude of intervention in the market.[9] Assuming that α_t is purchases/sale-symmetric, the only asymmetric effect comes from the second term on the right-hand side of (3). To see this, we compute the marginal effect on the spot rate s_t of a fundamental draw f_t, received signals f_t^d and f_t^c, and sterilized intervention. To do this, we rewrite (1) in terms of (2) and (3). We call the new spot rate s_t',

$$s_t' - s_t = \alpha_t f_t^c + (1-\alpha_t)\left(f_t^d + \frac{cov(I_t^p, f_t|f_t^d)}{var(I_t^p|f_t^d)}\left[I_t^p - E[I_t^p|f_t^d]\right]\right) \tag{4}$$

[8]This motive is documented, for example, in Armas and Grippa (2006) and Rossini, Quispe and Serrano (2013). Accumulation of reserve buffers is done for precautionary motives.

[9]This weight can be approximated by the absolute value of intervention volumes relative to turnover.

From (4) it is clear that a purchase intervention has a lower marginal effect than does a sale. This is due to their differentiated effects on the covariance term.[10] Thus, according to this simple framework of asymmetric signalling effects, purchase interventions are more effective than sale interventions. We will show the empirical validity of this hypothesis in section (5) below.

Also, the effects are only transitory because they depend on the agents' conditional expectations. It can be noted also from (2) and (3) that the market's unconditional expectation is equal to $E(f)$, so that intervention does not have any long run impact on the exchange rate. This will be important for our identification assumption in the SVAR model of section 5.

4 The forex market in Peru

4.1 Features of the Peruvian forex market

Peru's interbank foreign exchange (forex) market is a local market primarily based on spot transactions. Although there is a forwards and options market, it is very small compared to the spot forex market.

Spot forex market transactions take place primarily on a private electronic trading platform operated by the company DATATEC. The platform is based on a blind system in which the bidders are known only to those involved in the transaction, and become generally known only after the transaction is closed. It operates between 9 am and 1:30 pm, Monday through Friday. The transactions are settled same day, under a real time gross settlement (RTGS) system on a payment versus payment platform through each bank's account at the central bank.

The participants in the forex market are commercial banks. However, about five banks are the major players in terms of average amount traded. Currently, the average amount traded in the interbank spot forex market is around USD 700 million a day. The record amount for one day is approximately USD 1,700 - almost 1 percent of GDP.

4.2 Central bank's intervention in the forex market

Forex operations are part of open market operations to regulate daily liquidity. Decisions on both forex operations and open market operations are made every day by a committee that meets between about 11:30 am and 1 pm. According to Rossini, Quispe and Rodriguez (2011), the Central Reserve Bank of Peru performs forex operations without pre-announcing the amount of operations, so that it does not signal or target any exchange rate level.

[10]The variance in (4) may be the same for purchases and sales because the way the central bank operates is the same.

The Central Reserve Bank's intervention in the forex market is conducted in order to reduce excessive daily volatility in the exchange rate. The main idea is to avoid the negative balance-sheet effect that can be generated by drastic changes in the exchange rate, which result in high volatility. Such negative effects can be very considerable, given the degree of dollarization of financial assets in the Peruvian economy - currently around 43%. The Central Reserve Bank believes that the level of the exchange rate is determined by fundamentals and therefore cannot be altered permanently; hence, it does not have an exchange rate target.

The main type of forex intervention conducted in Peru consists of direct operations with commercial banks in the spot market at the prevailing exchange rate. Rarely - when forward trading volume causes pressure in the foreign exchange position of banks, and thus in the spot exchange rate - the central bank intervenes through swap transactions to buy or sell dollars.

The interventions are sterilized in order to meet the prevailing interest rate target. Sterilization of forex operations employs two main instruments: central bank securities (CDs - central bank certificates of deposit), and Treasury deposits at the central bank.

The Central Reserve Bank purchases and sells dollars in the interbank FX market through the DATATEC system. These operations are discretionary, do not obey any pre-announced rule, and can be conducted on any day and at any time when the FX market is in operation.

The Central Reserve Bank is one more participant in the trading system. Given that the forex market operates through a blind system, other participants do not know the Central Reserve Bank's positions, and only after an operation has been concluded can they identify it as a counterparty. However, when it starts to intervene, the Central Reserve Bank announces the fact, so that all participants become aware of it, even if they do not conduct transactions with the Central Reserve Bank. The amount of the intervention is published when the market closes.

4.3 Data analysis

We use transaction-level data for intervention operations conducted by the Central Reserve Bank of Peru between January 5, 2009 and April 27, 2011. Table (1) shows a summary of purchase and sale operations and provides a grasp of the fact that purchase operations were different from sale operations in the sample. Sales are of lower magnitude and tend to be closer to each other. This difference in intervention operations may explain asymmetric exchange rate effects. However, for the Swiss case, Fischer and Zurlinden (1999) found that the number of trading partners in an intervention episode does not affect the effectiveness of the intervention.

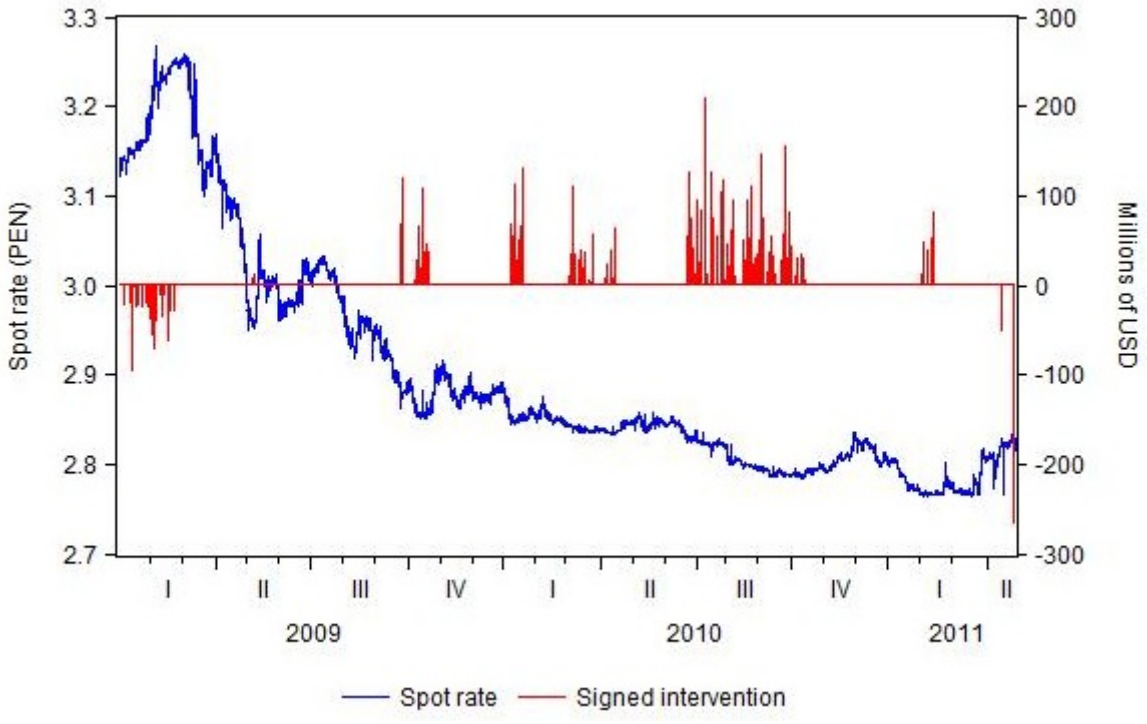
Table 1. *Descriptive statistics from transaction-level intervention data*

	Purchases	Sales	Whole sample
No of transactions	6,045	1,339	7,384
Average volume per transaction	1.8 m.	1.3 m.	1.7 m.
Mean interval between transactions	77.5 secs.	50.7 secs.	72.6 secs.
Stdev. of distance	470.9 secs.	388.0 secs.	457.1 secs.
Max distance	3.7 hrs.	3.3 hrs.	3.7 hrs.

Following Dominguez (2003), we transform the irregularly spaced intervention and spot price data to 5-minute intervals. After that, we obtain exchange returns r_t as the log difference of spot prices S_t, where the subscript t stands for each 5-minute interval. The FX market in Peru is local, and is open for about 4 and a half hours, from 9:00 am to 01:30 pm. Given that transactions between 9:00 and 9:15 are scarce in the data set, the 9:15-9:20 interval is considered the first interval for every day in the sample. The 5-minute time series starts at 9:20 am and ends at 1:30 pm for each business day; however, when calculating the 5-minute return series, we do not take into account the 9:15-9:20 interval.

Figure (1) shows the evolution of the PEN over the sample, together with intervention operations measured as net purchases of USD. After a peak ranging from PEN 3.26 to 3.27 to the US dollar between March and April 2009, the exchange rate tended to appreciate during the sample period.

Figure 1. *Exchange rates and FX intervention in the sample*



5 Measuring asymmetric effects

We apply two econometric approaches to measure asymmetric effects of intervention. First, we run event study regressions following Payne and Vitale (2003), Fischer and Zurlinden (1999) and Dominguez (2003). Next, we use a SVAR framework.

5.1 Event study regression

We run two types of regressions. In the first model, intervention is measured by the signed absolute volume of intervention. In the second model, intervention is measured as the ratio of those signed volumes to interbank turnover.

Model with intervention sizes

We run separate regressions for sale and purchase interventions, as follows:

$$r_t = \alpha + \sum_{i=-k}^{k} \beta_i Q_{t+i}^{j} + \sum_{i=-l}^{l} \gamma_i C_{t+i}^{dumm} + \sum_{i=1}^{m} \delta_i r_{t-i} + \epsilon_t \tag{5}$$

where r_t stands for the log difference of the transaction spot PEN price of USD multiplied by 100, $Q_t^p > 0$ is the size of purchases (zero otherwise), $Q_t^s < 0$ is the size of sales (zero otherwise), and C_{t+i}^{dumm} represents a dummy that controls for the first interval within an hour. We include lagged returns due to the presence of error autocorrelation and use Newey-West robust standard errors (See results regressions in tables 3 and 4 in the appendix).

Figure (2) depicts the response of cumulative returns to sales and purchases, respectively. Both impulses amount to USD 25 millon. Sales have a strong effect on cumulative returns through minute 15 following the intervention. Purchases do not have significant effects. These asymmetric effects are compatible with the theoretical framework outlined in section (3), and also support earlier empirical findings for Mexico and Turkey by Domac and Mendoza (2004) and for Peru by Flores (2003).

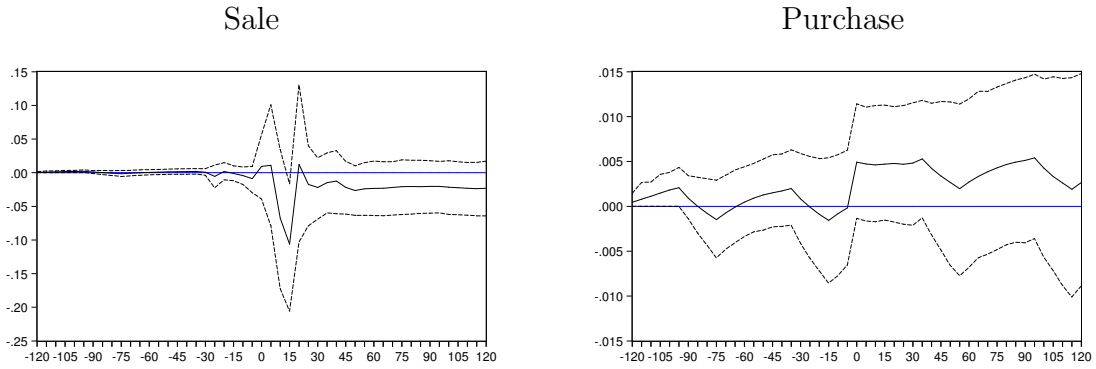
Model with intervention size scaled by interbank turnover

In this case, we replace the amounts of sales and purchases with relative amounts. The model is the same otherwise:

$$r_t = \alpha + \sum_{i=-k}^{k} \beta_i X_{t+i}^{j} + \sum_{i=-l}^{l} \gamma_i C_{t+i}^{dumm} + \sum_{i=1}^{m} \delta_i r_{t-i} + \epsilon_t \tag{6}$$

where X_t^j is the corresponding size Q_{t+i}^j, but scaled by daily interbank turnover. Figure (3) shows the responses of cumulative returns to a sale or purchase equiva-

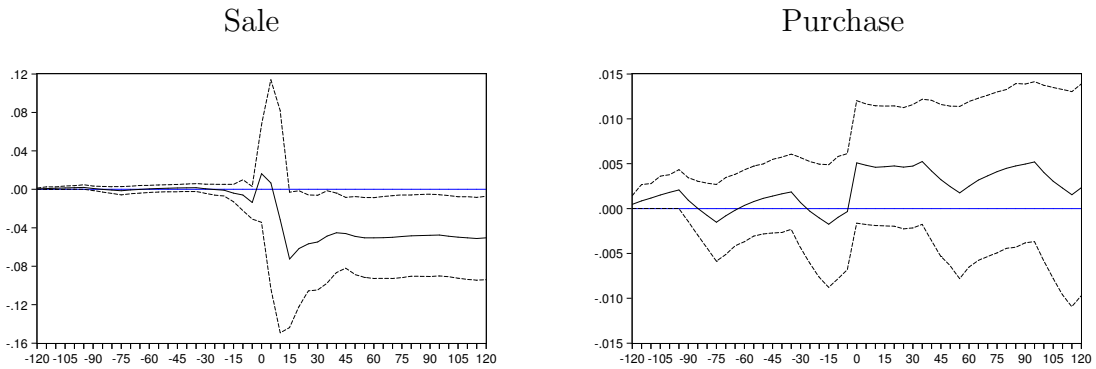
Figure 2. *Cumulative returns response due to a sale or purchase of USD 25 millions*



NOTE: Horizontal axis measures minutes, vertical axis are expressed in percentage (%)

lent to 10% of interbank turnover. Results are qualitatively similar to the previous result (see also results regressions in tables 5 and 6 in the appendix).

Figure 3. *Cumulative returns response due to a sale or purchase equivalent to 10 percent of turnover*



NOTE: Horizontal axis measures minutes, vertical axis are expressed in percentage (%)

Thus, event study regressions support the following conclusions: (1) purchase interventions have stronger effects on cumulative returns than do sale interventions; (2) the long-run value of the spot rate (2 hours after intervention) seems to be unaffected by either purchases or sales; and (3) the two foregoing results are compatible with the asymmetric signalling model outlined here, and therefore will serve as the basis for the SVAR identification strategy that follows

5.2 A structural VAR approach

In order to measure the effects of an exogenous change in forex intervention, we identify three structural shocks, assuming long-run restrictions. In particular, under the view that the exchange rate is determined by its fundamentals in the long

run, we use the identifying assumption that an exogenous change in forex intervention (either purchase or sale) has no long-run effect on the level of the exchange rate.

Let S denote the log interbank exchange rate, so that $r_t \equiv S_t - S_{t-1}$ is the exchange rate return, Q_t^p is the amount of dollars purchased by the central bank in the foreign exchange market and Q_t^s the amount of dollars sold by the central bank. Under the assumption that r_t, Q_t^p and Q_t^s are stationary time series, and that S_t is non-stationary, the vector moving average (VMA) representation for r_t, Q_t^p, and Q_t^s [11] in terms of fundamental innovations can be written as:

$$\begin{bmatrix} r_t \\ Q_t^p \\ Q_t^s \end{bmatrix} = \sum_{i=0}^{\infty} \begin{bmatrix} \phi_{11}(i) & \phi_{12}(i) & \phi_{13}(i) \\ \phi_{21}(i) & \phi_{22}(i) & \phi_{23}(i) \\ \phi_{31}(i) & \phi_{32}(i) & \phi_{33}(i) \end{bmatrix} \begin{bmatrix} \varepsilon_{t-i}^F \\ \varepsilon_{t-i}^P \\ \varepsilon_{t-i}^S \end{bmatrix} \tag{7}$$

where ε_t^F represents a shock to any fundamentals in the exchange rate, and ε_t^P and ε_t^S represent exogenous decisions to purchase and sell dollars, respectively. Given that all three series are assumed to be stationary, none of these disturbances will have permanent or long-run effects on them. However, the disturbances might have long-run effects on the log level of the exchange rate, S_t, given that it is assumed to be a unit root process.

Long-run identification of structural errors

In order to identify the structural errors of this VAR model, we follow the strategy suggested by Blanchard and Quah (1989), which is based on long-run restrictions. In particular, we assume that neither of the disturbance terms ε_t^P and ε_t^S has any long-run effect on the log exchange rate. In terms of (7), this assumption implies that $\sum_{i=0}^{\infty} \phi_{12}(i) = 0$ and $\sum_{i=0}^{\infty} \phi_{13}(i) = 0$.

Given that we need at least one more zero restriction to achieve identification, it is also reasonable to assume that a sale innovation ε_{t-i}^S will have no long-run effect on dollar purchases, i.e. $\sum_{i=0}^{\infty} \phi_{23}(i) = 0$. By symmetry, it is also possible to assume that a purchase innovation ε_{t-i}^P will have no long-run effect on dollar sales, i.e. $\sum_{i=0}^{\infty} \phi_{32}(i) = 0$.

Results

The first step was to test for the presence of unit roots in the series. Using the DF-GLS efficient unit root test proposed by Elliott et al. (1996), we found that the unit root hypothesis cannot be rejected for E, whereas this hypothesis is rejected for P and S. Based on these results we proceed to estimate the long-run effects matrix under the assumptions $\sum_{i=0}^{\infty} \phi_{12}(i) = 0$, $\sum_{i=0}^{\infty} \phi_{13}(i) = 0$, $\sum_{i=0}^{\infty} \phi_{23}(i) = 0$ and $\sum_{i=0}^{\infty} \phi_{32}(i) = 0$. Given that the model is over-identified, we also perform a

[11] Each variable in the VAR is expressed in terms of deviations from its sample mean

test of over-identifying restrictions. The results are shown in Table 2.

The estimated coefficients have the expected signs. In particular, a positive structural exchange rate shock has a negative cumulative effect on dollar purchases and a positive cumulative effect on dollar sales. The test of over-identifying restrictions cannot be rejected, and thus supports the joint validity of the proposed restrictions.

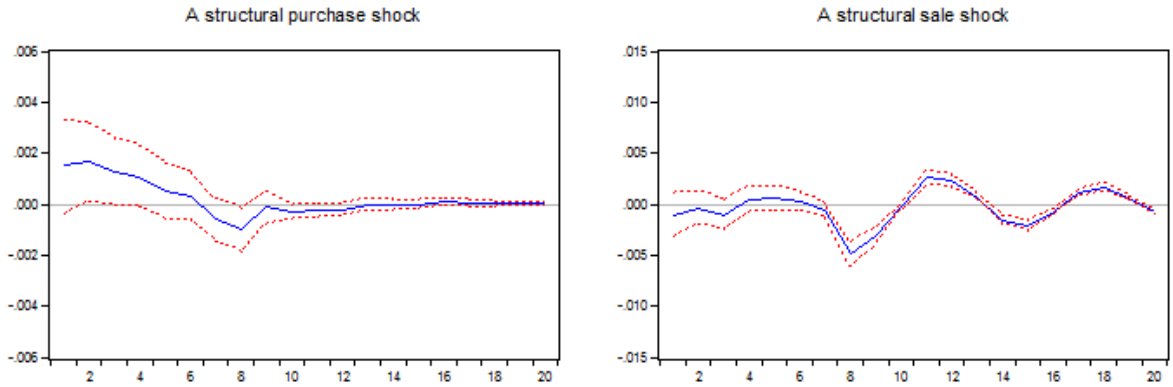
Table 2. *Structural VAR estimates: Long-run effects and over-identifying restrictions.*

	$\sum_{i=1}^{\infty}\phi_{11}(i)$	$\sum_{i=1}^{\infty}\phi_{21}(i)$	$\sum_{i=1}^{\infty}\phi_{22}(i)$	$\sum_{i=1}^{\infty}\phi_{31}(i)$	$\sum_{i=1}^{\infty}\phi_{33}(i)$
estimate	0.03	-0.00	0.00	0.02	0.01
prob.	0.00	0.00	0.08	0.00	0.00
LR test for over-identification					
Chi-square(1)	2.32				
Probability	0.13				

NOTE: The estimation of the SVAR was performed using the method of scoring.

Figure 4 shows the response of the interbank exchange rate to exogenous purchase and sale shocks.[12] According to Figure 4, forex interventions have significant effects on exchange rates. Furthermore, forex interventions have a greater effect in reducing exchange rates (sale operations) than raising exchange rates (purchase operations). These results further support the event study outcomes.

Figure 4. *Accumulated responses of five-minutes changes in exchange rates*



NOTE: *The impulse response functions display bootstrapped 95% confidence intervals.*

[12]The impulse response functions are obtained from the estimation of the SVAR with 9 lags. Bootstrapped 95% confidence intervals were constructed using the SVAR estimates.

6 Concluding remarks

Asymmetric effects of central bank intervention have not been much studied in the literature, even though there is a remarkable difference between the motives central banks have for purchasing foreign currency and their motives for selling. This paper studies asymmetric effects of central bank interventions under the premise that policy authorities view exchange rate depreciations and appreciations as having asymmetric implications.

The paper contributes to the literature on foreign exchange intervention in emerging market economies in three dimensions. First, it is the first time comprehensive intraday intervention data for Peru have been used. The data are from 2009 to 2011. Second, the paper shows that central bank interventions in the foreign exchange market have asymmetric effects on the spot exchange rate. In particular, sale interventions are more effective than purchase interventions. This result is robust to event study regressions and to a SVAR identification proposed in the paper. In addition, the result confirms a previous finding for Peru documented in Flores (2003).

Lastly, the asymmetric effect whereby sale interventions are more effective than purchase interventions is also compatible with the simple signalling framework outlined in this paper.

References

Armas, A. & F. Grippa (2006), Targeting Inflation in a Dollarised Economy: The Peruvian Experience in Armas, A., Ize, A. & Levy-Yeyati, E. (Eds.). *Financial dollarization: the policy agenda*. Palgrave Macmillan. International Monetary Fund, Washington DC.

Blanchard, O. & D. Quah. (1989), The Dynamic Effects of Aggregate Demand and Supply Disturbances. *American Economic Review* 79: 655-673.

Broto, C. (2012). The effectiveness of forex interventions in four latin american countries. Carmen Broto, The effectiveness of forex interventions in four Latin American countries, *Emerging Markets Review*, Available online 4 April 2013, ISSN 1566-0141, 10.1016/j.ememar.2013.03.003.

Bussiere, M., C. Lopez & C. Tille. (2013). Currency Crises in Reverse: Do Large Real Exchange Rate Appreciations Matter for Growth?, MPRA Paper 44053, University Library of Munich, Germany.

Calvo, G. & C. Reinhart(2002). Fear Of Floating, *The Quarterly Journal of Economics*, 117(2), 379-408.

Disyatat, P. & G. Galati. (2007). The effectiveness of foreign exchange intervention in emerging market countries: Evidence from the Czech koruna. *Journal of International Money and Finance*, 26(3), 383-402.

Domac, I., & A. Mendoza. (2004). Is there room for foreign exchange interventions under an inflation targeting framework? Evidence from Mexico and Turkey. Evidence from Mexico and Turkey (April 22, 2004). World Bank Policy Research Working Paper, (3288).

Dominguez, K. M. (2003). The market microstructure of central bank intervention. *Journal of International Economics*, 59(1), 25-45.

Elliott, G., T. Rothenberg & J. Stock (1996). Efficient tests for an autoregressive unit root. *Econometrica*: Journal of the Econometric Society, 813-836

Fatum, R., J. Pedersen & P. Srensen. (2010). Are the intraday effects of central bank intervention on exchange rate spreads asymmetric and state dependent?, Globalization and Monetary Policy Institute Working Paper 59, Federal Reserve Bank of Dallas.

Fatum, R., J. Pedersen & P. Sorensen. (2013). The Intraday Effects of Central Bank Intervention on Exchange Rate Spreads. Journal of International Money and Finance 33(1), 103-117.

Fischer, A. M., & Zurlinden, M. (1999). Exchange rate effects of central bank interventions: an analysis of transaction prices. The Economic Journal, 109(458), 662-676.

Flores, M. (2003). Un anlisis de las intervenciones del Banco Central de Reserva del Per en el mercado cambiario: 1999-2001. *Revista de Estudios Econmicos* 9: 51-72.

Fratzscher, M. (2012). Official Intervention in the Foreign Exchange Market. in J. James, I. W. Marsh & L. Sarno (Eds.), *Handbook of Exchange Rates* (717-749), John Wiley & Sons, Inc., Hoboken, NJ, USA. doi: 10.1002/9781118445785.ch26.

Galati, G. & W. Melick. (2002). Central bank intervention and market expectations. BIS Papers No. 10.

Kappler M., H. Reisen, M. Schularick & E. Turkisch (2011). The Macroeconomic Effects of Large Exchange Rate Appreciations, OECD Development Centre Working Papers 296, OECD Publishing.

Kearns, J., & R. Rigobon. (2005). Identifying the efficacy of central bank interventions: evidence from Australia and Japan. *Journal of International Economics*, 66(1), 31-48.

Levy-Yeyati, E., F. Sturzenegger, & P. Gluzmann. (2012). Fear of appreciation. *Journal of Development Economics*.

Pasquariello, P. (2007). Informative trading or just costly noise? An analysis of central bank interventions. *Journal of Financial Markets* 10, 107143.

Payne, R. & P. Vitale. (2003). A transaction level study of the effects of central bank intervention on exchange rates. *Journal of international economics*, 61(2), 331-352.

Rossini, R., Z. Quispe & D. Rodriguez. (2011). Capital Flows, Monetary Policy and FOREX Interventions in Peru, BCRP Working Paper 2011-008.

Rossini, R., Z. Quispe & E. Serrano (2013). Foreign Exchange Intervention in Peru, Forthcoming, BIS background papers.

Woodford, M. (2005). Central bank communication and policy effectiveness (No. w11898). National Bureau of Economic Research.

Appendix

Table 3. *Purchase regression with intervention volumes*

Regressor	Coefficient	p-value
β_0	0.000186	0.0000
γ_0	-0.001450	0.0230
δ_1	-0.139800	0.0001
δ_2	-0.131317	0.0009
δ_3	-0.066504	0.0041
δ_4	-0.057287	0.0026
δ_5	-0.097681	0.0016
δ_6	-0.065826	0.0084

[a] Equation is $r_t = \beta_0 Q_t^p + \gamma_0 C_{t+i}^{dumm} + \sum_{i=1}^{6} \delta_i r_{t-i} + \epsilon_t$

Table 4. *Sale regression with intervention volumes*

Regressor	Coefficient	p-value	Regressor	Coefficient	p-value
β_{-5}	0.000981	0.6771	β_4	-0.000299	0.2869
β_{-4}	-0.004216	0.0475	β_5	0.000227	0.5169
β_{-3}	0.001846	0.6075	γ_0	-0.001364	0.0314
β_{-2}	0.003024	0.3594	δ_1	-0.138783	0.0001
β_{-1}	4.81E-05	0.988	δ_2	-0.129683	0.0009
β_0	-0.000718	0.5511	δ_3	-0.067191	0.0036
β_1	0.00024	0.3735	δ_4	-0.058106	0.0022
β_2	0.000139	0.4869	δ_5	-0.097866	0.0016
β_3	8.04E-05	0.5971	δ_6	-0.06581	0.0088

[a] Equation is $r_t = \sum_{i=-5}^{5} \beta_i Q_{t+i}^s + \gamma_0 C_{t+i}^{dumm} + \sum_{i=1}^{6} \delta_i r_{t-i} + \epsilon_t$

Table 5. *Purchase regression with intervention volumes relative to turnover*

Regressor	Coefficient	p-value
β_0	0.048934	0.0000
γ_0	-0.001436	0.0243
δ_1	-0.139776	0.0001
δ_2	-0.131302	0.0009
δ_3	-0.066483	0.0041
δ_4	-0.05729	0.0026
δ_5	-0.097697	0.0016
δ_6	-0.065811	0.0084

[a] Equation is $r_t = \beta_0 X_t^p + \gamma_0 C_{t+i}^{dumm} + \sum_{i=1}^{6} \delta_i r_{t-i} + \epsilon_t$

Table 6. *Sale regression with intervention volumes relative to turnover*

Regressor	Coefficient	p-value	Regressor	Coefficient	p-value
β_{-3}	0.448559	0.6022	γ_0	-0.001355	0.0334
β_{-2}	0.369322	0.5454	δ_1	-0.139504	0.0001
β_{-1}	0.048151	0.9557	δ_2	-0.130626	0.0009
β_{-0}	-0.264396	0.4248	δ_3	-0.066126	0.0043
β_1	0.091251	0.1805	δ_4	-0.057644	0.0024
β_2	0.029937	0.6391	δ_5	-0.097952	0.0015
β_3	0.022311	0.5863	δ_6	-0.066223	0.0083

[a] Equation is $r_t = \sum_{i=-3}^{3} \beta_i X_{t+i}^s + \gamma_0 C_{t+i}^{dumm} + \sum_{i=1}^{6} \delta_i r_{t-i} + \epsilon_t$

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