Effectiveness of forex interventions in four Latin American economies *

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Abstract

Many central banks actively intervene in the foreign exchange (forex) market, although there is no consensus on its impact on the exchange rate level and volatility. We analyze these effects of daily forex interventions in four Latin American economies with inflation targets—namely, Chile, Colombia, Mexico and Peru—by fitting GARCH type models. Our sample countries represent a wide range of intervention strategies in terms of size and frequency that go from pure distretionary to intervention rules. We also provide new evidence on the presence of asymmetries which are present if foreign currency purchases have a different effect on the exchange rate from that of sales. Our results suggest that first interventions, either isolated or initial in a rule, reduce the exchange rate volatility, whereas the intervention size plays no role. This outcome supports the signalling effect of interventions under inflation targeting regimes.

Keywords: Exchange rate volatility; Foreign exchange interventions; GARCH.

JEL codes: F31; G15

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1 Introduction

Central banks frequently perform foreign exchange (henceforth forex) interventions to influence the exchange rate level or to moderate its volatility, even regardless of their monetary policy scheme (Stone et al., 2009). Forex interventions are sales or purchases of foreign assets (typically US dollars —USD hereafter—, but also other major currencies) aimed at impacting on the level and/or volatility of the domestic currency. If a central bank considers that the exchange rate has deviated excessively from its equilibrium, it would sell (buy) local currency during periods of appreciatory (depreciatory) pressures.[1]

Implicitly, monetary authorities support the idea that forex interventions do influence on the exchange rate level and volatility.[2] Given the policy implications of their effectiveness, a large empirical literature has flourished but the evidence is still mixed. In particular, the papers that analyze daily exchange rates, which is the mostly employed time frequency, provide three main views. First, most works conclude that interventions are ineffective in altering the exchange rate level and they can even increase the exchange rate volatility. See, for instance, Baillie and Osterberg (1997), Dominguez (1998) or Edison et al. (2006). This conclusion suggests that interventions might introduce market uncertainty. However, this might be the result of a simultaneity problem of daily data as during the intervention day the central bank is probably responding to an exchange rate volatility excess, so that both variables would be positively correlated. Thus, concluding that higher volatility is a result of interventions could be misleading (Kim et al., 2000). Endogeneity also lies behind some counterintuitive results regarding the effects on the exchange rate level which are consistent with 'leaning against the wind' strategies with, for instance, dollar purchases appreciating the local currency (Baillie and Osterberg, 1997).

On a more positive tone, other authors state that forex interventions can influence on the exchange rate level and 'calm disorderly markets', thereby moderating the exchange rate volatility (Kim and Pham, 2006; Hoshikawa, 2008).[3] Finally, the more skeptical

[1]Forex interventions should be distinguished from those operations of central banks in the forex market to manage official reserves or to meet transaction needs of the government (Chiu, 2003).

[2]For instance, according to the surveys by Neely (2000; 2008), central banks disagree with the assertion that intervention increases volatility.

[3]These authors find that high frequency forex interventions of the Reserve Bank of Australia and the

view states that forex interventions have a negligible impact on the currency level and volatility, as shown by Dominguez (2006) for the G3.[4]

As reported in Adler and Tovar (2011), very few economies publish their daily forex interventions, which justifies that most of this literature is focused on country specific analysis. Most papers analyze the G3 and Australia,[5] whereas the literature is much more scarce for emerging markets (EMEs hereafter) as authorities are more reluctant to provide official data on their operations. Although transparency is improving, at present daily releases are concentrated on a reduced number of countries—mainly from Latin America—, which have led to a few empirical papers. For instance, Humala and Rodriguez (2010) and Kamil (2008) analyze Peru and Colombia, respectively, whereas Domaç and Mendoza (2004) focus on Mexico and Peru. Forex interventions in EMEs have a different nature than in developed countries, so that, in principle, their effects should differ. Thus, EMEs tend to intervene more frequently in the forex markets than the developed ones, independently of their monetary policy regime (Berganza and Broto, 2012). Besides, a priori, it seems sensible that forex interventions in EMEs might be more effective than in developed countries (Disyatat and Galati, 2007).[6] However, for EMEs the evidence is not conclusive either. For instance, Disyatat and Galati (2007) find that interventions had no influence on the short-term volatility of the Czech koruna, whereas Domaç and Mendoza (2004) find the opposite result for Mexico and Turkey.

Another relevant aspect regarding forex interventions is their wide spectrum of characteristics in terms of frequency and size. For instance, in most developed countries such as Japan, the current policy is to intervene on a discretionary basis and only under

Bank of Japan, respectively, were effective to reduce the exchange rate volatility, whereas low frequency and officially announced interventions mainly affected the exchange rate level.

[4]this author analyzes intra-daily and daily exchange rates of the G3 and concludes that interventions can influence exchange rates only within the day.

[5]See, for instance, Rogers and Siklos (2003), Kim and Sheen (2002), Edison et al. (2006), Kim and Pham (2006) for some empirical papers on Australia; Baillie and Osterberg (1997) and Dominguez (1998) for the G3, and Frenkel et al. (2005), Watanabe and Harada (2006), Kim and Sheen (2006), Hillebrand and Schnabl (2008) or Hoshikawa (2008) for Japan.

[6]According to these authors, this is basically due to: (i) the larger size of forex interventions relative to market turnover in EMEs; (ii) the greater leverage of central banks in the case of existence of some form of capital controls; (iii) the informational advantage that represents their lower level of sophistication.

exceptional circumstances, whereas in EMEs their intervention strategies differ across countries and run from fully discretionary interventions (Brazil, Peru) to intervention rules (Chile). Introducing these features in the model specification could help to obtain additional information on the effect of interventions (Kim and Pham, 2006).

Besides, in this literature, the presence of asymmetries has not been much analyzed yet (Baillie and Osterberg 1997, Domaç and Mendoza, 2004 or Guimarães and Karacadag, 2004). Forex interventions will have an asymmetric effect if the sales of foreign currency (negative interventions) have a different impact on the exchange rate volatility than that of purchases (positive interventions). After the onset of the crisis, many central banks performed interventions of opposite sign than those of the previous period (BIS, 2010), which has allowed to increase the number of observations for the study of asymmetries.

The main objective of this paper is to analyze the the efficiency of forex interventions to influence on the exchange rate level and volatility with a particular focus on the possible asymmetric effects of interventions, as well as their size and frequency. We carry out a time series analysis for the daily bilateral exchange rates against the USD of four Latin American countries with inflation targets—namely, Chile, Colombia, Mexico and Peru—, by fitting a battery of univariate GARCH type models. This type of models have been broadly used in this literature since Baillie and Osterberg (1997) or Dominguez (1998). Although GARCH models entail the aforementioned simultaneity problems, this is a sensible procedure to deal with daily data. As far as we know, this is the empirical paper that studies the efficiency of daily interventions for a greater number of Latin American countries in an homogeneous way. Our results suggest that first interventions, either isolated or initial in a rule, reduce the volatility, whereas their size plays no role.

The paper is organized as follows. After the introduction, Section 2 describes the data set, which consists of the daily exchange rate returns and forex interventions of our four countries. Then, Section 3 presents the GARCH models that will be used to analyze the impact of interventions on the exchange rate level and volatility distinguishing the presence of asymmetries, as well as intervention characteristics such as size and frequency. In Section 4, we report the main empirical findings. Finally, Section 5 concludes the paper.

2 The data

We study the impact of interventions on the exchange rate level and volatility of four currencies. In particular, we analyze the daily returns of the USD vis-à-vis the Chilean peso (CLP), the Colombian peso (COP), the Mexican peso (MXN) and the Peruvian nuevo sol (PEN). That is, an increase (decrease) of the nominal bilateral exchange rate is an appreciation (depreciation) of the local currencies against the USD.[7] Daily forex interventions were obtained from national sources.[8] We only consider sales and purchases of US dollars, as this is the most widely used currency to implement interventions in all countries. See Appendix A for some description and data sources of forex intervention.

Figure 1 represents the four currency pairs and the daily forex interventions (net forex purchases or sales), where positive interventions indicate USD purchases and negative values are official USD sales. In the years preceding the crisis, forex interventions in Chile, Colombia and Peru were more targeted to foreign exchange purchases rather than sales, which reflects their appreciating trend in their role of commodity linked and high yield currencies. On the contrary, the accumulation of reserves in Mexico prompted the authorities to sell USD from 2003 (Guimarães and Karacadag, 2004). After the onset of the crisis in 2008 all countries suffered depreciatory pressures and sold dollars.

As shown in Figure 1, the four countries represent a variety of intervention strategies. Whereas in Peru the current policy is to intervene on a discretionary basis under exceptional circumstances the intervention strategy in other countries is based on rules (Chile, Colombia), which imply more frequent and relatively smaller interventions. There are two types of rules: Exchange rate-based rules, normally aimed at moderating the exchange rate volatility (Colombia), or quantity-based rules aimed at the accumulation of reserves (Chile). Since February 2010 Mexico also holds this latter type of rule (Adler and Tovar, 2011). According to Frankel and Dominguez (1993) interventions have a maximum impact when they occur unexpectedly, which would support the effectiveness of

[7] We have obtained all currency pairs from Datastream.

[8] Nowadays there is no comprehensive and updated database on daily forex interventions. Up to our knowledge, the Federal Reserve Bank of Sant Louis provides the best data compilation, but it is particularly focused on developed countries (http://research.stlouisfed.org/fred2/categories/32145).

isolated interventions, but other authors conclude that the series of interventions might be perceived as more credible to market participants (Kim et al., 2000). [9]

Apart from representing a wide range of intervention strategies, we have chosen these four currency pairs for other reasons. First and more importantly, their daily forex interventions are publicly available.[10] Indeed, our country sample represents all the economies that publish daily data, as reported in Adler and Tovar (2011), that meet certain prerequisites. For instance, we explicitly exclude those countries that have not performed interventions after the onset of the last crisis, although they publish daily releases. This is the case of Canada, United Kingdom, the United States and Turkey.[11] Besides, their sample sizes should also be large enough for a GARCH type analysis.[12] For instance, we do not analyze Israel as the central bank has only intervened three times after 1997 (Sorezcky, 2010). Finally, we do not consider Australia as interventions are published with a one year lag. All in all, we end up with a representative sample of Latin American countries, as our four economies are among the seven largest in the region in terms of GDP based on PPP valuation.[13]

Table 1 reports the exchange rate regime and monetary policy arrangement of the four countries, which can influence the impact of interventions (Disyatat, 2007). According to IMF's classification, all countries but Colombia and Peru, which follow a managed floating

[9] Nowadays all these forex interventions are sterilized. While non sterilized interventions directly impact on exchange rates through the monetary channel, sterilized intervention does not influence the exchange rate directly through the usual monetary mechanisms, but though indirect channels. See Neely (2008), for details on the portfolio, signaling and the coordination transmission channel of sterilized interventions.

[10] Data scarcity might justify the use of reserve variations as a proxy for intervention. However, daily reserve variations are a bad approximation of forex interventions (Adler and Tovar, 2011).

[11] The last forex intervention performed by Bank of Canada, the Federal Reserve and the Bank of England was in March 2011 and it was a coordinated action to stabilize the JPY, whereas that of Turkey was in 2006.

[12] For instance, if the sample of forex interventions is very small, their impact could be mislead with that of an additive outlier, which can affect the identification of conditional heteroscedasticity and the estimation of GARCH type models (Carnero et al., 2007).

[13] According to the World Economic Outlook Database of the International Monetary Fund (September 2011).

regime with no pre-determined path for the exchange rate, have floating currencies and all countries follow an inflation target. Note that even though the four EMEs have adopted inflation targets during the last years, so that in theory the exchange rate plays no role as nominal anchor, these economies intervene actively in the forex markets (Berganza and Broto, 2012).[14] The sample period varies across countries and runs from 31/7/1996 to 6/6/2011 for the USD/MXN ($T = 3873$) to 1/1/2004 to 15/6/2011 in the case of the CLP ($T = 1944$). The beginning of the sample period indicates the first official publication date of forex interventions. Table 1 also shows some descriptive statistics of total interventions, I_t, as well as for negative and positive interventions, denoted as I_t^- and I_t^+, respectively. Whereas the central bank of Colombia has intervened around 19% of the trading days during the sample period, the Central Reserve Bank of Peru intervened around 61% of the days. Net sales of dollars are much less frequent than net purchases. For instance, they represent 7% of total interventions in Colombia, whereas Mexico is the only country where negative interventions are more frequent than positive ones (89%).

Table 2 reports some descriptive statistics for the four exchange rate returns, r_t, for total interventions, I_t, and for I_t^+ and I_t^-. All these series are asymmetric and have excess kurtosis. The skewness of all exchange rate returns is negative. That is, extreme values of returns are related to currency depreciation. Box-Pierce Q-statistics for higher order serial correlation reveal that squared returns are much more autocorrelated than non-squared data, which implies the presence of conditional heteroscedasticity in all exchange rate returns and evidences the suitability of a GARCH type model in this setting. Regarding forex interventions, as illustrated in Table 2 and in line with the skewness coefficient sign, in Colombia, Mexico and Peru the absolute value of negative interventions is larger than that of positive interventions. In Chile, positive and negative interventions have a similar volume.

[14] Whereas Chile and Colombia adopted and inflation target in 1999, Mexico introduced this monetary policy framework in 2001 and Peru in 2002 (IMF, 2005).

3 Empirical model

We model the percent returns of the nominal exchange rate of the dollar against the four currencies, which are represented in Figure 2, and are given by,

$$r_t = 100 \times (\Delta \log E_t) \tag{1}$$

where E_t is the bilateral nominal exchange rate in t and Δ is the difference operator so that a positive r_t denotes a local currency appreciation against the USD.[15]

Our baseline model is a simplified version of that proposed by Dominguez (1998) to analyze forex interventions and exchange rate volatility in the G3, which follows this expression,

$$r_t = \beta_0 + \beta_1 r_{t-1} + \beta_2 I_t + \varepsilon_t \tag{2}$$

$$\varepsilon_t = \varepsilon_t^{\dagger} h_t^{1/2} \tag{3}$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \gamma_1 |I_t| \tag{4}$$

where, $\forall t = 1, ..., T$, r_t are the daily exchange rate returns, $|I_t|$ is the absolute value of forex interventions and $\varepsilon_t^{\dagger}$ is a Gaussian white noise process. As Dominguez (1998) or Hoshikawa (2008), we introduce I_t in the mean and in the conditional variance equation, where $|I_t|$ should appear in absolute value to guarantee its positivity. In (2) we also add r_{t-1} for pre-whitening purposes, as usual in the empirical finance literature. For the sake of simplicity, we omit any additional explanatory variables in the model.[16]

A negative (positive) coefficient of the variable I_t in (2) will indicate that a net purchase of foreign currency coincides with a depreciation (appreciation) of the local currency. Note that a positive estimate of β_2 could imply that interventions have not influenced r_t in the desired way, as USD purchases would be associated with a local currency appreciation. However, this outcome is consistent with a 'leaning against the wind' strategy,

[15] We subtract the mean of $\Delta \log E_t$ to guarantee zero mean returns (Harvey et al., 1994).

[16] Some authors such as Dominguez (1998) use interest rate spreads to control for the monetary policy stance. Our preliminary results including interest rate differentials do not vary significantly, so that in line with Edison et al. (2006), Beine et al. (2009) or Hoshikawa (2008) we do not consider this variable. In the mean equation we do not consider either day of the week and holiday dummy variables for simplicity. These last variables would lead to degenerated likelihood surfaces if they are included in the conditional variance (Doornik and Ooms, 2003).

which is also linked with the aforementioned endogeneity issues, as the central bank buys dollars as a response to the appreciatory pressures on their currency. On the other hand, the estimates of γ_1 in (4) would be negative if the exchange rate volatility moderates after the forex intervention.[17]

We also estimate a modified version of this baseline model modifying the conditional variance (4) to incorporate asymmetries.[18] This allows us to analyze if interventions to stabilize the currency under depreciatory or appreciatory pressures have a different impact on the exchange rate volatility. For this purpose we substitute the conditional variance in (4) with this expression,

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \gamma_2 \left| I_t^- \right| + \gamma_3 I_t^+, \tag{5}$$

where $\left| I_t^- \right|$ and I_t^+ stand for $|I_t|$. The effect of negative interventions on the exchange rate returns is γ_2 whereas that of positive interventions is γ_3. This conditional variance equation in (5) also allows to perform Wald-type tests for the null that interventions have a symmetric effect on the conditional variance, $H_0 : \gamma_2 = \gamma_3$.

In a third stage we analyze if considering some characteristics of forex interventions is useful to disentangle their link with the exchange rate volatility. With this purpose we use the following specification,

$$r_t = \beta_0 + \beta_1 r_{t-1} + (\beta_2 + \beta_3 FIRST_t + \beta_4 SIZE_t) I_t + \varepsilon_t \tag{6}$$

$$\varepsilon_t = \varepsilon_t^{\dagger} h_t^{1/2} \tag{7}$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + (\gamma_1 + \gamma_4 FIRST_t + \gamma_5 SIZE_t) \left| I_t \right| \tag{8}$$

where $FIRST_t$ is a dummy variable that is one if I_t is the first intervention in a series or an isolated intervention, that is, if $I_{t-1} = 0$ and $I_t \neq 0$, and zero otherwise.[19] As in Kim and Shenn (2006) and Kim and Pham (2006), $SIZE_t$ is a dummy variable that is

[17] In the estimation process we have imposed positivity constraints on h_t to avoid negative variances resulting from these negative coefficients.

[18] We do not consider asymmetries in the mean equation to distinguish the effect of positive and negative forex interventions in the exchange rate returns. Our preliminary exercises, which are available upon request, show that this asymmetry is hardly significant in our data.

[19] In a complementary way, Kim and Sheen (2006) have analyzed intervention effectiveness if they persist over a number of days.

one if the absolute value of I_t is greater than the average daily absolute interventions. Note that $FIRST_t$ and $SIZE_t$ can be highly correlated, as isolated interventions use to be bigger than consecutive interventions.[20]

Finally, we perform some statistical inference on the presence of asymmetries in the conditional variance equation (8) by also considering this alternative specification,

$$h_t = \alpha_0+\alpha_1\varepsilon_{t-1}^2+\alpha_2 h_{t-1}+(\gamma_2+\gamma_6 FIRST_t+\gamma_7 SIZE_t)\left|I_t^-\right|+(\gamma_3+\gamma_8 FIRST_t+\gamma_9 SIZE_t)I_t^+, \tag{9}$$

which also allows to test for the presence of asymmetries depending on the size and the systematic character of interventions. For instance, a test of the null hypothesis that large and first interventions, either isolated or first in a row, are symmetric is $H_0 : \gamma_2+\gamma_6+\gamma_7 = \gamma_3+\gamma_8+\gamma_9$.

As mentioned, these GARCH-type specifications, as well as those used in all previous studies in this literature, have in common the simultaneity between the interventions and the exchange rate returns. This fact constitutes an endogeneity issue inherent to this literature. Indeed, assuming that interventions are exogenous to market conditions would be rather strong taking into account that monetary authorities explicitly declare that they intervene to calm disorderly markets (Dominguez, 1998; Kim and Sheen, 2002; Frenkel et al., 2005). As noted by Kim and Pham (2006) one possible approach to overcome this problem lies in the own data selection. One option would be to use high-frequency intra daily data, but the specific time of intervention is not available. Other alternative solution would be to use the lagged interventions, but they usually lack explanatory power (Baillie and Osterberg, 1997).[21] Nevertheless, as it is a normal practice to intervene during business operating hours (Neely, 2000) and the exchange rate data are market closing data, interventions in t are already predetermined (Dominguez, 1998).

[20]The correlation between $FIRST_t$ and $SIZE_t$ in our sample run from 0.01 in Peru to 0.64 in Colombia.

[21]See Kim and Pham (2006) for further analysis on endogeneity in this literature.

4 Main results

4.1 Baseline model

Table 3 reports the estimates of the baseline model in equations from (2) to (4) for the USD against the four currencies.

Regarding the level equation, the estimated coefficient of forex interventions, $\hat{\beta}_2$, is significant in all countries but Chile, which means that interventions have a contemporaneous effect in the exchange rate level. This coefficient is positive and significant for the USD against the COP, MXN and PEN, and non significant for the USD/CLP returns. This indicates that dollar purchases by these three central banks are related to an appreciation of their currencies—in line with Edison et al. (2006) for Australia—. However, one possible interpretation of this coefficient for Colombia, Mexico and Peru, as highlighted by Edison et al. (2006) for Australia, is that these interventions are not inconsistent with a 'leaning against the wind' behavior, in that its net purchases (sales) of foreign assets coincided with an appreciation (depreciation) of the local currencies so that both variables are positively correlated. Thus, this is consistent with the previously stated endogeneity problems of these models. As expected, $\hat{\beta}_1$ is significant but small or not significant.

As reported in Table 3, the GARCH estimates $\hat{\alpha}_0$, $\hat{\alpha}_1$ and $\hat{\alpha}_2$ of the conditional variance equation in (4) are positive and significant. As usual in empirical applications, $(\hat{\alpha}_1 + \hat{\alpha}_2)$, which approximates volatility persistence, is close to unity. The estimates of the absolute value of interventions, $\hat{\gamma}_1$, show a variety of results. On the one hand, they are positive and significant for Chile and Colombia, so that forex interventions would be even associated with greater exchange rate volatility in line with Edison et al. (2006). This positive sign indicates that in the periods of forex interventions (either USD purchases or sales) the exchange rate volatility increases. The interpretation of this sign can be ambiguous rooted on causality issues. Again, one possible interpretation is that forex interventions add uncertainty to the market but, on the other hand, it can be interpreted that forex interventions simply coincide with periods of higher uncertainty, which is precisely the reason to intervene. On the other hand, $\hat{\gamma}_1$ is negative and significant for Peru, meaning that interventions are linked to a lower contemporaneous volatility, and not significant for Mexico. Finally, Box-Pierce statistics for high-order serial correlation of the squared standardized residuals of all models in Tables 3 and 4 strongly support the role of these GARCH models to capture the dynamics of the exchange rate conditional variance.

However, as well as intervention policies have changed across time, the impact of interventions on the exchange rate could have also varied throughout the sample period, as illustrated in Figure 3. This figure shows the t-statistics of $\hat{\gamma}_1$ for the four countries obtained with a rolling window of 1500 observations for Colombia, Mexico and Peru and 750 for Chile. As shown by these statistics, whereas in Chile interventions tend to have a moderating effect on volatility, the opposite holds for Colombia. In Mexico and Peru $\hat{\gamma}_1$ helped to moderate volatility at certain subperiods previous to the onset of the financial crisis.[22]

All in all, the estimates for the baseline model could seem rather disappointing regarding the effect of forex interventions on the exchange rate level and volatility. However, in the next subsections the introduction of asymmetries and intervention characteristics in the model specifications will allow to disentangle further implications of the link between these two variables.

4.2 Capturing asymmetric effects in the conditional variance

In Table 4 we estimate asymmetric effects in the conditional variance to distinguish between purchases and sales of dollars through the estimates of $\hat{\gamma}_2$ and $\hat{\gamma}_3$ in (5).

First, we perform Wald type test for the null $H_0 : \gamma_2 = \gamma_3$ to distinguish if positive and negative interventions have a significantly different impact on the conditional variances. We reject this hypothesis for Mexico and Peru, which is a first evidence of the importance of asymmetries in this setting, whereas for Chile and Colombia we cannot reject the null of symmetry.

[22]In the remaining subsections we do not show the estimates of the rolling regressions due to identification problems for some countries. Thus, if a country has not performed interventions of a certain sign or $FIRST_t = 0$ or $SIZE_t = 0$ for a prolonged period the model cannot be estimated. The complete battery of figures for the rolling regressions are available upon request.

As reported in Table 4, in Chile the effects of interventions on the conditional volatility are mainly driven by dollar sales (negative interventions), where $\hat{\gamma}_2$ has a positive sign, which would indicate the destabilizing effect of such interventions. On the contrary, in Colombia, where $\hat{\gamma}_3$ is positive, these effects would be mostly driven by positive interventions (dollar purchases). In the Mexico and Peru both positive and negative interventions do shape the exchange rate volatility. After fitting the asymmetric conditional variance, whereas positive interventions are associated with lower exchange rate volatility, negative interventions are linked to higher uncertainty, as in Guimarães and Karacadag (2004) and opposite to Domaç and Mendoza (2004) for Mexico. Indeed, in Mexico negative interventions have a bigger effect than that of positive interventions (in absolute value), which was masking the moderating effect of the latter in previous Table 3.

4.3 The role of forex intervention characteristics

Table 5 reports the estimates for the model in equations from (6) to (8), which incorporate the variables $FIRST_t$ and $SIZE_t$ to analyze the role of the characteristics of forex interventions to affect the exchange rate level and volatility. Given the estimates for β_3 and β_4, it seems not relevant to introduce $FIRST_t$ and $SIZE_t$ in the level equation, as both variables are not significant, but in Mexico, where, under dollar purchases, first and sizeable interventions would coincide with peso appreciations. These results are contrary to the outcomes of other authors for developed countries.[23]

On the contrary, the estimates of the conditional variance in (8) do highlight the importance of introducing $FIRST_t$ and $SIZE_t$ in the estimation process. For instance, first interventions would lead to a lower conditional variance of the Mexican and Colombian peso, whereas in Peru the negative estimate of γ_1 would indicate that small and "not first" interventions would be associated with a lower conditional variance.

Finally, Table 6 reports the conditional variance estimates of (9), where previous model is augmented distinguishing a different effect of positive and negative interventions.

[23]For instance, Kim et al. (2000) and Kim and Pham (2006) conclude that large interventions in Australia have been effective in controlling the exchange rate level, whereas Hoshikawa (2008) conclude that low frequency and officially announced interventions in Japan mainly affect the exchange rate level.

Again, Wald type tests for different null hypothesis show that introducing asymmetries is relevant to improve the model specification as the null of symmetry is rejected in the four countries. Modeling asymmetries and intervention characteristics is useful to disentangle some conclusions.

For instance, in Mexico, not all first interventions are helpful to lower the conditional variance. Indeed, only positive first interventions play this moderating role, as shown by the estimates of γ_8. In Mexico positive interventions where performed as a way to accumulate foreign reserves. As shown in Table 1, positive interventions are less frequent than negative interventions, so possibly these first USD purchases (which just represent a 3% of total interventions) played a stabilizing role on the MXN. Besides, contrary to Guimarães and Karacadag (2004), who stated that negative interventions increase the MXN short term volatility, small and consecutive USD sales would also play this role according to the estimate of γ_2 in Table 6.[24] These interventions, that represent around 80% of total interventions, were mostly preannounced, so that this result might hint at the signaling role of these interventions throughout the sample period, which supports the stabilizing role of intervention rules in Mexico.

This is also the case of the Chilean peso, where first and positive interventions seem to be helpful to curb the exchange rate volatility, as evidenced by the negative and significant $\hat{\gamma}_8$. That is, once the intervention rule to buy USD is announced by the authorities, it has an immediate effect on the volatility, although, as shown in Table 5, this result does not hold for the exchange rate level. This initial effect on the volatility vanishes in the subsequent interventions, as shown by the lack of significance of $\hat{\gamma}_3$. That is, this result emphasizes the success of transparency and public announcements to moderate volatility, although these effects seem to have a short term impact that coincides with the announcement of the intervention rule.

On the contrary, in Colombia first and negative interventions, which barely represent 1% of total interventions, seem useful to lower the volatility, as shown by $\hat{\gamma}_6$. Finally, in Peru small and consecutive interventions, either positive or negative, which characterize

[24] Our result is in line with Domaç and Mendoza (2004), although they did not characterized size and frequency of interventions.

69% of interventions, are associated with lower exchange rate volatility, as shown by the estimates of $\hat{\gamma}_2$ or $\hat{\gamma}_3$. Note that Peru is the only country of our sample where $FIRST_t$ is not positive, and it is precisely the only economy that intervene in a discretionary way.

All in all, although apparently it seems difficult to infer empirical regularities across the four countries, there is certain homogeneity regarding the intervention characteristics that matter to shape volatility in the desired direction. For instance, in three out of these four Latin American economies first interventions, either positive or negative, play a role to curb the conditional variance than big interventions. That is, the estimates for $FIRST_t$, either $\hat{\gamma}_6$ or $\hat{\gamma}_8$, are significant and negative in the four countries. These three economies—namely, Chile, Colombia and Mexico—have in common to have implemented an intervention rule, either exchange rate-based or quantity based. On the other hand the estimates for $SIZE_t$, ($\hat{\gamma}_7$ or $\hat{\gamma}_9$), are not significant or negative for any country.[25]

As our four countries are inflation targeters, so that the exchange rate is not their nominal anchor, this result might indicate that first interventions, either isolated or first in a row, do play a signaling role to the markets calming their expectations and reducing their exchange rate volatility. This signalling effect happens regardless the intervention size.[26] This finding is possibly linked to the credibility of the own inflation targeting regime. Indeed, given this credibility of the monetary regime, the transparency of their intervention announces would probably contribute to their favorable effect on volatility, which is an additional element that supports the role of intervention rules. This outcome is in line with other papers that defend the selective and transparent use of forex interventions under inflation targeting regimes.[27]

[25]This last result is contrary to the results for some developed countries such as Australia. For instance, Kim et al. (2000) and Kim and Pham (2006) state that sustained and large interventions do moderate volatility.

[26]In some sense, this result could be related with the signalling channel, which is one of the theoretical explanations for intervention effectiveness—together with the portfolio balance and the international coordination channel (Sarno and Taylor, 2001)—, in the sense that interventions manage to change and calm the exchange rate expectations of the markets.

[27]See for instance Berganza and Broto (2012).

5 Conclusions

Although many central banks actively intervene in the forex market, there is still no consensus on the efficiency of interventions to influence on the exchange rate level and to moderate its volatility. In this paper we use daily data of the USD against four Latin American currencies (namely, the CLP, COP, MXN and PEN) to analyze the impact of forex interventions of central banks on their currency returns. These four economies are among the few that publish their daily forex interventions. We analyze if the intervention sign, which is positive or negative if there are USD purchases or sales, does make a deal to disentangle the effect of interventions on the exchange rate dynamics. We also study the role of certain intervention characteristics. Namely, we study their size and the fact or being an isolated intervention or the first intervention in a row. To this purpose, we fit several univariate GARCH models, which provide new evidence on the asymmetric effects of interventions on the exchange rate volatility. However, the daily frequency entails a simultaneity bias that should be taken into account to qualify our results.

Our results indicate that forex interventions in Latin America have an asymmetric effect, specially in the conditional variance. However, there is no homogeneous pattern across countries regarding which type of interventions—positive (purchases of USD) or negative (sales of USD)—dominate the exchange rate volatility dynamics and help to stabilize it. For instance, whereas in Peru dollar purchases helped to moderate volatility, in Colombia they are linked to higher volatility. Nevertheless, distinguishing the intervention sign in the model becomes a useful tool to analyze which interventions succeed to curb volatility.

Thus, once asymmetries are introduced in the conditional variance specification it is easier to disentangle which interventions, in terms of frequency and size, did play a role to impact on the exchange rate level and volatility in the desired direction. Again, it is difficult to establish regularities across the four countries but one clear pattern emerges from our results: the intervention size does not play a role to influence on the exchange rate. That is, sizeable interventions have no greater influence on the exchange rate than small interventions. On the contrary, first in a row or isolated interventions are helpful to curb the currency volatility in three of the four countries. As the four countries are inflation targeters, so that in principle their exchange rate is fully flexible, this result might indicate that first or isolated interventions do play a signaling role to the markets, regardless the their size, which becomes useful to reduce their currency volatility. This outcome could be linked to the credibility of their inflation targeting regime.

These results are important for central banks to make an assessment on the effect of forex interventions. However, this analysis still lacks other relevant elements such as the generalization of the model to include other characteristics of forex interventions, such as persistence, or further control variables in the level equation, such as the degree of exchange rate misalignment or a measure of carry-trade attractiveness, like the carry-to-risk, that can play a role in the case of high yielding commodity linked currencies like these. We leave these extensions for future research.

Appendix: Forex intervention data sources

Chile

- Source: Banco Central de Chile (http://www.bcentral.cl/estadisticas-economicas/series-indicadores/index _db.htm).

- Notes: During our sample period, consistent with its foreign exchange policy since Chile adopted an inflation target in 1999, the central bank implemented intervention rules in several occasions but only under exceptional circumstances. From April 2008 to September 2008 the central bank made daily purchases of 50 million US dollars to accumulate 8 billion US dollars. The purpose was to increase the foreign reserves in a context of increasing uncertainty. However, this program was suspended before completion in September 2008 after the onset of the crisis. From March 2009 to November 2009 the Treasury sold US dollars on a daily basis. Finally, on January 2011 the central bank announced to buy 12 billion US dollars in reserves throughout 2011 through daily purchases of 50 million US dollars.

Colombia

- Source: Banco de la República de Colombia (http://www.banrep.gov.co/series-estadisticas/see_s_externo_2.htm#banda).

- Notes: From November 1999 to October 2009, after the inflation targeting adoption in September 1999, the authorities followed an exchange rate based rule which allowed the possibility to intervene in the forex market by auctioning (put or call). The aim of these interventions was to increase or decrease the level of international reserves and controlling the exchange rate volatility. Most interventions in that period consisted in auctions in put options to accumulate reserves, but the central bank also announced occasionally call options for reserve disaccumulation. To control for the exchange rate volatility, each time the COP depreciated (appreciated) more than 4% below (above) the average exchange rate of the previous 20 days, volatility auctions were held to sell put (call) options. Since then, this program has been replaced by a direct intervention mechanism consisting on the purchase of at least 20 million US dollar a day. Fully discretionary interventions are not included in our sample as they are not publicly available. See the webpage of Banco de la Republica de Colombia for details.

Mexico

- Source: Banco de Mexico (http://www.banxico.org.mx/sistema-financiero/estadisticas/mercado-cambiario/operaciones-vigentes-del-banc.html).

- Notes: From 1996 to June 2001 the Mexican authorities intervened 14 times in a discretionary way while they frequently purchased dollars through auctions of put options. From May 2003 to July 2008, a significant reserve accumulation led the authorities to sell dollars to the market in a preannounced volume (see Guimarães and Karacadag, 2004). From October 2008, to alleviate the depreciatory pressures and high volatility of the MXN after the onset of the crisis, Banco de Mexico performed several discretionary interventions based on extraordinary dollar auctions whenever the MXN depreciated more than 2%. From March 2009, this mechanism was combined with US dollar auctions without a minimum price. Finally, on February 2010 the authorities announced a put options mechanism as a way to build forex reserves, in a similar way to that of the period from 1996 to 2001. This last mechanism was suspended in November 2011. Se Banco de Mexico webpage for further historical information.

Peru

- Source: Central Reserve Bank of Peru (http://estadisticas.bcrp.gob.pe/index.asp?sIdioma=1&sTitulo=OPERACIONES%20CAMBIARIAS%20BCRP%20(mill.%20US$)&sFrecuencia=D).

- Notes: The Central Reserve Bank of Peru classifies their forex operations in four broad categories (namely, over the counter purchases and sales, net swap operations, certificates of deposit in US dollars and operations with the public sector). These mechanisms were combined throughout our sample period.

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Figure 1: Daily bilateral exchange rates against the dollar and forex interventions in Chile, Colombia, Mexico and Peru.

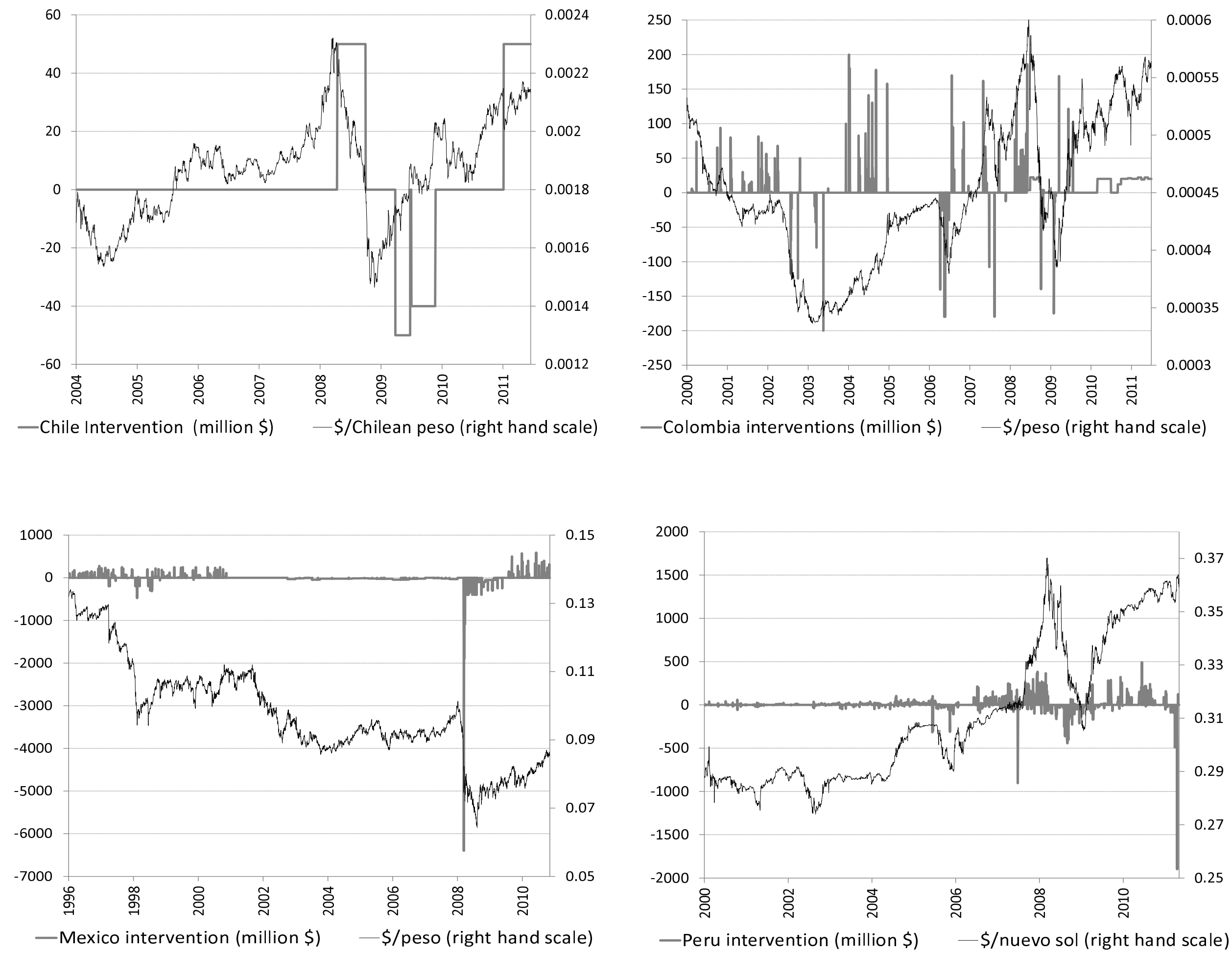

Table 1: Data description

Country	Exchange Rate Arrangement	Monetary Policy Framework	Sample period	I_t (% on total)	I_t^- (% on I_t)	I_t^+ (% on I_t)
Chile	Independently floating	Inflation targeting	01/01/2004-15/06/2011	21	41	59
Colombia	Managed floating	Inflation targeting	03/01/2000-30/06/2011	19	7	93
Mexico	Independently floating	Inflation targeting	31/07/1996-06/06/2011	42	89	11
Peru	Managed floating	Inflation targeting	01/02/2000-03/06/2011	61	34	66

Notes: Intervention data obtained from national sources. The exchange rate regime follows the de facto classification of exchange rate regimes and monetary policy frameworks of IMF (2009). Colombia and Peru have a managed floating regime with no pre-determined path for the exchange rate.

Figure 2: Daily returns of the US dollar against the Chilean peso (CLP), the Colombian peso (COP), the Mexican peso (MXN) and the Peruvian nuevo sol (PEN).

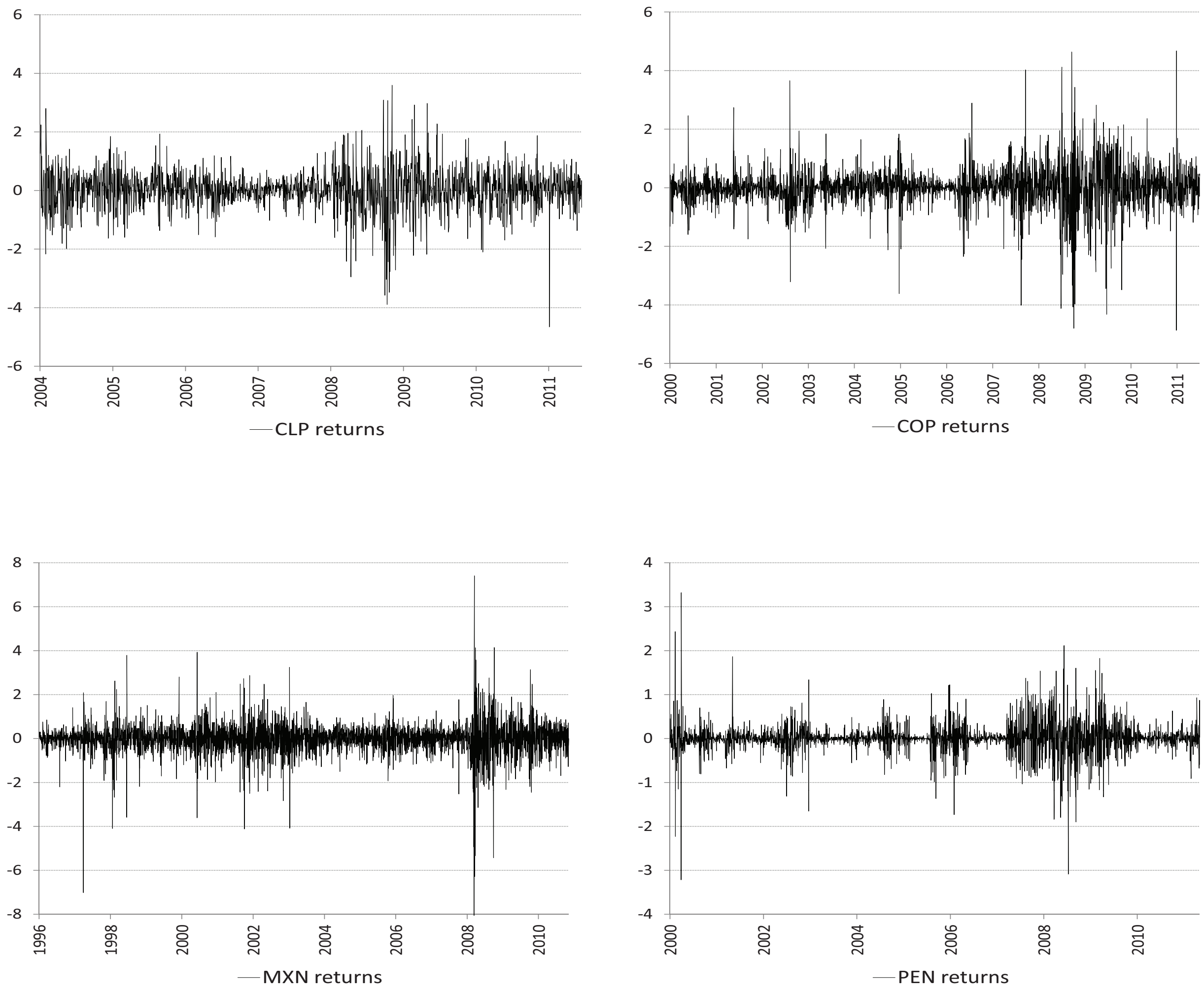

Figure 3: Rolling baseline model, equations (2) to (4); t-statistics for $\hat{\gamma}_1$. Rolling window of 1500 observations for Colombia, Mexico and Peru and 750 observations for Chile.

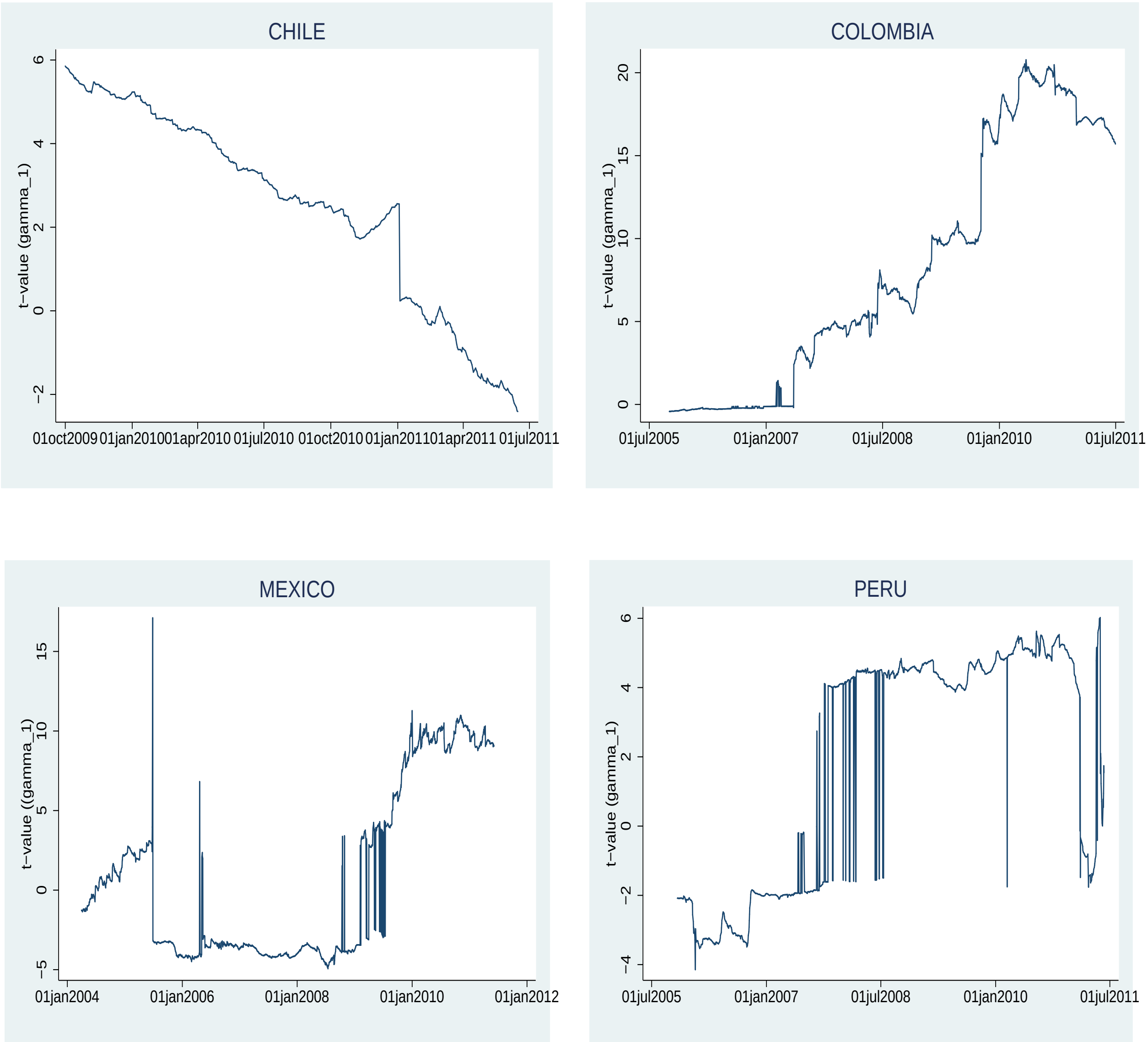

Table 2: Descriptive statistics of daily exchange rate returns and forex interventions.

	Chile				Colombia			
	r_t	I_t	I_t^-	I_t^+	r_t	I_t	I_t^-	I_t^+
Mean	0.0120	11.3647	-43.7951	50.000	0.0019	18.4288	-68.1748	24.8378
SD	0.6885	46.3264	4.8673	0	0.6899	37.9296	61.3347	26.0057
Maximum	3.5972	50.000	-40.000	50.000	4.6754	200.000	-1.000	200.000
Minimun	-4.6574	-50.000	-50.000	50.000	-4.8712	-199.900	-199.900	0.500
Skewness	-0.4300^{***}	-0.3719^{***}	-0.4965^{***}		-0.4054^{***}	-0.7768^{***}	-0.6844	4.0564^{***}
Kurtosis	7.3539^{***}	1.1577^{***}	1.2465^{***}		11.6327^{***}	15.5041^{***}	2.2286^{***}	21.6638^{***}
Observations	1944	403	166	237	2998	566	39	527
$Q(20)$	61.173^{***}				52.941^{***}			
$Q^2(20)$	953.01^{***}				1665.5^{***}			
	Mexico				**Peru**			
	r_t	I_t	I_t^-	I_t^+	r_t	I_t	I_t^-	I_t^+
Mean	-0.0111	-27.1721	-43.7217	110.1429	0.0077	11.5776	-33.2135	33.5443
SD	0.6966	187.845	188.6894	107.6463	0.3325	83.2301	105.7776	58.1132
Maximum	7.4085	592.000	-6.000	592.000	3.3218	493.5	$-9.75E-04$	493.5
Minimun	-8.7164	-6400.000	-6400.000	2.000	-3.2174	-1898.606	-1898.606	$3.7E-05$
Skewness	-1.0833^{***}	-25.0712^{***}	-27.6280^{***}	1.7874^{***}	-0.1517^{***}	-7.4751^{***}	-11.1517^{***}	2.9867^{***}
Kurtosis	22.9544^{***}	825.2344^{***}	898.2819^{***}	7.0584^{***}	18.7094^{***}	170.6581^{***}	175.6535^{***}	13.8622^{***}
Observations	3873	1627	1452	175	2958	1790	589	1201
$Q(20)$	80.344^{***}				110.77^{***}			
$Q^2(20)$	2055.5^{***}				631.77^{***}			

Notes: r_t are the exchange rate returns. Forex interventions, I_t, expressed in million USD. I_t^- stands for negative forex interventions whereas I_t^+ are positive forex interventions $Q(20)$ is the Ljung-Box Q-statistic (with 20 lags) for the exchange rate returns and $Q_2(20)$ is the Ljung-Box Q-statistic (with 20 lags) for the squared returns.

Table 3: Estimates of the baseline model for the exchange rate returns of four Latin American countries.

	Chile	**Colombia**	**Mexico**	**Peru**
β_0	0.0200	0.0030	0.0234^{***}	0.0013
	(0.0123)	(0.0070)	(0.0075)	(0.0025)
β_1	0.0769^{***}	0.0479^{**}	-0.0864^{***}	-0.0761^{***}
	(0.0258)	(0.0198)	(0.0183)	(0.0189)
β_2	-0.0006	0.0041^{***}	0.0015^{***}	0.0003^{***}
	(0.0006)	(0.0007)	(0.0001)	$(4.46E-05)$
α_0	0.0148^{***}	0.0032^{***}	0.0192^{***}	0.0010^{***}
	(0.0018)	(0.0004)	(0.0018)	$(3.20E-05)$
α_1	0.1122^{***}	0.1528^{***}	0.2143^{***}	0.1817^{***}
	(0.0137)	(0.0086)	(0.00810)	(0.0081)
α_2	0.8523^{***}	0.8432^{***}	0.7588^{***}	0.8157^{***}
	(0.0150)	(0.0071)	(0.0091)	(0.0033)
γ_1	0.0002^{**}	0.0004^{***}	$7.76E-06$	$-9.89E-06^{***}$
	$(9.41E-05)$	$(9.77E-05)$	$(4.55E-05)$	$(7.39E-07)$
$LogL$	-1798.465	-2324.449	-3215.892	193.0233
$Q(20)$	32.684^{**}	42.398^{***}	17.447	21.554
$Q^2(20)$	3.3545	15.131	19.618	9.1367

Note: Estimation results of the exchange rate GARCH model:

$$\begin{aligned} r_t &= \beta_0 + \beta_1 r_{t-1} + \beta_2 I_t + \varepsilon_t \\ \varepsilon_t &= \varepsilon_t^{\dagger} h_t^{1/2} \\ h_t &= \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \gamma_1 \left| I_t \right| \end{aligned}$$

See Tables 1 and 2 for the sample size and period of each country; Dependent variable: Exchange rate returns (log difference of US dollar / local currency) ; $LogL$ denotes the value of the log likelihood function; $Q(20)$ denotes the Ljung-Box Q-statistic (with 20 lags) for the standardized residuals; $Q_2(20)$ denotes the Ljung-Box Q-statistic (with 20 lags) for the squared standardized residuals. Standard errors in brackets; ***, **, and * refer to significance at 1%, 5% and 10% level.

Table 4: Estimates of the model with asymmetries in the conditional variance for the exchange rate returns of four Latin American countries.

	Chile	**Colombia**	**Mexico**	**Peru**
α_0	0.0145^{***}	0.0033^{***}	0.0222^{***}	0.0004^{***}
	(0.0018)	(0.0004)	(0.0019)	$(2.77E-05)$
α_1	0.1110^{***}	0.1554^{***}	0.2204^{***}	0.1322^{***}
	(0.0136)	(0.0089)	(0.0092)	(0.0061)
α_2	0.8544^{***}	0.8418^{***}	0.7390^{***}	0.8671^{***}
	(0.0149)	(0.0072)	(0.0096)	(0.0028)
γ_2	0.0003^{**}	0.0002	0.0002^{**}	$2.62E-05^{***}$
	(0.0001)	(0.0003)	$(7.04E-05)$	$(8.40E-06)$
γ_3	0.0002	0.0005^{***}	-0.0001^{**}	$-5.30E-06^{***}$
	(0.0001)	$(9.85E-05)$	$(4.10E-05)$	$(1.06E-06)$
$H_0 : \gamma_2 = \gamma_3$	0.3914	0.2385	0.000^{***}	0.000^{***}
$LogL$	-1798.216	-2324.358	-3210.620	217.6491
$Q(20)$	32.483^{**}	42.573^{***}	16.021	23.540
$Q^2(20)$	3.3246	14.837	20.132	13.658

Note: Estimation results of the exchange rate GARCH model:

$$\begin{aligned} r_t &= \beta_0 + \beta_1 r_{t-1} + \beta_2 I_t + \varepsilon_t \\ \varepsilon_t &= \varepsilon_t^{\dagger} h_t^{1/2} \\ h_t &= \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \gamma_2 \left| I_t^- \right| + \gamma_3 I_t^+ \end{aligned}$$

See Tables 1 and 2 for the sample size and period of each country; Dependent variable: Exchange rate returns (log difference of US dollar / local currency) ; $LogL$ denotes the value of the log likelihood function; $Q(20)$ denotes the Ljung-Box Q-statistic (with 20 lags) for the standardized residuals; $Q_2(20)$ denotes the Ljung-Box Q-statistic (with 20 lags) for the squared standardized residuals. Standard errors in brackets. $H_0 : \gamma_2 = \gamma_3$ indicates the p-value of the Wald type test of this linear restriction. ***, **, and * refer to significance at 1%, 5% and 10% level.

Table 5: Estimates of the baseline model for the exchange rate returns of four Latin American countries.

	Chile	**Colombia**	**Mexico**	**Peru**
β_0	0.0202	0.0032	0.0118	0.0058
	(0.0124)	(0.00702)	(0.0089)	(0.0048)
β_1	0.0769***	0.05162***	−0.0887***	−0.1309***
	(0.0259)	(0.01992)	(0.0186)	(0.0247)
β_2	−0.0007	0.0044***	0.0004	0.0009**
	(0.0006)	(0.0016)	(0.0005)	(0.0004)
β_3	−0.0020	−0.0003	0.0006**	$-7.50E-06$
	(0.0126)	(0.0018)	(0.0003)	(0.0001)
β_4		−0.0004	0.0009*	−0.0006
		(0.0019)	(0.0005)	(0.0004)
α_0	0.0152***	0.0039***	0.0221***	0.0120***
	(0.0019)	(0.0005)	(0.0022)	(0.0004)
α_1	0.1145***	0.1653***	0.2194***	0.3317***
	(0.0140)	(0.0096)	(0.0101)	(0.0200)
α_2	0.8491***	0.8313***	0.7496***	0.6469***
	(0.0153)	(0.0076)	(0.0112)	(0.0088)
γ_1	0.0002**	0.0010***	$-7.49E-05$	−0.0006***
	$(9.59E-05)$	(0.0002)	$(7.03E-05)$	$(4.04E-06)$
γ_4	0.0010	−0.0012**	−0.0005***	$3.07E-05$
	(0.0048)	(0.0006)	(0.0002)	$(4.13E-05)$
γ_5		0.0001	0.0004***	0.0005***
		(0.0006)	(0.0001)	$(1.02E-05)$
$LogL$	−1798.433	−2317.258	−3208.983	−67.36309
$Q(20)$	32.726**	43.565***	18.565	26.768
$Q^2(20)$	3.3545	15.208	18.897	10.481

Note: Estimation results of the exchange rate GARCH model:

$$r_t = \beta_0 + \beta_1 r_{t-1} + (\beta_2 + \beta_3 FIRST_t + \beta_4 SIZE_t) I_t + \varepsilon_t$$
$$\varepsilon_t = \varepsilon_t^{\dagger} h_t^{1/2}$$
$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + (\gamma_1 + \gamma_4 FIRST_t + \gamma_5 SIZE_t)\,|I_t|$$

See Tables 1 and 2 for the sample size and period of each country; Dependent variable: Exchange rate returns (log difference of US dollar / local currency) ; $LogL$ denotes the value of the log likelihood function; $Q(20)$ denotes the Ljung-Box Q-statistic (with 20 lags) for the standardized residuals; $Q_2(20)$ denotes the Ljung-Box Q-statistic (with 20 lags) for the squared standardized residuals. Standard errors in brackets. $FIRST_t$ is a dummy variable that is one if $FIRST_{t-1} = 0$ and $FIRST_t \neq 0$, and cero otherwise. $SIZE_t$ is a dummy variable that is one if $|I_t|$ is bigger than the average forex intervention. ***, **, and * refer to significance at 1%, 5% and 10% level.

Table 6: Estimates of the asymmetric model for the exchange rate returns of four Latin American countries.

	Chile	**Colombia**	**Mexico**	**Peru**
α_0	0.0017^{**}	0.0038^{***}	0.0338^{***}	0.0082^{***}
	(0.0007)	(0.0004)	(0.0024)	(0.0004)
α_1	0.0442^{***}	0.1609^{***}	0.1914^{***}	0.2917^{***}
	(0.0040)	(0.0029)	(0.0126)	(0.0157)
α_2	0.9532^{***}	0.8325^{***}	0.7201^{***}	0.7000^{***}
	(0.0034)	(0.0044)	(0.0137)	(0.0071)
γ_2	$3.19E-05$	0.0046^{**}	-0.0002^{**}	-0.0007^{***}
	$(5.80E-05)$	(0.0021)	$(7.97E-05)$	$(1.30E-05)$
γ_3	$3.84E-05$	0.0010^{***}	-0.0007^{***}	-0.0005^{***}
	$(4.25E-05)$	(0.0001)	$(9.10E-05)$	$(1.97E-05)$
γ_6	-0.0024	-0.0091^{***}	0.0028^{***}	0.0004^{***}
	(0.0040)	(0.0023)	(0.0006)	(0.0001)
γ_7		0.0044^{***}	0.0022^{***}	0.0006^{***}
		(0.0015)	(0.0005)	$(6.14E-06)$
γ_8	-0.0145^{***}	-0.0009	-0.0005^{***}	$4.36E-05$
	(0.0026)	(0.0006)	(0.0001)	$(3.89E-05)$
γ_9		-0.0001	0.0007^{***}	0.0004^{***}
		(0.0006)	(0.0002)	$(1.82E-05)$
$H_0: \gamma_2 = \gamma_3$	0.9246	0.0940^{*}	0.0000^{***}	0.0000^{***}
$H_0: \gamma_2 + \gamma_6 = \gamma_3 + \gamma_8$	0.0088^{***}	0.0041^{***}	0.0000^{***}	0.3270
$H_0: \gamma_2 + \gamma_7 = \gamma_3 + \gamma_9$		0.0007^{***}	0.0002^{***}	0.0066^{***}
$H_0: \gamma_2 + \gamma_6 + \gamma_7 = \gamma_3 + \gamma_8 + \gamma_9$		0.6771	0.0000^{***}	0.0168^{**}
$LogL$	-1790.173	-2306.440	-3160.851	38.6317
$Q(20)$	32.625^{**}	44.989^{***}	17.297	24.006
$Q^2(20)$	7.8192	16.122	21.572	6.2674

Note: Estimation results of the conditional variance of the exchange rate GARCH model:

$$
\begin{aligned}
r_t &= \beta_0 + \beta_1 r_{t-1} + (\beta_2 + \beta_3 FIRST_t + \beta_4 SIZE_t) I_t + \varepsilon_t \\
\varepsilon_t &= \varepsilon_t^{\dagger} h_t^{1/2} \\
h_t &= \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + (\gamma_2 + \gamma_6 FIRST_t + \gamma_7 SIZE_t) \left| I_t^- \right| + (\gamma_3 + \gamma_8 FIRST_t + \gamma_9 SIZE_t) I_t^+
\end{aligned}
$$

See Tables 1 and 2 for the sample size and period of each country; Dependent variable: Exchange rate returns (log difference of US dollar / local currency) ; $LogL$ denotes the value of the log likelihood function; $Q(20)$ denotes the Ljung-Box Q-statistic (with 20 lags) for the standardized residuals; $Q_2(20)$ denotes the Ljung-Box Q-statistic (with 20 lags) for the squared standardized residuals. Standard errors in brackets. $FIRST_t$ is a dummy variable that is one if $FIRST_{t-1} = 0$ and $FIRST_t \neq 0$, and cero otherwise. $SIZE_t$ is a dummy variable that is one if $|I_t|$ is bigger than the average forex intervention. p-values of the Wald type test of four linear restrictions are also included. ***, **, and * refer to significance at 1%, 5% and 10% level.