# Flexible inflation targets and exchange rate volatility in emerging countries*

Juan Carlos Berganza — Banco de España

Carmen Broto — Banco de España

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**Abstract**

We analyze the policymakers' dilemma between fulfilling the theoretical conditions of formal inflation targets (IT), which imply a fully flexible exchange rate, or applying a flexible IT, which entails using FX interventions to moderate exchange rate volatility. Our contribution is twofold. First, we study the exchange rate volatility of eight IT and non-IT emerging countries to get some primer information about their volatility dynamics and its relation with FX interventions. Second, we estimate a panel data model to analyze in a wider sample the effect of IT and FX interventions on the exchange rate volatility. We conclude that, although IT leads to higher instability than alternative regimes, FX interventions in some IT countries are more effective to lower volatility than in non-IT countries.

**Keywords:** Inflation targeting; Exchange rate volatility; Foreign exchange interventions; Emerging economies.

**JEL codes:** E31; E42; E52; E58; F31

*Contact authors: jcberganza@bde.es; carmen.broto@bde.es. We thank Esther López for excellent assistance with the databases and Enrique Alberola, Raquel Carrasco, Luis Molina, Juan Ruiz, José Maria Serena and Xavier Torres for their helpful comments. The opinions expressed in this document are solely responsibility of the authors and do not represent the views of the Banco de España.

# 1 Introduction

Since the 90's, an increasing number of emerging countries (EMEs onwards) have abandoned exchange rate pegs to adopt inflation targets (IT hereafter) as their monetary policy framework. According to IMF (2005) and Little and Romano (2009), since Israel adopted an IT in 1997, 18 EMEs have already changed their exchange rate regime (from fixed to floating) and their nominal anchor (from exchange rate to inflation) -see Table 1 for a summary of the dates of IT adoption in EMEs-. These countries have tended to adopt an IT once a series of preconditions were fulfilled[1] and they have benefited from the credibility gains from explicitly announcing the IT (see Fraga et al., 2003). Although the effectiveness of IT to lower inflation and inflation variability still remains controversial (see, for instance, Lin and Ye, 2009), this framework has been more durable than other monetary policy strategies (see Mihov and Rose, 2008).[2]

As noted by some authors, a flexible nominal exchange rate framework is a requirement for a well functioning full-fledged IT regime (Mishkin and Savastano, 2001), as in a world of capital mobility, independent monetary policy cannot coexist with a pegged exchange rate regime (the so-called policy dilemma of the "Impossibility of the Holy Trinity"). Thus, some economists state that one of the costs of IT is its associated increase in exchange rate volatility. This greater uncertainty is the basis of the so-called "fear of floating" (Calvo and Reinhart, 2002), which is a phenomenon mostly associated to EMEs.[3] As a result, for these countries the monitoring of exchange rates under IT poses some challenges that differ from those in advanced economies, which might justify a more active role of the exchange rate policy. Consequently, EMEs with IT generally have less flexible exchange rate arrangements, intervene more frequently in foreign exchange markets than their advanced economy counterparts and have a greater response to real exchange rate movements (Aizenmann et al, 2008).[4] They do so not only for the attainment of

[1] Among these preconditions, IT requires a publicly announced IT and the commitment of the central bank to gear monetary policy toward achieving this target. See, IMF (2005) for more details.

[2] Currently, the unique emerging country which has left an IT regime is the Slovak Republic (January 2009) due to euro adoption.

[3] Following Cavoli (2009), the main reasons to justify this "fear of floating" can be roughly summarized in three: (i) trade openness –higher exchange rate volatility will discourage other countries to engage trade-; (ii) a higher pass-through from exchange rate to domestic prices, which is bigger in EMEs than in developed countries, in part reflecting lower policy credibility; and, (iii) balance sheets effects provoked by currency mismatches (liability dollarization). One additional reason could be to avoid or mitigate the adverse consequences of a sudden stop in capital inflows.

[4] According to Stone et al. (2009) the most common intervention objective for IT advanced economies is

the IT itself, but also as a response to the "fear of floating" (in times of financial turmoil) or "fear of appreciation" (triggered by economic bonanza or interest rates differentials). In sum, this role of exchange rates in EMEs evidences their greater vulnerability to currency shocks.

Their recurrent use of interventions in the exchange markets (FX interventions onwards), has opened an intense debate about the implementation of IT in EMEs. In this sense, this sharper focus on the exchange rates in these economies may cause some confusion about the commitment of their central banks to the IT and may also complicate policy implementation. That is, implicitly there is a dilemma between fulfilling the theoretical requirements of IT, or applying a flexible IT, in the sense of using FX interventions to smoothen the exchange rate volatility. To this respect, there are different views in the literature. On the one hand, some authors like Bernanke et al. (1999) hold that attending to IT and reacting to the exchange rate are mutually exclusive because interventions could confuse the public regarding the priorities of the central bank, which distorts expectations. On the other hand, a less strict vision argues that central banks might interfere against the volatility of the exchange rate. For instance, according to Cordero (2009), FX interventions are fully justified, as far as EMEs need to maintain stable and competitive real exchange rates. In fact, some authors include the exchange rate in the policy reaction function arguing that it could help to mitigate the impact of shocks, by dampening exchange rate volatility (Taylor, 2000).

The main objective of our paper is to analyze the relationship between the adoption of IT, FX interventions and the exchange rate volatility. Note that much of the existing literature on exchange rate regimes has focused on the dichotomy between fully fixed and floating exchange rates and, similarly, the literature on IT use to strictly distinguish the performance of IT and non-IT countries. This paper tries to move away from the fixed vs. floating or IT vs. non-IT dichotomy, as we want to analyze if in the event of a financial turmoil, the "fear of floating" behavior of some central banks may justify halfway policies between these two theoretically opposite regimes.

In this context, the current financial crisis that began in mid-2007 –whose effects on the relationship between IT, FX interventions and exchange rate volatility have not being analyzed in detail yet (among the few exceptions, see de Carvalho, 2010)– constitutes a very good framework to test the link between these three variables as it represents a stress tests of the performance of

to correct an exchange rate misalignment, whereas for EMEs it is to smooth exchange rate volatility, promote competitiveness and limit the pace of currency appreciation.

IT (see Habermeier et al. 2008). The tensions following the onset of the crisis were heightened by inflation pressures –nearly all EMEs with IT overshot their targets in 2008–, great exchange rate volatility, and financial stress arising from the financial and the subsequent economic crisis in most EMEs. The study of these links in this period allows us to reach some conclusions regarding the IT flexibilization, in the sense of combining in the same policy framework FX interventions and IT, which can entail relevant policy implications.

Our approach to the link between these three variables consists of two empirical exercises. First, we get some primer on the dynamics of the exchange rate volatility, as well as on its relation with IT adoption and FX interventions. To that purpose, we carry out a time series analysis for eight EMEs, some of which have already adopted IT, that consists of the identification of different volatility regimes and its relation with IT adoption, and a univariate GARCH type model estimation for the exchange rate returns that also considers IT adoption and FX interventions as explanatory variables in the conditional variance equation. Second, we try to reinforce the conclusions reached in the previous eight case studies by means of the analysis of a panel of 37 IT and non-IT EMEs. After analyzing the whole sample period, we also replicate the analysis for the time previous to the onset of the financial crisis and the subsequent sub-sample.

With both exercises we will try to answer questions such as: Does the fact of being an IT-country necessarily imply an increase in exchange rate volatility with respect to non-IT countries? Is there any difference in terms of volatility of the exchange rate between the use of FX interventions in IT and non-IT countries? Has the recent financial crisis altered those relationships? In general, does IT make a difference for the relationship between the exchange rate volatility and FX interventions?

The paper is organized as follows. After the introduction, Section 2 briefly describes the literature and Section 3 reports some evidence on the relation between exchange rate volatility, IT adoption and FX interventions by means of a first exercise based on a time series analysis of the exchange rate returns of eight EMEs. Then, Section 4 presents the methodology that will be used to analyze our panel data set in the remaining of the paper and to reach conclusions about the link between the three variables. In Section 5, we report the main empirical findings. Finally, Section 6 concludes the paper.

## 2 Literature review

The main focus of this paper is to analyze the relationship between IT and FX interventions with the exchange rate volatility in EMEs. On the one hand, the literature on the effects of IT on the exchange rate volatility is not conclusive. For instance, De Gregorio et al. (2005) show that exchange rate uncertainty increased in Chile in the first five years of full-fledged IT regime (1999-2004). However, its real exchange rate had lower extreme values than in the past and the pass-through from the exchange rate to inflation was also lower. Edwards (2007) investigates whether the exchange rate volatility is different in IT countries and non-IT countries and conclude that the exchange rate volatility increases with IT due to their flexible exchange rate regime. After controlling for this variable there is no evidence of volatility increase after IT adoption. In the same line, Rose (2007) studies a panel dataset and provides evidence that IT seems to deliver the best outcomes in terms of lower exchange rate volatility, as well as higher output growth and lower inflation, than alternative regimes. He also highlights the IT durability, in contrast to other monetary regimes, even when this paper was written before IT regimes were tested under extreme financial conditions.

On the other hand, the empirical literature on the link between FX interventions and exchange rate volatility has not been quite developed either. Most of these contributions estimate GARCH family (see, Dominguez, 1998, or Edison et al., 2006), but in the context of IT, the evidence is even more scarce and focused on case studies for specific countries. For instance, Domaç and Mendoza (2004) analyze this link for two IT countries -Mexico and Turkey-. After estimating a battery of E-GARCH models they conclude that these interventions could play a useful role in containing the adverse effects of temporary exchange rate shocks on financial stability. For Brazil, Minella et al. (2003), whose main focus is on the pass-through to domestic prices, highlight the importance of transparency of interventions to avoid a credibility deterioration of monetary policy as a result of misunderstandings about the policy objective. From a more general point of view, Hausmann et al. (2001) analyze a set of developed and EMEs with floating exchange rates and conclude that the ability to float freely is closely associated to their degree of development.

In the next sections we analyze the link between the three variables combining previous methodologies: First, we develop a time series exercise in line with Dominguez (1998) and then we deepen into their study through a broader dataset in a panel data context.

# 3 Exchange rate volatility, FX interventions and IT in EMEs: preliminary evidence

## 3.1 Some primer on the link between exchange rate volatility and IT

In this Section we study the dynamics of the exchange rate volatilities for a sample of eight countries, both inflation targeters and non-inflation targeters, to get some insight into the link between these volatilities, the adoption of IT and the impact of FX interventions. We analyze the returns of the nominal exchange rates against the dollar of five IT countries –Brazil, Mexico, Korea, Poland and South Africa- and three non-IT countries –Argentina, China and India– from January, 1995 to June, 2010.[5] These countries have been chosen due to their economic relevance, to represent all emerging regions and a broad range of currency flexibilization. Thus, the percent return of the nominal exchange rate against the dollar follows this expression,

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

where $E_t$ is the bilateral nominal exchange rate in $t$ and $\Delta$ is the difference operator (a positive $r_t$ is a depreciation of the local currency against the dollar).[6] daily and monthly

We use the nominal bilateral exchange rate against the dollar across the paper as it has advantages in terms of data availability and, as the dollar is used in most EMEs to borrow in, its choice seems rather intuitive (see Carranza et al., 2009).[7] Nevertheless, since the main currency might change across regions –for instance, the European currencies are more linked to the euro than to the dollar-, we have also analyzed the nominal effective (trade weighted) exchange rate and the results are available upon request, although the conclusions are similar.

In this subsection we explore the link between exchange rate volatility and IT by means of a time series exercise. To that purpose, we formally test for the presence of breaks in the exchange rate volatility and then analyze its relation with IT adoption. The returns are daily to enhance the identification of the breaks. In particular, we use the iterated cumulated sum of squares (ICSS) procedure introduced by Inclán and Tiao (1994). Inclán and Tiao (1994) ICSS

[5] The beginning of the sample period has been chosen to avoid the potential problem of the presence of hyperinflation in many countries in Latin America until the mid-nineties.

[6] Following Harvey et al. (1994), we subtract the mean of $\Delta \log E_t$ to guarantee zero mean series of $r_t$.

[7] Nominal effective exchange rates are available by JP Morgan only for a small number of emerging countries, whereas IFS data, which were used by Edwards (2007) and Rose (2007), also suffer from this limitation.

test statistic -$I\&T$ hereafter- is given by

$$I\&T = \sqrt{\frac{T}{2}} \max_k |D_k| \tag{2}$$

where $D_k$ follows

$$D_k = \left(\frac{C_k}{C_T}\right) - \frac{k}{T} \tag{3}$$

and $C_k$ is the sum to $k$ of the squared returns for $k = t = 1, ..., T$. The value of $k$ that maximizes 3 is the estimated break date.[8] This kind of algorithm has also been used, for instance, by Rapach and Strauss (2008) to detect structural breaks in the volatilities of nominal exchange rates for a sample of developed countries.[9]

Figure 1 represents the eight returns of the nominal exchange rates against the dollar, as well as three standard deviation bands for the volatility regimes identified by the modified ICSS algorithm. The red line represents the date of adoption of the formal IT, according to IMF (2005) and Little and Romano (2009). As in these two papers, given that dating the adoption of IT is not straightforward, we consider the date of adoption of the formal or explicit IT mechanism for all countries, which may differ from the date of the IT announcement -when it could have been combined with alternative objectives-.

The identified volatility breaks can coincide with significant economic events, but this simultaneous occurrence does not necessarily imply any causality, but we just highlight their coincidence. In particular, there is a higher volatility regime during the last financial crisis in five out of eight currencies (the Chinese yuan, the Indian rupee, the Mexican peso, the Polish zloty and the South African rand).[10] For Brazil, Korea and Argentina, we cannot distinguish a different volatility regime as there are bigger volatility spikes in previous years that difficult its

[8] This test statistic can suffer from serious distortions in terms of size and/or power (Andreou and Ghysels, 2002) and it is useful to identify just one break. To overcome these problems and identify multiple breaks in volatility at the same time, an alternative is to use an iterative algorithm based on successive applications of an adjusted Inclán and Tiao (1994) test to pieces of the series. It is used a nonparametric adjustment based on the Barlett kernel of Kokoszka and Leipus (1999).

[9] We calculate the modified ICSS algorithm using the GAUSS procedures available from Andreu Sansó web page http://www.uib.es/depart/deaweb/personal/profesores/personalpages/andreusanso/we. We thank David Rapach for providing the modification of the code that allows computing critical values using a response surface appropriate for sample sizes up to 7000 observations.

[10] In India, we also identify a volatility break around March 2004, when the rupee regime changed from a dollar peg to a basket peg where the weight of the dollar was lower. In South Africa, among other breaks, there is a higher volatility regime from November 2001, when the rand strongly depreciated.

identification.[11]

This small empirical application raises some preliminary results that we are going to test in a panel data context in the following sections. First, the relationship between the date of adoption of IT and the exchange rate volatility is not obvious. Only in the case of Brazil and Poland the ICSS test identifies a higher volatility regime approximately coinciding with the adoption of IT. In other words, following these results, only in these two cases the adoption of IT implies a structural change in terms of higher volatility. This anecdotic evidence could be against the a priori of a higher volatility after IT adoption.

Second, the volatility increase of IT countries during the last crisis is at least as large as that of previous ones, except for Mexico, where the exchange rate volatility was much higher during the 1995 Tequila crisis. This is the case of the Korean won and the Brazilian real, whose volatilities increased as much as during the Asian crisis of late 90's or after the Real plan, respectively, whereas the volatility of the Poland zloty and the South African rand registered historical maximums during the recent crisis.

Finally, as shown in Figure 1, exchange rate volatility increases during turmoil periods in all EMEs –regardless whether they have adopted IT or not-. For instance, all of them experienced a volatility increase during the recent financial crisis. In principle, flexible exchange rates should be more volatile than other regimes as any change in the financial conditions translates immediately into changes in the exchange rate, which seems to happen despite their interventions in the FX market as a result of their "fear of floating".

### 3.2 The effects of IT and FX interventions on the exchange rate volatility: A preliminary exercise with GARCH models

Table 2 reports some summary statistics for the monthly return series before and after the onset of the financial crisis. Only the standard deviation of the Argentinean peso returns is much lower after the crisis, due to the 2001 crisis when the currency moved from a peg with the dollar to a crawling peg. All volatility returns exhibit evidence of non-normality (severe excess kurtosis and asymmetry), which might imply the presence of conditional heteroscedasticity in these returns.

[11] For instance, in February 1998 the Korean won lost almost half of its value in the context of the Asian crisis, which shot up volatility in a more severe way than in the last crisis. On the other hand, in Brazil we identify a volatility break around January 1999, which coincides with the end of the Real Plan. However, volatility breaks during the crisis would had been identified in the three countries for a shorter sample period.

Given these characteristics of the series, we fit a univariate GARCH type model for the monthly exchange rate returns to disentangle to what extent the exchange rate conditional volatility is associated with FX interventions.[12] Figure 2 represents both variables for the eight countries, where FX interventions are proxied as the monthly percentage change of the stock of FX reserves in dollars (a positive value indicates a net purchase of foreign currency), and it shows that periods of high exchange rate volatility match well with large interventions (either positive or negative). This fact evidence the suitability of a GARCH type model with explanatory variables in the conditional variance equation.

In particular, we estimate a modified version of the model proposed by Dominguez (1998) to analyze FX interventions and exchange rate volatility in the G-3, which follows this expression,

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

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \gamma_1 IT_t + \gamma_2 \left| I_t \right| + \gamma_3 IT_t \ \left| I_t \right| \tag{4}$$

where $r_t$ are the monthly exchange rate returns, $IT_t$ is a binary dummy variable that takes value one after IT adoption and zero otherwise, $|I_t|$ is the absolute value of FX interventions and $\varepsilon_t^{\dagger}$ is a Gaussian white noise process. Neither the level shift variable $IT_t$ nor $|I_t|$ are new in a GARCH setting (see Edwards, 2007 or Dominguez, 1998, respectively), but, as far as we know, this is the first specification that combines both variables, which will allow to directly disentangle if the adoption of IT or the performance of active FX interventions have an impact on the exchange rate volatility. Note that, in the conditional variance equation $|I_t|$ should appear in absolute value to guarantee the positivity of the conditional variance. Finally, for the sake of simplicity, we have omitted any additional explanatory variable the conditional mean equation, as our focus is on the conditional variance equation.

Alternatively, we have also considered this specification for the conditional variance equation,

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \gamma_1 IT_t + \gamma_4 \left| I_t^- \right| + \gamma_5 IT_t \ \left| I_t^- \right| \tag{5}$$

which is almost identical to equation (4), but where $\left| I_t^- \right|$ stands for the absolute value of negative $I_t$ (FX interventions that imply a net sale of foreign currency). The purpose of this specification is to analyze if interventions to stabilize the currency under depreciatory pressures have

[12] Our GARCH(1,1) specification uses monthly exchange rate returns data as it is the highest frequency at which the IMF International Financial Statistics (IFS) data on FX reserves are available.

a different impact on the exchange rate volatility than positive interventions (foreign exchange accumulation).

Table 3 reports the estimated parameters after fitting models (4) and (5). Box-Pierce statistics for high-order serial correlation of the squared standardized residuals strongly support the role of GARCH models to capture the dynamics of the exchange rate conditional variance.[13] In general, $\hat{\gamma}_1$ is positive in almost all regressions, so that IT would be associated with greater exchange rate volatility as, in theory, its exchange rate regime is more flexible. The estimates of the absolute value of interventions, $\hat{\gamma}_2$, are positive and significant in all countries but Poland. This positive sign indicates that in the months of FX interventions (either US dollars purchases or sales) the exchange rate volatility increases. The interpretation of this sign can be ambiguous rooted on causality issues. Thus, one possible interpretation is that FX interventions add uncertainty to the market but, on the other hand, it can be interpreted that FX interventions simply coincide with periods of higher uncertainty, which is precisely the reason to intervene. Mexico and China have negative $\hat{\gamma}_2$: for China, this sign seems rather intuitive, as FX interventions practically coincide with a peg to the dollar, but in Mexico, this result might point at a greater effectiveness of interventions to lower the exchange rate volatility, compared to other countries. Finally, in Brazil the estimated parameter of the interaction between IT and FX interventions, $\hat{\gamma}_3$, is also negative, which would support the role of FX interventions to lower uncertainty.

Regarding $\hat{\gamma}_4$, which corresponds to the effects of sales of foreign reserves on volatility, the evidence is similar to that of the absolute value of FX interventions: its sign is positive all counties, IT and non-IT, but in China. However, the estimates of its interaction with IT, $\hat{\gamma}_5$, in Brazil and Mexico also point out a possible greater efficiency of FX interventions in some IT countries.

All in all, up to this point our evidence on the role of FX interventions on the exchange rate uncertainty is still ambiguous, based on a small country sample. Thus, we have not answered yet if IT countries experience systematically higher exchange rate volatility as a result of its flexible currency or if the effect of their FX interventions on the exchange rate volatility is different to that of non-IT countries in a consistent way. In the next section we will disentangle this questions by means of a panel data model with a broader country sample.

[13] Note that these diagnostics statistics are rejected for the standardized residuals in the three non-IT countries, which might imply that the specification that we are assuming for the mean process is too simple to capture all the dynamics in the mean equation

## 4 Empirical model and econometric issues

Next, we develop a panel data analysis to disentangle numerically the effects of IT and FX interventions on the exchange rate volatility and if this relation has varied across time. In particular, we want to know if IT adoption has "made a difference" in terms of exchange rate volatility after the onset of the financial crisis, what is the role of FX interventions in this setting and if these relations vary across regions. To do so, we compare the group of 18 EMEs that, according to IMF (2005) and Little and Romano (2009), have already adopted IT –note that all of them adopted IT before the crisis- and a control group of 19 non-targeting countries –see Appendix A for a complete country list-. In the control group we explicitly exclude fully dollarized countries and countries with a fixed exchange rate with the dollar or a different currency (euro). For the sake of comparability of both groups and following Lin and Ye (2009), our control group includes non-targeting EMEs that have a real GDP per capita and population at least as large as that of the poorest and smallest IT country. Our sample period goes from 1Q1995 to 1Q2010.

Again, we use nominal exchange rates against the dollar and the dependent variable is precisely their own volatility, which is measured as the quarterly standard deviation of daily returns. This volatility proxy is not necessarily the best approximation of exchange rate volatility and it is chosen so as to have a suitable frequency for our analysis.[14] Our measure is less smooth to that proposed in Rose (2007), who uses the standard deviation over a four year window of monthly data.[15] Table 4 reports some summary statistics of our exchange rate volatility measure. As in the time series exercise in Section 2, the mean volatility is higher in IT countries in all periods. The significance of these volatility differences will be tested later on. Nevertheless, non-IT countries exhibit a higher coefficient of variation than IT countries, which means that volatility jumps in these economies are greater.

We fit nine panel data models that we denote as M1 to M9. The estimation procedure is based on pooled OLS with time dummies. Models M1 to M3 are built out of this expression,

[14] For instance, in a country with fixed exchange rate its volatility is zero, but if the exchange rate collapses as a result of persistent misalignments their volatility jumps. That is, an alternative could be the standard deviation, but not around the mean rate of change, but around some definition of equilibrium exchange rate, as noted by De Gregorio et al. (2005).

[15] Nevertheless, as noted by De Gregorio et al. (2005), if in short spans the exchange rate follows a random walk, the volatility of returns should be independent of the frequency of the data.

$$\sigma_{ERit} = \beta_0 + \beta_1 \sigma_{ERit-1} + \beta_2 IT_{it} + \beta_3 RES_{it} + \beta_4 RES_{it} \times IT_{it} + \sum_j \delta_j X_{jit} + \varepsilon_{it} \qquad (6)$$

where the exchange rate volatility, $\sigma_{ERit}$, is a function of $\sigma_{ERit-1}$ –to capture volatility persistence–, $IT_{it}$, a binary dummy that takes value one for countries after IT adoption and zero otherwise (see Rose, 2007), the ratio of foreign exchange reserves over GDP, $RES_{it}$,[16] [17] the interaction between both variables and a set of control variables, $X_{it}$. Although a popular method in dynamic panel data estimation is GMM, which is consistent in short panels ($N >> T$), this is not our case.

The next two models are M4 and M5, where we increase the number of drivers in (6) by introducing a dummy variable, $D_{it}$, that is 1 if the stock of reserves over GDP decreases and zero otherwise. That is,

$$\begin{aligned} D_{it} &= 1, \qquad \text{if} \quad \Delta RES_{it} < 0 \\ D_{it} &= 0, \qquad \text{otherwise} \end{aligned} \qquad (7)$$

This variable is useful to analyze if there is a different effect on the exchange rate volatility in the case of an accumulation or a loss of reserves (positive or negative FX intervention). In particular, in M4 and M5 we extend the specification with $D_{it} \times RES_{it}$ and $IT_{it} \times D_{it} \times RES_{it}$, that will provide information about the possible different impact of reserve variations on the exchange rate volatility depending whether there is an accumulation or a loss of reserves. Note that one weakness of $D_{it}$ is that we cannot distinguish if the reserve variation was associated to a real intervention in the exchange rate markets or to alternative reasons.[18]

Finally, in models from M6 to M9 we introduce $\Delta RES$, which approximates the pace of reserve accumulation -or losses- as well as FX interventions of a certain country. In these models we introduce this variable and its interaction with $IT_{it}$ and $D_{it}$ in model (6). The combination of these variables lead us to analyze if in IT countries the effect of FX interventions in the exchange rate volatility is different to that in non-IT countries. At the same time, we

[16] We have made some proofs to check the robustness of $RES$ to minimize the distortional effects of local currency depreciation on the measure of the nominal GDP denominated in dollars. Thus, $RES$ is calculated as the stock of foreign reserves divided by the 12-month accumulated GDP in dollars.

[17] We have also performed several proofs trying to clean the effect of IMF disbursements and repayments on $RES_{it}$. Nevertheless, this process is not straightforward, so that we have just considered the two biggest repayments of our sample (Brazil (4Q2005) and Argentina (1Q2006)).

[18] One option would be to estimate an unobservable threshold to disentangle those reserve variations that are truly linked to interventions (see, for instance, Kim and Sheen, 2002). Nevertheless, the formal estimation of this threshold is out of the scope of this paper.

could also study if this effect is asymmetric, that is, if the effect of purchases or sales of reserves on the volatility is different.

These nine specifications are based on the proper combination of $IT_{it}$, $RES_{it}$ and $D_{it}$. $RES_{it}$ is going to play a crucial role to disentangle the effect of FX interventions (negative $\Delta RES_{it}$) during the last financial crisis and to check whether there has been a punishment for these interventions under an IT regime in the form of higher exchange rate volatility than in non-IT countries.

However, with these specifications we cannot handle causality issues, as we are analyzing the degree of association between the exchange rate volatility and the explanatory variables, whose causality relation is not clear. For instance, whereas Edwards (2007) analyzes the effect on the exchange rate volatility of following an IT, Gonçalves and Carvalho (2008) analyze the opposite causality relation and show that the volatility of the real exchange rate (as a proxy of adverse shocks) is not statistically significant to explain the probability of IT adopting. Nevertheless, we consider FX interventions, $\Delta RES$, as exogenous to $\sigma_{ER}$ in $t$ after performing several tests similar to Hausman-Wu test, where all tests failed to reject the null of exogeneity (available upon request). Therefore, $\Delta RES$ is independent of the errors in (6).

For the robustness of our results and to identify possible omitted variable bias, we include in the nine equations a set of control variables, $X_{it}$ (see Appendix B for more details).[19] Specifically, we use (1) the degree of trade openness, as higher openness increases the reaction to real exchange rate shocks (Cavoli, 2008); (2) Current account (as percentage of GDP); (3) the natural logarithm of population, (4) the real GDP per capita and (5) one financial variable that approximates global risk aversion, proxied by the implied volatility of the S&P index (VIX).[20]

As a final point, our approach is in line with Rose (2007), although we cover the period of the last financial crisis and we also analyze the role of FX interventions in the relation between IT and exchange rate volatility. We fit the models for the full sample, and also for two sub-samples: From 1Q1995 to 2Q2008, to characterize the period previous to the turmoil, and from 3Q2008 to 1Q2010, to analyze the impact of the recent financial crisis.

[19] Note that country fixed effect dummies are not considered in our model: as some variables, like $IT$ are time-invariant in certain subperiods, their effect would translate to the intercept. Control variables also allow o account for the unobservable heterogeneity across countries.

[20] In preliminary versions of the paper we also included other control variables, which have been omitted due to its lack of significance or multicolinearity problems. This is the case of the volatility of commodities prices (as measured by the CRB index) and foreign exchange reserves as percentage of trade.

## 5 Empirical results

Table 5 reports the estimates for models from M1 to M9 for the whole sample period –upper panel–, as well as for the pre-crisis period –central panel- and the post crisis period –lower panel-. Is IT associated with higher exchange rate volatility? As a first result and confirming the findings of the time series exercise, $IT$ seems to be related to higher $\sigma_{ER}$, as shown by the positive and significant coefficients for the $IT$ dummy variable in column M1 of Table 5. This relation is robust to other specifications with more regressors and it is even higher and more significant for the post-crisis period, when this link exacerbated (as also shown in Table 4). Note that, this positive relation between both variables goes against the evidence found by Rose (2007), which concluded that IT does not come at the expense of higher exchange rate volatility, and it is in line with De Gregorio et al. (2005) for Chile.

This positive link between IT and the exchange rate volatility could be mostly explained by the exchange rate regime. To demonstrate this a priori assumption, we have added this control variable as measured by Ilzetzki et al. (2008) monthly coarse classification (see Appendix B),[21] but this control leads to non-significant $IT$ coefficients. Our results are line with those of in Edwards (2007), but we exclude this control variable as it contains almost the same information as our $IT$ variable, which could lead to multicollinearity problems.[22]

What we find even more interesting is to analyze the impact of FX interventions in the exchange rate market. As already mentioned, central banks of EMEs intervene very frequently, even if they have adopted IT, and this is a common way to stabilize the exchange rate.[23] In our sample, while the mean $RES$ in the pre-crisis period was around 0.16 in both types of countries, after the crisis it was 0.32 for non-IT countries and 0.17 for IT countries. That is, non-IT countries strongly accumulated reserves in the aftermath of the crisis, whereas in IT countries this mean is rather stable.

As shown in Table 5 there is a negative link between $RES$ and $\sigma_{ER}$ for the whole sample

[21] Ilzetzki et al. (2008) label countries from 1 to 6 in increasing order according to their degree of exchange rate flexibility. We also performed some proofs with a dummy variable which is 0 for the three categrías that represent less flexible regimes and 1 otherwise.

[22] We have disregarded the exchange rate regime from our final analysis, but the results are available upon request.

[23] See for instance BIS (2005), where exchange rate stabilization is explicitly considered as one of the reasons of FX interventions. Despite the recent increase in the International Reserves of the central banks in EMEs, the social desirability and economic optimality of this phenomenon is another issue that warrants further research.

and the coefficients from M2 to M5, around -0.4 for the total sample, are quite robust across specifications. The interpretation of these coefficients could be that the higher stocks of reserves coincide with more stable exchange rates. The negative relation between $RES$ and the $\sigma_{ER}$ is even bigger in IT countries, as shown by the estimates of $IT \times RES$ in models from M3 to M5. This fact might be simply interpreted as a consequence of the higher flexibility of their exchange rate, which exacerbates the favorable effect of reserve accumulation on $\sigma_{ER}$. That is, in periods of reserve accumulation the volatility is even lower, whereas in periods of reserve losses the exchange rate is more unstable than in non-IT countries. This negative relation between $RES$ and $\sigma_{ER}$ disappears in the post-crisis period in non-IT countries, which might be interpreted from a statistical point of view as this effect might not be identified given that for IT countries these estimates –usually higher than in non-IT countries- are dominating the relation between $RES$ and $\sigma_{ER}$.

To distinguish periods of appreciatory pressures (when the central bank buys reserves) from those of depreciatory pressures (when the central bank sells reserves), we defined in (7) the dummy variable $D$. As shown by M4 and M5 of Table 5, the hypothesis of a different magnitude in the negative link between $RES$ and $\sigma_{ER}$ when facing appreciatory and depreciatory pressures can be rejected for the whole sample and for the pre-crisis and post-crisis periods. This result is robust from Table 5 to 8 and it also holds independently of having an IT or not.

Models from M6 to M9 in Table 5 report the results with $\Delta RES$, which allows to analyze the effect of higher FX interventions on the exchange rate volatility. For the sake of clarity we omit $RES$ in these specifications. We can conclude these results: (1) in the pre crisis period, more aggressive interventions were not associated to variations of the exchange rate volatility for IT and non-IT countries; (2) in the post crisis period, following an IT does make a difference and more aggressive FX interventions are associated with lower exchange rate volatility. That is, the estimate of $IT \times \Delta RES$ is negative and significant; (3) The effect of $\Delta RES$ in $\sigma_{ER}$ seems to be asymmetric relative to its sign in IT countries, so that the magnitude of the effect of accumulating or lowering reserves on the volatility is different –as shown by the significant coefficient for $IT \times D \times \Delta RES$, which is 9.30 for the whole sample and 15.82 for the post-crisis period–. This last outcome would support the role of FX interventions in IT countries during crisis periods.

Then, we divided the sample in three sub samples corresponding to Latin America, Emerging Asia and Eastern Europe to perform the same analysis by region. Tables 6 to 8 report these estimates, respectively. The interpretation of these results should be more cautious, as the sample size is much smaller, which increases identification difficulties.

Regarding the results for Latin America in Table 6, the main result is that the coefficients of $IT\times$ $\Delta RES$ and $IT \times D \times \Delta RES$ in the post crisis period are significant. That is, FX interventions carried out by IT countries during the crisis were associated with lower $\sigma_{ER}$, which is again a result favorable to the use of FX interventions during crisis times in IT countries. On the other hand, the positive link between $IT$ and $\sigma_{ER}$ found in the whole country sample is identified only in the post-crisis period. One possible interpretation might be that $\sigma_{ER}$ during the pre-crisis period in some non-IT or IT countries -before IT adoption- has extreme values corresponding to different domestic crisis episodes (for instance, Argentine, Mexico or Brazil). Finally, in Latin America the negative link between $RES$ and $\sigma_{ER}$ is stronger for IT countries, but only in the pre-crisis period, when a considerable amount of reserves was accumulated.

According to the estimates in Table 7 for Emerging Asia, $IT$ coefficient lose its significance in the post-crisis period. Besides, the coefficients of $RES$ are only significant in the post-crisis period and are higher than for the whole country sample. Finally, $\Delta RES$ seems to play no role in this region neither for IT nor non-IT countries. To conclude, regarding Eastern Europe, the positive link between $IT$ and $\sigma_{ER}$ is just identified in the pre-crisis period, as reported in Table 8. However, we do not find any significant relation between $RES$ and the exchange rate volatility and, as in Emerging Asia, $\Delta RES$ is not significant in any specification, as far as these estimates seem to be dominated by the dynamics of $\sigma_{ERt-1}$. That is, the full sample results for the post-crisis period regarding $\Delta RES$ reported in Table 5 are dominated by Latin America.

# 6 Conclusions

In this paper we have analyzed the link between exchange rate volatility, IT and to the variations of foreign reserves carried out by monetary authorities to manage exchange rate volatility in EMEs. As far as those central banks have tried to conduct monetary policy with some form of price stabilization objective and also manage movements in its currency, these FX interventions might have implications for monetary policy and the use of policy rules. That is, these developments imply a departure from the corner solutions derived from the “impossible Holy Trinity” of fixed exchange rates, independent monetary policy and perfect capital mobility and would have had several broad implications for the role of the exchange rate in IT countries.

To analyze this question we propose two exercises, with a particular focus on the aftermath of the recent financial crisis. First, we carried out a time series study to identify structural breaks in the exchange rate volatility of eight EMEs, some of which have already adopted IT, to get some primer on the link between the exchange rate volatility and IT adoption. We complete the individual country analysis fitting a GARCH model to disentangle the impact of IT and FX interventions on the conditional variance of exchange rates. Second, by means of a panel data model for 37 IT and non-IT EMEs we study the impact of IT adoption and foreign reserve movements –that we roughly interpret as FX interventions– on the exchange rate volatility. We also perform the same analysis for the period previous to the onset of the financial crisis and the subsequent sub-sample. With this second exercise we analyze the link between IT, FX interventions and exchange rate volatility, which will be useful to disentangle if IT does make a difference in terms of financial stability and impact of FX interventions.

Our results confirm that exchange rates are more volatile under IT than under other regimes as far as changes in the financial conditions seem to translate automatically in changes in the exchange rate, which is against the results in Rose (2007). We also show that FX interventions in IT countries could play a useful role in containing exchange rate volatility –as in Latin America– than in non-IT countries. These outcomes justify that if these interventions are performed in specific moments, as in periods of financial turbulence, they could play a useful role in containing the negative impact of transitory shocks on financial stability, so that there is some scope for EMEs that have adopted IT to interpret the implementation of their IT mechanisms with certain degree of flexibility.

## Appendix A: Country list

| Inflation Targeters | |
|---|---|
| Brazil | Peru |
| Colombia | Philippines |
| Czech Republic | Poland |
| Chile | Romania |
| Ghana | Slovak Republic |
| Hungary | South Africa |
| Indonesia | South Korea |
| Israel | Thailand |
| Mexico | Turkey |

| Non-Inflation Targeters | |
|---|---|
| Albania | Guatemala |
| Algeria | India |
| Argentina | Jamaica |
| Cambodia | Malaysia |
| China | Morocco |
| Costa Rica | Russia |
| Croatia | Singapore |
| Dominican Republic | Ukraine |
| Egypt | Uruguay |
| | Vietnam |

## Appendix B: Definition of variables and data sources

• IT: Dummy variable that is one if the country had a formal IT in that quarter. Source: IMF (2005) and Little and Romano (2009).

• FX interventions, $I_t$ (GARCH model):Montly variation of the logarithm of foreign exchange reserves in US dollars. Source: International Financial Statistics (IMF).

• Reserves, $RES_{it}$ (panel data model): Foreign exchange reserves over nominal GDP in US dollars. Source: International Financial Statistics (IMF).

• Openness: Exports plus imports as a percentage of GDP. Source: International Financial Statistics (IMF), Datastream and national sources.

• Current account: Current account as a percentage of GDP. Source: International Financial Statistics (IMF), Datastream and national sources.

• Population: Logarithm of population (thousand persons). Source: World Economic Outlook (IMF).

• GDP per capita: Gross domestic product based on purchasing-power-parity (PPP) per capita. Source: World Economic Outlook (IMF).

• VIX: Implicit volatility of the S&P 500 index. Source: Datastream.

# References

[1] Aizenman, J., M. Hutchison, and I. Noy (2008), Inflation targeting and real exchange rates in emerging markets, NBER Working Paper No. 14561.

[2] Aizenman, J and Y. Sun (2009), The financial crisis and sizeable international reserves depletion: From "fear of floating" to the "fear of losing international reserves"?, NBER Working Paper No. 15308.

[3] Andreou, E. and E. Ghysels (2002) Detecting multiple breaks in financial market volatility dynamics, *Journal of Applied Econometrics*, 17, 579-600.

[4] Ball, L. and N. Sheridan (2003) Does inflation targeting matter? NBER Working Paper 9577.

[5] Bernanke, B., T. Laubach, A. Posen and F. Mishkin (1999), "Inflation targeting: Lessons from the international experience", Princeton, NJ: Princeton University Press

[6] BIS (2005), Foreign exchange market intervention in emerging markets: motives, techniques and implications, BIS papers 24.

[7] Cagan, P. (1956), "The Monetary Dynamics of Hyperinflation", in *Studies in the Quantity Theory of Money*, ed. by Milton Friedman (Chicago: University of Chicago Press), pp. 25-117.

[8] Calvo, G. and C. Reinhart (2000) Fear of floating, *Quarterly Journal of Economics*, 117(2), 379–408.

[9] Carranza, L., J.E. Galdón-Sánchez and J. Gomez-Biscarri (2009), Exchange rate and inflation dynamics in dollarized economies. *Journal of Development Economics* 89, 98-108.

[10] de Carvalho, I. (2010) Inflation targeting and the crisis: An empirical assessment, IMF Working Paper 10/45.

[11] Catao, L. and M. Terrones (2003), Fiscal deficits and inflation, IMF Working Paper 03/151.

[12] Cavoli, T. (2008), The exchange rate and optimal monetary policy rules in open and developing economies: some simple analytics, *Economic Modelling* 25, 1011-1021.

[13] Cavoli, T. (2009), "Is fear of floating justified? The East Asia experience", *Journal of Policy Modeling* 31, 1-16.

[14] Cordero, J. (2009), "Inflation Targeting and the Real Exchange in a Small Economy: a Structuralist Approach", in Beyond Inflation Targeting, eds. G. Epstein and E. Yeldan, pp. 44-67.

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

[16] Dominguez, K. M. (1998), Central bank intervention and exchange rate volatility, *Journal of International Money and Finance* 17, 161-190.

[17] Edison, H., P. Cashin, and H. Liang (2006), Foreign exchange intervention and the Australian dollar: has it mattered?, *International Journal of Finance and Economics* 11, 155-171.

[18] Edwards, S. (2007), The relationship between exchange rates and inflation targeting revisited, in "Monetary Policy under Inflation Targeting", eds. F. Mishkin and K. Schmidt-Hebbel, pp. 373-413.

[19] Fraga, A., I. Goldfajn and A. Minella (2003), Inflation targeting in emerging market economies, NBER Macroeconomics Annual, Vol. 18, pp. 365-400.

[20] Gonçalves, C.E. and A. Carvalho (2008), Who chooses to inflation target? *Economics Letters* 99, 410-413.

[21] De Gregorio, J., A. Tokman and R. Valdés (2005), Flexible exchange rate with inflation targeting in Chile: Experience and issues, Inter-American Development Bank,working paper #540.

[22] Habermeier, K., I. Ötker, L. Jácome, A. Giustiniani, K. Ishi, D. Vávra, T. Kisingay, and F. Vázquez (2009), Inflation pressures and monetary policy options in emerging and developing countries – A cross regional perspective, IMF Working Paper 06/278.

[23] Harvey, A., E. Ruiz and Shephard (1994), Multivariate stochastic variance models, *The Review of Economic Studies*, 61, 247-264.

[24] Hausmann, R., U. Panizza and E. Stein (2001) Why do countries float the way they float?, *Journal of Development Economics*, 66, 387-414.

[25] Inclán, C., and Tiao, G. C. (1994) Use of cumulative sums of squares for retrospective detection of changes of variance, *Journal of the American Statistical Association*, 89, 913–923.

[26] International Monetary Fund (IMF) (2005), Does inflation targeting work in emerging markets?, in World Economic Outlook, September 2005, IMF, pp. 161-186.

[27] Ilzetzki, E., C. Reinhart and K. Rogoff (2008), Exchange rate arrangements into the 21st Century: Will the anchor currency hold?, *Quarterly Journal of Economics* 119, 1-48. (Updated database).

[28] Kang, I. (1999), International foreign exchange agreements and nominal exchange rate volatility: a GARCH application, *North American Journal of Economics and Finance*, 10, 453-472.

[29] Kim, S. and J. Sheen (2002), The determinants of foreign exchange intervention by central banks: evidence from Australia, *Journal of International money and Finance* 21, 619-649.

[30] Kokoszka, P. and R. Leipus (1999), Testing for parameter changes in ARCH models. *Lithuanian Mathematic Journal*, 39, 182-195.

[31] Lin, S. and He, H. (2009), "Does inflation targeting make a difference in developing countries?", *Journal of Development Economics* 89, p.p. 118-123.

[32] Little, J. S. and T. F. Romano (2009), Inflation targeting - Central bank practice overseas. Federal Reserve Bank of Boston, Public Policy Briefs #08-1.

[33] Lobo, B.J. and D. Tufte (1998), Exchange rate volatility: does policy matter?, *Journal of Macroeconomics*, 20, 351-365.

[34] Mihov. I. and A. Rose (2008), Is old money better than new? Duration and monetary regimes, *Economics: The Open-Access, Open-Assessment E-Journal* 2, 2008-13.

[35] Minella, A., Springer de Freitas, P., Goldfajn, I., Muinhos, M.K., (2003) Inflation targeting in Brazil: Constructing credibility under exchange rate volatility. *Journal of International Money and Finance* 22, 1015-1040.

[36] Mishkin, F. and M. Savastano (2001), Monetary policy strategies for Latin America, *Journal of Development Economics* 66, 415-444.

[37] Rapach, D. and J. Strauss (2008) Structural breaks and GARCH models of exchange rate volatility, *Journal of Applied Econometrics*, 23, 65-90.

[38] Rose, A. (2007), A stable international monetary system emerges: Inflation targeting is Bretton Woods, reversed, *Journal of International Money and Finance*, 26, 663-681.

[39] Stone, M, S. Roger, S. Shimizu, A. Nordstrom, T. Kisinbay and J. Restrepo (2009), The role of exchange rate in inflation-targeting emerging economies, IMF Ocassional Paper no. 267.

[40] Taylor, J. (2000), Low inflation, pass-through and the pricing power of firms, *European Economic Review*, 7 (44), pp. 1.389-1.408.

Figure 1: Bilateral exchange rate returns against the dollar and three standard deviation bands for the regimes defined identified by the modified ICSS algorithm for eight selected countries. The red line represents the date of adoption of the formal IT.

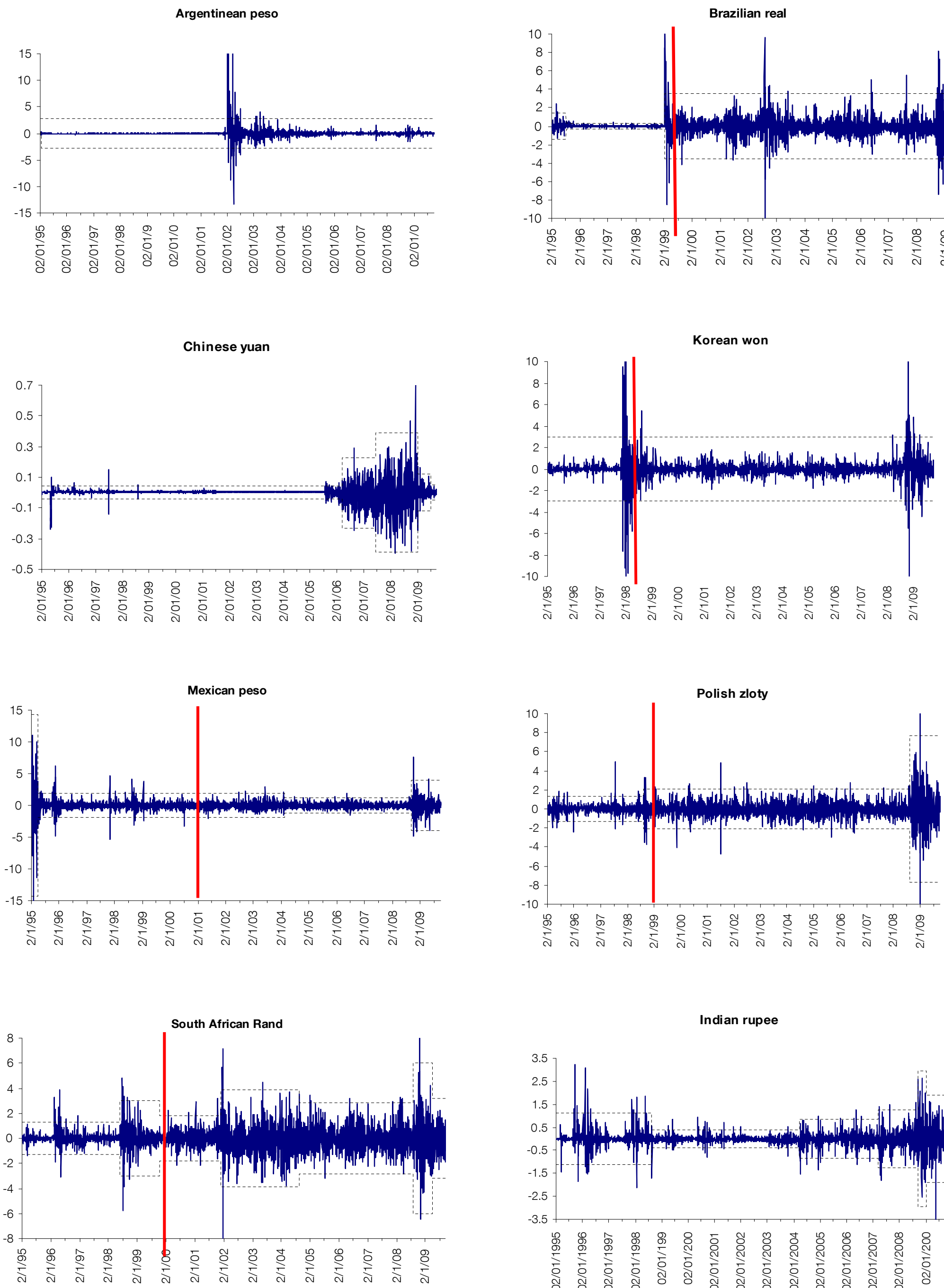

Figure 2: Monthly bilateral exchange rate returns against the dollar and FX interventions (aproximated by the monthly percentage change of the stock of foreign reserves).

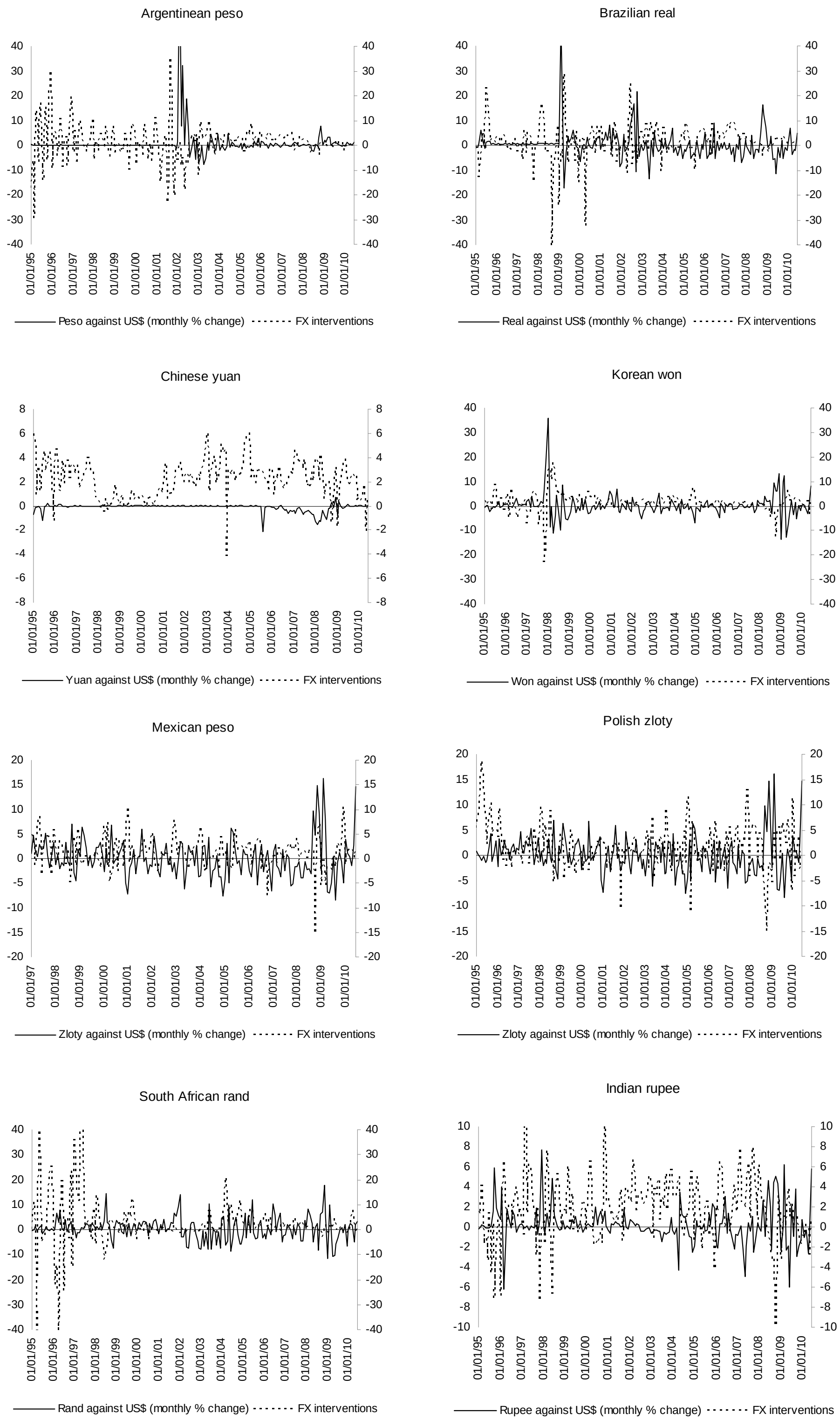

Table 1: Date of adoption of the formal IT in emerging markets and current target. Sources: IMF (2005), Little and Romano (2009) and national sources.

| | **IT adoption date** | **Point target (%)** | **Target range (%)** |
|---|---|---|---|
| Israel | Jun. 1997 | None | $1-3$ |
| Czech Republic | Jan. 1998 | 3.0 | $\pm$ 1.0 |
| South Korea | Apr. 1998 | None | $3.5-4.0$ |
| Poland | Jan. 1999 | 2.5 | $\pm$ 1.0 |
| Brazil | Jun. 1999 | 4.5 | $\pm$ 2.0 |
| Chile | Sep. 1999 | 3.0 | $\pm$ 1.0 |
| Colombia | Sep. 1999 | None | $2-4$ |
| South Africa | Feb. 2000 | None | $3-6$ |
| Thailand | May. 2000 | None | $0-3.5$ |
| Mexico | Jan. 2001 | 3.0 | $\pm$ 1.0 |
| Hungary | Jul. 2001 | 3.0 | $\pm$ 1.0 |
| Peru | Jan. 2002 | 2.0 | $\pm$ 1.0 |
| Philippines | Jan. 2002 | None | $4-5$ |
| Slovak Republic | Jan. 2005 | None | $< 2.0$ |
| Indonesia | Jul. 2005 | 5.0 | $\pm$ 1.0 |
| Rumania | Aug. 2005 | 3.8 | $\pm$ 1.0 |
| Turkey | Jan. 2006 | 7.5 | $\pm$ 2.0 |
| Ghana | May. 2007 | None | $6-8$ |

Source: IMF(2005) and Little and Romano (2009); current IT point target and range target also obtained with national sources. Slovak Republic became non-IT in January 2009 after Euro adoption

Table 2: Summary statistics, monthly exchange rate returns of eight emerging market currencies against the dollar, January, 1995 to June, 2010. We consider September, 2008 as the beginning of the crisis.

| | **Argentina** | | **Brazil** | | **China** | | **India** | |
|---|---|---|---|---|---|---|---|---|
| | Before crisis | After crisis | Before crisis | After crisis | Before crisis | After crisis | Before crisis | After crisis |
| Mean | $-0.058$ | 0.436 | $-0.040$ | 0.295 | $-0.015$ | 0.110 | $-0.037$ | 0.279 |
| Standard Deviation | 6.442 | 1.853 | 5.684 | 6.323 | 0.328 | 0.284 | 1.542 | 3.315 |
| Skewness | 8.767* | 2.307 | 3.942* | 0.670 | $-3.289$* | $-0.714$ | 0.644* | 0.244 |
| Kurtosis | 92.225* | 9.617* | 35.975* | 3.697* | 15.259* | 8.318* | 9.854* | 2.202* |

| | **South Korea** | | **Mexico** | | **Poland** | | **South Africa** | |
|---|---|---|---|---|---|---|---|---|
| | Before crisis | After crisis | Before crisis | After crisis | Before crisis | After crisis | Before crisis | After crisis |
| Mean | $-0.080$ | 0.594 | $-0.059$ | 0.443 | $-0.278$ | 2.073 | 0.022 | $-0.165$ |
| Standard Deviation | 4.134 | 7.298 | 4.088 | 5.004 | 2.888 | 7.228 | 4.191 | 6.970 |
| Skewness | 4.442* | $-0.135$ | 4.265* | 0.609 | $-0.049$ | 0.536 | 0.405* | 0.282 |
| Kurtosis | 39.637* | 2.682* | 37.835* | 5.014* | 2.920* | 2.446* | 4.072* | 3.667* |

Exchange rate returns are 100 times the log-differences of monthly nominal exchange rates against the dollar; * denotes significant at 5% ($p < 0.05$)

Table 3: Monthly GARCH model for the exchange rate

| | IT | | | | | | | | | | non-IT | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Brazil** | | **Korea** | | **Mexico** | | **Poland** | | **South Africa** | | **Argentina** | | **China** | | **India** | |
| $\alpha_0$ | $-4.937^{**}$ | $0.016^{**}$ | $-0.244$ | 0.332 | $3.842^{**}$ | $-0.112$ | $6.348^{*}$ | $0.442^{**}$ | $-0.234$ | $-0.054$ | $-1.924^{**}$ | $-0.226^{**}$ | $0.045^{**}$ | $0.054^{**}$ | $-0.281^{**}$ | $0.080^{*}$ |
| $\alpha_1$ | $0.272^{**}$ | $0.353^{**}$ | $0.419^{**}$ | $0.474^{**}$ | $0.061^{*}$ | 0.055 | $0.154^{*}$ | 0.038 | $0.386^{*}$ | $0.296^{*}$ | $0.022^{*}$ | $0.029^{**}$ | $0.184^{**}$ | $0.331^{**}$ | $0.126^{**}$ | $0.512^{**}$ |
| $\alpha_2$ | $0.385^{**}$ | $0.155^{**}$ | $0.279^{**}$ | $0.371^{**}$ | $0.789^{**}$ | $0.607^{**}$ | $0.414^{*}$ | $0.855^{**}$ | $0.397^{*}$ | $0.493^{**}$ | $0.757^{**}$ | $0.839^{**}$ | $0.655^{**}$ | $0.551^{**}$ | $0.803^{**}$ | $0.551^{**}$ |
| $\gamma_1$ | $11.702^{**}$ | $9.538^{**}$ | 0.510 | $1.103^{**}$ | $-3.604^{**}$ | $1.334^{*}$ | $-1.523$ | $-0.317$ | 1.905 | $4.884^{*}$ | | | | | | |
| $\gamma_2$ | $4.614^{**}$ | | $0.716^{**}$ | | $-0.848^{**}$ | | $-0.476$ | | $0.293^{*}$ | | $2.015^{**}$ | | $-0.012^{**}$ | | $0.207^{**}$ | |
| $\gamma_3$ | $-4.363^{**}$ | | $1.556^{**}$ | | $1.208^{**}$ | | 0.845 | | 2.629 | | | | | | | |
| $\gamma_4$ | | $8.741^{**}$ | | $0.582^{**}$ | | $1.674^{**}$ | | 0.364 | | $0.505^{**}$ | | $0.983^{**}$ | | $-0.024^{**}$ | | $0.291^{**}$ |
| $\gamma_5$ | | $-7.520^{**}$ | | 0.458 | | $-0.916^{*}$ | | 0.463 | | 0.556 | | | | | | |
| $LogL$ | $-538.247$ | $-520.001$ | $-444.201$ | $-448.864$ | $-456.234$ | $-451.075$ | $-488.693$ | $-482.889$ | $-522.014$ | $-514.920$ | $-526.224$ | $-479.509$ | $-27.562$ | $-19.414$ | $-338.346$ | $-340.589$ |
| $Q(12)$ | 13.416 | 13.686 | 11.729 | 13.595 | 11.736 | 9.850 | 6.793 | 8.225 | 10.483 | 9.433 | $26.892^{*}$ | $22.580^{*}$ | $43.762^{*}$ | $104.90^{*}$ | $23.057^{*}$ | $26.499^{*}$ |
| $Q^2(12)$ | 1.400 | 2.0304 | 11.491 | 11.459 | 11.914 | 20.629 | 10.579 | 8.674 | 4.044 | 11.475 | 1.591 | 0.524 | 0.2059 | 0.3783 | 2.515 | 1.6564 |

Notes: Monthly exchange rate GARCH model; conditional variance equation sample: 1/1995-1/2010; T=186

$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \gamma_1 IT_t + \gamma_2 |I_t| + \gamma_3 IT_t \, |I_t|$ $\qquad$ $h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \gamma_1 IT_t + \gamma_4 \left|I_t^-\right| + \gamma_5 IT_t \left|I_t^-\right|$

$IT_t$ denotes a dummy variable that is 0 if the country has an inflation target in period $T$; $|I_t|$ is a variable that approximates the FX interventions (in absolute value) and it is measured as $\Delta res_t$, where $res_t$ is the volume of foreign reserves; $\left|I_t^-\right|$ approximates the FX interventions that imply selling foreign currency reserves (in absolute value), that is, negative $\Delta res_t$; $^*$ denotes significant at 5% ($p < 0.05$);
$LogL$ denotes the value of the log likelihood function; $Q(12)$ denotes the Box-Pierce Q-statistic (with 12 lags) for the standardized residuals; $Q_2(12)$ denotes the Box-Pierce Q-statistic (with 12 lags) for the squared standardized residuals.

Table 4: Summary statistics of our measure of exchange rate volatility for a sample of 38 countries (quarterly data, based on nominal exchange rates against the dollar). We consider 3Q 2008 as the date of the beginning of the crisis.

| | Mean | | CV | | Max | | Min | |
|---|---|---|---|---|---|---|---|---|
| | IT | Non-IT | IT | Non-IT | IT | Non-IT | IT | Non-IT |
| Full sample | 0.645 | 0.540 | 0.673 | 1.629 | 4.507 | 18.717 | 0.041 | 0.000 |
| Pre crisis | 0.565 | 0.535 | 0.561 | 1.692 | 2.818 | 18.717 | 0.041 | 0.000 |
| After crisis | 0.966 | 0.588 | 0.668 | 0.868 | 4.507 | 4.251 | 0.141 | 0.000 |

Summary statistics of exchange rate volatility -based on nominal exchange rates againt the dollar-.
CV: coefficient of variation (standard deviation / mean); Max: Maximum; Min: Minimum.

Table 5: OLS coefficient estimates from regressions of exchange rate volatility on IT dummy and foreign reserves.

| | M1 | M2 | M3 | M4 | M5 | M6 | M7 | M8 | M9 |
|---|---|---|---|---|---|---|---|---|---|
| **Total sample** | | | | | | | | | |
| $\sigma_{ER,t-1}$ | 0.53*** | 0.52*** | 0.51*** | 0.51*** | 0.51*** | 0.53*** | 0.53*** | 0.53*** | 0.53*** |
| $IT$ | 0.07** | 0.05 | 0.15** | 0.15** | 0.15** | 0.07** | 0.07** | 0.07** | 0.10*** |
| $RES$ | | −0.45*** | −0.40*** | −0.39** | −0.39** | | | | |
| $IT \times RES$ | | | −0.56** | −0.56** | −0.54** | | | | |
| $D \times RES$ | | | | −0.01 | 0.01 | | | | |
| $IT \times D \times RES$ | | | | | −0.31* | | | | |
| $\Delta RES$ | | | | | | −0.57 | −0.45 | 0.70 | 1.70 |
| $IT \times \Delta RES$ | | | | | | | −0.58 | | −3.32 |
| $D \times \Delta RES$ | | | | | | | | −3.03 | −4.85 |
| $IT \times D \times \Delta RES$ | | | | | | | | | 9.30** |
| $N$ | 2048 | 2039 | 2039 | 2039 | 2039 | 2036 | 2036 | 2036 | 2036 |
| $R^2$ | 0.39 | 0.40 | 0.40 | 0.40 | 0.40 | 0.39 | 0.39 | 0.39 | 0.39 |
| **Pre-crisis** | | | | | | | | | |
| $\sigma_{ER,t-1}$ | 0.52*** | 0.51*** | 0.51*** | 0.51*** | 0.51*** | 0.53*** | 0.53*** | 0.53*** | 0.52*** |
| $IT$ | 0.06* | 0.04 | 0.12* | 0.12* | 0.13* | 0.06* | 0.06* | 0.07* | 0.09** |
| $RES$ | | −0.48*** | −0.44** | −0.44** | −0.44** | | | | |
| $IT \times RES$ | | | −0.48* | −0.49* | −0.46* | | | | |
| $D \times RES$ | | | | 0.01 | 0.02 | | | | |
| $IT \times D \times RES$ | | | | | −0.35** | | | | |
| $\Delta RES$ | | | | | | −0.68 | −0.82 | 1.11 | 1.61 |
| $IT \times \Delta RES$ | | | | | | | 0.80 | | −1.96 |
| $D \times \Delta RES$ | | | | | | | | −4.49 | −6.05 |
| $IT \times D \times \Delta RES$ | | | | | | | | | 8.99** |
| $N$ | 1819 | 1810 | 1810 | 1810 | 1810 | 1807 | 1807 | 1807 | 1807 |
| $R^2$ | 0.35 | 0.36 | 0.36 | 0.36 | 0.36 | 0.35 | 0.35 | 0.36 | 0.36 |
| **Post-crisis** | | | | | | | | | |
| $\sigma_{ER,t-1}$ | 0.51*** | 0.51*** | 0.48*** | 0.48*** | 0.48*** | 0.51*** | 0.52*** | 0.52*** | 0.50*** |
| $IT$ | 0.11 | 0.10 | 0.31** | 0.32** | 0.32** | 0.13* | 0.14* | 0.12* | 0.20** |
| $RES$ | | −0.15 | −0.02 | −0.05 | −0.04 | | | | |
| $IT \times RES$ | | | −0.98** | −0.97** | −0.95* | | | | |
| $D \times RES$ | | | | 0.08 | 0.10 | | | | |
| $IT \times D \times RES$ | | | | | −0.28 | | | | |
| $\Delta RES$ | | | | | | −1.53 | −0.38 | −2.50 | 2.19 |
| $IT \times \Delta RES$ | | | | | | | −3.49 | | −7.41* |
| $D \times \Delta RES$ | | | | | | | | 1.95 | −4.05 |
| $IT \times D \times \Delta RES$ | | | | | | | | | 15.82* |
| $N$ | 229 | 229 | 229 | 229 | 229 | 229 | 229 | 229 | 229 |
| $R^2$ | 0.57 | 0.57 | 0.58 | 0.58 | 0.58 | 0.57 | 0.57 | 0.57 | 0.58 |

* p<0.05; ** p<0.01; *** p<0.001; We consider 3Q2008 as the start of the financial crisis; Dependent variable: Exchange rate volatility (proxied by the quarterly standard deviation of daily $r_t$ -log difference of the bilateral exchange rate against the dollar-); IT: binary dummy, IT=1 if countries have adopted IT; RES: Foreign reserves over GDP; D: binary dummy, D=1 if ΔRES<0; Controls not reported but included: (1) Current account as percentage of GDP; (2) Trade openness; (3) Log of population; (4) GDP per capita; (5) VIX index; Intercept and time controls included but not reported.

Table 6: OLS coefficient estimates from regressions of exchange rate volatility on IT dummy and foreign reserves. Latin America.

| | Latin America: Total sample | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **M1** | **M2** | **M3** | **M4** | **M5** | **M6** | **M7** | **M8** | **M9** |
| $\sigma_{ER,t-1}$ | 0.50*** | 0.42*** | 0.42*** | 0.42*** | 0.42*** | 0.50*** | 0.50*** | 0.50*** | 0.49*** |
| $IT$ | 0.03 | 0.11 | 0.04 | 0.04 | 0.04 | 0.02 | 0.02 | 0.03 | 0.08 |
| $RES$ | | −2.40*** | −2.60*** | −2.59*** | −2.63*** | | | | |
| $IT \times RES$ | | | 0.56 | 0.57 | 0.69 | | | | |
| $D \times RES$ | | | | −0.05 | 0.10 | | | | |
| $IT \times D \times RES$ | | | | | −0.88 | | | | |
| $\Delta RES$ | | | | | | −3.86 | −4.94* | −1.64 | −0.11 |
| $IT \times \Delta RES$ | | | | | | | 4.45 | | −4.38 |
| $D \times \Delta RES$ | | | | | | | | −4.97 | −10.78 |
| $IT \times D \times \Delta RES$ | | | | | | | | | 22.96* |
| $N$ | 591 | 591 | 591 | 591 | 591 | 59 | 591 | 591 | 591 |
| $R^2$ | 0.40 | 0.43 | 0.43 | 0.43 | 0.43 | 0.40 | 0.40 | 0.40 | 0.41 |

| | Latin America: Pre-crisis | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $\sigma_{ER,t-1}$ | 0.48*** | 0.41*** | 0.41*** | 0.41*** | 0.41*** | 0.48*** | 0.48*** | 0.48*** | 0.48*** |
| $IT$ | −0.01 | 0.07 | −0.02 | −0.02 | −0.01 | −0.01 | −0.02 | −0.01 | 0.02 |
| $RES$ | | −2.42*** | −2.66*** | −2.66*** | −2.69*** | | | | |
| $IT \times RES$ | | | 0.71 | 0.72 | 0.75 | | | | |
| $D \times RES$ | | | | −0.02 | 0.08 | | | | |
| $IT \times D \times RES$ | | | | | −0.60 | | | | |
| $\Delta RES$ | | | | | | −4.82* | −5.60* | −1.71 | −1.07 |
| $IT \times \Delta RES$ | | | | | | | 3.52 | | −1.99 |
| $D \times \Delta RES$ | | | | | | | | −7.20 | −10.32 |
| $IT \times D \times \Delta RES$ | | | | | | | | | 15.00 |
| $N$ | 524 | 524 | 524 | 524 | 524 | 524 | 524 | 524 | 524 |
| $R^2$ | 0.37 | 0.41 | 0.41 | 0.41 | 0.41 | 0.38 | 0.38 | 0.38 | 0.38 |

| | Latin America: Post-crisis | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $\sigma_{ER,t-1}$ | 0.44** | 0.31* | 0.24 | 0.20 | 0.21 | 0.43** | 0.42** | 0.43** | 0.42** |
| $IT$ | 0.19 | 0.37** | 0.91*** | 1.02*** | 0.95*** | 0.19 | 0.20 | 0.21 | 0.34* |
| $RES$ | | −2.64** | −0.46 | −0.70 | −0.83 | | | | |
| $IT \times RES$ | | | −3.60** | −4.04** | −3.28* | | | | |
| $D \times RES$ | | | | 0.82 | 1.16 | | | | |
| $IT \times D \times RES$ | | | | | −1.44 | | | | |
| $\Delta RES$ | | | | | | 3.21 | 1.34 | −2.82 | 7.92 |
| $IT \times \Delta RES$ | | | | | | | 4.20 | | −18.72* |
| $D \times \Delta RES$ | | | | | | | | 9.95 | −12.66 |
| $IT \times D \times \Delta RES$ | | | | | | | | | 45.73* |
| $N$ | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 |
| $R^2$ | 0.61 | 0.66 | 0.68 | 0.69 | 0.70 | 0.61 | 0.62 | 0.62 | 0.67 |

* p<0.05; ** p<0.01; *** p<0.001; We consider 3Q2008 as the start of the financial crisis; Dependent variable: Exchange rate volatility (proxied by the quarterly standard deviation of daily $r_t$ -log difference of the bilateral exchange rate against the dollar-); IT: binary dummy, IT=1 if countries have adopted IT; RES: Foreign reserves over GDP; D: binary dummy, D=1 if ΔRES<0; Controls not reported but included: (1) Current account as percentage of GDP; (2) Trade openness; (3) Log of population; (4) GDP per capita; (5) VIX index; Intercept and time controls included but not reported.

Table 7: OLS coefficient estimates from regressions of exchange rate volatility on IT dummy and foreign reserves. Emerging Asia.

| | **Asia: Total sample** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **M1** | **M2** | **M3** | **M4** | **M5** | **M6** | **M7** | **M8** | **M9** |
| $\sigma_{ER,t-1}$ | 0.65*** | 0.62*** | 0.62*** | 0.62*** | 0.62*** | 0.66*** | 0.66*** | 0.66*** | 0.66*** |
| $IT$ | −0.17* | −0.24* | −0.36* | −0.36* | −0.36* | −0.16* | −0.14 | −0.16* | −0.14 |
| $RES$ | | −1.12* | −1.18* | −1.18* | −1.18* | | | | |
| $IT \times RES$ | | | 0.50 | 0.49 | 0.49 | | | | |
| $D \times RES$ | | | | −0.01 | −0.01 | | | | |
| $IT \times D \times RES$ | | | | | 0.21 | | | | |
| $\Delta RES$ | | | | | | −2.38 | −1.66 | −2.96 | −1.64 |
| $IT \times \Delta RES$ | | | | | | | −3.91 | | −4.25 |
| $D \times \Delta RES$ | | | | | | | | 1.44 | −0.05 |
| $IT \times D \times \Delta RES$ | | | | | | | | | 2.15 |
| $N$ | 415 | 415 | 415 | 415 | 415 | 415 | 415 | 415 | 415 |
| $R^2$ | 0.64 | 0.65 | 0.65 | 0.65 | 0.65 | 0.64 | 0.65 | 0.64 | 0.65 |

| | **Asia: Pre-crisis** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $\sigma_{ER,t-1}$ | 0.65*** | 0.63*** | 0.63*** | 0.63*** | 0.63*** | 0.65*** | 0.65*** | 0.66*** | 0.66*** |
| $IT$ | −0.18* | −0.24* | −0.45* | −0.45* | −0.45* | −0.18* | −0.17* | −0.18* | −0.18* |
| $RES$ | | −1.00 | −1.01 | −1.02 | −1.02 | | | | |
| $IT \times RES$ | | | 0.95 | 0.94 | 0.94 | | | | |
| $D \times RES$ | | | | −0.03 | −0.04 | | | | |
| $IT \times D \times RES$ | | | | | 0.21 | | | | |
| $\Delta RES$ | | | | | | −1.71 | −1.58 | −2.37 | −2.47 |
| $IT \times \Delta RES$ | | | | | | | −0.87 | | 0.09 |
| $D \times \Delta RES$ | | | | | | | | 1.61 | 2.11 |
| $IT \times D \times \Delta RES$ | | | | | | | | | −3.45 |
| $N$ | 367 | 367 | 367 | 367 | 367 | 367 | 367 | 367 | 367 |
| $R^2$ | 0.64 | 0.65 | 0.65 | 0.65 | 0.65 | 0.64 | 0.64 | 0.64 | 0.64 |

| | **Asia: Post-crisis** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $\sigma_{ER,t-1}$ | 0.50** | 0.22* | 0.22* | 0.22 | 0.21 | 0.47*** | 0.55** | 0.47** | 0.52** |
| $IT$ | −0.19 | −0.34 | −0.40 | −0.39 | −0.36 | −0.17 | 0.01 | −0.17 | 0.11 |
| $RES$ | | −2.46* | −2.55* | −2.54* | −2.49 | | | | |
| $IT \times RES$ | | | 0.12 | 0.11 | 0.06 | | | | |
| $D \times RES$ | | | | 0.02 | 0.02 | | | | |
| $IT \times D \times RES$ | | | | | −0.38 | | | | |
| $\Delta RES$ | | | | | | −6.37 | −3.72 | −6.78 | −2.34 |
| $IT \times \Delta RES$ | | | | | | | −8.71 | | −11.45 |
| $D \times \Delta RES$ | | | | | | | | 1.03 | −1.13 |
| $IT \times D \times \Delta RES$ | | | | | | | | | 26.23 |
| $N$ | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| $R^2$ | 0.66 | 0.73 | 0.73 | 0.73 | 0.73 | 0.70 | 0.73 | 0.70 | 0.75 |

* p<0.05; ** p<0.01; *** p<0.001; We consider 3Q2008 as the start of the financial crisis; Dependent variable: Exchange rate volatility (proxied by the quarterly standard deviation of daily $r_t$ -log difference of the bilateral exchange rate against the dollar-); IT: binary dummy, IT=1 if countries have adopted IT; RES: Foreign reserves over GDP; D: binary dummy, D=1 if $\Delta$RES<0; Controls not reported but included: (1) Current account as percentage of GDP; (2) Trade openness; (3) Log of population; (4) GDP per capita; (5) VIX index; Intercept and time controls included but not reported.

Table 8: OLS coefficient estimates from regressions of exchange rate volatility on IT dummy and foreign reserves. Eastern Europe.

| | **Eastern Europe: Total sample** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **M1** | **M2** | **M3** | **M4** | **M5** | **M6** | **M7** | **M8** | **M9** |
| $\sigma_{ER,t-1}$ | 0.36*** | 0.36*** | 0.36*** | 0.36*** | 0.36*** | 0.37*** | 0.37*** | 0.37*** | 0.37*** |
| $IT$ | 0.13** | 0.11* | 0.10 | 0.11 | 0.12 | 0.12** | 0.12** | 0.13** | 0.12** |
| $RES$ | | −0.64 | −0.65 | −0.70 | −0.70 | | | | |
| $IT \times RES$ | | | 0.04 | −0.04 | −0.06 | | | | |
| $D \times RES$ | | | | 0.23 | 0.27 | | | | |
| $IT \times D \times RES$ | | | | | −0.24 | | | | |
| $\Delta RES$ | | | | | | −1.46 | −2.04 | −1.11 | −2.04 |
| $IT \times \Delta RES$ | | | | | | | 1.73 | | 2.00 |
| $D \times \Delta RES$ | | | | | | | | −0.87 | −0.01 |
| $IT \times D \times \Delta RES$ | | | | | | | | | −1.41 |
| $N$ | 604 | 604 | 604 | 604 | 604 | 604 | 604 | 604 | 604 |
| $R^2$ | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 |

| | **Eastern Europe: Pre-crisis** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $\sigma_{ER,t-1}$ | 0.36*** | 0.35*** | 0.35*** | 0.35*** | 0.35*** | 0.36*** | 0.36*** | 0.36*** | 0.36*** |
| $IT$ | 0.12** | 0.09 | 0.09 | 0.11 | 0.13 | 0.11* | 0.11* | 0.11** | 0.11* |
| $RES$ | | −0.82 | −0.82 | −0.87 | −0.88 | | | | |
| $IT \times RES$ | | | 0.04 | −0.11 | −0.16 | | | | |
| $D \times RES$ | | | | 0.27 | 0.32 | | | | |
| $IT \times D \times RES$ | | | | | −0.33 | | | | |
| $\Delta RES$ | | | | | | −1.92 | −2.91 | −1.17 | −2.03 |
| $IT \times \Delta RES$ | | | | | | | 3.45 | | 2.92 |
| $D \times \Delta RES$ | | | | | | | | −2.01 | −2.31 |
| $IT \times D \times \Delta RES$ | | | | | | | | | 1.90 |
| $N$ | 532 | 532 | 532 | 532 | 532 | 532 | 532 | 532 | 532 |
| $R^2$ | 0.26 | 0.26 | 0.26 | 0.27 | 0.27 | 0.26 | 0.26 | 0.26 | 0.26 |

| | **Eastern Europe: Post-crisis** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $\sigma_{ER,t-1}$ | 0.35*** | 0.34*** | 0.31* | 0.31* | 0.31* | 0.35*** | 0.36*** | 0.35** | 0.35** |
| $IT$ | 0.19 | 0.16 | −0.80 | −0.91 | −0.94 | 0.19 | 0.19 | 0.17 | 0.14 |
| $RES$ | | −0.58 | −4.04 | −4.30 | −4.31 | | | | |
| $IT \times RES$ | | | 4.23 | 4.66 | 4.66 | | | | |
| $D \times RES$ | | | | −0.32 | −0.45 | | | | |
| $IT \times D \times RES$ | | | | | 0.66 | | | | |
| $\Delta RES$ | | | | | | 0.11 | 1.68 | −1.36 | −0.71 |
| $IT \times \Delta RES$ | | | | | | | −3.30 | | −0.59 |
| $D \times \Delta RES$ | | | | | | | | 3.31 | 3.89 |
| $IT \times D \times \Delta RES$ | | | | | | | | | −9.31 |
| $N$ | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 |
| $R^2$ | 0.53 | 0.53 | 0.54 | 0.54 | 0.54 | 0.53 | 0.53 | 0.53 | 0.53 |

* p<0.05; ** p<0.01; *** p<0.001; We consider 3Q2008 as the start of the financial crisis; Dependent variable: Exchange rate volatility (proxied by the quarterly standard deviation of daily $r_t$ -log difference of the bilateral exchange rate against the dollar-); IT: binary dummy, IT=1 if countries have adopted IT; RES: Foreign reserves over GDP; D: binary dummy, D=1 if ΔRES<0; Controls not reported but included: (1) Current account as percentage of GDP; (2) Trade openness; (3) Log of population; (4) GDP per capita; (5) VIX index; Intercept and time controls included but not reported.