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Asymmetric Monetary and Exchange Rate Policies in Latin-America

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Abstract

During the last decades, the number of countries that adopted more flexible exchange rate regimes, in particular Inflation Targeting, has been increasing steadily. Latin-America was no exception. Some authors have argued that there is a flaw in the way in which the system has been conducted in the region. When inflation falls, the Central Bank is reluctant to cut interest rates, but when inflation increases, the Central Bank is willing to raise interest rates very aggressively, adding an unnecessary bias to monetary and exchange rate policies. This paper analyzes the asymmetry of monetary and exchange rate policies in the five largest Latin-American Inflation Targeting countries, Brazil, Chile, Colombia, Mexico, and Peru. Using different econometric techniques, I find that the Central Banks, with the exception of Chile, suffer from “fear of floating”. This is a more pronounced phenomena for the case of Brazil and Mexico, as the literature has argued.

JEL Classification Codes: E58, F30, F43.

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1 Introduction

During the last decades several developed and non-developed countries adopted more flexible exchange rate arrangements. More precisely, Inflation Targeting has become the poster child of exchange rate regimes. That regime works as follows. The Central Bank commits to deliver a low and stable rate of inflation, using as the main policy instrument a short-term interest rate. In an open economy set-up, countries on Inflation Targeting keep a relatively open capital account. The usual prescription is that they should refrain from intervening in the foreign exchange market and let the exchange rate float as freely as possible.

In practice this is hardly the case. As monetary policy is used to target inflation (and possibly the output-gap), changes in the interest rate may create large swings in exchange rates, well beyond what most Central Banks are willing to tolerate. In fact the theory does not necessary precludes sales and purchases of foreign assets by authorities (as well as other types of interventions), as long as they reflect attempts to cushion temporary shocks or other exchange rate movements not justified by economic fundamentals.

The largest Latin-American countries have adopted the framework, including Brazil (1999), Chile (1991), Colombia (1999), Mexico (2002), and Peru (2003). These countries are the perfect specimens to analyze how Inflation Targeting works on a set-up subject to a myriad of external nominal and real shocks. Although their exchange rate regimes are de facto much more flexible than in the past, their Central Banks intervened heavily in the foreign exchange market to cushion large movements in exchange rates (Chang, 2008).

There are good reasons to believe that this type of intervention was not implemented during episodes of appreciation and depreciation with the same intensity. Authors such as Barbosa-Filho (2015) and Ros (2015) have argued that the Central Banks of Brazil and Mexico have conducted an “asymmetric policy”, tightening the stance of monetary policy too much when inflation accelerates, and softening it too little when inflation falls. Because the capital account of the balance of payments was extremely open, the required changes in the interest rate may have triggered movements in the exchange rate with a bias in the downward direction.¹ On the other hand, intervention in the foreign exchange market via sales of dollars (when exchange rate depreciates) may have been more pronounced than purchases of dollars (when the exchange rate appreciates).

This paper analyzes the nature of monetary and exchange rate policy in Latin-American Inflation Targeting countries. Using non-linear econometric techniques, I test whether the Central Banks from these countries were more willing to tolerate appreciations than depreciation, for the period 1999-2015. The purpose of

¹In this paper I stick to the following convention: the exchange rate is defined as the number of units of domestic currency per unit of dollars, so a reduction in the exchange rate is an appreciation, while an increase is a depreciation.

my econometric estimation is to test for the presence of asymmetries in the evolution of the exchange rate. But because exchange rate may behave asymmetrically for reasons other than policy, I also estimate a set of Central Bank reaction functions for interest rates and reserve accumulation, to determine the impact of monetary and exchange rate policy on the observed exchange rate behavior.

A brief summary of my results is as follows: there are some signs that the Central Banks from Latin-America dislike depreciations more than appreciations, with the exception of Chile. Moreover, this behavior seems to be more pronounced for the cases discussed by Barbosa-Filho and Ros, Brazil and Mexico.

This paper is structured as follows. After this introduction, section 3.2 comments on the related literature. Section 3.3 describes the econometric techniques and presents the results. Finally, section 3.4 concludes.

2 Related Literature

The recent thinking in macroeconomics have converged on a sort of synthesis, known as the “New Consensus Macroeconomics”. This consensus agrees on the desirability of an autonomous monetary policy, and how to conduct it. The interest rate has replaced monetary aggregates on the monetary policy rules. It has been shown that a fully microfounded model based on a representative and forward looking agent framework is able to determine the equilibrium without any reference to the quantity of money, provided that the interest rate rule is sufficiently sensitive to changes in the rate of inflation.

This is known as the “Taylor-Principle”, and it is embodied in the famous “Taylor-Rule”.² Intuitively, the principle says that the rate of interest should be increased by more than inflation when inflation increase above the inflation target, to avoid a feedback from higher inflation to lower real interest rates, and from lower real interest rates to more aggregate demand and higher inflation. Conversely, when inflation falls below the target, the interest rate should be reduced by more than inflation.

When the “Taylor-Principle” is satisfied, the equilibrium is “determined”, so inflationary expectations are “anchored” by the inflation target.³ It is believed, In the context of Dynamic Stochastic General Equilibrium (DSGE) models, that if there are no real frictions, stabilizing inflation implies the stabilization of the output-gap, and thus Inflation Targeting seems to be a cost free approach to control inflation. This very convenient feature is called the “Divine Coincidence”, following the terminology of Blanchard and Gali (2007). Due to the popularity of the DSGE approach, it is not surprising that Inflation Targeting has emerged as the most

²Both are due to John Taylor (see Taylor, 1993).

³Equilibrium Determinacy in models with forward looking behavior means that the number of positive roots is equal to the number of non-predetermined variables, so the system can be placed into the equilibrium trajectory. For monetary policy models, when the “Taylor-Principle” is not satisfied, the number of positive roots is larger than the number of non-predetermined variables.

popular macroeconomic regime.⁴

Although the record of Inflation Targeting in terms of inflation reduction (at no noticeable output cost) seems to be quite remarkable in some countries, there is some debate on whether the observed disinflation is due to the adoption of Inflation Targeting per se, or due to other global factors, for instance the emergence of China as a provider of cheap manufacturing goods. For example Ball and Sheridan (2003) suggest that “Inflation Targeting does not matter”: dis-inflation has happened almost everywhere, not only in countries that adopted Inflation Targeting.

On the other hand, the reduction in the rates of inflation was not translated into fast output growth and employment opportunities in several non-developed economies (see for instance the volume edited by Epstein and Yeldan, 2009). It may not be correct to argue that Inflation Targeting per se is responsible for a disappointing macroeconomic performance. Rather, this seems to be the result of a set of policies mainly concerned with keeping inflation in single and lower digits, with little emphasis on the promotion of growth and development.

Perhaps an important but often neglected aspect of the debate on Inflation Targeting is related on how it is implemented in an open economy. Very often is implicitly assumed that the open economy set-up should work as if the economy were closed. The core propositions presumably apply in an open economy as well (i.e., interest rate should response to inflation shocks aggressively, etc.), but there are additional complications associated with additional monetary and real shocks from the rest of the world. Unsurprisingly, the effects of exchange rate fluctuations, and the scope of Central Bank interventions in the foreign exchange market are subject to intense controversies.

It is often claimed that Inflation Targeting requires a fully flexible exchange rate, but some authors believe that there is a role for Central Bank intervention (see Ball, 1999, for a discussion). In practice, for a small open economy there is no really such a thing as a fully flexible exchange rate regime. To let the exchange rate to be determined entirely by market forces is a luxury around the world, especially in non-developed economies. Central Bank often intervene to avoid large fluctuations of the exchange rate, and despite being banned from the policy debate, capital controls have not totally disappeared yet.⁵

Then, how does Inflation Targeting works in an open economy? Is a less than fully flexible exchange rate regime incompatible with Inflation Targeting? Although in non-developed countries the exchange rate regimes are much more flexible than in the past, there is substantial evidence that the Central Banks

⁴See Bernanke and Mishkin (1997) for a more precise description of Inflation Targeting.

⁵See for example the new data set on capital controls by Fernandez et. al. (2015). Also see Chang (2008) and Céspedes et. al. (2014), for an analysis that shows how in Latin-American countries using Inflation Targeting, the Central Banks intervened heavily to control exchange rate fluctuations.

intervened heavily to cushion large movements in the exchange rates.⁶ There are good reasons to believe that this type of intervention is not implemented during episodes of appreciations and depreciations with the same intensity. As discussed by Calvo and Reinhart (2002), when the financial system is highly dollarized, the Central Bank may fear that currency depreciations will trigger bank failures.⁷ This behavior is often called “fear of floating”. On the other hand, when competitiveness of the tradable sector is an issue, or when the policy makers want to build a “war chest” of foreign exchange reserves, the Central Bank may intervene to prevent currency appreciations, a phenomena known as “fear of floating in reverse”, and illustrated by the recent East-Asian experience (Levy-Yeyati and Sturzenegger, 2007).

Some observers of the Latin-American cases argued that Inflation Targeting have introduced a bias in evolution of the exchange rate because the Central Banks react strongly to control depreciations, but more timid to fight appreciations (Barbosa-Filho, 2015, and Ros, 2015.⁸ Unlike East-Asian countries that used interventions in the foreign exchange market to prevent appreciations (Pontines and Rajan, 2001, and Pontines and Siregar, 2012), Latin-American countries seem to intervene mainly in the opposite direction.

Also according to the observers of the Latin-American experience (Barbosa-Filho and Ros), it seems to be the case that Inflation Targeting is responsible for a persistent appreciation of the real exchange rate. Whether this process was permanent or temporary is not fully spelled out, although these authors seem to suggest that the appreciation was long-lasting. I personally do not find the argument that the effects of Inflation Targeting on the real exchange rate are permanent very convincing, and in fact the most recent experience illustrates how that regime can also accommodate large real depreciations.

However, even if Inflation Targeting does not have an effect on the long-run level of the real exchange rate, this does not mean that an asymmetric policy do no have important implications. The rate of devaluation can be bounded, and thus certain shocks may not a produce a convenient re-allocation of resources. Furthermore, the distribution of the possible levels for the real exchange rate may become bounded. Consider the following example. Imagine that the real exchange rate index has a mean of 1. Assume that the real exchange rate

⁶See for example Chang (2008) for the Latin-American case.

⁷It is also possible that Central Banks fear the effects of depreciations on inflation, although the exchange rate pass-through have recently declined by non-trivial amounts.

⁸“There is a fundamental asymmetry in the way macroeconomic policy deals with changes in the exchange rate in developing economies, especially in Latin America. Because appreciations are deflationary and depreciations are inflationary in the short run, any democratic government tends to tolerate appreciations but fight depreciations of their currencies. In fact, the adjusting period of the economy after a depreciation of its domestic currency may be longer than the mandate of elected officials, and this creates an asymmetric response of democratic governments to changes in the real exchange rate,” (Barbosa-Filho, 2015). “To the extent that the Central Bank reacts only to changes in the inflation rate it becomes very tempting for the monetary authority to subordinate the exchange rate to its inflation objectives or to respond in an asymmetrical way to appreciations and depreciations. There is then as a consequence a ‘fear to depreciate’, more than a ‘fear of floating’. This tends to make monetary policy pro-cyclical in the fact of external shocks. For example, in the face of a negative export demand shock, which tends to lower economic activity, the monetary authority tends to moderate the pressure towards depreciation through an increase in interest rates which aggravates the recession”, (Ros, 2015).

remains constant in the long-run, but it can increase to 1.5, and decrease to 0.5, due to shocks if the Central Banks refrains from intervening in the foreign exchange market. Certainly, the real exchange rate may not fall below 0.5, but the Central Bank may also want avoid increases above 1.2.

Thus, an asymmetric monetary or exchange rate policy may not have an effect on the level of the long-run real exchange rate, but it may affect its short-run behavior or other moments of its distribution, like the variance of the skewness, and it can constraint the limit the adaptation of sectorial production and consumption to different shocks. Moreover, even if the long-run real exchange rate does not change (it remains 1 as in our example), an asymmetric policy may imply that the real exchange is more appreciated on average during a given span of time. If the tradable sector holds debt, then the unfavorable shocks increase its financial fragility, while the favorable shocks are not enough to compensate for the bad times. Thus, the tradable sector is hurt, in the sense that a different monetary and exchange rate policy will provide a higher relative price of tradable goods “on average”.

The presence of asymmetries on monetary policy rules have been tested. Authors such as Barros-Campello et. al. (2016) have estimated asymmetric monetary policy rules using GMM for the European case. They find that the European Central Bank monetary policy is more sensible to changes in the output-gap when output is below the trend than when output is above. The authors also argue that their findings are not consistent with other explanations, such as non-linearities in the Phillips curve. Surico (2003, 2007) obtains similar results, and Dolado et. al. (2005) also find that the European Central Bank conducts an asymmetric policy, but with respect to changes in inflation and not with respect to changes in output.

The leitmotiv of this paper is the potentially existence of this type bias, but in the Latin-American context, and with more emphasis on exchange rate behavior. The next sections will analyze the behavior of the exchange rate in the main Latin-American countries using Inflation Targeting during the last 15 years.⁹ The main questions are the following: are authors such as Barbosa-Filho (2015) and Ros (2015) correct? Are monetary and exchange rate policies in Brazil and Mexico (or in general in Latin-American countries using Inflation Targeting) asymmetric?

To tackle the questions, I follow Pontines and Sireger (2012) approach and I estimate a Panel Smooth Transition Autoregressive Model with three regimes (and two transition thresholds), and a Markov Switching model. These two models will estimate the upper and the lower bound of an exchange rate band, and the transition probabilities for different “regimes” (appreciations and depreciations), respectively, for the rate of change of the exchange rate. This is a simple way to test whether monetary and exchange rate policy

⁹The largest countries from the region have adopted Inflation Targeting, including Brazil (1999), Chile (1991), Colombia (1999), Mexico (2002) and Peru (2003).

in Latin-American countries using Inflation Targeting was in fact asymmetric, and whether there is “fear of floating” or “fear of depreciation” (or neither of both). As far as I know, this paper is the first to apply the models used by Pontines and Sireger (2012) to analyze East Asian cases, to the Latin-American countries.

In my view, Pontines and Sireger (2012) do not correctly identify the origin of the observed exchange rate behavior, and because it is possible that the exchange rate moves more in one direction due to factors other than monetary and exchange rate policy. Hence, I extend their approach by also estimating a set of reaction function for the reference interest rate and reserve accumulation, to analyze the role of Central Bank policies in shaping the observed exchange rate dynamics.

3 Exchange rate trends and empirical approach

Before presenting the empirical strategy, it is interesting to take a look at the evolution of one variable of interest: the nominal exchange rate. In the recent Latin-American experience, the Central Bank intervention in the foreign exchange market was widespread, as shown for example by Chang (2008). Precisely because the Central Bank can intervene to moderate exchange rate fluctuations, it is interesting to capture the overall pressures on the exchange rate excluding the effect of the sales and purchases of foreign assets due to policy reasons. This requires to remove the effect of the intervention somehow.

A popular method is to also look at the evolution of foreign exchange reserves and the interest rate to create an index of exchange rate pressure. One example is the Exchange Market Pressure Index (EMP), as proposed by Kaminsky et. al. (1998) and Reinhart and Kaminsky (1999). The EMP is calculated as follows:

$$EMP_{i,t} = \frac{\Delta xr_{i,t}}{xr_{i,t}} - \frac{\sigma_e}{\sigma_r} \frac{\Delta reserves_{i,t}}{reserves_{i,t}} + \frac{\sigma_e}{\sigma_{Int}} \Delta rate_{i,t} \quad (1)$$

Where $EMP_{i,t}$ is the Exchange Market Pressure Index,¹⁰ $xr_{i,t}$ is the exchange rate (units of domestic currency per dollar), $reserves_{i,t}$ are gross foreign reserves, $rate_{i,t}$ is the domestic short-term reference rate. The variables σ_{xr} , σ_r , and σ_{Int} are the standard deviations of the rate of devaluation $\frac{\Delta e_{i,t}}{e_{i,t}}$, the rate of growth of foreign reserves $\frac{\Delta reserves_{i,t}}{reserves_{i,t}}$, and the change in the domestic rate $\Delta rate_{i,t}$.

Because the Central Bank can deal with them in different ways (i.e., for instance buying or selling reserves, or changing the interest rate), just looking at the evolution of the nominal exchange rate is not enough. For example, it is perfectly possible to observe no change in the exchange rate, despite the fact that the

¹⁰The subscripts represent country i in period t . I use 24 month rolling averages for the standard deviations. The data frequency is monthly.

Central Bank is increasing the interest rate very aggressively (or selling reserves) to combat pressures towards devaluation. The idea of the EMP index is to capture all the pressures on the exchange rate.

The graphs included in figures 1, 2, 3, 4, and 5 show the EMP index for Brazil, Chile, Colombia, Mexico, and Peru during the 15 years spanning the period 2000-2015. They also display the natural log of the exchange rate (“ln of xr”), so the slope of the line captures the rate of devaluation. The figures clearly show that Latin-American Inflation Targeters experienced significant pressures towards appreciation, but also important pressures towards depreciation. The general trend was appreciation, and that was only reverted recently by abrupt depreciations, but it is also evident that other factors, such as reserve accumulation, played a role by reverting exchange rate pressures, both upwards and downwards. For example, consider the figure 3 during 2012-2015. Most of the time Colombia experienced pressures towards appreciation, but it is evident from the picture that the exchange rate did not appreciate a lot, as it never crossed the lower bound of 7.5 (remember the variable is the natural log of exchange rate).

As shown by Ponties and Sireger (2012), in East Asian countries using, “fear of appreciation” was the rule. Under pressures towards nominal appreciation, the Central Banks intervened more heavily when the exchange rate appreciated than when the exchange rate depreciated. Does this result hold for Latin-American countries as well? Or did the Central Banks intervene mainly in the opposite direction, as argued by Barbosa-Filho and Ros?

In the next subsections I follow the approach of Pontines and Sireger, and I estimate a set of logistic smooth transition auto-regressive models (also known as LSTAR models) and a set of Markov-Switching models, to find out whether exchange rate behavior displayed any signs of asymmetry. Then I expand the results by asking whether Central Bank was responsible for the observed developments, using a set of GMM type reaction functions for monetary policy and reserve accumulation.

The sample (for the non-linear models) spans the period 1999-2015, for Brazil, Chile, Colombia, Mexico, and Peru, the larger Inflation-Targeting countries in Latin-America. But unlike Pontines and Siregar (2012), who use monthly and weekly data for nominal exchange rates, I use daily data instead.¹¹

3.1 LSTAR-2 and Markov-Switching Models

A natural approach to test if Latin-American central banks intervention was biased in one particular direction is to follow the methodology proposed by Pontines and Siregar (2012). They implement a set of LSTAR and

¹¹The data comes from the national Central Banks. Lower frequency data is often the result of the estimation of an average (monthly or yearly), so the lower frequency is presumably better, as the figures are subject to less manipulation, and additional information (i.e., more observations) increase the precision of the estimation.

Markov-Switching model for the nominal exchange rate in East Asian countries that us Inflation Targeting. As far as I know, mine is the first attempt to use the same non-linear econometric models for the Latin-American case. I am certainly not aware of any similar attempt.

The advantage of the procedure suggested by Pontines and Siregar (2012) is that it provides as an output a precise size for both the lower and upper bound for the rate of change of the nominal exchange rate. In other words, a de facto exchange rate band is estimated.

More precisely, Pontines and Siregar (2012) implemented a LSTAR model to test for the presence of asymmetric bands for intervention in East Asian countries.¹² The basic model has the following form:

$$\Delta \ln(xr_t) = \alpha_0 + \sum_{i=1}^p \alpha_i [\Delta \ln(xr_{t-i})] + \{\beta_0 + \sum_{i=1}^p \beta_i [\Delta \ln(xr_{t-i})]\} F[(\Delta \ln(xr_{t-d}))] + \epsilon_t \quad (2)$$

The variable of the interest is the log of the nominal exchange rate $\ln(xr_t)$. In the equation (2), α_0 is the intercept, α_i (with $i = 1, \dots, p$), stands for the autoregressive parameters, β_0 is the nonlinear intercept term, β_i (with $i = 1, \dots, p$) represents the nonlinear auto-regressive parameters, and F is the transition function which characterizes the smooth transition dynamics between two regimes. The function F depends on the lagged term of the first difference of the log of the nominal exchange rate, $\Delta \ln(xr_{t-d})$, where d is the delay lag length. Finally ϵ_t is a white noise with zero mean and constant variance.

The F function may adopt different forms. A natural starting point is the two-regime LSTAR-1 model with the following general logistic transition function, which takes values in the interval between zero and one:

$$F = \frac{1}{1 + e^{-\{\gamma[\ln(xr_{t-d}) - c]\}}} \quad (3)$$

Where $\gamma > 0$ is the slope parameter (which measures the speed of transition between regimes), c is the threshold parameter (which indicates the location of the transition) and $\ln(xr_{t-d})$ is the transition variable with the associated delay parameter d . As in Pontines and Siregar's paper, $\ln(xr_{t-d})$ represents the lagged change in the natural of log of the exchange rate. Notice that if γ approaches zero the model is linear, while if γ approaches infinity the model becomes a two regime model. In the intermediate case, the transition between the two regimes is "smooth" (hence the name of the model). The farther away the system is outside the band, the strong the effect of the non-linear part of the model. And the larger is γ , the larger the difference between regimes.

¹²See Terasvirta and Anderson (1992) and van Dijk et. al. (2002), for a discussion of the more general family of smooth transition autoregressive models.

It turns out that a variant of the LSTAR-1 model is well-suited to test whether the Central Banks exhibits aversion to appreciations or depreciations. In particular, one can resort to the LSTAR-2 model suggested in Terasvirta (1998):

$$F = \frac{1}{1 + e^{-\{\gamma[\ln(xr_{t-d}) - c_L][\ln(xr_{t-d}) - c_H]\}}} \quad (4)$$

The main difference is that LSTAR-2 includes two transition parameters c_L , and c_H , for the lower and upper threshold. These threshold parameters capture the switching points between regimes, and hence their absolute size measure the relative tolerance of monetary authorities to exchange rate variations, as they capture they rates of change of the exchange rate at witch there is a change in the exchange rate behavior. Using equation 4 I can estimate a de facto exchange rate band.

Pontines and Siregar (2012) find that $|c_L| < |c_H|$ so East Asian central banks have an aversion to appreciations. This means that for East Asian countries, the authorities tolerated larger depreciations than appreciations. For example, if the upper bound is 6% and the lower bound is -2% , this means that there is a regime switch when the exchange rate moves up by 6% or down by 2%, triggering a reaction by the central bank which tends to move the exchange rate in the opposite direction (or at least to keep it constant).

Notice that the way the model is specified does not constraint the level of the nominal exchange rate. The exchange rate may appreciate by more in countries where $|c_L| < |c_H|$ than in countries where $|c_L| > |c_H|$. For example the nominal exchange rate may appreciate by 1% on a more or less permanent basis on a country with $c_L = -2\%$ and $c_L = 2\%$, and it may depreciate by 0.5% on a more or less daily basis if $c_L = -3\%$ and $c_L = 1\%$.¹³

Pontines and Siregar supplement their finding using a Markov-Switching model, to test whether the exchange rates were more likely to remain in the “upper” regime (given that they were already there) than to remain in the “lower” regime (also given that they were already there). These regimes can represent depreciations and appreciations, respectively.¹⁴ The Markov-Switching model has the following form:

$$\Delta \ln(xr_t) = \alpha_0(s) + \sum_{i=1}^p \alpha_i(s) [\Delta \ln(xr_{t-i})] + \epsilon_t(s) \quad (5)$$

It is assumed that the regime variable s follows an irreducible ergodic two-regime Markov process with the

¹³Keep in mind that the data shows persistent trends in the nominal (and also the real) exchange rates. See the evolution of the (natural log of) the nominal exchange rates in figures 1, 2, 3, 4, and 5.

¹⁴But that may not be the case. It is possible that the upper regime represents “depreciation” and the lower regime “less depreciation”. However, most of the time in the five Latin-American cases the results from the Markov-Switching model suggest a mean rate of change that does not fit this problematic scheme.

following transition matrix P:

$$P = \begin{vmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{vmatrix} \quad (6)$$

Where the terms p denote the transitions probabilities. Thus, p_{11} is the probability that the rate of change of the exchange rate remains in the regime 1, given that the exchange rate was in regime 1 in the previous period, while p_{12} is the that the rate of change of the exchange rate will move to the regime 2, given that it was in regime 1 in the previous period, and so on.

Although Pontines and Siregar argue that their models capture mainly the motivations of the Central Banks in East Asia, it is possible that the observed behavior of the exchange rate is due to something else. Nevertheless, the estimations of the de facto bands and the average duration of each regime provide important information regarding the nature of the pressures that each Central Bank face. On the section 3.3 I deal with the problem.

3.2 Empirical Results

Now I am ready to implement the LSTAR-2 and the Markov Switching models discussed previously. The first step is to select the lag length for the models. I inspect the Akaike Information Criteria (AIC) and the Bayesian Information Criteria (BIC), although I choose the model with the lowest AIC value. As argued by Teravista (1998), using the BIC (which penalizes large models) often results in residuals with poor properties (i.e., serial correlation may remain in the residuals) and on the incorrect acceptance of the non-linear model (if a non-linearity test is implemented), among other problems. The AIC suggest that large auto-regressive models, between 7 and 19 lags, are preferred. More precisely, the criteria suggest to adopt an AR(16) for Brazil, an AR(7) for Chile, an AR(15) for Colombia, an AR(17) for Mexico, and an AR(19) for Peru. They may seem too large, but a large model is better than a bad model.

To determine the correct model from the STAR family, a non-linearity test could be implemented.¹⁵ Alternatively, and following the literature, a particular model is implemented and later validated by the

¹⁵Testing non-linearity requires taking a second order approximation around $\gamma = 0$ (that is, assuming a linear model) to estimate the following equation:

$$\Delta \ln(xr_t) = \alpha_0^* + \sum_{i=1}^p \alpha_i^* [\Delta \ln(xr_{t-i})] + \sum_{i=1}^X \sum_{i=1}^p \beta_i^* [\Delta \ln(xr_{t-i}) \Delta \ln(xr_{t-d})^X] + \epsilon_t \quad (7)$$

Where $X = 2, 3, 4$. In a nutshell, I should estimate an auto-regressive model of order p , with interaction terms that multiply each lag by the lag d (the lag decay length), by d^2 , d^3 , and d^4 . Linearity requires to accept the null that all the interaction terms are statistically not different from zero. An LSTAR model is chosen if we can reject the null that the terms multiplied by d^3 , and d^4 are not statistically significant, and that d and d^2 are statistically significant. Finally, if I jointly reject the null that all the interaction terms are significantly different from zero, I should specify an LSTAR-2.

data (see Teravista 1998). I follow this approach here, and I adopt a three regime logistic model (an LSTAR-2) because it fits my needs better, by allowing me to estimate a system of de facto exchange rate bands.¹⁶ To choose the lag-decay length, I pick the one that fits the data better. Thus, I choose different values for d , from 1 to 12, I estimate the full set of models, and I pick the model with the largest F value.

Table 2 shows a summary of the result of the estimation of the LSTAR-2 models. I skip most of the autoregressive coefficients, but they are available on the tables 4 and 5. All the residuals pass the Portmanteau test for white noise (using 4, 8, and 12 lags) except for Mexico. For that country the residuals do not pass the heteroscedasticity test, but the estimations use robust standard errors to correct this. Table 2 also presents the ratio of variance of the residuals of the LSTAR-2 models to the variance of the residuals of the linear models. In all cases the residual variances are lower for the non-linear model, suggesting that using the non-linear model is a good idea.

We can verify that for most countries, the upper threshold is larger in absolute value than the lower threshold, except for the case of Peru. However, for Chile and Colombia the difference is very small, while for Brazil and Mexico the difference is large. While for the case of Brazil the upper threshold is 1.75%, for the lower threshold the number is -3.81% (see the column “Brazil”), and for the Mexican case the figures are 1.84% and -2.27%, respectively (see the column “Mexico”). Notice that these are daily rates of changes, so even the smaller numbers are very important figures.¹⁷

As a general rule, all the thresholds are statistically significant, except for the upper threshold in the estimation for Mexico. In the worst case scenario, this suggests that Mexican rate of change of the exchange rate is not clearly bounded from below. It is interesting to notice that the speed of adjustment are very large for Chile and Colombia, suggesting an abrupt transition from the regimes outside the bands to the regime inside them. In the case of Brazil, Mexico, and Peru, the transition is much more smooth (see the rows “Speed of Adjustment”). Thus, the exchange rate seems to revert to the central part of the band faster in Chile and Colombia than in Brazil, Mexico, and Peru.

Table 3 shows a summary of result from the estimation of the Markov-Switching models. The full list of coefficient is reported on tables 6 and 7. Once again, except for the case Mexico, all the residuals pass the Portmanteau test for white noise (using 4, 8, and 12 lags), although they are heteroscedastic. But once again, the inclusion of robust standard errors come to the rescue.

Our main interest lies in the transition probabilities. The rows “Transition PB” on the table 3 displays the

¹⁶Results from the non-linearity test suggest that the LSTAR-2 model should be preferred for Brazil, Chile and Colombia, but not necessarily for Mexico and Peru (see table 1).

¹⁷For example, a 1% daily rate of devaluation, considering 250 trading days a year (just to pick a reasonable number) implies an annual rate of increase of the exchange rate of about 1,200%!

probabilities that there is a change in the regime. Both the lower and the upper regime are very persistent, but as a general rule, the lower regime is much more persistent, perhaps with the sole exception of Peru.

It is easier to understand what is going on if we take a look at the number of periods (in our case, days) that are associated with each transition probability. These figures are displayed in the rows “Expected Duration” (also from table 3). Notice that Brazil, Chile and Mexico display appreciations that last for very long periods of time (37, 33, and 64 days). Comparing this number with the duration of depreciations, we can verify that appreciation last more than three times more than depreciations (for Brazil and Chile), and more than six times for Mexico. For Colombia, while appreciation last longer than depreciations, the number is lower (22 days vs. 10 days). For Peru, appreciations last only 8-9 days, versus 6 days for depreciations. It is also worth to notice that for all the countries, for the upper regime, the variance of the rate of change of the exchange rate is about 3-4 times larger than for the lower regime, suggesting that appreciations represent a less turbulent scenario than depreciations.

To summarize, combining the results from the LSTAR-2 and the Markov Switching models, I find evidence that that exchange rate behaves asymmetrically mainly in Brazil and Mexico. For these cases, the lower threshold is larger in absolute value than the upper threshold. Moreover, the transition between regimes seems to be smoother than in Chile and Colombia (but not than in Peru). Notice this suggest that Brazil and Mexico are different than the other three countries, as suggested by the literature. As a general rule, appreciations seem to last longer than depreciation, and they are also less volatile. For Brazil, Chile, and Mexico, appreciations last at least three times as much as depreciation (but keep in mind that in Chile the exchange rate band looks symmetric and that transition between regimes seems to be less smooth).

3.3 GMM Reaction Functions

The previous sub-section shows that there is some evidence of asymmetric behavior of the exchange rate, at least for Brazil and Mexico, and that appreciations last longer than depreciations, perhaps with the exception of Peru where they last more or less the same. Are monetary or exchange rate policies to be blamed? Or to put the question differently: did the Central Banks deliberately behave in way such that the observed behavior of the exchange rate should be attributed to interest rate targeting or foreign exchange reserves accumulation? Although an answer that accounts for all the observed changes in exchange rates is beyond the scope of the present study, I can analyze if interest rate targeting and reserve accumulation show some sensitivity with respect to exchange rate changes. This is a simply way to test whether market forces or policies account for the findings of section 3.2.

This section estimates a set of reaction functions for Latin-American countries using Inflation Targeting, considering changes in the target interest rate and on the stock of gross foreign exchange reserves.¹⁸

I estimate a set of reaction functions using GMM because of the potential correlation between the error term and the independent variables. Instrument variables for GMM are selected from the observable information sets for the Central Bank. The instruments are the lags, from 2 to 12, of all the dependent variables, plus the natural log of the Federal Funds interest rate. The Newey-West heteroscedasticity and autocorrelation consistent (HAC) covariance matrix is used to eliminate the serial correlation in the error term. More precisely, I estimate the following two equations:

$$\Delta \ln(rate_t) = \beta_0 + \beta_1 \Delta \pi_{t-1} + \beta_2 (Y_{t-1} - \bar{Y}_{t-1}) + \beta_3 \Delta \ln(xr_{t-1}) + u_t \quad (8)$$

$$\Delta \ln(reserves_t) = \beta_0 + \beta_1 \Delta \pi_{t-1} + \beta_2 (Y_{t-1} - \bar{Y}_{t-1}) + \beta_3 \Delta \ln(xr_{t-1}) + u_t \quad (9)$$

Where $\Delta \pi_{t-1}$ is the increase in the rate of inflation, $(Y_{t-1} - \bar{Y}_{t-1})$ is the output gap, and $\Delta \ln(xr_{t-1})$ is the rate of devaluation.¹⁹ The u_t is the error term. All the variables are lagged one period.²⁰ Equations 8 and 9 are the kind of Taylor rules (augmented by the inclusion of the exchange rate changes) that the Central Bank supposedly follow under Inflation Targeting. Because they differ from usual Taylor-Rules, they deserve some comments. The inclusion of the change of interest rates as the dependent variable seems reasonable because the lagged interest rate is highly significant and close to one, and the result will not be affected due to this choice. It is possible to estimate a similar equation with the level of the (log) of the interest rate and the lagged (log) of the interest rate on the right hand side, but I also decide not to estimate such equation because doing so makes the comparison between equations (8) and (9) less appealing and it hardly affects the results.

Notice that the inclusion of the change in the rate of inflation, rather than deviations from the target, may seem strange. Because the definition of “deviation from the target” is not clear, I resort to this simple procedure.²¹ The Appendix B presents results using the month-by-month deviation from the target (using

¹⁸Due to data limitations, the samples do not always coincide, and I use monthly data. Our sample includes, Brazil (April of 2000-July of 2015), Chile (January of 1999-January of 2014), Colombia (January of 1999-October of 2005), Mexico (February of 2009-July of 2015), and Peru (October of 2004-May of 2014).

¹⁹The output gap is defined as the deviation of monthly output from the HP trend, the inflation-gap is the difference between the annualized rate of CPI inflation and the target, and the reserves are the gross reserves. The interest rates are the central bank short-term interest rate (that explain why the sample is usually shorter for Mexico and Peru, which did not target an interest rate until 2002/2003). All the “rates” are defined as percentage points. Thus, a 5% inflation rate is 5, not 0,05. A 1% interest rate is not 0,01 (nor 1,01), but 1.

²⁰The results hold if I use contemporaneous values and I add the first lag to the set of instruments.

²¹For example, should I use the deviation of the annualized rate of inflation from the annual target, the deviation of the accumulated inflation in the year from a target, or the deviation of the monthly inflation from a monthly target? For the target inflation, and considering that most Central Banks use a band for the target rather than a single number, should I consider the

the mean of the target). These additional estimation show that the gist of the results will not change by the inclusion of alternative definitions of the inflation-gap.

Finally, it may worth to consider that policy makers may react to changes in exchange rates by imposing capital controls, so our equations (8) and (9) may not capture the entire story. Implementing a similar equation with a measure of capital controls (or capital account openness) as the dependent variable is not plausible due to data limitations (most data set have yearly frequency), and the account of the most recent experience of Latin-American Inflation Targeting countries suggest that capital controls were not the main tool (see Chang, 2008). The five countries analyzed in this paper never departed from the “rules of the game” (keep the capital account relatively open, intervene occasionally in the foreign exchange market, and so on), with exceptions. In particular Brazil during the period 2002-2003 resorted to drastic measures, such as increasing the upper bound for the Inflation Targeting when facing large exchange rate depreciation that triggered an acceleration of inflation. Even before and during the Presidency of the “left-wing” Lula da Silva capital controls were softened.²² Thus, capital account regulation was not the main tool used to combat exchange rate pressures, and the experience suggest a long-run trend towards deregulation (at least until 2009-2010), but very little day-to-day adjustments.

The first set of results analyze the data as if monetary and exchange rate policies were symmetric. Tables 8 and 9 show the results for interest rates and reserves under the assumption of symmetry. Notice that all the model pass the Hansen’s misspecification test.²³ The main interest lies in the coefficient associated with the rate of devaluation, β_3 . Notice that they are only significant for the reserve accumulation equations, except for the case of Chile, where β_3 is not significantly different from zero in both cases. Moreover, the signs are negative, suggesting that when the exchange rate depreciates, reserves fall, while when the exchange rate appreciates, reserves increase.

To check for the presence of asymmetries more explicitly, I re-estimate the reaction function introducing a different variable for appreciations and depreciations. Now I estimate:

$$\Delta \ln(rate_t) = \beta_0 + \beta_1 \Delta \pi_{t-1} + \beta_2 (Y_{t-1} - \bar{Y}_{t-1}) + \beta_3 APP_{t-1} + \beta_4 DEP_{t-1} + u_t \quad (10)$$

$$\Delta \ln(reserves_t) = \beta_0 + \beta_1 \Delta \pi_{t-1} + \beta_2 (Y_{t-1} - \bar{Y}_{t-1}) + \beta_3 APP_{t-1} + \beta_4 DEP_{t-1} + u_t \quad (11)$$

The most interesting variables are APP_{t-1} and DEP_{t-1} . They represent variables that are equal to one mean, the upper bound, or the lower bound?

²²The presidential campaign of Lula was precisely the source of uncertainty that triggered capital outflows during the period 2002-2003.

²³That means that I cannot reject the null that the models are correctly specified.

when the exchange rate appreciates and zero otherwise, and equal to one when the exchange rate depreciates and zero otherwise, respectively (notice they are not dummy variables). The rest of the variables are defined as before. If monetary or exchange rate policy are asymmetric, then I should find that $\beta_3 = 0$ and $\beta_4 < 0$, or at least that $|\beta_3| < |\beta_4|$.

The tables 10 and 11 contain the results. Once again, all the models pass the Hansen's misspecification test. Consider the interest rate reaction function. We can see in table 10 that except for Brazil and Mexico, exchange rate movements are not significant. For Mexico, the coefficients are significant, but the signs are wrong (appreciations trigger an increase in the interest rate, while depreciations trigger a decrease), and for Brazil only depreciations affect interest rates. This suggest that interest rates do not usually react to exchange rate changes. This is not surprising at all: the interest rates used to conduct monetary policy are hardly changed as a much as the exchange rate, and one should not expect a Central Bank that targets inflation to worry about all exchange rate changes.

Consider now the behavior of reserves in table 11. We can find a very different picture here. The constant term is highly significant and positive, consistent with the large accumulation of foreign exchange reserves. More important for my purposes, we can also see that depreciations seems to reduce reserve accumulation, and the results are significant except for Chile. In other words, when the exchange rate goes up, the Central Bank losses reserves. This is interesting because it suggest that the symmetric exchange rate band observed in section 3.2 is not necessarily related to Central Bank policies (including both reserve accumulation and interest rate management) in all the countries. At least Chile seems to be an exceptional case.²⁴

The Central Bank of Peru (a highly dollarized economy) seems to be the most averse country, closely followed by Brazil. Only in Mexico appreciations are significant, but the size of the effect is small. This suggest that reserve accumulation was significantly affected by currency depreciations, but not by appreciations.

To summarize, the estimation of reaction functions suggest that intervention in the foreign exchange market, except for a constant trend of reserve accumulation, was focused mainly on preventing depreciations.

This behavior seems to explain the asymmetric behavior of the exchange rate, in particular for Brazil and

²⁴Perhaps the large Economic and Stabilization Fund is responsible for the observed exchange rate behavior. But according to the official statement the Fund has no explicit role in the foreign exchange market: "The Economic and Social Stabilization Fund (ESSF) was established on March 6th, 2007 with an initial contribution of US\$ 2.58 billion, much of which (US\$ 2.56 billion) was derived from the old Copper Stabilization Fund, which was replaced by the ESSF. The Economic and Social Stabilization Fund allows financing of fiscal deficits and amortization of public debt. Thus, the ESSF provides fiscal spending stabilization since it reduces its dependency on global business cycles and revenue's volatility derived from fluctuations of copper price and other sources. For example, budget reductions originated from economic downturns can be financed in part with resources from the ESSF, reducing the need for issuing debt. According to the Fiscal Responsibility Law, the ESSF receives each year the positive balance resulting from the difference between the effective fiscal surplus and the contributions to the Pension Reserve Fund and to the Central Bank of Chile, discounting the payment of public debt and advances made the year before." (source <http://www.hacienda.cl/english/sovereign-wealth-funds/economic-and-social-stabilization-fund.html>)

Mexico. Interestingly, the Chilean Central Bank does not seem to care about the nature of the exchange rate fluctuations. This is consistent with the informal observation that Chile has the most flexible regime in the region. Although the estimations bounds the change of the exchange rate between -0.3% and 0.3% , suggesting the presence of a symmetric band, I could not find evidence that Central Bank policies are responsible for the observed evolution of the exchange rate: neither depreciations nor appreciations seems to trigger a change in the policy interest rate or reserves.

4 Conclusions

This paper analyzed the potential presence of asymmetries in the behavior of the exchange rate, for a group of Latin-American countries that adopted Inflation Targeting. Using daily data for the period 1999-2015, I implement a set of LSTAR-2 models to estimate the threshold for the changes in the exchange rate, and I find evidence that the lower threshold is larger in absolute value than the upper threshold, at least for Brazil and Mexico, and that transition between regimes is smoother in these countries and in Peru than in Chile and Colombia.

I then proceed to implement a set of Markov-Switching models that highlights that appreciation usually last longer than depreciation, and they are less volatile. Moreover, Brazil, Chile, and Mexico show very long lasting appreciations (more than 30 trading days, about a month and half).

I extended the results to analyze the role of policy. Using a set of GMM equations, I estimate reaction functions for interest rates and reserve accumulation (using monthly data). I find that the observed asymmetric behavior of the exchange rate can be attributed (at least partially) to reserve accumulation, but not to interest rate policies. Interestingly, this result does not hold for Chile, consistent with the informal observation that this is the only country in Latin-America that is willing to tolerate larger fluctuations in the exchange rate in any direction.

The evidence that I was able to gather suggest that there is “fear of floating” in Latin-American countries using Inflation Targeting, with the exception of Chile, and that this behavior seems to be more pronounced for Brazil and Mexico. More precisely, in these two countries appreciations last longer than depreciations, the exchange rate band has a larger lower threshold, the transition between regimes is very smooth, and the Central Banks intervene mainly via sales of foreign exchange reserves when the exchange rate depreciates. This evidence is consistent with Barbosa-Filho (2015) and Ros (2015), and it contrast with the work of Pontines and Siregar (2012), who find that East Asian countries using Inflation Targeting display “fear of

floating in reverse” or “fear of appreciation”.²⁵

²⁵I am not aware of other author that have claimed a similar thing for the other three countries of my sample.

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Tables and Figures

Table 1: Lagrange Multiplier “LM” Non-Linearity Tests

	Brazil	Chile	Colombia	Mexico	Peru
Lag Decay Length	3	11	7	4	1
	Linear Model Nested in LSTAR				
<i>LM</i>	376.6835***	-1307.7203	93.2464***	110.0916***	-463.2886
	Linear Model Nested in LSTAR-2				
<i>LM</i>	578.9817***	-920.5965	144.6916***	214.9019***	-316.8815
	LSTAR model Nested in LSTAR-2				
<i>LM</i>	221.0704***	298.9841***	52.5499 ***	107.4777***	132.5625***
*** p<0.01, ** p<0.05, * p<0.1					

Table 2: LSTAR-2 Model

	Brazil	Chile	Colombia	Mexico	Peru
Lower Threshold	-3.8055*** (0.0537)	-0.3110*** (1.8850)	-0.3459*** (0.0021)	-2.2718*** (0.0026)	-1.1031*** (0.0842)
Upper Threshold	1.7507*** (0.0873)	0.3008*** (0.0026)	0.2055*** (0.0017)	1.8378 (.)	1.4677*** (0.0986)
Speed of Adjustment	4.3972 (7.0863)	7577.5060 (80147.43)	9327.3200 (59160.59)	86.6119 (.)	12.9158** (6.0913)
Linear σ^2	0.4137	0.1802	0.1727	0.1364	0.0453
Non-Linear σ^2	0.3457	0.1780	0.1697	0.1525	0.0421
Ratio	0.8354	0.9878	0.9827	0.8947	0.9299
Observations	4436	4436	4436	4436	4436
R-Squared	0.467	0.2187	0.2839	0.3837	0.1932

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3: Markov-Switching Model

	Brazil	Chile	Colombia	Mexico	Peru
	Lower Regime				
Transition Pb	0.9733 (0.0048)	0.9696 (0.0065)	0.9552 (0.0073)	0.9846 (0.0047)	0.8832 (0.0146)
Expected Duration	37.4223 (6.7705)	32.9040 (7.0379)	22.3039 (3.6313)	64.9711 (19.9761)	8.5613 (1.0669)
Variance	0.3557	0.2575	0.2091	0.2545	0.0725
	Upper Regime				
Transition Pb	0.8983 (0.0222)	0.9057 (0.0264)	0.8964 (0.0167)	0.9148 (0.0219)	0.8431 (0.0235)
Expected Duration	9.8320 (2.1457)	10.6001 (2.9759)	9.6509 (1.5544)	11.7398 (3.0161)	6.3725 (0.9558)
Variance	1.2112	0.7201	0.6836	0.7099	0.3128

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4: LSTAR-2 Model Linear Part (Full List of Coefficients)

	Brazil	Chile	Colombia	Mexico	Peru
Constant	0.0138 (0.0086)	0.0102 (0.0081)	-0.0035 (0.0072)	0.0081 (0.0051)	0.0010 (0.0031)
L1	0.6507*** (0.0221)	0.4782*** (0.0211)	0.6060*** (0.0487)	0.7162*** (0.0333)	0.4320*** (0.0269)
L2	-0.3646*** (0.0406)	-0.1516*** (0.0230)	-0.2983*** (0.0543)	-0.4088*** (0.0578)	-0.2435*** (0.0226)
L3	0.2304*** (0.0356)	0.1232*** (0.0234)	0.1302** (0.0517)	0.2344*** (0.0369)	0.1416*** (0.0206)
L4	-0.1512*** (0.0346)	-0.0001 (0.0239)	-0.0573 (0.046)	0.2310*** (0.0442)	-0.0448** (0.0193)
L5	0.0739** (0.0340)	0.0080 (0.0243)	-0.0023 (0.0391)	-0.0345 (0.0441)	0.0745*** (0.0198)
L6	-0.0357 (0.0339)	-0.0211 (0.0233)	0.0098 (0.0294)	0.0466 (0.0443)	-0.0401** (0.0196)
L7	0.0082 (0.0312)	0.0414** (0.0211)	-0.0230 (0.0577)	-0.0112 (0.0273)	0.0266 (0.0233)
L8	0.0244 (0.0300)		0.0572* (0.0327)	0.0568* (0.0323)	-0.0247 (0.0298)
L9	-0.0095 (0.0289)		-0.0088 (0.0336)	-0.0711** (0.0307)	0.0071 (0.0222)
L10	0.0630* (0.0353)		0.0258 (0.0317)	0.0609** (0.0281)	-0.0285 (0.0231)
L11	-0.0605* (0.0295)		-0.0170 (0.0265)	-0.070 (0.064)	0.0283 (0.0216)
L12	0.0722 (0.0281)		0.0081 (0.0313)	0.237** (0.109)	0.0111 (0.0181)
L13	0.0026 (0.0239)		0.0083 (0.0267)	-0.0205 (0.0191)	-0.0113 (0.0180)
L14	0.0073 (0.0247)		-0.0021 (0.0244)	-0.3260 (.)	-0.0050 (0.0187)
L15	-0.0110 (0.0292)		-0.0098 (0.0218)	-0.0341* (0.0199)	0.0278 (0.0185)
L16	0.0489* (0.0227)			0.0406* (0.0204)	-0.0282 (0.0197)
L17				-0.0516*** (0.0190)	0.0155 (0.0188)
L18					0.0210 (0.0168)
L19					0.0457*** (0.0167)
Observations	4436	4436	4436	4436	4436
R-Squared	0.3364	0.2187	0.2839	0.3837	0.1932

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 5: LSTAR-2 Model Non-Linear Part (Full List of Coefficients)

	Brazil	Chile	Colombia	Mexico	Peru
Constant	-0.4875 (0.3767)	-0.0104 (0.0130)	0.0289** (0.0134)	-7.6688*** (0.0051)	-1.5227 (4.5099)
L1	0.0315 (0.1204)	0.0593* (0.0300)	-0.0105 (0.0667)	1.3603*** (0.0333)	-24.1173*** (7.2930)
L2	0.0735 (0.1521)	-0.1954*** (0.0338)	0.0614 (0.0782)	0.3593*** (0.0578)	-24.6934** (11.6151)
L3	-0.1411 (0.1798)	0.0390 (0.0345)	0.0175 (0.0708)	1.4989*** (0.0369)	34.6984** (17.7269)
L4	0.4407** (0.1837)	-0.1176*** (0.0346)	-0.0065 (0.0582)	35.2727 (.)	64.3030*** (12.8336)
L5	-0.4209** (0.1640)	0.0647* (0.0344)	0.0643 (0.0513)	-0.1131*** (0.0441)	-118.7485 (114.5918)
L6	0.3677** (0.1759)	-0.0464 (0.0337)	-0.0668 (0.0442)	1.8344*** (0.0443)	230.3089*** (72.6696)
L7	0.2302 (0.2400)	-0.0221 (0.0299)	0.0577 (0.0640)	-2.7652*** (0.0273)	292.2510** (132.5638)
L8	-0.3729* (0.2138)		-0.1102** (0.0442)	4.3374*** (0.0323)	-213.6767** (101.1127)
L9	0.2776 (0.2710)		0.0275 (0.0442)	1.4860*** (0.0307)	82.4195*** (30.0557)
L10	-0.1285 (0.2183)		-0.0354 (0.0440)	1.9861*** (0.0281)	327.6850*** (23.8769)
L11	-0.1410 (0.2094)		0.1161*** (0.0441)	-0.8618*** (0.0238)	-342.5000 (.)
L12	0.0047 (0.2770)		0.0775* (0.0449)	-0.8647*** (0.0225)	-94.8187*** (33.5089)
L13	-0.1530 (0.1488)		0.0229 (0.0431)	-0.1036*** (0.0191)	-22.3516 (15.7596)
L14	-0.3481* (0.2018)		0.0289 (0.0422)	-38.3190*** (0.0527)	-175.8334*** (19.3134)
L15	0.3320 (0.2402)		0.0554 (0.0384)	2.9429*** (0.0199)	57.7587*** (19.8360)
L16	0.1184 (0.2223)			-0.1400*** (0.0204)	295.1587*** (97.2449)
L17				-2.6107*** (0.0190)	226.1584*** (38.7235)
L18					314.4840*** (39.2204)
L19					-327.6949*** (57.8781)
Observations	4436	4436	4436	4436	4436
R-Squared	0.3364	0.2187	0.2839	0.3837	0.1932

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 6: Markov-Switching Model Lower Regime (Full List of Coefficients)

	Brazil	Chile	Colombia	Mexico	Peru
Constant	-0.0082 (0.0072)	-0.0024 (0.0049)	0.0005 (0.0043)	-0.0089* (0.0050)	-0.0028 (0.0021)
L1	0.7090*** (0.0228)	0.6747*** (0.0222)	0.6328*** (0.0238)	0.6733*** (0.0227)	0.4438*** (0.0339)
L2	-0.4306*** (0.0268)	-0.3755*** (0.0241)	-0.3356*** (0.0264)	-0.4201*** (0.0231)	-0.3173*** (0.0168)
L3	0.2351*** (0.0254)	0.2302*** (0.0236)	0.2174** (0.0263)	0.2404 (0.0262)	0.1584*** (0.0191)
L4	-0.1555*** (0.0240)	-0.1351** (0.0240)	-0.0903 (0.0249)	-0.1640*** (0.0267)	-0.1033*** (0.0136)
L5	0.0896** (0.0233)	0.0755*** (0.0220)	0.0786*** (0.0232)	0.0993 (0.0261)	0.0590*** (0.0168)
L6	-0.0248 (0.0262)	-0.0359 (0.0232)	-0.0352* (0.0206)	-0.0877 (0.0228)	-0.0416** (0.0168)
L7	0.1023 (0.052)	0.0062 (0.0216)	0.0378 (0.0208)	0.0452 (0.0224)	0.0495*** (0.0158)
L8	0.0146 (0.0264)		-0.0306 (0.0198)	-0.0208 (0.0217)	-0.0158 (0.0153)
L9	-0.0108 (0.0225)		0.0342* (0.0195)	-0.0089 (0.0226)	0.0232 (0.0149)
L10	0.0371* (0.0218)		0.0283 (0.0177)	0.0057 (0.0233)	-0.0420* (0.0192)
L11	-0.0475* (0.0228)		0.0261 (0.0188)	-0.064 (0.050)	0.0260 (0.0197)
L12	-0.0529* (0.0252)		0.0111 (0.0201)	0.017 (0.024)	-0.0124 (0.0155)
L13	-0.0235 (0.0242)		0.0217 (0.0169)	-0.076* (0.046)	0.0311* (0.0160)
L14	0.0547** (0.0216)		0.0116 (0.0196)	0.074 (0.048)	0.0166 (0.0157)
L15	-0.0406* (0.0240)		0.0138 (0.0174)	-0.068 (0.050)	-0.0294 (0.0202)
L16	0.0310 (0.0208)			0.091 (0.0223)	0.0235 (0.0187)
L17				-0.0070 (0.0189)	-0.0057 (0.0141)
L18					0.0127 0.0152
L19					0.0077 (0.0136)
Variance	0.3557	0.2575	0.2091	0.2545	0.0725
Observations	4436	4436	4436	4436	4436

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Markov-Switching Model Upper Regime (Full List of Coefficients)

	Brazil	Chile	Colombia	Mexico	Peru
Constant	0.1053** (0.0464)	0.0336 (0.0245)	0.0316 (0.0199)	0.1124*** (0.0407)	0.0060 (0.0075)
L1	0.604*** (0.0388)	0.4230*** (0.0471)	0.5862*** (0.0446)	0.6503 *** (0.1028)	0.3427*** (0.0539)
L2	-0.3051*** (0.0645)	-0.1814*** (0.0427)	-0.2396*** (0.0562)	-0.4112*** (0.1246)	-0.1854*** (0.0388)
L3	0.1511* (0.0727)	0.1099** (0.0436)	0.1026* (0.0519)	0.2200* (0.1164)	0.1203*** (0.0325)
L4	-0.0034** (0.0699)	0.0178 (0.0484)	-0.0484 (0.0417)	-0.0898 (0.1033)	-0.0010 (0.0326)
L5	-0.1013 (0.0935)	0.0320 (0.0374)	0.0093 (0.0375)	-0.1465 (0.1012)	0.0800** (0.0319)
L6	0.0511 (0.0784)	-0.0692 (0.0446)	-0.0181 (0.0366)	0.1820* (0.0983)	-0.0437 (0.0322)
L7	0.0031 (0.0886)	0.0562 (0.0631)	-0.0137 (0.0357)	-0.1418* (0.0751)	0.0099 (0.0370)
L8	-0.0253 (0.0700)		0.0050 (0.0378)	0.1269 (0.0883)	-0.0547 (0.0467)
L9	0.0325 (0.0823)		-0.0097 (0.0389)	-0.0424 (0.0956)	0.0248 (0.0406)
L10	0.0320 (0.0858)		-0.0147 (0.0407)	-0.0302 (0.0960)	-0.0365 (0.0383)
L11	-0.0453 (0.0714)		0.0685 (0.0447)	-0.005 (0.249)	0.0330 (0.0374)
L12	0.0402 (0.0931)		-0.0699 (0.0449)	-0.098 (0.151)	0.0167 (0.0320)
L13	0.0261 (0.0638)		0.0188 (0.0435)	0.227 (0.166)	-0.0303 (0.0310)
L14	-0.1086 (0.0892)		0.0176 (0.0415)	-0.167 (0.124)	-0.0194 (0.0311)
L15	0.0503 (0.0720)		0.0263 (0.0383)	-0.111 (0.230)	0.0744** (0.0295)
L16	0.0602 (0.0428)			0.1354*** (0.0516)	-0.0492 (0.0320)
L17				-0.1575*** (0.0485)	0.0211 (0.0332)
L18					0.0220 (0.0302)
L19					0.0575* (0.0308)
Variance	1.2112	0.7201	0.6836	0.7099	0.3128
Observations	4436	4436	4436	4436	4436

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: GMM Estimation of Interest Rate Reaction Functions

$\Delta \ln(\text{Rate})$	Brazil	Chile	Colombia	Mexico	Peru
Constant	-0.0002 (0.0029)	-0.0065** (0.0029)	-0.0083*** (0.0015)	-0.0033* (0.0017)	0.0086*** (0.0023)
Δ Inflation (t-1)	0.2950*** (0.0057)	0.1344*** (0.0400)	0.1779*** (0.0359)	-0.0017 (0.0055)	0.0833*** (0.0230)
Outputgap (t-1)	-0.0003 (0.0008)	0.0008 (0.0009)	0.0008** (0.0003)	0.0011* (0.0006)	0.0022** (0.0007)
$\Delta \ln(\text{XR})$ (t-1)	0.2199** (0.0897)	0.3888** (0.1502)	0.0166 (0.0580)	0.0221 (0.0156)	-0.0521 (0.2546)
Observations	183	147	82	78	103
Hansen's J χ p-value	0.5273	0.2812	0.6157	0.9986	0.8821

Instruments: Lags 2/12 of Output-gap, Δ Inflation,
Domestic and Federal Funds Rates (in logs)

Standard error in parentheses (Newey-West "HAC" Covariance Matrix)

*** p<0.01, ** p<0.05, * p<0.1

Table 9: GMM Estimation of Reserve Accumulation Reaction Functions

$\Delta \ln(\text{Reserves})$	Brazil	Chile	Colombia	Mexico	Peru
Constant	0.0110*** (0.0025)	0.0031 (0.0021)	0.0079*** (0.0011)	0.0110*** (0.0011)	0.0107*** (0.0013)
Δ Inflation (t-1)	-0.0657* (0.0331)	-0.0037 (0.0069)	0.0222 (0.0188)	-0.0138 (0.0106)	-0.0154*** (0.0062)
Outputgap (t-1)	0.0011* (0.0006)	0.0018*** (0.0005)	0.0006*** (0.0001)	0.0014*** (0.0003)	0.0006* (0.0003)
$\Delta \ln(\text{XR})$ (t-1)	-0.2307*** (0.0580)	0.0222 (0.0934)	-0.2303*** (0.0420)	-0.0842** (0.0357)	-0.2428** (0.1194)
Observations	179	147	82	74	103
Hansen's J χ p-value	0.3998	0.5052	0.7820	0.1700	0.6098

Instruments: Lags 2/12 of Output-gap, Δ Inflation,

Domestic and Federal Funds Rates (in logs)

Standard error in parentheses (Newey-West "HAC" Covariance Matrix)

*** p<0.01, ** p<0.05, * p<0.1

Table 10: GMM Estimation of Interest Rate Reaction Functions

$\Delta \ln(\text{Rate})$	Brazil	Chile	Colombia	Mexico	Peru
Constant	-0.0013 (0.0043)	-0.0065 (0.0060)	-0.0116*** (0.0033)	-0.0017* (0.0010)	0.0125** (0.0042)
Δ Inflation (t-1)	0.2949*** (0.0403)	0.1344*** (0.0422)	0.1806*** (0.0391)	-0.0109 (0.0092)	0.0788*** (0.0227)
Outputgap (t-1)	-0.0002 (0.0008)	0.0008 (0.0010)	0.0008** (0.003)	0.0019*** (0.0007)	0.0024*** (0.0007)
Appreciation (t-1)	0.1774 (0.1484)	0.3865 (0.3256)	-0.2248 (0.2249)	0.2531** (0.1050)	0.4560 (0.5695)
Depreciation (t-1)	0.2243* (0.1153)	0.3894 (0.2386)	0.1224 (0.0969)	-0.1301* (0.0615)	-0.3710 (0.3010)
Observations	183	147	82	78	103
Hansen's $J \chi^2$ p-value	0.4992	0.2695	0.6542	0.8652	0.8202

Instruments: Lags 2/12 of Output-gap, Δ Inflation,
Domestic and Federal Funds Rates (in logs)
Standard error in parentheses (Newey-West "HAC" Covariance Matrix)
*** p<0.01, ** p<0.05, * p<0.1

Table 11: GMM Estimation of Reserve Accumulation Reaction Functions

$\Delta \ln(\text{Reserves})$	Brazil	Chile	Colombia	Mexico	Peru
Constant	0.0169*** (0.0040)	0.0043 (0.0044)	0.0079*** (0.0017)	0.0139*** (0.0017)	0.0144*** (0.0017)
Δ Inflation (t-1)	-0.0631* (0.0034)	-0.0040 (0.0050)	0.0235 (0.0194)	-0.0166* (0.0090)	-0.0097* (0.0054)
Outputgap (t-1)	0.0011 (0.0007)	0.0017*** (0.0005)	0.0006*** (0.0002)	0.0013*** (0.0003)	0.0007** (0.0003)
Appreciation (t-1)	0.0034 (0.1337)	0.0705 (0.1750)	-0.2189 (0.1430)	0.0914* (0.0502)	0.0892 (0.1140)
Depreciation (t-1)	-0.3200*** (0.0633)	-0.0089 (0.1716)	-0.2303*** (0.0665)	-0.1707*** (0.0534)	-0.5477*** (0.2045)
Observations	179	147	82	74	103
Hansen's J χ^2 p-value	0.3554	0.5013	0.7376	0.1848	0.5598

Instruments: Lags 2/12 of Output-gap, Δ Inflation,
Domestic and Federal Funds Rates (in logs)
Standard error in parentheses (Newey-West "HAC" Covariance Matrix)
*** p<0.01, ** p<0.05, * p<0.1

Figure 1: EMP and Natural Log of the Nominal Exchange Rate

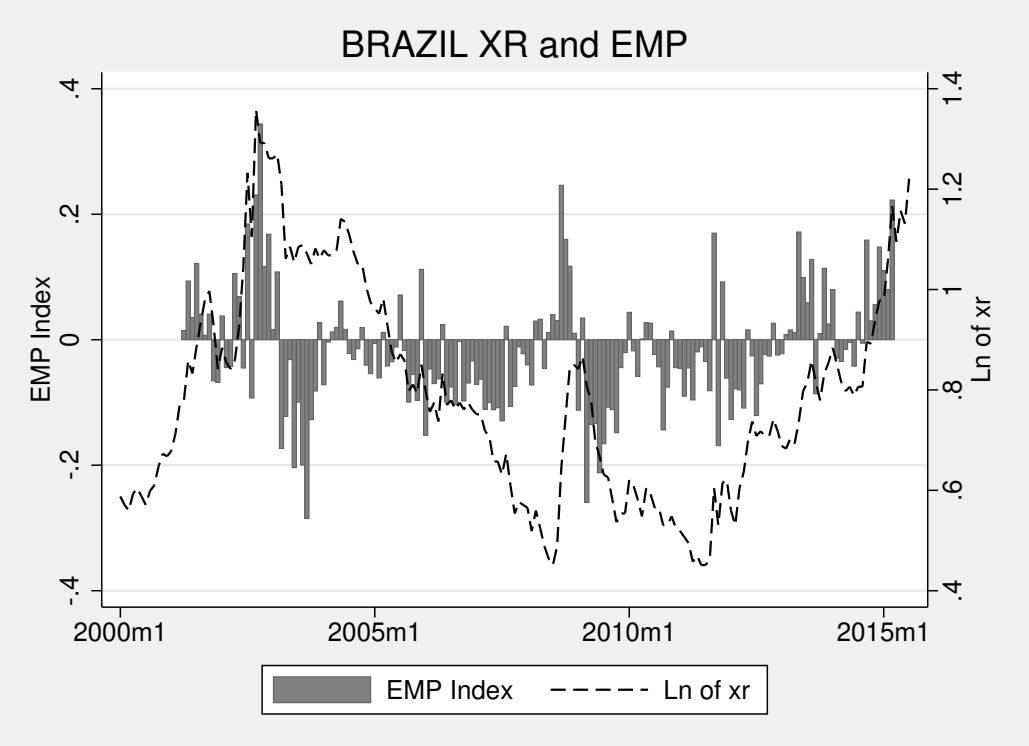


Figure 2: EMP and Natural Log of the Nominal Exchange Rate

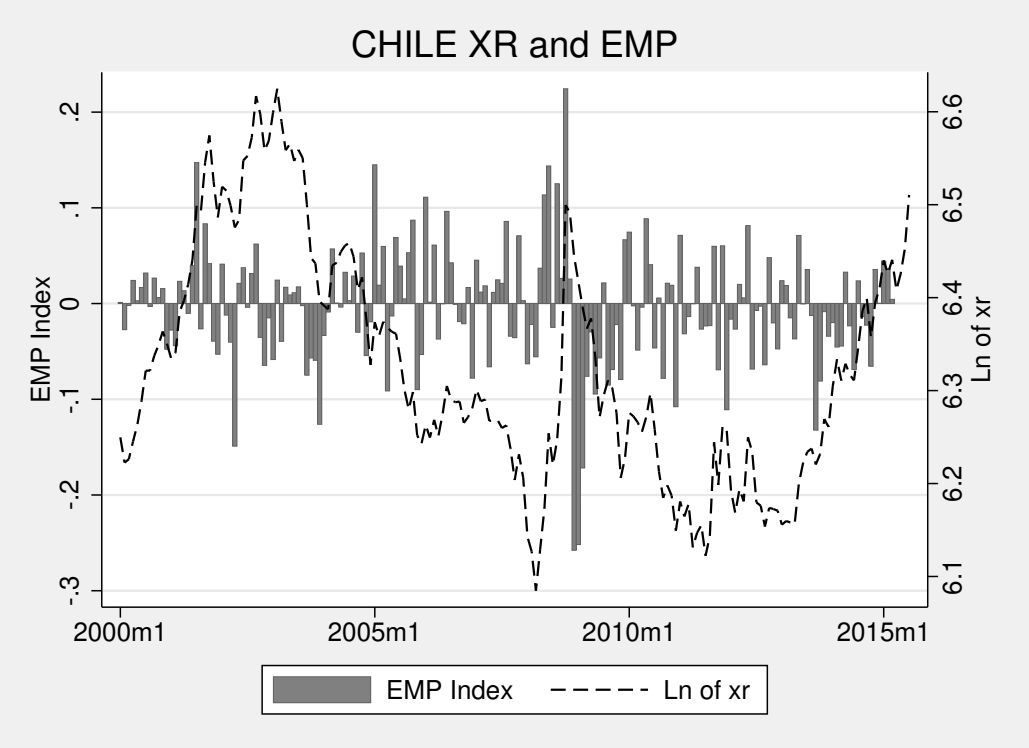


Figure 3: EMP and Natural Log of the Nominal Exchange Rate

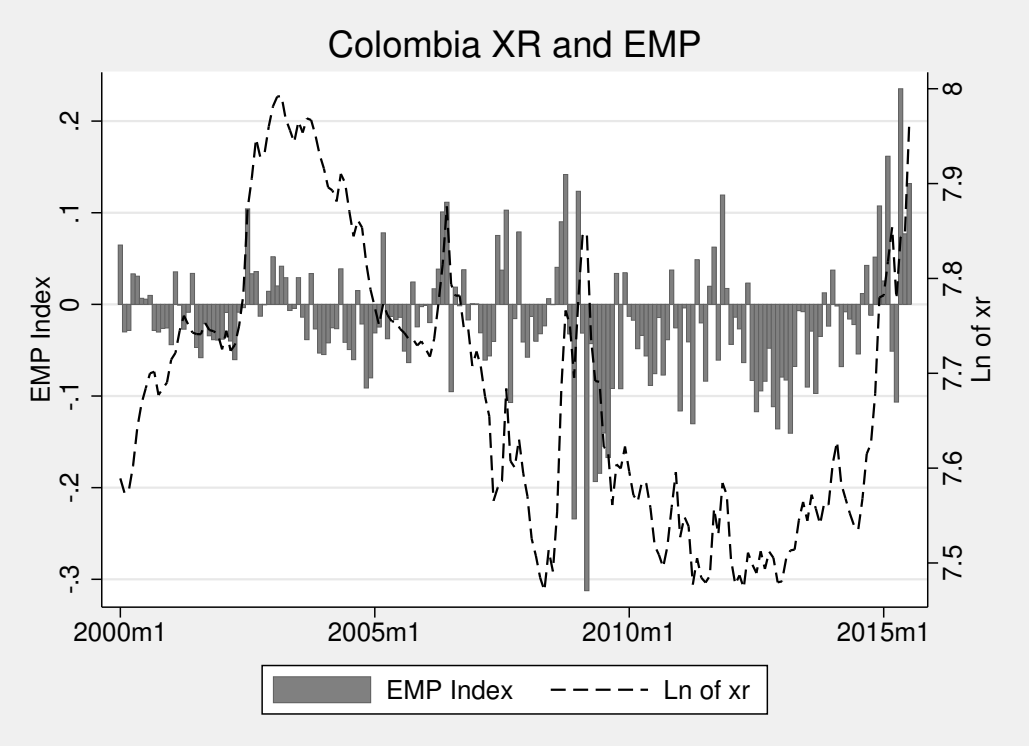


Figure 4: EMP and Natural Log of the Nominal Exchange Rate

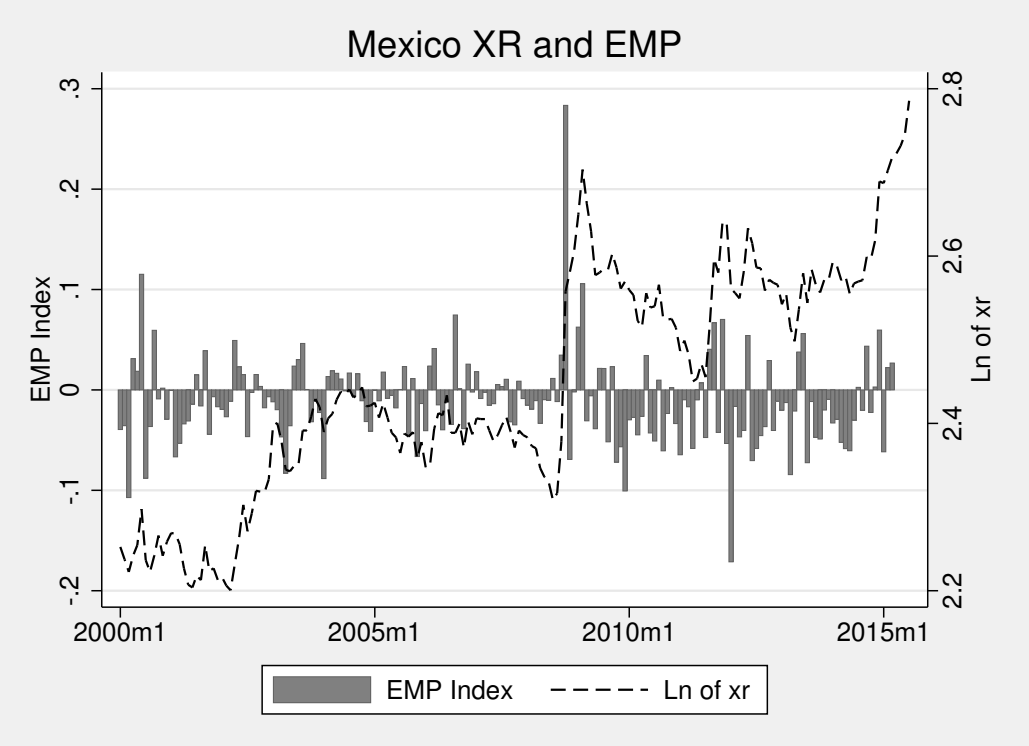
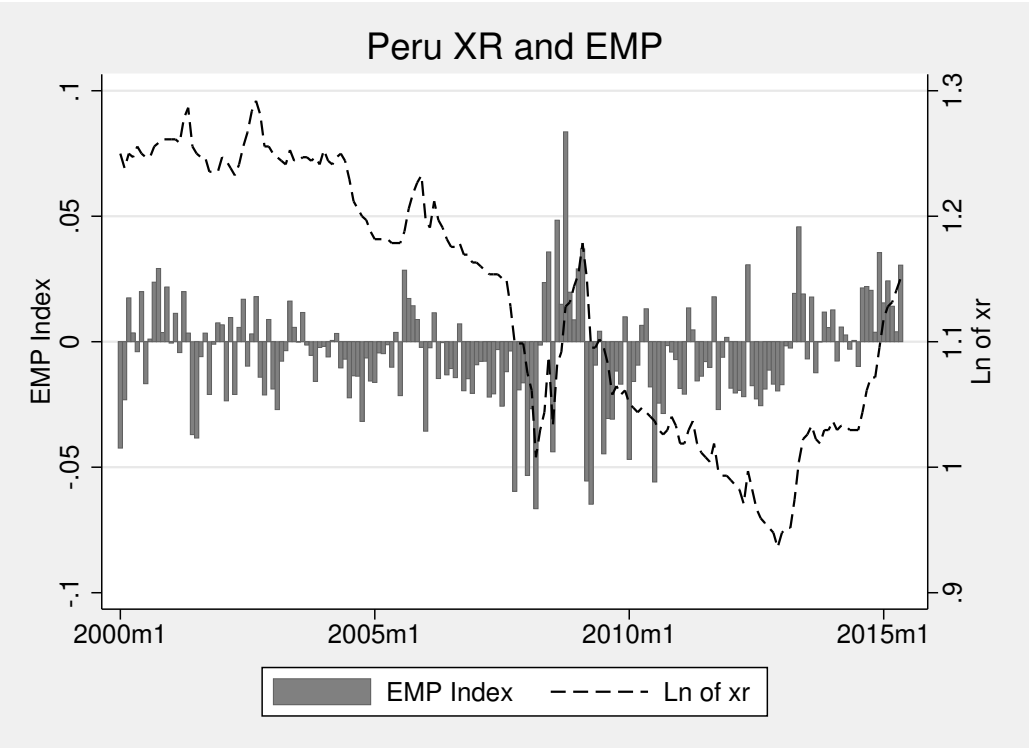


Figure 5: EMP and Natural Log of the Nominal Exchange Rate



5 Appendix. Estimations Using the Inflation Gap

This Appendix includes the additional GMM estimations for the third paper, section 4. Here I reproduce the tables 8, 9, 10, and 11. But instead of the change in the rate of inflation, here I show the results using the difference between observed inflation and the target inflation. Because the Central Bank use a band for the target inflation, rather than a single number, I choose to use the mean. Thus, if the Central Bank has a target inflation between 2% and 4%, I set the target to 3%.

Tables 12, 13, 14, and 15 include the results. It is comforting to notice that the main lesson holds. In all the countries, with the sole exception of Chile, depreciations seems to trigger a sale of foreign exchange reserves, while appreciation matter very little: either the sign of the coefficient is wrong, as in Colombia in Peru, or the results are not significant and the coefficient is smaller in absolute size (see table 15). Interest rate changes do not seem to be clearly related to exchange rate changes.

It is worth to notice that the coefficient associated with inflation gap often has the wrong sign (it is negative but it should be positive), and its size is small, and always much smaller than the coefficient associated with exchange rate changes (see table 12). Although the problem could be the precise definition of the inflation gap, this may also imply that Latin-American Central Banks pay much more attention to exchange rates than to inflation, at least in a month by month basis. This is clearly inconsistent with the usual description of the way Inflation Targeting works.

Table 12: GMM Estimation of Interest Rate Reaction Functions

$\Delta \ln(\text{Rate})$	Brazil	Chile	Colombia	Mexico	Peru
Constant	-0.0061*** (0.0038)	0.0057*** (0.0033)	-0.0054* (0.0029)	0.0033* (0.0015)	0.0077*** (0.0020)
Inflationgap (t-1)	0.0019** (0.0009)	-0.0003* (0.0013)	0.0006 (0.0004)	-0.0077** (0.0030)	-0.0057*** (0.0020)
Outputgap (t-1)	0.0009 (0.0008)	0.0029** (0.0013)	0.0002 (0.0002)	0.0011*** (0.0004)	0.0028*** (0.0008)
$\Delta \ln(\text{XR})$ (t-1)	0.1532* (0.0794)	0.4318** (0.1938)	0.0399** (0.0193)	0.0342 (0.0299)	0.2350 (0.2342)
Observations	183	169	70	78	116
Hansen's $J \chi^2$ p-value	0.4024	0.6186	0.9867	0.9923	0.3175

Instruments: Lags 2/12 of Output-gap, Inflation-gap,
Domestic and Federal Funds Rates (in logs)
Standard error in parentheses (Newey-West "HAC" Covariance Matrix)
*** p<0.01, ** p<0.05, * p<0.1

Table 13: GMM Estimation of Reserve Accumulation Reaction Functions

$\Delta \ln(\text{Reserves})$	Brazil	Chile	Colombia	Mexico	Peru
Constant	0.0161*** (0.0037)	0.0056*** (0.0019)	0.0108*** (0.0025)	0.0194*** (0.0014)	0.01667*** (0.0017)
Inflationgap (t-1)	-0.0018** (0.0008)	0.0016** (0.0008)	-0.0005 (0.0006)	-0.0074*** (0.0010)	-0.0043*** (0.0011)
Outputgap (t-1)	0.0002 (0.0007)	0.0022*** (0.0006)	0.0003** (0.0001)	0.0009*** (0.0002)	0.0013*** (0.0004)
$\Delta \ln(\text{XR})$ (t-1)	-0.1606** (0.0666)	-0.1588*** (0.0842)	-0.2322*** (0.0375)	-0.0364 (0.0270)	-0.5139*** (0.1533)
Observations	179	169	70	74	116
Hansen's J χ p-value	0.2410	0.6849	0.4230	0.5787	0.7475

Instruments: Lags 2/12 of Output-gap, Inflation-gap,
Domestic and Federal Funds Rates (in logs)
Standard error in parentheses (Newey-West "HAC" Covariance Matrix)
*** p<0.01, ** p<0.05, * p<0.1

Table 14: GMM Estimation of Interest Rate Reaction Functions

$\Delta \ln(\text{Rate})$	Brazil	Chile	Colombia	Mexico	Peru
Constant	-0.0070* (0.0040)	0.0151* (0.0080)	-0.0076** (0.0034)	0.0038*** (0.0014)	0.0018 (0.0025)
Inflationgap (t-1)	0.0017* (0.0010)	0.0005 (0.0014)	0.0005 (0.0003)	-0.0057*** (0.0020)	-0.0066*** (0.0020)
Outputgap (t-1)	0.0008 (0.0009)	0.0022 (0.0013)	0.0003** (0.002)	0.0007*** (0.0003)	0.0028*** (0.0007)
Appreciation (t-1)	0.0792 (0.1355)	0.7536* (0.4119)	-0.1472** (0.2526)	0.1406 (0.0855)	-0.6188** (0.3087)
Depreciation (t-1)	0.1916* (0.1039)	-0.0778 (0.3001)	0.1403 (0.0660)	-0.0252* (0.0134)	0.6756 (0.3843)
Observations	183	149	70	78	116
Hansen's J χ^2 p-value	0.3675	0.6242	0.9756	0.9947	0.7043

Instruments: Lags 2/12 of Output-gap, Inflation-gap,
Domestic and Federal Funds Rates (in logs)
Standard error in parentheses (Newey-West "HAC" Covariance Matrix)
*** p<0.01, ** p<0.05, * p<0.1

Table 15: GMM Estimation of Reserve Accumulation Reaction Functions

$\Delta \ln$ (Reserves)	Brazil	Chile	Colombia	Mexico	Peru
Constant	0.0220*** (0.0046)	0.0019 (0.0046)	0.0088*** (0.0028)	0.0208*** (0.0016)	0.0174*** (0.0024)
Inflationgap (t-1)	-0.0017** (0.0008)	0.0015 (0.0009)	-0.0002 (0.0006)	-0.0073*** (0.0011)	-0.0042*** (0.0011)
Outputgap (t-1)	0.0002 (0.0007)	0.0024*** (0.0007)	0.0004*** (0.0002)	0.0009*** (0.0002)	0.0013*** (0.0004)
Appreciation (t-1)	0.1352 (0.1452)	0.0311 (0.1637)	-0.2610** (0.1326)	0.0405 (0.0625)	-0.4568** (0.2258)
Depreciation (t-1)	-0.2219*** (0.0701)	0.3439 (0.2174)	-0.1491*** (0.0496)	-0.0799*** (0.0424)	-0.5811** (0.2423)
Observations	179	169	70	74	116
Hansen's J χ p-value	0.2360	0.7017	0.3981	0.5119	0.7287

Instruments: Lags 2/12 of Output-gap, Inflation-gap,
Domestic and Federal Funds Rates (in logs)
Standard error in parentheses (Newey-West "HAC" Covariance Matrix)
*** p<0.01, ** p<0.05, * p<0.1