Foreign Exchange Market Intervention and Asymmetric Preferences

Helena Glebocki Keefe[a], Hedieh Shadmani[b,]

[a]*Department of Economics, Fairfield University, 1073 N. Benson Rd. Fairfield, CT 06824 (USA), (203) 254-4000, email: hkeefe@fairfield.edu*
[b]*Corresponding Author. Department of Economics, Fairfield University, 1073 N. Benson Rd. Fairfield, CT 06824 (USA), (203) 254-4000, email: hshadmani@fairfield.edu*

Abstract

Central banks in many emerging market economies intervene in currency markets to mitigate volatility and counter appreciation/depreciation pressure. This paper investigates whether central banks in twenty four emerging economies are "leaning against the wind" in their intervention strategies, whether they have an asymmetric response to exchange rate movements, and whether the response changes after the Global Financial Crisis. Our empirical investigation finds solid evidence that they prefer to dampen appreciation pressures more substantially than depreciation pressures, even after the crisis.

Keywords: Exchange Rates, Optimal Policy, Asymmetric Preferences, Foreign Exchange Market Intervention, Emerging Markets
JEL: E58, E61, F31, G15

1. Introduction

In the era of the managed floating system, the exchange rate is determined not only by supply and demand forces from market participants. Central banks in many emerging market economies actively manipulate the relative value of their currencies by purchasing and selling foreign currency. In other words, they attempt to stabilize the exchange rate system by "leaning against the wind".

Foreign exchange (FX) intervention can be very important for emerging market economies to calm disorderly markets and relieve liquidity shortages, as well as to correct misalignment and stabilize volatile exchange rates that may cause banking crises, economic instability, slowing growth and decrease in trade. However, it can also be risky. Under fixed or managed floating exchange rate regimes, failure to maintain stability in the FX market may not only erode the central bank's credibility, but may also result in serious credit crises such as the currency crisis of Mexico in 1994, the Asian financial crisis of 1997 and the subsequent crises in Russia, Brazil, and Turkey. Therefore, investigating how central banks truly respond to changes in FX markets and understanding the rationale for and consequences of their interventions has been an ongoing concern for economists, researchers, and policymakers alike.

In this paper, we examine the responsiveness and asymmetry in FX interventions by policymakers in twenty four emerging market economies with three goals. First, to determine whether central banks are in fact using foreign exchange intervention to "lean against the wind" and mitigate drastic movements in their exchange rates, even if they declare a free floating currency. Second, to identify whether central banks have an asymmetric response to exchange rate movements, reacting more strongly to appreciation or depreciation pressure. Lastly, to determine whether these responses have changed or remained consistent after the Global Financial Crisis of 2008-2009. We derive an optimal reaction function for the central bank and estimate the model using Generalized Method of Moments (GMM) with monthly data over three different intervals: full sample (2000:01-2016:12),

pre-crisis (roughly 2000/2001:01 to 2007:12), and post-crisis(roughly 2010:01 to 2016:12) for individual countries. We also analyze the crisis period to compare the policy responses during this volatile time.

Previous literature on the subject of asymmetric FX intervention has focused primarily on "fear of floating" versus "fear of floating in reverse" as presented in Calvo and Reinhart (2002) and Levy-Yeyati and Sturzenegger (2007) respectively, during the 1990's and pre-crisis 2000's, and with a focus on Asian markets that suffered after the Asian Crisis of 1997-98 (see Pontines and Rajan (2011) and Srinivasan et al. (2009)). This paper contributes to the literature by expanding the sample of countries examined to include emerging markets in Latin America, Eastern Europe and Africa, in addition to the Asian markets. Furthermore, it explores the post-crisis reality of exchange rate management in these economies and whether FX interventions have changed after the Global Financial Crisis of 2008-09.

Our empirical results show solid evidence that central banks in each of these regions have been intervening in foreign exchange markets by "leaning against the wind". The results confirm that policymakers have been trying to dampen sharp appreciations and depreciations through the purchase and sale of foreign currency. Moreover, we find strong evidence of an asymmetric response by central banks in all the regions. For many of the countries in our sample, central banks present a stronger aversion to appreciation than depreciation pressures, and these results remain significant in the post-crisis period. There are a few cases where the aversion switches after crisis, which may be explained by a weakening exchange rate pass-through effect or increased volatility in reserve accumulation/decumulation over the period of study.

The rest of the paper is organized as follows. Section 2 discusses recent literature on foreign exchange interventions and asymmetric policy responses to exchange rate movements. Section 3 describes the empirical model analyzed in this paper and includes details on methodology. Section 4 discusses the main empirical findings. Finally, Section 5 concludes.

2. Literature Review

The literature on foreign exchange intervention is vast. Early works in this area mostly focus on intervention and its effectiveness over different exchange rate regimes in industrialized economies, as seen in Almekinders and Eijffinger (1996). Recent studies concentrate on emerging markets and developing countries, particularly after the introduction of the "fear of floating" concept in these economies by Calvo and Reinhart (2002). "Fear of floating" is linked to aversion by central banks to depreciation pressures. Many countries that officially claim to have floating systems appear to actively manage the exchange rate and limit the fluctuations in the value of their currencies in practice. However, this aversion to floating can occur both in terms of excessive depreciations and excessive appreciations.[1] As seen in the empirical literature, while central banks in most emerging market economies show stronger aversion to depreciations in the 1990s, they intervene heavily to limit appreciations in the 2000s, as demonstrated in Calvo and Reinhart (2002), Levy-Yayati (2012), and Pontines and Rajan (2011).

Emerging market economies are unique in their vulnerability to drastic and sudden movements in exchange rates. As noted in Devereux and Yu (2017), their exposure to volatile capital flows, including the risk of sudden stops, has led to large swings in exchange rates. In times of crises, nominal exchange rate adjustments play a large and positive role in mitigating the impact of capital flow reversals. Flexible exchange rate policies may do

[1] Moderate depreciations/appreciations may not provoke a policy response.

little in facilitating independent monetary policy when swings in capital flows result largely from external shocks (Rey (2013a) and Rey (2013b)).

Levy-Yeyati, Sturzenegger, and Gluzmann (2012) and Slavov (2011) argue that incentives to intervene in order to avoid appreciations are different from those to avoid depreciations. Aversion to depreciation, or the tendency to intervene to appreciate the local currency, is mostly associated with short-run crisis and financial distress and occurs under a high degree of dollarization or a strong pass-through effect. Countries with higher degrees of liability dollarization are more likely to float, and a depreciating exchange rate increases the domestic currency value of liabilities. Therefore, in countries with vulnerable financial systems, depreciations are associated with financial distress or even bankruptcy (see Slavov (2011), Rossini, Quisoe and Rodriguez (2011), Levy-Yeyati, Sturzenegger, and Gluzmann (2012) and Lahura and Vega (2013)). Under this scenario, sharp depreciations are avoided as they may trigger a financial crisis in the short run (Lahura and Vega (2013)).

On the other hand, the fear of appreciation, or the aversion to appreciation, has a more mercantilistic leaning, where the primary fear is becoming less competitive than fellow exporting countries, thereby creating a tendency to fight against appreciation of the local currency. Levy-Yeyati and Sturzenegger (2007) find that interventions tied to fear of appreciation lead to faster output and productivity growth and have a significant positive effect on long run GDP growth, derived from the impact of these interventions on domestic savings and investment rates.

Asymmetry in foreign exchange intervention refers to the central bank's perception that an appreciation (depreciation) is more costly or has more significant negative economic effects than a depreciation (appreciation), thereby creating a stronger reaction by policymakers to the changes in the exchange rate when it moves in one particular direction. This asymmetric response leads to more sizable or more frequent interventions in response to that movement. In advanced economies, asymmetric intervention has been discussed in early literature by Almekinders and Eijffinger (1996). They find that monetary authorities in the U.S. and Germany have tried to dampen appreciations more strongly than depreciations during the Post-Louvre period. Recent work has empirically tested the hypothesis of asymmetric FX intervention in several emerging market economies. Although these studies vary in their methodology, estimation method, data frequency, the countries in the sample, and the period of studies, majority of them have found evidence of stronger aversion to appreciation pressures especially after 2000.

Recent discussion of asymmetric FX intervention policy has been paired with trying to understand the motivation behind rapid and sizable reserve accumulation in emerging market economies and whether the build up has been an asymmetric response by policymakers to appreciation pressures. The motivation for rapid reserve accumulation has been explained as insurance for preventing potential currency crises, as a way stimulate growth, or as a tool to reduce exchange rate volatility. The last is the main motivation stated by many emerging market central banks. Previous literature on this topic has focused mainly on Asian countries (see Pontines and Rajan (2011) and Srinivasan et al. (2009)) and the build up of foreign exchange reserves following the Asian crisis of 1997-98. Both papers find that central banks in Asian countries have a distinct fear of appreciation and respond more significantly and sizably to appreciation pressure.

The Global Financial Crisis of 2008-09 led to a sharp appreciation of the US dollar against almost all other currencies. Fratzscher (2009) finds that countries with lower foreign exchange reserves, weaker current account positions and higher direct financial exposure against the US experienced notably larger depreciations overall. Interestingly, despite the rapid build up of reserves in many emerging market economies following the Asian crisis in 1997-98, countries with below-average FX reserve to GDP ratios experienced depreciations of 23% during

the Global Financial Crisis compared to only 7% in countries with above-average FX reserves to GDP ratios.[2] Therefore, even though the debate continues on excessive build up of reserves, it appears those countries with the extra cushion were not affected quite as severely by the US dollar appreciation in the 2008-09 crisis.

In terms of methodology, the literature on asymmetric FX intervention can be divided into three groups. The first group examines the asymmetry by deriving an optimal intervention reaction function for the central bank which faces an asymmetric loss function. Srinivasan, Muhambare, and Ramachandran (2009) have used this methodology to investigate the asymmetry in reaction of the central bank in India. Using weekly data for November 2000 to February 2006, they showed that policymakers in India are more sensitive to appreciations than depreciations. Pontines and Rajan (2011), Pontines and Siregar (2012), and Wang, Li, Li, Liu (2015) have focused on the persistent increase in reserve accumulation in Eastern Asian economies and tried to rationalize the causes of this increase in the context of asymmetric preferences in FX intervention. They refer to the fact that Asian economies hold more than enough reserves as a financial safeguard and they link this issue to the asymmetric desire of policymakers to avoid appreciations.

The second group examine the asymmetry in FX intervention by employing popular regime-switching models. These studies mostly focus on developing countries which have adopted inflation targeting (IT). As argued in the literature, the adoption of an inflation targeting (IT) policy may lead to more flexible exchange rate movements. Whether this flexibility is significantly higher on one side of market or not has been investigated in these papers. Pontines and Siregar (2012) study this issue by employing two classes of regime-switching models (smooth transition auto regressions and Markov-Switching models) that capture the asymmetry in exchange rate behavior. They investigate four Asian economies—namely, Indonesia, Korea, the Philippines and Thailand— that were among the first group of emerging markets to embrace the inflation targeting framework of monetary policy. They find strong evidence that the monetary authorities of these four Asian economies tend to adopt a form of asymmetrical exchange rate behavior wherein appreciation pressures are restrained more substantially than depreciation pressures. Using a nearly similar approach, Benlialper, Cömert, and Öcal (2015) have tried to answer a slightly different question, whether central banks in IT developing countries have a different policy stance with respect to appreciations versus depreciations. They analyze central banks' interest rate decisions by estimating a nonlinear monetary policy reaction function using a panel threshold model for twelve IT developing countries. In contrast to what Pontines and Siregar (2012) find, their empirical results show that during the period of 2002 to 2008, central banks in these countries responded to depreciation pressures beyond some threshold, but they remained inactive to appreciation.

Finally, a distinct but related body of work has focused on the asymmetric effects of FX intervention on exchange rate. For example, Lahura and Vega (2013) employed a structural vector auto-regression (SVAR) model to investigate whether sale interventions have a greater effect on exchange rate than purchase interventions. Using minute-by minute intervention data for Peru between January 2009 to April 2011, the paper provides evidence in supporting the hypothesis.

There are a number of limitations in previous literature that we attempt to address in this paper. As mentioned above, recent literature on asymmetric FX intervention focuses mostly on explaining rapid reserve accumulation in Asia. Yet, there are many regions that actively manage their exchange rates, such as Latin America, and others where there is limited research on FX intervention policies, such as Africa, which have not been explored in

[2]Fratzscher (2009) refers to below-average and above-average ratios in the context of average FX reserves to GDP across a sample of 54 countries.

previous literature on asymmetric FX interventions. Furthermore, with the drastic appreciation of the US dollar following the Global Financial Crisis, and the subsequent slow recovery around the world, it is imperative to understand how emerging market economies are coping with the effects of these shocks in their currency markets. This paper expands and builds upon past literature on asymmetric FX intervention by covering emerging markets from every major region globally and focusing on the asymmetric policy responses in the crisis and post-crisis periods.

3. Empirical Model and Methodology

3.1. Empirical Model

Foreign exchange intervention occurs when policymakers buy or sell foreign currency in order to influence the exchange rate. An important aspect of foreign exchange intervention is that the policy actions are taken before the realization of an economic shock. In other words, policymakers take action before the variables in the system are determined. Therefore, the problem that the central bank faces is to choose the level of intervention at the beginning of period t conditional upon the information available at the end of period $t-1$. Accordingly, the central bank minimizes the following intertemporal loss function by choosing an optimal level of intervention:

$$\min_{\{R_t\}} E_{t-1}\left\{\sum_{\tau=0}^{\infty}\delta^{\tau}L_{t+\tau}\right\} \tag{1}$$

where δ is the discount factor, and L_t is the loss function at time t. R_t denotes the level of intervention, which is defined as foreign currency purchases and reflects the change in foreign exchange reserves. Instead of using the typical quadratic loss function, we rely on the asymmetric loss function of the central bank to determine whether the central bank has asymmetric preferences for foreign exchange intervention during times of appreciation versus depreciation. We build on the methodology introduced in Surico (2007) for monetary policy and used by Pontines et al. (2011) and Srinivasan et al. (2009) for foreign exchange policy in specifying the loss function in linear-exponential (linex) form.

$$L_t = \frac{1}{2}(R_t - R^*)^2 + \left(\frac{\lambda}{\gamma^2}\right)\left(\exp(\gamma(\tilde{e}_t - e^*)) - \gamma\left(\tilde{e}_t - e^*\right) - 1\right) \tag{2}$$

where $\lambda > 0$ is the relative weight and γ is asymmetric preferences parameter on exchange rate stabilization. $\tilde{e}_t$ denotes the percentage change in the exchange rate. e_t is national currency per unit of foreign currency, such that $\tilde{e}_t < 0$ implies appreciation and $\tilde{e}_t > 0$ implies depreciation. Once again, R_t represents the change in foreign exchange reserves, and serves as a proxy for foreign exchange intervention.[3] R^* is the optimal level of foreign exchange intervention and e^* is the Central Bank's target depreciation rate, which is assumed to be zero.

The critical component in determining whether the central bank has an asymmetric response to movements in exchange rates is derived from γ, which captures any asymmetry in the objective function of the central bank. The linex specification of the loss function can nest the quadratic loss function as a special case when $\gamma = 0$ which is consistent with symmetric preferences (positive and negative changes in the exchange rate yield similar loss). A negative value of γ implies that, all else equal, an appreciation ($\tilde{e}_t < 0$) yields a greater loss than depreciation

[3] Although the change in reserves is an imperfect estimation of foreign exchange intervention by the central bank, it is widely used in FX intervention literature as a proxy for gauging FX interventions by the central bank, especially when other measures are unavailable, see Srinivasan et al. (2009).

($\tilde{e}_t > 0$). A positive value of γ implies that, all else equal, a depreciation ($\tilde{e}_t > 0$) yields a greater loss than appreciation ($\tilde{e}_t < 0$).

We follow the strategy in Surico (2007), van Dijk et al. (2002), and Luukkonen et al. (1988) and linearize the exponential terms in Eq. 2 by using a first-order Taylor series expansion to get the following loss function.[4]

$$L_t = \frac{1}{2}(R_t - R^*)^2 + \left(\frac{\lambda}{2}\right)\left((\tilde{e}_t - e^*)^2 + \frac{\gamma(\tilde{e}_t - e^*)^3}{3}\right) \tag{3}$$

It is assumed that $e^* = 0$, therefore,

$$L_t = \frac{1}{2}(R_t - R^*)^2 + \left(\frac{\lambda}{2}\right)\left(\tilde{e}_t^2 + \frac{\gamma\tilde{e}_t{}^3}{3}\right) \tag{4}$$

Since our focus is on the motives of central bank interventions, it is assumed that interventions can reduce the rate of depreciation or appreciation such that:

$$\tilde{e}_t = a_0 + a_1 R_t + \varepsilon_t, \tag{5}$$

$$a_0 > 0 \ , \ a_1 > 0 \text{ and } \varepsilon_t \sim iid(0, \sigma^2)$$

which implies that during periods of appreciation, when $\tilde{e}_t$ is decreasing, the central bank intervenes in the foreign exchange market to purchase foreign currency (US dollars, for example) or sell domestic currency. This action causes foreign exchange reserves (R_t) to rise, offsetting the change in $\tilde{e}_t$ when $a_1 > 0$. During periods of depreciation, when $\tilde{e}_t$ is increasing, the central bank intervenes in the foreign exchange market to sell foreign currency (buy domestic currency), thereby lowering foreign exchange reserves (R_t).[5] The fall in R_t offsets the rise in $\tilde{e}_t$ from the depreciation according to Eq. 5.

Solving the optimization problem from Eq. 1 subject to Eq. 5 we derive the first order condition:

$$E_{t-1}\{\frac{\partial}{\partial R_t}[\frac{1}{2}(R_t - R^*)^2 + \left(\frac{\lambda}{2}\right)\left(\tilde{e}_t{}^2 + \frac{\gamma\tilde{e}_t{}^3}{3}\right)]\} = 0 \tag{6}$$

$$(R_t - R^*) + E_{t-1}\{\lambda a_1 \tilde{e}_t\} + E_{t-1}\{\frac{\lambda\gamma a_1 \tilde{e}_t{}^2}{2}\} = 0 \tag{7}$$

We replace expectations with realized values. Therefore, the reaction function is re-parametrized as follows:

$$R_t = C_1 + C_2\tilde{e}_t + C_3\tilde{e}_t^2 + \nu_t \tag{8}$$

where $C_1 = R^*$, $C_2 = -\lambda a_1$, $C_3 = -\frac{\lambda a_1 \gamma}{2} = \frac{\gamma C_2}{2}$, therefore:

$$\gamma = \frac{2C_3}{C_2} \tag{9}$$

Since a_1 is assumed to be positive, C_2 is expected to be negative if in fact the central bank is intervening in foreign exchange markets in a way that counters appreciation or depreciation pressure. If C_2 is negative and

[4] See Appendix for further details.

[5] As argued by Almekinders (1996), intervention is effective if $a_1 > 0$. Purchases (sales) of foreign currency by the domestic central bank lead to higher (lower) value of foreign currency in terms of domestic currency.

Table 1: Description of γ and Preference Symmetry

If $C_3 = 0$	then $\gamma = 0$	Yields Symmetric preferences *$\tilde{e}_t$ is weighted equally*
If $C_3 > 0$	then $\gamma < 0$	Yields Stronger Aversion to Appreciation *Negative $\tilde{e}_t$ is weighted more severely*
If $C_3 < 0$	then $\gamma > 0$	Yields Stronger Aversion to Depreciation *Positive $\tilde{e}_t$ is weighted more severely*

significant, then in fact the central bank is effective in "leaning against the wind" and intervening in a way that mitigates the appreciation or depreciation happening in currency markets. Whether there is a bias towards more action during appreciation versus depreciation depends on γ and therefore on the sign of C_3. Based on the sign of C_3 we can decide whether the central bank has asymmetric preferences in response to changes in the exchange rate. More details on the interpretation of C_3 and γ are presented in Table 1.

3.2. Methodology

Our estimation is based on monthly data for 24 emerging market economies. We focus on three periods for each country: (1) 2000:01 to 2016:12, (2) the period prior to the Global Financial Crisis (roughly 2000/2001:01 to 2007:12) and (3) the period after the Global Financial Crisis (roughly 2010:01 to 2016:12). Finally, using a dummy variable to control for the crisis period (2008:01-2009:12), we run the GMM estimation for the whole sample for each country to test the effect of the Global Financial Crisis on the asymmetric policy reactions.

The variables used in the estimation of Eq. 8 are as follows:

$$R_t = 100 \times (\triangle \log \ \mathit{Reserves}) \tag{10}$$

$$\tilde{e}_t = 100 \times (\triangle \log \ e_t) \tag{11}$$

where we define R_t as percentage change in Official Foreign Exchange Reserves and e_t as domestic currency units per unit of foreign currency (or $\frac{LCU}{USD}$).[6]

We estimate the central bank reaction function using the Generalized Method of Moments (GMM) model with an optimal weighting matrix that accounts for possible heteroskedasticity and serial correlation in the error terms (Hansen, 1982). We employ a four lag Newey – West estimate of the covariance matrix. We use 1 to 10, 12, 15^{th} lag of R_t and $\tilde{e}_t$, as well as the current and 1 to 4^{th} lag of the U.S. federal funds rate as instruments. We separate our sample countries into four regions: Latin America, Asia, Eastern Europe and Africa.

To analyze the central bank responses and asymmetric preferences during the crisis period, we conduct the same GMM estimation on an individual country basis described above with the inclusion of a dummy variable D for the crisis period so that:

$$R_t = C_1 + C_2\tilde{e}_t + C_3\tilde{e}_t^2 + C_4 D + \nu_t \tag{12}$$

[6]Data is collected from the IMF International Financial Statistics database.

where D equals one for the crisis period (2008:01-2009:12) and zero otherwise. We also analyze the change in the asymmetric response of policymakers during the crisis period by estimating:

$$R_t = C_1 + C_2\tilde{e}_t + C_3\tilde{e}_t^2 + C_4 D + C_5 D\tilde{e}_t + C_6 D\tilde{e}_t^2 + \nu_t \tag{13}$$

providing evidence of how asymmetric responses may have changed during the crisis period. We calculate the asymmetric preference parameter for the crisis period, ${\gamma_2}$[7] as:

$$\gamma_2 = \frac{2(C_3 + C_6)}{C_2 + C_5} \tag{14}$$

4. Empirical Results

In this section, we start with an overview of statistics on reserve accumulation and exchange rate movements for the countries in our sample. We then discuss the individual country GMM results in Latin America, Asia, Eastern Europe, and Africa.

To provide a summary on foreign exchange reserve accumulation and exchange rate dynamics in the period under study, Table 2 presents data on reserves as a share of GDP, average annual growth in reserves, the depreciation occurring during the 2008-2009 crisis, and the volatility in reserves. The pre-crisis period covers 2000-2007, the crisis period represents 2008-2009 and the post-crisis period represents 2010-2016. The share of reserves to GDP increased across all regions except Africa after the onset of the Global Financial Crisis. The average annual growth in reserves slowed in the crisis and post-crisis eras, as can be seen for individual countries in Figures 1 to 4. For some countries, such as Dominican Republic, Jamaica, Venezuela, South Korea, Vietnam, Turkey, and Nigeria, reserves fell during the crisis period. This may be an indication of efforts by policymakers to stabilize exchange rates. The correlation between the depreciations and the slowed growth in reserves during the crisis period is correlated at -63 percent. Additionally, the volatility in reserves seems to have diminished slightly in the post-crisis era, although this varies widely across countries.

[7]For both γ and γ_2, we calculate standard errors using the delta method.

Table 2: Summary Statistics on Reserves and Exchange Rates

	Reserves/GDP (%)		Average Annual Growth in Reserves (%)			Depreciation	Volatility in Reserves (%)		
	pre-crisis	post-crisis	pre-crisis	crisis	post-crisis	2008-2009	pre-crisis	crisis	post-crisis
Latin America									
Argentina	74.74	49.92	24.52	11.00	17.12	18.61	3.90	1.82	2.54
Brazil	28.30	61.57	19.13	19.15	9.43	-1.17	5.27	1.49	1.11
Chile	64.27	56.01	0.06	17.40	8.49	4.61	3.25	2.53	2.64
Colombia	54.41	62.32	10.71	10.16	14.33	5.25	2.33	5.66	3.66
Dom Rep	14.65	25.52	21.85	-2.24	11.68	7.31	8.22	3.84	8.49
Guatemala	47.55	46.92	11.53	6.43	9.09	7.88	3.38	2.76	3.26
Jamaica	64.80	59.06	10.60	-10.09	7.50	21.75	6.06	5.49	7.14
Mexico	27.82	52.52	10.01	2.84	11.55	16.28	2.47	3.45	1.44
Venezuela	70.31	8.22	24.79	-5.12	-5.44	0.00	4.62	0.23	6.02
Asia									
Bangladesh	15.38	38.82	14.38	22.28	20.71	0.79	8.55	6.89	4.30
India	11.77	14.33	13.59	10.25	-2.51	18.49	1.13	2.51	2.57
Indonesia	54.74	44.55	5.66	5.72	10.66	1.28	2.30	2.43	2.43
Philippines	62.90	101.33	6.88	17.52	12.10	12.79	2.85	1.99	1.65
S. Korea	80.80	100.89	12.88	-4.47	7.93	21.39	0.99	1.69	0.74
Sri Lanka	23.32	31.02	20.78	18.12	5.52	5.77	1.14	2.55	2.59
Thailand	29.49	25.11	9.88	24.74	6.18	8.99	1.36	1.94	1.07
Vietnam	57.99	58.38	22.98	-2.25	9.33	14.54	2.93	3.26	4.24
Eastern Europe									
Czech Rep	83.65	97.95	11.13	7.95	11.48	1.16	1.81	1.45	2.30
Hungary	66.63	129.09	8.95	26.15	-2.95	7.53	4.46	5.55	3.16
Poland	54.11	76.36	8.76	10.19	7.71	14.87	3.05	4.03	2.39
Turkey	37.57	43.44	13.49	-1.10	6.56	24.89	4.87	1.99	2.75
Africa									
Kenya	32.36	42.61	15.24	5.89	14.82	9.95	2.69	2.93	3.81
Nigeria	76.65	31.00	23.43	-1.10	-6.18	24.23	4.61	2.65	2.92
S.Africa	22.30	44.40	18.75	9.40	4.53	7.15	2.48	1.06	1.38
Regional Averages									
Lat. Am.	41.23	50.27	12.19	5.58	9.62	9.44	4.78	3.26	4.01
Asia	50.22	61.51	12.11	10.59	11.15	9.96	3.16	3.03	2.41
E. Europe	60.49	86.71	10.58	10.80	5.70	12.11	3.55	3.26	2.65
Africa	43.77	39.33	19.14	4.73	4.39	13.78	3.26	2.21	2.70

This table presents summary statistics on reserve ratios, reserve accumulation and exchange rate changes for the sample period in this research. The pre-crisis period covers 2000 - 2007, the crisis period represents 2008-2009 and the post-crisis period represents 2010-2016. Changes in exchange rates are based on local currency units per US dollar. Volatility in reserves is calculated as the standard deviation of the monthly log difference in reserves over one quarter. Data is sourced from the IMF International Financial Statistics database.

4.1. Latin America

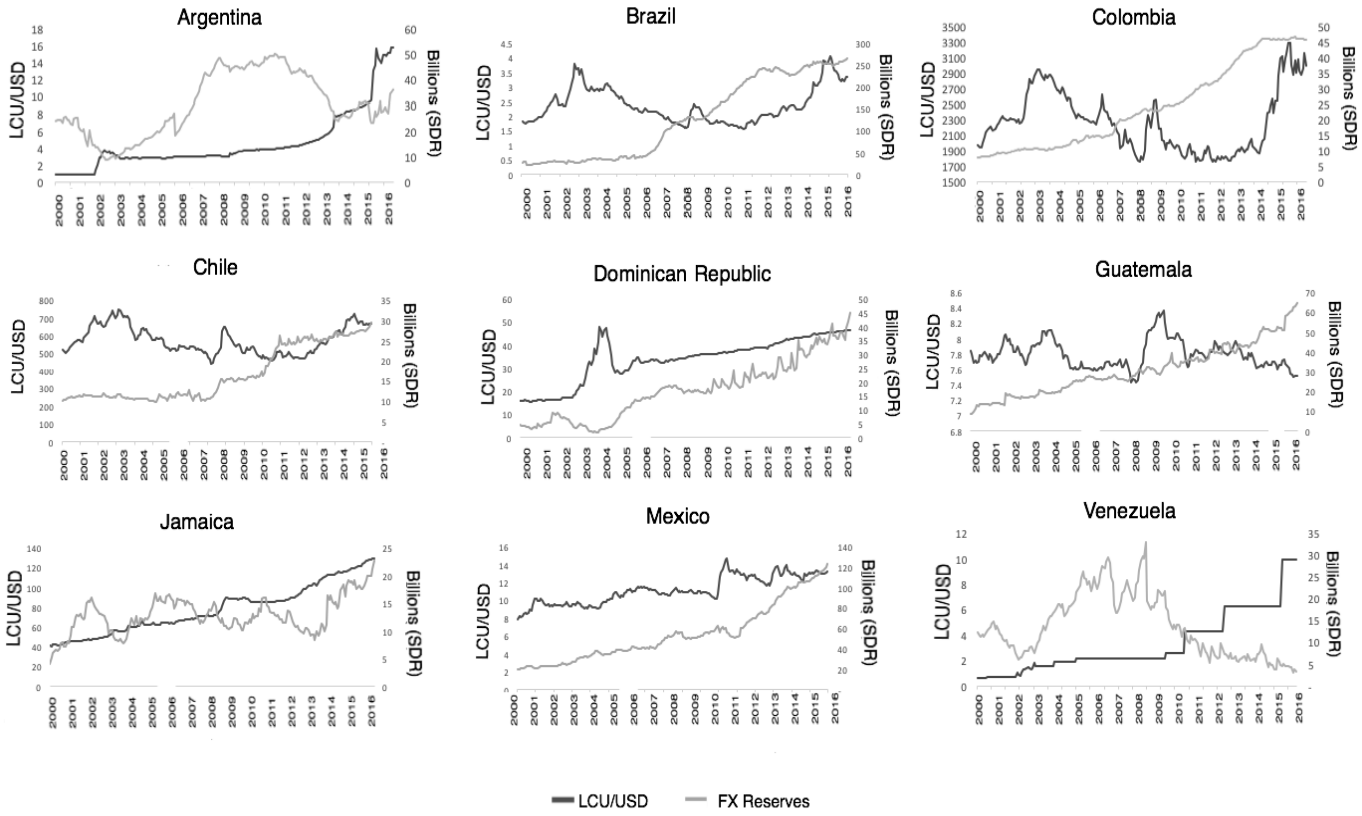
Table 3 presents the results for nine Latin American countries. In all nine countries across the three periods, C_2 is negative and significant, with the exception of Chile and Jamaica from 2001 to 2016.[8] It is evident from this variable that in fact central banks in Latin America have been responding to changes in their exchange rates in a way that would counter appreciation or depreciation of their currencies. In other words, there is statistically significant evidence that these central banks are in fact "leaning against the wind" and have been doing so both before and after the crisis.

Moreover, according to the outcomes of C_3 and γ, there is strong evidence that central banks in these economies

[8]In the case of Chile, the sizable depreciation from 2008 to 2009 along with relatively volatile changes in reserve accumulation as seen in Figure 1 may explain the lack of significance in the "whole" period sample. C_2 remains negative and significant in both the pre- and post- crisis period for Chile.

also have an asymmetric response. γ is consistently negative and significant in Argentina, Chile, Guatemala, Jamaica and Mexico in both the pre- and post-crisis era, as well as when the Global Financial Crisis is included in the sample. This indicates a stronger aversion to appreciation pressure, and therefore relatively greater responsiveness with some form of FX intervention during periods of appreciation than in periods of depreciation.

Figure 1: Exchange Rates and FX Reserves: Latin America



This figure presents the exchange rate (LCU/USD) and foreign exchange reserves from 2000 to 2016 for the nine Latin American countries in our study.

In the post-crisis era as well as in the whole sample including the crisis, Brazil exhibits the same properties, where policymakers have a strong and significant aversion to appreciation. Yet, during the pre-crisis period, the positive γ and negative C_3 are indicative of greater aversion to depreciation pressure by Brazilian policymakers. This may be attributed to the period between 2000 and 2003 when Brazil experienced a sizable depreciation in its currency while reserve accumulation was still low relative to current levels (see Figure 1). In addition, Brazil experienced a sharp rise in inflation between 2002 and 2003, reaching 17.2 percent in May 2003, from an average of 7.0 percent in the pre-crisis period. Since emerging market economies tend to have a stronger pass through effect, the sharp depreciation of 2002 translating to a bout of high inflation in early 2003 may have motivated this asymmetric response of policymakers to the depreciationary pressure.

In Colombia and Venezuela, the pre-crisis and whole sample periods indicate an aversion to appreciation based on a negative and significant γ, whereas the post-crisis period reflects an aversion to depreciation. Both countries experienced sharp, consistent, and significant depreciations in the post-crisis era, as can be see in Figure 1. During

the pre-crisis era, Colombia experimented with the use of currency options as a means of controlling exchange rate volatility. This was paired with the purchase/sale of USD on the spot market, which influenced the level of reserves held by the Colombian Central Bank. The use of currency options was particularly successful in curbing exchange rate volatility (Keefe and Rengifo, 2015).

In the case of Jamaica, none of the coefficients are significant from 2001 to 2016, a result that may be influenced by the Global Financial Crisis of 2008-2009, when Jamaica experienced a sharp and sudden depreciation. In addition, as can be seen from Figure 1, Jamaica's reserve accumulation/decumulation has been more volatile while exchange rates have remained fairly stable. This is indicative of interventions with the main purpose of mitigating exchange rate volatility. In the pre- and post- crisis periods, C_2 is negative and significant, signaling that the central bank is "leaning against the wind", and C_3 is positive and significant while γ is negative and significant, showing the central bank has an aversion to appreciation more so than depreciation.

Lastly, in the Dominican Republic, the actions of the central bank were strong and significant prior to the crisis, yet in the post-crisis era, although they are acting to "lean against the wind", they do not appear to have a bias towards appreciation or depreciation, indicated by the lack of significance in γ. Similar to the case of Jamaica in 2001-2016, from 2010 onwards, reserve accumulation/decumulation becomes more volatile and exchange rates more stable, seen in Figure 1. In the post-crisis era, although the central bank is in fact "leaning against the wind", it does not have a greater aversion to appreciation versus depreciation, but rather an aversion to volatility in exchange rates in the post-crisis era.

4.2. Asia

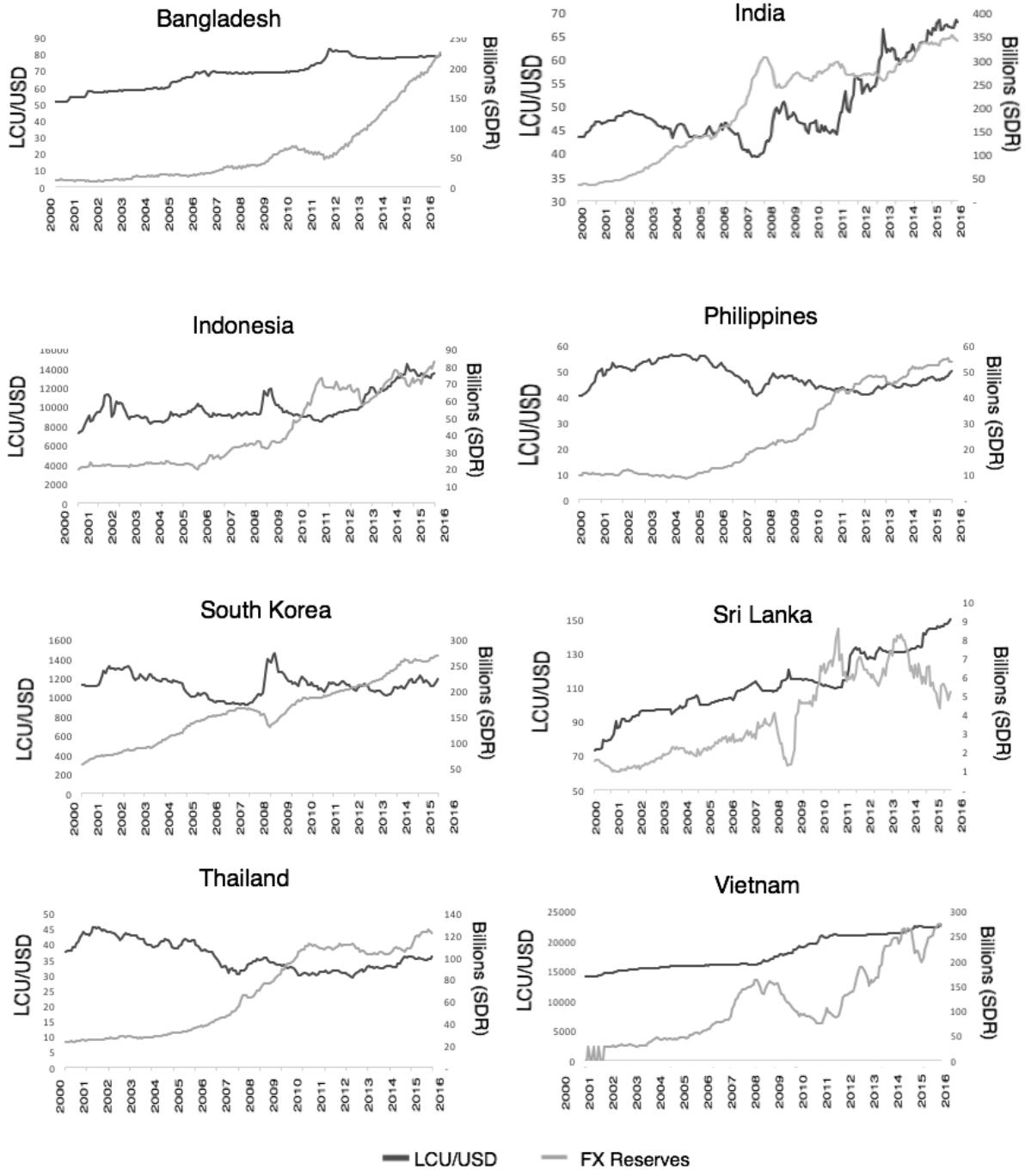
Table 4 presents the results for eight Asian countries. In all eight countries across the three periods, C_2 is negative and significant, with the exception of India. Similar to what is seen in Latin America, central banks in Asia have been responding to changes in their exchange rates in a way that would counter appreciation or depreciation of their currencies, showing statistically significant evidence that these emerging market central banks are also "leaning against the wind" and have been doing so both before and after the crisis. As seen in Figure 2, countries such as Bangladesh and Vietnam have had relatively stable exchange rates, indicating intervention by the central bank to mitigate volatility. All countries have also had sizable accumulation of reserves, as has been noted in previous literature.

Table 3: Asymmetric Intervention Response in Latin America

		C2		C3		γ		J Test
Argentina	2001:1-2016:12	-4.607	***	0.303	***	-0.132	***	6.74
		(1.201)		(0.084)		(0.003)		(0.978)
	Pre-Crisis	-1.07	**	0.094	***	-0.177	***	5.54
		(0.427)		(0.034)		(0.009)		(0.992)
	Post-Crisis	-1.374	***	0.083	***	-0.121	***	9.42
		(0.226)		(0.018)		(0.001)		(0.895)
Brazil	2001:1-2016:12	-0.474	**	0.325	***	-1.369	***	14.59
		(0.182)		(0.082)		(0.397)		(0.95)
	Pre-Crisis	-0.053	***	-0.032	***	1.204	***	11.78
		(0.019)		(0.006)		(0.252)		(0.988)
	Post-Crisis	-0.138	***	0.018	***	-0.258	***	8.02
		(0.023)		(0.005)		(0.008)		(0.999)
Chile	2001:1-2016:12	0.181	*	-0.064	**	-0.708	**	8.73
		(0.097)		(0.03)		(0.256)		(0.557)
	Pre-Crisis	-0.235	***	0.103	***	-0.881	***	6.02
		(0.045)		(0.024)		(0.07)		(0.999)
	Post-Crisis	-0.5	**	0.201	**	-0.802	***	6.60
		(0.219)		(0.089)		(0.25)		(0.762)
Colombia	2002:1-2016:12	-0.943	***	0.006		-0.131	***	10.69
		(0.026)		(0.008)		(0.036)		(0.907)
	Pre-Crisis	-0.268	***	0.023		-0.17	***	14.48
		(0.069)		(0.024)		(0.035)		(0.697)
	Post-Crisis	-0.025	**	-0.027	***	2.102	***	8.23
		(0.011)		(0.003)		(0.977)		(0.975)
Dom. Republic	2001:1-2016:12	-0.79	***	0.123	***	-0.311	***	16.71
		(0.253)		(0.029)		(0.015)		(0.891)
	Pre-Crisis	-0.329	***	0.02	*	-0.122	***	11.45
		(0.111)		(0.011)		(0.007)		(-0.99)
	Post-Crisis	-1.758	*	0.538		-0.612		2.2
		(0.903)		(0.954)		(1.276)		(0.999)
Guatemala	2001:1-2016:12	-1.261	***	1.003	***	-1.591	***	6.93
		(0.144)		(0.199)		(0.133)		(0.999)
	Pre-Crisis	-0.726	***	1.686	***	-4.646	***	7.71
		(0.259)		(0.454)		(4.306)		(0.999)
	Post-Crisis	-0.774	***	0.324	***	-0.836	***	5.52
		(0.145)		(0.134)		(0.145)		(0.999)
Jamaica	2001:1-2016:12	-0.463		0.03		-0.131		3.31
		(1.168)		(0.323)		(2.053)		(0.992)
	Pre-Crisis	-2.375	***	0.7	***	-0.59	***	9.48
		(0.785)		(0.209)		(0.069)		(0.998)
	Post-Crisis	-1.276	**	0.627	*	-0.983	**	16.92
		(0.545)		(0.356)		(0.487)		(0.884)
Mexico	2001:1-2016:12	-0.145	***	0.068	***	-0.938	***	12.58
		(0.05)		(0.016)		(0.155)		(0.981)
	Pre-Crisis	-0.135	***	0.161	***	-2.377	***	12.66
		(0.049)		(0.027)		(0.894)		(-0.98)
	Post-Crisis	-0.107	***	0.055	***	-1.027	***	8.83
		(0.015)		(0.006)		(0.032)		(0.999)
Venezuela	2001:1-2016:12	-1.028	***	0.031	***	-0.061	***	4.75
		(0.178)		(0.005)		(0.000)		(0.999)
	Pre-Crisis	-9.384	***	0.147	***	-0.031	***	3.87
		(1.49)		(0.034)		(0.000)		(0.998)
	Post-Crisis	0.125	***	-0.005	***	0.08	***	1.00
		(0.011)		(0)		(0.000)		(0.999)

This table presents the asymmetric response of central bank foreign exchange intervention in nine Latin American countries. We present results for the period from approximately 2000 to 2016, as well as periods prior to and following the global financial crisis of 2008-2009. Values under coefficients in parenthesis represent standard errors, value in parenthesis for J-test represents p-value. *, **, *** represent significance levels of 10, 5, and 1 percent respectively.

Figure 2: Exchange Rates and FX Reserves: Asia



This figure presents the exchange rate (LCU/USD) and foreign exchange reserves from 2000 to 2016 for the eight Asian countries in our study.

Table 4: Asymmetric Intervention Response in Asia

		C2		C3		γ		J Test
Bangladesh	2001:1-2016:12	-4.183	***	1.005	***	-0.481	***	11.81
		(1.15)		(0.316)		(0.04)		(-0.85)
	Pre-Crisis	-2.365	***	0.811	***	-0.686	***	8.63
		(0.856)		(0.231)		(0.1)		(-0.96)
	Post-Crisis	-4.151	***	0.772	***	-0.372	***	6.69
		(0.44)		(0.111)		(0.004)		(-0.99)
India	2001:1-2016:12	0.073		-0.257	***	-7.109		3.85
		(0.244)		(0.083)		(584)		(-0.95)
	Pre-Crisis	-0.232		0.127		-1.10		6.04
		(0.497)		(0.485)		(23.10)		(-0.64)
	Post-Crisis	-0.257	***	-0.042	***	0.324	***	8.66
		(0.062)		(0.021)		(0.033)		(-0.56)
Indonesia	1998:1-2016:12	-1.24	**	0.042	***	-0.067	***	5.60
		(0.429)		(0.015)		(0.001)		(-0.84)
	Pre-Crisis	-0.73	**	0.039	***	-0.107	***	3.23
		(0.308)		(0.014)		(0.004)		(-0.97)
	Post-Crisis	-0.509	***	0.092	**	-0.363	***	9.00
		(0.119)		(0.037)		(0.029)		(-0.99)
Philippines	2001:1-2016:12	-0.452	***	0.172	**	-0.759	***	18.805
		(0.083)		(0.086)		(0.164)		(-0.80)
	Pre-Crisis	-0.311	***	0.127	***	-0.817	***	11.74
		(0.073)		(0.041)		(0.106)		(-0.98)
	Post-Crisis	-0.526	***	0.106	*	-0.404	***	13.73
		(0.086)		(0.057)		(0.052)		(-0.96)
South Korea	2001:1-2016:12	-0.055	***	0.038	***	-1.36	***	17.71
		(0.021)		(0.007)		(0.332)		(-0.85)
	Pre-Crisis	-0.068	***	0.054	***	-1.588	***	15.18
		(0.016)		(0.003)		(0.148)		(-0.93)
	Post-Crisis	-0.026	***	-0.019	**	1.449	***	14.86
		(0.009)		(0.007)		(0.56)		(-0.94)
Sri Lanka	2002:1-2016:12	-2.027	***	-0.849	***	0.838	***	1.00
		(0.009)		(0.001)		(0.000)		(-0.99)
	Pre-Crisis	-4.846	***	-2.171	***	0.896	***	8.49
		(1.188)		(0.501)		(0.091)		(-0.74)
	Post-Crisis	-2.68	***	0.795	**	-0.593	***	4.87
		(1.182)		(0.352)		(0.138)		(-0.96)
Thailand	1998:1-2016:12	-0.564	***	0.452	***	-1.602	***	7.76
		(0.215)		(0.124)		(0.563)		(-0.90)
	Pre-Crisis	-0.218	***	0.011	**	-0.099	***	10.54
		(0.032)		(0.004)		(0.002)		(-0.72)
	Post-Crisis	-0.515	***	0.525	***	-2.042	***	7.94
		(0.135)		(0.197)		(0.869)		(-0.89)
Vietnam	1998:1-2016:12	-3.922	***	0.627	***	-0.32	***	16.10
		(0.954)		(0.289)		(0.028)		(-0.91)
	Pre-Crisis	-2.081	***	0.308	**	-0.296	***	11.91
		(0.611)		(0.116)		(0.02)		(-0.98)
	Post-Crisis	-4.646	***	1.37	*	-0.59	***	16.48
		(1.639)		(0.703)		(0.135)		(-0.89)

This table presents the asymmetric response of central bank foreign exchange intervention in eight Asian countries. We present results for the period from approximately 2000 to 2016, as well as periods prior to and following the global financial crisis of 2008-2009. Values under coefficients in parenthesis represent standard errors, value in parenthesis for J-test represents p-value. *, **, *** represent significance levels of 10, 5, and 1 percent respectively.

According to the outcomes of C_3 and γ, there is strong evidence that central banks in these economies have an asymmetric response towards appreciation in the pre-crisis period. γ is consistently negative and significant in seven of the eight countries before the onset of the crisis as well as for the whole sample period. In Bangladesh, Indonesia, Philippines, Thailand and Vietnam, this asymmetric response is consistent in all three sample periods, showing the greater sensitivity of policymakers in these economies to appreciation pressures.

Yet, for South Korea and Sri Lanka, policymakers' aversion switches after the crisis. In South Korea from 2010 onward, there is a statistically significant asymmetric response to depreciation pressure with a positive γ, indicating that South Korea's central bank is in fact responding relatively more strongly to depreciation than appreciation pressures after the crisis. South Korea experienced a sharp depreciation during the crisis with an immediate response by the central bank, as seen in the fall in reserves between 2008 and 2009. After the crisis, it continues to accumulate reserves, yet the exchange rate is volatile but on a steady trajectory over this period. In Sri Lanka, the central bank preferences switch from an aversion to depreciation in the pre-crisis era, to an aversion to appreciation in the post-crisis era. This result is consistent with results from other less developed emerging markets, such as Nigeria and Kenya presented in Table 6. With high and volatile inflation, strong pass through effect and weaker institutions in the pre-crisis era, the central bank is more concerned with the effects of depreciation pressure on the stability of the economy. In Sri Lanka, inflation in the pre-crisis era ranged from 6.3 percent in 2003 to 14.2 percent in 2002, with price volatility of 47.2 percent.

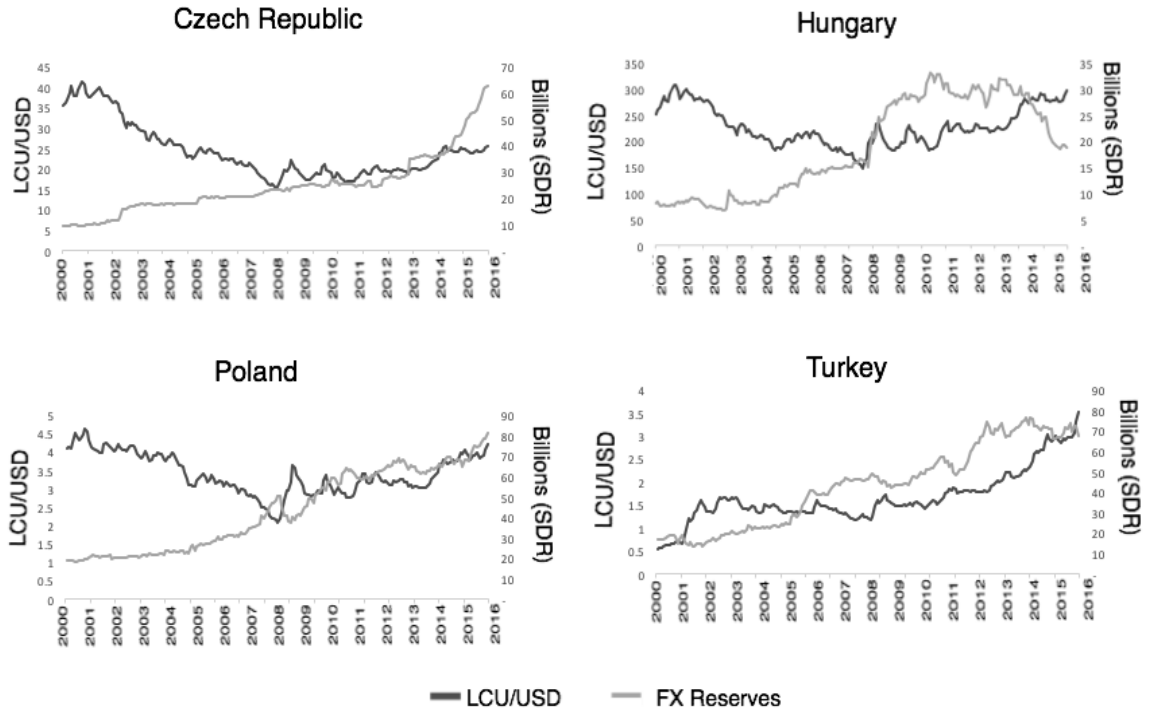
For India, we find significant results for an aversion to depreciation in the post-crisis era, but results are not significant in the pre-crisis era. India experienced a number of sharp depreciations in the post-crisis era, along with greater volatility in reserve accumulation, as seen in Figure 2 and Table 2. Results from Srinivasan et al. (2009) use weekly data from the Central Bank of India to show a significant aversion to appreciation from 2000 to 2006.[9]

4.3. Eastern Europe

Table 5 presents the results for three Eastern European countries and Turkey. Once again, C_2 is negative and significant consistently across all countries in all time periods. These central banks have also been responding to changes in their exchange rates in a way that would counter appreciation or depreciation of their currencies, once again showing statistically significant evidence that they are "leaning against the wind" and have been doing so both before and after the crisis. As seen in Figure 3, Czech Republic, Hungary and Poland have all experienced steady appreciation of their currencies since 2000 leading up to the crisis in 2008, with a sharp depreciation in 2008-2009. The period immediately following the crisis, which includes the European Debt Crisis in 2011, presents greater volatility in their exchange rates.

[9] We are not able to replicate the results from Srinivasan et.al (2009) for the pre-crisis era. We believe this is due to issues with data frequency. The authors used weekly data from the central bank, whereas we are using monthly data.

Figure 3: Exchange Rates and FX Reserves: Eastern Europe



This figure presents the exchange rate (LCU/USD) and foreign exchange reserves from 2000 to 2016 for the three Eastern European countries and Turkey in our study.

Table 5: Asymmetric Intervention Response in Eastern Europe

		C2		C3		γ		J Test
Czech Rep	1999:1-2016:12	-0.109	**	0.103	**	-1.885	***	11.02
		(0.043)		(0.033)		(0.901)		(-0.80)
	Pre-Crisis	-0.06	***	0.013	*	-0.432	***	8.96
		(0.04)		(0.008)		(0.147)		(-0.91)
	Post-Crisis	-0.22	***	0.057	***	-0.517	***	9.38
		(0.029)		(0.015)		(0.024)		(-0.89)
Hungary	2001:1-2016:12	-0.19	**	0.105	***	-1.104	***	10.67
		(0.084)		(0.032)		(0.355)		(-0.71)
	Pre-Crisis	-0.112	***	0.025	**	-0.452	***	7.13
		(0.022)		(0.011)		(0.046)		(-0.99)
	Post-Crisis	-0.075	***	0.062	***	-1.648	***	10.44
		(0.025)		(0.007)		(0.334)		(-0.99)
Poland	1999:1-2016:12	-0.097	***	0.016	**	-0.338	***	22.10
		(0.032)		(0.008)		(0.037)		(-0.62)
	Pre-Crisis	-0.071	**	0.039	***	-1.109	***	7.36
		(0.021)		(0.016)		(0.314)		(-0.91)
	Post-Crisis	-0.093	***	0.008	***	-0.166	***	18.52
		(0.026)		(0.005)		(0.012)		(-0.81)
Turkey	2001:1-2016:12	-0.154	***	0.01	**	-0.126	***	5.92
		(0.048)		(0.004)		(0.005)		(-0.82)
	Pre-Crisis	-0.154	*	0.023	***	-0.298	***	3.76
		(0.089)		(0.008)		(0.041)		(-0.95)
	Post-Crisis	-0.101	**	-0.073	***	1.458	**	8.01
		(0.043)		(0.017)		(0.496)		(-0.78)

This table presents the asymmetric response of central bank foreign exchange intervention in three Eastern European countries, and Turkey. We present results for the period from approximately 2000 to 2016, as well as periods prior to and following the global financial crisis of 2008-2009. Values under coefficients in parenthesis represent standard errors, value in parenthesis for J-test represents p-value. *, **, *** represent significance levels of 10, 5, and 1 percent respectively.

Similar to the countries in the previous regions discussed above, the outcomes of C_3 and γ present evidence that central banks in these economies have a stronger aversion towards appreciation. γ is consistently negative and significant in all countries, with the exception of Turkey in the post-crisis era. Policymakers in Czech Republic, Hungary and Poland all respond more significantly to incidences of appreciation in their currencies consistently throughout the all three periods in question.

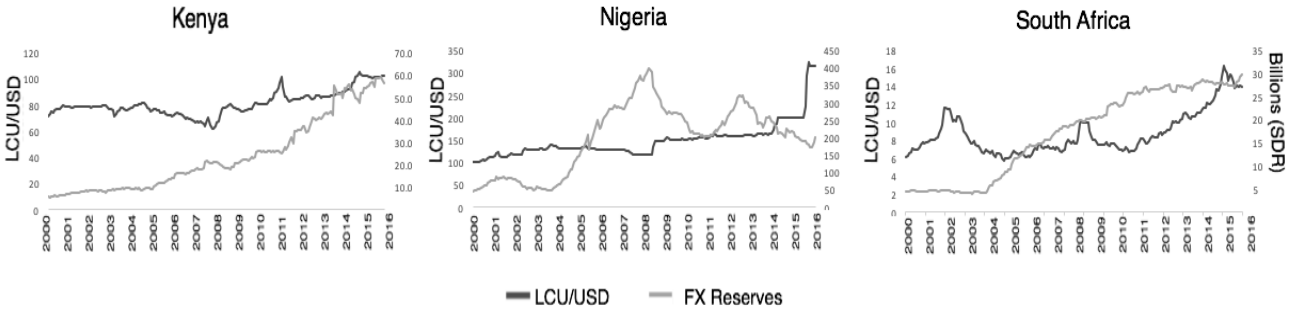
In Turkey after 2010, the negative C_3 and positive γ indicate that policymakers now have a greater aversion to depreciation pressure and take stronger action to restrain depreciation rather than appreciation. This may be due to the fact that after the crisis, the Turkish lira steadily depreciated while reserves continued to rise as a whole, but the accumulation/decumulation process became more volatile (Figure 3), similar to what is observed in Figure 2 South Korea.

4.4. Africa

Table 6 presents the results for three African countries. Once again, C_2 is negative and significant consistently across all countries in all time periods. These central banks have also been responding to changes in their exchange rates in a way that would counter appreciation or depreciation of their currencies, once again showing statistically

significant evidence that they are "leaning against the wind" and have been doing so both before and after the crisis.

Figure 4: Exchange Rates and FX Reserves: Africa



This figure presents the exchange rate (LCU/USD) and foreign exchange reserves from 2000 to 2016 for the three African countries in our study.

Table 6: Asymmetric Intervention Response in Africa

		C2		C3		γ		J Test
Kenya	2001:1-2016:12	-0.439	***	0.124	***	-0.566	***	14.95
		(0.109)		(0.052)		(0.075)		(0.942)
	Pre-Crisis	-0.75	***	-0.437	***	1.166	***	12.62
		(0.167)		(0.101)		(0.141)		(-0.98)
	Post-Crisis	-0.593	***	0.052	***	-0.176	***	13.93
		(0.092)		(0.025)		(0.008)		(0.962)
Nigeria	2001:1-2016:12	-2.016	***	0.106	***	-0.105	***	14.64
		(0.342)		(0.032)		(0.001)		(0.949)
	Pre-Crisis	-0.506	**	-0.307	***	1.214	***	12.41
		(0.204)		(0.079)		(0.339)		(0.982)
	Post-Crisis	-0.942	***	0.04	***	-0.085	***	11.48
		(0.274)		(0.014)		(0.002)		(-0.99)
South Africa	2001:1-2016:12	-0.143	***	0.034	***	-0.473	***	15.96
		(0.03)		(0.008)		(0.022)		(0.915)
	Pre-Crisis	-0.053	***	0.018	***	-0.661	***	11.04
		(0.022)		(0.005)		(0.119)		(0.992)
	Post-Crisis	-0.061	***	0.013	***	-0.44	***	12.10
		(0.019)		(0.007)		(0.069)		(0.985)

This table presents the asymmetric response of central bank foreign exchange intervention in three African countries. We present results for the period from approximately 2000 to 2016, as well as periods prior to and following the global financial crisis of 2008-2009. Values under coefficients in parenthesis represent standard errors, value in parenthesis for J-test represents p-value. *, **, *** represent significance levels of 10, 5, and 1 percent respectively.

Similar to the countries in the previous regions discussed above, the outcomes of C_3 and γ, present evidence that central banks in these economies have an asymmetric response to exchange rate movements. In South Africa, γ is consistently negative and significant across all periods. Yet, in Nigeria and Kenya, the negative C_3 and positive γ in the pre-crisis period indicate that policymakers reacted more strongly to depreciation pressure than

appreciation pressure in this time period.[10] For both countries, the period between 2001 and 2008 corresponds with high and volatile inflation rates. For Kenya, inflation ranged between 0.45 percent in January 2002 and 21.6 percent in January 2008, with price volatility over this period of 31.7 percent. For Nigeria, inflation ranged from a low of 5.37 percent in October 2002 to a high of 28.2 percent in August 2005, with price volatility of 27.1 percent. Countries with a high pass-through effect between exchange rates and domestic prices are more susceptible to high inflation as a result of depreciations. This may explain why policymakers in these two economies responded more drastically to depreciation pressures in the pre-crisis period. After the crisis, inflation rates stabilized in both countries, with average rates of 7.6 and 11.2 percent and price volatility of 12.7 and 7.2 for Kenya and Nigeria respectively.[11] Once inflation rates stabilized in the post-crisis era, these countries exhibit an asymmetric response to appreciation, similar to what is seen in the other regions.

Overall, the general consensus for central bank asymmetric response to appreciation is upheld in our findings for the majority of countries. Twenty three out of 24 emerging market economies experienced at least one period with an asymmetric response to appreciation. Eight countries experienced a change in their asymmetric responses after the crisis. For Colombia, South Korea, Turkey, and Venezuela, policymakers switch from an aversion to appreciation to an aversion to depreciation. In these economies, there was either greater depreciation pressure (Turkey and Venezuela) or a sharp depreciation followed by greater volatility (Colombia and South Korea) in the post-crisis era. In Brazil, Kenya, Nigeria, and Sri Lanka, policymakers switch from an aversion to depreciation to an aversion to appreciation in the post-crisis era, possibly corresponding to bouts of high and/or volatile inflation resulting from a strong pass through effect, making policymakers more wary of the depreciationary pressures. It is also clear that, across the board, central banks do react strongly and significantly to changes in their exchange rates by "leaning against the wind" with FX interventions. This is true in both pre- and post-crisis era, as well as for those economies that declare a managed float or a free float.

4.5. Crisis Period Analysis

Tables 7 and 8 present the GMM estimation results over the whole sample controlling for the crisis period (2008:1 - 2009:12) for each country. In Table 7, we are testing whether there is a change in coefficients C_2 and C_3 when controlling for the effects of the crisis period with dummy variable D, as seen in Eq. 12. For 16 countries, the crisis period response differs statistically from the non-crisis period response, indicated by the significant C_4 coefficients. For the majority of countries, C_2 remains negative and significant, indicating action to "lean against the wind" by policymakers through FX intervention. For 11 countries, C_3 remains positive and significant, showing a persistence in the asymmetric response to appreciation. For 6 countries, C_3 is negative and significant, indicative of a stronger aversion to depreciation. γ is calculated using C_2 and C_3 coefficients, as noted in Eq. 9. When controlling only for the presence of the crisis period via the dummy variable, D, there is still evidence of an aversion to appreciation in 10 out of 24 countries.

[10] This result is in line with Slavov (2011) that investigates central bank's reactions to depreciation as termed "fear of floating" by Calvo (2002) in 22 sub-Saharan African economies with floating regimes.

[11] Authors calculations, data from IMF International Financial Statistics.

Table 7: GMM Results Controlling for Crisis Period - 1

	C2		C3		C4		γ		J test
Latin America									
Argentina	-1.367	***	0.047	***	1.414	**	-0.068	***	13.48
	(0.174)		(0.007)		(0.567)		(-0.00)		(0.957)
Brazil	0.053		-0.003		-2.831	***	-0.109		8.93
	(0.034)		(0.004)		(0.791)		(0.907)		(0.997)
Chile	0.122		-0.124	***	0.879	**	-2.020		14.15
	(0.076)		(0.031)		(0.420)		(6.711)		(0.943)
Colombia	-0.104	***	0.012		0.302		-0.230	*	11.44
	(0.030)		(0.010)		(0.470)		(-0.15)		(0.832)
Dom Rep	-0.708	***	0.037		-2.442	***	-0.106	***	25.76
	(0.223)		(0.025)		(0.874)		(-0.00)		(0.365)
Guatemala	-0.412	***	0.475	**	-0.379		-2.310	***	7.27
	(0.142)		(0.214)		(0.287)		(0.412)		(0.999)
Jamaica	0.659		-0.133		-2.230	**	-0.403		10.40
	(0.635)		(0.185)		(1.019)		(0.882)		(0.992)
Mexico	0.268	***	0.028	***	-2.088	***	0.212	***	16.03
	(0.040)		(0.008)		(0.217)		(-0.01)		(0.994)
Venezuela	-0.872		0.022		-4.711	***	-0.050		4.62
	(1.432)		(0.032)		(1.640)		(-0.14)		(0.947)
Asia									
Bangladesh	-3.579	***	0.733	**	1.240	**	-0.410	***	9.94
	(0.837)		(0.315)		(0.537)		(0.024)		(0.906)
India	-0.234	**	-0.052		1.104		0.442		8.31
	(0.112)		(0.070)		(1.330)		(0.792)		(0.685)
Indonesia	-0.544	***	-0.058	**	0.227		0.212	***	14.22
	(0.101)		(0.026)		(0.458)		(0.023)		(0.941)
Philippines	-0.456	***	0.204	**	-0.817	*	-0.895	***	17.16
	(0.089)		(0.096)		(0.474)		(0.103)		(0.841)
S. Korea	-0.036	**	-0.012	***	-0.682	***	0.658		15.81
	(0.016)		(0.002)		(0.100)		(4.035)		(0.894)
Sri Lanka	4.882		-2.954	**	-10.587	**	-1.210	***	6.69
	(4.081)		(1.152)		(4.553)		(0.396)		(0.668)
Thailand	-0.398	***	0.251	***	0.667		-1.262	***	11.21
	(0.133)		(0.094)		(0.436)		(-0.13)		(0.592)
Vietnam	-1.053		-0.764		-4.982		1.451		15.51
	(1.191)		(0.598)		(1.279)		(3.054)		(0.904)
Eastern Europe									
Czech Rep	-0.019		-0.017	**	0.777	***	1.810		11.08
	(0.021)		(0.007)		(0.177)		(124.5)		(0.746)
Hungary	-0.058		-0.056	***	-0.259		1.925		7.65
	(0.057)		(0.019)		(0.568)		(32.34)		(0.865)
Poland	-0.142	**	0.033	**	-1.581	***	-0.471		7.15
	(0.061)		(0.012)		(0.562)		(-0.59)		(0.786)
Turkey	-0.227	***	0.024	**	-1.227	***	-0.211	***	8.12
	(0.069)		(0.011)		(0.351)		(-0.07)		(0.701)
Africa									
Kenya	-0.444	***	0.013		-1.324	***	-0.060	***	12.43
	(0.065)		(0.025)		(0.372)		(0.010)		(0.974)
Nigeria	-1.547	***	0.070	***	-0.761		-0.090	***	12.29
	(0.315)		(0.021)		(0.654)		(-0.00)		(0.976)
S.Africa	-0.060	***	0.018	***	0.216	*	-0.594		12.32
	(0.015)		(0.004)		(0.119)		(-0.66)		(0.975)

This table presents the asymmetric response of central bank foreign exchange intervention controlling for the crisis period from 2008:1 - 2009:12. γ is calculated based on Eq. 9. Values under coefficients in parenthesis represent standard errors, value in parenthesis for J-test represents p-value. *, **, *** represent significance levels of 10, 5, and 1 percent respectively.

Table 8 analyzes whether the asymmetric response by policymakers is altered during the crisis period by

allowing the dummy variable D to interact with $\tilde{e}_t$ and $\tilde{e}_t^2$.[12] In this table, γ_2 is calculated using the crisis period coefficients of C_5 and C_6 in addition to C_2 and C_3, as described in Eq. 14. What is most interesting to note from the results is that when controlling for the responsiveness of policymakers during the crisis period, not all policymakers are "leaning against the wind". It is evident that the reaction of policymakers is statistically different in the crisis versus non-crisis periods.

In half of the countries, C_5 is significant, indicating that the central bank's reaction to changes in exchange rates is different during the crisis period versus the non-crisis periods. The significant C_6 in 13 countries shows that policymakers' aversion to depreciation/appreciation differs during crisis period from the non-crisis period. Furthermore, since γ_2 is significant only for 5 countries, we can conclude that asymmetric preferences virtually disappear in the crisis period. What we can gather from the results is that the responses of policymakers were counterproductive or ineffective in trying to curb the depreciation pressure during this volatile period. These results uphold the general consensus in the literature that FX interventions tend to be ineffective when there are structural changes or changes in macro-fundamentals.

5. Conclusion

Foreign exchange intervention is a topic heavily discussed in economic literature and has real world implications for many emerging market economies. Policymakers in these economies are acutely aware of the risks associated with drastic exchange rate movements. Many have stated that the purpose of intervening is to minimize volatility in currency values, yet from this research, there is a clear preference to intervene when the value of the domestic currency is rising.

From the research presented in this paper, we have found that the preference to intervene during periods of appreciation has remained consistent both before and after the crisis in the majority of countries under study. Therefore, policymakers in emerging market economies are concerned with the effect on competitiveness from an appreciation, knowing that keeping the currency undervalued may in fact promote growth and stimulate economic activity.

We also find that there is statistically significant evidence that policymakers are intervening to mitigate excessive movements in their exchange rates, even when declaring a free floating currency. This is true across regions, as well as across periods. Therefore, even with an asymmetric preference to mute appreciation pressure, policymakers continue to intervene to promote exchange rate stability.

Our next steps in research extend the asymmetric model to analyze the monetary policy responses in times of appreciation versus depreciation for emerging market economies that have adopted inflation targeting. This research will examine whether the asymmetric bias in intervention during appreciationary periods also translates to an asymmetric policy with respect to reaching inflation targets. With a growing number of emerging market economies dedicated to inflation targeting, yet also susceptible to fluctuations in exchange rates, it is critical to understand whether policymakers react differently to maintain credibility and reach their stated monetary policy goals. As we have already discussed, emerging markets differ from advanced economies in their vulnerability to exchange rate volatility, and therefore policymakers in these economies may also react to exchange rate fluctuations differently to reach their monetary policy goals.

[12] Venezuela is excluded from the analysis since the value of the currency remained fixed during the crisis period, yielding an error in the results. See Figure 1 as reference.

Table 8: GMM Results Controlling for Crisis Period - 2

	C2		C3		C4		C5		C6		γ_2		J test
Latin America													
Argentina	-1.402	***	0.045	***	0.866		2.698	***	-0.270	***	-0.348	***	15.6
	(0.266)		(0.011)		(0.701)		(0.559)		(0.098)		(0.051)		(0.830)
Brazil	0.067		-0.038		0.120		0.196		0.041		0.028		14.9
	(0.056)		(0.017)		(0.303)		(0.183)		(0.023)		(0.049)		(0.863)
Chile	-0.030		-0.072		2.707	***	1.103	***	-0.035		-0.199		14.8
	(0.161)		(0.135)		(0.617)		(0.284)		(0.131)		(0.127)		(0.867)
Colombia	-0.022		-0.041		-1.249		-0.010		0.046		-0.313		9.95
	(0.04)		(0.011)		(0.339)		(0.074)		(-0.01)		(1.807)		(-0.98)
Dom Rep	-0.502	***	0.037		-2.367	*	13.375		-22.063	*	-3.422		19.18
	(0.180)		(0.024)		(1.468)		(10.36)		(12.57)		(11.41)		(0.633)
Guatemala	-0.071		0.903	***	0.650		-1.002	**	-1.137	**	0.436		7.16
	(0.226)		(0.336)		(0.500)		(0.566)		(0.532)		(1.439)		(0.998)
Jamaica	0.781		-0.249		-3.049	**	0.664		0.024		-0.312		10.04
	(0.828)		(0.283)		(1.347)		(2.172)		(0.488)		(0.862)		(0.985)
Mexico	0.144		0.058	**	-1.709	***	0.244	**	-0.035		0.119	***	17.20
	(0.087)		(0.025)		(0.321)		(0.111)		(0.032)		(0.046)		(0.978)
Asia													
Bangladesh	-3.529	**	0.732	**	0.908		12.622	*	-37.655	**	-8.122		10.05
	(0.862)		(0.321)		(1.045)		(7.191)		(18.91)		(59.16)		(0.816)
India	-0.225	***	-0.054		-2.229	**	-0.460		0.180	*	-0.367	***	12.21
	(0.106)		(0.047)		(1.004)		(0.314)		(0.102)		(0.140)		(0.952)
Indonesia	-0.648		-0.369	***	0.110		1.467	***	0.302	***	-0.163		12.61
	(0.207)		(0.108)		(0.637)		(0.352)		(0.110)		(0.150)		(0.943)
Philippines	-0.078		0.520	***	1.499	**	0.369		-1.111	***	-4.067		16.02
	(0.202)		(0.187)		(0.610)		(0.234)		(0.185)		(22.07)		(0.814)
S. Korea	-0.026	*	0.026		-0.318	**	-0.230	***	-0.026		0.000		16.34
	(0.025)		(0.022)		(0.149)		(0.037)		(0.023)		(0.064)		(0.798)
Sri Lanka	-2.379	**	0.205		-4.352	***	10.017	***	-0.723		-0.136	***	3.154
	(1.434)		(0.471)		(1.553)		(1.885)		(0.569)		(0.039)		(0.977)
Thailand	-0.543		0.471	**	1.445	**	1.440	*	-0.036		0.970		8.890
	(0.248)		(0.183)		(0.720)		(0.786)		(0.376)		(1.666)		(0.632)
Vietnam	-2.801		-0.982		-5.547	***	3.271		0.488		-2.100		17.28
	(2.563)		(1.558)		(1.455)		(3.194)		(1.937)		(610.2)		(0.747)
Eastern Europe													
Czech Rep	-0.027		0.025		1.344	***	0.144		-0.063	**	-0.659		7.54
	(0.034)		(0.016)		(0.346)		(0.118)		(0.024)		(0.742)		(0.872)
Hungary	-0.002	*	-0.071		4.148	**	0.454		-0.286	**	-1.580		5.15
	(0.090)		(0.073)		(1.853)		(0.321)		(0.122)		(1.760)		(0.923)
Poland	-0.268	*	0.127	*	3.647	**	1.142	***	-0.195	**	-0.155	***	3.91
	(0.153)		(0.067)		(1.582)		(0.433)		(0.087)		(0.070)		(0.916)
Turkey	-0.131		-0.021		-0.917	***	-0.075		0.044	*	-0.223		7.92
	(0.070)		(0.021)		(0.286)		(0.212)		(0.023)		(0.154)		(0.541)
Africa													
Kenya	-0.647	***	-0.039		-1.611	***	0.674	**	0.046		0.495		11.83
	(0.190)		(0.075)		(0.527)		(0.307)		(0.069)		(105.5)		(0.960)
Nigeria	-1.520	***	0.068	***	-1.078		1.225		-0.113	*	0.307		12.02
	(0.436)		(0.025)		(0.785)		(0.772)		(0.055)		(1.017)		(0.956)
S.Africa	-0.166		0.028	**	0.067		0.137	**	-0.028	**	-0.018		13.79
	(0.033)		(0.010)		(0.190)		(0.055)		(0.011)		(1.259)		(0.908)

This table presents the asymmetric response of central bank foreign exchange intervention controlling for the crisis period from 2008:1 - 2009:12. This table presents the asymmetric response of central bank foreign exchange intervention controlling for the crisis period from 2008:1 - 2009:12. γ_2 is calculated based on Eq. 14, representing the asymmetric preference parameter for the crisis period. Values under coefficients in parenthesis represent standard errors, value in parenthesis for J-test represents p-value. *, **, *** represent significance levels of 10, 5, and 1 percent respectively.

Almekinders, G. J. and S. C. W. Eijffinger (1996). A Friction Model of Daily Bundesbank and Federal Reserve Intervention. *Journal of Banking and Finance 20*, 1365–1380.

Benlialper, A., H. Cömert, and N. Öcal (2015). Asymmetric Exchange Rate Policy in Inflation Targeting Developing Countries. *Economic Research Center Working Paper* (1702), 1365–1380.

Calvo, G. and C. Reinhart (2002). Fear of Floating . *The Quarterly Journal of Economics 117*.

Devereux, M. and C. Yu (2017). Exchange Rate Adjustment in Financial Crises. *IMF Economic Review*, 1 – 35.

Fratzscher, M. (2009). What Explains Global Exchange Rate Movements During the Financial Crisis? *European Central Bank Working Paper Series* (1060).

Hansen, L. (1982). Large Sample Properties of Generalized Method of Moments Estimators. *Econometrica 50*, 1029 – 286.

Keefe, H. G. and E. Rengifo (2015). Options and Central Bank Currency Market Intervention: The Case of Colombia. *Emerging Markets Review* (23), 1–25.

Lahura, E. and M. Vega (2013). Asymmetric Effects of FOREX Intervention Using Intraday Data: Evidence from Peru. *BIS Working Paper 430*, 1 – 47.

Levy-Yeyati, E., F. Sturzenegger, and P. Gluzmann (2012). Fear of appreciation. *Journal of Development Economics 101*, 233–247.

Levy-Yeyati, P. and F. Sturzenegger (2007). Fear of Floating in Reverse: Exchange Rate Policy in the 2000s . *Harvard Faculty Research Working Papers Series*.

Luukkonen, R., P. Saikkonen, and T. Terasvirta (1988). Testing Linearity Against Smooth Transition Autoregressive Models. *Biometrika 75*, 491–499.

Pontines, V. and R. Rajan (2011). Foreign Exchange Market Intervention and Reserve Accumulation in Emerging Asia: Is There Evidence of Fear of Appreciation? *Economic Letters 111*, 252 –255.

Pontines, V. and R. Siregar (2012). Exchange Rate Asymmetry and Flexible Exchange Rates under Inflation Targeting Regimes: Evidence from Four East and Southeast Asian Countries. *Review of International Economics 20*(5), 893–908.

Rey, H. (2013a). Dilemma not Trilemma: The Global Cycle and Monetary Policy Independence. *Proceedings - Economic Policy Symposium - Jackson Hole*.

Rey, H. (2013b). International Channels of Transmission of Monetary Policy and the Mundellian Trilemma. *CEPR Discussion Papers* (11027).

Rossini, R., Z. Quispe, and E. Serrano (2011). Capital Flows, Monetary Policy and FOREX Interventions in Peru. *Central Reserve Bank of Peru Working Paper Series 008*.

Slavov, S. (2011). De Jure versus De Facto Exchange Rate Regimes in Sub-Saharan Africa. *IMF Working Paper Series IMF/11/198*.

Srinivasan, N., V. Mahambare, and M. Ramachandran (2009). Preference Asymmetry and International Reserve Accretion in India. *Applied Economic Letters 16*(15), 1543 –1546.

Surico, P. (2007). The Fed's Monetary Policy Rule and U.S. Inflation: The Case of Asymmetric Preferences . *Journal of Economic Dynamics and Control 31*, 3305 – 3324.

van Dijk, D., T. Terasvirta, and P. Franses (2002). Smooth Transition Autoregressive Models—A Survey of Recent Developments. *Econometric Reviews 21*, 1 – 47.

Wang, Y., X. Li, Y. Li, and L. M. (2015). A Study on Asymmetric Preference in Foreign Exchange Market Intervention in Emerging Asia. *ICHSSR Conference Paper*.

6. Appendix

Taylor Series Expansion to derive the loss function:

$$f(x) = f(a) + f'(x)(x-a) + \frac{f''(a)}{2!}(x-a)^2 + \frac{f'''(a)}{3!}(x-a)^3 + ... + \frac{f^{(n)}(a)}{n!}(x-a)^n + ...$$

when $a = e^*$, and $f(\tilde{e}_t) = \exp(\delta(\tilde{e}_t - e^*)) - 1$, we see $f(e^*) = 0$, $f'(\tilde{e}_t)|_{e^*} = \gamma \exp(\gamma(\tilde{e}_t - e^*))|_{e^*} = \gamma$, $f''(\tilde{e}_t)|_{e^*} = \gamma^2 \exp(\gamma(\tilde{e}_t - e^*))|_{e^*} = \gamma^2$, $f'''(\tilde{e}_t)|_{e^*} = \gamma^3 \exp(\gamma(\tilde{e}_t - e^*))|_{e^*} = \gamma^3$, ...

Loss function:

$$L_t = \frac{1}{2}(R_t - R^*)^2 + \left(\frac{\lambda}{\gamma^2}\right)\left(0 + \frac{\gamma(\tilde{e}_t - e^*)}{1} + \frac{\gamma^2(\tilde{e}_t - e^*)^2}{2!} + \frac{\gamma^3(\tilde{e}_t - e^*)^3}{3!} + ... - \gamma(\tilde{e}_t - e^*)\right). \tag{15}$$