# Chapter 7

# Do Asian Countries Fear Appreciation Against the Renminbi ?

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# CHAPTER 7

# Do Asian Countries Fear Appreciation Against the Renminbi?

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*Our study brings out the evidence of a fundamental role for the Chinese renminbi in shaping the exchange rate behavior of other major Asian currencies. Our results suggest that there is an additional dimension to the 'fear of appreciation' or 'fear of floating in reverse'—a term initially coined by Levy-Yeyati and Sturzenegger (2007). In particular, we find that there is a greater degree of aversion to appreciation of the same Asian currencies against the renminbi than against the US dollar during the period that characterized the heavy reserve accumulation of 2000–06 and prior to the Global Financial Crisis (GFC). While this phenomenon all but disappeared during the GFC, there are indications in the results that a reassertion of this fear of appreciation after the GFC has re-emerged among Asian currencies, particularly against the US dollar but not against the Chinese renminbi. Nonetheless, it is most likely the case that this fear of appreciation against the Chinese currency will re-emerge in the near term in view of direct trade competition between countries in the region as well as in third markets. The policy implication may be that for the process of global rebalancing to begin in Asia governments must be able to address the wariness of other Asian currencies to losing their competitiveness to China as well as their general fear of appreciation.*

***Keywords***: exchange rate asymmetry, fear of floating, fear of appreciation, regime switching model

***JEL Classifications***: E58, F31, F41

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## 1. Introduction

It has been argued that one of the biggest inconsistencies in the global economy today is the fact that emerging Asian economies have rebounded faster than any other region, with a widening gap between their average growth rate and that of developed economies, yet most of their currencies have fallen since 2008 in real trade-weighted terms (The Economist, 2009). Moreover, concerns about the global consequences of exceptionally loose monetary policy in the United States and other developed markets continue as capital flows to emerging markets around the globe, especially in Asia, have been picking up and fears of appreciating local currencies remain a key policy concern.

Against this backdrop, the objectives of our paper are as follows. The first is to investigate and assess the exchange market interventions carried out by selected central banks in the East and Southeast Asian region—namely, Bank Indonesia, Bank of Korea, Bangko Sentral Ng Pilipinas, Bank of Thailand and the Monetary Authority of Singapore. For this purpose and noting that these five Asian countries do not release their respective foreign exchange positions to the public, we will imperfectly resort to exploiting the underlying concept of an exchange market pressure (henceforth EMP) and construct the EMP index for these five major Asian currencies. In doing so, we hope that, based on the sign and magnitudes of the EMP index, we are able to initially ascertain the *de facto* exchange rate policy stance of these five Asian countries. This is understandably important as four of the five countries we examined in this paper have officially adopted inflation-targeting regimes and, as such, we intrinsically expect that being official inflation targeters should lead to greater flexibility in their exchange rates. In conformity with the voluminous literature on the fear of floating, however, there is a general reluctance on the part of emerging market countries, including the five economies examined here, to float their currencies freely.[1]

Nonetheless, a current nuance of the apparent move towards allowing some greater flexibility in exchange rates is that for various reasons it is possible that the degree of

[1] The typical reasoning advanced is that in the presence of large stocks of un-hedged foreign currency-denominated debt and high pass-through, allowing currencies to float freely means tolerating the substantial exchange rate volatility that ensues, which can be harmful to the economy.

flexibility is significantly higher on one side of the market.[2] In other words, the monetary authorities in these four Asian economies can asymmetrically manage their exchange rates wherein they can allow for some currency depreciation while substantially limiting the extent of currency appreciation. For lack of better alternatives, this exchange rate intervention behavior has been called by Levy-Yeyati and Sturzenegger (2007) "fear of floating in reverse" or "fear of appreciation". Accordingly, the next important objective of this paper is to verify evidence of asymmetrical exchange rate behavior—that is, the presence, if any, of fear of appreciation on the part of the five monetary authorities mentioned. Lastly, we also investigate whether this fear, if it exists, extends not just to the exchange rates of the five Asian currencies with respect to the US dollar but also *vis-à-vis* the Chinese renminbi.

There have been a few recent works that examine such central bank aversion to exchange rate appreciations in East Asia. Ramachandran and Srinivasan (2007), for instance, employ a simple dummy variable to account for depreciations and appreciations. On the other hand, Srinivasan et al. (2008) explore a cubic loss function to account for possible asymmetrical behavior. The study of Stigler et al. (2009) applies time-series techniques in the context of structural change of the exchange rate regime. Furthermore, Pontines and Rajan (2010) similarly employ the cubic loss function of Srinivasan et al. (2008) and test the model that includes not only India, but also a broader set of emerging Asian economies known to operate a variety of managed floats: Indonesia, Korea, the Philippines, Singapore and Thailand.

None of these earlier studies, however, goes further and examines possible factors contributing to this asymmetrical exchange rate behavior in Asia. In particular, none has considered the plausible influence of the Chinese renminbi on asymmetrical exchange rate management of these Asian currencies, especially post the 2005 exchange rate policy reform in China.[3] It is quite surprising that in spite of the rapidly emerging

[2] See, for instance, Stigler et al. (2009) for this set of plausible reasons.

[3] In July 2005, the People's Bank of China (PBC) announced its policy intention to set the value of the renminbi with reference to a basket of foreign currencies, and to allow the currency to move more flexibly. The outcome was arguably a more measured and deliberate approach akin to a managed crawl whereby the currency was allowed to appreciate by about 20 percent against the US dollar from 2005 to late 2008.

role of the Chinese economy in Asia in particular, and in the world in general, the literature to our knowledge has been silent on the possible influence of the renminbi with regards to the issue of asymmetrical exchange rate behavior in Asia. In view of the potential ramifications of this fear of appreciation in Asia to the issue of global rebalancing, let alone that it touches on sensitive regional 'competitiveness' issues, the latter of which we will expound on later in the analysis, it is a logical and interesting research issue that is worth pursuing.

The rest of the paper is set out as follows. Discussion on exchange rate intervention and its underlying motivation is presented next. Section 3 discusses model specifications and the econometric testing employed to assess the degree of asymmetrical exchange rate behavior. The key empirical findings are analyzed and highlighted in Section 4. In the following section, we present and examine bilateral trade patterns of the five Asian economies. The main objective of this section is to further substantiate the analyses presented in Section 4. A brief concluding section ends the paper.

## 2. Exchange Rate Intervention and Exchange Market Pressure

As is illustrated and documented in early seminal works, countries often intervene to limit a sudden or large currency depreciation (Calvo and Reinhart, 2002) or strongly fear a sudden or large currency appreciation (Levy-Yeyati and Sturzenegger, 2007). In other words, even under an observed shift to flexible exchange rate regimes, the pursuit of an active exchange rate policy as part of a "leaning against the wind exchange rate policy" might still be the norm.[4] To initially investigate the possibility of what can be labeled an asymmetrical exchange rate regime, we resort to a useful and commonly applied concept of EMP index in the spirit of Kaminsky et al. (1998) and Kaminsky and Reinhart (1999), which can be formally expressed as follows:

[4] The earlier study of Almekinders and Eijffinger (1996) finds that during the post-Louvre period, US and German central banks tried to counteract appreciations of their currency more strongly than depreciations.

$$EMP_{i,t} = \frac{\Delta e_{i,t}}{e_{i,t}} - \frac{\sigma_e}{\sigma_r}\frac{\Delta r_{i,t}}{r_{i,t}} + \frac{\sigma_e}{\sigma_{\text{int}}}\Delta \text{int}_{i,t} , \tag{1}$$

where $(EMP_{i,t})$ is the exchange market pressure index for country $(i)$ in period $(t)$; $e_{i,t}$ is the unit of country *i*'s currency per US dollar in period *t*; $(\sigma_e)$ is the standard deviation of the rate of change in the exchange rate $\left(\frac{\Delta e_{i,t}}{e_{i,t}}\right)$; $(r_{i,t})$ is the gross foreign reserves of country $(i)$ in period *t*; and $(\sigma_r)$ is the standard deviation of the rate of change in reserves $\left(\frac{\Delta r_{i,t}}{r_{i,t}}\right)$; $(\text{int}_{i,t})$ is the nominal interest rate for country $(i)$ in period *t*, and $(\sigma_{\text{int}})$ is the standard deviation of the change in the nominal interest rate, $(\Delta \text{int}_{i,t})$.

As contrasted with similar constructions of the EMP index,[5] in the above equation, one can see the different weights given to these three key components of the exchange market pressure index. In particular, the weights of the interest rate and reserve fluctuations depend on the relative size of their standard deviations—$(\sigma_r)$ and $(\sigma_{\text{int}})$, respectively—against that of the exchange rate, $(\sigma_e)$. Hence, a positive (negative) EMP index suggests the presence of selling/depreciation (buying/appreciation) pressures on the local currency.

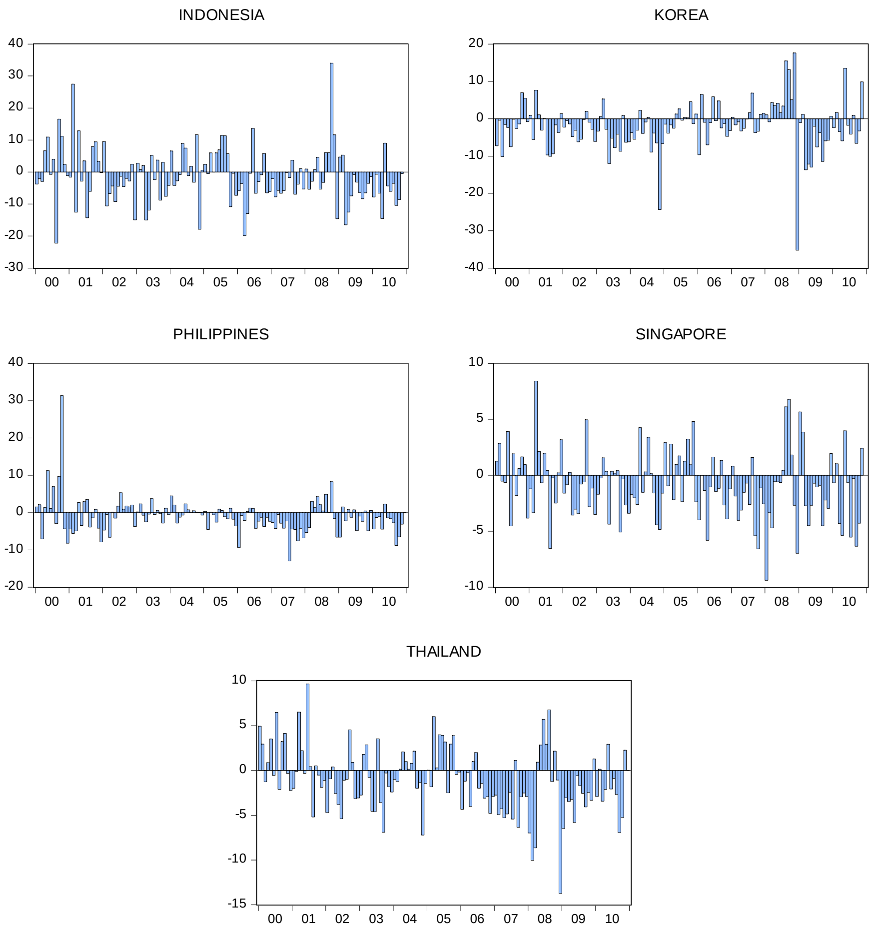
Given the lack of either official disclosure on the foreign exchange intervention or the currency composition and denominations of foreign exchange reserves of these five economies included in our study, we follow the standard approach of calculating the EMP based on the US dollar exchange rate and the foreign exchange reserves expressed in US dollars. For the basic purpose of tracing the presence of active foreign exchange market intervention, it is sufficient for the EMP construction to be derived as above.

In general, we found all currencies included in our study experienced buying pressure (negative EMP) before the Global Financial Crisis (GFC: 2000–07) and for

[5] See, for instance, Eichengreen et al. (1995, 1996).

most of 2008–10, with the exception of the last quarter of 2008 and the first quarter of 2009, when the currencies of most emerging markets were under selling pressure following the closure of Lehman Brothers (Figure 1). We also found, during most parts of 2000–10, a steady accumulation of foreign exchange reserves. Combining this evidence of buying/appreciation pressures and reserve accumulation, one cannot dismiss the possibility of a "leaning against the wind" policy stance adopted by the central banks of these countries during the period of observation. The trends and individual components of the EMP provide indications of policy interventions to manage the volatility of the local currencies. More importantly, the initial evidence also shows that the efforts tend to be biased towards mitigating appreciation pressures rather than depreciation pressures. Hence, there seems to be evidence of asymmetrical exchange rate intervention behavior. In turn, a set of empirical testing will be carried out to formally confirm the presence of fear of appreciation and to trace the possible role of the Chinese renminbi in this asymmetrical exchange rate intervention behavior.

**Figure 1. Exchange Market Pressure Index**



## 3. Empirical Approach

### 3.1. Smooth Transition Auto-Regressive (STAR) Model

The smooth transition auto-regressive (STAR) model is a nonlinear time-series model that allows the variable under investigation—in the present case denoted as Δln*exr*, the first difference of the log of the nominal exchange rate (local currency per US dollar or the Chinese renminbi)—to adjust smoothly every moment within different regimes. This model may be written as:

$$\Delta \ln exr = \alpha_0 + \sum_{i=1}^{p} \alpha_i (\Delta \ln exr_{t-i}) + \left[ \beta_0^* + \sum_{i=1}^{p} \beta_i^* (\Delta \ln exr_{t-i}) \right] F(\Delta \ln exr_{t-d}) + \varepsilon_t \quad (2)$$

,

where $\alpha_0$ is the linear intercept term; $\alpha_i$ ($i$ = 1, …, $p$) stand for the linear auto-regressive parameters; $\beta_0^*$ is the nonlinear intercept term, $\beta_1^*$ ($i$ = 1, …, $p$) stand for the nonlinear auto-regressive parameters, $F(\Delta \ln exr_{t-d})$ is the transition function that characterized the smooth transition between two regimes that depend on the lagged term of the first difference of the log of the nominal exchange rate, $\Delta \ln exr_{t-d}$, where $d$ is the delay lag length, and $\varepsilon_t$ is a white noise with zero mean and constant variance.

The theoretical and empirical aspects of this model are rather involved and extensively discussed in a number of studies. Interested readers should refer to Dijk et al. (2002) and Terasvirta and Anderson (1992) for a thorough discussion of STAR models. Nonetheless, depending on the specification of the transition function, the natural starting point in describing the STAR model is the two-regime LSTR1 model with the following general logistic transition function, which takes values in the interval between zero and one:

$$F(\gamma, c; y_{t-d}) = \frac{1}{1+\exp(-\gamma(y_{t-d}-c))}, \quad \gamma > 0 \quad (3)$$

,

where $\gamma$ is the slope parameter (the magnitude of which measures the speed of transition between the two regimes), $c$ is the threshold parameter (the value of which indicates the location of the transition) and $y_{t-d}$ is the transition variable with the associated delay parameter $d$.

It turns out that a variant of the LSTR1 model is well suited to testing whether East Asian currencies exhibit aversion to appreciations. In particular, one can resort to the LSTR2 model suggested in Terasvirta (1998).[6] The transition function of the LSTR2 model is the second-order logistic function:

$$F(\gamma, c_L, c_H; y_{t-d}) = \frac{1}{1+\exp(-\gamma(y_{t-d}-c_L)(y_{t-d}-c_H))}, \quad \gamma > 0 \tag{4}$$

Notice that the LSTR2 transition function resembles the transition function of the LSTR1 model but the LSTR2 transition function involves two threshold parameters: $c_L$ (the lower or appreciation threshold) and $c_H$ (the upper or depreciation threshold). These lower ($c_L$) and upper ($c_H$) threshold parameters can be utilized to test for asymmetrical exchange rate behavior as these thresholds measure the relative tolerance of monetary authorities of exchange rate variations. To be more specific, if the upper threshold, $c_H$, is larger than the (absolute value of the) lower threshold, $c_L$, this suggests monetary authorities' aversion to currency appreciations.[7]

## 4. Empirical Results

Our estimation is based on weekly data for the five Asian countries—namely, Indonesia, Korea, the Philippines, Singapore and Thailand—and we divided the estimation into three distinct periods: pre GFC (January 2000 – December 2006), GFC (January–July 2009), and post GFC (August 2009 – March 2011). All nominal exchange rate (domestic currency per US dollar and Chinese renminbi, respectively) data for these countries are obtained from the Pacific Exchange Rate Service (http://fx.sauder.ubc.ca). The rationale for the choice of the three distinct periods is

[6] The other possible choice of the transition function is given by the exponential transition function: $F(\gamma,c;\ y_{t-d}) = 1 - \exp(-\gamma(y_{t-d} - c)^2)$. One limiting behavior though of the ESTAR model is that for large values of $\gamma$, this model becomes practically indistinguishable from a linear model.

[7] It should be noted at this point that since the nominal exchange rate is defined in this paper as the local currency with respect to either the US dollar or the Chinese renminbi, the lower ($c_L$) threshold parameter corresponds with the central banks' tolerance of appreciation (appreciation threshold), whereas the upper ($c_H$) threshold parameter corresponds with the central banks' tolerance of depreciation (depreciation threshold) of its local currency with respect to the two benchmark currencies.

based on the view that the bulk of reserve accumulation occurred during the pre-GFC period, as evidenced from official reserves data and numerous academic studies; the period of the GFC captures the massive volatilities experienced by the countries examined and, consequently, led to the drawdown or de-accumulation of reserves by these same countries; while the post-GFC period correspond with the several months after the collapse of Lehman Brothers and is in agreement with official announcements and publications by international multilateral institutions of a global economic recovery that is under way.

In general, the construction of STAR models follows the same steps as in the ARIMA–Box–Jenkins modeling approach,[8] wherein the modeling cycle consists of model specification, parameter estimation, and diagnostic evaluation. While the linearity tests conducted easily reject in favor of STAR-type models in all cases, in view of the stated objective of this paper, it is only sensible that we automatically resort to fitting a LSTR2 model to the data and leave to the diagnostic stage the question of whether this choice is appropriately supported by the data.[9] Appendix Tables A1a–c present the estimation results of our LSTR2 models for the pre-GFC (Table A1a), GFC (Table A1b), and post-GFC periods (Table A1c) in that respective order using the first-difference of the log of the nominal exchange rate defined as the domestic currency per US dollar. The Appendix Tables A2a–c present the estimation results of our LSTR2 models using the first-difference of the log of the nominal exchange rate defined as the domestic currency per Chinese renminbi for the same respective periods of the pre-GFC (Table A2a), GFC (Table A2b), and post-GFC periods (Table A2c) also in that respective order.

In every table, the first two rows of results present the auto-regressive order $p$ chosen (first row) and the optimal delay lag length $d$ (second row).[10] From these reported $p$ and $d$ values in each table, Appendix Tables A1a–c and A2a–c also report the

[8] See Box and Jenkins (1970).

[9] For more discussion of this procedure, see Terasvirta (1998).

[10] The reported auto-regressive order $p$ was chosen according to the partial auto-correlation function (PACF) and selection criterion such as the Akaike information criterion, whereas the reported optimal delay lag length $d$ was chosen according to the smallest $p$-value of the linearity tests. These results are not reported here for the sake of brevity, but are available from the authors upon request.

corresponding estimation results of fitting LSTR2 models for the five East Asian currencies. The majority of the estimated coefficients in each table is statistically different from zero. More importantly, as reported in the last row of Appendix Tables A1a–c and A2a–c, the residuals from the fitted LSTR2 models are all random and white noise, which suggests the suitability of fitting an LSTR2 model in the nominal exchange rate data of the five East Asian currencies.

We now examine our main focus of interest: the lower or appreciation threshold ($c_L$) and upper or depreciation thresholds ($c_H$) from the fitted LSTR2 models, which are presented in Table 1. This table is divided into three panels: the upper panel contains the estimated lower and upper thresholds for the pre-GFC period, the middle panel reports the lower and upper thresholds for the GFC period, and the lower panel contains the lower and upper thresholds for the post-GFC period. Each period would then report the lower and upper thresholds for the two nominal exchange rate definitions of the domestic currency with respect to the US dollar and the Chinese renminbi, respectively. Turning first to the estimated lower and upper thresholds for the pre-GFC period (domestic currency with respect to the US dollar), these are at 1.34and 3.83 percent, respectively, for the Indonesian rupiah; 1.49 and 2.12 percent for the Korean won; –1.8 and 3.88 percent for the Philippine peso; –0.39 and 0.71 percent for the Singapore dollar; and –0.07 and 1.9 percent for the Thai baht. This shows that in all five of the East Asian currencies considered, the upper threshold, $c_H$, is larger than the (absolute value of the) lower threshold, $c_L$, which indicates a lower threshold tolerance or aversion from the concerned monetary authorities in these countries to currency appreciations against the US dollar. This is likewise the outcome we obtain when we examine the case of the nominal exchange rate defined in terms of the domestic currency per Chinese renminbi: 0.84 and 7.02 percent, respectively, for the Indonesian rupiah; 1.2 and 2.49 percent for the Korean won; 0.26 and 0.24 percent for the Philippine peso; 0.57 and 1.93 percent for the Singapore dollar; and 0.95 and 1.96 percent for the Thai baht.

In other words, our results firmly support the case that during the pre-GFC period the monetary authorities in these five countries exemplified a lower threshold tolerance of or aversion to currency appreciations regardless of whether one looks at the nominal exchange rate defined as the domestic currency against the US dollar or the Chinese renminbi. More interestingly, it is also clear from the absolute differences between $c_H$ and $c_L$ that, with the lesser exception of the Philippine peso, the remainder of the East Asian currencies considered exemplify a much greater aversion to appreciations when the Chinese renminbi is used as the comparator base currency. Furthermore, apart from the clear absence of a relative tolerance or allowance for sizeable appreciations against the Chinese renminbi, we also observe a greater relative tolerance (based on $c_H$) for currency depreciations against the Chinese renminbi than against the US dollar.

**Table 1. Threshold Values (percent)**

| | Pre-GFC period, January 2000 – December 2006 | | | |
|---|---|---|---|---|
| | per US$ | | per Chinese renminbi | |
| | Lower threshold ($c_L$) | Upper threshold ($c_H$) | Lower threshold ($c_L$) | Upper threshold ($c_H$) |
| Indonesian rupiah | 1.34 (0.01)*** | 3.83 (0.28)*** | 0.84 (0.07)*** | 7.02 (0.06)*** |
| Korean won | 1.49 (0.04)*** | 2.12 (0.08)*** | 1.20 (0.18)*** | 2.49 (1.09)** |
| Philippine peso | –1.80 (0.18)*** | 3.88 (0.03)*** | 0.26 (0.02)*** | 0.24 (0.06)*** |
| Singapore dollar | –0.39 (0.11)*** | 0.71 (0.13)*** | 0.57 (0.02)*** | 1.93 (0.02)*** |
| Thai baht | –0.07 (0.01)*** | 1.90 (0.08)*** | 0.95 (0.05)*** | 1.96 (0.05)*** |
| | GFC period, January 2007 – July 2009 | | | |
| | per US$ | | per Chinese renminbi | |
| | Lower threshold ($c_L$) | Upper threshold ($c_H$) | Lower threshold ($c_L$) | Upper threshold ($c_H$) |
| Indonesian rupiah | –0.78 (0.02)*** | 0.88 (6.9) | –1.46 (0.07)*** | –0.24 (0.04)*** |
| Korean won | –0.37 (0.02)*** | 1.61 (1.20) | –3.17 (0.19)*** | 10.0 (27.4) |
| Philippine peso | –2.57 (0.06)*** | –1.58 (0.05)*** | –1.76 (0.34)*** | –0.80 (0.10)*** |
| Singapore dollar | –2.07 (0.17)*** | –1.11 (4.15) | –2.40 (0.05)*** | –0.22 (0.04)*** |
| Thai baht | –3.02 (0.23)*** | –1.25 (0.16)*** | –1.43 (0.02)*** | 0.58 (0.47) |
| | Post-GFC period, August 2009 – March 2011 | | | |
| | per US$ | | per Chinese renminbi | |
| | Lower threshold ($c_L$) | Upper threshold ($c_H$) | Lower threshold ($c_L$) | Upper threshold ($c_H$) |
| Indonesian rupiah | 0.44 (0.06)*** | 1.31 (0.23)*** | 0.59 (0.04)*** | 1.35 (0.32)*** |
| Korean won | –1.60 (0.09)*** | 3.09 (0.07)*** | –1.64 (0.18)*** | 3.08 (0.15)*** |
| Philippine peso | 0.22 (0.05)** | 2.12 (0.13)*** | 0.84 (0.06)*** | 1.77 (0.08)*** |
| Singapore dollar | 0.10 (0.01)*** | 0.24 (0.01)*** | 0.09 (0.05) | 0.63 (0.10)*** |
| Thai baht | –0.69 (0.10)*** | 0.87 (0.02)*** | 0.10 (0.07) | 0.22 (0.08)*** |

*Note*: Numbers in parentheses are standard errors. Significance levels: * 10%; ** 5%; *** 1%.

According to our findings, however, this phenomenon of fear of appreciation all but disappeared during the height of our chosen period of the GFC. Understandably, the preference of the monetary authorities in these countries is to avoid a free fall in the value of their currencies so they adopt the typical strategy during financial turmoil of resisting or leaning against the significant selling pressures that are brought to bear on these currencies by international financial markets. In light of the proposed testing strategy laid out in this paper, this is interpreted as either significantly negative lower and upper thresholds or a significantly negative lower threshold but with an insignificant upper threshold.[11] As reported in the middle panel of Table 1, the former applies to the cases of the Philippine peso, Singapore dollar and Thai baht *vis-à-vis* the US dollar as well as the cases of the Indonesian rupiah, Philippine peso and Singapore dollar *vis-à-vis* the Chinese renminbi. The latter applies to the cases of the Indonesian rupiah and Korean won *vis-à-vis* the US dollar as well as to the cases of the Korean won and Thai baht this time *vis-à-vis* the Chinese renminbi.

More interestingly, once this tumultuous period of the GFC subsided, can we find a reappearance of the behavior akin to the pre-GFC period of fear of or aversion to currency appreciation? And, more so, similar to what we find in the pre-GFC period, is this fear of or aversion to appreciations exemplified to a greater extent in the case of the Chinese renminbi than with the US dollar in the aftermath of the GFC? As to the first question, based on the most recent data at the time of writing, there are indications that the GFC only briefly and temporarily interrupted this behavior and as such this phenomenon might have reasserted itself on the part of the monetary authorities in these countries. To varying degrees, all five countries show a revealed preference for limiting the extent of strengthening their currencies against the US dollar (0.44 and 1.31 percent, respectively, for the Indonesian rupiah; –1.60 and 3.09 percent for the Korean won; 0.22

[11] Both of these cases are the results we expect and this is reasonably logical since in any crisis situation, the preference of a monetary authority is to mitigate or alleviate the pressure of its currency depreciating or sliding in a free fall such that both threshold parameters ($c_L$ and $c_H$) must either be significantly negative (indicating its preference for its currency to strengthen) or, to a lesser extent, a significantly negative lower threshold but with an insignificant upper threshold (again to indicate that it is willing to accept a much stronger currency in a crisis situation, while averting the possibility of a free fall in the value of its own currency).

and 2.12 percent for the Philippine peso; 0.10 and 0.24 percent for the Singapore dollar; and –0.7 percent and 0.87 percent for the Thai baht).

In other words, it is only understandable that after coming out of a tumultuous period punctuated by sharp and volatile movements in their exchange rates, it is necessary for these countries to slow the pace of the depreciation of their currencies with respect to the US dollar, while at the same time retain their preference to restrain the strengthening of their currencies against the US dollar. For instance, when compared with their respective pre-GFC behavior, we observed that this analysis applies in the cases of the Indonesian rupiah, Singapore dollar and Thai baht. In the case of the Korean won, however, which can be depicted as the most affected amongst the five Asian currencies in the group during the GFC, we observe some loosening in the resistance to the appreciation of this currency against the US dollar after the GFC, which is in marked contrast with the outcome found during the pre-GFC period. Furthermore, to some extent, this alleged reappearance, akin to the pre-GFC period, of fear of or aversion to currency appreciations can also be argued to apply in the case of the Chinese renminbi as the base comparator currency (0.59 and 1.35 percent, respectively, for the Indonesian rupiah; –1.64 and 3.08 percent for the Korean won; 0.84 and 1.77 percent for the Philippine peso; 0.09 and 0.63 percent for the Singapore dollar; and 0.1 and 0.22 percent for the Thai baht).

With regards to the second question posed earlier as to whether the pre-GFC finding of a greater fear of appreciating against the Chinese renminbi than the US dollar also applies in the aftermath of the GFC—as depicted in the lower panel of Table 1, the relative values of the lower and upper thresholds seem to indicate that the greater fear of appreciation of these currencies pre-GFC with respect to the Chinese renminbi than against the US dollar is not yet strongly supported in the data. Only the further passage of time can validate this important exchange rate policy question for this set of economies.

## 5. Bilateral Trade Patterns and Beyond: The dominant role of Mainland China

How can we possibly explain the renminbi having such an influential role on the Asian currencies? One of the frequently advanced factors behind the increasing influence of the Chinese renminbi is the rise of China as a major trading partner of countries around the globe, including the five Asian economies in our study. In fact, China has become both a major exporter and a major importer of tradable goods in Asia. China, the second-largest economy in the world, ultimately accounted for about 50 percent of all trade flows in imported inputs in Asia in 2009—more than double its share in 1995 (IMF, 2011). At the same time, China's share of direct and indirect intermediate goods exports within Asia doubled to nearly 30 percent in 2009—from 15 percent a decade earlier.

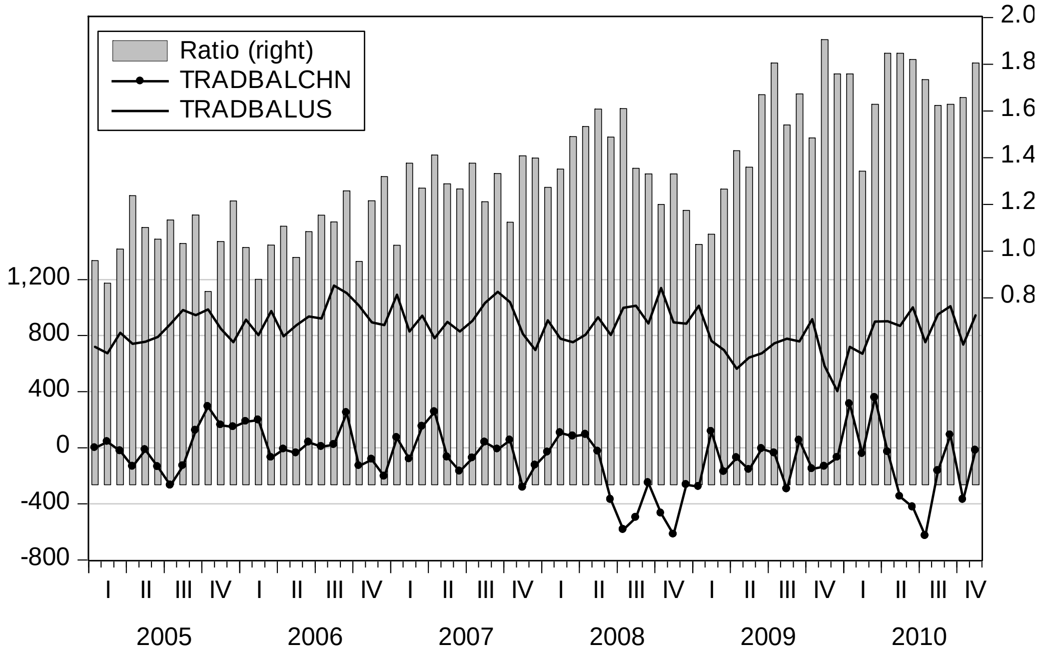
A simple calculation of trade ratios for all five Asian economies in terms of their bilateral trade patterns with China, the United States and Japan consistently reveals the rapidly emerging dominant role of China as a major trading partner (Figures 2–6).[12] The steep increase in total trade with China started to be noticeable in the early 2000s—only a few years after the 1997 East Asian crisis in all five Asian economies examined. The monthly total trade of Indonesia with China, for instance, was averaging only about 52 percent and 31 percent of the country's trade with the United States and Japan, respectively, in 2000. In 2006, just before the outbreak of the sub-prime crisis, the average monthly trade with China rose to less than 10 percent of the trade with the US economy. By 2010, Indonesia's average monthly trade with China was about 70 percent higher than with the United States, and about 1.1 times the monthly trade with Japan. The story of rising Chinese influence and trade importance for these major East

[12] The calculation of the trade ratio proceeds as follows. We take the ratio of total trade (exports plus imports) with China and total trade with the United States and Japan, respectively. So, for the case of Indonesia, for instance, the ratio of total bilateral exports and imports of Indonesia with China against the total bilateral exports and imports of Indonesia with the United States is calculated. We also do this for the ratio of total bilateral exports and imports of Indonesia with China against the total bilateral exports and imports of Indonesia with Japan. An increasing ratio, therefore, suggests the relative increasing role of China in the bilateral trade patterns of the five Asian economies, and a diminishing one for both the United States and Japan.

and Southeast Asian economies can be very much repeated for all five economies included in our study. In particular, the rapid rise of China's bilateral trade with its regional neighbors is most evident in the case of Korea. By the end of 2010, Korea's monthly trade with China was averaging about 2.4 times the country's trade with the traditional markets: the United States and Japan.

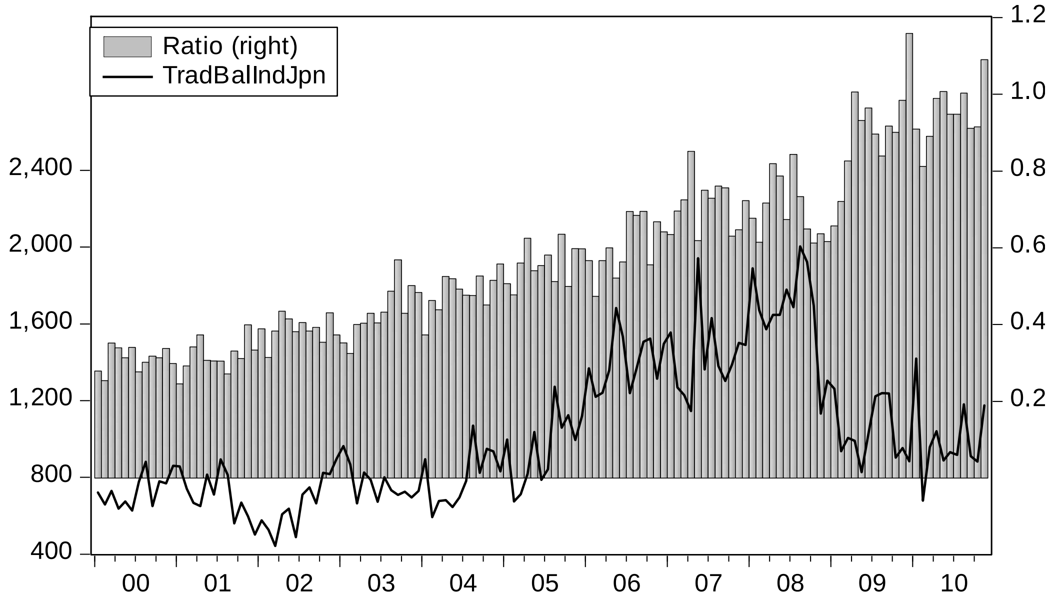
More importantly for policymakers in these East and Southeast Asian regions, maintaining trade surpluses with China is critical to achieve an overall strong current account position. W ith the exception of Indonesia and Singapore, and to a lesser extent the Philippines, the other major Asian countries had successfully maintained trade surplus positions during the past decade with China. Korea and Thailand, in particular, saw a growing trade surplus with China during the latter half of the past decade. Indonesia, on the other hand, saw its monthly marginal trade surplus of about US$70 million during the first half of the 2000s (until 2006) turn into a deficit of about US$150 million following the sub-prime crisis. As an export-processing economy, Singapore has been the processing hub of imported goods from all three major trading partners (China, Japan and the United States).

**Figure 2. Indonesia**



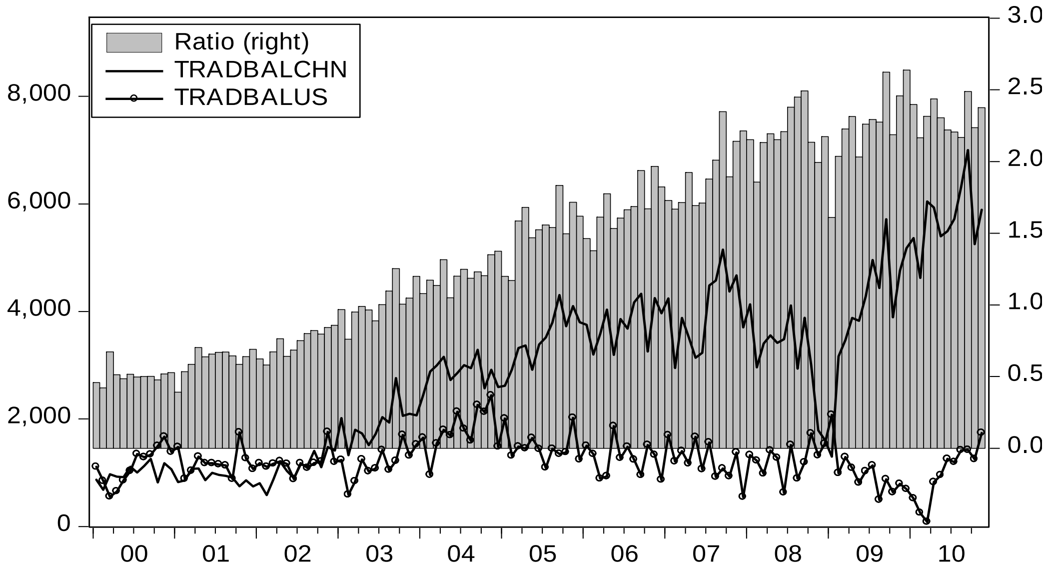

*Note*: Ratio is the ratio of total trade with China (exports and imports) and total trade with the United States. TRADBALCHN and TRADBALUS are trade balances with China and the United States, respectively. Trade balance is calculated as export minus import.

**Figure 2b. Indonesia–Japan–China**



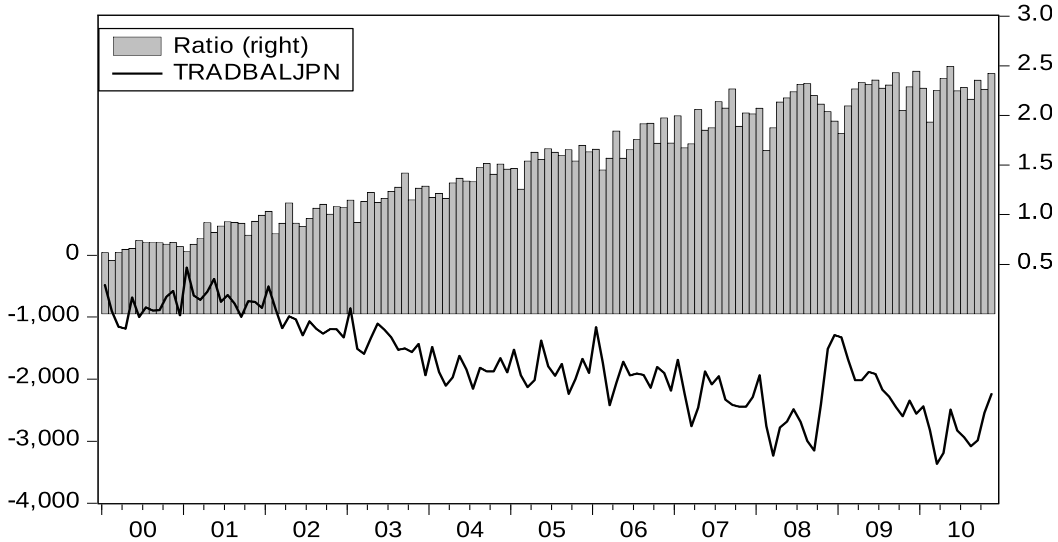

*Note*: Ratio is the ratio of total trade with China (exports and imports) and total trade with Japan. TRADBALJPN is trade balance with Japan. Trade balance is calculated as export minus import.

**Figure 3. Korea–China–US Trade**



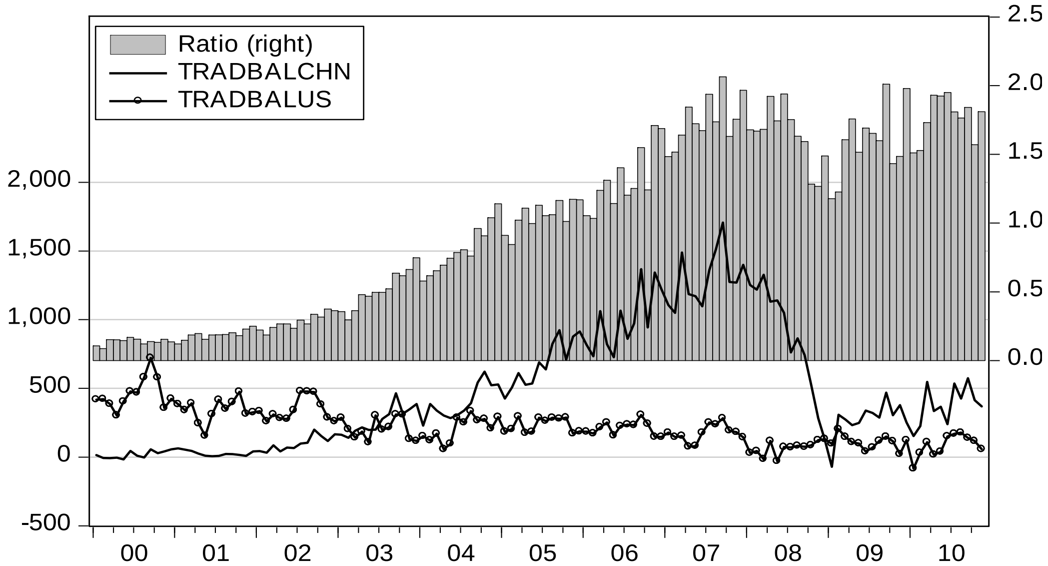

*Note*: Ratio is the ratio of total trade with China (exports and imports) and total trade with the United States. TRADBALCHN and TRADBALUS are trade balances with China and the United States, respectively. Trade balance is calculated as export minus import.

**Figure 3b. Korea–China–Japan**



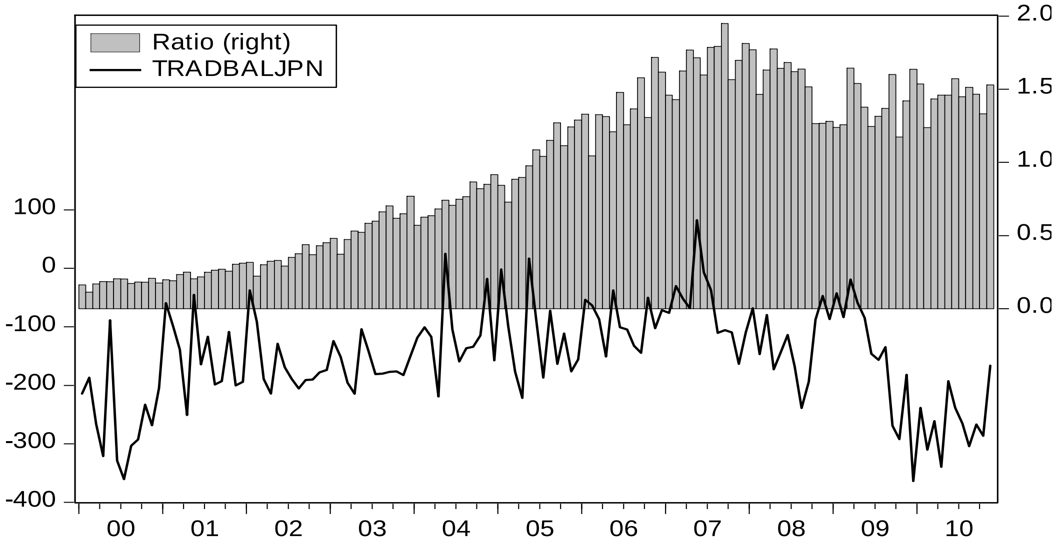

*Note*: Ratio is the ratio of total trade with China (exports and imports) and total trade with Japan. TRADBALJPN is trade balance with Japan. Trade balance is calculated as export minus import.

**Figure 4. The Philippines–China–US Trade**



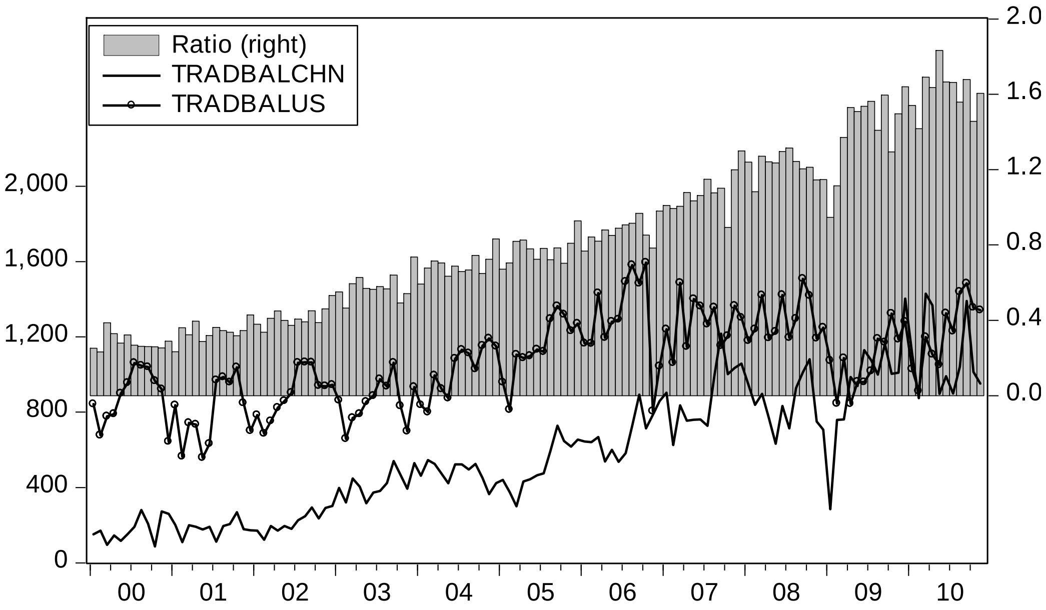

*Note*: Ratio is the ratio of total trade with China (exports and imports) and total trade with the United States. TRADBALCHN and TRADBALUS are trade balances with China and the United States, respectively. Trade balance is calculated as export minus import.

**Figure 4b. The Philippines–China–Japan Trade**



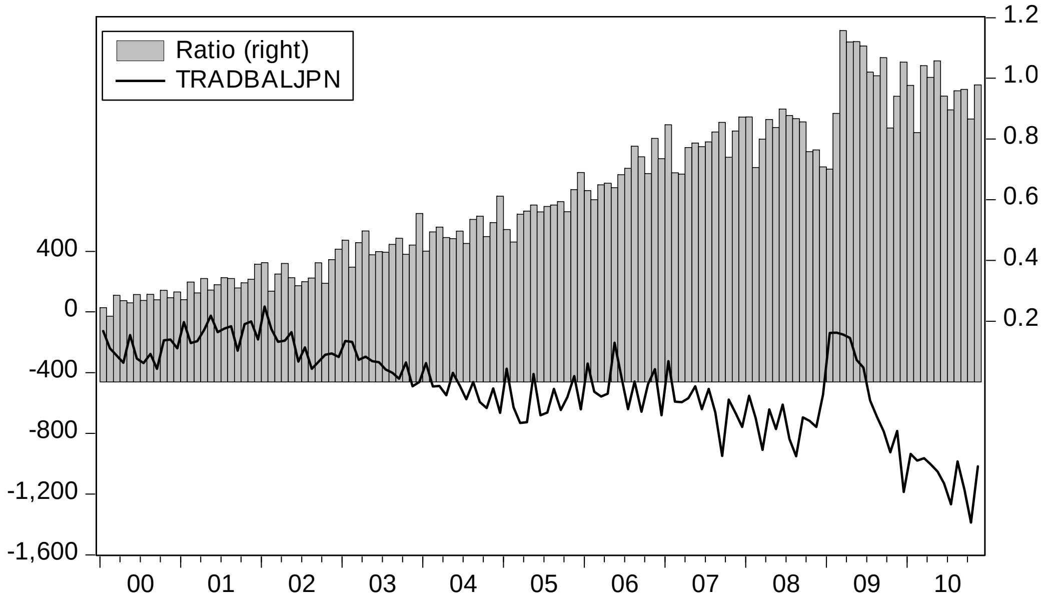

*Note*: Ratio is the ratio of total trade with China (exports and imports) and total trade with Japan. TRADBALJPN is trade balance with Japan. Trade balance is calculated as export minus import.

**Figure 5. Thailand–China–US Trade**



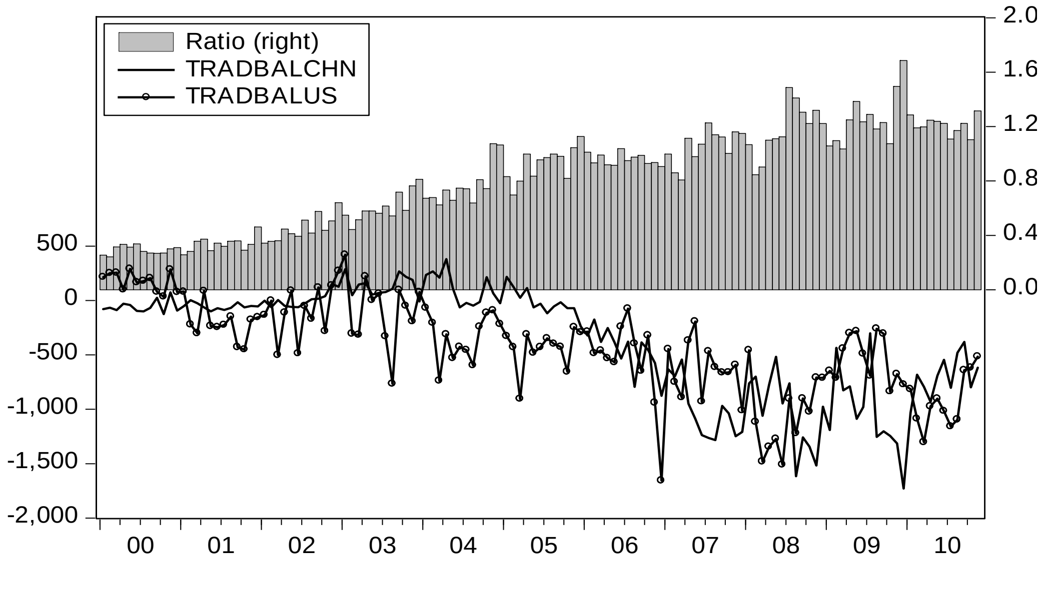

*Note*: Ratio is the ratio of total trade with China (exports and imports) and total trade with the United States. TRADBALCHN and TRADBALUS are trade balances with China and the United States, respectively. Trade balance is calculated as export minus import.

**Figure 5b. Thailand–China–Japan**



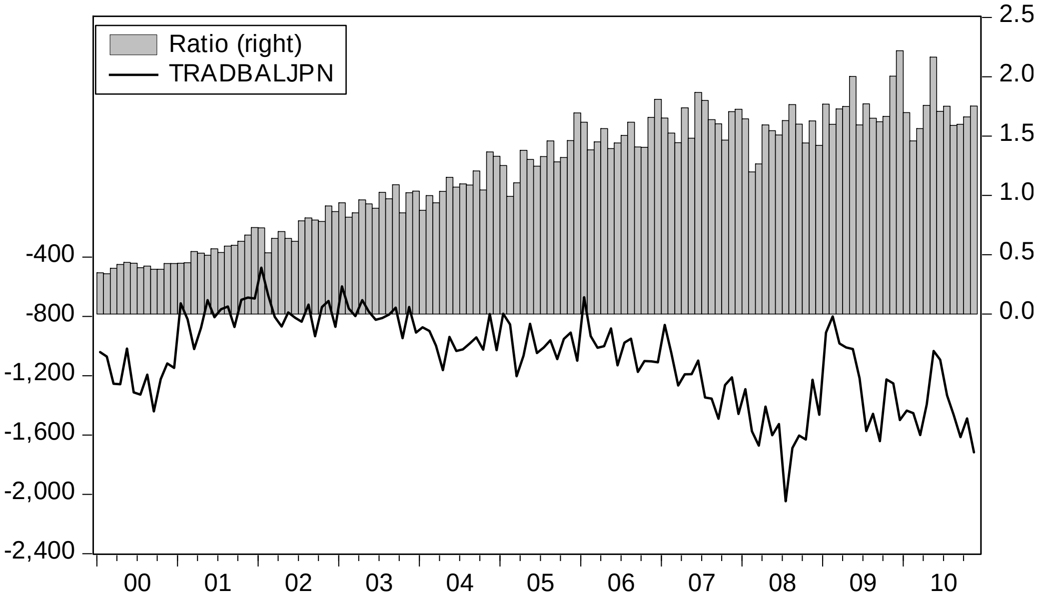

*Note*: Ratio is the ratio of total trade with China (exports and imports) and total trade with Japan. TRADBALJPN is trade balance with Japan. Trade balance is calculated as export minus import.

**Figure 6. Singapore–China–US**




*Note*: Ratio is the ratio of total trade with China (exports and imports) and total trade with the United States. TRADBALCHN and TRADBALUS are trade balances with China and the United States, respectively. Trade balance is calculated as export minus import.

**Figure 6b. Singapore–China–Japan**




*Note*: Ratio is the ratio of total trade with China (exports and imports) and total trade with Japan. TRADBALJPN is trade balance with Japan. Trade balance is calculated as export minus import.

To understand further the influence of Chinese trade on these five Asian economies, it is imperative to look further into the structures of trade in what is the world's second-largest economy. It is estimated that processing trade accounted for more than 40 percent of China's total trade by the mid-2000s, and these processing trades explained most of China's trade balances with its trading partners globally (Xing, 2011).[13] Four of our East and Southeast Asian economies examined here—namely, Korea, the Philippines, Thailand and Singapore—have been competing in this processing trade. In 2008, these four economies were in fact listed as among the top-10 sources of China's processing imports (Xing, 2011). Korea, for example, exported about US$60 billion worth of China's processing imports, while the processing exports of Thailand, the Philippines and Singapore were worth about US$12.5 billion, US$10 billion and US$8.8 billion, respectively.

[13] A typical example of processing trade is iPhone trade between the People's Republic of China (PRC) and the United States. This advanced mobile phone is assembled exclusively in China. All the components, however, are produced in Germany, Japan, Republic of Korea, Taipei, China and the United States. These components are shipped to and the final products are fully assembled in the PRC, before being exported to the rest of the world (Xing, 2011).

China has also been the largest exporter of labor-intensive goods to the rest of the world and a major competitor for a number of labor-abundant East and Southeast Asian economies examined here—namely, Indonesia, the Philippines and Thailand. Studies such as Thorbecke (2011) and Thorbecke and Zhang (2009) found labor-intensive exports from China and Association of South-East Asian Nations (ASEAN) countries to be very sensitive to exchange rates in both the exporting country and other countries exporting labor-intensive exports to third markets. Based on panel data analysis looking at about 30 countries over the 1987–2006 period, Thorbecke and Zhang (2009) reported that for China a 10 percent appreciation of the renminbi would reduce labor-intensive exports by about 17 percent, and a 10 percent depreciation among competing countries would decrease exports by about 9 percent. Similarly, analyzing an annual panel data set including exports to 25 countries over the 1983–2007 period, Thorbecke (2010) found that for ASEAN countries, a 10 percent appreciation in the exporting country would reduce that country's labor-intensive exports by about 20 percent, and a 10 percent depreciation among competing countries would decrease the ASEAN countries' exports by about 12 percent. These results support the claim that profit margins for these goods are thin, and that exchange rates play a critical role in the overall competitiveness of the labor-intensive export products of these economies.

Going forward, the influence of the Chinese renminbi and the exchange rate policy of China is likely to gain further momentum with the internationalization of its currency. As a result of the use of the renminbi for conducting trade and investment, coupled with the gradual movement of the renminbi towards greater exchange rate flexibility, there will be a pressing need to strengthen regional cooperation in the broad arena of trade and finance. For example, in order to ensure stability in trade and investment activities between and during the peak of the recent sub-prime GFC, the monetary authorities of Hong Kong, Indonesia, Malaysia, Korea and Singapore signed swap agreements, denominated in renminbi, with the central bank of China (Table 4). In fact, this swap arrangement has been widely extended by the Chinese central bank to other trading partners outside the region.[14]

[14] Since the onset of the GFC, China has also signed swap arrangements with Belarus, Argentina, Iceland, New Zealand and Uzbekistan.

**Table 4. People's Bank of China's Swap Agreements with Asian Central Banks**

| Counterparty central bank | Date of announcement | Terms of agreements | Amount (RMB billion) | Stated purpose |
|---|---|---|---|---|
| Bank of Korea | 12 December 2008 | 3 | 180.0 | Address short-term liquidity in financial system and improve bilateral trade |
| Hong Kong Monetary Authority | 20 January 2009 | 3 | 200.0 | Extend short-term liquidity support to mainland operations of Hong Kong banks |
| Bank Negara Malaysia | 8 February 2009 | 3 | 80.0 | Bilateral trade and investment |
| Bank Indonesia | March 23, 2009 | 3 | 100.0 | Bilateral trade and investment |
| Monetary Authority of Singapore | 23 July 2010 | 3 | 150.0 | Bilateral trade and investment |

*Source*: Web site of the People's Bank of China.

## 6. Conclusion

There are still significant concerns in the Asian economies examined in this paper about allowing market forces to completely determine their exchange rates. To be more specific, these economies continue to be characterized by a great aversion to appreciation, or what is now known as 'fear of appreciation'. Our findings confirm those of earlier works. Our study, however, goes one step further by bringing to light the vital role of the Chinese renminbi in shaping the exchange rate behavior of these same five major Asian currencies. Whereas some of the previous studies continue to underscore the return of the soft US dollar pegging in Asia post crisis, our findings indicate that there is an even greater dimension to this story: the greater fear of appreciation against the renminbi than against the US dollar, especially prior to the GFC.

Our finding, therefore, lends further support to the claim that links the exchange rate policy of China to the overall fear of appreciation in Asia. Bergsten (2004), for instance, asserts that China continued to "strengthen its competitiveness" by "riding the dollar down", which in turn "severely truncated the adjustment process" because other Asian countries fear losing competitiveness against China and thus block their appreciation against the US dollar. This will preserve appreciation expectations among other Asian currencies and fuel further demand for emerging market currencies that foster a further need to intervene to prevent currency appreciation. This will likely derail the supposed global rebalancing process (Kiguel and Levy-Yeyati, 2009). This in turn implies that only if China allows the renminbi to rise, are other Asian countries likely to follow suit. Only then will Asia play its full part in the issue of global rebalancing.

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# Appendix

**Table A1a. Estimation Results of LSTR2 Models for East Asian Currencies *vis-à-vis* US Dollar (pre-GFC sample period, weekly data, January 2000 – December 2006)**

| | Indonesian rupiah | Korean won | Philippine peso | Singapore dollar | Thai baht |
|---|---|---|---|---|---|
| *P* | 5 | 1 | 3 | 8 | 1 |
| *d* | 2 | 3 | 1 | 5 | 9 |
| **Linear part** | | | | | |
| Intercept | 0.037 (0.01)*** | 0.004 (0.00) | 0.001 (0.00) | –0.000 (0.00) | –0.000 (0.00) |
| $\Delta\ln exr_{t-1}$ | –0.478 (0.15)*** | –0.708 (0.26)** | 0.369 (0.06)*** | 0.365 (0.08)*** | 0.471 (0.07)*** |
| $\Delta\ln exr_{t-2}$ | –0.889 (0.38)** | | 0.170 (0.04)*** | –0.005 (0.10) | |
| $\Delta\ln exr_{t-3}$ | –0.579 (0.16)*** | | 0.062 (0.05) | 0.038 (0.09) | |
| $\Delta\ln exr_{t-4}$ | 0.123 (0.12) | | | –0.182 (0.10)* | |
| $\Delta\ln exr_{t-5}$ | –0.271 (0.10)*** | | | 0.248 (0.15)* | |
| $\Delta\ln exr_{t-6}$ | | | | –0.027 (0.10) | |
| $\Delta\ln exr_{t-7}$ | | | | –0.091 (0.14) | |
| $\Delta\ln exr_{t-8}$ | | | | –0.222 (0.13)* | |
| **Nonlinear part** | | | | | |
| Intercept | –0.037 (0.01)*** | –0.005 (0.00) | –0.096 (0.01)*** | –0.000 (0.00) | 0.001 (0.00) |
| $\Delta\ln exr_{t-1}$ | 0.893 (0.15)*** | 1.023 (0.27)*** | –2.311 (0.23)*** | –0.056 (0.18) | –0.319 (0.10)*** |
| $\Delta\ln exr_{t-2}$ | 0.823 (0.39)** | | –1.791 (0.29)*** | –0.181 (0.17) | |
| $\Delta\ln exr_{t-3}$ | 0.827 (0.17)*** | | 3.870 (0.76)*** | –0.101 (0.16) | |
| $\Delta\ln exr_{t-4}$ | –0.189 (0.13) | | | 0.229 (0.19) | |
| $\Delta\ln exr_{t-5}$ | 0.187 (0.12) | | | –0.197 (0.19) | |
| $\Delta\ln exr_{t-6}$ | | | | –0.229 (0.17) | |
| $\Delta\ln exr_{t-7}$ | | | | 0.425 (0.19)** | |
| $\Delta\ln exr_{t-8}$ | | | | 0.412 (0.22)* | |
| LB-*Q* test | 0.20 | 0.72 | 0.67 | 0.74 | 0.33 |

*Note*: *p* is the number of lags of the linear auto-regressive model; *d* is the optimal delay parameter; numbers in parentheses are standard errors, whereas numbers in the LB-Q test are *p*-values. Significance levels: * 10%; ** 5%; *** 1%.

**Table A1b. Estimation Results of LSTR2 Models for East Asian Currencies *vis-à-vis* US Dollar (GFC sample period, weekly data, January 2007 – July 2009**

| | Indonesian rupiah | Korean won | Philippine peso | Singapore dollar | Thai baht |
|---|---|---|---|---|---|
| $p$ | 2 | 1 | 2 | 1 | 1 |
| $d$ | 4 | 12 | 1 | 2 | 5 |
| **Linear part** | | | | | |
| Intercept | 0.000 (0.01) | 0.002 (0.00) | –0.142 (0.08)* | –0.010 (0.00)** | 0.007 (0.00) |
| $\Delta \ln exr_{t-1}$ | 0.206 (0.13) | –0.216 (0.12)* | –6.567 (3.74)* | –0.974 (0.50)** | 1.704 (0.91)* |
| $\Delta \ln exr_{t-2}$ | 0.242 (0.13)** | | –1.971 (0.86)** | | |
| **Nonlinear part** | | | | | |
| Intercept | 0.001 (0.00) | –0.002 (0.00) | 0.143 (0.075)* | 0.010 (0.00)** | –0.007 (0.00) |
| $\Delta \ln exr_{t-1}$ | –0.358 (0.29) | 0.911 (0.18)*** | 6.735 (3.73)* | 1.310 (0.50)*** | –1.679 (0.92)* |
| $\Delta \ln exr_{t-2}$ | –0.839 (0.36)** | | 2.047 (0.87)** | | |
| LB-$Q$ test | 0.57 | 0.58 | 0.62 | 0.13 | 0.16 |

*Note*: $p$ is the number of lags of the linear auto-regressive model; $d$ is the optimal delay parameter; numbers in parentheses are standard errors, whereas numbers in the LB-Q test are $p$-values. Significance levels: * 10%; ** 5%; ***1%.

**Table A1c. Estimation Results of LSTR2 Models for East Asian Currencies *vis-à-vis* US Dollar (post-GFC sample period, weekly data, August 2009 – March 2011)**

| | Indonesian rupiah | Korean won | Philippine peso | Singapore dollar | Thai baht |
|---|---|---|---|---|---|
| $p$ | 1 | 1 | 1 | 1 | 1 |
| $d$ | 2 | 2 | 1 | 7 | 11 |
| **Linear part** | | | | | |
| Intercept | –0.002 (0.00) | –0.001 (0.00) | –0.010 (0.00)*** | –0.014 (0.01)** | –0.001 (0.00) |
| $\Delta \ln exr_{t-1}$ | –0.840 (0.35)** | 0.607 (0.13)*** | 1.237 (0.37)*** | –1.259 (0.86) | 0.577 (0.12)*** |
| **Nonlinear part** | | | | | |
| Intercept | 0.001 (0.00) | 0.006 (0.00) | 0.009 (0.004)** | 0.013 (0.00)*** | 0.003 (0.00)* |
| $\Delta \ln exr_{t-1}$ | 1.077 (0.37)*** | –1.364 (0.26)*** | –1.242 (0.42)*** | 1.398 (0.88) | –0.837 (0.28)*** |
| LB-$Q$ test | 0.75 | 0.97 | 0.16 | 0.98 | 0.40 |

*Note*: $p$ is the number of lags of the linear auto-regressive model; $d$ is the optimal delay parameter; numbers in parentheses are standard errors, whereas numbers in the LB-Q test are $p$-values. Significance levels: * 10%; ** 5%; *** 1%.

**Table A2a. Estimation Results of LSTR2 Models for East Asian Currencies *vis-à-vis* Chinese Renminbi (pre-GFC sample period, weekly data, January 2000 – December 2006)**

| | Indonesian rupiah | Korean won | Philippine peso | Singapore dollar | Thai baht |
|---|---|---|---|---|---|
| *P* | 3 | 1 | 1 | 1 | 1 |
| *D* | 2 | 4 | 5 | 1 | 11 |
| **Linear part** | | | | | |
| Intercept | 0.003 (0.00) | 0.004 (0.00) | 0.017 (0.00)*** | 0.005 (0.00)** | 0.004 (0.00)*** |
| $\Delta\ln exr_{t-1}$ | –0.528 (0.13)*** | 1.316 (0.23)*** | –2.248 (0.16)*** | –0.236 (0.29) | –0.180 (0.16) |
| $\Delta\ln exr_{t-2}$ | 0.166 (0.20) | 0.297 (0.19) | | | |
| $\Delta\ln exr_{t-3}$ | 0.072 (0.11) | | | | |
| **Nonlinear part** | | | | | |
| Intercept | –0.003 (0.00) | –0.005 (0.00) | –0.016 (0.00)*** | –0.006 (0.00)*** | –0.004 (0.00)*** |
| $\Delta\ln exr_{t-1}$ | 0.976 (0.14)*** | –1.099 (0.24)*** | 2.349 (0.17)*** | 0.496 (0.30)* | 0.516 (0.17)*** |
| $\Delta\ln exr_{t-2}$ | –0.267 (0.21) | –0.316 (0.194) | | | |
| $\Delta\ln exr_{t-3}$ | 0.114 (0.12) | | | | |
| LB-*Q* test | 0.19 | 0.76 | 0.18 | 0.13 | 0.60 |

*Note*: *p* is the number of lags of the linear auto-regressive model; *d* is the optimal delay parameter; numbers in parentheses are standard errors, whereas numbers in the LB-Q test are *p*-values. Significance levels: * 10%; ** 5%; *** 1%.

**Table A2b. Estimation Results of LSTR2 Models for East Asian Currencies *vis-à-vis* Chinese Renminbi (GFC sample period, weekly data, January 2007 – July 2009)**

| | Indonesian rupiah | Korean won | Philippine peso | Singapore dollar | Thai baht |
|---|---|---|---|---|---|
| *P* | 2 | 5 | 1 | 1 | 3 |
| *D* | 6 | 2 | 9 | 1 | 8 |
| **Linear part** | | | | | |
| Intercept | 0.003 (0.00) | 0.004 (0.00)** | –0.004 (0.00) | 0.007 (0.00)** | 0.002 (0.00) |
| $\Delta\ln exr_{t-1}$ | 0.255 (0.33) | 0.253 (0.10)*** | –0.350 (0.43) | 1.299 (0.33)*** | 0.257 (0.12)** |
| $\Delta\ln exr_{t-2}$ | 0.819 (0.42)** | –0.229 (0.12)** | | | –0.171 (0.13) |
| $\Delta\ln exr_{t-3}$ | | –0.010 (0.09) | | | –0.157 (0.13) |
| $\Delta\ln exr_{t-4}$ | | –0.411 (0.085)*** | | | |
| $\Delta\ln exr_{t-5}$ | | 0.337 (0.09)*** | | | |
| **Nonlinear part** | | | | | |
| Intercept | –0.002 (0.00) | 0.006 (0.01) | 0.006 (0.003)** | –0.006 (0.00)** | –0.001 (0.00) |
| $\Delta\ln exr_{t-1}$ | –0.041 (0.38) | 0.119 (0.47) | 0.678 (0.44) | –1.054 (0.35)*** | 0.005 (0.19) |
| $\Delta\ln exr_{t-2}$ | –0.921 (0.46)** | 0.983 (0.24)*** | | | 0.530 (0.20)** |
| $\Delta\ln exr_{t-3}$ | | –0.546 (0.34) | | | 0.523 (0.18)** |
| $\Delta\ln exr_{t-4}$ | | 1.508 (0.40)*** | | | |
| $\Delta\ln exr_{t-5}$ | | –0.392 (0.66) | | | |
| LB-*Q* test | 0.55 | 0.14 | 0.73 | 0.17 | 0.47 |

*Note*: *p* is the number of lags of the linear auto-regressive model; *d* is the optimal delay parameter; numbers in parentheses are standard errors, whereas numbers in the LB-Q test are *p*-values. Significance levels: * 10%; ** 5%; *** 1%.

**Table A2c. Estimation Results of LSTR2 Models for East Asian Currencies *vis-à-vis* Chinese Renminbi (post-GFC sample period, weekly data, August 2009 – March 2011)**

| | Indonesian rupiah | Korean won | Philippine peso | Singapore dollar | Thai baht |
|---|---|---|---|---|---|
| *p* | 1 | 3 | 3 | 1 | 1 |
| *d* | 4 | 2 | 3 | 7 | 11 |
| **Linear part** | | | | | |
| Intercept | –0.002 (0.00) | –0.004 (0.00) | –0.087 (0.06) | –0.003 (0.00) | –0.004 (0.00) |
| $\Delta \ln exr_{t-1}$ | –0.982 (0.35)*** | 0.617 (0.15)*** | –0.328 (0.73) | 0.589 (0.32)* | 1.526 (1.605) |
| $\Delta \ln exr_{t-2}$ | | –0.282 (0.14)*** | 0.189 (0.85) | | |
| $\Delta \ln exr_{t-3}$ | | 0.106 (0.137) | 7.938 (5.00) | | |
| **Nonlinear part** | | | | | |
| Intercept | 0.002 (0.00) | 0.008 (0.01) | 0.086 (0.06) | 0.002 (0.00) | 0.003 (0.00) |
| $\Delta \ln exr_{t-1}$ | 1.180 (0.37)*** | –1.628 (0.58)*** | 0.411 (0.74) | –0.549 (0.35) | –1.119 (1.62) |
| $\Delta \ln exr_{t-2}$ | | 0.343 (0.24) | –0.384 (0.86) | | |
| $\Delta \ln exr_{t-3}$ | | –0.162 (0.263) | –8.060 (5.01) | | |
| LB-*Q* test | 0.68 | 0.98 | 0.70 | 0.43 | 0.55 |

*Note*: *p* is the number of lags of the linear auto-regressive model; *d* is the optimal delay parameter; numbers in parentheses are standard errors, whereas numbers in the LB-Q test are *p*-values. Significance levels: * 10%; ** 5%; *** 1%.