Renminbi Misalignment and the Competitors' Exports: a New Perspective

Jhih-Hong Zeng
Department of Finance, National Sun Yat-sen University

Pei-Fen Chen*
Department of International Business Studies, National Chi-Nan University

Chien-Chiang Lee
Department of Finance, National Sun Yat-sen University, Kaohsiung

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* Corresponding author. Department of International Business Studies, National Chi-Nan University, Nantou, Taiwan. Tel.: +886-49-2910960 ext.4643; fax: +886-49-2912595. Email address: pfchen@ncnu.edu.tw. Address: 4F., No.470, Dasyue Rd., Puli Township, Nantou County 54561, Taiwan (R.O.C.).

Abstract

The misalignment of China's Renminbi (RMB) currency has attracted much attention recently due to its impact/spillover toward other currencies or economic growth. This paper mainly targets the impacts of such misalignments on China's exports and the spillovers of these misalignments toward the exports of the 9 Asian countries. We provide new insights into the dynamics of the misalignments and the spillover effects of currency misalignment over time. For the Asian markets used in our analyses, most are impacted by RMB misalignments. Interestingly, experiencing many times of currency policies and transformation of China's economic or industrial structures, the externality RMB misalignments cause on other economies has been changing among the Asian countries over time. The findings imply several policy implications and suggestions.

Keywords: Renminbi, misalignment, exports, time-varying cointegration, spillover.
JEL classifications: F31, C32.

1. Introduction

China has become almost the largest exporter in the world, as its nominal export value has grown rapidly from US$521.42 billion in 2000 to US$3,961.47 billion in 2014, a growth rate of 660% or 47% annually at average. However, China's managed exchange rate policy in its Renminbi (RMB hereafter) value has led to a consistently debating issue worldwide. Some believe that Chinese government has kept an undervalued RMB so as to maintain its external trading competitiveness. In addition, the intervention in the foreign exchange markets from Chinese monetary authorities might also have led to RMB misalignment. Such that, a sizable and consistent RMB misalignment is considered one of the key influences to the substantial trade surpluses of China.

Assume that RMB is misaligned from time to time, this disequilibrium will raise a negative or a positive externality on the trading partners (e.g., Bahmani-Oskooee and Wang, 2006; Mattoo, et al., 2012). To be specific, if a country has kept its currency undervalued to maintain trade surplus for a long period of time, once the policymaker decides to let the currency appreciate but in a slow and mild manner, the traditional wisdom considers this as a move against the surplus country. On the other hand, the currency of the underlining country is probably still undervalued. In the scenario the real price for exports of the underline country is still competitive in the world market relative to its trading competitors despite that the exchange rate seems to favor the deficit countries.

The aims of this article are twofold. The first is to provide evidence for the importance of severe currency misalignment to trade competitiveness. The second is to reveal the dynamic relationship among RMB misalignment, China's exports, and its competitors' exports over time. Most importantly, we provide a new perspective that currency misalignment itself, rather than the change of exchange rates, play a key role of the trade imbalances of an economy. In this paper, we investigate interrelationship

between RMB misalignment and the real exports of China's Asian trading competitors across time. The primary motivation of our study is that the amount of China's trade surplus grows quickly, indicating the crucial role of China in the global markets (e.g., Yu and Qi, 2015). Therefore, China' exchange rate policies has becoming a target of causes for global trade imbalances.

Although China's monetary authority has announced a series of important reforms during the past decades, yet global trading has not reacted positively to the RMB exchange rate reforms. RMB misalignment against the US dollar remains to be an issue. However, the studies with respect to the time-variant influence of a series of RMB misalignments to China or to other economies, to the best of our knowledge, are quite limited. Therefore, this paper focuses on the time-variant impact and spillovers of RMB misalignments on the exports of China and some Asian countries via a time-varying cointegration method and time-varying spillover analysis. Note that although the main doctrine of the literature focuses on the influence of exchange rate change to trades (Goldstein, 2004; Thorbecke, 2009; Kwack et al., 2007; Ahmed, 2009; Thorbecke and Smith, 2010; Berman et al., 2012), we argue that the deviation from exchange rate equilibrium much benefits the research of trade competitiveness or complementariness with China.

How do RMB misalignments influence the exports of China's trading competitors? According to Armington (1969), there exists a substitution for goods between different markets. The elasticity of substitution (or called an Armington elasticity) refers to the substitution between home producers and import suppliers (macro-Armington elasticity). In addition, many international trade researchers address the substitution effect among different foreign suppliers (micro-Armington elasticity). However, studies focusing on the spillover of changes in the RMB exchange rates toward China's competitors are limited although a few studies (e.g., Hanson and Robertson, 2008) have

probed the impact of China's export performance on other countries' exports. In recent, Egger et al. (2013) find that cross-cluster spillovers stimulate multilateral environmental agreements participation across countries and clusters. The spillovers/externalities between countries have been concerned. Moreover, China's foreign exchange policy actions have caused a prominent RMB misalignment, compared with the degree of interventions by other countries in their own currencies. As a result, the exports of China's competitors can be impaired by such RMB misalignments.

The Chinese government modified its foreign exchange policy to a more flexible regime since 2005 (Lafrance, 2008). This indicates an adjustment in RMB misalignments toward the currency exchange rate's long-run equilibrium.[1] As a consequence, the spillover from changes in RMB exchange rates to other economies is partially subject to China's foreign exchange policy. Due to the mysterious political decision making of Chinese monetary authorities, the spillover effect from the RMB exchange rate to other competitors or complementors in international trade may vary over time.[2]

This paper investigates the impact of RMB misalignments on China's exports to the US. We also further provide evidence of the exchange rate spillovers from China to the nine Asian countries on their exports to the US. Our findings and contributions are as follows. First, to the best of our knowledge, this paper is the first to examine the relationship between exports and RMB misalignments. The literature which are closest

[1] According the IMF report, the Chinese Yuan is only undervalued 5% to 10%, which is no longer as large as the estimation in previous studies (e.g., Jeong and Mazier, 2003). http://www.actionforex.com/analysis/daily-forex-fundamentals/imf-report:-yuan%27s-real-exchange-rate-undervalued-5%25-10%25-20130802195122/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+ActionForexall+%28Action+Forex+%28ALL%29%29.

[2] The spillover effect indicates the externalities of one economy's activities that affect those economies that are not involved in the same market or region.

to our argument is the relationship between exports and exchange rate changes. One of the differences between currency misalignments and exchange rate changes is that any exchange rate change may have no influence on exports if the currency is still held at a much overvalued or undervalued level. Second, we measure RMB misalignment via the time-varying cointegration approach (Bierens and Martins, 2010) to prevent biased estimations resulting from structural breaks and non-linearity (e.g., Taylor et al., 2001; Sarno et al., 2004; Gehrig and Menkhoff, 2006; Beckmann et al., 2011). China's government has several reforms for currency policy over the past decades. A time-varying method is relatively more flexible to cope with this situation than other time-invariant linear models. We find a small degree (less than 5%) of an undervalued RMB during the period 2011-2012, which is similar to the report by the IMF. Third, we analyze the time-varying spillovers of RMB misalignment on the exports of China and its competitors or complementors in international trade. This allows us to look at the spillovers during each regime with respect to China's recent changes in economic or industrial structure and its spillovers towards other economies. Our empirical results present the time-varying spillover effect of RMB misalignment to some Asian economies. Fourth and finally, through specifying a fixed export market, it helps to shed light on the impact of RMB misalignments on exports in the U.S. market, one of the largest consumer markets over the world. Economies export substitutive or complementary goods with China's can thereby make some related policies against RMB misalignments. Interestingly, our analysis of the time-varying spillover effect indeed poses the spillover of RMB misalignments on economies across different subperiods that may be ascribed to structural transformation of the China's economy. We believe the findings are valuable to the existing literature and many policymakers.

The rest of this paper is organized as follows. Section 2 reviews related studies. Section 3 describes the measure of RMB misalignment, the empirical processes, and

the data. Section 4 briefly introduces our main empirical methodologies and models, and Section 5 presents our empirical analyses. The final section contains our conclusions and suggestions.

2. Related Studies

2.1 China's /interventions in the exchange rate markets

China has made several adjustments at its exchange rate policy due to economic development and in order to mitigate the impact of global crises on its economy. After substantial growth in inflation, the exchange rate for the Chinese Yuan (also Renminbi) to US dollar is more than 50% in 1994. China's authorities then pegged the RMB from 1997 to July 2005 to the US dollar with a restricted narrow trading range in order to initially stave off any contagion from the Asian crisis in 1997.[3] On May 18, 2007, the People's Bank of China announced that it was expanding the daily RMB trading band in the interbank foreign exchange market from 0.3% to 0.5%. After the occurrence of the global financial crisis in 2008, China re-narrowed the trading range of the RMB in order to stabilize China's economic growth. Later, RMB trading band was widened from 0.5% to 1% in April 2012 and was widened again from 1% to 2% in March 2014.

Innovations in policy or notable crises can possibly result in a structural break in the long-run equilibrium, and therefore short-term deviations or currency misalignments may occur. For example, You and Sarantis (2012) investigate the RMB equilibrium of the real effective exchange rate based on the natural real exchange rate model. They find that RMB misalignment is not as high as previous studies note, and they suggest the importance of structural breaks while estimating the long-term equilibrium of the RMB. Zurbruegg and Allsopp (2004) analyze the impact of the East

[3] Readers can read a survey of a part of China's exchange rate policy in Lafrance (2008).

Asian crisis on foreign exchange markets within the Asian region and propose the importance of structural breaks in testing the purchasing power parity (PPP) model. When existent structural breaks are ignored, they can substantially raise a bias in measuring currency misalignment.

As discussed above, one problem is to search for an appropriate approach to measure RMB misalignment in order to handle several times of China's exchange rate reforms during this period. Multiple structural breaks decided exogenously may raise a bias in estimation. In addition, although some well-developed econometric technologies (e.g., Gregory and Hansen, 1996; Kejriwal and Perron, 2012) allow us to endogenously detect single or multiple structural breaks in a cointegrated relation, too many structural breaks may make them break down due to the small sample in this period. To overcome this problem, we estimate the PPP model by employing the time-varying cointegration method of Bierens and Martins (2010). This method helps to illustrate the pattern of the time-varying RMB misalignments and furtherly analyze their time-varying impacts/spillovers on the exports of China and some Asian countries. Moreover, some studies suspect the linearity of short-term deviations in the long-run PPP via traditional linear models (Michael et al., 1997), and an inaccurate estimation of currency misalignment could thus arise.

2.2 Spillovers of RMB misalignment

Bilateral exchange rates are related to the trade balance between two countries. The monetary authorities , from time to time, attempt to intervene in foreign exchange markets for the purpose of stimulating their exports and economic conditions (see, for example, Kim, 2003; Taylor, 2004; Kearns and Rigobon, 2005).

Do China's managed currency policies impact its competitors or complements? On the one hand, the Armington elasticity indicates the substitutability of similar goods

among foreign imports forces China to concern the foreign exchange policies. The move of China distresses its competitors in international trade when they do not simultaneously exert equivalent interventions in the foreign exchange markets. The elasticity of substitution between different foreign suppliers is one of the most important elements in international trade, although Armington (1969) presents that imperfect substitution among countries is due to buyers' preferences or lags in buyers' responses.[4] On the other hand, economies exporting with complementary goods with China's in the same market may benefit from RMB undervaluation so that they should regard undervalued RMB as a good news.

A few of recent studies have examined the effect of China's export performance on other exporters. For example, Eichengreen et al. (2007) and Hanson and Robertson (2008) investigate the effect of China's exporting performance on other Asian exporters and find that China's rapid growth in international tradess crowds out the exports of other Asian and developing countries. Yu and Qi (2015) find high complementarity for agricultural product trade between China and a few central and eastern European countries. Furthermore, Mattoo et al. (2012) extend the model of Feenstra et al. (2012) and provide evidence for the spillover effect of China's real exchange rate changes on other exporters. Interestingly, China's enforced managed foreign exchange policy has induced a large RMB misalignment compared with other countries. However, the exchange rate change may not to be enough in explaining the spillovers of China's export to the other countries. By contrast, the size of RMB misalignment is the key measure in accounting for the spillover effect of China's exports to the other economies. In another word, changes of the RMB/USD rate may have no significant effect on

[4] In addition to the substitutive elasticity among foreign competitors, some analyses exist that focus on the substitutive elasticity of importable goods between domestic and foreign suppliers. See, for example, Reinert and Roland-Holst (1992).

exports when RMB is still under a large deviation from its long equilibrium. Therefore, we attempt to verify the spillovers of RMB misalignment on the exports of China's competitors or complementors in international trade employing the time-varying spillover approach (Diebold and Yilmaz, 2009, 2012).

3. RMB Misalignment, the Model, and Data

3.1 The data

This paper focuses on the impact and spillovers from RMB misalignments on the exports from China (CH) and the 9 Asian markets - including Indonesia (ID), India (IN), Japan (JP), South Korea (KO), Malaysia (MY), Philippines (PH), Singapore (SP), Thailand (TH), and Taiwan (TW) - to the U.S. market. The period spans from January 2001 through December 2014 due to that China's first influential reform of currency policies is starting the managed floating rate system in 1994, and the next important exchange rate policy refers to a basket of currencies in July 2005. In order to avoid the 1997-1998 Asian crisis and the recession in around 2000 and to conduct the rolling method of time-varying spillover estimation, we specify the period from January 2001 to November 2014 as the analytic period. The data of real exchange rates and real exports are deflated by consumer price indices (CPI) with the base year 2005. The data are gathered from Datastream and Global Financial Database (GFD). The patterns of exports are shown in Figure 1.

[Figure 1 about here]

To talk about the export data a little bit more. According to the report of the World's Richest Countries,[5] three categories - machines, engines, and pumps occupying 13% (US$293.9 billion), electronic equipment occupying 12.5% (US$283.3 billion), and

[5] http://www.worldsrichestcountries.com/top_us_imports.html.

vehicles excluding railways and trams occupying 9.1% (US$206 billion) - rank in the U.S. top 10 imports from the world. In particular, these three categories are mostly imported from China, Japan, South Korea, Thailand, Singapore, and several other countries, indicating that China has been a notable competitor of main Asian countries in international trade market to the U.S. As far as RMB currency is included in the basket of SDR, the value of it has becoming more crucial to the world trade.

3.2 RMB misalignment – time varying approach

The very first thing to uncover the degree of currency misalignment is to justify an equilibrium model for real exchange rates. There are so many models, such as relative purchasing power parity (PPP), absolute PPP and the Penn effect, behavioral equilibrium exchange rate (BEER), the fundamental equilibrium exchange rate (FEER), and the basic flows approach, etc. Whether one is superior to the other is another ongoing debate. Although each measure has its own supporters, this paper measures real RMB misalignment by employing the relative PPP model based on the Consumer Price Index (CPI). PPP model is one of the most adopted and is in accordance with real exchange rate measures. There is no reason to leave PPP behind while arguing with global competitiveness and world trades which are stated by the relative prices between two economies. What we try to argue is that there is persistent RMB misalignment which turns out with increasing trade imbalances to its trading partners.

With regard to the methodology, previous studies support non-linear adjustments in PPP deviations and the existence of structural breaks (e.g., Michael et al., 1997; Taylor et al., 2001; Sarno et al., 2004; Gehrig and Menkhoff, 2006; Beckmann et al., 2011). We apply the time-varying cointegration (TVC hereafter) of Bierens and Martins (2010) to characterize the nonlinear adjustment of PPP deviations. The methodology is introduced in the appendix. The aim of this approach is to assess RMB equilibrium

value so that we can estimate the misalignment of RMB. We define RMB misalignment as follows.

$$RMB\ misalignment = \frac{equilibriem - actual\ RMB/USD}{actual\ RMB/USD} \quad (1)$$

Where positive misalignment represents overvaluation and negative is undervaluation.

3.3 RMB misalignment – the empirical results

We first check the stationarity of the variables in the PPP model. The three unit root tests from Table 1 support the variables in the PPP model being integrated of order 1 (I(1)). Furthermore, we confirm the existence of the long-run PPP relationship by Johansen's cointegration test (Johansen, 1991). The evidence for one long-run cointegration is given on the lower panel of Table 1.

[Table 1 about here]

Getting back to the data. After a long period of RMB appreciation due to the international pressure, there are growing body of studies indicating that RMB could be overvalued (Coudert and Couharde, 2005; Cline and Williamson, 2007; Bineau, 2010). As shown in **Figure 2**, RMB has experienced real appreciation after year 2000s, while its real exports to the US keep soaring up. No wonder the literature question about the RMB appreciation as the resolution for trade imbalances between the US and China.

[Figure 2 about here]

Figure 3 shows the estimated RMB misalignments over the period 2001-2014 using the time-varying approach. The RMB exchange rate policy reforms are also indicated. Based on the time-varying method, we find that the magnitude of undervalued RMB decreased following a series of exchange rate reforms since 2005. Overvaluation appears from Nov. 2010. The misalignment ranges from about -7.9% to 3.8%. There are 140 undervaluations (84%) and 26 overvaluations (16%) respectively

out of 166 estimations. Most of the overvaluations appear after 2011, indicating that RMB might have over-appreciated from time to time since late 2010. This finding is in accordance with the recent development for RMB values which has been appreciated against USD since 2016. Note that we argue and add evidence for mild, not large, size of RMB misalignment to the literature. Also, it may shed light on the influence of China's deregulated foreign exchange policies by the abandon of dollar peg, which made its own currency modify against the long-run deviations.

[Figure 3 about here]

4. Time-varying spillovers

4.1 Causality and impulses responses

Before the time-varying spillover analyses, we need to justify the link between RMB misalignment and the competitors' exports. The benchmark evidence from linear approaches in Table 2 enables us to furtherly consider the variation of the relationships in the next subsection. In Panel A of Table 2, we find the evidence that RMB misalignments not only affect China's exports, but it also causes a significant externality to economies in the neighborhood. The further evidence of Panel B in Table 2 also presents the impact of China's exports on other economies over the specified U.S. market. The exports of Malaysia, Thailand, and Taiwan are associated with both China's exports and RMB misalignments. In fact, the following evidence of accumulated responses will indicate a negative and persistent influence (about 3-6 months) of RMB misalignments on the three economies' exports – that is, China is a notable exporter for the three economies.

[Table 2 about here]

Moreover, we check the link of RMB misalignments with the other Asian countries by using causality tests and impulse response analysis. The causality test

reveals their lead-lag relationships, and impulse response function analysis helps to realize when and how long the RMB misalignment impacts other countries. Figure 4 shows the self-impact of one standard deviation RMB misalignments to its exports.[6] The solid line represents the impulse response curve and the dash lines represent the 95% confidence interval. Note that the significant impulse response presents when the confidence interval locates outside the zero line. In figure 4, one standard deviation of RMB misalignment causes a negative impact on China's export at the beginning and gradually switch to a positive influence later, providing evidence of J-curve effect. A RMB misalignment shock benefits China's exports in about seven months later.

Figures 5-6 show the impulse responses and accumulated impulse responses of the RMB misalignment shock to 9 Asian economies' exports respectively. It is observed that all economies' exports decrease immediately by the shock. The significantly negative impact of RMB shock took place on exports of South Korea, Malaysia, Thailand, and Taiwan. Meanwhile, the exports of Japan and Singapore suffer several months later. In particular, the exports of Malaysia, Thailand, and Taiwan are negatively affected by RMB misalignments persistently more than 3 months. The result indicates that RMB misalignment significantly influences the exports of Asian countries. This may shed lights on strong substitutability in exports among China's and its neighborhood over the U.S. market.

[Figures 4-6 about here]

4.2 Time-varying spillovers – the approach and empirical results

Based on the given RMB misalignments over time, we furtherly examine the time-varying spillover effects of RMB misalignments on the exports of China and the 9 Asian countries. The calculation of the time-varying spillover index is based on the approach

[6] Both dot-lines indicate significance at the 5% level for figures of impulse response functions.

of Diebold and Yilmaz (2009 & 2012; D&Y hereafter). Refer to the appendix for the methodology.

Since the analysis is based on a time-varying method so that we could focus our attention to some sub-periods, such as the global financial crisis and reforms of China's currency policy, or look at the different spillover effects of RMB misalignments on individual countries. Figure 7 presents the time-varying influence and spillovers of RMB misalignments on the exports of China and the 9 Asian countries, respectively. In Figure 7, the horizontal dotted line is the average of RMB misalignment (-2.2%) over the 2006-2014.[7] RMB misalignments are denoted by the time-variant dotted line, and the solid line indicates the spillovers of RMB misalignments. There are three sub-periods that appear dramatic surges for most of the countries, including the 2007-2008 subperiod, the 2009-2010 subperiod, and the 2012-2014 subperiod. In these three subperiods, RMB misalignments explain the 1-step-ahead forecast error variance of China's export around 2%. Moreover, the presence of the prominent influences is where RMB was largely undervalued, rather than for overvalued RMB. Significantly, undervalued RMB can affect China's export.

As for the spillovers of RMB misalignments to the 9 Asian countries' exports, we discuss them in turn by the three subperiods. In the first subperiod (2007-2008), RMB was largely undervalued (more than 2.2%), and its misalignments had dramatic spillover effects on exports of the five countries, including Indonesia (ID), India (IN), Japan (JP), Malaysia (MY), and Taiwan (TW). This subperiod is the severest time for the global financial crisis. The much undervalued RMB may be more competitive for China's goods imported into the U.S. market than other importers because the consumers tend to curtail their expenditure at the bad economic situation. Therefore,

[7] The use of the rolling method with 5-year window leads to the loss of the data over the 2001-2005 period.

the spillover effect in this subperiod is relatively larger. In addition, we may furtherly propose that there exists a substitutability between the exports of China and the five countries in the U.S. market during this subperiod.[8]

In the second subperiod (2009-2010), the countries suffering significant spillovers (over 2%) from RMB misalignments are South Korea (KO), Philippine (PH), Thailand (TH), and Taiwan. In this subperiod, RMB is almost undervalued over the average level 2.2%. Notably, some countries, including KO, PH, and TH, are the first time to respond to RMB misalignments. To interpret it, we may first look at Figure 8, which illustrates the China's exports with respect to goods of agricultural raw materials, food, and manufactures.[9] The percentage of merchandise of China's manufactures exports grows rapidly from 2006 to 2009. Instead, the percentage of food exports declined quickly then. Prominently, China's economy has a transformation that impairs other economies with similar merchandise exports. Therefore, KO, PH, and TH encounter the significant spillovers from RMB misalignments over the subperiod 2009-2010, but they are moderate with the converging RMB misalignments

In the 2012-2014 subperiod of overvalued RMB at most time, RMB misalignments can affect only Taiwan and raise a little influence on Malaysia. Taiwan's exports seem to be impacted by large RMB misalignments throughout the three subperiods. Significantly, Taiwan's merchandise has a higher substitutability with China's in the U.S. market among the 9 Asian countries.

[Figures 7-8 about here]

[8] The examination of the substitutability between the exports of China and the other countries will take a lot of analyses, such as a comparison for many types of exports. Therefore, we leave it to the future research.

[9] The data in Figure 8 are gathered from the World Bank.

5. Analyses and Discussions

We summarize our main findings and contributions and offer relative suggestions in the following. First, a misaligned RMB Granger-causes a part of Asian countries' exports. To the best of our knowledge, this paper is the first to analyze the relationship between RMB misalignment and the exports of China and other Asian countries. China's currency policies do raise an externality to other economies. Such a result may occur in other regions in the world, and the government should notice the spillover of its competitors in international trade.

Second, RMB misalignments cause the J-curve effect to China's exports, like what exchange rate changes do to exports found in previous studies. Furthermore, the results of negatively accumulated responses by impulse response functions propose a negative and persistent influence (about 1 to 6 months) on some Asian countries for one standard deviation of RMB misalignment innovation. The substitutability of China's exports may dominate this result. It is worth further exploring for the future research.

Third, a large misalignment of RMB undervaluation and a bad economic situation, like the period of the global financial crisis, strengthen the spillovers of RMB misalignment to other economies. An economy's economic situation may sway the link between currency misalignment and exports. This result is helpful for policymakers who intend to operate currency policies to affect their export.

Fourth and finally, the illustration of the time-varying spillover effects presents an influence of the transformation of China's economic or industrial structure on different countries over time. In other words, the object impacted by RMB misalignments could be changed accompanying with China's economic transformation. The government should notice it and prevents it early.

6. Conclusions

This paper focuses on the impact of RMB misalignments on the exports of China and the 9 Asian countries. We employ the time-varying cointegration approach to measure RMB misalignment for the possible existence of non-linearity and structural breaks. In addition, we also examine the causalities, impulse responses, and time-varying spillovers for the RMB misalignment-export relation. According to our empirical findings, the degree of RMB misalignment becomes small following China's several reforms in exchange rate market, but it still affects part economies. In addition, RMB misalignment not only impacts China's exports, but it also has a spillover effect on other exporters. Importantly, factors, such as the size of RMB misalignment, economic situation, and China's industrial structure, can dominant the spillover effect of RMB misalignment on exports.

According to the findings, we have several suggestions. First, the degree of RMB misalignment has large shifts over the past two decades so that the related studies should notice the specified period. Second, RMB misalignment indeed raises an externality on some economies. A positive or negative externality should depend on the substation or complementarity of an economy's exports with China's. Third and finally, China has adjusted its economic structure, and it leads to the change of objects impacted by RMB misalignments.

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Appendix

A1 Time-varying cointegration approach

Based on PPP hypothesis, the real exchange rate is determined as follows in log form:

$$q_t = s_t + p_t^* - p_t \tag{A1}$$

where *s* is the nominal exchange rate of RMB per unit US dollar, *p* and p^* are prices of goods and service in China and the US respectively If the PPP hypothesis holds, then the cointegration relationship in Equation (A1) should be present. In particular, TVC approach developed a cointegration vector which varies across time. It is denoted by β_t so that the short-run deviations e_t herein are given as $\beta_t' y_t = e_t$.

Consider a time-varying *l*-lag vector error correction model (VECM(*l*)) without a drift[10].

$$\Delta Y_t = \Pi_t' Y_{t-1} + \sum_{j=1}^{l-1} \Gamma_j \Delta Y_{t-j} + \varepsilon_t, \quad t = 1,\ldots,T, \tag{A2}$$

where Y_t is a $k \times 1$ vector, Δ indicates the difference of Y_t, T is the number of samples, ε_t is an error correction term ($k \times 1$), and Γ_j is a fixed $k \times k$ matrix. By substituting Π_t' with $\alpha\beta_t'$, where β_t is a time-varying cointegrating vector $\beta_t = (\beta_{1t}, \beta_{2t}, \ldots, \beta_{rt})$ with the following orthonormal Chebyshev time polynomials:

$$P_{0,T}(t) = 1, \qquad P_{i,T}(t) = \sqrt{2}\cos(i\pi(t-0.5)/T), \tag{A3}$$

where $t = 1,2,\ldots,T$; $i = 1,2,3,\ldots$; $\frac{1}{T}\sum_{t=1}^{T} P_{i,T}(t)P_{j,T}(t) = 1$ for $i = j$ and 0 otherwise. Equation (A2) can be rewritten as

$$\Delta Y_t = \alpha\left(\sum_{i=0}^{m} \gamma_{i,T} P_{i,T}(t)\right)' Y_{t-1} + \sum_{j=1}^{l-1} \Gamma_j \Delta Y_{t-j} + \varepsilon_t, \quad t = 1,\ldots,T, \tag{A4}$$

[10] In the case of a drift term in the VECM, the asymptotic properties of the approach also apply. See Theorem 3 in Bierens and Martins (2010). The proofs are presented in Bierens and Martins (2009).

Therefore, we can test the time-varying cointegration, employing a likelihood ratio test:

$$LR^{tvc} = -2[\hat{l}_T(r,0) - \hat{l}_T(r,m)\,] \tag{A5}$$

where $\hat{l}(r,\cdot)$ is a log-likelihood. Following the means in Johansen (1988), the statistics of testing time-varying cointegration are:

$$LR_T^{tvc} = -2[\hat{l}_T(r,0) - \hat{l}_T(r,m)] = T\sum_{j=1}^{r} \ln\left(\frac{1-\hat{\lambda}_{0,j}}{1-\hat{\lambda}_{m,j}}\right), \tag{A6}$$

where $\hat{\lambda}_{0,j}$ and $\hat{\lambda}_{m,j}$ are the corresponding eigenvalues. According to the deduction in Bierens and Martins (2010), the distribution of LR_T^{tvc} approximates to χ^2_{mkr}.

To measure RMB misalignment, we estimate equation (A4) to obtain the equilibrium RMB. The equilibrium RMB is given from a vector error correction model (VECM) with the above short-run deviations e_t. Misalignment is given by the difference between actual real RMB/USD exchange rates and equilibrium real RMB/USD exchange rates.

A2 Time-varying spillover approach

The time-varying spillover approach developed by Diebold and Yilmaz (2009 & 2012; D&Y hereafter) is extended from the VAR model and equipped with the Cholesky factor orthogonalization in variance decomposition. We introduce a simple case of a 2-by-2 matrix. In 1-step-ahead forecasting, the error vector $e_{t+1,t}$ (forecast (t+1) term based on time t) is:

$$e_{t+1,t} = x_{t+1} - x_{t+1,t} = A_0 u_{t+1} = \begin{bmatrix} a_{0,11} & a_{0,12} \\ a_{0,21} & a_{0,22} \end{bmatrix} \begin{bmatrix} u_{1,t+1} \\ u_{1,t+1} \end{bmatrix}, \tag{A7}$$

where $x_t = (x_{1t}, x_{2t})'$ is a vector consisting of variables, A_0 is a matrix, and vector

$u_{t+1} = (u_{1,t+1}, u_{2,t+1})'$ is given from the moving average representation of x_t. In D&Y (2009), the spillover index takes the form of:

$$S = \frac{a_{0,12}^2 + a_{0,21}^2}{trace(A_0 A_0')} \times 100. \quad \text{(A8)}$$

A general case (N-step-ahead of K variables) can be represented as:

$$S = \frac{\sum_{n=0}^{N-1} \sum_{i,j=1, i \neq j}^{K} a_{n,ij}^2}{\sum_{n=0}^{N-1} trace(A_n A_n')} \times 100 \quad \text{(A9)}$$

We follow the revised method of D&Y (2012), who loosen the restriction in D&Y (2009), in which the variance decompositions depend on the ordering of variables. Furthermore, D&Y (2012) offer a relatively flexible directional measure in the spillover index. For instance, estimating the spillovers from a fixed market *i* to all other markets *j* can be shown as:

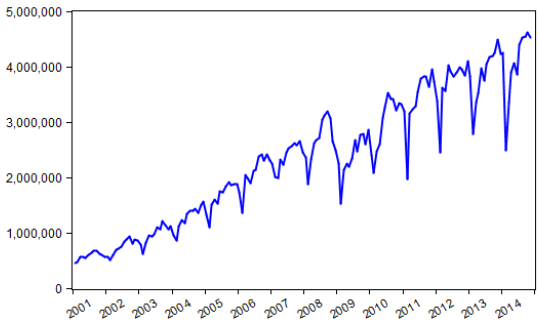
$$S = \frac{\sum_{n=0}^{N-1} \sum_{j=1, j \neq i}^{K} a_{n,ji}^2}{\sum_{n=0}^{N-1} trace(A_n A_n')} \times 100 \quad \text{(A10)}$$

where a_{ji} indicates the spillover from *i* to *j*.

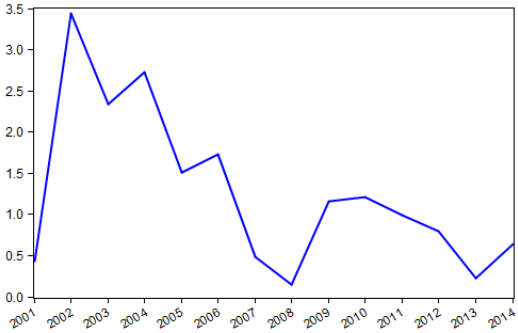
In our empirical examination, we are concerned about the spillovers of RMB misalignments to the exports of 8 Asian countries, which can be regarded as China's competitors in international trade. Thus, we take both the variables of RMB misalignments and the individual exports among China and the other Asian countries, in turn, and analyze their time-varying spillovers - that is, in Equation (A7), $x_t = (RM_t, EX_t)'$, where *RM* and *EX* are RMB misalignments and exports, respectively. We proceed with 1-step-ahead forecasting (N=1) of two variables (K=2). We further calculate time-varying spillovers by Equation (A10) with the rolling window method, where we set 60 months (5 years) as the rolling windows with 4 lags.[11]

[11] There is no strict criterion for deciding the size of rolling window estimations. A large window size

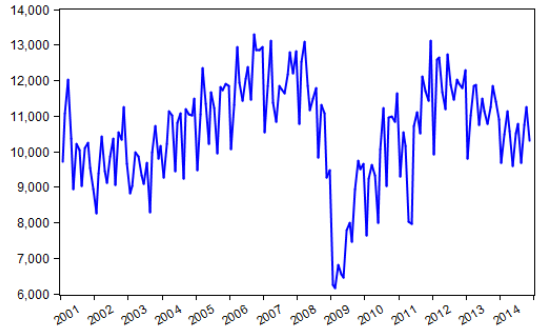
can imply a more precise estimate, but it simultaneously loses out in capturing heterogeneity compared with a small size window. More importantly, if there exist several structural breaks, then a short rolling window seems to be more appropriate than a large one (see, for example, Pesaran and Timmermann, 2005). Herein, we specify 5 years (60 observations) as the rolling window size.



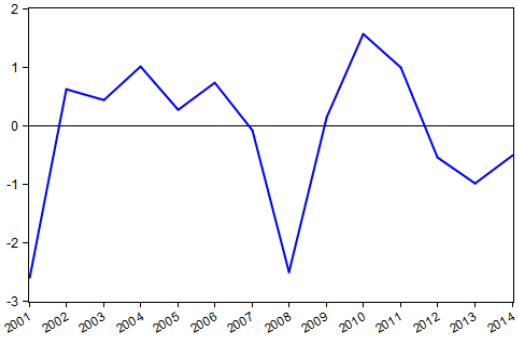
Exports of CH



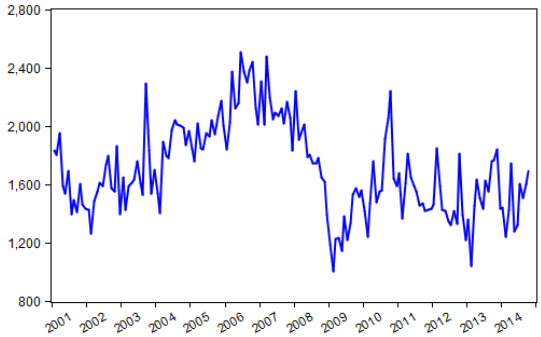
Export growth rate of CH



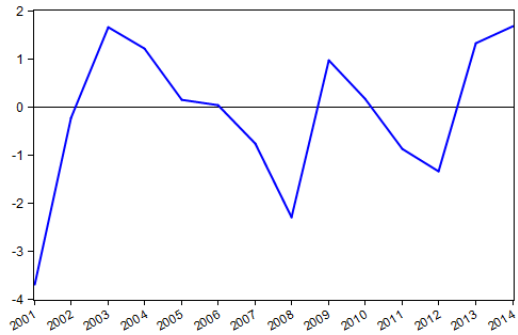
Exports of JP



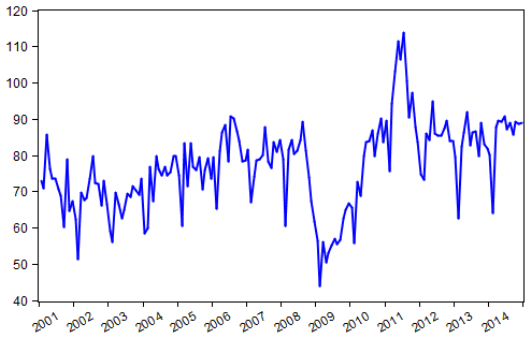
Export growth rate of JP



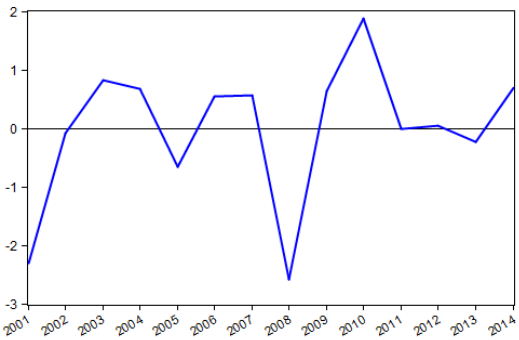
Exports of SP



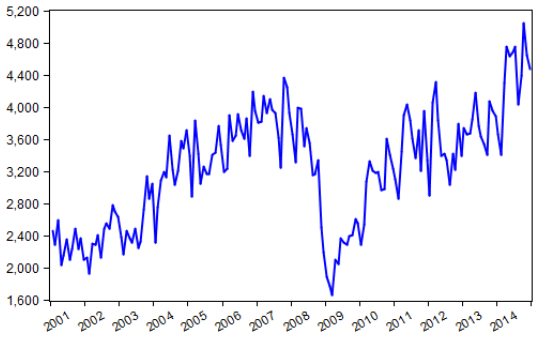
Export growth rate of SP



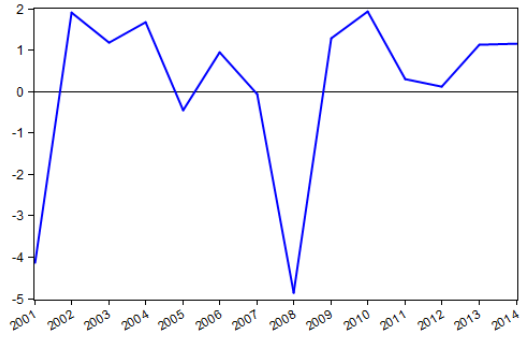
Exports of TW



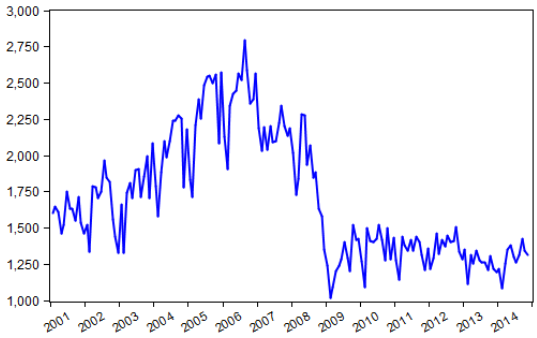
Export growth rate of TW



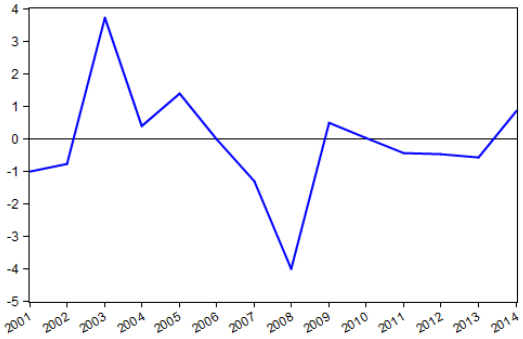
Exports of KO



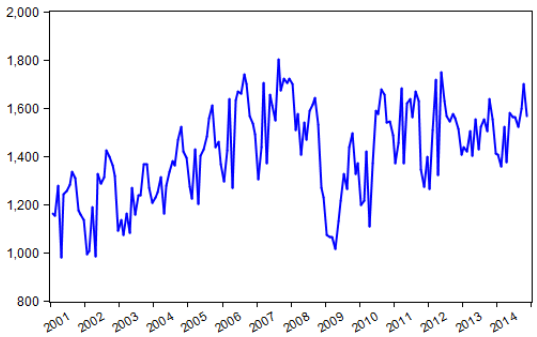
Export growth rate of KO



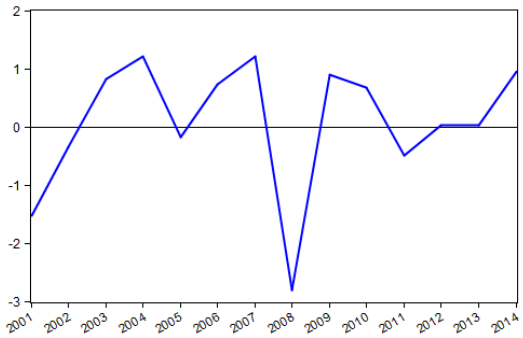
Exports of MY



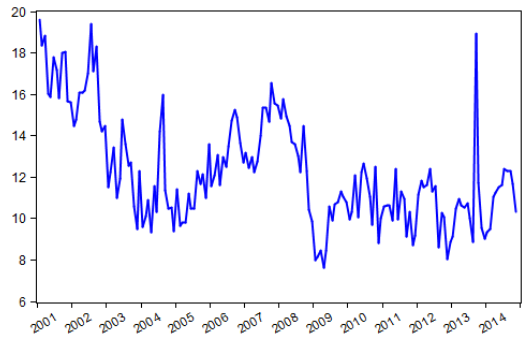
Export growth rate of MY



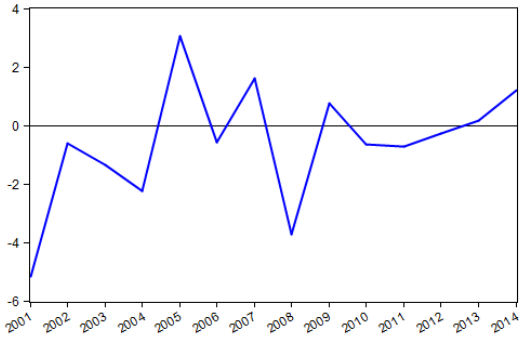
Exports of TH



Export growth rate of TH



Exports of PH



Export growth rate of PH

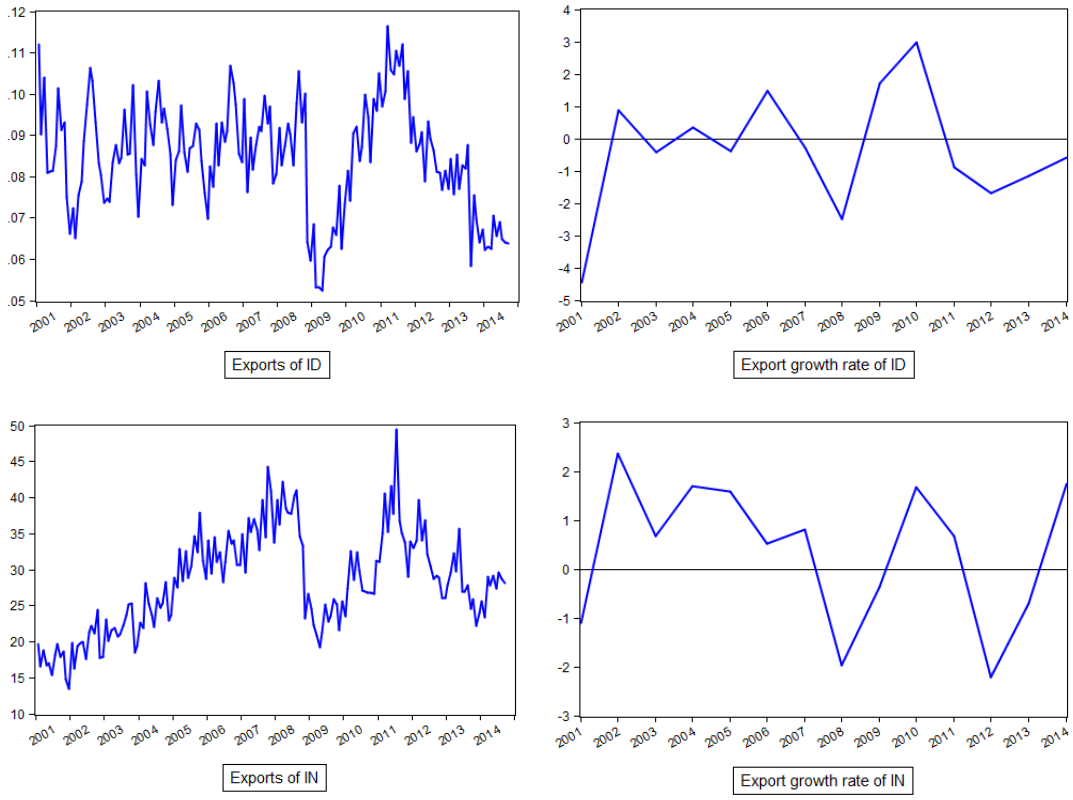


Figure 1. The real exports and export growth of China and 9 Asian countries

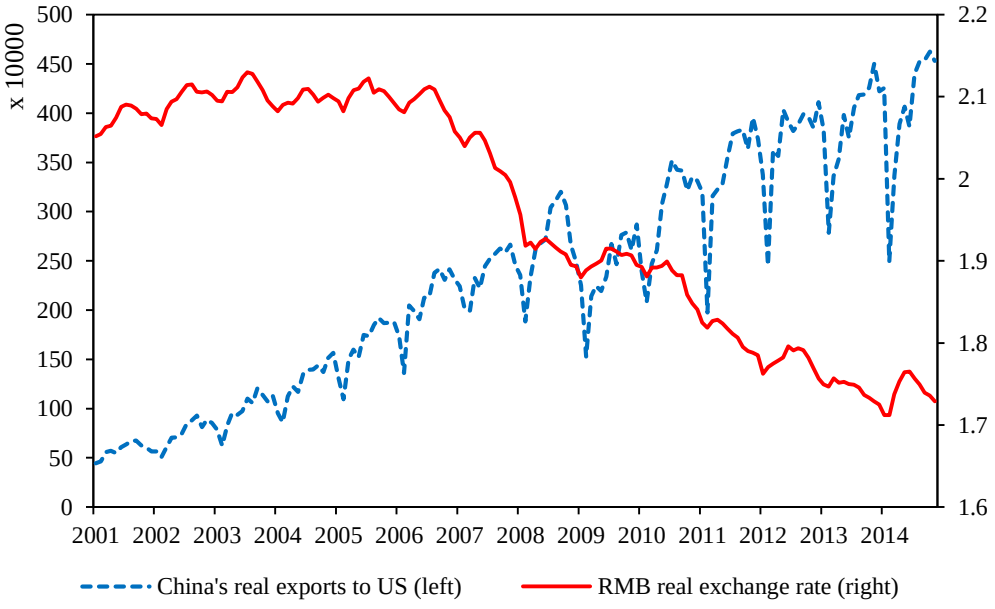


Figure 2 China's real exports to the US and RMB real exchange rate

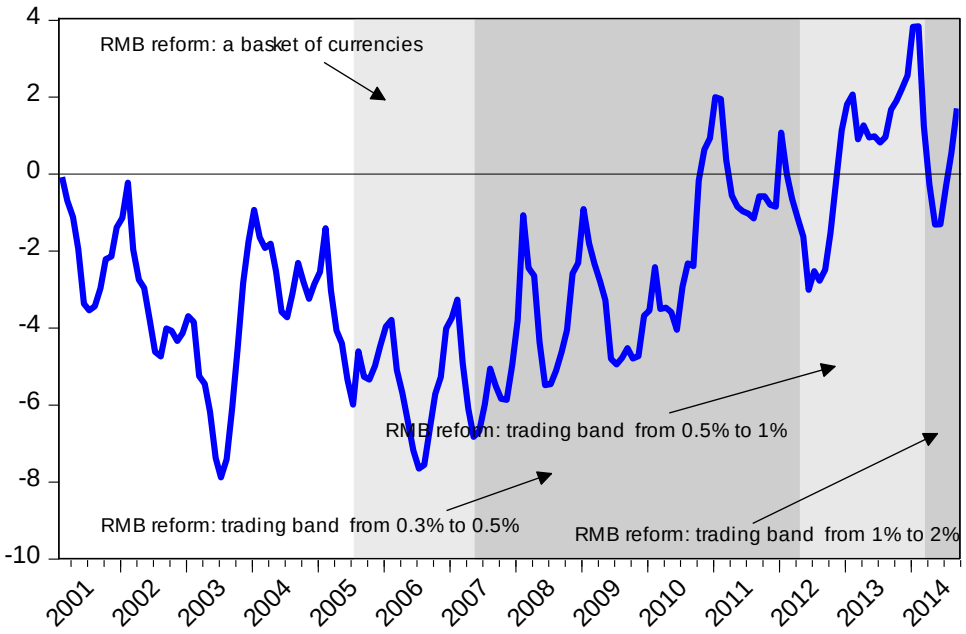


Figure 3. The estimated RMB misalignments

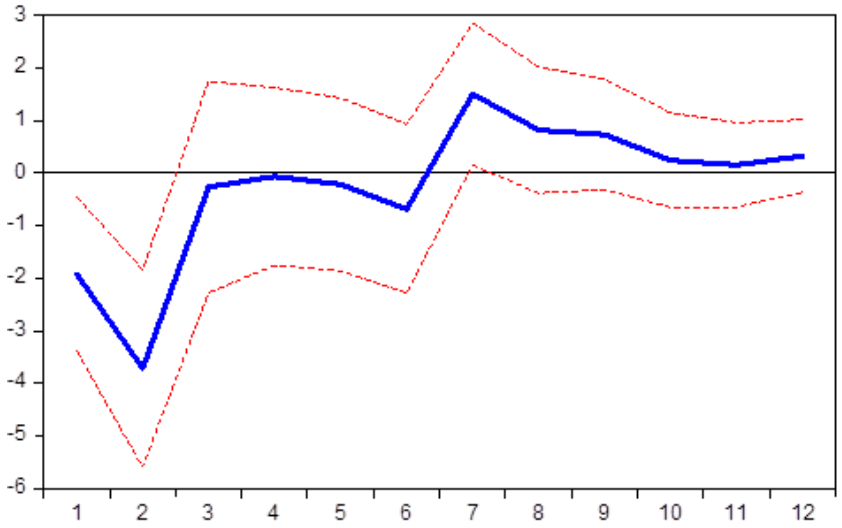


Figure 4. Response of dCH to generalized one s.d. RMB misalignment innovation

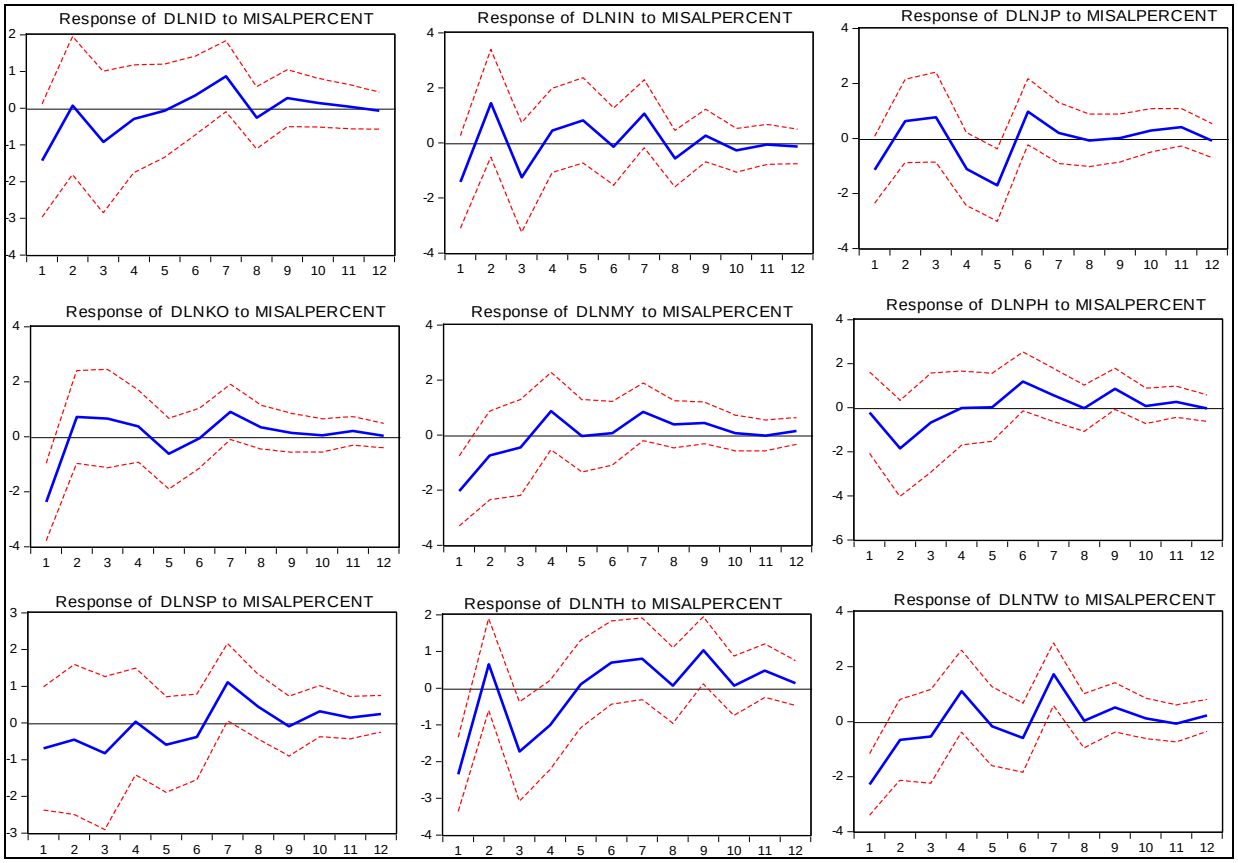


Figure 5. Responses of the trade of the others to generalized one s.d. RMB misalignment innovation

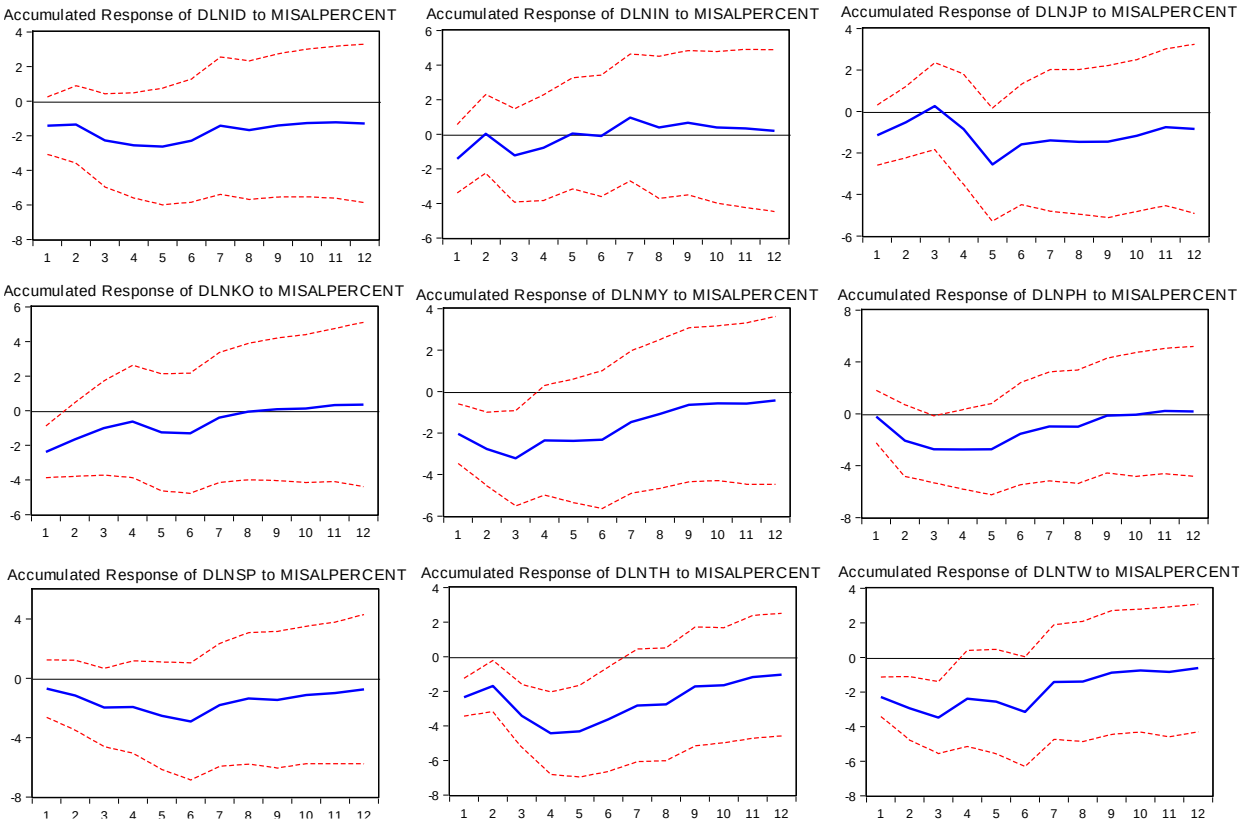


Figure 6. Accumulated responses of the trade of the others to generalized one s.d. RMB misalignment innovation

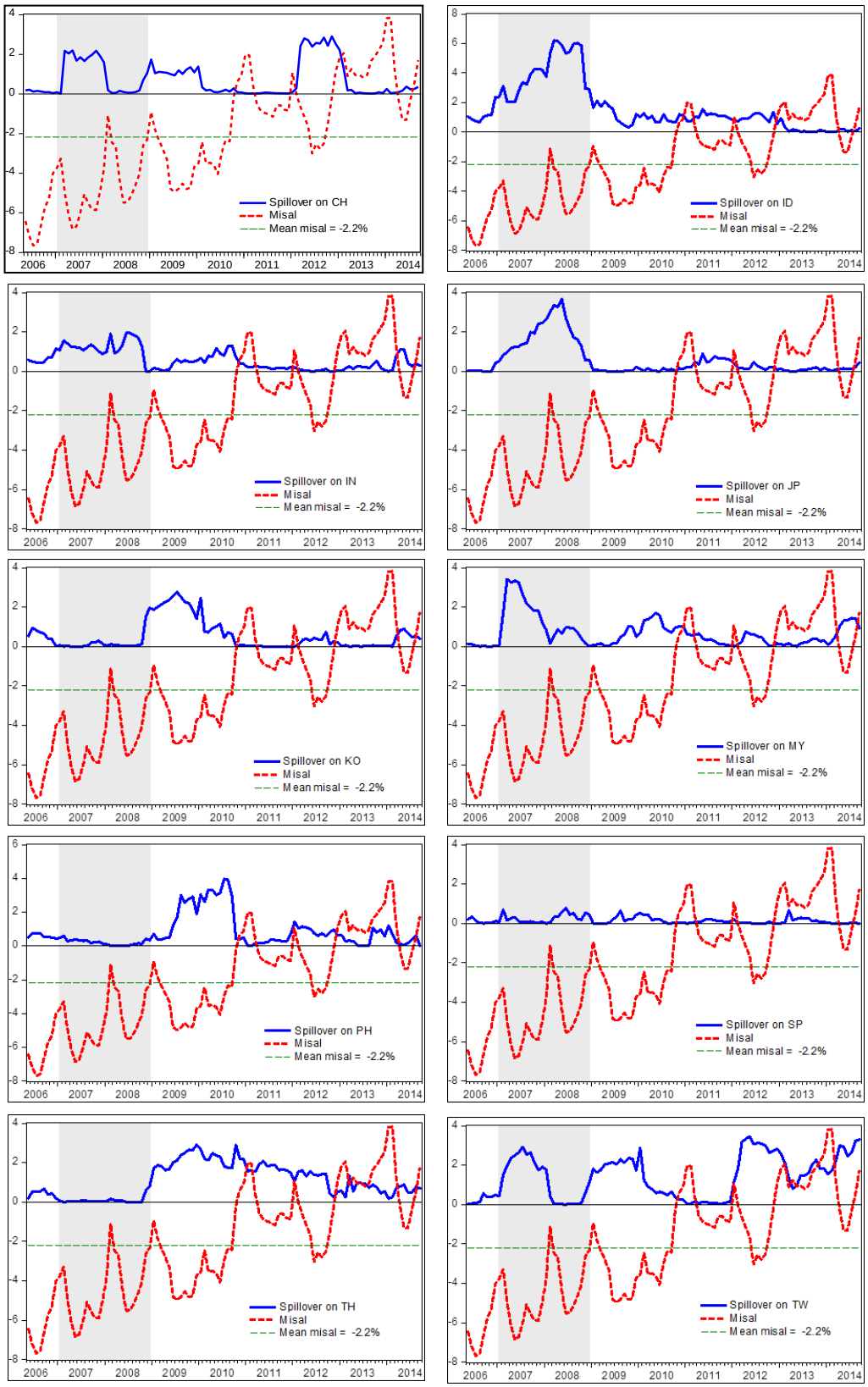


Figure 7. The time-varying spillovers of RMB misalignments to exports of the 9 Asian countries

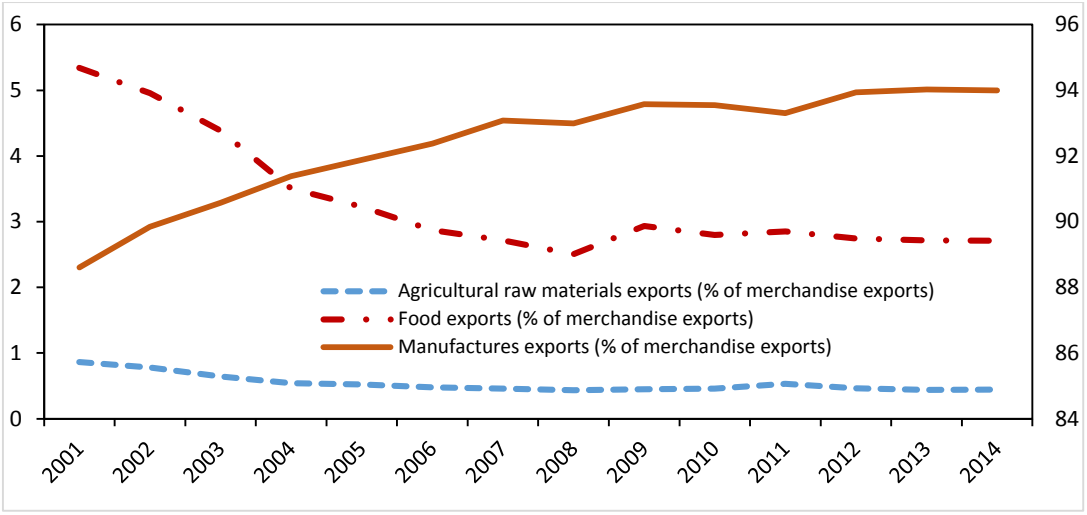


Figure 8. China's exports in percentage of merchandise exports

Table 1. Unit root and cointegration tests

Unit root test						
	ADF		***PP***		***KPSS***	
	Level	*1st differ.*	*Level*	*1st differ.*	*Level*	*1st differ.*
LnUS_CPI	-2.713	-7.493**	-3.512*	-8.919**	0.175*	0.021
LnCH_CPI	-1.022	-6.680**	-1.140	-7.329**	0.726*	0.133
EX	0.212	-9.5171**	0.401	-9.517**	1.051**	0.174

Johansen's cointegration test		
Number of Cointegrating Eqs.	*Trace test*	*Max-eigenvalue test*
None	53.620**	32.205**
At most 1	21.415	16.642
At most 2	4.773	4.773

Notes: LnUS_CPI, LnCH_CPI, and EX are the US CPI in log, China's CPI in log, and the exchange rate of RMB/USD, respectively. * and ** denote the statistical significance at the 5% and 1%, respectively. The null hypotheses of ADF and PP tests are that variable has a unit root, but the null hypothesis of KPSS test assumes a stationary variable. According to the AIC criterion, the model specification for cointegration test is restricted with intercept and time trend.

Table 2. The causality between/within RMB misalignment and exports

Panel A: Causality between RMB misal. and exports			
Null Hypothesis	Chi-sq. Stat.	Null Hypothesis	Chi-sq. Stat.
RMBM does not GC dCH	16.90**	RMBM does not GC dMY	6.50**
RMBM does not GC dID	1.02	RMBM does not GC dPH	2.68*
RMBM does not GC dIN	0.38	RMBM does not GC dSP	1.60
RMBM does not GC dJP	0.63	RMBM does not GC dTH	5.40**
RMBM does not GC dKO	0.63	RMBM does not GC dTW	7.02**
Panel B: Causality between exports of China and the 9 Asian countries			
dCH does not GC dID	0.10	dID does not GC dCH	10.17**
dCH does not GC dIN	4.89**	dIN does not GC dCH	13.67**
dCH does not GC dJP	7.85**	dJP does not GC dCH	13.11**
dCH does not GC dKO	1.95	dKO does not GC dCH	4.52**
dCH does not GC dMY	3.32*	dMY does not GC dCH	9.71**
dCH does not GC dPH	1.69	dPH does not GC dCH	6.94**
dCH does not GC dSP	1.24	dSP does not GC dCH	3.67**
dCH does not GC dTH	10.59**	dTH does not GC dCH	12.65**
dCH does not GC dTW	3.39*	dTW does not GC dCH	2.56*

Notes: RMBM and GC denote RMB misalignment and "Granger-cause", respectively. Here, we only show the causalities from RMB misalignment to the exports, whereas the results of the other direction are not reported to save space. * and ** denote statistical significance at the 5% and 1% levels, respectively. *dCH*, dID, dIN, *dJP*, *dKO*, *dMY*, *dPH*, *dSP*, *dTH*, and *dTW* indicate changes of exports from China, Indonesia, India, Japan, South Korea, Malaysia, Philippines, Singapore, Thailand, and Taiwan to the U.S. market, respectively. We examine the causality with the lag length 3 by the AIC criterion.