学籍番号：CD152007

The Significance of Renminbi in East Asian Currencies' Exchange Rate System

東アジア為替システムにおける人民元の有意性

大学院商学研究科

博士後期課程　会計・金融　専攻

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Contents:

Acknowledgements

Firstly, I want to express my sincere gratitude to my advisor, Prof. Ogawa Eiji, who is a learned and kindness supervisor. Facing to my poor Japanese, he is always patient. Secondly, I would also like to thank to associate Prof. Nakamura Hisashi. He provides a lot of advice for improving the methodology. In addition, when I was depressed by my study, he told me that drinking is not a good way to solve the problems; DOING is the best way to fall asleep at night. Thirdly, I also thank to Prof. Li Xiao, Jilin University. He is the person who changes my thoughts a lot. Finally, I thank to my father and mother. They always support my decisions, firmly.

Chapter 1. Introduction

1.1 The background

1.1.1 The economic background of Renminbi's increasing role in East Asia

China has made remarkable achievements in economic developments since the reform and opening-up policy lunched. From 2010 to 2016, the average annual growth rate of Chinese GDP was 8.1%. Now, China has already been the second largest economy in the world with the GDP of 74413 billion Yuan (11199 billion US dollars) in 2016.

A large economy always means a large economic power in the world as well as in the region. Subramanian (2011) argues that, the size of an economy is an important factor which can determine the status of its currency. As countries develop economically, interest also grows in the power of their currencies, such as the "German dominance hypothesis" in Europe and "Yen Bloc" in East Asia. Similar, the exchange rate relationship between Renminbi and East Asian currencies also has become an important topic as China's economy grows fast, as well as regional and economic reasons.

China's economic influence over other East Asian countries has expanded with its fast-growing economy. For example, from a perspective of gravity model of trade, there may be close trade relationships between China and other East Asian countries, because of China's huge economic mass and the short geographic distance. Its currency, known as Renminbi (RMB) or Chinese Yuan (CNY) is likely taken seriously because of the close economic ties with other East Asian countries.

In fact, as shown from Figures 1-2 to 1-6, China has already been the hub of the East Asian production chain and most East Asian countries maintain close trade relationships with China. In 2016, China was the largest trade partner of Malaysia, Singapore, Republic of Korea and Thailand out of the East Asia's important emerging

countries, in addition Taiwan and Hong Kong. Further, when we take some important East Asian countries (region) as a whole, for example: South Korea, Malaysia, Singapore, Taiwan and Thailand, we find that China is the largest market provider for these East Asian countries (region). For these five East Asian countries (region), more than 17% of the goods were exported to China each year, from 2010 to 2015 as shown in Figure 1-7.

China is not only the most important market provider but also the most important source of trade surplus for these East Asian countries (region). In Figure 1-8, the net export (trade surplus) from these East Asian countries to China was more than 50 billion dollars every year. We can conclude that China has become the important even the most important trade partners of these East Asian countries (region). These economic fundamentals can be thought as the base for a closer exchange rate relationship between the RMB and East Asian currencies (EACs).

1.1.2 The internationalization of the RMB

Chinese authorities also pursue the RMB internationalization and encourage using the RMB abroad. In recent years, the Chinese authorities have adopted a series measures to do this. For example, the Chinese authorities have pushed the Cross-Border Trade RMB Settlement Pilot Project since 2008 which allows companies import and export in RMB with neighboring countries including ASEAN countries. In 2012, the volume of Renminbi cross-border trade settlement was only 2.94 trillion Yuan; this number reached 6.13 trillion Yuan by the end of 2014. At the end of 2016, there were about 240,000 onshore companies use the RMB as the settlements in the cross-border trade.[1]

Also, the Chinese authorities have signed a series of currency swap agreements with foreign center banks. Under the agreements, the foreign banks can sell the RMB to the enterprises who can directly use the RMB in the international trade. In addition, the swaps can also provide the RMB liquid abroad. From 2008 to 2013, the People's

[1] The People's bank of China. (2017). *2017 RMB Internationalization report.*

bank of China has signed 21 currency swap agreements with foreign authorities. This number increased to 32 at the end of May, 2015, and then reached 36 at the end of 2016. The Renminbi swap programs include many East Asian countries such as Japan, the Rep. of Korea and Malaysia.

The Renminbi's internationalization is also promoted by establishing the RMB off-shore centers in Hong Kong, Singapore and London. The Renminbi off-shore markets are developing fast. Since 2007, Renminbi bonds (dim sum bonds) of Chinese and Hong Kong banks have been issued in Hong Kong. In 2009, the first sovereign Renminbi-denominated bond issued by Ministry of Finance was traded in Hong Kong. Not only Chinese companies and authorities, but also foreign institutions also issue the "dim sum bonds". For example, the Asian Development Bank issued the first supranational dim sum bond in October 2010. At the end of 2016, Renminbi deposit in the off-shore markets was 1 trillion and 120 billion Yuan. The outstanding "dim sum bonds" issued by foreign institutions was 698.72 billion Yuan, in the off-shore markets.

As a result, Renminbi became the fourth most used payments currency in the world in August 2015 according to the Society for Worldwide Interbank Financial Telecommunication (SWIFT). The Renminbiś participation in foreign exchange markets also increased obviously according to the Bank for International Settlements (BIS). In April 2013, the RMB ranked ninth in most-actively traded currency according the data released by the BIS on currency distribution of global foreign exchange market turnover. In aggregate, the RMB´s daily turnover increased from 34 billion dollars to 202 billion dollars in the period from 2010 to 2016. The weight also increased from 1% in 2010 to 4% in 2016.

The RMB is becoming more and more important in the international monetary system. On October 1, 2016, the RMB joined the International Monetary Fund's (IMF) Special Drawing Rights (SDR) basket, which is thought as recognition of Renminbi internationalization and exchange rate system reforms. The weight occupied by the RMB is 10.92%, even higher than that of Japanese yen and British pound sterling, which is 8.33% and 8.09%, respectively. According IMF's Currency Composition of

Official Foreign Exchange Reserves (COFER) database, 0.85% of the global total foreign reserves are claimed in the RMB at the end of 2016, the ratio increased to 0.89% in Q3 of 2017. The people's bank of China declared that more than 60 countries (regions) use the RMB as reserve currencies in their report.[1]

1.1.3 The evolution of Renminbi exchange rate fluctuation band

Since the mid-1990s, the Chinese authorities had carried out a series of measures trying to reform the RMB exchange rate system. On January 1, 1994, the Chinese authority unified its dual exchange rate system, and fixed the exchange rate of 8.26 RMB to per US dollar, which means that the RMB depreciated 50% percent sharply. After then, the exchange rate between the RMB and USD was fixed around 8.28, and there were no visible fluctuations at all.[2] To some extent, the *de facto* dollar-peg exchange rate system helped the Chinese authority control the inflation efficiently; maintained the growth of GDP at a high and steady level; also stimulated China's export (e.g. McKinnon and Schnabel, 2012; Nair and Sinnakkannu,2010).

However, this rigid exchange rate system is unsustainable for China's economic development. Since July 21, 2005, the Chinese authorities have done lots of efforts to push the RMB exchange rate system towards "market-oriented". A major content of these reforms is widening the fluctuation band of the RMB exchange rate and almost all of the RMB exchange rate system reforms are related to the fluctuation band of Renminbi exchange rate against the US dollar.

As presented in Table 1-1, four out of six reforms are related to the RMB exchange rate fluctuation band. The *de jure* daily fluctuation band of USD/RMB is expanded from almost 0% before July 21, 2005 to 2% after March 17, 2014. Although the People's bank of China unloosed the rate of USD/RMB to a certain extent after the 2005 reform, the 2008 crisis interrupted the progress of promoting the RMB exchange rate system reform. The Chinese authorities re-pegged the RMB to the US dollar

[1] The People's bank of China. (2017). *2017 RMB Internationalization report.*

[2] A prevailing opinion is that China has employed a managed floating exchange rate regime since July 21, 2005. But it is not true.

again during the period of 2008 crisis to avoid the economic risk. On June 19, 2010, after the most serious period of the global economic crisis, the People's bank of China announced that "It is desirable to proceed further with reform of the RMB exchange rate regime and increase the RMB's exchange rate flexibility"[1]. The RMB exchange rate is more normal after the 2008 crisis. During the period from 2010 to 2016, the USD/RMB rate experienced both appreciation and depreciation trend, as shown in Figure1-9. The rate of USD/RMB got the lowest point at 6.07 on January 14, 2014. After then, the RMB turned into a deprecation trend, at least until December 30, 2016.

1.2 The motivations and main contents

In East Asia, the exchange rate system has been studied since 1990s. When we think one currency's exchange rate system, we should consider how this currency fluctuates against other currencies, such as the fluctuation band, its anchor currency and currency basket, and the intervention. These sides can be reflected in the exchange rate relationships. The East Asian countries have some common economic properties such as "export-oriented". In this case, the East Asian currencies also have some commonalities, for example, most of them kept relatively close relationships with the USD. Keeping their currencies stabilization against the USD can help the East Asian countries achieve economic growth and reduce external risks. In other words, the USD is very important in East Asia, both for the East Asian monetary authorities and foreign exchange market participants. However, according some studies, the USD's position has been changed in recent years, and the East Asian currencies show various characteristic in recent years.

According to Kenen (1983), an international currency always has three functions, which are "medium of exchange", "unit of account" and "store of value". For the public sectors, although the data of reserves claims in Renminbi has released since Q4 2016 by the IMF, the data is still insufficient to be used for researching. Moreover, it is seems unlikely that the foreign monetary authorities intervene the exchange rate by

[1] PBC: Further Reform the RMB Exchange Rate Regime and Enhance the RMB Exchange Rate Flexibility.http://www.pbc.gov.cn/publish/english/955/2010/20100622144059351137121/20100622144059351137121_.html.

using the RMB. For private sectors, the RMB's role is still limited in the financial markets, although it has become greater because of the developing Renminbi off-shore markets and higher degree of capital account liberalization. Thus, we mainly detect the relationship between the RMB and East Asian currencies from a perspective of exchange rate in this study.

As mentioned in part 1.1, China has been a significant role in economic field in East Asia and there is a very close trade relationship between China and East Asian countries. Meanwhile, the more international Renminbi and its more flexible exchange rate may be positive factors for the RMB exchange rate playing a significant role in East Asia. In this study, we will check whether or not the RMB plays a significant role in the field of exchange rate in East Asia, as well as the evolution. Because of the small margin of the return of USD/RMB, the interaction between the RMB and East Asian currencies are neglected for a long time. However, when the fluctuation band of the rate of USD/RMB became larger in recent years, it is unavoidable to reconsider the relationship between the RMB and East Asian currencies, as well as the importance of China's currency: Renminbi's role in East Asian foreign exchange market.

Firstly, we study whether or not the RMB exchange rate shocks can influence East Asian currencies' exchange rate. If so, what is the evolution with the expanding RMB exchange rate fluctuation band. To do this, Vector Autoregressive (VAR) models are employed in this study. The sample East Asian currencies are South Korean Won (KRW), Malaysian Ringgit (MYR), Singapore Dollar (SGD), New Taiwan Dollar (TWD) and Thai Baht (THB). Because of the important position of the US dollar in East Asia, we choose the New Zealand dollar (rather than the USD, Special Drawing Rights (SDR) or Swiss Franc (CHF)) as the numeraire currency. By doing this we can put the US dollar and Renminbi, as well as the Euro into one model simultaneously. Although the daily fluctuation band of the rate of USD/RMB increased during the whole sample period, the relatively small band may still cause the multicollinearity problem. To remove the "US dollar factor" from the RMB exchange rate, we use the residuals obtained by ordinary least squares regression (OLS) as the proxy of the

RMB exchange rate. As the promotion of the RMB exchange rate system, the daily fluctuation of the RMB became larger. Thus, we choose the days on which the People's bank of China launched the RMB exchange rate system reforms and widen the fluctuation band as the break points. The sample period is from June 21, 2010 to December 30, 2016 is divided into three sub-periods.

Secondly, the expanding RMB exchange rate fluctuation band and the promotion of RMB internationalization also mean a larger risk not only for itself, but also for other currencies, for example, the East Asian currencies. In this part, we employ the BEKK (Baba-Engle-Kraft-Kroner) GARCH model to detect whether or not the RMB exchange rate shocks and volatilities can affect the East Asian currencies' exchange rate volatilities. In other words, whether or not there are spillover effects between the RMB and East Asian currencies, further, how about the directions. Through the exchange rate spillover effects, we can judge the RMB's role in East Asia. Since the step of the RMB internationalization and the promotion of exchange rate system reform are fast from 2010 to 2016, it is not suitable to detect the spillover effects during the whole period. In this part, we divide the whole sample period into three sub-periods, each one contains two years. By doing this, we can judge the significance of the RMB exchange rate's role from a perspective of spillover effects in each sub-period, as well as its evolution.

Thirdly, after detecting the shock and spillover effects between the RMB and East Asian currencies, we focus on detecting the exchange rate return correlations among some important international currencies (such as US dollar, Euro and Japanese Yen), the RMB and East Asian currencies during the whole sample period from June 2010 to September 2016. To do this, we employ the DCC-GARCH (Dynamic Conditional Correlation Generalized Autoregressive Conditional Heteroskedasticity) model which can detect the conditional correlations between these sample currencies' returns. The exchange rate return reveals the degree of stability of one currency to its numeraire currency. Then, a higher DCC means a closer exchange rate relationship between two currencies. In other words, the DCC(s) can reveal whether the two currencies move together against their numeraire currency, if so, to what extent. Unlike dividing the

whole sample period into some sub-periods, the DCC-GARCH model can obtain the dynamic and continuous correlations among these sample currencies. From June 2010 to December 2016, the rate of USD/RMB experienced both appreciation trends and depreciation trends. When there is a close economic relationship between China and East Asian countries, for example China has been the most important source of trade surplus for most East Asian countries, the exchange rate relationship between the RMB and East Asian currencies may be different when the RMB exchange rate was on the appreciation and depreciation trends. We choose the day on which the rate of USD/RMB got its lowest point at 6.04 to detect whether or not the correlations between the RMB and East Asian currencies show different characteristics when the RMB was on different trends. In more detail, whether or not the exchange rate return conditional correlation between the RMB and East Asian currencies was strengthened when the RMB became more flexible and shifted into a depreciation trend after January 14, 2014.

1.3 The contributions and main findings

Comparing with the previous studies, there are some contributions in this study.

Firstly, the traditional studies mainly focus on the currency baskets when they study the exchange rate relationships between the RMB and East Asian currencies. In this study, we research the issue from many perspectives, which are shocks, volatilities and correlations. The methods employed in this study can avoid the shortages exist in the currency basket regression model. In addition, these methods can provide supports or paradoxes to each other.

Secondly, the existing studies are mainly “whole sample period” model. However, this method is not appreciable as the fast change of the RMB exchange rate system. In this study, we analyze the issue periodically, even dynamically. The periodical and dynamic methods can obtain more detail and accurate results.

Thirdly, we analyze the correlation of the RMB and East Asian currencies when the RMB was on appreciation and depreciation trends, separately. This is a new approach of studying the RMB’s role in East Asia. From an economic perspective, there are

differences between a weak RMB and strong RMB for some East Asian countries, as well as their currencies. Through this method, we connect the economic factors and currency market to some extent.

We obtain some findings following.

Firstly, we find that the RMB exchange rate shocks could more and more significantly affect some East Asian currencies exchange rate with the expanding exchange rate fluctuation band from 2010 to 2016. During the first sub-period when the daily fluctuation band of the USD/RMB was limited in 0.5%, the RMB exchange rate shocks could not affect East Asian currencies exchange rate at all. From the results obtained by the VAR models, none of the accumulated responses of East Asian currencies to the RMB exchange rate shocks are significant as we cannot reject that the responses equal 0 within 95% confidence interval. This means that the RMB's role was not significant during the first sub-period. When the daily RMB exchange rate fluctuation band was expanded to 1%, the East Asian currencies responded to the RMB exchange rate shocks significantly to a certain extent, however, the impacts were still small that the RMB was still not significant currency in East Asia. However, when the RMB daily fluctuation band was expanded to 2% during the sub-period A3, the more flexible RMB could significantly affect all of the sample East Asian currency exchange rates movements, except for the THB. This means that the flexible RMB played a significant role in East Asia when it deviates from the US dollar. Meanwhile, the US dollar was always the dominant currency since all of the East Asian currency exchange rates movements were significantly influenced by the US dollar exchange rate shocks. The EUR was another important currency in East Asia, particularly during the period from June, 2010 to March, 2014. However, its role was not significant during the sub-period A3.

Secondly, the RMB exchange rate could also transfer more and more exchange rate risks to other currencies. When we break up the whole sample period, we find that the spillover effects transferred from the RMB to some East Asian currencies became more and more significant during the period from 2010 to 2016. This progress also developed gradually. During the first sub-period, almost all of the parameters in the

BEKK-GARCH model which represent the exchange spillover effects were not significant, except for the TWD. These results show that there were almost no exchange rate spillover effects from the RMB to East Asian currencies, and the RMB played an insignificant role in the field of exchange rate risks in East Asia. However, during the second and third sub-periods, especially the third period, the RMB could significantly transfer exchange rate spillover effects to East Asian currencies. Among these currencies, the THB is the only currency whose volatility is immune to the RMB exchange rate return shocks and volatilities, this also means that the relatively loose relationship between these two currencies. In this part, we also detect the exchange rate spillover effects between the US dollar and East Asian currencies by choosing the New Zealand dollar as the numeraire currency. From the results, the USD can transfer not only return shock but also volatility spillover effects to these sample East Asian currencies' volatilities during the period from 2010 to 2016, except for the KRW. This demonstrates the very important role of the US dollar in East Asia.

Thirdly, through the DCC-GARCH model, we found that the US dollar was always a dominant currency for East Asian currencies comparing with the Euro and Japanese Yen when we choose New Zealand dollar as the numeraire currency, although the exchange rate return co-movements between the US dollar and East Asian currencies became weaker during the sample period. Meanwhile, the RMB was still subdued because of it stood too near to the US dollar while other East Asian currencies showed greater flexibility against the US dollar. This also suggests that the exchange rates of these East Asian currencies became more flexible, while the RMB's exchange rate flexibility has increased slowly, comparing with other East Asian currencies. However, when we choose the USD as the numeraire currency, the exchange rate return co-movements between the RMB and some of the EACs showed a rise during the period in which the RMB exchange rate run into a depreciation trend against the US dollar. These results confirm the existence of the "fear of appreciation and fluctuation" against the Renmibi in SGD, KRW and TWD. We also find that these three countries (region) kept large trade surplus with China, while China was not Malaysia and Thailand's most important source of trade surplus. It seems that the results are quite

mixture even contradictory when we employ the NZD and USD as the numeraire currency respectively. In fact, this just reveal the RMB's increasing but limited role in East Asia. The RMB is neither a polar of East Asian exchange rate system nor a challenger to the USD. If the RMB exchange rate system can be reformed further in the future, the RMB could potentially attract more attention in East Asia.

Chapter 2. Literature reviews

2.1 Regional currency: the case of East Asia

After the collapse of the Bretton Woods regime in 1970s, the international monetary system became a "no regime" system (Gilpin and Gilpin, 2001). Many experts consider that the international monetary system is moving towards multi-polar international monetary system (Eichengreen, 2009 and 2010; Angeloni et al. 2011). Subramanian (2011) argues that, the size of an economy, the size of its trade and external financial strength can determine a currency's status.

In Europe and East Asia, Deutsche Mark，US dollar and Japanese Yen's role in exchange rate have been enthusiastically studied. In Europe, the "German dominance hypothesis" has been studied during the 1980-1990s. The studies show that the Deutsche Mark played a dominant role in Europe (Giavazzi and Giovannini, 1987; Giavazzi and Pagano, 1988; Russo and Tullio, 1988; Von Hagen and Frattianni, 1990). In East Asia, the US dollar and Japanese Yen's roles have been widely studied. As the most important currency in the world, the US dollar is also very important for East Asian countries. McKinnon and Schnabl (2004) argue that many East Asian counties "fear of floating" against the USD not only before the Asian Financial crisis, but also until the year of 2002.Their joint pegging to the dollar benefits the East Asian dollar bloc as a whole. However, this situation changed some years later. Kim et al. (2009) examine the exchange rate in eight East Asian countries. Their results show that five of the eight countries move toward a more flexible exchange rate system during the post-Asian crisis period. The USD's role as an anchor currency in East Asia declined to some extent. For Japan, the "Yen Bloc" has been studied during Japan's economic boom in the late 1980s and early 1990s (Frankel, 1992; Frankel and Wei, 1994; Kwan, 1994 and 1999). Most of these studies show that the Yen bloc was not significant although Japan played a very important role in the field of economy in East Asia.

Since mid-2000s, the People's bank of China had reformed the RMB exchange rate

system many times. The RMB internationalization is also promoted by Chinese authorities. Besides, because of China's huge size economy and close international trade relationship with East Asian countries, the RMB's role has caused some experts' interests. Through a parallel analysis of the international monetary system during the 1920s and 1930s, Eichengreen and Flandreau (2009) consider that the RMB would play an important role in East Asia. In 2015, Eichengreen and Lombardi (2015) confirmed the view again mentioned above. From the perspective of China's GDP, international trade relationships, trade costs and political factors, they predict that the RMB will be a more important role not only in East Asia, but also in the world. Ito (2010) also studies the RMB's role in East Asia. The author examines whether or not China can become the number one economy, which is a very important factor for the RMB becoming a key currency in East Asia, even in the world. The author considers that China will be the largest economy under a set of assumptions, which can support the RMB to become an anchor currency in the regional exchange rate arrangement. However, because of China's limited capital account openness and RMB's transactions, there is a still long way for the RMB to be a key currency in East Asia and world.

2.2 The RMB's role in East Asia: from a perspective of currency basket

Since July 21, 2005, the People's bank of China had reformed the RMB exchange rate system many times. The daily fluctuation band of the exchange rate band of USD/RMB has been expanded from almost 0% to 2%. The RMB's role, such as from a perspective of exchange rate, has caused experts' interests. As proposed by Kenen (1983), an international currency has three functions: store of value, medium of exchange and unit of account. For the first two functions, it seems that there is still a long way for the RMB to be popularly used as international reserves or substitutes for a domestic currency for other countries; neither to be used as a setting currency widely. Moreover, the data is difficult to be got. Until now, the existing studies are mainly focused on the last function: the RMB's exchange rate, to be more precisely

speaking, the exchange rate relationships between the RMB and East Asian currencies.

When the exchange rate relationship between the RMB and East Asian currencies is investigated, Frankel and Wei's currency basket regression model (Frankel and Wei, 1994, hereinafter referred to as the "Frankel-Wei model") is always popularly employed as a workhorse model. In the Frankel-Wei model, a high weight occupied by currency A in currency B's basket always means a closer relationship between these two currencies. This also means currency A is important for currency B.

Ito (2010) chooses the Swiss franc (CHF) as the numeraire currency to check EACs' currency baskets. To investigate the RMB's status in the East Asian currencies' (EAC) currency baskets, the author only uses the data for the period from July 4, 2005 to December 31, 2008 during when the RMB showed some fluctuations against the USD. The result shows that for most EACs' currency baskets, there were already a significant weight on the RMB. If the RMB appreciates 1% against the USD, the Singaporean dollar (SGD), Malaysian ringgit (MYR), New Taiwan dollar (TWD), Indian rupee (INR) and Indonesian rupiah (IDR) will appreciate somewhere between 0.3% and 0.5%. Henning (2012) divides the 12 years sample period into four sub-periods, depending on the changes in the Chinese exchange rate regime. Through the results obtained by Frankel-Wei model, the author argues that the RMB's weight in these EACs' currency baskets is increasing, even greater than the USD in the baskets for four of the main Southeast Asian currencies plus the New Taiwan dollar. Further, Subramanian and Kessler (2013) even consider that there is already an RMB bloc in East Asia because the RMB has become the dominant reference currency in East Asia. Through the results obtained from the Frankel-Wei model, 7 currencies out of 10 move closely with the RMB than with the US dollar. They even forecast that there will be a global RMB bloc by the mid-2030s.

However, some experts also consider that the RMB's role is still limited although the RMB is becoming important for East Asian currencies. Balasubramaniam et al.(2011) find that more and more currencies are sensitive to the rate of USD/RMB after the RMB exchange rate reform on July 21, 2005.The null-hypothesis that

"Renminbi effect is 0" is rejected when the RMB was not pegged to the USD. However, The RMB's role declined in 2008, during when the fluctuation of the rate of USD/RMB was almost 0% as the People's bank of China re-pegged the RMB to US dollar to avoid the possibility of exchange rate risk caused by the 2008 crisis. They consider that, if the flexibility of the rate of USD/RMB can be greater, the RMB's role could potentially rise. Similar to the "German dominance hypothesis" which expresses that German mark played a key role in Europe in the 1980s-1990s, Fratzscher and Mehl (2011) also find that the RMB has become a key driver of currency movements in East Asia by studying the EACs' currency baskets. Although they consider that "China's dominance hypothesis" is supported by the results, this dominance remained weaker at that time than that of Germany. Kawai and Pontines (2014a; 2014b) also consider that the RMB has taken on some importance in the currency baskets of many East Asian economies. However, the USD continues to be the dominant anchor currency in East Asia, and there is no Renminbi bloc in East Asia.

The Frankel-Wei model can also reveal some characteristics of the exchange rate, for example, according to some experts, there is not only "fear of floating", but also "fear of appreciation" for emerging countries (Levy-Yeyati et al., 2013). In recent years, with the wider fluctuation band of the rate of USD/RMB and closer trade relationship between China and East Asian countries, some experts argue that there is also "fear of appreciation" against the RMB in East Asia. For example, some studies take into account the different reactions of the East Asian currencies when the RMB appreciates and depreciates. Pontines and Siregar (2012)'s findings indicate that there is "fear of appreciation" against the RMB in some East Asian countries. They even point out that the higher fear of appreciation against the RMB than against the USD. China's exchange rate policy can significantly drive the behavior of an overall fear of appreciation in East Asia. Keddad (2016) also uses the Frankel-Wei model with Markov-switching to detect the co-movement between the RMB and EACs. The author finds that the East Asian currencies kept greater co-movement with the RMB when the RMB depreciated and fixed the USD. However, when the RMB appreciated

against the USD, these currencies tended to underreact to the RMB's exchange rate fluctuation. This result confirms the East Asian currencies' "fear of appreciation" against the RMB.

When the Frankel-Wei model is used in investigating the exchange rate relationships between the RMB and East Asian currencies, multicollinearity is a main problem the experts should face to. In comparison with other East Asian currencies, the range of daily fluctuation of the USD/RMB was always very narrow in a long period. Thus, if we simultaneously take the RMB and USD as the independent variables and put them on the same side of the OLS regression, the RMB's "US dollar factor" could affect the model's accuracy. The researchers have attempted to address this multicollinearity problem with technical improvements. For example, Subramanian and Kessler (2013) choose the periods of July, 2005 – August, 2008 and July 2010 - July 2013 as the sample periods. They believe that the rate of USD/RMB showed sufficient variation during these periods, because the RMB was pegged to the US dollar before the July 21, 2005 on which day first exchange rate system reform was lunched, and was pegged to the US dollar again during the 2008 crisis. For the same reason, Ito (2010) chooses the period from July 4, 2005 to December 31, 2008 as the sample period. Similarly, Henning (2012) picks out the period from 2008 to 2010 during when the RMB was pegged to the US dollar. To investigate the RMB's weight in EACs' currencies baskets, Balasubramaniam, Patnaki and Shah (2011) remove the US dollar factor from the RMB by Ordinary Least Squares regression (OLS). Then, the estimated residual obtained by the OLS are used as a proxy of the RMB exchange rate. This method is also employed by Fratzscher and Mehl (2011), Kawai and Pontines (2014a, 2014b). Ho, Ma and McCauley (2005) choose the USD as the numeraire currency, and use the rate of the RMB NDF as the RMB exchange rate.

2.3 The spillover effects between different financial markets

The spillover effect is another perspective of investigating the relationship between different financial markets. A larger spillover effect always indicates a greater

integration, as well as contagion in financial markets. The spillover effects exist in many financial markets. Extensive researches reveal that there are spillover effects in world stock markets (Chan and Karim, 2010; Li and Giles, 2014; Xiao and Dhesi, 2010; Li, 2007; Brooks and Henry, 2000; Padhi and Lagesh, 2012). What's more, there are also spillover effects between different types of financial markets. For example, the spillover effects can be transferred between the currency market and equity market (Arifin and Syahruddin, 2011; Caporale and Ali, 2013; Dark, et al.2005; Fedorova and Saleem, 2010).

As the foreign exchange market becomes more integrated, more and more literatures pay attention to the currency relationships from a perspective of spillover effects. Studies which examined exchange rate spillover effects are initiated by Engle et al. (1990). The USD and EUR always attract researchers' interests because of their importance. McMillan and Speight (2010) consider that the USD can dominate the GBP and JPY significantly in terms of return and volatility spillovers. Bubák et al. (2011) find that there are volatility spillovers among the Central European foreign exchange markets. However, there are no significant spillovers running from the EUR to the Central European foreign exchange markets. Patnaik (2013) and Kumar (2014) also find spillover effects among the USD, EUR, GBP and JPY, which are important currencies in the world.

In recent years, the progress of RMB's internationalization has been significantly promoted. Some literatures are concerned whether or not the spillovers effects exist between the RMB market and other currencies markets. Kou and Kong (2014) find that the yield spillovers and volatility spillovers between the RMB Non-Deliverable Forward (NDF) and SPOT market have undergone significant changes after the establishment of CNH (offshore).Thus they consider that the CNH market is important for the pricing mechanism of the RMB. Colavecchio and Funke (2008) suggest that the RMB NDF can transfer volatility to various Asian currency markets. As the closer integration with China in finance and economy, the East Asian countries are difficult to have immunity to the RMB exchange rate.

The BEKK-GARCH model is a widely employed method in detecting the spillover

effects because it can not only reveal the short-run movements but also capture the volatility spillovers. Baba, Engle, Kraft and Kroner (1991) proposed the BEKK-GARCH model. Then, Engle and Kroner (1995) republished this model in their paper. Since then, the BEKK-GARCH model has been widely used to detect the spillover effects in financial markets, including the foreign exchange markets.

By employing the BEKK-GARCH model, Bekiros (2014) finds the exchange rate spillover effects among the international currencies. In particular, the author finds bilateral spillover effects between Japanese Yen and Euro during the pre-crisis period. However, they do not find spillover effects among these currencies during the crisis period. Bekiros and Diks (2008) investigate the exchange rate spillover effects among the most 7 important currencies which are the most and liquid and widely traded currencies and make up about 90% of total foreign exchange market trading worldwide. By employing the BEKK-GARCH model, they find that there was a strong spillover effects from the EUR to some other currencies both before and after the Asian crisis. Kearney and Patton (2000) employ the BEKK-GARCH model to investigate exchange rate volatility transmission across the important European Monetary System (EMS) currencies. Based on both daily and weekly data from April 1979 to March 1997, they find that the German mark plays a dominant role insofar as it is relatively insulated from outside shock while transmitting more volatilities than the other currencies.

For other less important currencies, the BEKK-GARCH model also indicates that there are spillover effects in them. For example, Innocent and Mungatu (2016) find that there are significant spillover effects from the USD to Kenyan Shillings when they choose the Rwandan Francs as the reference currency. For East Asian currencies, Kim et al. (2015) consider that the exchange rate spillover effects can be transferred from US dollar and Euro to emerging Asian currencies. However, the effects are not great in opposite direction. For China, Leung and Fu (2014) employ the BEKK-GARCH model to detect the spillover effects between the CNY market and CNH market. The results suggest that cross-market spillovers were very limited in 2011-2012. However, they became larger in 2013, and this suggests an increasing

integration between these two markets.

2.4 The dynamic conditional correlation between different exchange rate returns

For the Frankel-Wei model, when currency A occupies large weight in currency B's currency basket, they always fluctuate closely against their numeraire currency. For example, Keddad (2016) uses the results obtained from the Frankel-Wei model to represent the degree of exchange rate return "co-movement". Besides the Frankel-Wei model, there is another method, DCC-GARCH (Dynamic Conditional Correlation GARCH) model, also can reveal this exchange rate relationship. Some researchers use the DCC-GARCH to investigate the return co-movement, through which to evaluate the exchange rates or the financial markets' integration. Further, because the DCC are time-varying, the changes and unusual points in these correlations can also be observed.

The DCC-GARCH model is an adaptation of the MGARCH (multivariate GARCH). Bollerslev (1990) employs an MGARCH model in which the conditional correlation is constant (namely CCC-GARCH) to study the co-movements in nominal exchange rates return of five European currencies against the US dollar. He finds that the co-movements of these European currencies were stronger during the post European Monetary System (EMS) period suggesting the EMS promotes the exchange rate integration in Europe. Then, a generalization of the CCC-GARCH model, the DCC-GARCH model, has been proposed by Engle and Sheppard (2001), Christodoulakis and Satchell (2002), Tse and Tsui (2002) to allow for dynamic conditional correlations.

The DCC-GARCH model has been used widely in detecting the financial assets' return relationships. For example, Malhotra and Krishna (2015) employ the DCC-GARCH model to detect the relationships between crude oil prices and inflation as well as interest rates. They find that the condition correlations between global crude oil prices and inflation in India are very close. Uddin et al. (2013) detect the relationship between German stock market and other important stock markets.

Through the results obtained by the DCC-GARCH model, they point out that the DCC show some difference during the financial crisis or a change in regime. Acatrinei et al. (2013) employ the DCC-GARCH model to investigate the relationship between Bucharest stock exchange trading index (BET) and Deutscher Aktien index (DAX).The results show that the DCC between the BET and DAX increased during the European debt sovereign crisis period. Imen and Rim (2012) employ the DCC-GARCH model to study 13 emerging and developing stock markets in the period from March 11, 2005 to July 31, 2010. Through the results, they find 10 out of 13 stock markets showed increasing dynamic condition correlations with the US stock market during the 2008 subprime crisis. For China's equity markets, Hua and Sanhaji (2015) argue that the relationships between China and Asian markets are closer than China and non-Asian markets.

Also, the DCC-GARCH model has been employed to study the exchange rate relationship. Engle (2002) estimates the DCC(s) among the Italian Lira, French franc and Deutschmark. The author finds that the sample currencies' correlations were leading up to the launch of Euro after 1999. The lira has lower correlations with the Franc and Deutschmark during the year from 1993 to 1996, but gradually approach one later. The dynamic conditional correlation between Franc and Deutschmark was always high. Through the DCC-GARCH model, Kurasawa (2016) studies the dynamic conditional correlation between the economic policy uncertainty (EPU) index and USD/JPY exchange rate. The results show that the DCC between the EPU and the exchange rate are time-varying. However, they argue that the drive forces are mostly unknown random factors. Martinez and Ramirez (2011) study the relationships of Latin-American currencies' exchange rate by the DCC-GARCH model. The pair-wise DCC between the exchange rate markets of Brazil, Colombia, Mexico and Peru are exhibiting an upward shift since 2004. Antonakakis (2012) also detects the relationships between the Deutsche Mark (EUR latter), Great Britain Sterling Pound, Japanese Yen and Swiss Franc by employing the DCC-GARCH model. Through the time-varying correlations, he finds that the JPY always keeps lowest DCC with other sample currencies. This result shows the fact that currency contagions are of

intra-regional rather that inter-regional nature. For the RMB, when Colavecchio and Funke (2008) research the DCC(s) between Chinese non-deliverable forward (NDF) market and seven of its Asia-Pacific counterparts, they find the time-varying conditional correlations are all positive and display changes in their patterns throughout time span under consideration. Also, these coefficients tend to increase in magnitude towards the end of the sample period suggesting that the relationship between the RMB NDF and Asian currency markets became closer.

Chapter 3. Impacts of Renminbi exchange rate shocks on East Asian currencies' return movements: from an VAR approach

3.1 The hypothesis

After the hardest period of the 2008 crisis, the People's bank of China declared that "the daily trading price of the RMB against the US dollar is allowed to float from the central parity of RMB against the U.S. dollar within a band of 0.5 percent" on June 19, 2010. From June 19, 2010 to March 17, 2014, there are two Renminbi exchange rate system reforms which are focused on widening the RMB exchange rate fluctuation band against the USD. As a result, the daily fluctuation band is widened from 0.5% to 2%.When the RMB became far away from the USD in exchange rate fluctuation, we are interest in whether or not the RMB's role becomes significant in East Asia.

In this part, we assume that the RMB's exchange rate shocks can more and more significantly influence the East Asian currencies exchange rate movements. In more detail, when the exchange rate fluctuation band of USD/RMB was narrow, the RMB exchange rate shocks could not affect the East Asian currencies' movements. However, when the band becomes larger as the RMB exchange rate system reforms, the RMB exchange rate shocks can significantly affect East Asian currencies' exchange rate movements which also mean that the RMB exchange rate may play a more important role.

Meanwhile, we also assume that the US dollar is always the most important currency in East Asia during the whole sample period, and the US dollar's position is not fundamentally changed. In more detail, the US dollar exchange rate shocks can affect East Asian currencies exchange rate movements significantly.

3.2 Methodology and data

3.2.1 Methodology

In this part, we will detect the exchange rate relationships between the US dollar Euro, Renminbi and East Asian currencies. As the US dollar is still at the center of the international monetary system, we inevitably consider the US dollar when discussing East Asian exchange rate system as well as the relationship between the RMB and East Asian currencies. From currency distribution data involving global foreign exchange market turnover released by the Bank for International Settlements (BIS), the US dollar occupied the first rank, with an 87% share in April 2013.[1] Also, the US dollar is still the most important reserve currency in the world. At the end of the year of 2015, 64.1% of the world's allocated reserves comparing foreign exchange holdings are claimed in the USD. By comparison, the Euro ranks second with a share of only 19.9%.[2] "The East Asian Dollar Standard" proposed by Mckinnon and Schnabl (2004) is well known as a description of the East Asian exchange rate system. Many East Asian countries including China had chosen the US dollar as the common peg currency in order to maintain smooth international trade and financial stability. Although the extent of pegging the dollar has declined during the last decade, as substantial variation can be seen in the weights of the US dollar in various East Asian currency baskets, it is difficult to deny that the US dollar remains important for East Asian currencies. [3]

When the experts studied the exchange rate relationships between the RMB and East Asian currencies, the Frankel-Wei currency basket regression method has been always chosen as the framework. However, there are two issues should be addressed. The first one is: the Frankel-Wei model is a simultaneous model, which can only reveal the exchange rate relationships based on the synchronous exchange rate data.

[1] The sum of the percentage shares are 200% because two currencies are involved in each transaction.
[2] Data source: Currency Composition of Official Foreign Exchange Reserves, IMF.
[3] See Subramanian and Kessler (2013); Henning (2012); Ho, Ma and McCauley (2005); Balasubramaniam, Patnaki and Shah (2011); Kawai and Pontines (2014a; 2014b).

Secondly, when the Frankel-Wei model is used to detect the exchange rate relationship between the RMB and East Asian currencies, it is unavoidable to put the US dollar and Renminbi on the same side of equation. When the RMB keeps very close relationship with the USD, multicollinearity problems will occur.

In this study, we will employ the VAR model to avoid simultaneity bias problem. The New Zealand dollar is chosen as the numeraire currency in this model. The exchange rates of other sample currencies are expressed as I/NZD in this study, where I represents currency I such as US dollar, Euro Renminbi and East Asian currencies. NZD is a far and relatively remote currency for East Asian countries. Also, it is a floating currency. During the period from June 21, 2010 to December 30, 2016, the average value of the squared daily return of USD/NZD is 0.0000598. Among these East Asian currencies, the second most flexible currency is the KRW with the average squared daily return of 0.0000324. For the RMB, the average squared daily return against the US dollar is only 0.0000020. The International Monetary Fund (IMF) classifies the exchange rate arrangement of New Zealand as "floating".[1] Oppositely, SDR is a composite currency which contains US dollar and other currencies, such as Euro and Renminbi. The Swiss Franc (CHF), which is often used as a numeraire currency, had been pegged to the euro from 2011 to 2015. After the Swiss National Bank abandoned the ceiling on 15 January 2015, the CHF re-fluctuates to the EUR.

Then, if we intend to analyze the relationships among the USD, RMB and other currencies in one model, we cannot avoid the problem caused by the "US dollar factor" in the RMB exchange rate. In this part, we will employ the OLS method to remove the "US dollar factor" from the RMB. This method is also used in Kawai and Pontines (2014a), Balasubramaniam, Patink, and Shah (2011)'s studies.

The RMB exchange rate return against the NZD can be expressed as:

$$\Delta \log\left(\frac{\mathrm{RMB}}{\mathrm{NZD}}\right) = \theta_0 + \theta_1 * \Delta \log\left(\frac{\mathrm{USD}}{\mathrm{NZD}}\right) + \varepsilon_0 \qquad (3\text{-}1)$$

In equation (3-1), the estimated residuals $\widehat{\varepsilon_0}$ obtained by equation (3-1) are used as a proxy for the logarithmic change in the exchange rate between the RMB and NZD.

[1] IMF: *Annual Report on Exchange Arrangements and Exchange Restrictions 2014.*

To detect the relationships among the US dollar, Renminbi and East Asian currencies, we also put Euro into the model, which is commonly regarded as the second important currency in the world. The EUR can also be taken as a reference to the RMB's role in East Asia.

The VAR model is:

$$\Delta \mathbf{e}_t = \mathbf{A}_0 + \sum_{k=1}^{p} \mathbf{A}_k(L)\, \Delta \mathbf{e}_{t-k} + \mathbf{u}_t \qquad (3\text{-}2)$$

Where $\Delta \mathbf{e}_t = (\Delta \log \mathrm{USD}_t/\mathrm{NZD}_t,\ \Delta \log \mathrm{EUR}_t/\mathrm{NZD}_t,\ \widehat{\varepsilon_{0,t}},\ \Delta \log \mathrm{X}_{i,t}/\mathrm{NZD}_t)\mathrm{T}$. X_i represents the sample East Asian currencies, which are KRW (South Korean won), MYR (Malaysian ringgit), SGD (Singapore dollar),TWD (New Taiwan dollar) and THB (Thai Baht).

The lag length for the VAR(p) model is very important. In this study, we use the Akaike's Information Criterion (AIC) to select the value of p. The AIC is given by:

$$\mathrm{AIC}(k) = \mathrm{T} * \log\hat{\sigma}^2 + 2k \qquad (3\text{-}3)$$

where k is the number of parameters to be estimated; T is denotes the number of observations; $\hat{}^2 = (\sum_{t=1}^{T} \hat{\varepsilon}_t^2)/\mathrm{T}$ is estimated residual variance. Smaller AIC are preferred. So we will choose the length of a lag distribution which has the lowest value of the AIC.

3.2.2 The data

In this part, the daily exchange rates of the New Zealand Dollar (NZD), US dollar (USD), Renminbi (RMB), Euro (EUR), Japanese Yen (JPY), Malaysia Ringgit (MYR), Republic of Korea Won (KRW), Singapore Dollar (SGD), New Taiwan Dollar (TWD) and Thailand Baht (THB) are used.

The sample period chosen in this part is from June 21, 2010 to December 30, 2016. Although the PBC carried out the first RMB exchange rate system reform on July 21, 2005, this reform was interrupted by the 2008 crisis as the RMB was re-pegged the USD during the global economic crisis. On June 19, 2010, the PBC announced "It is desirable to proceed further with reform of the RMB exchange rate regime and

increase the RMB's exchange rate flexibility". [1] Since then, the PBC has launched four exchange rate system reforms. So the RMB exchange rate is more marketable and flexible, also has much more research value after the 2008 crisis. We remove the data of some long Chinese holidays, such as the Spring Festival, International Labour Day and National Day. In these holidays, the RMB exchange rate returns are 0, which may disturb the results.

To detect the evolution of the RMB's significance in the field of exchange rate, we divide the whole sample period into three sub-periods during which the daily fluctuation band of the USD/RMB is set as 0.5%, 1% and 2% respectively by the People's bank of China. The days on which the People's bank of China reformed the RMB exchange rate system and widened the fluctuation band are chosen as the breakpoint. Thus, there are three sub-periods in this part. The first sub-period, defined as sub-period A1 is from June 21, 2010 to April 13, 2012 during when the daily fluctuation band is set as 0.5% by the People's bank of China. The second period is from April 16, 2012 to March 14, 2014, during when the band is set as 1%. The last sub-period, sub-period A3 is from March 17, 2014 to December 30, 2016, the band is set as 2%. When we divide the whole sample period into three sub-periods, there are 15 VAR models.

When the VAR model is used, it is necessary to make sure that the variables are stationary. In this study, we will use two methods to detect whether or not the series are stationary which are argued Dickey-Fuller (ADF) and Phillips-Perron (P-P) test. As shown from Tables 3-4 to 3-6, all of the return series are stationary.

3.3 The estimation results

To determine the lag order for these VAR models, we identify the VAR models by using AIC method. As presented in Table 3-7, the results suggest it is appropriate to choose 1 to be the lag lengths for all of the models, except for the USD-EUR-RMB-TWD model during the sub-period A3.

According Lütkepohl (1991), the VAR model is stable (stationary) if all of the roots

[1] June 19 and 20, 2010 are weekend.

have modulus less than one, as well as lie inside the unit circle. If not so, it means that the VAR is not stable (stationary), and some results are suspicious obtained from the VAR model, for example, the impulse response standard errors. As shown in the Figures from 3-1 to 3-5, for all of the VAR models, all of the roots of characteristic polynomials lie inside the unit circle, suggesting that the models are stable.

To detect the relationships between the US dollar, Euro, Renminbi and East Asian currencies, we examine the impulse response in the VAR models, as shown from Tables 3-8 to 3-12.

During the first sub-period, which is from June 21, 2010 to April 12, 2012, the daily fluctuation band of the RMB exchange rate against the US dollar was limited within 0.5%. At that time, according Tables 3-8 to 3-12, a standard shock on the RMB exchange rate could not significantly influence the East Asian currencies exchange rate. For the KRW, the accumulated response to the RMB is not significant because 0 is included in the 95% confidence interval. For other four East Asian currencies, although the one deviation shock to the RMB exchange rate can significantly influence the exchange rate movement of East Asian currencies in the first lag, the margins are too small. Moreover, all of the responses are insignificant after the second lag. These results suggest that the RMB exchange rate is not significant in East Asia during the first sub-period.

On the contrary, the US dollar played a significantly dominant role in East Asia during the first sub-period. For all of the sample currencies, the accumulated responses are significant since 0 are not included in the band. One deviation shock on the US dollar exchange rate could significantly affect the East Asian currencies' movements. The EUR was also an important currency for some East Asian currencies, for example, the KRW, MYR and SGD. However, the response margins are not as large as that to the US dollar, which suggest that the EUR was not as significant as the US dollar in East Asian exchange rate arrangement.

When the daily exchange rate fluctuation band of the RMB was expanded to 1% after the RMB exchange rate reform launched on April 14, 2012, some of the sample East Asian currencies were more responsive to the RMB exchange rate shocks. For

example, the KRW responded to the RMB exchange rate shocks significantly beyond the first lag which was insignificant during sub-period A1. The margin of the response of the MYR to the RMB exchange rate shocks became larger during the sub-period A2. For the SGD and TWD, there were no basic changes in the relationships between them and the RMB. However, the THB did not respond to the RMB exchange rate shocks, which is different from the situation during the sub-period A1. As a whole, the RMB exchange rare was still not a significant factor for East Asian currencies exchange rate movements during the sub-period A2 because the accumulated responses are not significant after the second lag, although its importance rose to a certain extent.

Meanwhile, the US dollar was still the most important currency in East Asia. In all of the VAR models, the US dollar could significantly affect the East Asian currencies exchange rates with large margin. The Euro was also an important currency since all of the East Asian currencies significantly responded to the Euro exchange rate shocks. However, the margin of the East Asian currencies' responses to Euro exchange rate shocks were not as large as to the US dollar, which reveals the fact that the Euro's position was not as important as the US dollar's in East Asia.

During the last sub-period from March 17, 2014 to December 30, 2016, the daily RMB exchange rate fluctuation band was expanded to 2%. The more flexible RMB exchange rate could significantly affect the East Asian currencies movements. According the VAR models, three out of five East Asian currencies, the KRW, MYR and TWD significantly responded to RMB exchange rate shocks. The accumulated response of KRW, MYR and TWD are significantly positive as shown in Tables 3-8, 3-9 and 3-11.This is a new phenomenon which never happened. For the SGD, the accumulated response was also significant although the margin was only relatively large in the first lag. The THB exchange rate was not responsive to the RMB exchange rate shocks as before.

During the sub-period A3, the US dollar was still the dominant currency in East Asia. The US dollar exchange rate shocks could significant affect all of the sample East Asian currencies exchange rate movements. The Euro's position decreased

obviously since the Euro exchange rate shocks could only affect the KRW, TWD and THB in the first lag, and could not affect the MYR exchange rate movement at all.

3.4 Summary

In this part, we have investigated the exchange rate relationships between the US dollar, Euro, Renminbi and East Asian currencies. To investigate whether or not the three important currencies (US dollar, Euro and Renminbi) exchange rate shocks could affect the East Asian currencies exchange rate movements, the VAR models are employed in this part.

To avoid the problem caused by the relatively close relationship between the US dollar and Renminbi, we choose the New Zealand dollar as the numeraire currency and used the OLS method to remove the "US dollar factor" from the Renminbi.

According to the results obtained by the VAR models, we found that the RMB was playing a more and more important role in East Asian exchange rate arrangements. When daily Renminbi exchange rate fluctuation band was limited within 0.5% during the first sub-period, one deviation shock could not affect the East Asian currency exchange rates movements at all. In other words, the RMB played a insignificance role in East Asia when the RMB exchange rate was rigid. During the second sub-period when the People's bank of China expanded the daily Renminbi exchange rate fluctuation band to 1%, the RMB exchange rate shocks could influence the East Asian currency exchange rates movements to a certain extent. But the influence was still little at that time. During the last sub-period, the RMB was more flexible after the 2014 exchange rate system reform. The more flexible Renminbi played a significant role in East Asia. Most of the sample currencies were responsive to the RMB exchange rate shocks, except for the THB.

Meanwhile, we also found that the US dollar was always the most important currency in East Asia; the US dollar exchange rate shocks could influence all of the sample East Asian exchange rates movements during each sub-period. Moreover, the margins of the responses were large comparing with other currencies. The Euro is another important currency in East Asia since the East Asian currencies were also

responsive to the Euro exchange rate shocks in most cases. However, the responses were not significant during the last sub-period which indicates the decrease of Euro's position in East Asia.

Chapter 4. Renminbi's exchange rate spillover effects on East Asian currencies' volatilities：under the BEKK-GARCH model

4.1 Hypothesis

As the promotion of Renminbi's internationalization and China's economic influence, the RMB's importance in East Asia may become greater. However, from a perspective of exchange rate, it is difficult or meaningless to investigate the exchange rate relationships between the RMB and East Asian currencies if the RMB still pegged to the US dollar.

After the worst period of the 2008 economic crisis, the People's bank of China reformed the RMB exchange rate system four times, and the *de jure* and *de facto* fluctuation band against the US dollar is becoming larger as mentioned above. As the being larger exchange rate fluctuation band, it is reasonable to suppose that the RMB can play a more important role in East Asian exchange rate market. Meanwhile, a more flexible RMB also means a higher exchange rate risk, not only for China, but also for other East Asian countries. It is also likely that this risk may be transferred from the RMB to EACs when the RMB became important.

In recent years, Renminbi has become more international. To measure the degree of the RMB's internationalization, the Renmin university of China has released the RMB Internationalization Index (RII) since 2010Q1. In Figure 4-1, the RII increased from 0.02 in 2010Q1 to its highest point at 3.14 in 2016Q2. Although the value decreased during the second half of 2016, it still was at a high level. From Figure 4-1, we can conclude that the progress of the RMB internationalization has been pushed obviously since 2010. This may bring two results. Firstly, the RMB's importance in the world as well as in the East Asia may become greater. Secondly, as shown in Figure 4-1, the fast progress of RMB's internationalization may lead to the change of the RMB's role in East Asia is different during the whole period.

Therefore, we suppose that the integration between the RMB and East Asian currencies have been becoming closer in recent years. In addition, the RMB played a more and more important role in East Asian foreign exchange market. Also, the RMB can release exchange rate risks to other East Asian currencies. From a perspective of spillover effects, we assume that the spillover effects between the RMB and East Asian currencies were different during the whole sample period, and they became more significant as a whole, at least in some currencies. The RMB exchange rate can significantly affect some of the EACs' exchange rate return volatilities.

4.2 Methodology and data

4.2.1 Methodology

In this part, we will detect the relationship between the RMB and East Asian currencies from a perspective of spillover effects: whether or not there are spillover effects between the RMB and East Asian currencies. Further, how about the directions. Through the spillover effects, we can judge the RMB's role in East Asia such as whether or not it can cause exchange risk for other East Asian currencies.

Multivariate GARCH models are always employed to estimate the conditional covariance matrix of at least two series of financial returns, through which we can learn the interactions between these series. The first multivariate GARCH model is proposed by Bollerslev, Engle and Wooldrigde (1988) named VEC model. The VEC model is an expandtion of a univariate GARCH. Suppose there is a 2-vector of foreign exchange rate returns $\mathrm{y_t}$, as:

$$\mathbf{y_t} = \boldsymbol{\mu_t} + \mathbf{u_t} \tag{4-1}$$

$$\mathbf{u_t}|\mathcal{F}_{t-1} \sim \mathrm{N}(0, \mathbf{H_t}) \tag{4-2}$$

In equation (4-1), $\mathbf{y_t}$ a $n \times 1$ vector stochastic process represents the return serials; $\boldsymbol{\mu_t}$ is a mean vector of $\mathbf{y_t}$, and $\mathbf{u_t}$ is a column vector of residual of $\mathbf{y_t}$. In equation (4-2), $\mathcal{F}_{t-1}$ means all past information until time t-1. $\mathbf{H_t}$ is a $n \times n$ matrix represents the conditional variance-covariance.

In the VEC model, the formulation of conditional covariance matrix $\mathbf{H_t}$ is:

$$\mathrm{VEC}(\mathbf{H}_t) = c + \sum_{i=1}^{q} \mathbf{A}_i \eta_{t-i} + \sum_{i=1}^{p} \mathbf{G}_i \, h_{t-i} \tag{4-3}$$

Where $\mathrm{VEC}(\mathbf{H}_t)$ is $\boldsymbol{\eta}_{t-i} = \mathrm{vech}(u_t u_t')$, $\mathbf{A}_i$ and $\mathbf{G}_i$ represent squared matrices. For example, the bivariate VEC (1,1) is:

$$\begin{bmatrix} h_{11,t} \\ h_{21,t} \\ h_{22,t} \end{bmatrix} = \begin{bmatrix} c_1^* \\ c_2^* \\ c_3^* \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} u_{1,t-1}^2 \\ u_{1,t-1}u_{2,t-1} \\ u_{2,t-1}^2 \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{bmatrix} h_{11,t-1} \\ h_{21,t-1} \\ h_{22,t-1} \end{bmatrix} \tag{4-4}$$

Although the VEC model is a very general form of the multivariate GARCH model, it is difficult to be sure of the positivity of $\mathbf{H}_t$. To overcome this shortcoming, Baba, Engle, Kraft and Kroner (1989) proposed the BEKK-GARCH model which imposes positive definiteness restrictions. The BEKK-GARCH model is an extension of the VEC-GARCH model which is developed from an univariate GARCH. Comparing with the VEC-GARCH model, the widely employed BEKK-GARCH can ensure the positivity of the covariance matrix. Through the parameters matrix, we can know whether or not there are spillover effects between the RMB and East Asian currencies as well as their directions.

In the BEKK-GARCH (p, q, k), $\mathbf{H}_t$ can be stated as:

$$\mathbf{H}_t = \mathbf{C}'\mathbf{C} + \sum_{k=1}^{K} \sum_{j=1}^{q} \mathbf{A}_{jk}' (\mathbf{u}_{t-j}\mathbf{u}_{t-j}') \mathbf{A}_{jk} + \sum_{k=1}^{K} \sum_{i=1}^{p} \mathbf{B}_{ik}' \mathbf{H}_{t-i} \mathbf{B}_{ik} \tag{4-5}$$

In equation (4-5), **C** is an upper triangular constant matrix which can be thought as the constant matrix. **A** is the ARCH parameter matrix; **B** is GARCH parameter matrix. The K element refers to the generality of the model and a higher K implies a more general process. Just as Engle (1995) states: "The GARCH (1, 1) is the leading model for almost of returns…it is quite robust and does most of the work in almost all cases." Bollerslev et al. (1992) also consider that the GARCH (1, 1) model is sufficient for long sample periods. Thus, in a bivariate BEKK-GARCH model, $\mathbf{H}_t$ can be written as:

$$\mathbf{H}_t = \mathbf{C}'\mathbf{C} + \mathbf{A}'(\mathbf{u}_{t-1}\mathbf{u}_{t-1}')\mathbf{A} + \mathbf{B}'\mathbf{H}_{t-1}\mathbf{B} \tag{4-6}$$

Thus equation (4-6) can also be written as:

$$\begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{bmatrix}' * \begin{bmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}' *$$

$$\begin{bmatrix} u_{1,t-1}^2 & u_{1,t-1}u_{2,t-1} \\ u_{2,t-1}u_{1,t-1} & u_{2,t-1}^2 \end{bmatrix} * \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}' *$$

$$\begin{bmatrix} h_{11,t-1} & h_{12,t-1} \\ h_{21,t-1} & h_{22,t-1} \end{bmatrix} * \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \quad (4\text{-}7)$$

In more details, the conditional variance h_t can be written as:

$$h_{11,t} = c_{11}^2 + a_{11}^2 u_{1,t-1}^2 + 2a_{11}a_{21}u_{1,t-1}u_{2,t-1} + a_{21}^2 u_{2,t-1}^2 + b_{11}^2 h_{11,t-1} + 2b_{11}b_{21}h_{12,t-1} + b_{21}^2 h_{22,t-1} \quad (4\text{-}8)$$

$$h_{12,t} = c_{11}c_{21} + a_{11}a_{12}u_{1,t-1}^2 + (a_{21}a_{12} + a_{11}a_{22})u_{1,t-1}u_{2,t-1} + a_{21}a_{22}u_{2,t-1}^2 + b_{11}b_{12}h_{11,t-1} + (b_{21}b_{12} + b_{11}b_{22})h_{12,t-1} + b_{21}b_{22}h_{22,t-1} \quad (4\text{-}9)$$

$$h_{22,t} = c_{21}^2 + c_{22}^2 + a_{12}^2 u_{1,t-1}^2 + 2a_{12}a_{22}u_{1,t-1}u_{2,t-1} + a_{22}^2 u_{2,t-1}^2 + b_{12}^2 h_{11,t-1} + 2b_{12}b_{22}h_{12,t-1} + b_{22}^2 h_{22,t-1} \quad (4\text{-}10)$$

In more specific terms, for example, a significant a_{12} represents that there exists innovation (shock) spillover effect from asset 1 to asset 2 shown in equation (4-10); a significant b_{12} means that there is volatility spillover effect transferred from asset 1 to 2. Likewise, for a_{21} and b_{21} in equation (4-8) too. It is notable that, since the parameters are squared, it doesn't matter whether or not the parameters' signs are positive or negative (Kim et al. (2015); Tsopanakis, et al. (2015)).

In this part, we set the RMB as the first financial asset in the bivariate BEKK-GARCH model, other East Asian currencies as the second. If, for example, the a_{12} is significant at a certain significance level, we can consider that there are return shock spillover effects from the RMB to the other currency in the model. Thus our interest is focused on the significance of a_{12}, b_{12}, a_{21} and b_{21} in equations (4-10) and (4-8) which represent the spillover effects between the RMB and East Asian currencies.

In addition, we also detect the spillover effects between US dollar and East Asian currencies in this part. Similarly, we take US dollar as the first financial asset, East Asian currencies as the second. This can not only reveal the relationship between the US dollar and Asian currencies, but also can be taken as a reference to the relationships between the RMB and East Asian currencies. When we detect the relationships between the US dollar and East Asian currencies, we choose the New Zealand dollar as the measurement. In other words, the exchange rate here is NZD/I where I is currency I, including the US dollar.

The parameters of the BEKK-GARCH system are estimated by the maximum likelihood method. The log-likelihood function for the BEKK-GARCH model is given by:

$$L(\theta) = -\frac{TN}{2}\ln(2\pi) - \frac{1}{2}\sum_{t=1}^{T}\left(\ln|\mathbf{H}_t(\theta)| + \mathbf{u}_t(\theta)'|\mathbf{H}_t(\theta)^{-1}|\mathbf{u}_t(\theta)\right) \qquad (4\text{-}11)$$

where T is the number of observations. N is the number of the assets. When we choose a bivariate BEKK-GARCH model, there are two financial assets in each model. θ is the vector of parameters to be estimated. Although the innovations are assumed to follow a normally distribution, Bollerslev and Wooldridge (1992) propose that the results are robust even when the normality assumption is violated.

4.2.2 The data

The sample period is from June 21, 2010 to December 30, 2016. We remove the data in some long Chinese holidays, such as the Spring Festival, International Labour Day and National Day. In these holidays, the RMB exchange rate returns are 0, which may disturb the results. To detect whether or not the spillover effects are different during the sample period, we divide the sample period into three sub-periods, each of them is two-years long. Firstly, as the RMB became more international during the whole sample period as mentioned above, it is necessary to divide the whole sample period into some sub-periods. Secondly, as the promotion the RMB exchange rate system reform, the *de jure* Renminbi exchange rate fluctuation band is expanded from 0.5% to 2%. Although the expanding *de jure* fluctuation band does not mean that the RMB exchange rate can play a more and more important role in East Asian exchange rate market, it still can provide a possibility. Thus, we divide the whole sample period into three sub-sample periods, each one contains two years.[1] In addition, we can ensure that there is one exchange rate system reform in each sub-period.

Tables 4-2 to 4-5 provide the descriptive analysis of the series used in this paper. They show the description of the exchange rate data during each sub-period, respectively. The Ljung-Box Q test (Q test for short hereafter) is employed to reveal

[1] The first sub-period is from June 21, 2010 to 31 December, 2012.

whether or not there is serial correlation. A significant Q statistic for the squared exchange rate returns means the null hypothesis that the squared series are homoskedastic should be rejected. In these tables, all of the Q statistics are significant at 10 lags for the squared series. We can conclude that these squared series are heteroscedastic. Therefore, it is appropriate to use the GARCH model.

4.3 The estimation results of the BEKK-GARCH model

Table 4-6 shows the results of the BEKK-GARCH models. a_{12} and b_{12} represent the return and volatility spillover effects from the RMB to East Asian currencies such as mentioned in equation (4-10). Similarly, a_{21} and b_{21} represents the return and volatility spillover effects from the East Asian currencies to the RMB.

From June, 2010 to December, 2016, more and more significant spillover effects emerged between the RMB and East Asian currencies. This means the integration between the RMB and East Asian currencies became closer in the sample period. This also means that the RMB exchange rate shocks can make some of the sample East Asian currency exchange rates unstable.

For example, during the first sub-period, defined as sub-period B1, the RMB could only transfer volatility spillover effects to the TWD (TWD (a_{12}, b_{12})). For other East Asian currencies, the RMB exchange rate was not serious. In other words, the RMB exchange rate's return shocks and volatilities could not affect most of the sample currencies just after the 2008 economic crisis. This also reflects the fact that the RMB's influence was very limited, even none during that time. The RMB did not transfer exchange rate risk at that time.

During the second sub-period, the RMB could affect more currencies comparing with the first period. The RMB could transfer spillover effects to the MYR (MYR (a_{12})), SGD (SGD (a_{12})), and TWD (TWD (a_{12})) during the second period. All of the spillover effects were innovation spillover effects. For the KRW and THB, the RMB exchange rate could not cause any risk. Overall, we can say that the RMB's role was still insignificant during sub-period B2.

During the third sub-period, the RMB exchange rate could affect the East Asian

currencies' exchange rate volatilities more significantly comparing with the previous sub-periods. The results show that the RMB exchange rate innovation and volatility could exert influence to all of the sample East Asian currencies, except for the SGD and THB. For the SGD, only innovation could affect the SGD exchange rate volatility. For the THB, the RMB exchange rate played an insignificant role. This result illustrates the relatively loose relationships between the RMB and these two currencies, particularly the THB, from a perspective of exchange rate risk.

As a reference, the US dollar always played a significant role in East Asian exchange market. Because there was no fundamental change in the US dollar's position in East Asia, we detect the spillover effects between the US dollar and East Asian currencies in the whole sample period. As presented in Table 4-7, US dollar can transfer the spillover effects to almost all of the East Asian currencies, except for the KRW. This also demonstrates that the KRW is more near the floating exchange system than other East Asian currencies.

4.4 Renminbi exchange rate risk, from a perspective of foreign reserves

The foreign reserves are very important tool for adjusting the exchange rate. Girton and Roper (1977) introduce the concept of "exchange market pressure" to reveal the true pressure exchange rate suffered. Then, many experts, such as Frankel and Wei (2008) put the "exchange market pressure" as a variable into the currency basket regression to investigate the exchange rate regime.

For China, the foreign reserves grew obviously before 2010, the growth rate was higher than 20% each year. However, the growth became lower than 20% after 2010, and became negative in 2015 and 2016. Less foreign reserves always means an increase in the difficulty of managing the exchange rate, particularly when the exchange rate is on a depreciation trend. The being large capital flows are another factor may cause the RMB exchange rate unstable. In the impossible trinity, capital flows and exchange rate occupy two poles. For China, although capital control is still in effect in China, the capital flows has been growing substantially. For example, the

average value of the quarterly net financial account excluding reserve assets was only 0.113 billion dollars in 2006 which is the next year of the "Milestone" exchange rate system reform in 2005. But this number was -1.21 billion dollars in 2015, the absolute value increase by 100 times. The huge capital flows may bring pressure to the RMB exchange rate, also the Chinese authorities' reactions.

Figure 4-2 shows the ratio of China's foreign reserves at the end of time t-1 to the net capital outflows in time t. From Q2, 2010 to Q4, 2013, the net capital outflows only occurred in very few quarters. However, after the year of 2014, the capital outflows often exceeded the inflows. As a result, the ratio was always negative while the RMB was depreciating. Moreover, the value of the ratio has become higher in recent years. A smaller absolute value means a relative smaller foreign reserves scale to the capital outflows. As a result, the Chinese authorities might be reluctant or it is difficult to use the foreign reserves to offset the capital outflows, as well as "lean against the wind".

The evolution of the RMB exchange rate system is inconvertible. The RMB exchange rate is more and more "market-oriented". We should face the RMB exchange rate risk when the RMB is more and more "far away" the US dollar.

4.5 Summary

In this part, we detect the relationships between the RMB and East Asian currencies, from a perspective of spillover effects. We detect whether or not the RMB exchange rate can cause risks to other East Asian currencies.

As the rapid promotion of the RMB's internationalization, as well as the reforms of Renminbi exchange rate system, we divide the whole sample period into three sub-periods. We found that the RMB's significance in the East Asian foreign exchange became greater from 2010 to 2016. It could cause more and more exchange rate risks, particularly during the last sub-period.

During the first sub-period, the People's bank of China just reformed the RMB exchange rate system again after the 2008 crisis, and the RMB was not as international as later. From the results obtained from the BEKK-GARCH model, there

were almost no spillover effects between the RMB and most East Asian currencies. During the second sub-period, although the RMB could influence some of the sample currency exchange rate volatilities, its role was still insignificant. However, when the RMB was more flexible and international during the third sub-period, Renminbi exchange rate could significantly influence the East Asian currency exchange rate volatilities, except for the THB. This means that Renminbi played a significant role in East Asian currency exchange rate system.

When the RMB exchange rate is more and more "market-oriented", it is also more difficult for the Chinese authorities to control the RMB exchange rate, for example, by using their foreign reserves. So, it is worth noting the RMB exchange rate risks particularly when it can influence many East Asian currency exchange rate volatilities.

Chapter 5. The exchange rate return co-movements between Renminbi and other East Asian currencies

5.1 Hypothesis

In this part, we will check three hypotheses as follows.

Hypothesis A: US dollar is still the most important currency in East Asia. The exchange rate return relationships between US dollar and East Asian currencies are close.

As the US dollar still plays the center role in international monetary system, it is reasonable to suppose that the US dollar still maintains its importance in East Asia. From a perspective of exchange rate returns, the relationships between the US dollar and East Asian currencies are very close. The US dollar is the most important currency in East Asia also means other international currencies are not as important as the USD. For example, the EUR and Yen.

Hypothesis B: as the promotion of the RMB exchange rate system reforms, the RMB has been far away from the US dollar in exchange rate return. This also means that the exchange rate return correlation between the RMB and US dollar becomes lower.

The People's Bank of China has reformed the RMB exchange rate system five times during the past decade; the *de jure* fluctuation band has been gradually expanded to 2% since the year of 2014. As a result, the exchange rate relationship between the RMB and US dollar may be looser in recent years.

Hypothesis C: when the RMB shifted into a depreciation trend and became more flexible, the exchange rate relationship between the RMB and East Asian currencies was closer meanwhile.

This hypothesis is inspired by the statements of “fear of appreciation” (against the RMB and USD) and “fear of floating” (against the USD) proposed by Pontines and Siregar (2012), Calvo and Reinhart (2002), Mckinnon and Schnabl (2004). China has

achieved remarkable success in economic growth; the economic relations between China and East Asian countries have been strengthened. In addition, China has become the most important source of trade surplus for many East Asian countries. When the RMB became more flexible and was in a depreciation trend after January 2014, the East Asian currencies may be closer to the RMB because of some economic fundamentals.

5.2 Data and methodology

5.2.1 Data and descriptive statistics

To examine the exchange rate return co-movements of the USD, RMB, EUR, JPY and EACs, the daily exchange rates of the New Zealand Dollar (NZD), US dollar (USD), Renminbi (RMB), Euro (EUR), Japanese Yen (JPY), Malaysian Ringgit (MYR), Republic of Korean Won (KRW), Singapore Dollar (SGD), Taiwan Dollar (TWD) and Thai Baht (THB) are used in this part.

We also use unconventional exchange rates which are defined as I/NZD in this part, where I includes not only the various East Asian currencies but also the USD. We also choose EUR and JPY as the sample currencies, because they are helpful in investigating the relationships among the USD, RMB and other East Asian currencies.

The return series are:

$$r_{i,t} = \ln(E_{i,t}) - \ln(E_{i,t-1})$$

Where $E_{i,t}$ is the nominal exchange rate of currency I (against the USD or NZD) at the end of time t.

The sample period chosen in this part is from June 21, 2010 to September 30, 2016. Because the DCC-GARCH model which will be introduced later is a time-varying model, it is not necessary to divide the whole sample period into sub-periods firstly as done in previous parts.

Tables 5-1 and 5-2 show the summary statistics of the exchange rate return series. Ljung-Box Q statistics are significant at 10 and 30 lags for all the squared returns

series; this means the presence of heteroskedasticity for these series. To test whether or not the series come from a normal distribution, Jarque-Bera (J-B) test will be employed in this part. In these two tables, the series do not come from a normal distribution under the J-B test.

5.2.2 The DCC-GARCH Model

The relationships between currencies can be studied from many aspects. For example, the exchange rate return co-movement can reveal the currencies' nominal exchange rates relationships when they fluctuate.

CCC-GARCH model is the early model of DCC-GARCH model. In the CCC-GARCH model, the conditional correlations are undynamic. As a result, the conditional correlations can only rudely reveal the overall situation and it cannot catch some unusual points.

Comparatively speaking, the DCC-GARCH is an appropriate model for detecting these co-movement relations. One of the merits of the DCC-GARCH model is: it is a time-varying model. Just as Cho and Parhizgari (2008) argue, the DCC-GARCH offers a superior measure of correlation by continuously adjusting the correlation for time varying volatility. The correlation coefficients obtained by the DCC-GARCH model are time-varying which can contain more information. For example, Engle (2002) estimates the DCC(s) among the Italian Lira, French franc and Deutschmark. By detecting some special points, for example, August of 1992 and January 1999, he finds that the DCC(s) between these currencies obviously changed during the EMS crisis and after the launching of the Euro. Cho and Parhizgari (2008) employ the DCC-GARCH model to detect the East Asian financial market correlation. The DCC-GARCH model can provide some unusual sharp change in the correlations. They choose two special days as the break points to investigate the contagion source of the East Asian financial market turbulence in 1997.

Another merit of the DCC-GARCH models is: we can compare the conditional correlations of different periods in one DCC-GARCH model. However, if we employ

the CCC-GARCH model, we have to divide the whole period into some sub-periods at the breakpoints if we intend to study the changes. As a result, there are more than one CCC-GARCH models should be employed. The DCC-GARCH model can avoid this problem. Antonakakis (2012) chooses the January, 1999 when the EUR was born as the break point. He compares the average DCC(s) of the sample currencies before and after the introduction of Euro. Through the time-varying correlations, he finds that these currencies showed greater correlations when economic crises occurred in the post-euro period.

In Engle (2002) and Engle and Sheppard (2001), the DCC-GARCH model is defined from:

$$\mathbf{y}_t = \boldsymbol{\mu}_t + \mathbf{u}_t \tag{5-1}$$

$$\mathbf{u}_t | \mathcal{F}_{t-1} \sim N\ (0, \mathbf{H}_t) \tag{5-2}$$

In equation (5-1), $\mathbf{y}_t$ a $n \times 1$ vector stochastic process represents the return serials; $\boldsymbol{\mu}_t$ is a mean vector of $\mathbf{y}_t$, and $\mathbf{u}_t$ is a column vector of residual of $\mathbf{y}_t$. In equation (5-2), $\mathcal{F}_{t-1}$ means all past information until time t-1. $\mathbf{H}_t$ is a $n \times n$ matrix represents the conditional variance-covariance.

$$\mathbf{H}_t = \begin{bmatrix} h_{11,t} & h_{12,t} & \cdots & h_{1n,t} \\ h_{12,t} & h_{22,t} & & h_{2n,t} \\ \vdots & & \ddots & \vdots \\ h_{1n,t} & h_{2n,t} & \cdots & h_{nn,t} \end{bmatrix}$$

The matrix of covariance $\mathbf{H}_t$ can be written as the product of $\mathbf{D}_t$ and $\mathbf{R}_t$.

$$\mathbf{H}_t = \mathbf{D}_t \mathbf{R}_t \mathbf{D}_t \tag{5-3}$$

where $\mathbf{D}$ is a diagonal matrix of square root conditional variances, like $\mathbf{D}_t = \mathrm{diag}\left(h_{11,t}^{\frac{1}{2}}, \cdots, h_{nn,t}^{\frac{1}{2}}\right)$. Then, $h_{ij,t} = \sqrt{h_{ii,t} h_{jj,t}}\ _{ij,t}$. $\mathbf{R}_t = \left[\ _{ij,t}\right]$ is matrix of conditional correlation. Then, $h_{ij,t} = \sqrt{h_{ii,t} h_{jj,t}}\ _{ij,t}$. In Engle and Sheppard (2001) and Bollerslev (1990), $h_{ii,t}$ is described by a univariate GARCH (p, q) progress:

$$h_{ii,t} = \alpha_{i,0} + \sum_{q=1}^{q_i} \beta_{i,q}\, u_{i,t-q}^2 + \sum_{p=1}^{p_i} \gamma_{i,p} h_{ii,t-p} \tag{5-4}$$

The $\mathbf{u}_t$ is transformed by its estimated standard deviations in order to be used to estimate the conditional correlations.

$$\boldsymbol{\varepsilon}_t = \mathbf{D}_t^{-1} \mathbf{u}_t \tag{5-5}$$

then, $\rho_{ij,t}$ can be written as:

$$\rho_{ij,t} = \frac{E_{t-1}[u_{it}u_{jt}]}{\sqrt{E_{t-1}[u_{it}^2]E_{t-1}[u_{jt}^2]}} = \frac{E_{t-1}\left[\sqrt{h_{iit}}\varepsilon_{it}\sqrt{h_{jjt}}\varepsilon_{jt}\right]}{\sqrt{E_{t-1}[h_{iit}\varepsilon_{it}^2]E_{t-1}[h_{jjt}\varepsilon_{jt}^2]}} = \frac{E_{t-1}[\varepsilon_{it}\varepsilon_{jt}]}{\sqrt{E_{t-1}[\varepsilon_{it}^2]E_{t-1}[\varepsilon_{jt}^2]}} = E_{t-1}[\varepsilon_{it}\varepsilon_{jt}] \quad (5\text{-}6)$$

As mentioned above, $\rho_{ij,t}$ constitute the $\mathbf{R_t}$.Let $\mathbf{Q_t}$ as the conditional covariance matrix of $\boldsymbol{\varepsilon_t}$.

$$\mathbf{Q_t} = E_{t-1}[\boldsymbol{\varepsilon_t}\boldsymbol{\varepsilon_t'}] \quad (5\text{-}7)$$

Then introducing $\mathrm{diag}(\mathbf{Q_t})$ to ensure the $\mathbf{R_t}$ is a positive definite correlation matrix with ones on the diagonal.

$$\mathrm{diag}(\mathbf{Q_t})^{-\frac{1}{2}} = \begin{bmatrix} 1/\sqrt{q_{11,t}} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1/\sqrt{q_{nn,t}} \end{bmatrix} \quad (5\text{-}8)$$

Introducing $\mathrm{diag}(\mathbf{Q_t})$ to ensure the $\mathbf{R_t}$ is a positive definite correlation matrix with ones on the diagonal. $\mathbf{R_t}$ can be written as:

$$\mathbf{R_t} = \mathrm{diag}(\mathbf{Q_t})^{-\frac{1}{2}}\mathbf{Q_t}\mathrm{diag}(\mathbf{Q_t})^{-\frac{1}{2}} \quad (5\text{-}9)$$

So, if we obtain the time-varying $\mathbf{Q_t}$, a dynamic $\mathbf{R_t}$ can also be got. To obtain the time-varying correlation coefficients, it is assumed that $\mathbf{Q_t}$ follows an autoregressive process as:

$$\mathbf{Q_t} = (1 - a - b)\overline{\mathbf{Q}} + a\boldsymbol{\varepsilon_{t-1}}\boldsymbol{\varepsilon_{t-1}'} + b\mathbf{Q_{t-1}} \quad (5\text{-}10)$$

In equation (5-10), a and b are the parameters needed to be got. The equation (5-10) can also be rewritten as:

$$\mathbf{Q_t} = \overline{\mathbf{Q}} + a(\boldsymbol{\varepsilon_{t-1}}\boldsymbol{\varepsilon_{t-1}'} - \overline{\mathbf{Q}}) + b(\mathbf{Q_{t-1}} - \overline{\mathbf{Q}}) \quad (5\text{-}11)$$

The equation (5-11) means that the adaptive $\mathbf{Q_t}$ varies around $\overline{\mathbf{Q}}$ for all time. In a short term, $\mathbf{Q_t}$ is affected by two factors. The first part is reaction of the covariance to changes which is weighted by a; the other one is standing for persistence weighted by parameter b. In the CCC-GARCH model, the conditional correlations are fixed and we cannot catch the dynamic conditional correlations. The DCC-GARCH is more detailed than the CCC-GARCH model. In the DCC-GARCH model, the $\mathbf{a(\boldsymbol{\varepsilon_{t-1}}\boldsymbol{\varepsilon_{t-1}'} - \overline{Q})}$ and $b(\mathbf{Q_{t-1}} - \overline{\mathbf{Q}})$ can represent the change of the conditional correlations. When the $\boldsymbol{\varepsilon_{t-1}}$ and $\mathbf{Q_{t-1}}$ change from the $\overline{\mathbf{Q}}$, they will affect the correlation of the next

time. Through the DCC-GARCH model, we can catch some points in some certain time t (s) through this approach, such as the unusual points and break points, which are hided in the CCC-GARCH model. To ensure the $\mathbf{Q}_t$ is positive, a and b must satisfy $a \geq 0, b \geq 0$ and $a + b \leq 1$. Extremely, if a=b=0, the conditional covariance matrix is constant and $\mathbf{Q}_t$ turns into unconditional covariance matrix $\bar{\mathbf{Q}}$.

Although the dynamic of the conditional correlations have a merit of varying with time, it also brings a problem that we cannot directly grasp the correlations overall from the results. To investigate the exchange rate return relationships among these sample currencies conveniently, we also compute the average values of the estimated dynamic conditional correlations $\overline{DCC}_{ij} = \frac{1}{T}\sum_{t=1}^{T}{}_{ij,t}$. This method has been also employed by Cho and Parhizgari (2008) and Antonakakis (2012).

Following Engle and Sheppard (2001) and Engle (2002), the DCC-GARCH model can be estimated by maximum likelihood method, whereby the log-likelihood function of the DCC-GARCH model is:

Following Engle and Sheppard (2001) and Engle (2002), the DCC-GARCH model can be estimated by maximum likelihood method, whereby log-likelihood function of the DCC-GARCH model is:

$$\begin{aligned} L &= -\frac{1}{2}\sum_{t=1}^{T}\left(n * \ln(2\pi) + \ln(|\mathbf{H}_t|) + \mathbf{u}_t'\mathbf{H}_t^{-1}\mathbf{u}_t\right) \\ &= -\frac{1}{2}\sum_{t=1}^{T}\left(n * \ln(2\pi) + \ln(|\mathbf{D}_t\mathbf{R}_t\mathbf{D}_t|) + \mathbf{u}_t'\mathbf{D}_t^{-1}\mathbf{R}_t^{-1}\mathbf{D}_t^{-1}\mathbf{u}_t\right) \\ &= -\frac{1}{2}\sum_{t=1}^{T}\left(n * \ln(2\pi) + 2\ln(|\mathbf{D}_t|) + \mathbf{u}_t'\mathbf{D}_t^{-1}\mathbf{D}_t^{-1}\mathbf{u}_t - \boldsymbol{\varepsilon}_t'\boldsymbol{\varepsilon}_t + \ln(|\mathbf{R}_t|) + \right. \\ &\qquad \left. \boldsymbol{\varepsilon}_t'\mathbf{R}_t^{-1}\boldsymbol{\varepsilon}_t\right) \end{aligned} \tag{5-12}$$

Engle (2002) suggests that let the parameters in D be represented by θ; others in R to be φ .The equation (5-12) can be written as the sum of two parts: a volatility part and a correlation part:

$$L(\theta, \varphi) = L_v(\theta) + L_c(\theta, \varphi) \tag{5-13}$$

$L_v(\theta)$ is the volatility term:

$$L_v(\theta) = -\frac{1}{2}\sum_{t=1}^{T}\left(n * \ln(2\pi) + 2\ln(|\mathbf{D}_t|) + \mathbf{u}_t'\mathbf{D}_t^{-1}\mathbf{D}_t^{-1}\mathbf{u}_t\right) \tag{5-14}$$

$L_c(\theta, \varphi)$ is the correlation component:

$$L_c(\theta, \varphi) = -\frac{1}{2}\sum_{t=1}^{T}\left(\ln(|\mathbf{R}_t|) + \boldsymbol{\varepsilon}_t'\mathbf{R}_t^{-1}\boldsymbol{\varepsilon}_t - \boldsymbol{\varepsilon}_t'\boldsymbol{\varepsilon}_t\right) \quad (5\text{-}15)$$

However, the assumption that $\boldsymbol{\varepsilon}_t$ follows a normal distribution is not always appropriate for some financial data such as a daily exchange rate. Therefore, the multivariate student's distribution is used in this paper (see Harvey, Ruiz, and Shephard, 1992; Fiorentini, Sentana, and Calzolari, 2003), equation (5-14) can be written as:

$$L = \sum_{t=1}^{T}\left(\ln\left[\ \left(\frac{v+n}{2}\right)\right] - \ln\left[\ \left(\frac{v}{2}\right)\right] - \frac{n}{2}\ln[\ (v-2)] - \frac{1}{2}\ln[|\mathbf{D_t}\mathbf{R_t}\mathbf{D_t}|] - \frac{v+n}{2}\ln\left[1 + \frac{\mathbf{u_t}\mathbf{D_t^{-1}}\mathbf{R_t^{-1}}\mathbf{D_t^{-1}}\mathbf{u_t}}{v-2}\right]\right) \quad (5\text{-}16)$$

Jenson and Lunde (2001) consider that the results of the first stage are virtually unaffected by the change in error distribution, hence the first stage is the same as equation (5-14).The second stage is:

$$L_c(\theta,\ ) = \sum_{t=1}^{T}\left(\ln\left[\ \left(\frac{v+n}{2}\right)\right] - \ln\left[\ \left(\frac{v}{2}\right)\right] - \frac{n}{2}\ln[\ (v-2)] - \frac{1}{2}\ln[|\mathbf{R_t}|] - \frac{v+n}{2}\ln\left[1 + \frac{\mathbf{u_t}\mathbf{D_t^{-1}}\mathbf{R_t^{-1}}\mathbf{D_t^{-1}}\mathbf{u_t}}{v-2}\right]\right) \quad (5\text{-}17)$$

5.3 Estimation of dynamic conditional correlations

The DCC-GARCH (1, 1) model is estimated by the econometric software Oxmetrics 6. As presented in Tables 5-3 and 5-4, $+ < 1$ and $a + b < 1$ hold for all the currencies both against the NZD and USD. The dynamic conditional correlations between these currencies' exchange rate returns are shown from Figures 5-1 to 5-6. According to these figures, we can see the correlations are varying in time.

In Figure 1-9, the rate of USD/RMB reaches its valley bottom on January 14, 2014. If we choose that day as the break point, the sample period can be divided into two sub-periods: sub-periods C1 and C2. The RMB appreciated against the USD during the first period (sub-period C1); then depreciated during the second period (sub-period C2). The RMB's fluctuation also presented different features before and after January of 2014. On March 17, 2014, just about two months after the beginning of the sub-period C2, the PBC expanded the RMB's *de jure* daily fluctuation band

from 1% to 2%. As a result, the RMB's exchange rate was more flexible. For example, the average absolute values of RMB's daily exchange change (the square of the exchange rate return) was 0.0017 (0.17%) after January 14, 2014; while it was only 0.0011(0.11%) before that time.

The DCC-GARCH model allows us to compare the results of these two sub-samples before and after the break point. Tables 5-3 and 5-4 display the results and mean values of these DCC(s) and DCC(s)* when we choose the NZD and USD as the numeraire currency respectively.

5.3.1 The USD's status in East Asian exchange rate return co-movements

By introducing the NZD as the numeraire currency, the dynamic conditional exchange rate returns correlations between the USD and other currencies can be detected. In Table 5-3, for the RMB and EACs, the exchange rate return co-movements with the USD were significantly larger than with the EUR and JPY during both periods.[1] This means that the East Asian currencies including the RMB always keep closer relationship with the USD than with the EUR and JPY.

This result coincides with some other researchers' conclusions (for example, Kawai and Pontines, 2014a; 2014b)) obtained by the Frankel-Wei model, in which the USD occupied a highest weight in the currency baskets. Among these currencies, the DCC of the KRW and USD was the lowest one which seldom exceeded 0.8.This result means that the KRW is the "farthest" currency from the USD. This result coincides with reality that Korea has a *de jure* floating exchange rate regime.

Comparing with the EACs, the RMB kept a much closer relationship with the USD in exchange rate return which can be seen from the average values of the DCC(s) in Table 5-3. The $\overline{\mathrm{DCC}}_{\mathrm{USD-RMB}}$ is the highest one among these average values, even higher than 0.98 during both periods. Moreover, there are no significant differences in average value between the $\overline{\mathrm{DCC}}_{\mathrm{SGD-RMB}}$ and $\overline{\mathrm{DCC}}_{\mathrm{SGD-USD}}$, also $\overline{\mathrm{DCC}}_{\mathrm{THB-RMB}}$ and

[1] These means are also compared by t-test. All of the p-values are 0 demonstrates the means are significantly different.

$\overline{\mathrm{DCC}}_{\mathrm{THB-USD}}$ during both periods. These DCC(s) can also be intuitively observed through Figures 5-1 to 5-5 in which the lines of the $\mathrm{DCC}_{\mathrm{EACs-RMB}}$ and $\mathrm{DCC}_{\mathrm{EACs-USD}}$ twist together most of the time. This consequent is due to a very tight fluctuation range in the rate of USD/RMB, both before and after January 2014. There is an unusual point in $\mathrm{DCC}_{\mathrm{USD-RMB}}$ should be noticed. On August 11, 2015, the PBC launched a violent exchange rate system reform; the exchange rate of RMB against the USD decreased by 1.84% on that day and sharply fluctuated in the next few days. As a result, the $\mathrm{DCC}_{\mathrm{USD-RMB}}$ sharply decreased during that time. However, it returned to high level gradually after then.

After some exchange rate system reforms, the RMB's exchange rate became more flexible to some extent. However, the RMB has not radically extricated itself from the USD in terms of exchange rate return, at least until September of 2016. In the "impossible trinity", the Chinese monetary authority may not give up the independence of its monetary policy. For the capital account, its openness is based on the reform of China's domestic financial sector which is a very complicated project, and this reform has not been very successful (Volz, 2014). In this case, for the risk-averse Chinese government, there is not sufficient motivation to promote capital account liberalization. As a coin has two sides, the effect of RMB exchange rate system reform has not been obvious.

Meanwhile, four (MYR, SGD, KRW and TWD) of the five EACs showed obviously lower average DCC(s) with the USD during the second period suggesting that these currency have become more significantly flexible in recent years. This result can also be observed from Figures 5-4, 5-5 5-6 and 5-7, the DCC(s) between these currencies and USD are presented as down-trend lines in the second period.

For the EACs, the USD and RMB look like the same currency when we choose the NZD as the numeraire currency. As a result, when these four currencies (MYR, SGD, KRW and TWD) got away from the USD, they were also far away from the RMB in the long-run. In Table 5-3, all of the average DCC(s) between the RMB and EACs become lower during sub-period C2, except for the THB. In this view, the exchange rate return co-movement between the RMB and EACs had not been stronger after the

RMB shifted into depreciation trend.

5.3.2 The exchange rate returns co-movements between the RMB and EACs, excluding the USD

However, there is a different scence when we use the USD as the numeraire currency. Choosing the USD as the numeraire currency is much nearer to reality, although this means that we have to exclude the USD from the sample currencies and we are unable to detect the USD's role in East Asia from an outside perspective. The results are presented in Table 5-4, the DCC(s) are rewritten as DCC(s)*. We also take the January 14, 2014 as a break-point. Figure 5-6 shows the evolution of the DCC(s)* between the RMB and EACs.

In Table 5-4, three (SGD, KRW, TWD) of the EACs showed relatively higher average DCC(s)* during the sub-period C2 than during sub-period C1. In other words, the exchange rate returns co-movements between the RMB and these three currencies became closer after the RMB turned into a depreciation trend and became more flexible. By contrast, $\overline{\mathrm{DCC}}_{\mathrm{MYR-RMB}}{}^*$ and $\overline{\mathrm{DCC}}_{\mathrm{THB-RMB}}{}^*$ did not increase significantly during the sub-period C2.

Figure 5-6 intuitively shows the evolution of the $\mathrm{DCC}_{\mathrm{EACs-RMB}}(\mathrm{s})^*$ when the RMB was in the depreciation trend. August 11, 2015 is a meaningful point caught by the DCC-GARCH model. When the RMB sharply fluctuated against the USD after the PBC launched a new exchange rate system reform, the $\mathrm{DCC}_{\mathrm{EACs-RMB}}{}^*$ also changed obviously in short-run. The increasing $\mathrm{DCC}_{\mathrm{SGD-RMB}}{}^*$, $\mathrm{DCC}_{\mathrm{KRW-RMB}}{}^*$ and $\mathrm{DCC}_{\mathrm{TWD-RMB}}{}^*$ mean that the exchange rate return co-movements between the RMB and these three currencies were stronger when the RMB depreciated and fluctuated against the USD suddenly. However, the MYR and THB were far away from the RMB during those days. The $\mathrm{DCC}_{\mathrm{MYR-RMB}}{}^*$ dropped from 0.24 to 0.09; the $\mathrm{DCC}_{\mathrm{THB-RMB}}{}^*$ decreased from 0.13 to 0.05. This unusual point is a short-run evidence that the co-movement of RMB-MYR and RMB-THB did not rise significantly when the RMB devaluated to the USD accidentally. The reality also supports these results.

On August 11, 2015, the SGD, KRW and TWD simultaneously depreciated against the USD by 1.5%, 1.7% and 1.7% when the RMB suddenly depreciated against the USD. These fluctuations are very large for these currencies. On the other hand, the MYR and THB were very stable, the exchange rate returns against the USD were almost 0.

5.3.3 Economic fundamentals of the increasing DCC(s) between the RMB and EACs*

We will discuss why some DCC(s)* became lager while others not when the RMB became more flexible and depreciating during sub-period C2. For the exchange rate relationships, there are always some economic fundamentals on which the relationships are based on. The international trade relationship is one of the very important economic relationships between two countries. In East Asia, China does not abandon the capital account controlling, although loose it to a certain extent. The obvious economic relationship between China and East Asian countries is more reflected in the field of international trade mentioned in the part of Introduction.

With the close international trade relationship, Pontines and Sirega (2012) consider that the East and Southeast countries' "fear of appreciation" against the RMB because they competed with China in the field of export in the US market. Keddad (2016) also finds that the East Asian currencies over-react to the depreciating RMB partly because of the close trade relationships. In this part, we will discuss the exchange rate relationships (such as "fear of appreciation) between the RMB and East Asian currencies from another perspective: bilateral trade between China and East Asian countries (region).

Until now, China has been the very important, even the most important trade partner for many East Asian countries as shown from Figures 1-2 to 1-6. Moreover, China is also an important trade surplus source of some export-oriented countries (region) during the sample period. Among these five countries (region), Singapore, Korea and Taiwan keep huge trade surplus with China, not only in values but also in shares according to Figures 5-8-B, 5-9-B and 5-10-B. As shown in Figures 5-9-B and

5-10-B, more than 100% trade surplus of Korea and Taiwan came from China during the whole period. In other words, China is the most important market and surplus provider for Korea and Taiwan during the sample period. For Singapore, Although China possess neither an obvious advantage in the share of Singapore's export nor trade surplus; it can still kept about 10% of the trade surplus throughout the whole sample period.

From a perspective of trade competition, a weak RMB may deteriorate other East Asian countries' trade competitiveness, not only in the USA market (Pontines and Siregar, 2012) but also in Chinese market, when some of the sample East Asian countries keep huge trade flow and surplus with China. As a result, these currencies are more sensitive to the RMB exchange rate when the RMB was on the depreciation trend after the year of 2014. For Korea, Taiwan and Singapore, who run large trade surplus with China, the exchange rate return co-movements between their currencies and the RMB became larger when the RMB shifted into a depreciation trend.

Malaysia had trade deficit with China after the year of 2012. At the end of 2016, Malaysia had a 24.03 billion dollars trade surplus, while a 10.5 billion dollars trade deficit with China. Although the $DCC_{MYR-RMB}^{*}$ was large during both sub-periods, it did not increase obviously when the RMB exchange rate showed a depreciation trend in the sub-period C2. It seems that the $DCC_{MYR-RMB}^{*}$ was already high, and there is little space for increasing.

On the other hand, the trade balance between China and Thailand was different from other East Asian countries (region). Thailand always kept trade deficit with China and the share was not always obvious. For Thailand, Japan rather than China is the most important deficit source country. In other words, China did not occupy a favorable position in Thailand's international trade unlike the case of Korea, Taiwan, Singapore. By comparison, the $DCC_{THB-RMB}^{*}$ was not significantly larger during the sub-period C2, than during sub-period C1. Moreover, the average values of the DCC* between the RMB and THB were lowest among these DCC(s)*.

5.3.4 The force pushing the DCC between the RMB and EACs

Although the DCC-GARCH model cannot distinguish the official interventions from pure market force, we can still discuss this issue from the perspective of exchange rate regime.

The People's bank of China declared that "shares of trade in goods and services should be the fundamental considerations in the selection of the basket currencies and the weights assigned to the currencies in the basket". This means, when the RMB exchange rate is still under controlled to some extent, the trade relationship between China and one country is an important factor for China when they consider how to deal the exchange rate relationship with that country.

From a perspective of the international trade, the East Asian countries are not the most important trade partners for China. In Table 5-5, the USA is the most important export partner for China. It occupied a very high export share of 16-19% during the whole sample period. The second place was occupied by Japan. For other countries, particular the East Asian countries, the share are relativity low. Meanwhile, the East Asian countries (regions) are not important import partners for China. In Table 5-5, the USA, Japan and Germany are still important import partners for China. Although Korea occupied the largest share in China's import after the year of 2013, this advantage is not obvious. For other East Asian countries (regions), China keep relatively low import share with them.

It is reasonable to think that neither of the EACs is an important currency in the RMB's currency basket. For example, the PBC Governor Zhou Xiaochuan stated that the U.S. Dollar (USD), Euro (EUR) and Japanese Yen (JPY) were the most important currencies in the RMB's currency basket.[1] In December 2015, China Foreign Exchange Trading System & National Interbank Funding Center (CFETS), which is a sub-institution of the People's bank of China, introduced the CFETS RMB index. According to the CFETS RMB index, the USD, EUR and JPY are the three most

[1] PBC: Speech of Governor Zhou Xiaochuan: http://www.pbc.gov.cn/english/130724/2829809/index.html.

important currencies. As a result, it is unlikely that the PBC actively adjust the exchange rate co-movements of RMB-EACs.

For the EACs, the IMF classifies Korea (KRW) and Thailand (THB)'s exchange rate arrangement as "floating".[1] Thus the official intervention is not the main force pushing the KRW close to the RMB during sub-period C2. For the THB, because the trade relationships between China and Thailand were relatively loose, neither the marketers nor the Thai authorities would pay much attention to the co-movement between the RMB and THB.

Singapore has a "stabilized" exchange arrangement with a secretive composite anchor which is established by Monetary Authority of Singapore. This currency basket is composed by their major trade partners and competitors' currencies, thus we consider the RMB is an important currency in this basket because of the close trade relationship between these two countries. [2] In the short-run, the SGD exchange rate fluctuates freely within a target band. However, the currency basket is the center of the exchange rate in the long-run. The Center Bank of the Republic of China (Taiwan) declares that "the TWD exchange rate is determined by the market. However, when the market is disrupted by seasonal or irregular factors, the Bank will step in." [3] So, Taiwan's exchange rate regime can be thought as a "management floating" arrangement. We deduce that the co-movement of the SGD-RMB and TWD-RMB are forced by both marketers and authorities. According to the IMF, Malaysia has an "other managed" exchange rate arrangement; the Bank of Negara Malaysia (the central bank of Malaysia, BNM) declares they have a managed floating exchange rate arrangement. This means that the MYR exchange rate is decided by both pure market and authority. However, the relationship between the MYR and RMB seems to be

[1] IMF: *Annual Report on Exchange Arrangements and Exchange Restrictions 2014*.

[2] Some studies estimate the RMB's weight in the SGD's currency basket. For example, Kawai and Pontines (2014a; 2014b) consider the weight occupied by the RMB is higher than 0.2 after the year of 2010. Henning (2012) obtains the result of 0.364 during the period between June, 2010 to December, 2011. The RMB's weight is even higher than 0.49 in Subramanian and Kessler (2013)'s paper. Although these results are debatable, they can still illustrate that the RMB is an important currency in the SGD's currency basket.

[3] Center Bank of the Republic of China (Taiwan): http://www.cbc.gov.tw/ct.asp?xItem=856&CtNode=480&mp=2.

closer than it should be. The $DCC_{MYR-RMB}^{*}$ is the highest DCC^{*} during the both periods, as high as about 0.29, although it increased insignificantly. Another noteworthy event is: when the People's bank of China pronounced that the RMB would no longer be pegged to the US dollar on July 21, 2005, the BNM (Bank Negara Malaysia) also announced the end of the MYR's peg to the USD on the same day. Therefore, we conclude that the co-movement between the MYR and RMB is also forced by a mix force.

5.4 Summary

This part has examined the dynamic conditional correlations among the sample currencies by applying the DCC-GARCH model.

By choosing the NZD as the numeraire currency, we have fund that the USD was still the most important currency in East Asia. However, its importance has been weakened as the DCC(s) between the USD and EACs, except the THB, became less during recent years. This also suggests that the exchange rates of these East Asian currencies became more flexible. Meanwhile, the dynamic conditional correlation of the USD/RMB were very high (although it became lower during sub-period C2) during both periods due to RMB's narrow fluctuation band against the USD. This reflects the RMB's exchange rate flexibility has increased slowly, comparing with other East Asian currencies. As a result, the exchange rate return co-movements between the EACs and RMB became weaker during the second period. The EACs also departed from the RMB when they attached less importance to the USD.

However, when we choose the USD as the numeraire currency, the exchange rate return co-movements between the RMB and some of the EACs showed a rise during the second sub-sample period. We have found that: when a country (region) kept huge trade surplus with China, their currencies also fluctuated nearly with the RMB after January 2014, during when the RMB exchange rate showed a deprecation trend. These results confirm the existence of the "fear of appreciation" against the RMB in SGD, KRW and TWD. By investigating the EACs' exchange rate regimes, we consider that Korea's "fear" mainly came from pure market; Singapore and Taiwan's

“fear” came from both marketers and authorities. For Thailand, neither the authority nor marketers “fear of appreciation” against the RMB.

It seems the results are quite mixture even contradictory when we employ the NZD and USD as the numeraire currency respectively. In fact, this just reveals the RMB’s increasing but limited role in East Asia. On the one hand, the close economic relationships between China and some countries was a fundamental for strong exchange rate co-movement, particularly, when the RMB became more flexible and was on a deprecation trend. On the other hand, the relatively slow pace of further exchange rate system reform causes the RMB to be still near to the USD. Therefore, the RMB had been neither a polar of East Asian exchange rate system nor a challenger to the USD, at least until September 2016. If the RMB exchange rate system can be reformed further in the future, the RMB could potentially attract more attention in East Asia.

Chapter 6. Conclusions

6.1 Conclusions

In East Asia, the monetary authorities always give a high weight to the USD. The East Asian exchange rate system has some characteristics, such as “East Asian dollar standard”, “competitive exchange depreciation”, “fear of floating” and “fear of appreciation”. To stabilize the economy and avoid external risks, the East Asian monetary authorities always adjust the exchange rate relationships with other currencies, specifically, with the US dollar. In recent years, the East Asian exchange rate system has changed to some extent, for example, most of the East Asian currencies are more flexible against the US dollar.

Since the year of 2005, the RMB exchange rate system reform has been constantly promoted. The *de jure* daily fluctuation band of the USD/RMB rate has been expanded from almost 0% to 2%. The *de facto* band also has been increased. The RMB internationalization is also encouraged by Chinese authorities. Meanwhile, as the second large economy in the world, China keep very close economic relationship with East Asian countries, particularly in the trade field. China already has been the most important source of trade surplus for many East Asian countries. In this case, the RMB’s role in East Asian exchange rate arrangement may also change. This study mainly focuses on the significance of the RMB’s role in East Asia.

There are some contributions in this study. Firstly, we research the issue from many perspectives, which are shocks, volatilities and correlations. The methods employed in this study can avoid the shortages exist in the traditional method, for example, currency basket regression model. Secondly, we analyze the issue periodically, even dynamically. The periodical and dynamic methods can obtain more detail and accurate results. Thirdly, we analyze the correlation of the RMB and East Asian currencies when the RMB was on appreciation and depreciation trends, separately. This is a new approach of studying the RMB’s role in East Asia. From an economic

perspective, there are differences between a weak RMB and strong RMB for some East Asian countries, as well as their currencies. Through this method, we connect the economic factors and currency market to some extent.

Through the research, we find that the RMB has played a more and more significant role in East Asia since 2010, but it is still not one pole in East Asian exchange rate system.

Firstly, we find that the RMB exchange rate shocks could significantly affect some East Asian currencies exchange rate return movements after the daily RMB exchange rate fluctuation band was expanded to 2% as the RMB exchange rate reform launched on 17 March, 2014.While, the East Asian currencies insignificantly responded to the RMB exchange rate shocks when the RMB was too near the US dollar, particularly during the period when the daily RMB exchange rate fluctuation band was only set as 0.5%. Thus, the RMB exchange rate reforms make the RMB more flexible, also release its influence.

Secondly, when the RMB exchange rate could influence some of the East Asian currencies, it also means that the RMB can transfer exchange rate risks. The exchange rate turn risks can be represented by volatilities. From the BEKK-GARCH model, we find that the RMB can significantly affect more and more East Asian currencies exchange rate return volatilities in recent years. The being flexible and international RMB also means a source of exchange rate risks which should be paid attentions.

Thirdly, after detecting the influence from the RMB to East Asian currencies, it is necessary to investigate the exchange rate return correlations between the RMB and East Asian currencies. To obtain time-varying correlations, the DCC-GARCH models are employed. Comparing with the CCC-GARCH model, the DCC-GARCH has many merits. For example, the conditional correlations are dynamic and we can compare the average values of DCC in one model rather than divide the sample period into some sub-periods and employ more than one model. When we choose the NZD as the numeraire, we find that the RMB was still close to the USD comparing with other East Asian currencies. However, when we choose the USD as the numeraire, the dynamic conditional correlations of RMB-SGD, RMB-KRW and RMB-TWD

increased obviously when the RMB showed a depreciation trend after 2014, there was "fear of appreciation" against the RMB in these three currencies. For these three countries (region), from a perspective of international trade, South Korea, Singapore and Taiwan, they all keep large trade surplus with China. Meanwhile, the trade relationship between China and Thailand were relatively loose, and Malaysia kept trade deficits with China. For these two currencies, the DCC(s) did not increase when the RMB exchange rate showed a depreciation trend.

We also detect the USD's importance in East Asia in each part. All of the results show that the USD was always the most important currency in East Asian exchange rate arrangements. The USD exchange rate shocks could significantly affect East Asian currencies movements during the whole sample period, and could also transfer exchange rate risks. Although the dynamic conditional correlations between the USD and East Asian currencies decreased in recent years, they were still high, which suggests that the USD's position did not basically change.

In summary, we find that the RMB played a more and more significant role for some East Asian currencies, for example, the KRW and TWD, as well as the MYR and SGD. The RMB could not only affect these currencies exchange rate movements, but also cause exchange rate risks. When the RMB showed a depreciation trend, there was "fear of appreciation against the RMB" in these currencies. Among these sample currencies, the relationship between the RMB and THB was not significant, and the RMB did not play a significant role at all for the THB.

6.2 Shortcomings and future researches

There are still some shortcomings in this study.

Firstly, two of the three models, which are VAR and BEKK-GARCH models employed in this study are undynamic models. To detect the evolution of RMB's role, we have to divide the whole period into some sub-periods. Although this method can reveal the change of RMB's significance in East Asia from 2010 to 2016 to some extent, it is still rude.

Secondly, this research mainly focuses on the RMB's significance in the foreign

exchange markets. The connection between the exchange rate relationships and economic relationships are not sufficiently studied. Although the economic relationship (for example, the trade relationship) between China and East Asian countries are discussed in the fifth part when we study the DCC(s) between the RMB and East Asian currencies, they are still not put into one econometric model.

Thirdly, when we study the dynamic conditional correlations between the RMB and East Asian currencies, we employ the DCC-GARCH. However, the DCC-GARCH model is still a symmetric model. However, the financial series, for example, the exchange rate returns, are always not symmetry series. A positive shock and a negative shock may cause different volatilities. It is necessary to detect the correlations between the RMB and East Asian currencies in more detail.

In the future, we will do some researches from the following aspects.

Firstly, we plan to employ time-varying parameter VAR (TVP-VAR) model to detect the response of the East Asian currencies to the RMB exchange rate shocks. Through the TVP-VAR, we can obtain the time-varying responses of the East Asian currencies to the USD, RMB and EUR exchange rate shocks. Through these results, we can study the RMB's role in more detail, rather than a fix result during a certain period. Secondly, we will analyze the economic factors and exchange rate relationships in a model, in other words, what is the economic determinants of the RMB's role in East Asia. For example, we will consider the factors such as the FDI, export, import and portfolio flows in the model. Thirdly, we also plan to consider the asymmetric effects in exchange rate returns. For example, the multivariate exponential GARCH (EGARCH) model may be an appreciate model to distinguish the different relationships between the RMB and East Asian currencies when the RMB appreciates and depreciates. Fourthly, the sample period chosen in study is from 2010 to 2016. Although this sample period is very representative, the RMB exchange rate may show more characteristics in the future. Also, the RMB exchange rate may do not show any obvious trend, rather than a appreciation trend and a depreciation trend like from 2010 to 2016. It is necessary to consider these cases in the future studies.

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Figures and Tables

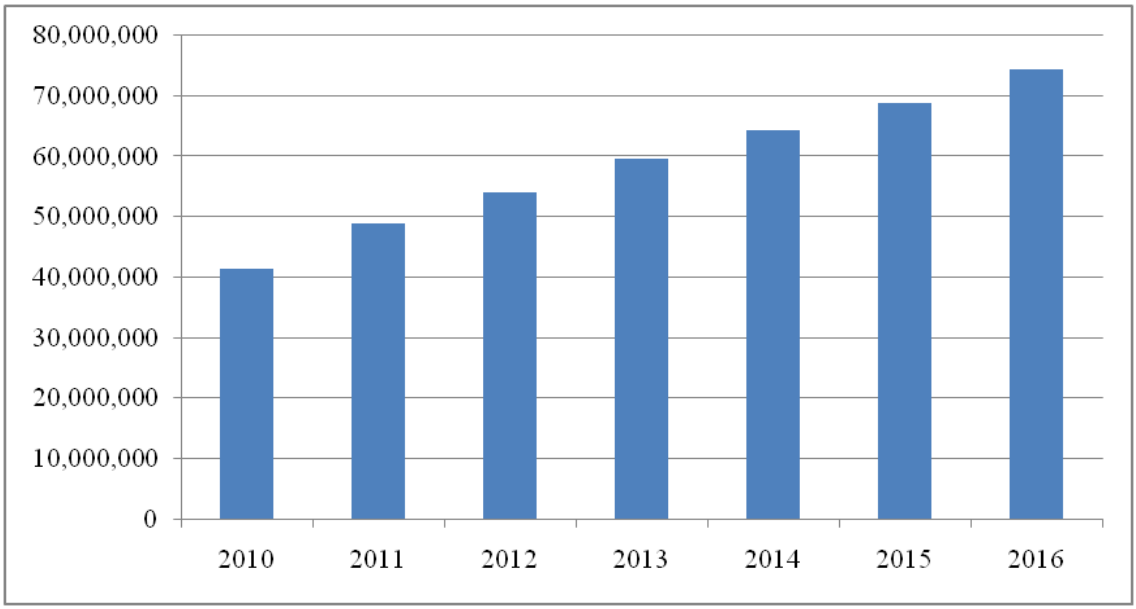


Figure 1-1. The Gross Domestic Product (GDP) in China (2010-2016, million Yuan)

Data Source: National Bureau of Statistics of China.

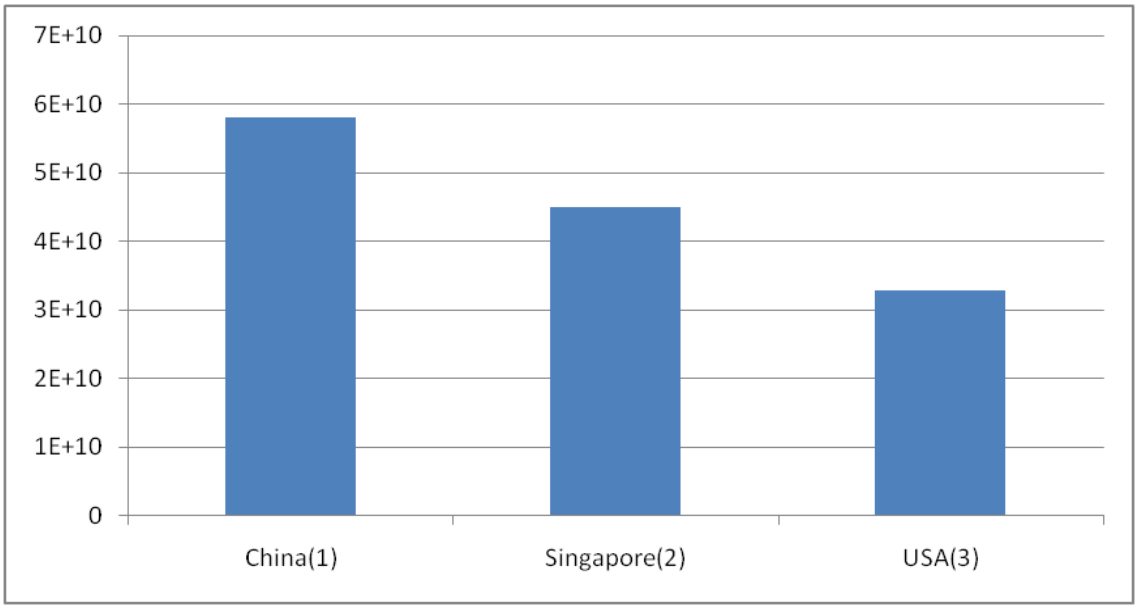


Figure 1-2. Malaysia's most important trade partners and their positions in 2014 (dollars)

Data Source: UNComtrade database.

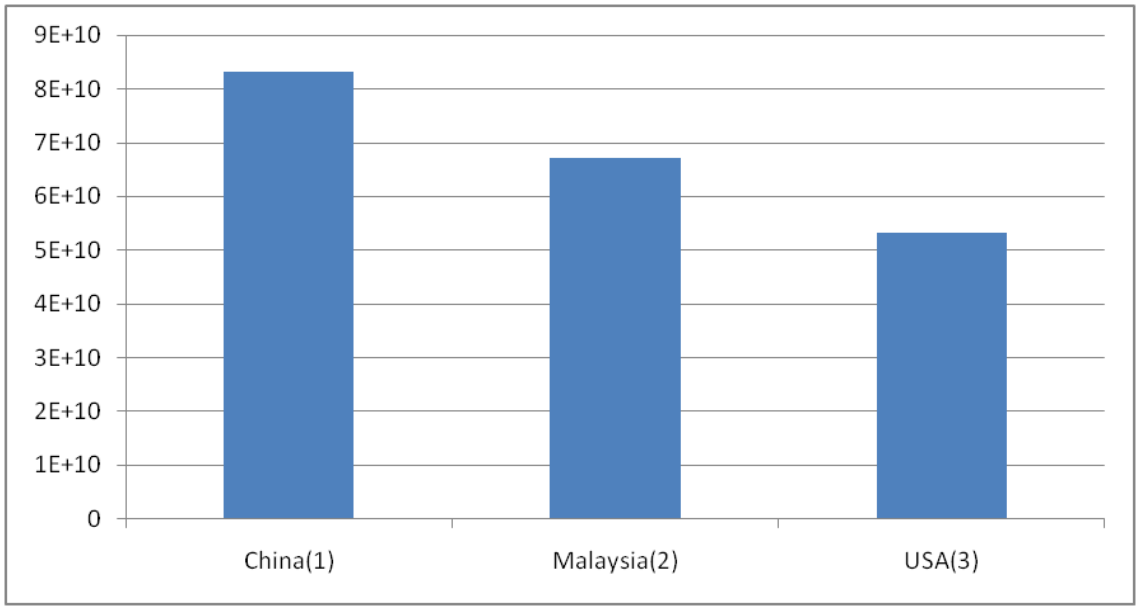


Figure 1-3. Singapore's most important trade partners and their positions in 2014 (dollars)

Data Source: UNComtrade database.

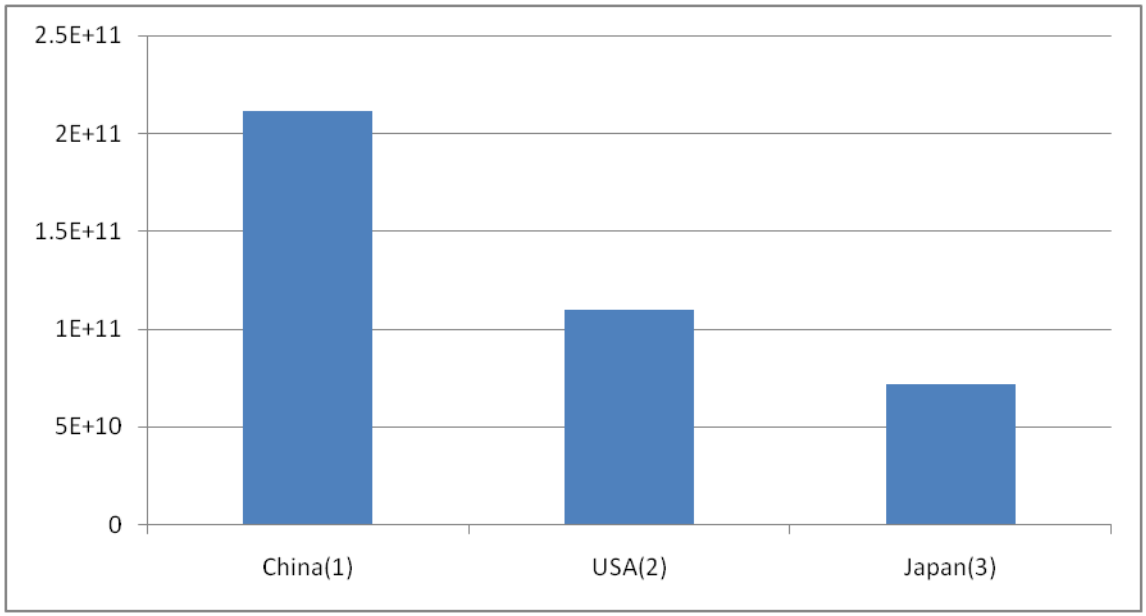


Figure 1-4. South Korea's most important trade partners and their positions in2014 (dollars)

Data Source: UNComtrade database.

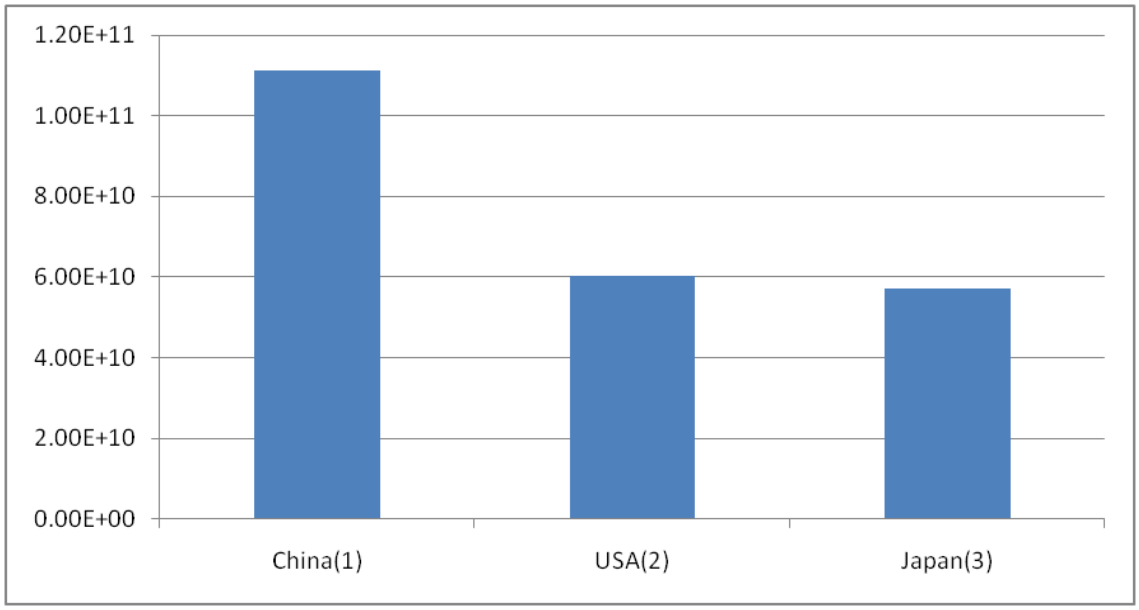


Figure 1-5 Taiwan's most important trade partners and their positions in 2014 (dollars)

Data Source: UNcomtrade database.

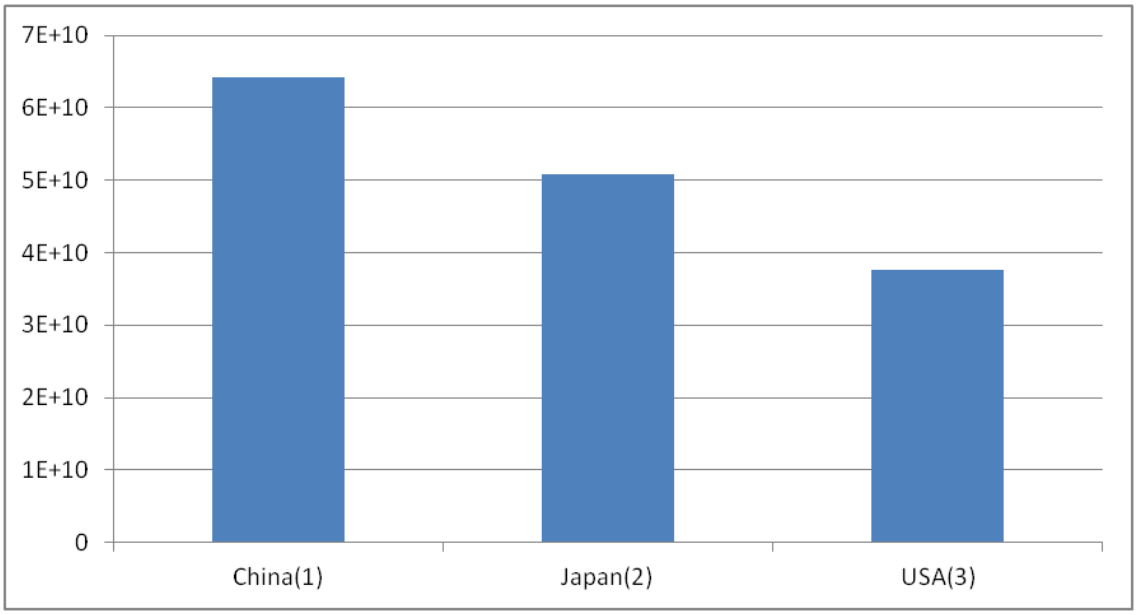


Figure 1-6. Thailand's most important trade partners and their positions in 2014 (dollars)

Data Source: UNcomtrade database.

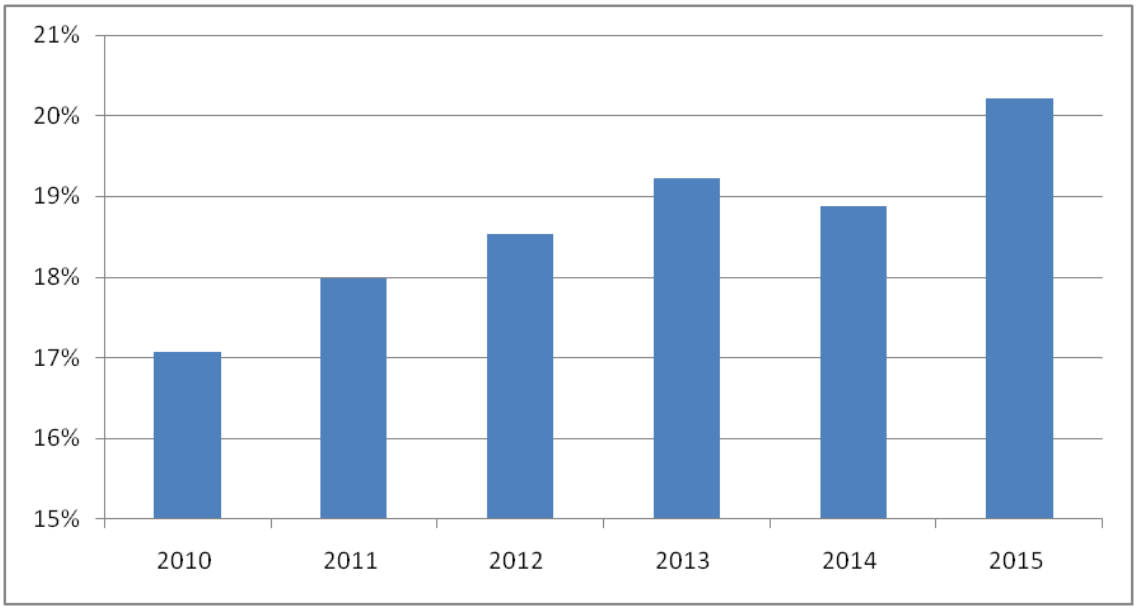


Figure 1-7. The sample East Asian countries' export share with China (Korea, Malaysia, Singapore, Taiwan and Thailand, totally).

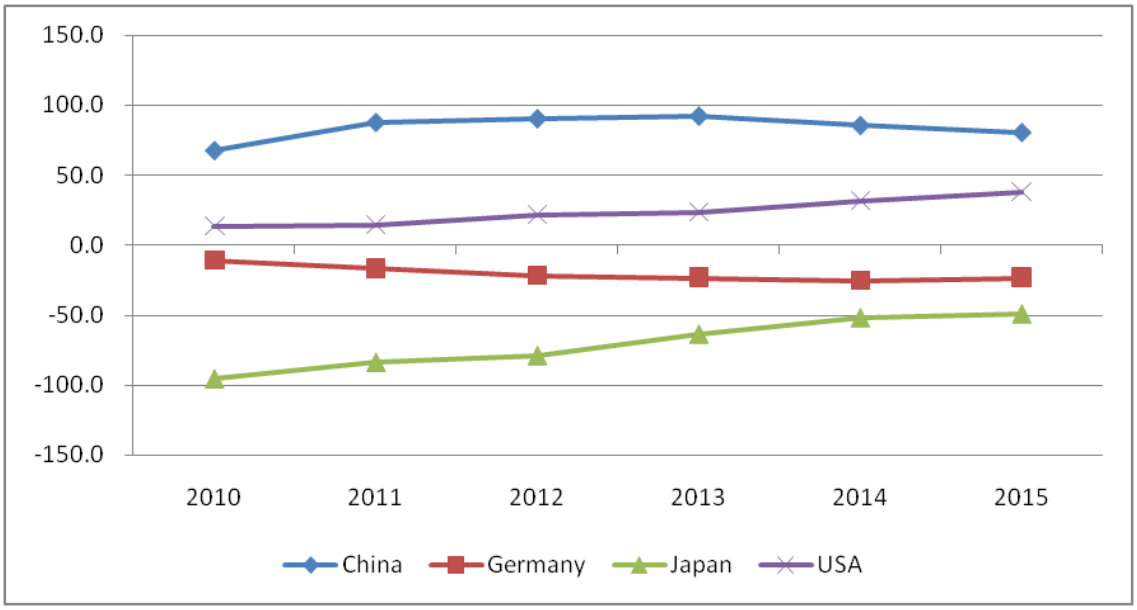


Figure 1-8. The trade balance between the sample East Asian countries and region (Malaysia, Singapore, South Korea, Taiwan and Thailand) and their major trade partners (billion dollars).

Data source: UNComtrade; Customs Administration, Republic of China.

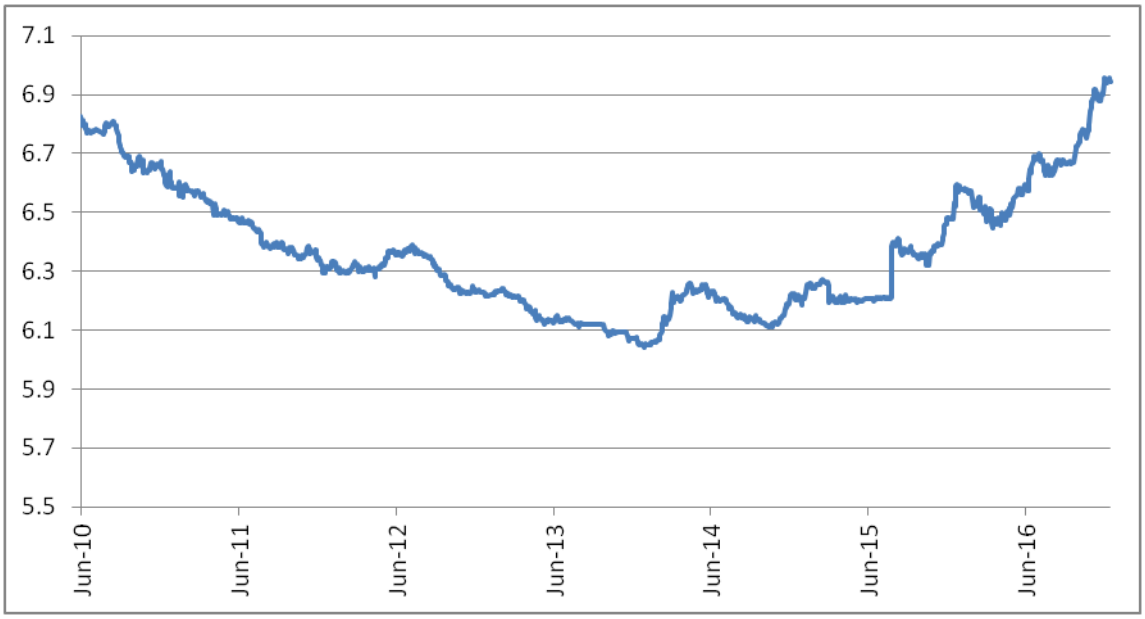


Figure 1-9. The daily exchange rate between the USD and RMB from June 21, 2010 to December 30, 2016.

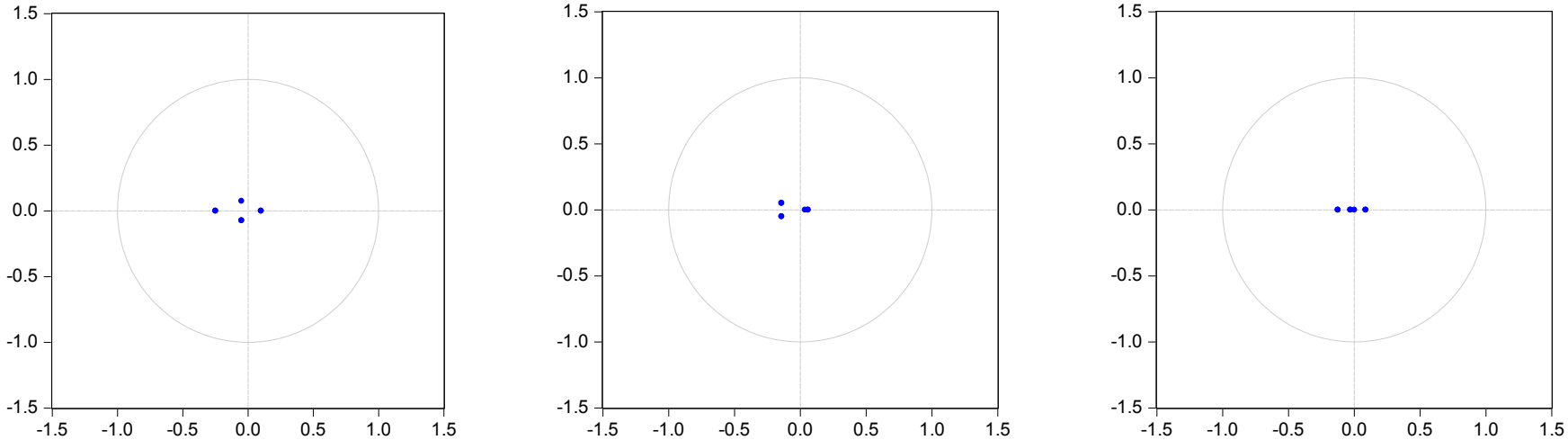


Figure 3-1. Inverse Roots of AR Characteristic Polynomial (USD-RMB-KRW, Sub-period A1, A2 and A3).

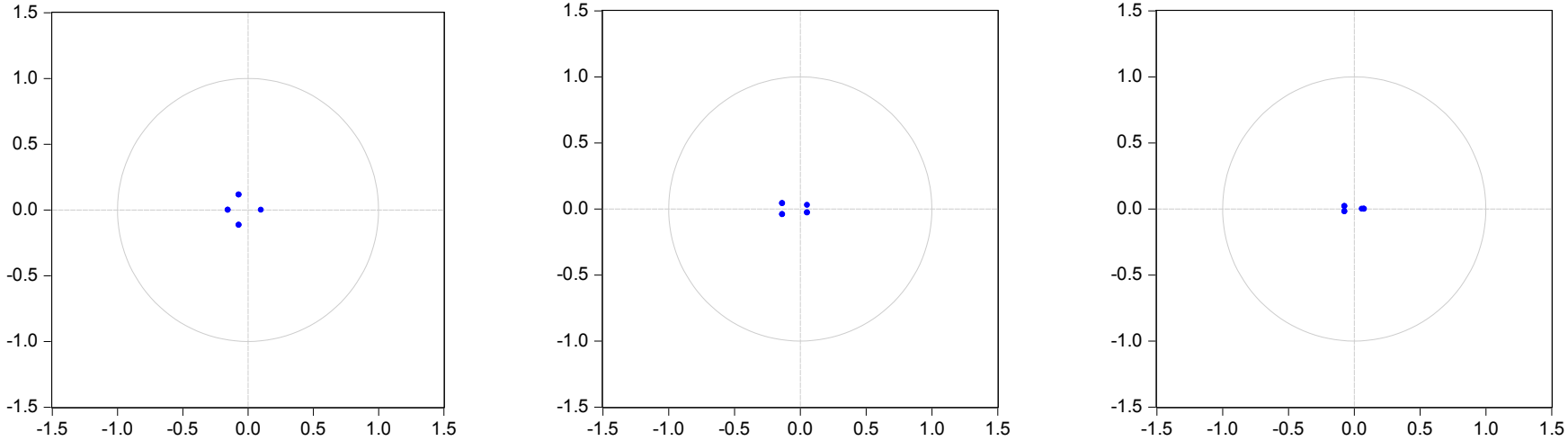


Figure 3-2. Inverse Roots of AR Characteristic Polynomial (USD-RMB-MYR, Sub-period A1, A2 and A3).

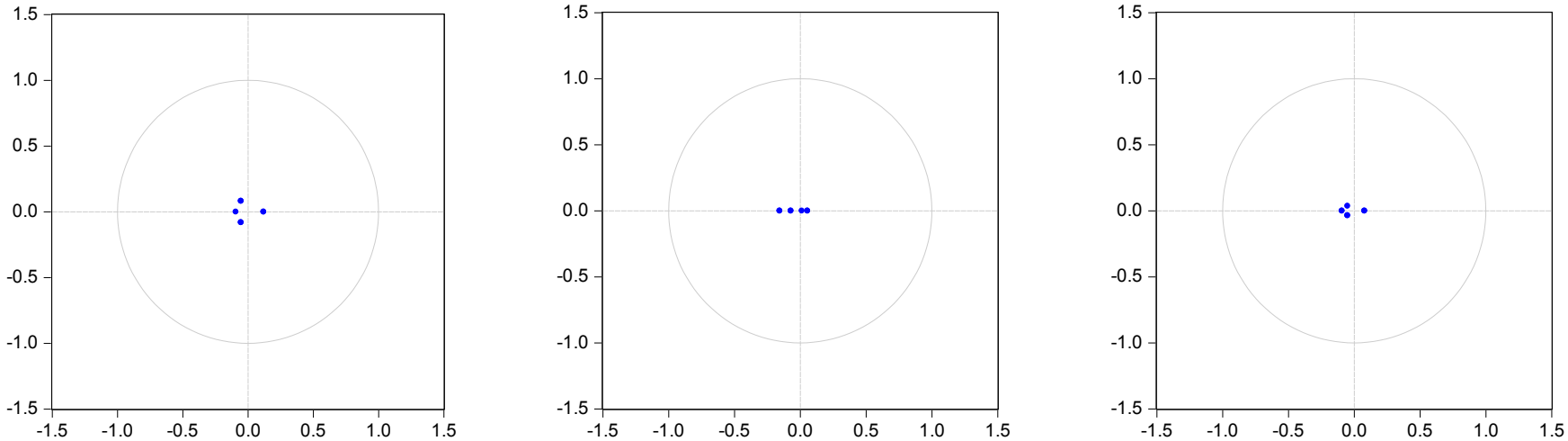


Figure 3-3. Inverse Roots of AR Characteristic Polynomial (USD-RMB-SGD, Sub-period A1, A2 and A3).

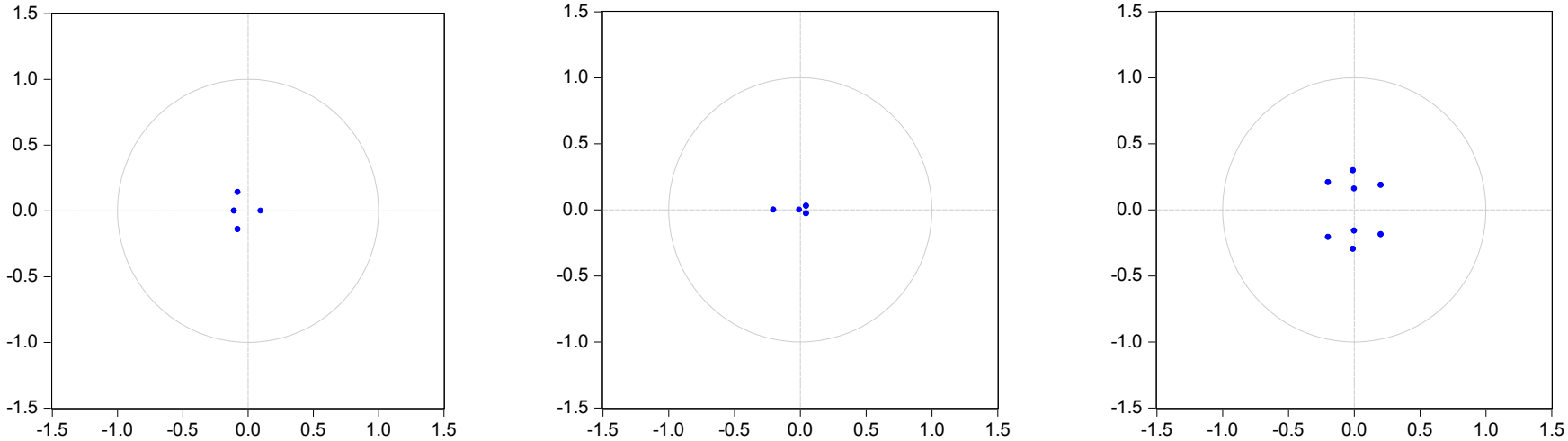


Figure 3-4. Inverse Roots of AR Characteristic Polynomial (USD-RMB-TWD, Sub-period A1, A2 and A3).

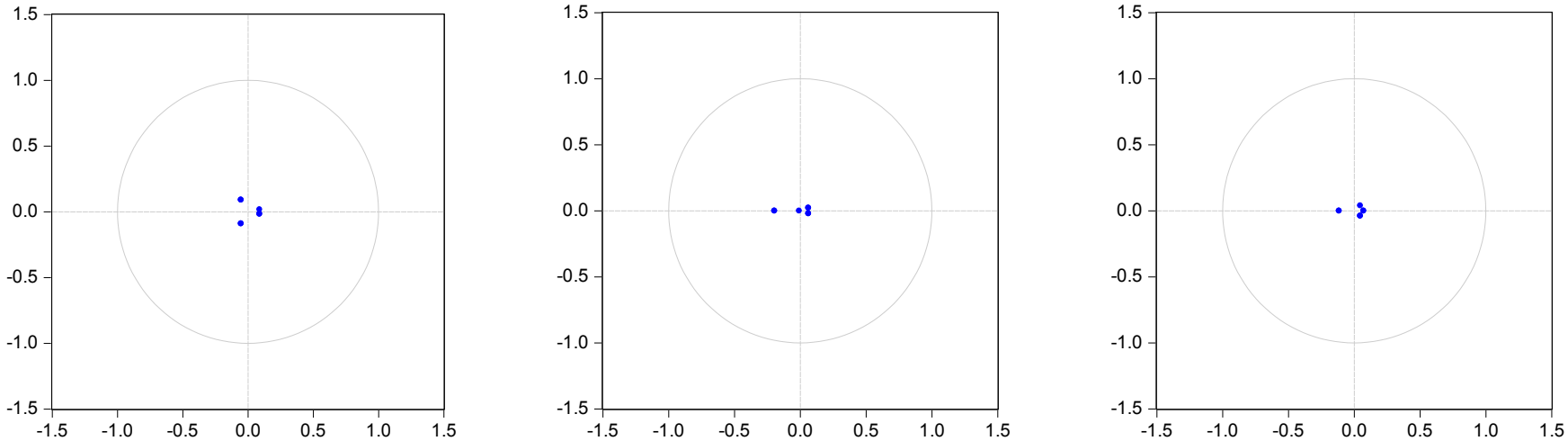


Figure 3-5. Inverse Roots of AR Characteristic Polynomial (USD-RMB-THB, Sub-period A1, A2 and A3).

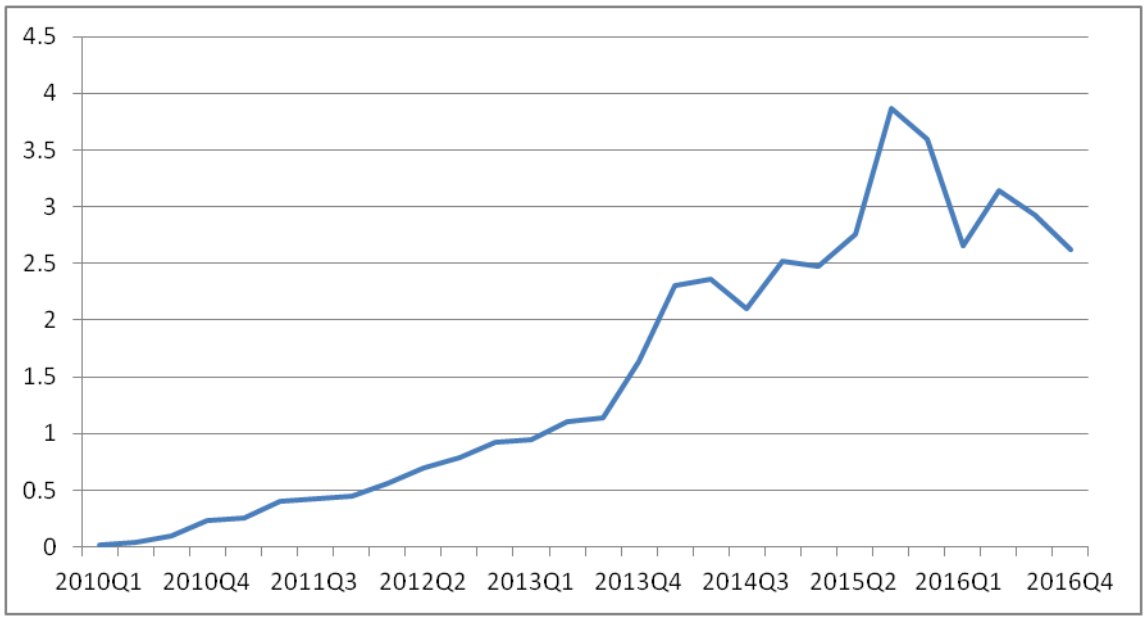


Figure 4-1. Renminbi internationalization index (2010Q1-2016Q4).

Data source: *RMB Internationalization Report,* International Monetary Institute, Renmin University of China.

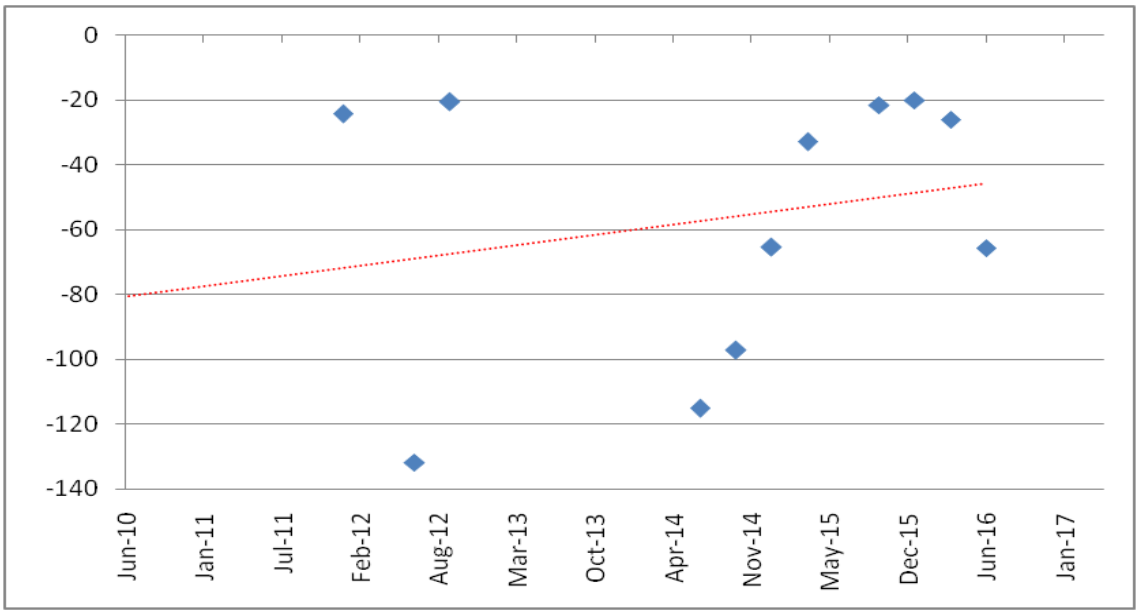


Figure 4-2. The ratio of China's foreign reserves (t-1) to net capital outflows (t).

Data source: People's bank of China.

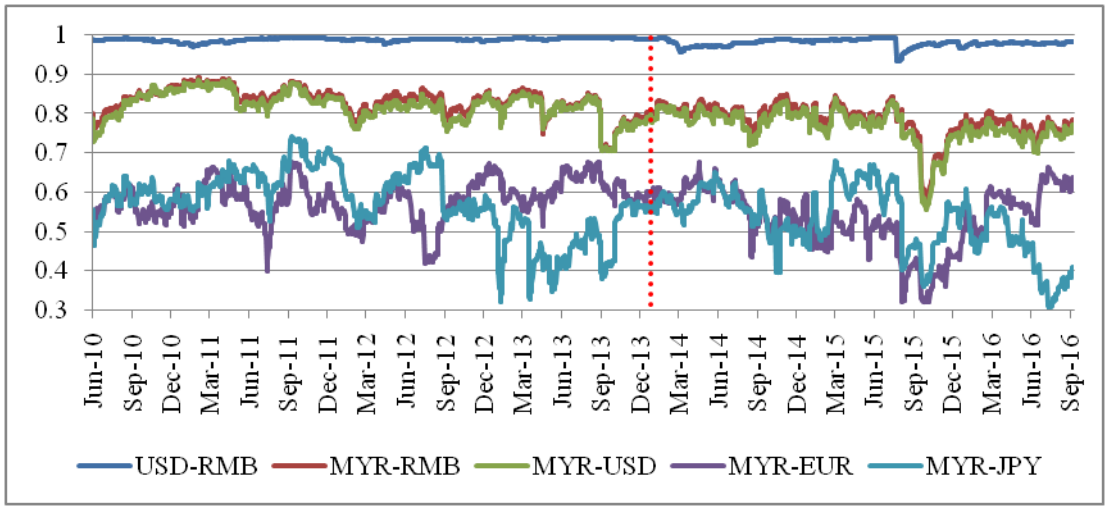


Figure 5-1. Dynamic conditional correlations between the MYR and other currencies (Numeraire currency: NZD)

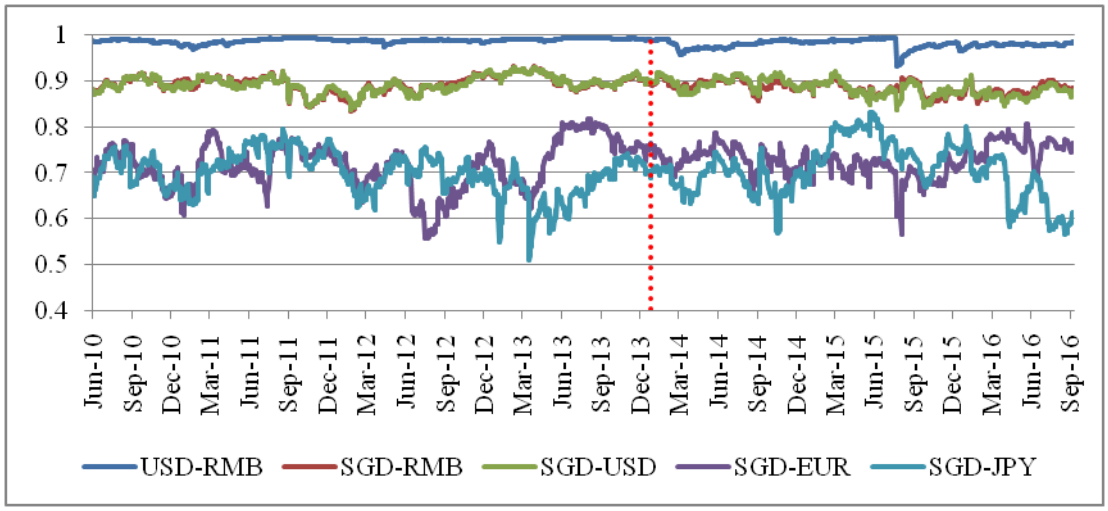


Figure 5-2. Dynamic conditional correlations between the SGD and other currencies (Numeraire currency: NZD)

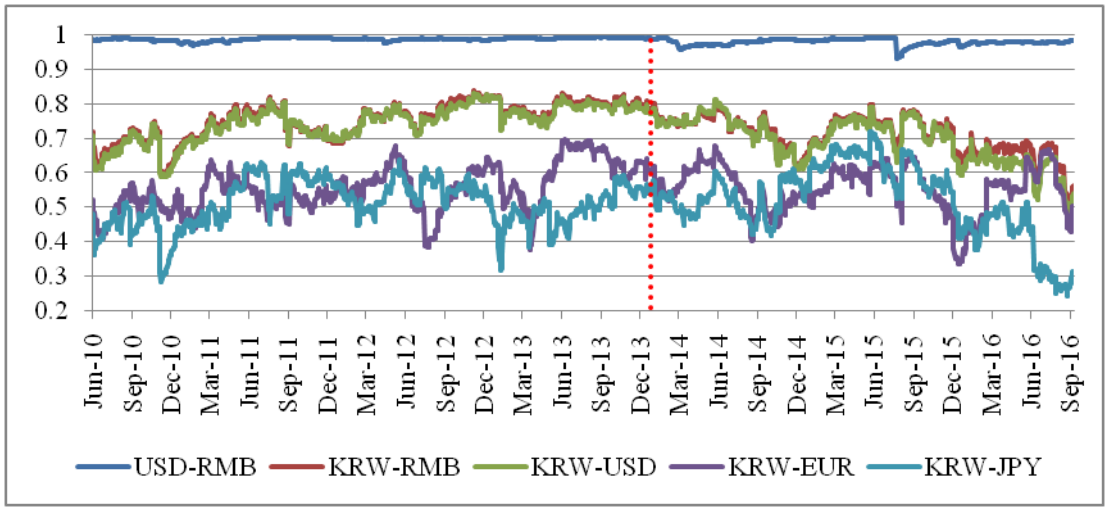


Figure 5-3. Dynamic conditional correlations between the KRW and other currencies (Numeraire currency: NZD)

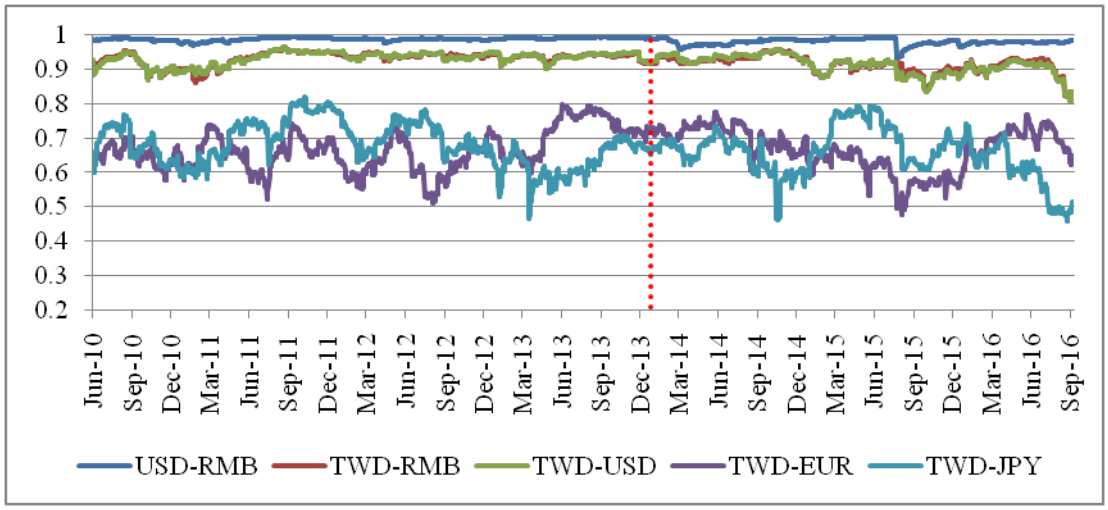


Figure 5-4. Dynamic conditional correlations between the TWD and other currencies (Numeraire currency: NZD)

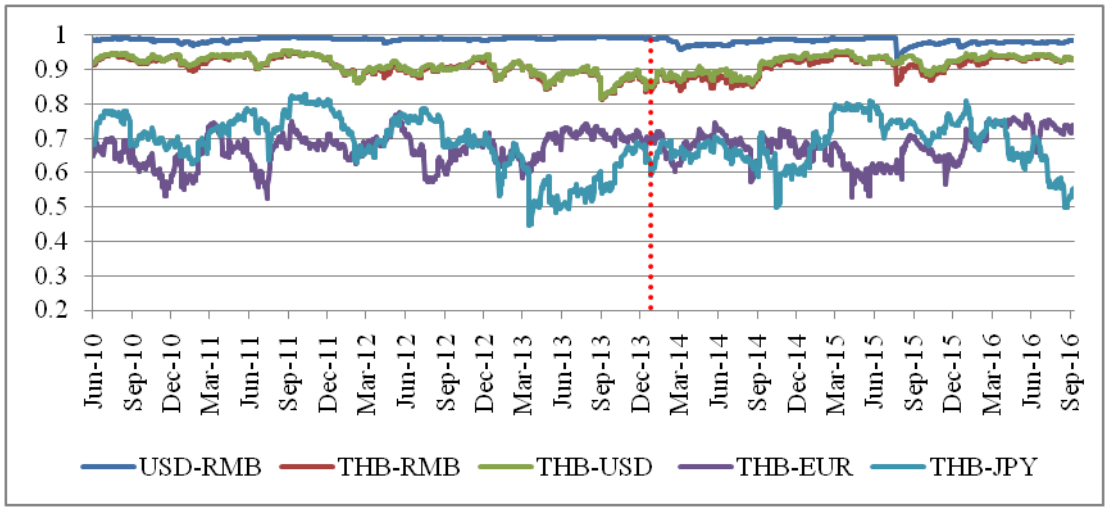


Figure 5-5. Dynamic conditional correlations between the THB and other currencies (Numeraire currency: NZD)

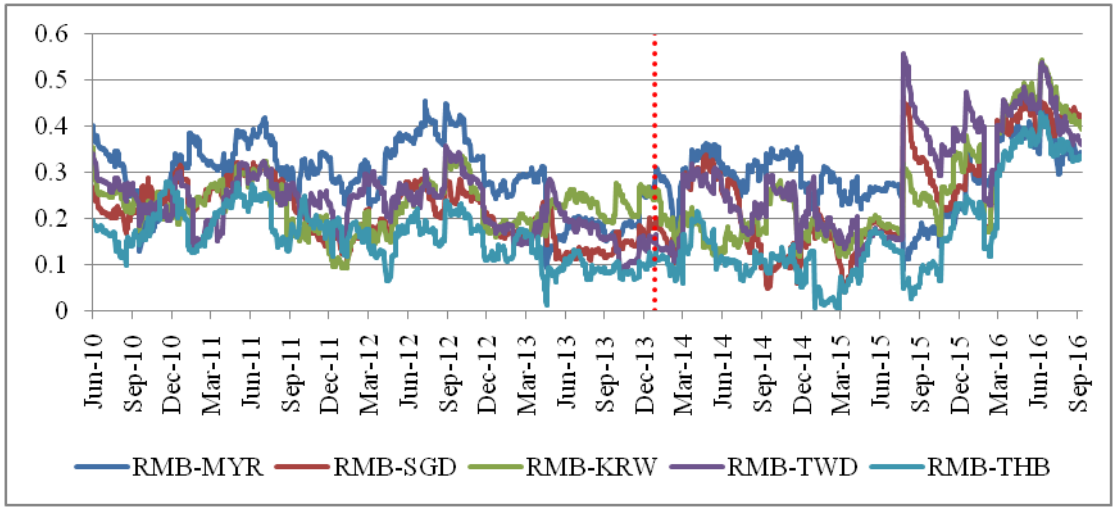


Figure 5-6. Dynamic conditional correlations between the RMB and other currencies. (Numeraire currency: USD)

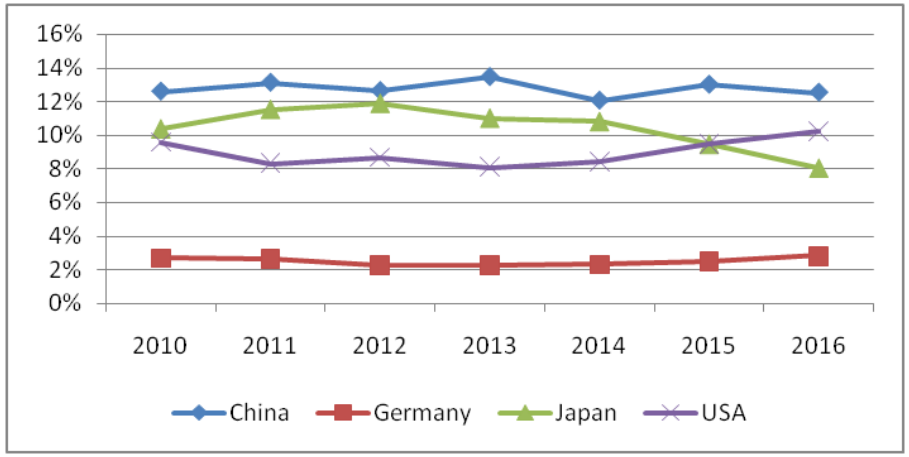


Figure 5-7-A. Malaysia's major export partners (partly)

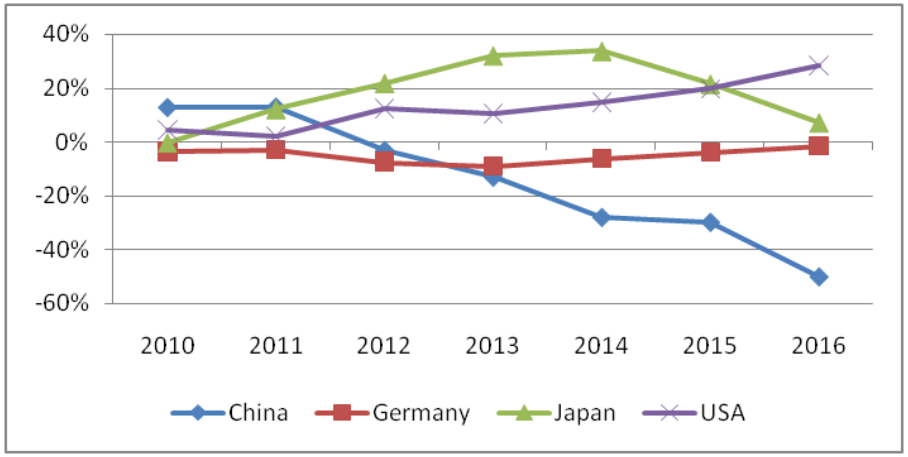


Figure 5-7-B. Major source of Malaysia's trade surplus (partly)

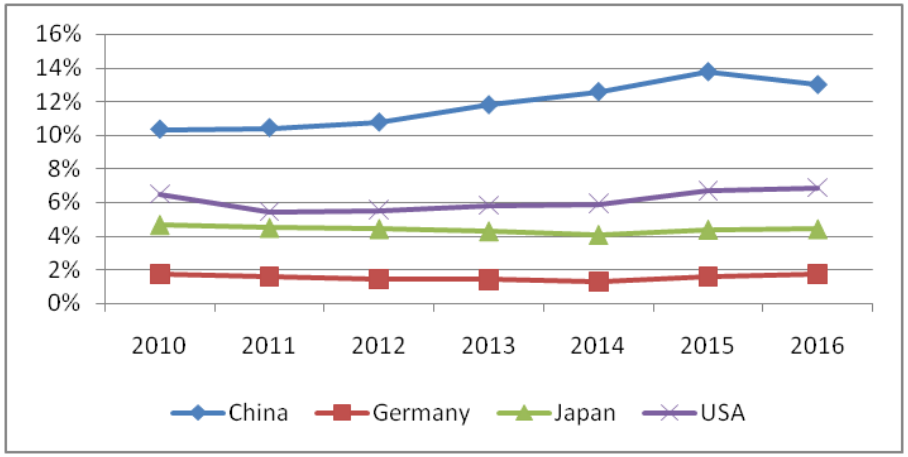


Figure 5-8-A. Singapore's major export partners (partly)

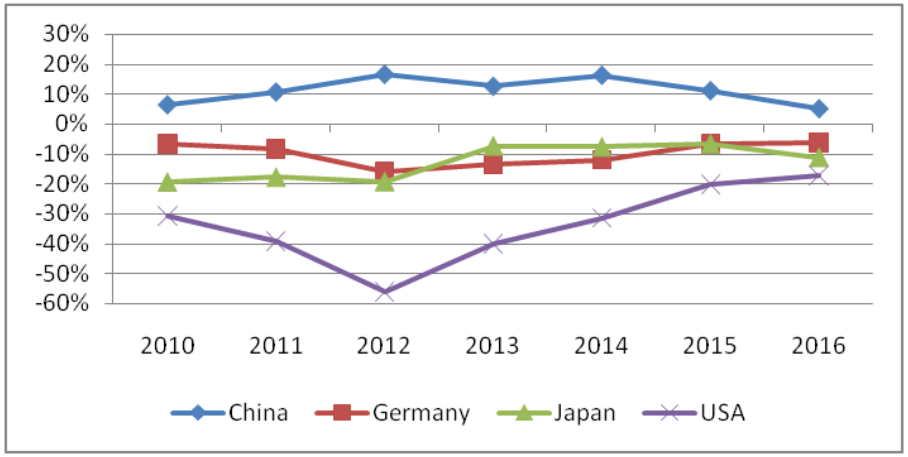


Figure 5-8-B. Major source of Singapore's trade surplus (partly)

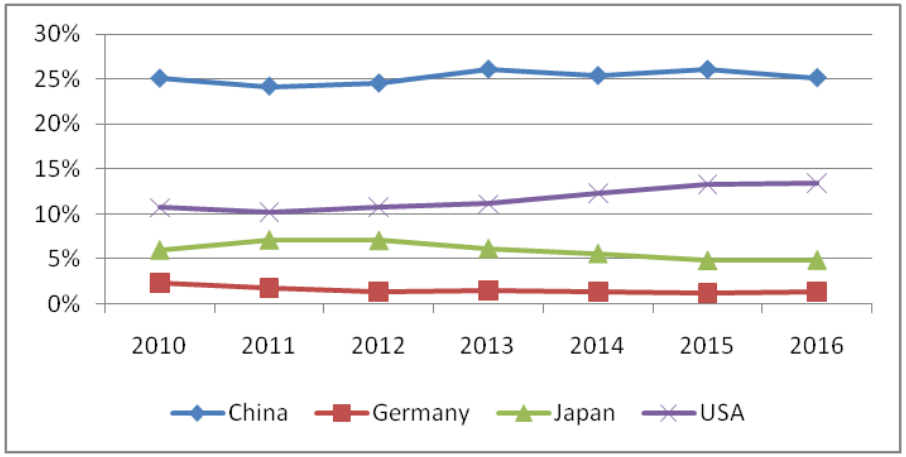


Figure 5-9-A Korea's major export partners (partly)

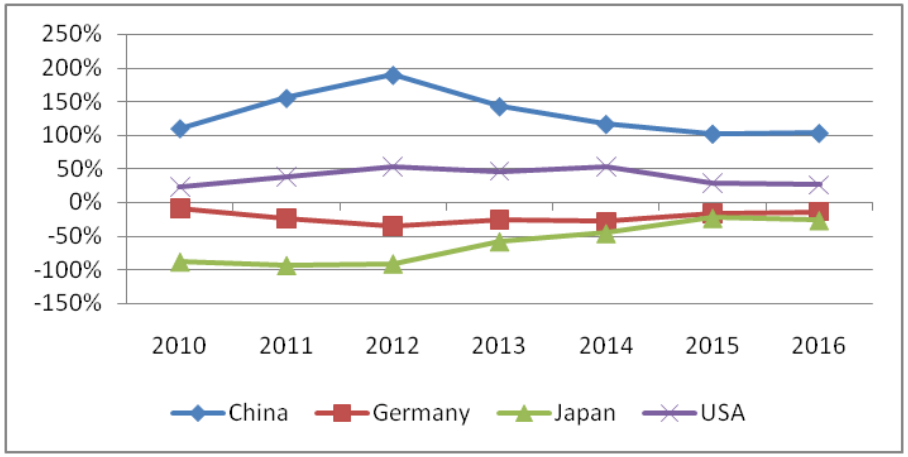


Figure 5-9-B Major source of Korea's trade surplus (partly)

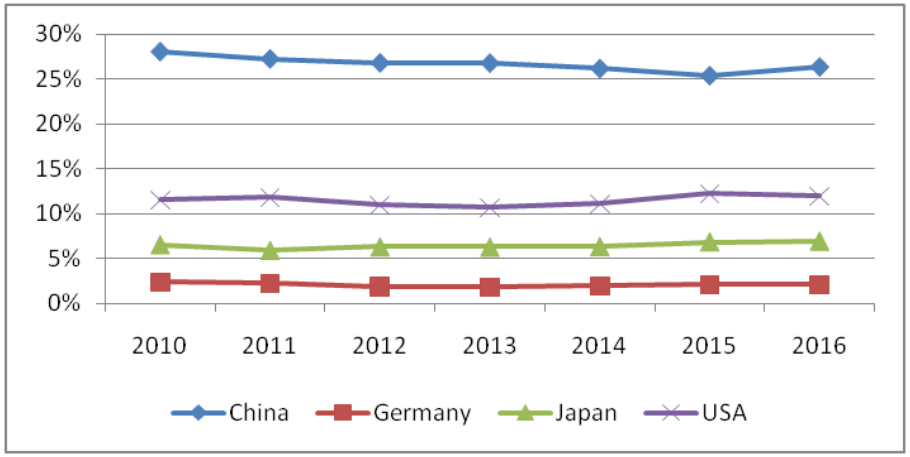


Figure 5-10-A. Taiwan's major export partners (partly)

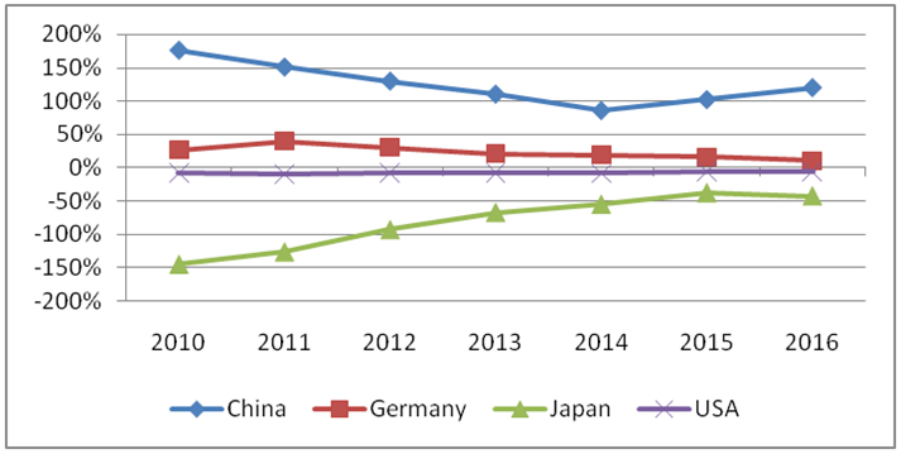


Figure 5-10-B. Major source of Taiwan's trade surplus (partly)

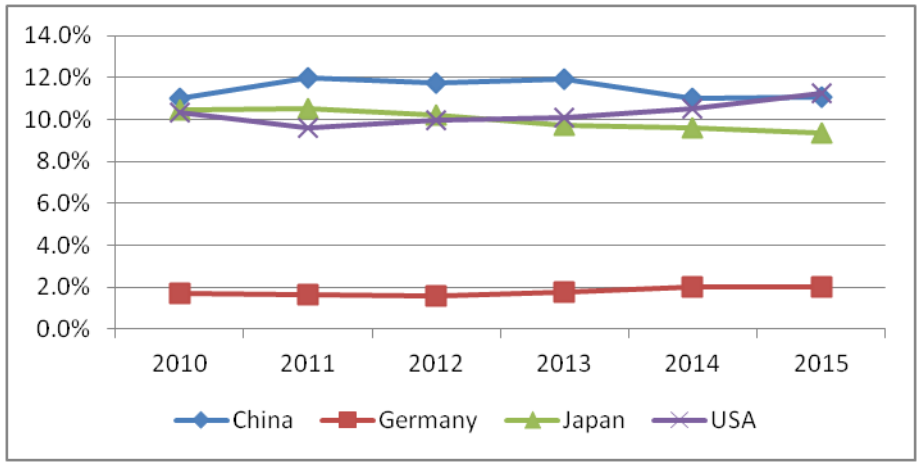


Figure 5-11-A. Thailand's major export partners (partly)

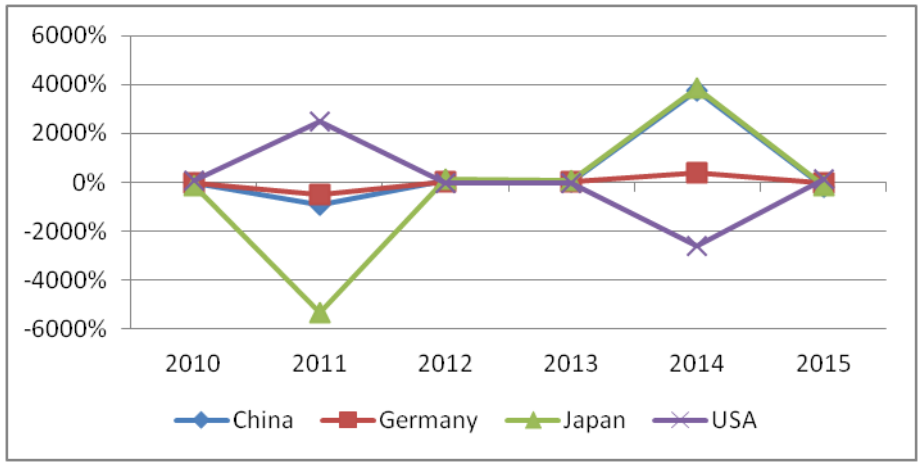


Figure 5-11-B. Major source of Thailand's trade surplus (partly)

Table 1-1. The related contents about the fluctuation band of RMB-USD

Date(abbreviation)	Margin	Related expression
July 21,2005 (2005 reform)	0% →0.3%	"The daily trading price of the US dollar against the RMB in the inter-bank foreign exchange market will continue to be allowed to float within a band of ±0.3 percent around the central parity published by the People's Bank of China, while the trading prices of the non-US dollar currencies against the RMB will be allowed to move within a certain band announced by the People's Bank of China."
May 21,2007 (2010 reform)	0.3%→0.5%	"The floating band of RMB trading prices against the US dollar in the inter-bank spot foreign exchange market is enlarged from 0.3% to 0.5%, i.e., on each business day, the trading prices of the RMB against the US dollar in the inter-bank spot foreign exchange market will float within a band of ±0.5 percent around the central parity publicized on the same day by the China Foreign Exchange Trading System."
June 19,2010 (2010 reform)	--	"Under the current regulation, the daily trading price of the RMB against the US dollar on the inter-bank foreign exchange market is allowed to float from the central parity of RMB against the U.S. dollar within a band of 0.5 percent."
April 14,2012 (2012 reform)	0.5%→1%	"Effective from April 16, 2012 onwards, the floating band of RMB's trading prices against the US dollar in the inter-bank spot foreign exchange market is enlarged from 0.5 percent to 1 percent, i.e., on each business day, the trading prices of the RMB against the US dollar in the inter-bank spot foreign exchange market will fluctuate within a band of ±1 percent around the central parity released on the same day by the China Foreign Exchange Trade System."
March 17,2014 (2014 reform)	1%→2%	"Effective from 17 March 2014 onwards, the floating band of RMB against US dollar on the inter-bank spot foreign exchange market is enlarged from 1 percent to 2 percent, i.e., on every trading day on the inter-bank spot market, the trading prices of RMB against U.S. dollar will fluctuate within a band of ±2 percent below and above the central parity as released by the China Foreign Exchange Trade System on that day."
August 11,2015 (2015 reform)	--	"For the purpose of enhancing the market-orientation and benchmark status of central parity, the PBC has decided to improve quotation of the central parity of RMB against US dollar."

Source: The website of the PBC: http://www.pbc.gov.cn.

Table 3-1. Summary statistics of daily returns of the currencies (I/NZD, June 21, 2010 – April 13, 2012)

	USD	EUR	RMB	KRW	MYR	SGD	TWD	THB
Mean	-0.00015	-9.60E-05	-7.36E-05	-9.43E-05	-9.11E-05	-5.01E-05	-6.80E-05	-0.0001
Median	-0.00034	-0.000417	-0.00034	-7.70E-05	-0.000157	-0.00017	-0.000103	-0.00019
Maximum	0.01946	0.010573	0.018998	0.009292	0.016205	0.011596	0.012838	0.016345
Minimum	-0.01428	-0.009218	-0.014665	-0.012044	-0.010656	-0.00855	-0.013416	-0.01031
Std. Dev	0.00381	0.003192	0.003753	0.00336	0.003477	0.00271	0.003471	0.003337
Skewness	0.353033	0.38941	0.312385	-0.104651	0.242351	0.316373	0.043412	0.431501
Kurtosis	4.647103	3.132098	4.614143	3.286489	3.892204	3.578734	3.671419	4.268065
Jarque-Bera	60.08141	11.67421	56.04631	2.355073	19.28761	13.75623	8.574815	44.01627
Sum	-0.06777	-0.043117	-0.033054	-0.042359	-0.040915	-0.022486	-0.030525	-0.04506
Sum Sq. Dev	0.006503	0.004566	0.006309	0.005059	0.005417	0.00329	0.005396	0.004988

Table 3-2. Summary statistics of daily returns of the currencies (I/NZD, April 16, 2012 – March 14, 2014)

	USD	EUR	RMB	KRW	MYR	SGD	TWD	THB
Mean	-3.48E-05	2.44E-05	-1.16E-05	1.93E-05	-0.000102	-4.79E-05	-6.21E-05	-8.06E-05
Median	-5.14E-05	-7.12E-05	-6.59E-05	-0.000104	-0.000102	-0.000185	-0.00012	3.76E-05
Maximum	0.017353	0.011153	0.017261	0.011381	0.010907	0.011141	0.011847	0.011169
Minimum	-0.009327	-0.009152	-0.010115	-0.01	-0.010787	-0.008298	-0.008754	-0.01077
Std. Dev	0.00299	0.002728	0.002987	0.002866	0.003053	0.002445	0.002753	0.002751
Skewness	0.321446	0.178032	0.291508	0.012144	-0.062138	0.248931	0.146647	-0.06307
Kurtosis	5.539638	3.717739	5.490337	3.680241	3.891213	4.092403	3.823115	4.052096
Jarque-Bera	130.9702	12.25018	124.8372	8.84166	15.45187	27.5031	14.57087	21.42708
Sum	-0.015932	0.011158	-0.005315	0.008835	-0.046515	-0.021948	-0.02842	-0.0369
Sum Sq. Dev	0.004084	0.0034	0.004077	0.003753	0.00426	0.002732	0.003463	0.003459

Table 3-3. Summary statistics of daily returns of the currencies (I/NZD, March 17, 2014 – December 30, 2016)

	USD	EUR	RMB	KRW	MYR	SGD	TWD	THB
Mean	0.000133	-4.58E-05	5.46E-05	5.77E-05	-6.90E-05	4.63E-05	9.04E-05	6.53E-05
Median	0.000131	-0.000196	0.000189	0.000115	-0.00017	7.38E-06	0.000152	0.000107
Maximum	0.013492	0.021566	0.012423	0.014346	0.012432	0.011508	0.011369	0.011986
Minimum	-0.015373	-0.012205	-0.015168	-0.013384	-0.018514	-0.009375	-0.010983	-0.01152
Std. Dev	0.003467	0.003279	0.003344	0.003004	0.003637	0.002666	0.002899	0.003058
Skewness	-0.083621	0.437373	-0.124755	0.150766	-0.217773	0.124356	-0.126644	-0.07359
Kurtosis	4.943973	7.564361	4.660675	5.630762	4.739262	4.817979	4.300985	4.419223
Jarque-Bera	107.0719	607.4597	79.31521	197.2077	90.4144	94.69424	49.40763	57.25839
Sum	0.089532	-0.030897	0.03686	0.038927	-0.046573	0.031236	0.061003	0.044058
Sum Sq. Dev	0.008102	0.007246	0.007539	0.006082	0.008915	0.00479	0.005665	0.006303

Table 3-4. Augmented Dickey-Fuller (ADF) and Philips-Perron (PP) unit root tests for the log-returns of I/NZD during the Sub-period A1

		t-Statistic	Prob.*
USD	**Augmented Dickey-Fuller test statistic**	-19.95577	0.0000
	Phillips-Perron test statistic	-19.92982	0.0000
EUR	**Augmented Dickey-Fuller test statistic**	-18.89244	0.0000
	Phillips-Perron test statistic	-18.87259	0.0000
RMB	**Augmented Dickey-Fuller test statistic**	-20.21350	0.0000
	Phillips-Perron test statistic	-20.19511	0.0000
KRW	**Augmented Dickey-Fuller test statistic**	-24.26141	0.0000
	Phillips-Perron test statistic	-24.89777	0.0000
MYR	**Augmented Dickey-Fuller test statistic**	-23.11741	0.0000
	Phillips-Perron test statistic	-23.37979	0.0000
SGD	**Augmented Dickey-Fuller test statistic**	-20.65451	0.0000
	Phillips-Perron test statistic	-20.64915	0.0000
TWD	**Augmented Dickey-Fuller test statistic**	-21.49382	0.0000
	Phillips-Perron test statistic	-21.60158	0.0000
THB	**Augmented Dickey-Fuller test statistic**	-20.00193	0.0000
	Phillips-Perron test statistic	-19.97073	0.0000
Test critical values	**1% level**	-3.44472	
	5% level	-2.86777	
	10% level	-2.57015	

Table 3-5. Augmented Dickey-Fuller (ADF) and Philips-Perron (PP) unit root tests for the log-returns of I/NZD during the Sub-period A2

		t-Statistic	Prob.*
USD	**Augmented Dickey-Fuller test statistic**	-22.87504	0.0000
	Phillips-Perron test statistic	-22.85422	0.0000
EUR	**Augmented Dickey-Fuller test statistic**	-21.03215	0.0000
	Phillips-Perron test statistic	-21.03293	0.0000
RMB	**Augmented Dickey-Fuller test statistic**	-23.43112	0.0000
	Phillips-Perron test statistic	-23.42960	0.0000
KRW	**Augmented Dickey-Fuller test statistic**	-24.64706	0.0000
	Phillips-Perron test statistic	-24.64506	0.0000
MYR	**Augmented Dickey-Fuller test statistic**	-25.17264	0.0000
	Phillips-Perron test statistic	-25.64116	0.0000
SGD	**Augmented Dickey-Fuller test statistic**	-21.94107	0.0000
	Phillips-Perron test statistic	-21.94610	0.0000
TWD	**Augmented Dickey-Fuller test statistic**	-22.84576	0.0000
	Phillips-Perron test statistic	-22.83117	0.0000
THB	**Augmented Dickey-Fuller test statistic**	-22.72701	0.0000
	Phillips-Perron test statistic	-23.30180	0.0000
Test critical values	**1% level**	-3.444436	
	5% level	-2.867645	
	10% level	-2.570085	

Table 3-6. Augmented Dickey-Fuller (ADF) and Philips-Perron (PP) unit root tests for the log-returns of I/NZD during the Sub-period A3

		t-Statistic	Prob.*
USD	**Augmented Dickey-Fuller test statistic**	-27.41922	0.0000
	Phillips-Perron test statistic	-27.59132	0.0000
EUR	**Augmented Dickey-Fuller test statistic**	-29.13134	0.0000
	Phillips-Perron test statistic	-29.20306	0.0000
RMB	**Augmented Dickey-Fuller test statistic**	-27.99591	0.0000
	Phillips-Perron test statistic	-28.03436	0.0000
KRW	**Augmented Dickey-Fuller test statistic**	-28.50946	0.0000
	Phillips-Perron test statistic	-28.52834	0.0000
MYR	**Augmented Dickey-Fuller test statistic**	-30.08457	0.0000
	Phillips-Perron test statistic	-30.38321	0.0000
SGD	**Augmented Dickey-Fuller test statistic**	-28.33675	0.0000
	Phillips-Perron test statistic	-28.37629	0.0000
TWD	**Augmented Dickey-Fuller test statistic**	-26.57424	0.0000
	Phillips-Perron test statistic	-26.57463	0.0000
THB	**Augmented Dickey-Fuller test statistic**	-28.05214	0.0000
	Phillips-Perron test statistic	-28.17677	0.0000
Test critical values	**1% level**	-3.439824	
	5% level	-2.865611	
	10% level	-2.568995	

Table 3-7. VAR Lag Order Selection Criteria: AIC (Akaike information criterion)

		0	1	2	3	4	5
USD-EUR-RMB-KRW	Sub-period A1	-38.9483	-39.06287*	-39.0338	-38.983	-38.9554	-38.9345
	Sub-period A2	-41.4091	-41.43076*	-41.3816	-41.3541	-41.3194	-41.2936
	Sub-period A3	-38.7776	-38.77764*	-38.7638	-38.7346	-38.7121	-38.7144
USD-EUR-RMB-MYR	Sub-period A1	-39.6309	-39.80804*	-39.7868	-39.7365	-39.6994	-39.666
	Sub-period A2	-41.2348	-41.27234*	-41.2187	-41.1944	-41.1627	-41.1335
	Sub-period A3	-38.5854	-38.63280*	-38.6109	-38.5904	-38.5629	-38.5614
USD-EUR-RMB-SGD	Sub-period A1	-40.3166	-40.37531*	-40.3462	-40.2891	-40.267	-40.2339
	Sub-period A2	-42.4766	-42.48270*	-42.4242	-42.4068	-42.3631	-42.3527
	Sub-period A3	-40.112	-40.12932*	-40.1193	-40.0854	-40.0635	-40.0676
USD-EUR-RMB-TWD	Sub-period A1	-40.3375	-40.47407*	-40.445	-40.3923	-40.3626	-40.3389
	Sub-period A2	-42.7566	-42.75829*	-42.712	-42.6865	-42.6427	-42.6326
	Sub-period A3	-39.8317	-39.8359	-39.83902*	-39.8121	-39.7813	-39.7758
USD-EUR-RMB-THB	Sub-period A1	-40.3681	-40.42364*	-40.3818	-40.3501	-40.3172	-40.2757
	Sub-period A2	-41.7867	-41.78753*	-41.7306	-41.7078	-41.6666	-41.6739
	Sub-period A3	-40.1616	-40.16525*	-40.153	-40.13	-40.1026	-40.0924

* indicates lag order selected by the criterion

Table 3-8. Accumulated Response of the KRW to USD, EUR and RMB

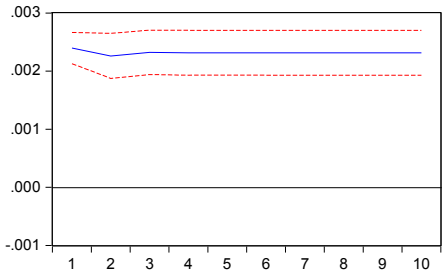
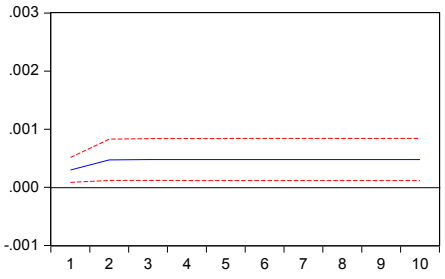
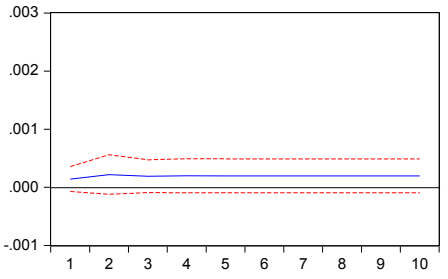
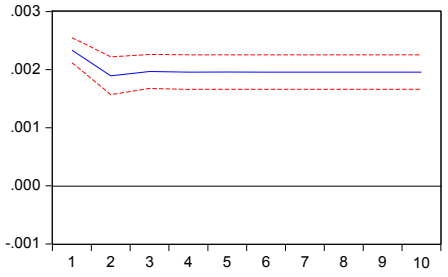
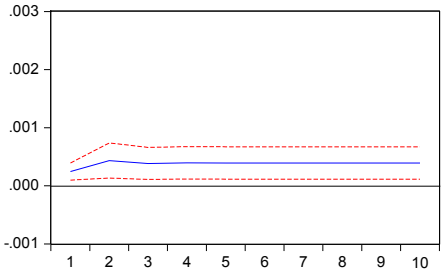
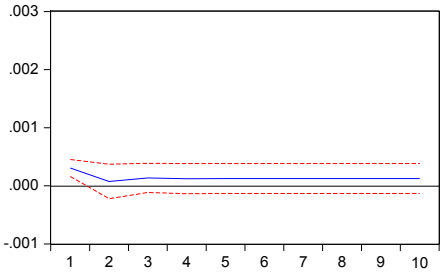
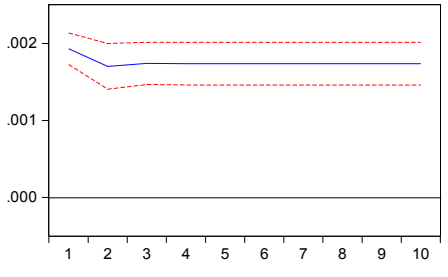
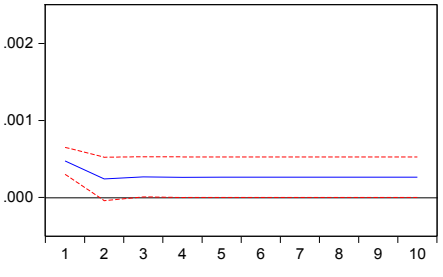
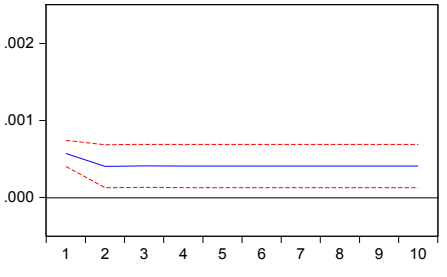
	USD shock	EUR shock	RMB shock
Sub-period A1			
Sub-period A2			
Sub-period A3			

Table 3-9. Accumulated Response of the MYR to USD, EUR and RMB

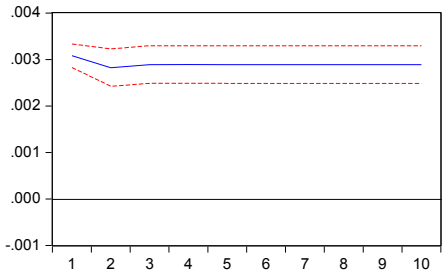
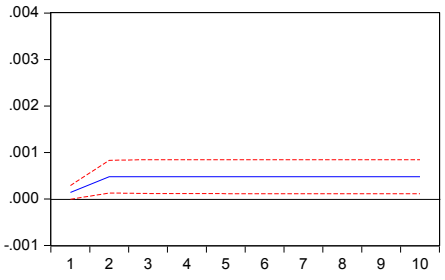
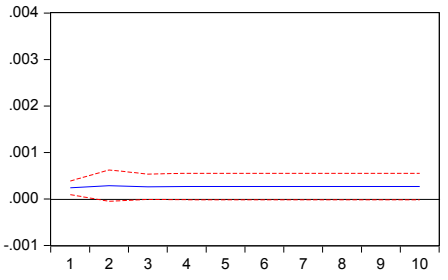
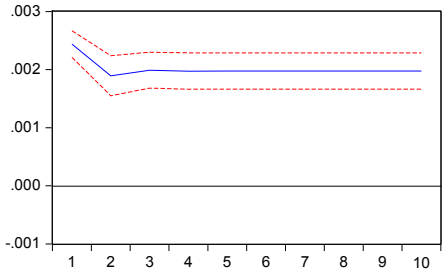
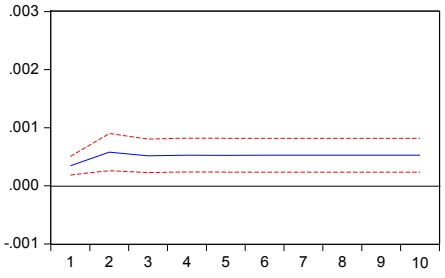
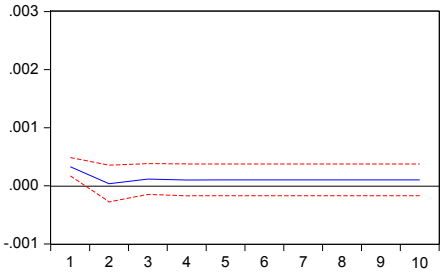
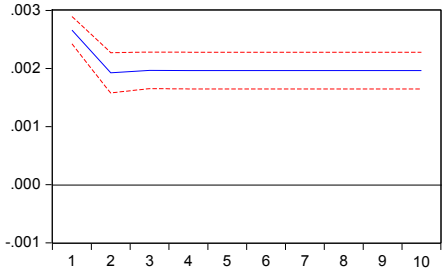
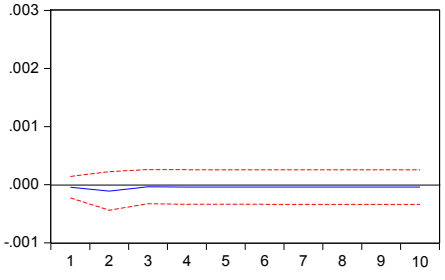
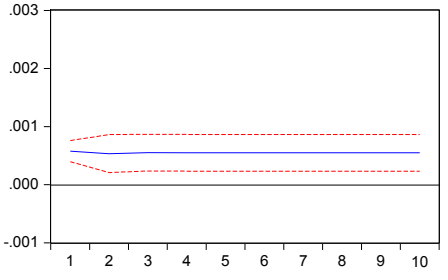
	USD shock	EUR shock	RMB shock
Sub-period A1			
Sub-period A2			
Sub-period A3			

Table 3-10. Accumulated Response of the SGD to USD, EUR and RMB

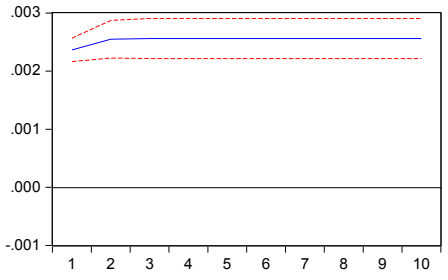
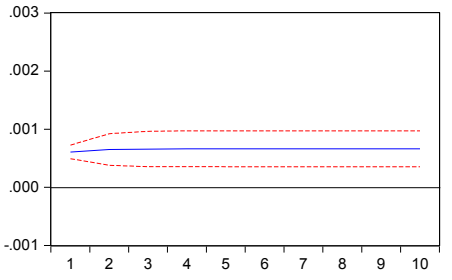
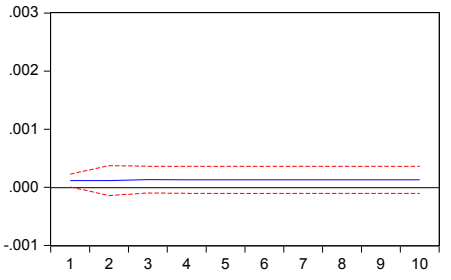
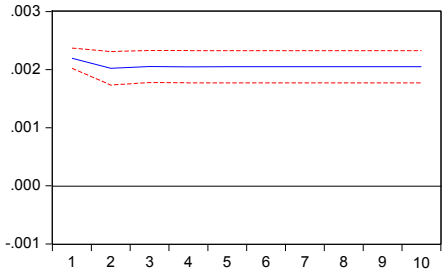
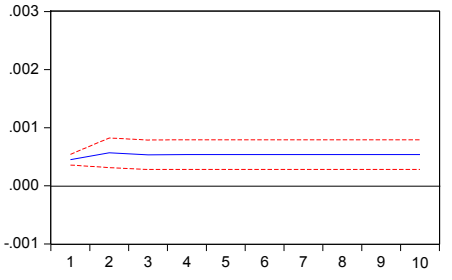
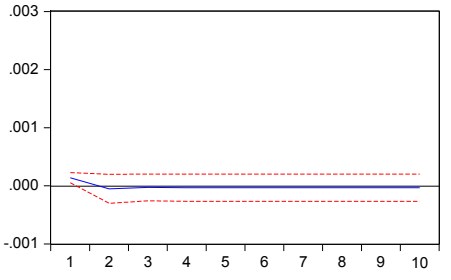
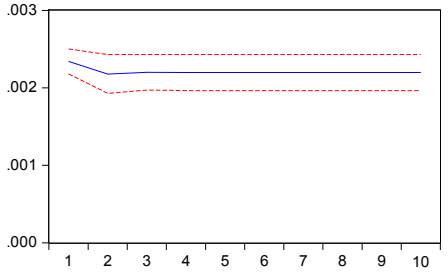
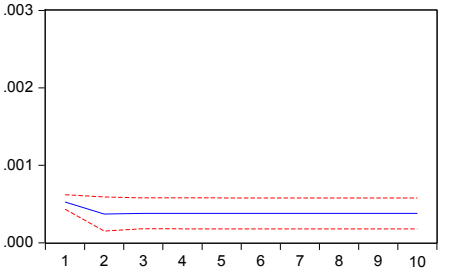
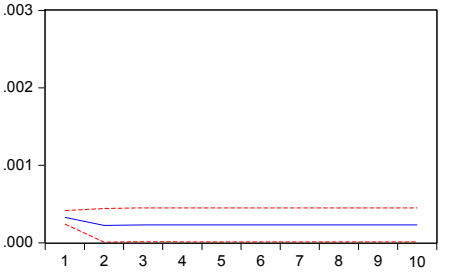
	USD shock	EUR shock	RMB shock
Sub-period A1			
Sub-period A2			
Sub-period A3			

Table 3-11. Accumulated Response of the TWD to USD, EUR and RMB

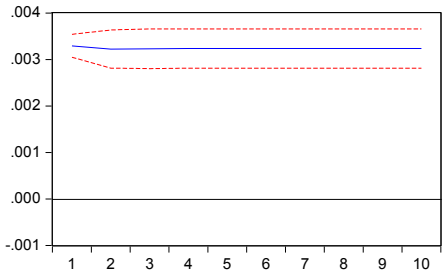
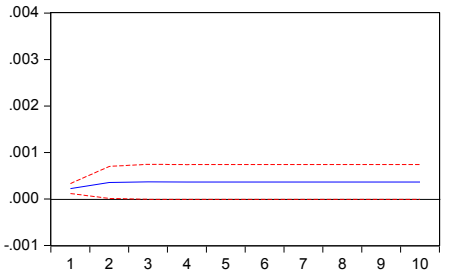
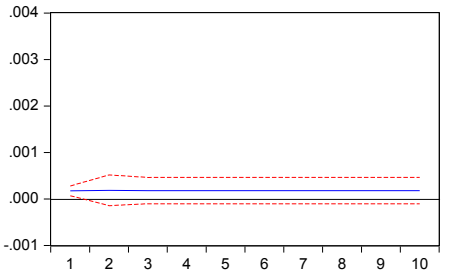
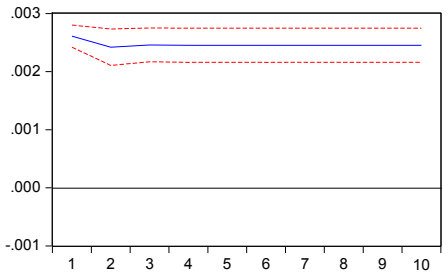
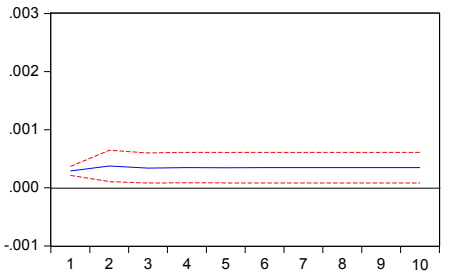
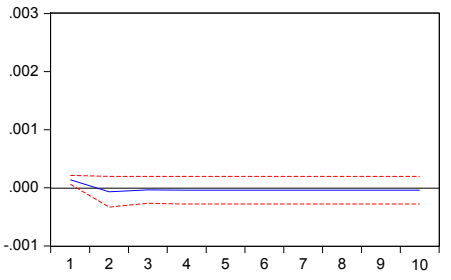
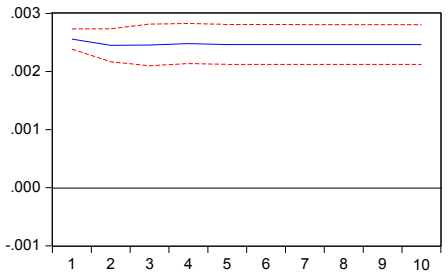
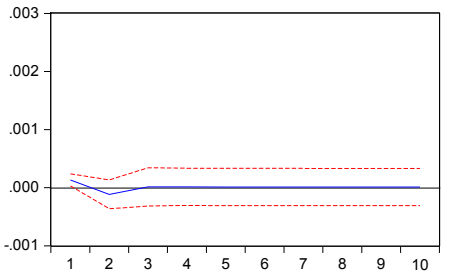
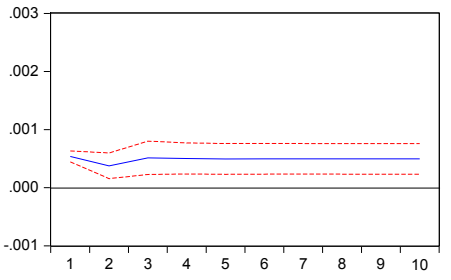
	USD shock	EUR shock	RMB shock
Sub-period A1			
Sub-period A2			
Sub-period A3			

Table 3-12. Accumulated Response of the THB to USD, EUR and RMB

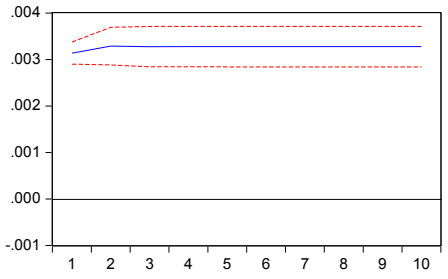
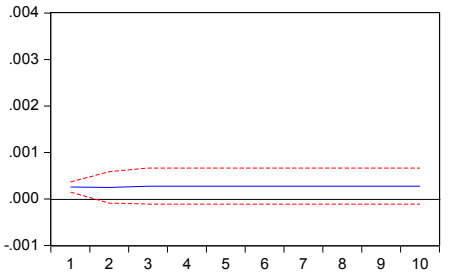
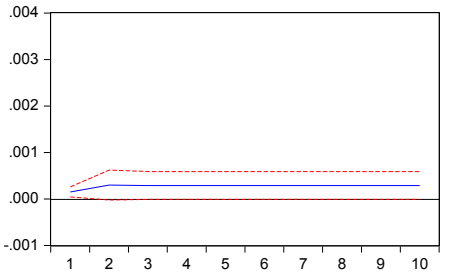
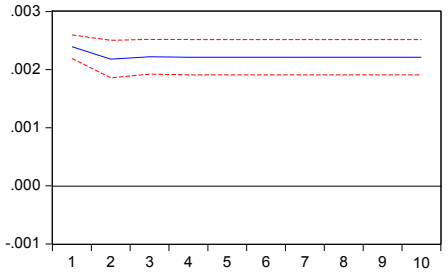
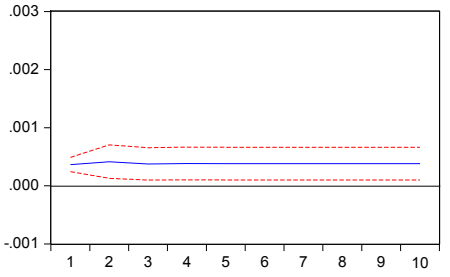
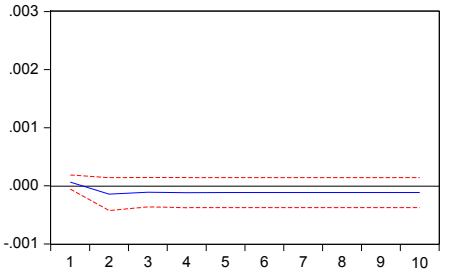
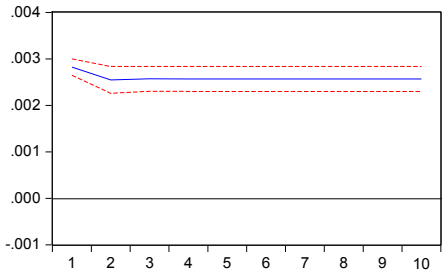
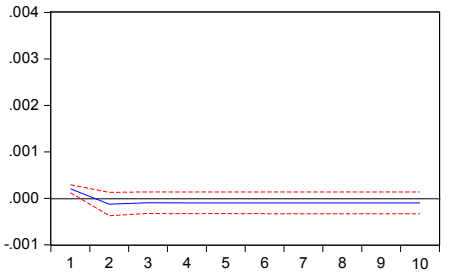
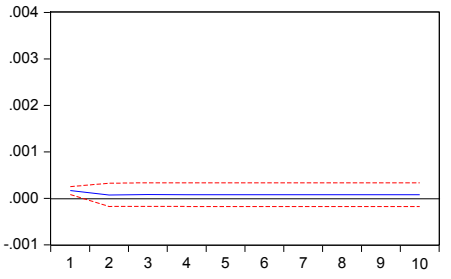
	USD shock	EUR shock	RMB shock
Sub-period A1			
Sub-period A2			
Sub-period A3			

Table 4-1. The RMB internationalization index indicators

General indicators	Main indicators	Subordinate indicators	Introduction
Function of pricing and settlement	trade	Proportion of settlement of RMB in world trade	Amount of cross-border trade in RMB / Amount of cross-border trade in the world
		Proportion of RMB overseas credit in international credit	RMB overseas credit / International overseas credit
		Proportion of RMB security in announced issues of international bonds and notes	Amount of RMB security in announced issues of international bonds and notes / Amount of security in announced issues of international bonds and notes
	finance	Proportion of RMB security in amounts outstanding of international bonds and notes	Amount of RMB security in amounts outstanding of international bonds and notes / Amount of security in amounts outstanding of international bonds and notes
		Proportion of RMB direct investment in international direct investment	RMB direct investment / International direct investment
Function of international reserve	Reserve Government reserve	Proportion of foreign exchange reserves of RMB in world reserve	Foreign exchange reserves of RMB / Foreign exchange reserves

Source: http://news.ruc.edu.cn/wp-content/uploads/2014/07/%E7%AC%AC1%E7%AB%A0%E8%8B%B1%E6%96%87%E7%A8%BF20140705.pdf.

Table 4-2. Summary statistics of daily returns of Currency, USD/I (June 21, 2010-December 31, 2012)

	RMB	MYR	SGD	KRW	TWD	THB
Mean	-0.000143	-7.74E-05	-0.00017	-0.00016	-0.00016	-7.43E-05
Median	-6.35E-05	-0.00015	-0.00032	-0.00034	-0.00031	-0.00023
Maximum	0.006226	0.016629	0.027316	0.031972	0.015364	0.010224
Minimum	-0.005718	-0.019385	-0.02189	-0.02472	-0.0133	-0.011207
Std. Dev	0.001234	0.004117	0.00411	0.005777	0.002825	0.002963
Skewness	-0.075712	0.107947	0.788561	0.601628	-0.09589	-0.00638
Kurtosis	7.429495	4.657785	8.943719	6.983639	6.864115	4.406974
Jarque-Bera	518.9119	73.83093	998.9491	457.4629	395.409	52.29812
Sum	-0.090976	-0.049049	-0.11037	-0.09972	-0.09826	-0.04708
Sum Sq. Dev.	0.000965	0.010727	0.010692	0.021125	0.005052	0.005559
$Q^2(10)$	55.819***	80.145***	242.86***	164.42***	34.078***	37.926***

Notes: $Q^2(10)$ is the Ljung-Box statistic for serial correlation in squared series, respectively. *** denotes statistical significant at 1% level.

Table 4-3. Summary statistics of daily returns of Currency, USD/I (January 3, 2013-December 31, 2014)

	RMB	MYR	SGD	KRW	TWD	THB
Mean	-6.63E-06	0.000287	6.97E-05	0.000161	0.000169	0.000151
Median	-9.35E-05	0.000286	-9.76E-05	8.09E-05	0.000321	0.000212
Maximum	0.005474	0.015084	0.018286	0.014406	0.01276	0.014342
Minimum	-0.004691	-0.02676	-0.015853	-0.01108	-0.00711	-0.01959
Std. Dev	0.000995	0.004097	0.004241	0.00267	0.002039	0.003124
Skewness	0.503143	-0.64583	0.492846	0.222412	0.916431	-0.47046
Kurtosis	7.982798	8.306161	4.584575	6.114384	7.73185	7.537863
Jarque-Bera	537.2752	620.0848	72.40634	205.7805	535.3811	446.5538
Sum	-0.00331	0.143218	0.034792	0.080163	0.084558	0.075268
Sum Sq. Dev.	0.000493	0.008359	0.008959	0.00355	0.00207	0.00486
$Q^2(10)$	91.222***	39.787***	34.416***	27.536***	24.758***	58.875***

Notes: $Q^2(10)$ is the Ljung-Box statistic for serial correlation in squared series, respectively. *** denotes statistical significant at 1% level.

Table 4-4. Summary statistics of daily returns of Currency, USD/I (January 5, 2014-December 30, 2016)

	RMB	MYR	SGD	KRW	TWD	THB
Mean	0.000226	0.000508	0.000196	0.000176	4.99E-05	0.000171
Median	0.000134	0.000228	0.000232	7.36E-05	0.000321	0.00032
Maximum	0.018327	0.028139	0.023907	0.017643	0.016756	0.014605
Minimum	-0.00846	-0.03591	-0.0292	-0.02357	-0.01617	-0.01159
Std. Dev	0.001917	0.006568	0.006735	0.004306	0.004192	0.003025
Skewness	2.134028	-0.35364	-0.11822	-0.45592	-0.1898	0.354792
Kurtosis	22.16167	5.822727	4.480969	5.8767	4.969698	4.97105
Jarque-Bera	8044.934	176.7703	46.95144	190.1053	83.99691	91.61092
Sum	0.113372	0.254444	0.098081	0.08839	0.024978	0.085832
Sum Sq. Dev.	0.001838	0.02157	0.022677	0.00927	0.008788	0.004576
$Q^2(10)$	27.793**	43.645***	42.86***	34.061***	34.078***	37.926***

Notes: $Q^2(10)$ is the Ljung-Box statistic for serial correlation in squared series, respectively. *** denotes statistical significant at 1% level.

Table 4-5. Summary statistics of daily returns of Currency, NZD/I (June 21, 2010-December 30, 2016)

	USD	MYR	SGD	KRW	TWD	THB
Mean	2.17E-05	1.67E-05	0.000219	3.59E-05	2.05E-05	7.70E-05
Median	0.000117	0.00012	0.000283	0.000273	1.97E-06	5.50E-05
Maximum	0.035449	0.031297	0.043552	0.021774	0.031374	0.026882
Minimum	-0.04382	-0.03249	-0.03663	-0.02635	-0.02913	-0.03694
Std. Dev	0.007732	0.006973	0.007782	0.005885	0.006846	0.006889
Skewness	-0.15389	0.017382	0.070722	-0.22989	0.00481	-0.11245
Kurtosis	4.816161	4.378364	4.493373	4.225779	4.057231	4.336551
Jarque-Bera	210.5216	231.5839	129.7498	153.5741	116.9756	76.29193
Sum	0.050574	0.03556	0.027356	0.358127	0.058761	0.033628
Sum Sq. Dev.	0.094121	0.09787	0.079589	0.099136	0.056692	0.076732
$Q^2(10)$	51.045***	42.554***	52.179***	66.046***	33.229***	55.24***

Notes: $Q^2(10)$ is the Ljung-Box statistic for serial correlation in squared series, respectively. *** denotes statistical significant at 1% level.

Table 4-6. The spillover effects between the RMB and East Asian currencies

		KRW	MYR	SGD	TWD	THB
06/21/2010-12/31/2012	a_{12}	-0.0074 (-0.4920)	-0.0112 (-0.6303)	-0.0171 (-1.0049)	-0.0615*** (-2.8839)	-0.0200 (-1.0570)
	a_{21}	0.0230 (0.2016)	-0.1154 (-0.7279)	-0.0208 (-0.0965)	0.0060 (0.0435)	-0.0355 (-0.3123)
	b_{12}	0.0069 (0.0273)	0.0204 (1.4340)	0.0043 (0.4370)	0.0535*** (3.8328)	0.1390 (1.3540)
	b_{21}	0.0002 (0.1176)	0.0876 (0.4105)	0.1529 (0.9795)	-0.2314 (-1.2323)	0.0134 (0.9683)
01/03/2013-12/31/2014	a_{12}	0.0001 (0.0048)	-0.0223** (-2.3938)	-0.0522*** (-4.5198)	-0.0401*** (-2.7622)	-0.0074 (-0.4920)
	a_{21}	0.1117 (0.4632)	0.1290 (0.6998)	0.3080*** (3.1236)	0.1266 (0.4449)	0.0230 (0.2016)
	b_{12}	-0.0171 (-1.1478)	0.0081 (1.0851)	0.0127 (1.5295)	-0.0026 (-0.1587)	0.0002 (0.0273)
	b_{21}	-0.0712 (-0.5677)	-0.0222 (-0.2333)	-0.1242 (-1.2091)	-0.0528 (-1.1838)	0.0069 (0.1176)
01/05/2015-12/30/2016	a_{12}	-0.0281** (-1.9383)	0.2785*** (2.8540)	-0.0814*** (-4.6473)	0.0819** (2.1362)	-0.0271 (-0.7324)
	a_{21}	-0.0185 (-0.0847)	0.0110 (0.7933)	-0.2015 (-0.8041)	-0.0980 (-0.4672)	-0.0269 (-0.2531)
	b_{12}	0.0314*** (2.7642)	-0.4391** (-2.5390)	0.0543 (1.1247)	0.0566*** (2.7561)	-0.0929 (-1.1180)
	b_{21}	0.0013 (0.9428)	0.0028 (0.4371)	0.0370 (0.1193)	-0.1249 (-0.5682)	-0.1517 (-0.7940)

Notes: a_{12} and b_{12} are the parameters in equation (4-10), which represent the exchange rate return shock and volatility spillover effects from Renminbi to East Asian currencies. a_{21} and b_{21} represent the opposite directions.

Table 4-7. The spillover effects between the US dollar and East Asian currencies

	MYR	SGD	KRW	TWD	THB
a_{12}	-0.10225*** (-3.00065)	-0.16823*** (-3.50925)	-0.04441 (-1.47100)	-0.22121*** (-3.79423)	-0.07966 (-1.48290)
a_{21}	-0.03574 (-1.08186)	0.03112 (1.02479)	0.00782 (0.27040)	0.06874 (1.41604)	-0.07555 (-1.52460)
b_{12}	0.02865*** (3.14346)	0.04827*** (3.26620)	0.00811 (0.64490)	0.06377*** (2.84431)	0.06908*** (3.12820)
b_{21}	0.01122 (1.16614)	-0.00834 (-0.96817)	-0.00180 (-0.20510)	-0.00652 (-0.36901)	0.02863 (1.41880)

Notes: a_{12} and b_{12} are the parameters in equation (4-10), which represent the exchange rate return shock and volatility spillover effects from US dollar to East Asian currencies. a_{21} and b_{21} represent the opposite directions.

Table 5-1. Summary statistics of daily returns of Currency I/NZD (2010.6.21-2016.9.30)

	USD	RMB	EUR	JPY	MYR	SGD	KRW	TWD	THB
Minimum	-0.034835	-0.033769	-0.027503	-0.042297	-0.042630	-0.021540	-0.030817	-0.030892	-0.026527
Mean	-0.000021	-0.000062	-0.000082	-0.000090	-0.000174	-0.000011	0.000367	-0.000041	-0.0000632
Maximum	0.044809	0.043775	0.049657	0.059627	0.031610	0.028460	0.034020	0.030220	0.033421
Std. Dev.	0.007775	0.007645	0.007111	0.008817	0.007820	0.005954	0.007050	0.006905	0.006938
Jarque-Bera	220.8523	208.8065	520.4798	893.7515	107.6183	164.7541	161.7871	67.2377	84.97649
$Q^2(10)$	40.229 [0.000]***	39.253 [0.000]***	75.351 [0.000]***	84.078 [0.000]***	64.669 [0.000]***	26.749 [0.000]***	47.795 [0.000]***	50.760 [0.000]***	39.643 [0.000]***
$Q^2(30)$	176.27 [0.000]***	175.96 [0.000]***	135.54 [0.000]***	131.05 [0.000]***	211.14 [0.000]***	101.59 [0.000]***	86.841 [0.000]***	208.63 [0.000]***	141.48 [0.000]***

Notes: Q2 () are the LB-Q Statistics on squared series. [] denote p-values. *** indicates the significance level at the 1%.

Table 5-2. Summary statistics of daily returns of Currency I/USD (2010.6.21-2016.9.30)

	RMB	MYR	SGD	KRW	TWD	THB
Minimum	-0.003690	-0.015883	-0.010357	-0.012868	-0.007081	-0.008592
Mean	-0.0000065	0.0000661	-0.0000044	-0.0000251	-0.0000074	0.0000183
Maximum	0.007887	0.012052	0.011704	0.013668	0.007217	0.006184
Std. Dev.	0.000605	0.002188	0.001651	0.002470	0.001351	0.001317
Jarque-Bera	8575.07	1231.472	1630.365	611.7995	1280.457	426.5666
$Q^2(10)$	63.976 [0.000]***	234.61 [0.000]***	211.46 [0.000]***	136.26 [0.000]***	123.57 [0.000]***	71.902 [0.000]***
$Q^2(30)$	67.667 [0.000]***	379.22 [0.000]***	258.07 [0.000]***	186.11 [0.000]***	211.48 [0.000]***	101.96 [0.000]***

Notes: Q2 () are the LB-Q Statistics on squared series. [] denote p-values. *** indicates the significance level at the 1%.

Table 5-3. The mean values of the dynamic conditional correlations and means comparison (Numeraire currency: NZD)

MYR			
	0.0241[0.0000]***		0.9693 [0.0000]***
Average value of DCC	**Sub-period C1**	**Sub-period C2**	**comparison of mean tests(A)**
$\overline{\mathrm{DCC}}_{\mathrm{MYR-USD}}$	0.8206	0.7666	(25.9968)***
$\overline{\mathrm{DCC}}_{\mathrm{MYR-RMB}}$	0.8317	0.7828	(24.7101)***
$\overline{\mathrm{DCC}}_{\mathrm{MYR-EUR}}$	0.5804	0.5352	(13.8919)***
$\overline{\mathrm{DCC}}_{\mathrm{MYR-JPY}}$	0.5742	0.5257	(11.2807)***
comparison of mean tests (B)	(-136.5372)***	(119.5809) ***	
comparison of mean tests (C)	(6.5607) ***	(6.6955) ***	
SGD			
	0.0268[0.0000]***		0.9635[0.0000]***
Average value of DCC	**Sub-period C1**	**Sub-period C2**	**comparison of mean tests(A)**
$\overline{\mathrm{DCC}}_{\mathrm{SGD-USD}}$	0.8944	0.8852	(10.7974)***
$\overline{\mathrm{DCC}}_{\mathrm{SGD-RMB}}$	0.8946	0.8857	(10.6049)***
$\overline{\mathrm{DCC}}_{\mathrm{SGD-EUR}}$	0.7169	0.7283	(-4.9437)***
$\overline{\mathrm{DCC}}_{\mathrm{SGD-JPY}}$	0.6992	0.7052	(-2.2551)**
comparison of mean tests (B)	(161.0609) ***	(129.4917) ***	
comparison of mean tests (C)	(0.2589)	(0.5878)	
KRW			
	0.0260[0.0000]***		0.9650 [0.0000]***
Average value of DCC	**Sub-period C1**	**Sub-period C2**	**comparison of mean tests(A)**
$\overline{\mathrm{DCC}}_{\mathrm{KRW-USD}}$	0.7467	0.6957	(16.9557)***
$\overline{\mathrm{DCC}}_{\mathrm{KRW-RMB}}$	0.7549	0.7097	(16.5104)***
$\overline{\mathrm{DCC}}_{\mathrm{KRW-EUR}}$	0.5551	0.5565	(-0.4061)
$\overline{\mathrm{DCC}}_{\mathrm{KRW-JPY}}$	0.5115	0.5196	(-1.8557)*
comparison of mean tests (B)	(132.7473) ***	(-125.5242) ***	
comparison of mean tests (C)	(-3.3046) ***	(4.1894) ***	
TWD			
	0.0297[0.0000]***		0.9608 [0.0000]***
Average value of DCC	**Sub-period C1**	**Sub-period C2**	**comparison of mean tests(A)**
$\overline{\mathrm{DCC}}_{\mathrm{TWD-USD}}$	0.9332	0.9129	(17.1274)***
$\overline{\mathrm{DCC}}_{\mathrm{TWD-RMB}}$	0.9331	0.9144	(16.7364)***
$\overline{\mathrm{DCC}}_{\mathrm{TWD-EUR}}$	0.6654	0.6662	(-0.2555)
$\overline{\mathrm{DCC}}_{\mathrm{TWD-JPY}}$	0.6814	0.6555	(7.5036)***
comparison of mean tests (B)	(87.8460)***	(59.0473)***	
comparison of mean tests (C)	(-0.1378)	(1.0410)	
THB			
	0.0291[0.0000]***		0.9607 [0.0000]***
Average value of DCC	**Sub-period C1**	**Sub-period C2**	**comparison of mean**

			tests(A)
$\overline{\mathrm{DCC}}_{\mathrm{THB-USD}}$	0.9121	0.9193	(-5.2761)***
$\overline{\mathrm{DCC}}_{\mathrm{THB-RMB}}$	0.9083	0.9090	(-5.0736)***
$\overline{\mathrm{DCC}}_{\mathrm{THB-EUR}}$	0.6680	0.6773	(-3.9398)***
$\overline{\mathrm{DCC}}_{\mathrm{THB-JPY}}$	0.6869	0.6853	(0.4156)
comparison of mean tests (B)	(80.9914)***	(58.9191)***	
comparison of mean tests (C)	(-2.7947) ***	(-6.9854) ***	
RMB			
$\overline{\mathrm{DCC}}_{\mathrm{USD-RMB}}$	0.9888	0.9805	(23.4734) ***
a	0.0192[0.0000]***	**b**	0.9664[0.0000]***

Notes: , , a and b are the parameters in equations (5-4) and (5-11), respectively. The table presents the t-test results for the null hypothesis: (A) the average DCC is the same before and after January 14, 2014; (B) the average DCC is the same for $\mathrm{DCC}_{\mathrm{USD-RMB}}$ and $\mathrm{DCC}_{\mathrm{EACs-USD}}$ during the same period; (C) the average DCC is the same for $\mathrm{DCC}_{\mathrm{EACs-RMB}}$ and $\mathrm{DCC}_{\mathrm{EACs-USD}}$ during the same period. [] and () denote p-values and t-values, respectively; ***, **, * represent significance at 1%, 5%, and 10% respectively. We also test the null hypothesis that $\overline{\mathrm{DCC}}_{\mathrm{EACs-USD}}$ equals to $\overline{\mathrm{DCC}}_{\mathrm{EACs-EUR}}$ and $\overline{\mathrm{DCC}}_{\mathrm{EACs-JPY}}$ by t-test. All the p-value(s) are 0 suggesting that $\overline{\mathrm{DCC}}_{\mathrm{EACs-USD}} \neq \overline{\mathrm{DCC}}_{\mathrm{EACs-EUR}}$; $\overline{\mathrm{DCC}}_{\mathrm{EACs-USD}} \neq \overline{\mathrm{DCC}}_{\mathrm{EACs-JPY}}$.

Table 5-4. The mean values of the dynamic conditional correlations and means comparison (Numeraire currency: USD)

MYR			
	0.0617 [0.0099] ***		0.9229 [0.0000]***
Average value of DCC	**Sub-period C1**	**Sub-period C2**	**comparison of mean tests(A)**
$\overline{\mathrm{DCC}}_{\mathrm{MYR-RMB}}$*	0.2926	0.2902	(0.6395)
SGD			
	0.0539 [0.0000]***		0.9433 [0.0000]***
Average value of DCC	**Sub-period C1**	**Sub-period C2**	**comparison of mean tests(A)**
$\overline{\mathrm{DCC}}_{\mathrm{SGD-RMB}}$*	0.2109	0.2501	(-8.8253)***
KRW			
	0.0487 [0.0000]***		0.9467 [0.0000]***
Average value of DCC	**Sub-period C1**	**Sub-period C2**	**comparison of mean tests(A)**
$\overline{\mathrm{DCC}}_{\mathrm{KRW-RMB}}$*	0.2255	0.2556	(-7.0323)***
TWD			
	0.0541 [0.0000]***		0.9394 [0.0000]***
Average value of DCC	**Sub-period C1**	**Sub-period C2**	**comparison of mean tests(A)**
$\overline{\mathrm{DCC}}_{\mathrm{TWD-RMB}}$*	0.2271	0.2888	(-13.7345)***
THB			
	0.0820 [0.0000]***		0.8676 [0.0000]***
Average value of DCC	**Sub-period C1**	**Sub-period C2**	**comparison of mean tests(A)**
$\overline{\mathrm{DCC}}_{\mathrm{THB-RMB}}$*	0.1600	0.1652	(-1.2400)
a	0.0143 [0.0000]***	**b**	0.9755 [0.0000]***

Notes: , , a and b are in equations (5-4) and (5-11), respectively. The table presents the t-test results for the null hypothesis: the average DCC is the same before and after January 14, 2014. [] and () denote p-values and t-values, respectively; ***, **, * represent significance at 1%, 5%, and 10% respectively.

Table 5-5. The trade situation between China and some countries (region)

	2010	2011	2012	2013	2014	2015	2016
Export							
Germany	4.31%	4.02%	3.38%	3.05%	3.10%	3.03%	3.10%
Japan	7.67%	7.81%	7.40%	6.80%	6.38%	5.96%	6.11%
USA	17.99%	17.12%	17.20%	16.71%	16.95%	18.00%	18.32%
Korea	4.36%	4.37%	4.28%	4.13%	4.28%	4.45%	4.47%
Malaysia	1.51%	1.47%	1.78%	2.08%	1.98%	1.94%	1.82%
Singapore	2.05%	1.87%	1.99%	2.07%	2.09%	2.33%	2.16%
Taiwan	2.28%	2.30%	2.00%	1.93%	2.05%	1.94%	2.08%
Thailand	1.25%	1.35%	1.52%	1.48%	1.46%	1.68%	1.78%
Import							
Germany	5.32%	5.32%	5.06%	4.83%	5.36%	5.21%	5.42%
Japan	12.66%	11.16%	9.78%	8.32%	8.32%	8.51%	9.18%
USA	7.36%	7.06%	7.36%	7.87%	8.16%	8.95%	8.50%
Korea	9.91%	9.33%	9.28%	9.39%	9.71%	10.38%	10.02%
Malaysia	3.61%	3.56%	3.21%	3.08%	2.84%	3.17%	3.09%
Singapore	1.77%	1.61%	1.57%	1.54%	1.57%	1.64%	1.63%
Taiwan	5.51%	4.82%	4.44%	4.19%	4.19%	4.23%	4.65%
Thailand	2.38%	2.24%	2.12%	1.98%	1.96%	2.21%	2.44%

Data source: UNComtrade Database; National Statistics, R.O.C. (Taiwan).