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This study investigates the relationship between the real exchange rate (RER) and economic growth in China applying a cointegrated VAR (CVAR) model. However, in contrast to the assumptions of trade partners, this paper finds that the Chinese economy has not benefited from the lower exchange rate of the RMB, and no direct linkages exist between the RER and growth in the long run. Interestingly, it appears that the Chinese economy is stimulated by the expansion of exports and inflow of foreign capital according to the empirical evidence, which also suggests that the long run equilibrium RER is jointly determined by the foreign trade, foreign reserves and the foreign direct investment. In addition, the 2005 RMB policy reform did not show any significant impact on the RER, but instead contributed to the steady economic growth. It is clear that, after the 2008 world crisis, the RMB exchange rates were largely dependent on the enhancing of the national strength and inflow of foreign capital, rather than the slow increase in foreign trade. As for policy implications, China may insist on the managed floating exchange rate policy making limited adjustments to the currency's daily floating range in response to the pressures from trade partners.

JEL Codes: F3, O24, F43, C32

Keywords: real exchange rate (RER), economic growth, CVAR, China

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1 Introduction

With an average annual growth rate of 9.1% from 1989 to 2014,[1] the rise of China and its currency system have received much attention from policy makers and researchers all around the world (Tyers *et al.*, 2008; Soleymani and Chua, 2013). It is believed that the lower RMB exchange rates have promoted the growth in China but have harmed the trade partners' economies. Actually, the Renminbi (RMB) has been appreciated by almost 38% since 1994, but it still cannot meet trade partners' expectations. The International community has been criticizing the slow speed of RMB appreciation (Morrison and Labonte, 2010). The US authorities are even increasingly pushing China to change its currency policy since the RMB was overvalued against the US dollar (USD) by 40% according to the US congressional bill in 2007 (Woo, 2008). It seems that RMB exchange rate has played a vital part in boosting the Chinese economy, therefore, trade partners are increasingly pressing Chinese authorities to appreciate currency and make RMB more flexible and tradable in the foreign exchange market (Zhang, 2013; McKinnon and Schnabl, 2014). Taking the above into consideration, the main aims of this paper are to explore the dynamic linkages between the RMB real exchange rate and economic growth both in the long run and short run, to investigate the structural changes in the currency policy reform which took place in 2005, and to look at the effects on the RMB exchange rate after the 2008 global financial crisis.

Previous studies have found the relationship between the real exchange rate (RER) fluctuation and economic growth (Tarawalie, 2010; De Vita and Kyaw, 2011; Benhima, 2012).[2] They suggest that undervalued currency helps to increase GDP but overvalued currency has negative impacts on growth. As trade partners believe that it is the undervalued currency stimulating China's growth, thus they ramp up pressures on RMB appreciation. Chinese authorities have to respond to those pressures by making appropriate adjustments to the currency policy although RMB sufferers continuously appreciation. This study is about to uncover the myth of whether the RMB exchange rate system stimulates the Chinese economy, and investigate the nexus between the RER and economic growth. Before the discussion, the general backgrounds of the Chinese economy and its currency policy will be represented.

The Chinese currency experienced two big shifts in the past two decades. Chinese authorities unified the currency system in 1994. After that, the single pegged currency policy was abandoned and the managed floating exchange rate regime was implemented in 2005. The index of nominal exchange rate (NER) of USD/RMB is shown in Figure 1. To maintain a stable currency, China owns a large amount of foreign reserves. It had an exponential growth since 2005 and reached a peak of $3,311 billion by the end of 2012. Figure 1 also demonstrates the growth rates for GDP and CPI. The annual growth rate averaged around 9%, but there was a sharp drop in 1989 due to the political turmoil. It became relatively stable since the start of market economy in 1992. Comparatively, the CPI curve shows more uncertainties. The sharp increase and decline around 1994 were due to the price mechanism reform. In contrast, foreign trade has been seeing a surprisingly growth in China. Trade volume increased dramatically since China jointed WTO in 2001, but there was a significant

[1] Source: National Bureau of Statistics of China.

[2] The general definition of RER is adjusting the NER with foreign (P_t^*) and domestic (P_t) price levels, $RER_t = NER_t \frac{P_t^*}{P_t}$

recession during the 2008 world financial crisis. Since 2009, China has been the largest exporter and second largest importer in the world. Lower part of Figure 1 gives the foreign direct investment (FDI) in China.[3] The foreign capital inflows were not much before 1990. The accumulated FDI from 1978 to 1984 was $4.1 billion. When China exercised the market-oriented economy and deepened the opening door policy in 1992, foreign capitals started flowing into China due to the nice investment environment and peaceful political process.

From trade partners' perspective, the rise of China is bound up with the managed floating exchange rate regime. So they are overflowing with questions that are aiming to uncover the secret of China's growth. This also stimulates the author's interest in exploring the mystery. Based on the existing research evidence and the real situation in China, this paper tries to answer the following questions: (1) Whether there is a long run equilibrium relationship between the RER and economic growth in China? (2) In the past decades, what has contributed to the stability of the Chinese currency and the continuous growth? (3)Were there structural changes in the currency policy reform after July 2005? (4)Whether the correlation between the RER and economic growth was constant after the great recession?

This study differs from previous studies in the following aspects: (1) the cointegrated vector autoregression (CVAR) and its vector error correction model (VECM) are applied to investigate the long run equilibrium and short run dynamics between the RER and growth, respectively; (2) the structural break for 2005 is examined both inside and outside of the VECM; (3) the great recession test has been conducted separately and (4) the determinants of RER have included the GDP, foreign reserves, foreign trade and foreign investment, which are the growth indicators as well.

The remaining sections are constructed as follows. Literature review is given in Section 2. Data and econometric methods are discussed in section 3. Section 4 has the details on the long run and short run relationships between the RER and economic growth, and last section concludes.

2 Literature Review

Foreign trade nowadays is much more complicated and influencing than the barter in ancient times. It is associated with the economic prosperity and currency stability. Unstable currency usually has significant impacts on foreign trade and local economy. Thus an increasing number of researchers shift their interests into the field of foreign exchange rate. The extant literature pays attention to the impact of exchange rate regimes on growth, and linkages between exchange rate and growth. The studies on the Chinese economy and its currency issues are also growing in the past two decades.

2.1 Impact of Exchange Rate Regime on Economic Growth

Previous studies on the impact of exchange rate regimes on economic growth try to find whether different exchange rate regimes have different impacts on economic growth. The extant literature suggests that the

[3] In Figure 1, the data of FDI in 1984 was the accumulated data from 1978 to 1984.

flexible exchange rate policy has positive impacts on growth (Sokolov *et al.*, 2011), while the fixed exchange rate regime has negative impacts on growth (Levy-Yeyati and Sturzenegger, 2003). Intermediate exchange rate regime is positively correlated with growth in emerging economies (Ma and McCauley, 2011), but it suffers from flexibility. Comparatively, floating exchange rate regimes do not show any significant impact on the advanced economies. Harms and Kretschmann (2009) find that various classifications of exchange rate regimes produce fairly similar results for industrial countries. These economies usually have a higher growth rate under the flexible exchange rate policy. While in developing countries and emerging markets, the announcement of a peg to the US currency and *de facto* stability in exchange rate normally have positive effects on growth. If a currency is pegged to USD only, it may hinder its economic development. As the higher the degree of dollarization, the more likely a negative effect on growth (Benhima, 2012). However, Vita and Kyaw (2011) argue that the choice of exchange rate regime does not have direct effects on the long term growth in developing countries.

2.2 The Linkages between the RER and Economic Growth

With regard to the linkages between the RER and growth, the existing studies have found a positive relationship between RER undervaluation and economic growth, but this nexus should be much stronger in developing countries (Rodrik, 2008). The fluctuation of the RER around its equilibrium level can cause negative or positive impacts on growth. To explore the equilibrium exchange rate, researchers use different terms to express the RER changes, such as exchange rate misalignment, exchange rate uncertainty and exchange rate disequilibrium. Exchange rate misalignment is defined as the deviation of the RER from its equilibrium value. The extant studies suggest that highly fluctuated exchange rate has negative impacts on economic growth (Tharakan, 1999; Vieira *et al.*, 2013), and moderately volatile exchange rate has positive impacts on growth (Tarawalie, 2010; Vieira *et al.*, 2013). In reality, the currencies in emerging economies usually undervalued or overvalued. Exchange rate undervaluation means that the currency is lower than it should be or seriously depreciated. Exchange rate overvaluation is that the exchange rate of one currency is higher than it ought to be. Exchange rate undervaluation (depreciation) has positive impacts on economic growth (Rodrik, 2008; Abida, 2011), but overvalued exchange rate reduces growth (A.Elbadawi and Kaltani, 2011). However, Glüzmann *et al.* (2012) hold different views on the effects of exchange rate undervaluation on the different components of GDP. Their results show that undervalued currencies in developing countries do not affect the export sectors, but promote greater domestic saving, investment and employment.

2.3 The RMB Exchange Rates Studies

The announcement of a switch to the managed floating exchange rate policy in China in 2005 has inspired the interests of many scholars and policy makers. Although it was said that the RMB exchange rate would be set with reference to a basket of currencies with different weights, the *de facto* policy remained pegged to the USD (Shah *et al.*, 2005; Frankel and Wei, 2007; Zeileis *et al.*, 2010). The structural effects of RMB policy change in 2005 are of interest to researchers, but it is still a controversial issue. Some studies have found the existence of structural effects (Willenbockel, 2006; Jianhuai *et al.*, 2008; Zeileis *et al.*, 2010; Houjun and Xiquan, 2011), while some studies claim the nonexistence of structural breaks (Shah *et al.*, 2005; Zhiwen, 2011). It is clear that the currency policy changes have contributed to the Chinese economy. While Ba and Shen (2010) represent that China's growth is driven by the export of labour intensive products in the short run. This may lead the China overtake the US as the largest economy in the world before 2015 (Maddison, 2009). However, this kind of growth depends on factor accumulation rather than productivity growth to some extent (Feng and Wu, 2008). Although the international community has been criticising the Chinese currency system, the managed floating exchange rate policy has played important role in the regional economy, since it opens an evolutionary path towards regional currency stability and monetary cooperation in East Asia (Ma and McCauley, 2011).

In terms of the RMB equilibrium exchange rate, Tyers *et al.* (2008) suggest that the continuous inflow of financial capital appreciates the Chinese currency in the short run, while the labour forces might appreciate RMB in the long run. However, Wang *et al.* (2007) find that the RMB exchange rates fluctuate around the equilibrium level within a narrow band. It means that the RMB is not consistently undervalued. You and Sarantis (2012) represent that the determinants of RMB equilibrium exchange rate consist of trade, population, liquidity constraints and government investment.

In general, the extant studies on the relationship between exchange rate and growth mainly focus on the impacts of exchange rate regime on growth and the volatility of exchange rate on growth. Previous RMB exchange rate studies have discussed the exchange rate pass through effect, in particular in the period of the RMB policy changes. However, the long run equilibrium and short run dynamics between the RER and economic growth in China have not been investigated. The effects from foreign exchange reserves and foreign direct investment were ignored in these studies, since they were interested in the domestic exchange rate pass through effects. The structural changes in the currency policy reform in 2005 are still a controversial issue. The evidence after the great recession has not been explored as well. These are the questions to be discussed in this paper.

3 Data and Econometric Methods

3.1 Data Collection and Transformation

The data were collected from several Chinese official websites,[4] ranging from January 1994 to December 2012. The selected variables consist of nominal exchange rate(NER) of USD against RMB, nominal GDP (NGDP),

[4] Data source: The People's Bank of China (PBC), National Bureau of Statistics of China, State Administration of Foreign Exchange, General Administration of Customs o the People's Republic of China and Invest in China.

US and China CPI (The US CPI was collected from IMF), foreign exchange reserves (FER), exports, imports and foreign direct investment (FDI).

Real exchange rate (RER) is defined as the adjustment of NER for foreign and domestic price levels (see footnote 2). Since the NGDP in China is announced each quarter, so the quarterly GDP will be directly applied to each month with seasonal effects adjusted. The real GDP (RGDP) is calculated by NGDP adjusting for inflation. That is RGDP= (NGDP/CPI) ×100. To revisit the existence of structural changes after 2005, the dummy variable (*D*) is set as 1 when the date was later than July 2005. Otherwise, D=0.

3.2 Econometric Methods for this study

3.2.1 Theoretical Model and Hypothesis

This study strives to directly explore the long run equilibrium and short run dynamics between the RER and growth, rather than the investigation of the linkages between exchange rate volatility and growth. The dynamic RER equation can be introduced and transformed from the equilibrium exchange rate equation (Edwards, 1988, 2011) and the exchange rate fundamentals equation (Rodrik, 2008; Glüzmann *et al.*, 2012). The theoretical model and expected signs of the coefficients are giving in equation (1).

$$lnRER_t = \beta_0 + \underset{(+)}{\beta_1 lnRGDP_t} + \underset{(+)}{\beta_2 lnFER_t} + \underset{(-)}{\beta_3 lnIMP_t} + \underset{(+)}{\beta_4 lnEXP_t} + \underset{(+)}{\beta_5 lnFDI_t} + \underset{(+)}{\beta_6 D} + \varepsilon_t \qquad (1)$$

This equation gives the theoretical model between the RER and its determinants for this study. This study assumes that the increase of RGDP, FER, exports and FDI will depreciate RMB, and the increase of imports appreciates RMB. The structural change dummy (*D*) is assumed to be positively correlated with the RER. All series are expressed in logs, except the dummy variable.

3.2.2 Methods for Stationery Test

To get robust stationery test results, both the univariate and multivariate unit root tests will be applied in this study. The Augmented Dickey Fuller (ADF) unit root test is testing the null hypothesis that a series has a unit root (Dickey and Fuller, 1979; Dickey and Pantula, 1987). The assumption for a *p*-th order *AR* process of series y_t with deterministic components is defined as follows:

$$\Delta y_t = \psi^* y_{t-1} + \sum_{i=1}^{p-1} \psi_i^* \Delta y_{t-i} + \mu + \gamma t + u_t \quad u_t \sim IID(0, \sigma^2) \qquad (2)$$

Where $\psi^* = \psi_1 + \psi_2 + \cdots + \psi_p - 1$. If ψ^* equals zero against the alternative hypothesis that ψ^* is less than zero, then y_t is said to be non-stationary. KPSS test differs from the ADF test in the null (stationary) (Kwiatkowski *et al.*, 1992). The test decomposed a series into deterministic trend (ξ_t), a random walk (γ_t) and an error term (ε_t):

$$y_t = \xi_t + \gamma_t + \varepsilon_t \quad and \quad \gamma_t = \gamma_{t-1} + u_t \qquad (3)$$

Where $u_t \sim IID(0, \sigma_u^2)$. The null hypothesis is $\sigma_u^2 = 0$. Ng-perron test is said to have more power and less size distortion when the data generating process (DGP) has negative moving average terms (Ng and Perron, 2001). In the DGP:

$$y_t = d_t + u_t, \qquad u_t = \rho u_{t-1} + v_t \tag{4}$$

The *M*-tests are famous for the Ng-perron approach. The lag length is determined by the modified Akaike Information Criterion (M-AIC). ADF, KPSS and Ng-perron tests are univariate unit root tests. They are said to notoriously own lower power and suffer from size distortion in the DGP (Taylor and Sarno, 1998; Crowder, 2001) . Therefore, the multivariate unit root test approach has been proposed by Taylor and Sarno (1998) based on the Johansen's VECM estimator (Johansen and Juselius, 1990). This approach has better power and more informative alternative hypothesis than the univariate unit root tests.

3.2.3 Cointegrated VAR (CVAR) Model

Following the studies of Aguirre and Calderón (2005)[5] and Wang *et al.* (2007), this paper applies the Johansen cointegration approach to analyse the relationship between the RER and economic growth in China. The Johansen cointegration approach is also known as cointegrated VAR (CVAR) approach. It requires that all the endogenous variables in the system have the same integration of order one (Johansen and Juselius, 1990; Johansen and Juselius, 1992). The vector correction representation form of the CVAR is expressed as follows:

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \cdots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi X_{t-k} + \mu + \delta_t + \varepsilon_t \tag{5}$$

Where X_t is a $n \times 1$ matrix of variables (n=6) and Γ_i is the $n \times n$ matrix of parameters. CVAR test for cointegration is testing the reduced rank π. It is estimated by the maximum likelihood estimation. The trace test and maximum eigenvalue test (known as λ_{max} test) are notable for testing cointegration relationship. The multivariate unit root test based on the CVAR approach is to test the stationarity of the cointegration system as a whole by imposing different restrictions on the deterministic components.

This study applies a forward recursive test to identify the cointegration vector (Juselius, 2006). The log likelihood of the recursive test statistic is given by:

$$Q_T(t_t) = \frac{t_1}{T}\sqrt{\frac{T}{2P}}\left[\frac{1}{t_1}\sum_{i=1}^{t_1} l_i(\hat{\theta}_i)\right] - \frac{1}{T}\sum_{i=1}^{T} l_i(\hat{\theta}_T) = \frac{t_1}{T}\sqrt{\frac{T}{2P}}\left(\log|\hat{\Omega}_{t_1}| - \log|\hat{\Omega}_T|\right) \tag{6}$$

In the equation, $l_i(\theta) = -2logf_\theta(x_i|x_{i-1}, \dots, x_{i-k}) = \log|\Omega| + \varepsilon_i'\Omega^{-1}\varepsilon_i$. If the test rejects the null of constancy, all of the subsequent tests may cease to have a meaning.

Once the cointegrating vector has been identified, it is possible to rewrite equation (5) into the VECM form to explore the short run dynamics (assume k=2):

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \alpha \hat{\beta}_1' + \Psi D_t + \varepsilon_t \tag{7}$$

[5] Aguirre and Calderón (2005) apply the panel cointegration technique to analyse the real exchange rate misalignment.

Where $D_t$usually includes the short run effects from exogenous variables, such as the policy intervention. In this context, the dummy variable is used to observe the structural changes in 2005.

4 Empirical Results

4.1 Unit Root Tests

The seasonal adjustment has been applied to separate the drift and circulation components before the empirical analysis. Table 1 reports the summary statistics and correlations. Table 2 and Table 3 report the univariate unit root test results. These series are integrated *I(1)* when a constant is included only. FDI is stationary at its level in the ADF test, but the Ng-perron test gives an unspecific conclusion. When only the constant restriction is imposed, the differenced series of the RER and FER can reject the null at the 10% and 5% levels respectively (see Table 3). The *M*-statistics for other series cannot reject the null simultaneously, although it has the properties of greater power and less size distortion. Possible reasons may be the linear DGP of the Ng-Perron approach, which may cause biased test results (Kapetanios *et al.*, 2003).

4.2 CVAR Test for Cointegration Vectors

Since the Ng-Perron test indicates the ambiguity of the unit roots, so this section will further examine the stationarity in the multivariate unit root test. Table 4 reports the Johansen test for stationarity. 2 lags have been selected initially,[6] and then subsequently increase one lag until lag 8. None of these statistics reject the null at the 5% level. It means that the cointegration system is not stationary. The differenced data also support the stationary of the cointegration system (not reported).

The next step is the test for cointegration. Lag length selection for the CVAR approach really matters the number and stationarity of cointegration vectors. The objective and effective method for determining the lag length is referring to the information criteria. Another method for the lag length selection is to choose the shortest lags which produce serially uncorrelated residuals. This study selects the lag length with the combination of the two methods. The default deterministic assumption of intercept without trend is selected, which allows for trends in the levels and non-zero means in the differencing series. The residuals of the CVAR test are well-behaved when 2 lags are included.

As the original tabulated critical values for the CVAR test do not take into account of the standard dummy in the deterministic part, if the standard 0-1 dummy variables are included, it will affect both the mean and trend of the level series X_t. Therefore, this test does not include the dummy variable in the CVAR test.

The trace test for cointegration rank is reported in Table 5. It indicates that there are 2 cointegration vectors in the system. Table 6 reports the maximum eigenvalue test results. It suggests the existence of one cointegration relationship, although the statistics partially show the rejection of 2 cointegration vectors.

[6] According to the Ljung-Box Q-statistics, a lag truncation choice of $k = 2$ is sufficient to remove all statistically significant residual autocorrelation from the VAR residuals.

4.3 Identifying the Cointegration Vectors

Trace test indicates the existence of 2 cointegration vectors but the maximum eigenvalue test indicates that there is only one cointegration vector. So how can we identify the cointegration vectors? Juselius (2006) suggests the usage of the combination of standard analysis and other available information. Generally, five kinds of methods can be used in identifying the cointegration vectors: (1) examine the characteristic roots; (2) check the significance of adjustment coefficients; (3) recursive graph of the trace estimates; (4) the graph of cointegration relations and (5) the economic interpretation of the cointegration vectors.

4.3.1 Checking the Stationary of the Cointegration Vectors

This study firstly applies the group unit root test to examine the stationary of these cointegration vectors, but the results are quite unclear (not reported). To further examine the stationary of cointegration vectors, two kinds of cointegration graphs are plotted in Figure 2. Intuitively, the second cointegration vector seems to be stationary. Both cointegration graphs fluctuate around the mid-2005. Figure 3 gives another version of these cointegration relations. x_t captures the short run dynamics. $\hat{R}_{kt}$ equals x_t but with all the short run effects removed. $\hat{R}_{kt} = x_{t-k} - (\hat{T}_1 \Delta x_{t-1} + \cdots + \hat{T}_{k-1} \Delta x_{t-k+1})$. The $\hat{R}_{kt}$ form graph is more stable than the X-form over the sample period, since the short run effects have been excluded and the degree of freedom for the X-form graph is less than the R-form plots. The plots of $\hat{\beta}_1' x_t$ and $\hat{\beta}_1' \hat{R}_{kt}$ are not quite different, therefore, it is not necessary to check the *I(2)* of the data set. [7]

4.3.2 Forward Recursive Test

Recursive tests are constituted by the eigenvalues, transformation of eigenvalues, log-transformed eigenvalues and the fluctuation tests (Juselius, 2006). Both the *X*-form and *R*-form model of the recursively calculated trace tests are plotted in Figure 4.[8] The test is scaled by 95% quantile of the asymptotic distribution. The upper and lower parts of the figure are the recursive estimation of the *X*-form and *R*-form, respectively. Both indicate the instability of the short run coefficients in the sample estimation period. To accept *r=2*, we have to wait unit the mid-2005 since it is unstable during the period 1997 to 2005. Figure 5 represents the recursively calculated eigenvalues based on the unrestricted VAR and the 95% confidence bands. Two eigenvalues are within the bands for all periods, except the baseline sample periods. λ_1 and λ_2 are quite large at the beginning of the recursion, then decline until the stable value appears around 2005. Figure 6 gives the log transformed eigenvalues. It allows a symmetrical confidence bands for the small eigenvalues. The first eigenvalue shows a considerable degree of constancy in Figure 7. The second eigenvalue is reasonably constant within the sample period except the *X*-form in the first several years. The final test is the combination of the two cointegration vectors, which shows the non-constancy around 2002 in the *X*-form. Figure 8 illustrates the max test of beta constancy, which is an important indicator of identifying β structure. The test is under the reject line of 1.0 for the baseline sample (1997:01-2012:12), except the *R*-form has a short rejection band around 1999. This test is

[7] When the plots of $\hat{\beta}_1' x_t$ and $\hat{\beta}_1' \hat{R}_{kt}$ are quite different, Johansen and Juselius (1994) suggest to check whether the data vector is *I(2)* or not.

[8] The forward recursive tests are based on the baseline sample: 1994:01-1997:01.

very conservative and there is strong evidence for non-constancy if the test is rejected. Test of β_t equals known beta is to check whether the null hypothesis of constancy is actually acceptable. The parameters are still constant if the statistics are within the reference period. Figure 9 demonstrates that both the *X*-form and *R*-form models are rejected for a certain period. It means that the cointegration vectors indicated by trace test are only somewhat constant, such as the *R*-form model since early 1999.

4.3.3 Interpretation of the Cointegration Vectors

The recursive test and group unit roots test are really indicative since some tests support the stationary of the cointegration vectors while others show that these eigenvalues are problematic. The economic interpretation and significance of the coefficients are important indicators for identifying cointegration vectors as well. The two normalized cointegration vectors are expressed in equation (8) and equation (9).

$$\underset{}{\mathrm{lnRER}} = -4.066 - \underset{(-4.993)}{2.811\mathrm{lnFER}} - \underset{(-4.04)}{4.298\mathrm{lnImp}} + \underset{(4.698)}{6.549\mathrm{lnExp}} + \underset{(6.225)}{3.673\mathrm{lnFDI}} + \varepsilon_1 \quad (8)$$

$$\mathrm{lnRGDP} = -17.697 - \underset{(-4.551)}{7.022\mathrm{lnFER}} - \underset{(3.838)}{11.175\mathrm{lnImp}} + \underset{(4.671)}{17.837\mathrm{lnExp}} + \underset{(6.359)}{10.295\mathrm{lnFDI}} + \varepsilon_2 \quad (9)$$

There is no direct connection between the RER and RGDP in the long run. In the RER equation, exports have positive impacts on the RER and imports have negative impacts on the RER. With other things being equal, 1% upturn of the exports lead the increase (depreciate) of the RER by 6.549%. The impact of exports is larger than those of imports in magnitude. It is due to the continuous trade surplus in China. FDI also has a positive impact on the Chinese currency. The RGDP equation demonstrates that China is currently indeed an export driven growth. FDI also plays an important role in boosting China's economy. Additional restrictions have been imposed to identify the cointegration vectors, but the results fail to reject the null. That implies that the RER and RGDP should not be included in each other's long run equilibrium relationship.

4.3.4 Identifying the Cointegration Vector from the Max-eigenvalue Test

The maximum eigenvalue test indicates the existence of one cointegration vector at the 5% level. The stationary of the cointegration vector is accepted (not reported). Figure 10 represents the cointegration relationship. The plots of the *X*-form and *R*-form models are not quite different. When two restrictions are imposed to test the weakly exogeneity of the RGDP and FER, the Chi-square equals 0.21, which accepts the null hypothesis that the RGDP and FER are weakly exogenous. However, we still have to further check the economic meaning of the cointegration vector.

$$\mathrm{lnRER} = 3.814 + \underset{(1.601)}{0.445\mathrm{lnRGDP}} + \underset{(1.089)}{0.316\mathrm{lnFER}} + \underset{(2.156)}{0.679\mathrm{lnImp}} - \underset{(3.219)}{1.394\mathrm{lnExp}} - \underset{(5.56)}{0.912\mathrm{lnFDI}} + \varepsilon \quad (10)$$

Equation (10) represents the long run relationship between the RER and the economic indicators. RGDP, FER and imports have positive impacts on the RER, which help to depreciate the Chinese currency. However, the coefficients of RGDP and FER are not significant at the 5% level. This cointegration relation goes against equation (8) in the sign and magnitude. The economic meaning of the cointegration vector does not comply with the reality and also some coefficients are not statistically significant. It further proves that the RGDP and FER are weakly exogenous. The two cointegration vectors from the trace test are more likely to be accepted.

4.4 Identifying the Short Run Structure

To further observe the structural changes of the RMB policy reform in 2005, the dummy variable (D_t) is included in the VECM. The information criteria suggest that 2 lags are the optimal lag length. The VECM estimation of the RER and RGDP equation is represented in Table 7. The coefficients for the error correction terms (ecm_1 and ecm_2) are negative and statistically significant. The first error correction term is -0.019, which indicates that the system corrects its previous disequilibrium by 1.9% within one month. Similarly, the disequilibrium in the RGDP equation will be adjusted by 0.7% each month. The Wald tests for some short run coefficients are not significant. It means that they are weakly exogenous and can be excluded from the model. Additional diagnostic tests are also reported in the table. The normal residuals can be reached when 11 lags are included, but the model suffers severe autocorrelation and heteroscedasticity. So a parsimonious error correction model is estimated by giving way to the homoscedasticity and non-autocorrelation of the residuals, rather than simply pursue the normality. Cumulative sum of residuals (CUSUM) test and cumulative sum of squares test (CUSUM of square test) are plotted in Figure 11.The upper and lower panels represent the recursive graph of $\Delta lnRER$ equation and $\Delta lnRGDP$equation, respectively. Both the CUSUM and CUSUM of squares test demonstrate the stability of the RER equation and RGDP equation.

The coefficient for the dummy (D_t) in the RER equation is small and negative, but it is not statistically significant. The Wald test accepts the null that the coefficient of D_t equals zero. It means that the exchange rate regime reform in 2005 did not affect the stability of Chinese currency. However, the coefficient of dummy variable is significant in the RGDP equation and the Wald test shows the non-rejection of the null. It implies that the currency policy reform in 2005 played an important part in stimulating the Chinese economy.

To further investigate the structural breaks of the RMB policy reform in the RER equation, Chow breakpoint test and Quandt-Andrews unknown breakpoint tests have been applied. Re-estimating the test by excluding the dummy, Table 8 represents the structural break tests. Both tests conclude that there are no structural changes after July 2005. Although the RMB exchange rate policy reform in 2005 was known for its historical meanings, this study would like to say that it does not have direct impact on the Chinese currency. The RMB policy reform only has positive impacts on the growth in the short run.

4.5 Impulse Response Analysis

Figure 12 shows the impulse response of the RER determinants. RER responds to its own shock in a negative pattern. Basically, an increase in the RER leads to the increase of RGDP, except the decline in the second stage. The increase of RER leads to a steady increase in FER across all periods. When RMB appreciates, the authorities can release the FER to ease the speed of currency appreciation. The upturn of RER leads to a slight decrease in imports and a small increase in exports. It means that the RER fluctuation does not show any significant impacts on the foreign trade. Finally, an increase of the RER leads to a decline of FDI inflows in the short run, but this effect becomes weaker in the long run.

4.6 Testing for Great Recession

This section re-estimates the RER equation over the period of January 2008 to December 2012, to examine the effects of the great recession on the Chinese economy. The diagnostic test implies that one lag is enough to remove autocorrelation and heteroscedasticity in the residuals. Table 9 represents that both the trace test and maximum eigenvalue test indicate that only one cointegration vector exists in the system. The diagnostic test does not show any sign of model instability. The cointegration vector does not exhibit any serious weakly exogeneity as well. The cointegration relationship in Figure 13 behaves much better than the cointegration relations from the whole sample period test. Both the *X*-form and *R*-form graphs of the cointegration relations mimic a white noise process. Although there was a recession in the mid-2008, it returns to the equilibrium very soon. The cointegration relationship is quite stable since 2010.

The cointegration vector is normalized in equation (11). RGDP and FDI have negative impacts on the RER, while others have positive impacts on the RER. The results indicate that RGDP appreciates RMB but exports depreciate RMB.[9] The *t* statistics for the coefficients of imports and exports are not statistically significant at the 10% level, which suggests the existence of possible weak exogeneity.

$$lnRER = -1.539 - 0.705lnRGDP + 0.989lnFER + 0.261lnImp + 0.252lnExp - 1.196lnFDI + \varepsilon \quad (1)$$

(-3.798) (4.258) (1.282) (1.319) (-8.325)

Additional restrictions have been imposed to check the weak exogeneity of the imports and exports. The Chi-square for the joint restriction test is 0.074, which suggests that both the coefficients of exports and imports are equal to zero. While the two restrictions are examined separately, the Chi-square is 0.356 (restriction on imports) and 0.441 (restriction on exports), respectively. It further proves that they are weakly exogenous and should be excluded from the equation.

5 Conclusions

This study has investigated the long run equilibrium and short run dynamics between the RER and economic growth in China applying a CVAR approach. The cointegration test results suggest that China's growth has not benefited from the depreciation of RMB, since the Chinese economy is stimulated from the expansion of exports and inflow of foreign capital according to the empirical evidence. In the long run, both exports and FDI have positive impacts on the RER and RGDP. FER and imports have negative impacts on the RER and RGDP. These determinants jointly maintain a stable Chinese currency. However, no direct connections can be found between the RER and RGDP in the long run. This is opposite to the assumption from trade partners that the lower RMB exchange rates help to boost the growth of Chinese economy. In the short run, the RMB policy reform in 2005 did not show any significant impact on the RER, but it contributed to the growth. Both the

[9] In equation (11), the significance of the coefficient of exports can be accepted at 10% level for the one tailed test.

VECM analysis and breakpoint tests indicate that there are no structural changes after July 2005. It is consistent with previous studies (Shah *et al.*, 2005; Zhiwen, 2011).

In addition, the great recession test represents that the RER has not been significantly affected by the foreign trade after 2008. Before the recession, the Chinese currency is jointly determined by the FER, foreign trade and FDI. After that, the RMB gradually becomes stable and flexible, which is mainly affected by the national strength, FER and inflow of foreign capital.

To conclude, several policy implications can be drawn from these empirical findings. In response to the continuous pressures from trade partners, the Chinese authorities may insist on the managed floating exchange rate system making appropriate adjustments to the daily floating range of the RMB exchange rates. Apart from this, in the global financial market, the large amount of FER also can be flexibly applied to protect the Chinese currency from instability. In addition, with the disappearance of the advantages in exporting labour intensive products due to the shift of global division (Ba and Shen, 2010), China should upgrade the existing export structure and focus on the development of capital and technical intensive products in the long run. This way not only contributes to growth, but also maintains the stability of the Chinese currency. It appears that the advantages of foreign trade in China are gradually diminishing according to the great recession test. Recent evidence also shows that China exports to the US and Europe slow down. To keep the growth momentum and the currency stability, it does not mean that China has to shift its exports to domestic consumption, but instead China can rebalance its economy by exporting to the BRICS countries, emerging economics and other developing economies, especially exporting the infrastructures they need. Finally, China should notice that there are plenty of pollutions during the economic development process, thus the domestic investment can also be an effective way for rebalancing the Chinese economy.

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Table 1: Summary statistics and correlations

	lnRER	LnRGDP	lnFER	lnExp	lnImp	lnFDI
Mean	2.150	6.072	6.033	3.686	3.547	3.891
Median	2.183	5.940	5.862	3.572	3.533	3.858
Std.Dev.	0.239	0.983	1.390	0.962	0.955	0.419
Skewness	0.148	0.027	0.025	0.083	0.089	0.224
Kurtosis	2.355	2.094	1.765	1.517	1.542	2.106
Jarque-Bera	4.781	7.825	14.501	21.138	20.504	9.506
Probability	0.092	0.020	0.000	0.000	0.000	0.009
Obs.	228	228	228	228	228	228
lnRER	1.000					
lnRGDP	-0.989	1.000				
lnFER	-0.976	0.992	1.000			
lnExp	-0.942	0.972	0.989	1.000		
lnImp	-0.934	0.967	0.981	0.995	1.000	
lnFDI	-0.873	0.893	0.894	0.886	0.888	1.000

Table 2: Unit root test (ADF and KPSS test)

Variable	Level		1st Difference	
	ADF	KPSS	ADF	KPSS
Include a constant only				
lnRER	-2.169(0)	1.874(11)***	-14.276(0)***	0.304(5)
lnRGDP	-1.681(0)	1.945(11)***	-14.580(0)***	0.324(7)
lnFER	-1.529(3)	1.990(11)***	-4.374(2)***	0.392(10)
lnExp	-0.615(2)	1.996(11)***	-15.268(1)***	0.101(7)
lnImp	-0.418(1)	1.990(11)***	-26.297(0)***	0.050(7)
lnFDI	-1.715(2)	1.835(11)***	-12.814(2)***	0.014 (1)
Include both the constant and trend				
lnRER	-1.564(0)	0.143(11)*	-14.500(0)***	0.122(4)*
lnRGDP	-2.301(0)	0.170(11)**	-14.700(0)***	0.272(7)***
lnFER	-1.894(3)	0.176(11)**	-4.559(2)***	0.191(10)
lnExp	-1.623(2)	0.216(11)**	-15.235(1)***	0.072(7)
lnImp	-2.662(1)	0.208(11)**	-26.236(0)***	0.048(7)
lnFDI	-6.255(1)***	0.282(11)***	-12.783(2)***	0.010 (1)

Critical value	Constant only			Constant and trend		
	1%	5%	10%	1%	5%	10%
ADF	-3.459	-2.874	-2.573	-3.999	-3.429	-3.138
KPSS	0.739	0.463	0.347	0.216	0.146	0.119

Notes:

1. ***, ** and * indicate the rejection of the null hypothesis at the 1%, 5% and 10% level.
2. The number in the parenthesis denotes the lag length. Schwarz information criteria (SIC) and Newey-West Bandwidth selection criteria are applied for the ADF test and for KPSS test, respectively.

Table 3: Unit root test (Ng-Perron test)

Variable	Level				1st Difference			
	MZ_α^{GLS}	MZ_t^{GLS}	MZ_t^{GLS}	MZ_t^{GLS}	MZ_α^{GLS}	MZ_t^{GLS}	MZ_t^{GLS}	MZ_t^{GLS}
Include a constant only								
lnRER	0.817(8)	0.949(8)	1.161(8)***	88.344(8)***	-6.321(7)*	-1.750(7)*	0.277(7)***	3.971(7)***
lnRGDP	1.288(8)	1.526(8)	1.185(8)***	101.005(8)***	-1.982(7)	-0.962(7)	0.485(7) ***	12.005(7)***
lnFER	1.242(9)	2.546 (9)**	2.049(9)***	285.413(9)***	-9.985(8)**	-2.165(8)**	0.216(8)***	2.764(8)***
lnExp	1.373(6)	3.011(6)***	2.194(6)***	334.943(6)***	-0.179(5)	-0.204(5)	1.136 (5)***	66.952(5) ***
lnImp	1.388(1)	2.576(1) **	1.856(1)***	241.461(1)***	-15.884(0)*	-2.781(0)*	0.175(0)***	1.683(0)
lnFDI	0.573(12)	0.464(12)	0.811(12)***	44.419(12)***	-94.0(0)***	-6.857(0)***	0.073(0)	0.261(0)
Include both the constant and trend								
lnRER	-2.001(0)	-0.804(0)	0.402(0)***	34.505(0)***	-2.168(13)	-1.013(13)	0.467(13)***	40.55(13)***
lnRGDP	-3.322(6)	-1.284(6)	0.386(6)***	27.332(6)***	-3.632(7)	-1.327(7)	0.365(7)***	24.769(7)***
lnFER	-4.454(3)	-1.336(3)	0.299(3)***	19.260(3)***	-1.529(8)	-0.841(8)	0.550(8)***	56.209(8)***
lnExp	-4.089(2)	1.370(2)	0.335(2)***	21.642(2)***	-0.611(5)	-0.397(5)	0.650 (5)***	84.003(5)***
lnImp	-8.840(2)	-2.079(2)	0.235(2)***	10.397(2)***	0.431(9)	-0.398(9)	0.922(9)***	158.84(5)***
lnFDI	-2.75(13)	-1.170(13)	0.425(13)***	32.995(13)***	-93.39(0)***	-6.833(0)***	0.073(0)	0.978(0)
Critical Value (constant only)		1%	5%	10%	Critical Value (constant and trend)	1%	5%	10%
MZ_α^{GLS}		-13.8	-8.1	-5.7		-23.8	-17.3	-14.20
MZ_t^{GLS}		-2.58	-1.98	-1.62		-3.4	-2.91	-2.62
MZ_t^{GLS}		0.174	0.233	0.275		0.143	0.168	0.185
MZ_t^{GLS}		1.78	3.17	4.45		4.03	5.48	6.67

Notes:

1. ***, ** and * indicate the rejection of the null hypothesis at the 1%, 5% and 10% level.
2. Each test has been included the restriction of a constant only, and both the constant and trend.
3. The numbers in the parenthesis are the optimal lag length.

Table 4: Multivariate unit root tests (Johansen test)

K	$H_0^*(r)$	$H_1(r)$	$H_{1.1}(r)$	$H_1^*(r)$	$H_2(r)$
2	2.214	0.216	0.005	1.665	1.489
3	2.610	0.118	0.256	1.485	1.454
4	2.587	0.071	0.180	1.934	1.903
5	3.581	0.612	0.348	2.220	2.201
6	3.124	0.164	0.001	2.368	2.018
7	3.680	0.305	0.418	3.827	1.733
8	2.357	0.015	0.525	2.329	1.262
5% critical Value	12.518	3.841	3.841	9.165	4.130

Notes:

1. K is the lag length for the Johansen test.
2. Critical values are from Hansen and Juselius(1995).
3. $H_0^*(r)$ denotes the restriction of liner constant and trend.
4. $H_1(r)$ denotes the restriction of liner constant and quadratic trend.
5. $H_{1.1}(r)$ denotes the restriction of liner constant and no trend.
6. $H_1^*(r)$ denotes the no-restricted constant and no trend.
7. $H_2(r)$ denotes the restriction of no constant and no trend.

Table 5: Trace test for the cointegration rank

Hypothesized No. of CE(s)	Eigenvalue	Trace statistics	0.05 Critical value	P-value
0	0.225	134.221	95.754	0.000*
1	0.130	76.872	69.819	0.012*
2	0.124	45.491	47.856	0.082
3	0.056	15.784	29.797	0.727
4	0.013	2.897	15.495	0.971

Notes:

1. Trace test indicates the existence of 2 cointegrating vectors at the 0.05 level.
2. * denotes the rejection of the hypothesis at the 5% level.
3. **denotes the MacKinnon-Haug-Michelis (1999) p-values.

Table 6: Maximum eigenvalue test for the cointegration rank

Hypothesized No. of CE(s)	Eigenvalue	Trace statistics	0.05 Critical value	P-value
0	0.225	57.349	40.078	0.000*
1	0.130	31.381	33.877	0.097
2	0.124	29.707	27.584	0.026
3	0.056	12.888	21.132	0.463
4	0.013	2.892	14.265	0.954
5	0.000	0.005	3.841	0.945

Notes:

1. Max-eigenvalue test indicates the existence of one cointegrating vector at the 0.05 level.
2. * denotes the rejection of the hypothesis at the 5% level.
3. **denotes the MacKinnon-Haug-Michelis (1999) p-values.

Table 7: A parsimonious VECM ΔlnRER and ΔlnRGDP

Regressor	$\Delta lnRER$ Coefficient (p-value)	$\Delta lnRER$ Wald test (p-value)	$\Delta lnRGDP$ Coefficient (p-value)	$\Delta lnRGDP$ Wald test (p-value)
Intercept	-0.059(0.021)	5.445(0.020)	-0.168(0.000)	18.486(0.000)
$\Delta lnRER(-1)$	0.111 (0.261)	1.270(0.260)	0.051(0.736)	0.114(0.735)
$\Delta lnRER(-2)$	0.126(0.196)	1.680(0.195)	-0.373(0.013)	6.222(0.013)
$\Delta lnRGDP(-1)$	0.102(0.103)	2.685(0.101)	-0.031(0.748)	0.103(0.748)
$\Delta lnRGDP(-2)$	0.071(0.252)	1.319(0.251)	-0.181(0.059)	3.612(0.057)
$\Delta lnFER(-1)$	-0.008(0.868)	0.028(0.868)	-0.132(0.088)	2.931(0.087)
$\Delta lnFER(-2)$	-0.40(0.433)	0.618(0.432)	0.065(0.405)	0.697(0.404)
$\Delta lnExp(-1)$	0.037(0.031)	4.730(0.030)	-0.048(0.068)	3.365(0.067)
$\Delta lnExp(-2)$	0.033(0.031)	4.703(0.030)	-0.021(0.364)	0.827(0.363)
$\Delta lnImp(-1)$	-0.022(0.088)	2.929(0.087)	0.027(0.173)	1.870(0.171)
$\Delta lnImp(-2)$	-0.015(0.187)	1.754(0.185)	0.025(0.142)	2.170(0.141)
$\Delta lnFDI(-1)$	0.009(0.131)	2.303(0.129)	-0.010(0.245)	1.360(0.244)
$\Delta lnFDI(-2)$	0.005(0.249)	1.335(0.248)	-0.008(0.294)	1.109(0.292)
D	-0.002(0.458)	0.417(0.519)	0.008(0.012)	6.379(0.012)
$ecm_1(-1)$	-0.019(0.083)	3.031(0.082)	0.065(0.000)	14.340(0.000)
$ecm_2(-1)$	0.007(0.009)	6.993(0.008)	-0.019(0.012)	23.247(0.000)
R-square	0.114		0.190	
DW-statistic	2.029		2.003	
S.E. of Regression	0.011		0.017	
LM test	$\chi^2_{(2)}$=2.365(0.307)		$\chi^2_{(2)}$=0.662(0.718)	
ARCH effect	$\chi^2_{(2)}$=0.446(0.800)		$\chi^2_{(2)}$=0.412(0.521)	

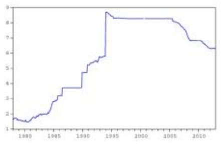
Table 8: Structural breaks test

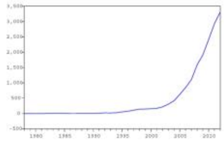
Test	Statistics(P-value)
Chow breakpoint test for the exchange rate regime reform in July 2005	
F-statistic	1.174(0.295)
Log likelihood radio	19.456 (0.194)
Wald statistic	17.612 (0.284)
Quandt-Andrews unknown breakpoint test with 30% trimming (1999:12-2007:05)	
Maximum LR F-statistic (2000:03)	1.335(0.621)
Maximum Wald F-statistic (2000:03)	20.036(0.621)
Exp LR F-statistic	0.540 (0.552)
Exp Wald F-statistic	8.841 (0.434)
Ave LR F-statistic	1.068 (0.361)
Ave Wald F-statistic	16.022(0.361)

Table 9: Test for the great recession

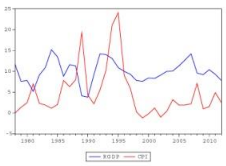
H_0r	n-r	Eigenvalue	$-T\log(1-\hat{\lambda}_r)$	$\lambda_{trace}(0.95)$	$-T\log(1-\hat{\lambda}_{r+1})$	$\lambda_{trace}(0.95)$
0	6	0.627	124.810**	95.754	57.217**	40.078
1	5	0.403	67.593	69.819	29.946	33.877
2	4	0.303	37.647	47.856	20.918	27.584
3	3	0.157	16.729	29.797	9.895	21.132
4	2	0.107	6.834	15.495	6.559	14.265
5	1	0.005	0.275	3.841	0.275	3.841

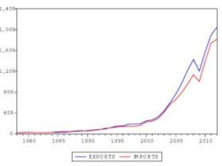
Figure 1： Chinese economic indicators





Nominal exchange rate（USD/RMB） Foreign exchange reserves





GDP and CPI growth rate Exports and imports

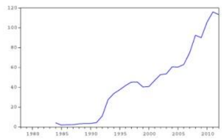


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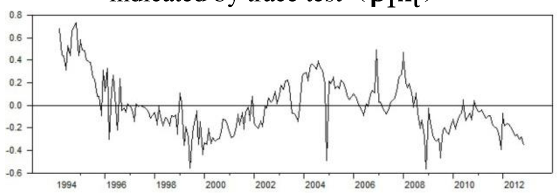
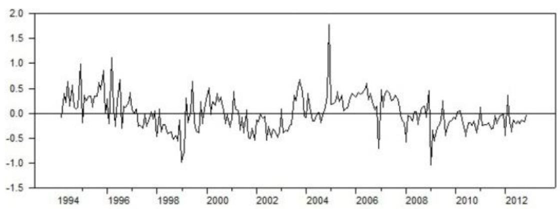
Figure 2： Plots of the cointegration relations indicated by trace test （$\hat{\beta}_1' x_t$）

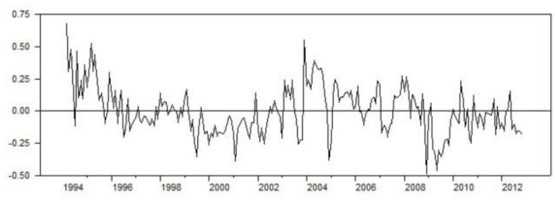


Cointegration relation 1

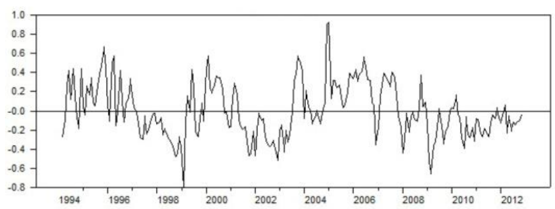


Cointegration relation 2

Figure 3: Plots of the cointegration relations indicated by trace test （$\hat{\beta}_1' \hat{R}_{kt}$）



Cointegration relation 1



Cointegration relation 2

Figure 4: The recursive trace test statistic

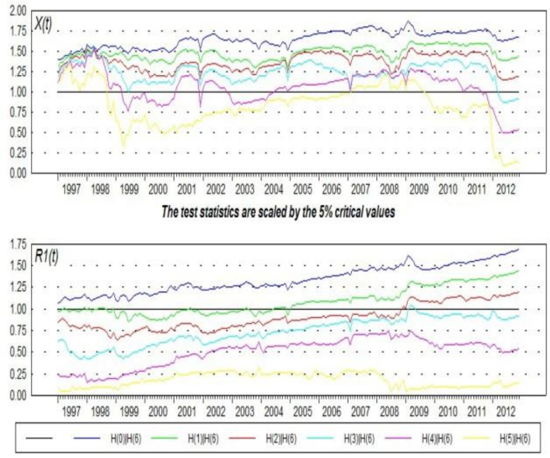


Figure 5: Recursively calculated eigenvalues

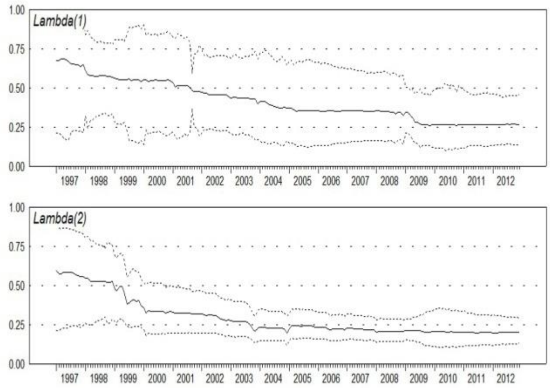


Figure 6: Recursively calculated log transformed eigenvalues

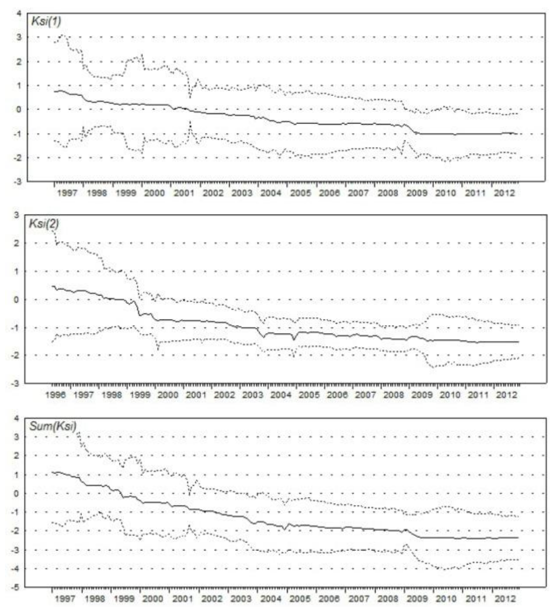


Figure 7: Eigenvalue fluctuation test

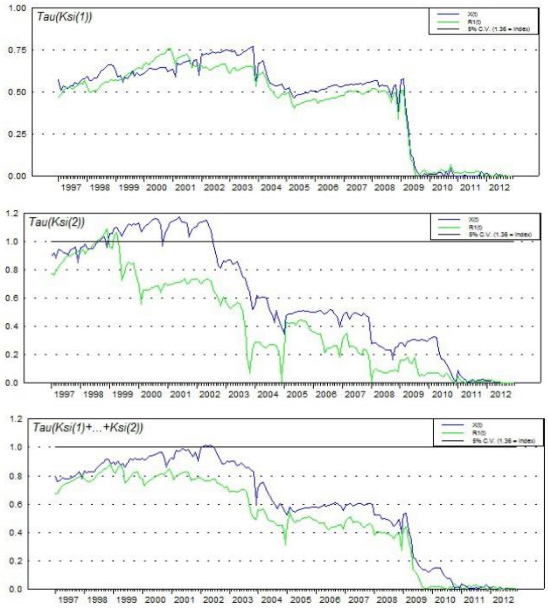


Figure 8: The max test of constancy

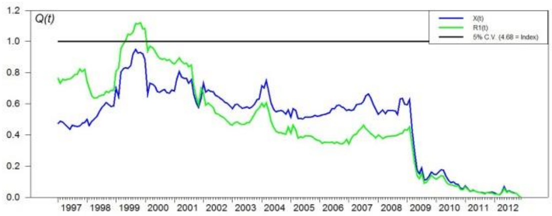


Figure 9: Test of $\boldsymbol{\beta_t}$= "known beta"

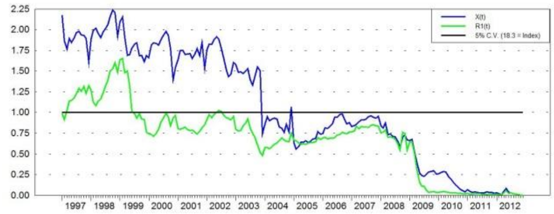


Figure 10: Plots of the cointegration relations indicated by $\boldsymbol{\lambda_{max}}$ test

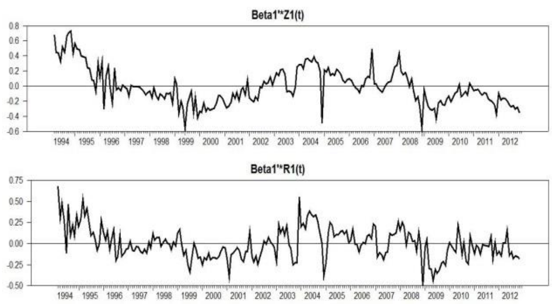
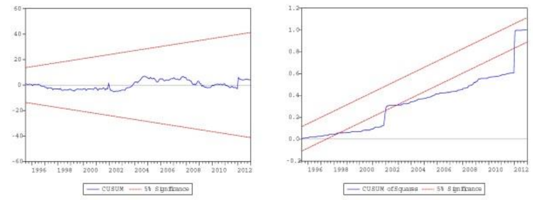
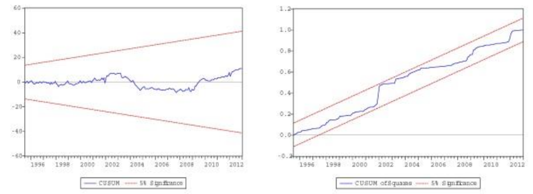


Figure 11: Plots of CUSUM and CUSUM of square test



$\Delta lnRER$ equation



$\Delta lnRGDP$ equation

Figure 12: Response of lnRER to Cholesky one S.D. innovations

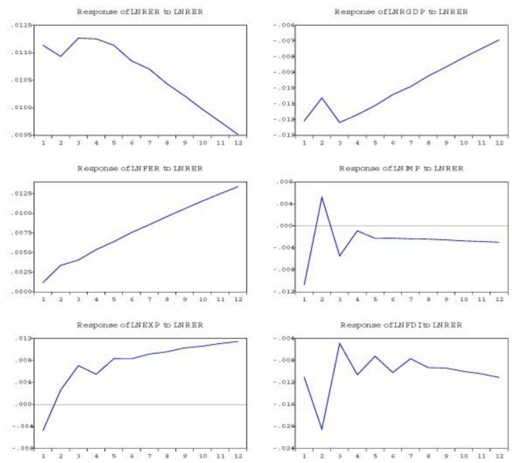


Figure 13: Plots of cointegration relationship after the great recession