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The relationship between exchange rate and macroeconomic variables in China*

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Abstract

The objective of this study is to provide evidences on the relationship between Renminbi (RMB) exchange rate and macroeconomic variables in China, as well as guidelines for reform of RMB exchange rate regime. The long-run equilibrium relationship between RMB exchange rate and macroeconomic variables of China is examined by applying the non-parametric rank tests proposed by Breitung. Furthermore, this study uses the threshold error-correction model (TECM) to detect the nonlinear casual relationship between RMB exchange rate and macroeconomic variables that are nonlinear forms. The results show that RMB exchange rate and macroeconomic variables have nonlinear relationship with each other. In the long run, these results demonstrate solid evidence that RMB exchange rate and macroeconomic variables support the hypothesis of an asymmetrical error-correction process in China. Our results have important policy implications for Chinese government under study.

Key words: *RMB exchange rate, nonlinear rank test, threshold error correction model*

JEL classification: *C22, F41*

1. Introduction

The appreciation of the Renminbi (RMB) has become a world-wide hot issue recently. Since the implementation of the policy of openness from 1978, China has achieved extraordinary economic growth while maintaining reasonable price stability in the last three decades through enormous reforms in various fields. Among these reforms, the exchange rate reform has been one of the most important regulatory changes in

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China. The RMB became fully convertible for current account transactions at the end of 1996 (Xu, 2000; Zhang, 2000, 2001a). Furthermore, China announced to implement the managed floating exchange rate system based on market supply and demand, with reference to a basket of currencies. RMB exchange rate is no longer pegged only to the US dollar, and instead China has formulated a more flexible RMB exchange rate mechanism. Even though China won applause in the battle against Asian financial crisis in 1997, in order to fight against world financial storm, Chinese government adopted an economic expansion plan by issuing 4 trillion RMB in 2008 so as to stimulate domestic economy under the severe circumstances and expect to push the world economy back to its original track. China seems to be obliged to do more. During the world financial storm in 2008, China was inevitably affected. However, due to China's huge amount of foreign exchange deposits and immense potentials to develop, the effect is comparably slight in comparison with its western counterparts. After the financial storm, China gets back to its economic development track soon, while many western countries are still experiencing painful process of restoration. At the same time, the friction in the field of world trade arises. Along with the devaluation of US dollar after the financial storm, the issue of too much manipulation on RMB exchange rate attracts more and more attention. China government gave up the pegged exchange rate system and allows the value of RMB to fluctuate freely, which means appreciation under the circumstances. RMB appreciation will pose a challenge on export-based enterprises in China. In order to adopt the proper exchange rate policy and improve the exchange rate formation mechanism, Chinese government needs to detect the real exchange rate (RER) and its long/short run relationship with other macroeconomic variables.

The major objective of this study is to investigate the impact of relationship among degree of openness, government expenditure, relative productive activity, real money supply and RMB exchange rate in China. It also provides deep view of the factors in determination of the exchange rate with empirical evidence. This study has several motivations to inspect this field of research, the first motivation is related to identifying whether RER and macroeconomic variables have cointegration relationship, for which this study use rank test for nonlinear cointegration situation. Second, this study applies asymmetrical error-correction models to investigate the relationship between RER and macroeconomic variables and try to serve as a guideline for macro policy. Finally, this study explains the causal relation between RMB and its macroeconomic variables. These variables are selected based on whether they influence the equilibrium exchange rate of RMB in accordance with economic theory as well as with China's national conditions. The hypothesis will test the relationship among these fundamental variables and real exchange rate and determinants of the equilibrium RER. The findings of this study yield some important policy implications for the policymakers who seek to make proper exchange rate policy in China.

The remainder of the paper proceeds as follows: Section 2 reviews previous literatures. Section 3 introduces the asymmetric test methodologies. Section 4 presents the data we use in our study and empirical results. Section 5 offers concluding remarks.

2. Literature review

Most research interests have been given to investigating whether the RMB exchange rate is at "equilibrium" level or not in previous studies over the last 20 years. Recent studies have centered on the relationship between the real exchange rate (RER) and China's exports and/or imports (Chou, 2000; Zhang, 1998, 1999, 2001a), the relationship between the RER and China's inflation rate (Phylaktis and Girardin, 2001; Lu and Zhang, 2003) and the RER misalignment of the RMB (Zhang, 2001, 2002). Many definitions of RER have been used in the literature, but in simplest form it is defined as the actual exchange rate adjusted for inflation effects in the two countries concerned (Madura, 2006). To observe whether the RER is at "equilibrium" or not, a benchmark of the equilibrium RER is necessary. Montiel (1999) proposed that relevant real fundamentals determine the equilibrium RER (Jin, 2003). Edwards (1994) found that only real "fundamental" variables influence the equilibrium RER in the long term. In an attempt to bond RER with its fundamental determinants, previous studies have treated the cumulated current account as a determinant of the RER (e.g. Blundell-Wignall and Browne, 1991; Edison and Pauls, 1993).

According to traditional economic theory, the equilibrium exchange rate affects a country's economic competitiveness, thus it is always a major concern for all countries to realize whether the RER is misaligned with respect to its long-run equilibrium level. Misalignment could result in reduced investments, withering business, declining productivity, deterioration of commercial positions and loss of established markets in the long run. Sekkat and Varoudakis (1998) point out that the acute misalignment of RER is a major factor to weaken economic performances of developing countries. In addition, misalignments can be used as an instrument to adjust the exchange rate. The RER misalignments (as well as its volatility) can also influence a country's economic performance (Krueger, 1983; Edwards, 1989; Dollar, 1992; Aguirre and Calderon, 2005). Besides, Zhang (2001b) adopts equilibrium RER approach and cointegration techniques to identify that investment, government consumption, growth rate of exports, and degree of openness of the economy to trade are main explanatory factors for the RMB's long-term equilibrium path from the mid-1950s to the mid-1990s. He finds that the Chinese currency was overvalued for the most of the estimation period (1955-1997) except a few years after the two oil shocks. Therefore, it does not matter whether the RMB is overvalued or undervalued, the misalignment of RER can have a negative impact on China's macroeconomic performance and economic structure. Some studies chose only a single fundamental

as a variable that determines the equilibrium RER. Hence, the scope of such studies is limited and their reliability is questionable. In order to improve upon previous researches, this study chooses four economic fundamental variables as the determinants of RER in our study which is: degree of openness of the economy, ratio of government expenditure to GDP, relative productive activity differential and real money supply. All of these variables are identified in some theoretical models, for example, Faruqee (1994), MacDonald (1997) and Montiel (1999) considers some of these economic fundamentals in their research respectively.

Moreover, most researches address the issue of the equilibrium between RER and macroeconomic variables without taking the asymmetric properties of the adjustment process in the equilibrium relationship between RER and macroeconomic variables into account. Granger and Terasvrita (1993) documented that most of the economic variables have nonlinear characters. For example, economic theory suggests that there are completely non-linear relationships in purchasing power parity (PPP) or the Phillips curve. Taylor and Allen (1992) argued that if the exchange rate deviates from the base to show the equilibrium exchange rate as nonlinearity, we can't grasp the exact movements of exchange rate. Sarantis (1999) thought that RER's nonlinear trend might be caused by outliers, but his results from Chow test rejected the hypothesis. If the relationship among variables is nonlinear, using linear model analysis might create specific error. Nevertheless, asymmetry and nonlinearity have been important properties in recent macroeconomic analyses, with a large number of studies providing evidence on both the asymmetric and nonlinear adjustment of macroeconomic variables (Enders and Dibooglu, 2001; Reitz and Taylor, 2008). As noted by Laxton *et al.* (1993), both bias and mistakes are increasing likely when a linear and symmetrical methodology is adopted to test economic variables which are nonlinear and asymmetric. According to these studies, better interpretations of the exchange rate movements can be found by using the nonlinear model when the relationship between economic variables are identified to be nonlinear. In order to obtain accurate empirical results, here we take the rank test for nonlinear cointegration method by Breitung (2001). This method demonstrates power in both linear and non-linear frameworks, and is also applicable to all kinds of data generating process of the variables under examination. The rank test for nonlinear cointegration method has been increasingly employed to analyze economic and financial data, and is especially useful in the study of time series which are characterized by asymmetric adjustment. It is worth pointing out that conventional cointegration methods are inappropriate, mainly because they assume the null hypothesis and a linear process of the variables (Juvenal and Taylor, 2008). It is clearly demonstrated by Balke and Fomby (1997) that the power of linear cointegration tests is depleted under a process of asymmetric adjustment. Present study differs from those earlier cases by providing nonlinear cointegration evidences on relation between RMB exchange rate and its macroeconomic determinants based on the non-parametric rank tests. In the final test, the result from the test based on corresponding threshold error correction

model (TECM) reveals one-way directional causality running from exchange rate to other variables.

3. M ethodology

3.1. Cointegration and non-linearity rank test

The first model of the equilibrium real exchange rate (ERER) is designed for developing countries by Edwards (1989). On the basis of Edwards' model, Elbadawi (1994) developed a more reasonable reduced-form equation. In general, the model of the ERER has been considered sufficient to depict the characteristics of the transformation process of developing countries and suitable for the measurement of a developing country's equilibrium exchange rate. This study choose the model to estimate the equilibrium exchange rate of RMB in present study. Here we can establish the RMB equilibrium exchange rate model as follows:

$$q^* = \alpha + \beta_1 OPEN + \beta_2 GOV + \beta_3 PROD + \beta_4 M2 + \mu \qquad (1)$$

where q^* represents equilibrium real exchange rate, and μ is the error term. OPEN stands for the degree of openness; GOV indicates government expenditure which captures the effect of fiscal policy; PROD can be viewed as a proxy for technological progress and M2 denotes money supply. α is constant, and $\beta_1, \beta_2, \beta_3$ and β_4 are the coefficients of OPEN, GOV, PROD and M2, respectively.

Theoretically, an estimated reduced-form equation is used to predict the behavior of the RER associated with economic fundamentals. Edwards (1994) found that only real "fundamental" variables influence the ERER in the long run. In order to carry out the cointegration analysis, this study chooses four economic fundamentals as the variables in the function, and this function is a reduced-form equation consisted of fundamental variables. In a compact way, we specify Equation (1) of these fundamentals is given as follows:

$$\text{RER} = (\text{OPEN}, \text{GOV}, \text{PROD}, \text{M2}) \qquad (2)$$

where the variables are selected based on whether they influence the equilibrium exchange rate of RMB in accordance with economic theory as well as with China's national conditions. The variables in the function are determinants of the equilibrium RER. The hypothesis is no relationship among these four fundamental variables and real exchange rate.

As our preferred alternative to the linear residual-based cointegration tests, this study employs the cointegration test based specifically on the Breitung (2001) time-series rank transformation; the reason for such preference is the inconsistency demonstrated

by the non-linear functions. Breitung (2001) proposed a cointegration test based on the rank transformation of the time series. Such rank transformation is the inconsistency demonstrated by the non-linear functions. Consider a slightly more general form:

$$\varepsilon_t = g(y_t) - f(x_t),$$

where $g(y_t) \sim I(1), f(x_t) \sim I(1)$ and $\varepsilon_t \sim I(0)$.

The standard assumption has been that $f(x_t)$ is a linear function. However, economic theory often points to situations of nonlinear relationship, so $f(x_t)$ here is assumed to be a nonlinear function. Breitung (2001) shows that residual-based linear cointegration tests are inconsistant for some classes of nonlinear functions (Sargan and Bhargava, 1983; and Phillips and Oularis, 1990). To overcome this problem Breitung proposed tests based on the rank transformation of the time series. The largest advantage of such rank transformation is no requirement with regard to the exact functional form of the non-linear cointegration relationship.

The null hypothesis is rejected when the test statistic is below the critical value; it provides evidence against the null hypothesis of no cointegration. Such a test identifies whether the ranked series move together over time towards long-run cointegration equilibrium. When cointegration relationship is existed which may be either linear or nonlinear. Furthermore, linearity test is testing if previously identified cointegration relationship is linear or not (i.e. nonlinear).

The rank test is based on a measure of the squared distance between the ranked series. Breitung defined a ranked series as:

$$R(w_t) = \text{Rank of } w_t \text{ among } (w_1, w_2, \ldots, w_T) \tag{3}$$

where $w = \{y, x\}$. Breitung (2001) demonstrated with Monte Carlo simulations that these tests perform reasonably well for small values of the correlation coefficient ρ_R^T between the ranked series $R(y_t)$ and $R(x_t)$. The primary idea behind these rank tests is that if there is cointegration between the two series, y_t and x_t, the rank sequences tend to have similar evolutionary paths; otherwise the sequences of the ranks will tend to be divergent. Breitung considered two "distance measures":

$$\psi_T = \sum_{t=1}^{T} d_t^2 \; / \; T^3 \hat{\sigma}_{\Delta d}^2 \tag{4}$$

where $d_t = R(y_t) - R(x_t)$, for $R(w_t) = \text{Rank of } w_t \text{ among } (w_1, w_2, \ldots, w_T)$ and $w = \{y, x\}$.

Meanwhile, $\hat{\sigma}_{\Delta d}^2 = T^{-2} \sum_{t=1}^{T} (d_t - d_{t-1})^2$ is used to adjust for the potential correlation between the two series under examination. The Monte Carlo experiments in Breitung

(2001) demonstrated that the rank tests have excellent properties not only in the nonlinear case but also in the linear case.

To decide whether a cointegration relation is linear or non-linear, Breitung proposed a score statistic $T \times R^2$ based on the rank transformation of the time series. This test is applied if the rank tests indicate cointegration. The regression is computed from the following:

$$\widetilde{\varepsilon}_t = a_0 + a_1 x_t + a_2 R(x_t) + e_t \tag{5}$$

where t is the sample size, R^2 is the coefficient of determination of Equation (4) and $\widetilde{\varepsilon}_t = y_t - (\widetilde{c}_0 + \widetilde{c}_1 x_t)$, where $\widetilde{c}_0$ and $\widetilde{c}_1$ in turn, are the least squares estimates from a regression of y_t on a constant and x_t. Under the assumptions that $\widetilde{\varepsilon}_t$ is a zero-mean white noise and that x_t is exogenous, the score test statistic $T \cdot R^2$ has asymptotic Chi-squared (χ^2) distribution with one degree of freedom. The null hypothesis of linear cointegration, $a_2 = 0$, may be rejected in favor of nonlinear cointegration when $T \cdot R^2$ exceeds the χ^2 critical value. Under the null hypothesis, $f^*(x_t) = 0$ and the $\widetilde{\varepsilon}_t$ are $I(0)$ so that there is linear cointegration. Under the alternative hypothesis, $f^*(x_t) \neq 0$ and the $\widetilde{\varepsilon}_t$ are $I(0)$ so that there is nonlinear cointegration.

The $\widetilde{\varepsilon}_t$ are the residuals under the null hypothesis, possibly corrected for serial correlation and endogeneity using, for example, the dynamic ordinary least squares method (DOLS) of Stock and Watson (1993). Under the null hypothesis, the test statistic is distributed as χ^2 with one degree of freedom. The extension of this test to more than two variables is straightforward.

3.2. Threshold Error-Correction Model (TECM)

Given the non-linear cointegration found in previous section, we advanced to test the transmissions using threshold error-correction model (TECM). The TECM can be presented as follows (Enders and Granger, 1998; Enders and Siklos, 2001):

$$\begin{aligned}\Delta(RER)_t = \alpha \; &+ \rho_1 Z^+_{t-1} - \rho_2 Z^-_{t-1} + \sum_{i=1}^{k_1} \theta_{1i} \Delta(RER)_{t-i} + \sum_{i=0}^{k_2} \theta_{2i} \Delta(OPN)_{t-i} \\ &+ \sum_{i=0}^{k_3} \theta_{3i} \Delta(GOV)_{t-i} + \sum_{i=0}^{k_4} \theta_{4i} \Delta(\ln PRO)_{t-i} + \sum_{i=0}^{k_5} \theta_{5i} \Delta(\ln M2)_{t-i} + v_t\end{aligned} \tag{6}$$

where $Z^{+}_{t-1}= I_t\varepsilon_{t-1}$, $Z^{-}_{t-1} = (1-I_t)\varepsilon_{t-1}$, I_t is the Heaviside indicator function, such that $I_t = 1$ if $\varepsilon_{t-1} \geq \tau_2$, $I_t = 0$ if $\varepsilon_{t-1} < \tau$ and ε_t is a white-noise disturbance. ε_{t-1} is the random error term in the long-run relationships between variables *RER, OPN, GOV,* ln *PRO* and ln*M2*. Through the system, the Granger-Causality tests are examined by testing whether all the coefficients of ΔOPN_{t-i}, ΔGOV_{t-i}, $\Delta(\ln PRO)_{t-i}$ and $\Delta(\ln M2)_{t-i}$ are statistically different from zero based on a standard *F*-test and if the θ_j coefficients of the error-correction are also significant. As emphasized in Ewing *et al.* (2003), this feature of the error-correction model is particularly useful for studies on markets that are specifically characterized by rapid transmissions and adjustments. Granger-Causality tests are very sensitive to the selection of lag length, we determine the appropriate lag lengths use 'Akaike Information Criterion' (AIC) criterion.

4. Empirical results

4.1. Data

The exchange rate reform of China has been moving into a managed floating exchange rate regime based on market demand and supply with reference to a basket of currencies. The government determines to improve the exchange rate system by achieving greater flexibility. This is one of the most dramatic changes in China, and it makes economy soar since the implementation of the policy of trade openness in 1994. Then Asian financial crisis in 1997 and world financial storm in 2008 occurred. It is very instructive to investigate how the RMB RER fluctuates in the period from 1994 to 2010 during which these two major economic shocks are included. Our dependent variables is the real exchange rate (RER), which is defined as the nominal exchange rate adjusted by the ratio of the foreign price level to the domestic price level in the long run. Then, we use the data in this study consisting of quarterly observations of RMB real exchange rate (RER), degree of openness of the economy (OPN), ratio of government expenditure to real GDP (GOV), natural logarithm (ln) of relative productivity activity differential (ln PRO), natural logarithm of the real M2 money supply (lnM2) from the first quarter of 1994 to the fourth quarter of 2010. It will briefly explain these determinants of RER for a more precise definition of their proxies. Firstly, the degree of openness of the economy (as proxy for commercial policy) is traditionally viewed as the degree of trade liberalization, and it is usually thought to be able to produce an important impact on the long-run equilibrium RER. The ratio of total trade (imports + exports) to GDP is a commonly used measure of

[2] τ is a threshold value which is consistent estimated, can be obtained by adopting the methodology of Chan (1993) to minimize the residual sum of the squares from the fitted model.

international trade liberalization. Increase of the openness of an economy is expected to worsen the trade balance, for example, abolishing the country's trade barriers would allow foreign goods to enter the country more freely. Therefore, increase of openness would cause the RER to depreciate. Secondly, the ratio of government expenditure to GDP (as proxy for fiscal policy) measures the impact of government expenditure on RER depending on its level and distribution between tradable and non-tradable goods. If government expenditure falls more on tradables than non-tradables, then it will raise the demand for imports and result in a trade deficit, causing the equilibrium RER to depreciate. Hence, the effect of government expenditure is a priori for RERs. Empirically, Edwards (1989) found that increasing government expenditure induced RER appreciation for 12 developing countries. Thirdly, relative productivity differential is well-known as technological progress, if productivity grows faster in the tradables than non-tradables sector, pressure on wages will emerge in the non-tradable sector and higher relative price of non-tradables will appear. This will require a RER appreciation for the country to sustain the higher relative productivity gain without losing external competitiveness. Finally, real M2 money supply is a proxy for financial development. Increase of money supply leads to a rise in domestic aggregate demand for money, thus increasing the demand for imports and worsening the current account, causing the equilibrium long-run RER to depreciate. The data are collected from AREMOS, China National Bureau of Statistics, and China Economic Net. The software we use in this study is GAUSS. Descriptive statistics and graphs about macroeconomic variables in China are shown in Table 1, and the Jarque-Bera tests show that all variables approximate non- normal distribution.

Table 1: Descriptive statistics of the macroeconomic variables in China

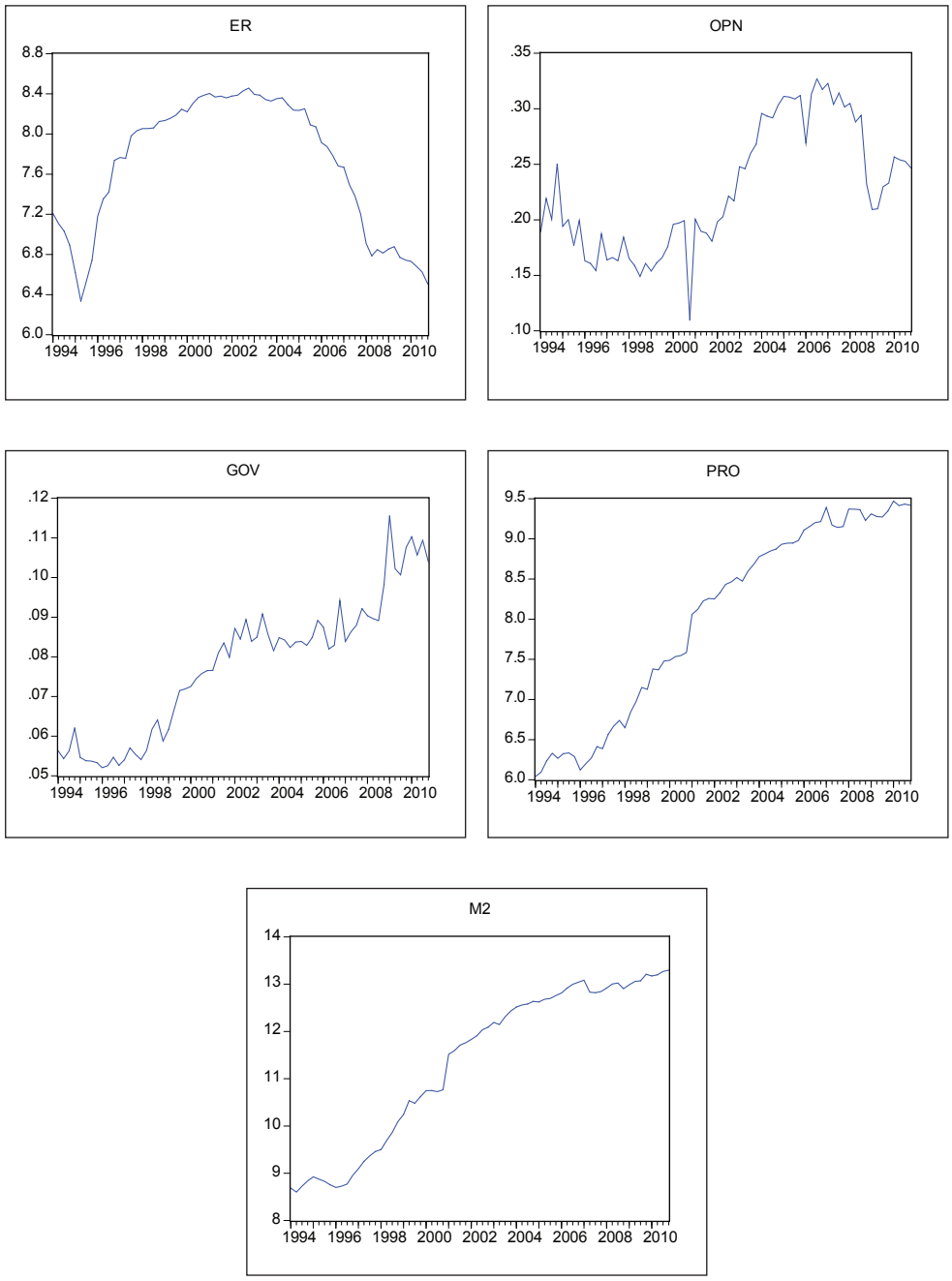
Variable	Mean	Minimum	Maximum	Std[1]	Skewness	Kurtosis	J-B[2]
RER[3]	7.957	6.335	8.457	0.578	-1.274	3.108	18.416***
OPN[4]	0.256	0.109	0.327	0.057	1.095	3.510	14.330***
GOV[5]	0.082	0.052	0.116	0.017	1.081	3.897	15.525***
lnPRO[6]	8.026	6.042	9.471	1.188	-0.369	1.584	7.231***
lnM2[7]	11.347	8.602	13.296	1.665	-0.457	1.612	7.837***

Notes:

1. Std denotes standard deviation.
2. J-B denotes the Jarque-Bera Test for Normality.
3. ER denotes the RMB RER.
4. OPN denotes the degree of the openness of economy.
5 GOV denotes the ratio of government expenditure to GDP.
6. lnPRO denotes natural logarithmic of the relative productivity activity differential.
7. lnM2 denotes natural logarithmic of the real M2 money balance.
8. The ***, **, and * indicate significance at the 0.01, 0.05 and 0.1 levels, respectively.

Source: Author's Calculation

Figure 1: Graphs about macroeconomic variables in China



Source: Author's calculation

4.2. Linear unit root tests

In previous studies, macroeconomic and/or financial time series are usually tested for "stationarity" of each variable by employing three traditional unit-root test techniques: ADF (Dickey and Fuller, 1981), PP (Phillips-Perron, 1988), and KPSS (Kwiatowsk, *et al*, 1992). The ADF and PP tests use Schwarz Bayesian information criterion (SBC) and the Bartlett kernel in Newey and West (1994) to select the appropriate lag lengths and bandwidth respectively. A necessary but not sufficient condition for cointegration is that each of time series must be integrated of the same order, or I(1) (Granger, 1987). It is well known that ADF tests have low power with short time spans of data, so we also use the KPSS test to complement the Dickey-Fuller test by comparing the significance of statistics from both tests. A stationary series tend to be significant on Dickey-Fuller statistics and insignificant effect on KPSS statistics. The results of the three unit root tests, ADF, PP and KPSS, are summarized in Table 2, which show that the null of non-stationarity cannot be rejected for any levels for all series.

Table 2: Unit root tests of macroeconomic variables in China

	Level			First-difference		
Variable	ADF	PP	KPSS	ADF	PP	KPSS
RER	0.692(1)	0.508 [4]	0.753[6]***	-5.395(0)***	- 5. 466 [3]***	0.267[5]
OPN	-1.035(4)	-8.055[7]	0.523[6]**	-4.381(3)***	-24.570[12]***	0.120[12]
GOV	-0.509(4)	-6.537[9]	1.517[3]***	-4.152(3)***	-27.643[11]***	0.123[12]
lnPRO	1.284(5)	-5.563[6]	1.213[5]***	-2.651(3)*	-41.823[11]***	0.109[12]
lnM2	-2.189(0)	-1.595[4]	1.082[6]***	-5.093(1)***	- 5. 492 [0]***	0.303[5]

Notes:

1. The ***, **, and * indicate significance at the 0.01, 0.05 and 0.1 levels, respectively.

2. The numbers in the parentheses of ADF is the appropriate lag lengths selected by SIC, whereas the numbers in the parentheses of PP and KPSS are the optimal bandwidths decided by the Bartlett kernel of Newey and West (1994).

Source: Author's Calculation

After the first order difference with the ADF and PP test, however, the nulls are rejected at least at the 10% significance level for all series. With the KPSS test, the null of stationarity can be rejected at least at the 1% significance level for all series. Thus, all the variables considered in this paper are of I (1) type.

4.3. Nonlinear unit root test

There is an increasing concern that macroeconomic variables might exhibit nonlinearities, and that conventional tests for stationarity, like the ADF unit root test and so forth, have lower power in detecting the mean reverting tendency of the series. In view of this, we employ a newly developed nonlinear stationary test advanced by

Kapetanios *et al*. (2003) (henceforth, KSS test) in Table 3 to examine whether RMB exchange rate and macroeconomic variables for China are nonlinearly stationary.

Table 3: Results of nonlinear unit root test – KSS test

Variable	RER	OPN	GOV	lnPRO	lnM2
t-Statistics (Level)	-0.688 (2)	-1.729 (3)	-0.170 (3)	-1.322 (3)	-0.650 (3)

Notes:

1.The 0.01, 0.05, 0.1 asymptotic null critical values for KSS tests are -3.48, -2.93 and -2.66, respectively (Kapetanios *et al*., 2003).

2. The numbers in the parentheses of KSS is the appropriate lag lengths.

Source: Author's calculation

It shows that all variables considered in this study are all of order one series, I(1). The results indicate that the null of a unit root is not rejected against the nonlinear stationary alternatives for all variables.

4.4. Multivariate cointegration and non-linear tests

The purpose of the multivariate cointegration test is to examine whether the data of time series are cointegrated or not. The test results in this study are summarized in Table 4. For the case of the rank test, this study computes the autocorrelation adjusted test statistics, ψ*. The null hypothesis of this rank test is that RMB exchange rate and macroeconomic variables in China are not cointegrated, and the alternative hypothesis is that RMB exchange rate and those variables are cointegrated. The rejection of null hypothesis approves the alternative hypothesis when the critical value exceeds the test statistic; otherwise, the null hypothesis is supported. Just as is clearly shown by the ψ* statistic in Table 4, the null hypothesis is rejected for RMB exchange rate series and variables examined in this study at the 1 percent significance level. Besides, according to the ψ* statistic, it is observed cointegration relationships between exchange rate and related macroeconomic variables under consideration. Therefore, evidence of the existence of long-run relationships between RMB exchange rate and China's macroeconomic variables is provided in this part.

The multivariate cointegration relationship identified above is further supported by the rank sum linearity test developed by Breitung (2001). The null hypothesis of the rank test is that no cointegration exists among variables of exchange rate, degree of openness of the economy, ratio of government expenditure to GDP, productive activity differential, and real money supply. The relevant multivariate $T \times R^2$ test statistics from Table 4 show that the null hypothesis of linear cointegration is rejected at all significance levels, which means that rank sum linearity test results for the $T \times R^2$ also indicate that the cointegration relationships can be nonlinear.

Table 4: Results of multivariate rank tests for cointegration and linearity

Statistics Approach Test Statistics	Rank Test[a] ψ^*	Linearity Test[b] $T\times R^2$
	0.0081***	14.4864***
Critical Value (%)		
10	0.0136	7.779
5	0.0117	9.488
1	0.0092	13.277

Notes:

a. The rank test is adjusted for autocorrelation. The null hypothesis of the rank test is that no cointegration exists between the RMB exchange rate and four macroeconomic variables in China; the alternative hypothesis is that cointegration does exist between the RMB exchange rate and four macroeconomic variables in China. The null hypothesis is rejected when the critical value exceeds the test statistic.

b. The null hypothesis of the linearity test is that a linear relationship exists with no cointegration between the RMB exchange rate and four macroeconomic variables in China; the alternative hypothesis is that a linear relationship does not exist and cointegration does exist between the RMB exchange rate and four macroeconomic variables in China. The null hypothesis is rejected when the computed $T\times R^2$ value exceeds the critical value.

c.***indicates significance at the 0.01 level.

Source: Author's calculation

4.5. Threshold error-correction models

Based on the positive findings of a nonlinear equilibrium relationship, this study uses the threshold error-correction model (TECM) to investigate the movement of the variables to detect their long-run equilibrium relationship. In the case of China, given the rank cointegration found in previous section, we test the transmission with threshold error-correction model (TECM):

$$\begin{aligned}\Delta(RER)_t = \alpha\ &+ \rho_1 Z^+_{t-1} - \rho_2 Z^-_{t-1} + \sum_{i=1}^{k_1}\theta_{1i}\Delta(RER)_{t-i} + \sum_{i=0}^{k_2}\theta_{2i}\Delta(OPN)_{t-i} \\ &+ \sum_{i=0}^{k_3}\theta_{3i}\Delta(GOV)_{t-i} + \sum_{i=0}^{k_4}\theta_{4i}\Delta(\ln PRO)_{t-i} + \sum_{i=0}^{k_5}\theta_{5i}\Delta(\ln M2)_{t-i} + v_t\end{aligned} \tag{6}$$

The threshold value $\tau = 0.05217$ is found based on the Chan's (1993) method. $Z^+_{t-1} = I_t\varepsilon_{t-1}$, $Z^-_{t-1} = (1-I_t)\varepsilon_{t-1}$, I_t is the Heaviside indicator function, ε_{t-1} is the random error term in the long-run relationships between variables RER, OPN, GOV, lnPRO and lnM2. The Heaviside indicator could be specified as $I_t = 1$ if threshold value is above 0.05217 and $I_t = 0$ if threshold value is less than 0.05217, v_t is a white-noise disturbance.

Table 5: Estimates of the error-correction models for China

Variable	Asymmetric[2]
Constant	0.055(0.060)
ΔRER_{t-1}	0.136(0.186)
ΔRER_{t-2}	0.040(0.167)
ΔRER_{t-3}	-0.077(0.157)
ΔRER_{t-4}	-0.041(0.154)
ΔOPN_{t-1}	0.025(0.096)
ΔOPN_{t-2}	-0.095(0.096)*
ΔOPN_{t-3}	-0.015(0.101)
ΔOPN_{t-4}	0.067(0.094)
ΔGOV_{t-1}	-0.072(0.296)
ΔGOV_{t-2}	-0.733(0.300)**
ΔGOV_{t-3}	-0.392(0.284)
ΔGOV_{t-4}	-0.176(0.260)
$\Delta \ln PRO_{t-1}$	-0.843(0.416)**
$\Delta \ln PRO_{t-2}$	-1.234(0.407)***
$\Delta \ln PRO_{t-3}$	-0.983(0.388)**
$\Delta \ln PRO_{t-4}$	-0.710(0.392)*
$\Delta \ln M2_{t-1}$	0.329(0.797)
$\Delta \ln M2_{t-2}$	1.288(0.851)
$\Delta \ln M2_{t-3}$	-1.171(0.563)**
$\Delta \ln M2_{t-4}$	0.537(0.743)
Z^{+}_{t-1}	0.827(0.307) ***
Z^{-}_{t-1}	-0.252(0.106)***
Adj. R-squared	0.449
RSS[4]	0.519
Q(4)[5]	2.116[0.715]
ARCH(4)[6]	0.978[0.913]
J-B[7]	1.315[0.518]

Notes:

1. Numbers in parentheses and brackets are standard errors and *p*-value, respectively.

2. Asymmetric error-correction model:

$$\Delta(RER)_t = \alpha + \rho_1 Z^{+}_{t-1} - \rho_2 Z^{-}_{t-1} + \sum_{i=1}^{k_1} \theta_{1i} \Delta(RER)_{t-i} + \sum_{i=0}^{k_2} \theta_{2i} \Delta(OPN)_{t-i} + \sum_{i=0}^{k_3} \theta_{3i} \Delta(GOV)_{t-i} + \sum_{i=0}^{k_4} \theta_{4i} \Delta(\ln PRO)_{t-i} + \sum_{i=0}^{k_5} \theta_{5i} \Delta(\ln M2)_{t-i} + v_t$$

where $Z^{+}_{t-1} = I_t \varepsilon_{t-1}$, $Z^{-}_{t-1} = (1 - I_t)\varepsilon_{t-1}$ such that $I_t = 1$ if $\varepsilon_{t-1} \geq 0.0521$, $I_t = 1$ if $\varepsilon_{t-1} \leq 0.0521$, and v_t is a white-noise disturbance.

3. The ***, **, and * indicate significance at the 0.01, 0.05 and 0.1 levels, respectively.

4. RSS is sum of squared residuals.

5. $Q(4)$ is the Ljung-Box autocorrelation tests for the residual.

6. ARCH(4) is the autoregressive conditional heteroscedasticity test of Engle (1982) and has χ^2 distribution with 4 degrees of freedom.

7. J-B denotes the Jarque-Bera Test for Normality.

Source: Author's calculation

This study applies the SBC to determine the appropriate lag lengths and empirically find that, for all cases, the four lag lengths of and are all five variables (i.e., $k_1 = k_2 = k_3 = k_4$). The estimated coefficients of Z^{+}_{t-1} and Z^{-}_{t-1} indicate the speed of adjustment for positive and negative deviations from the fundamental values.

Table 5 displays the causal relationship between RER and other variables. The null hypothesis of *H*0*:* $\theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = 0$ is applied to test the short-run causal relation running from *macroeconomic variables to RER.* Among other causal relations, the null hypotheses of *H*0: $\theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = \rho_1 = 0$ and $\theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = \rho_2 = 0$ are applied to test a causalityrunning from *macroeconomic variables* to *RER* when the difference in the previous disequilibrium term is above or below the threshold value in the long run.

For example, an increment in trade openness at second lag length is associated with a depreciation of RER by 0.095 units; a decrement in government expenditure at second lag length would increase the RER by 0.733 units growth rate in the long-run dynamics. Likewise, one unit reduction in productivity at first lag length to fourth lag length differential leads to -0.843, -1.234, -0.983 and -0.710 percent appreciation in RER. For adjustment speed toward the long-run equilibrium, the results in Table 5 for the macroeconomic variables show that the adjustment coefficient (82.7%) in the higher regime is statistically significant at the 1 percent level, but it is not statistically significant in the lower regime. This finding implies that 82.7 percent of the deviations revert back to equilibrium in the higher regime, also RMB exchange rate is adjusted by 25.2% adjustment toward the long-run equilibrium in the lower regime. For asymmetric error-correction model test, the Ljung-Box's *Q*-statistic fails to reject the hypothesis of no autocorrelation in residuals. In addition, the ARCH statistic of Engle (1982) fails to reject the hypothesis of no autoregressive conditional heteroscedasticity in residuals. Otherwise, the Jarque-Bera tests show that the error term of asymmetric error-correction model is normal distribution. These empirical findings from Table 5 indicate that the asymmetric ECM may be appropriate to describe the dynamics of the RMB exchange rate. There is a discontinuous adjustment in RMB exchange rate to a long-run equilibrium in two separate regimes, indicating an asymmetric causal relationship between the four variables considered. There exists a causal relationship running from OPN, GOV, lnPRO and lnM2 to RER in the long run, suggesting that these four macroeconomic variables are negative which have significant impacts to RMB appreciation. In other words, the short-run dynamics follows nonlinear adjustment towards the long-run equilibrium of the RMB exchange rate in China.

4.6. Impulse response and variance decomposition

Ordering of the variables may affect impulse response and variance decomposition results if the common trends are not absolutely uncorrelated. Here, following the

practice of Sims (1980) and Zhou (1996), the presumably exogenous variable is ordered first, followed by relatively endogenous variables. The trends are ordered RER, GOV, lnM2, OPN, lnPRO. Variance decompositions show the proportion of forecast error variance for each variable due to its own innovation and to other shocks. Variance decompositions in Table 6 capture both direct and indirect effects, and are generated by disturbing each variable one standard deviation up to 24 quarters.

For the RER, GOV, lnM2, OPN, lnPRO, most of the variance appear to be explained by movement in itself. After 24 quarters, 36.03%, 50.25%, 40.30% of the forecast error variance in RER, GOV, OPN, respectively, are explained by changes in the same variables, except for lnM2 and lnPRO. The forecast error variance in RER is accounted by its own innovation about 36.03%, secondarily explained by OPN about 31.60% after 24 quarters. The forecast error variance in GOV is accounted by its own innovation about 50.25%, secondarily explained by lnM2 about 24.14% after 24 quarters. The M2 accounts for only a small percentage of the forecast error variance in itself 8.25%. On the other hand, the OPN and lnPRO account for quite large percentage of the forecast error variance in lnM2 about 43.69% and 33.25% up to 24 quarters. RER and GOV account for about 20.52% and 22.10% of the forecast error variance in OPN that accounts for about 40.30% by its own innovation. The forecast error variance in lnPRO and OPN innovation is accounted for about 41.81% in excess of PRO about 32.94% up to 24 quarters. Results in Table 6 are consistent with the Granger causality from RER to GOV, lnM2, OPN and lnPRO. The strength of Granger causal relations can be measured by variance decompositions. As the results are known from the Table 6, when each of all variables fluctuates, some variables have robust exogeneity, and exists high explanatory power of their own, and they aren't affected by other variables. Even GOV has the highest innovation accounted in the forecast error variance about 50.25%, but it's still not absolutely exogeneity. In view of this point, it says that every single variable could be explained by other variables. In general, GOV has the most explanatory power on RER in the Table 6.

Impulse response over 24-quarter periods to a one unit positive shock to each variable is shown in Figure 2. In Figure 2(a), the solid line represents the impulse responses of ER to its own shock and the response of ER to its own shock first peaks at the third quarter and then decline after third quarter, and turn to negative response after the sixteenth quarter. In Figure 2(b), the solid line represents the impulse responses of GOV to the shock of RER and the response of GOV to the shock of RER first peak appears at the second quarter. This shock from GOV to RER is persistent and decline after the fourteenth quarter and never dies out after that period. In Figure 2(c), the solid line represents the impulse responses of lnM2 to the shock of RER and the response of lnM2 to the shock of RER has little volatility from the first quarter to the fifth and then decline from the ninth quarter. Finally turning to negative response after the fourteenth quarter and never dies out after 24 quarters.

Table 6: Variance decompositions

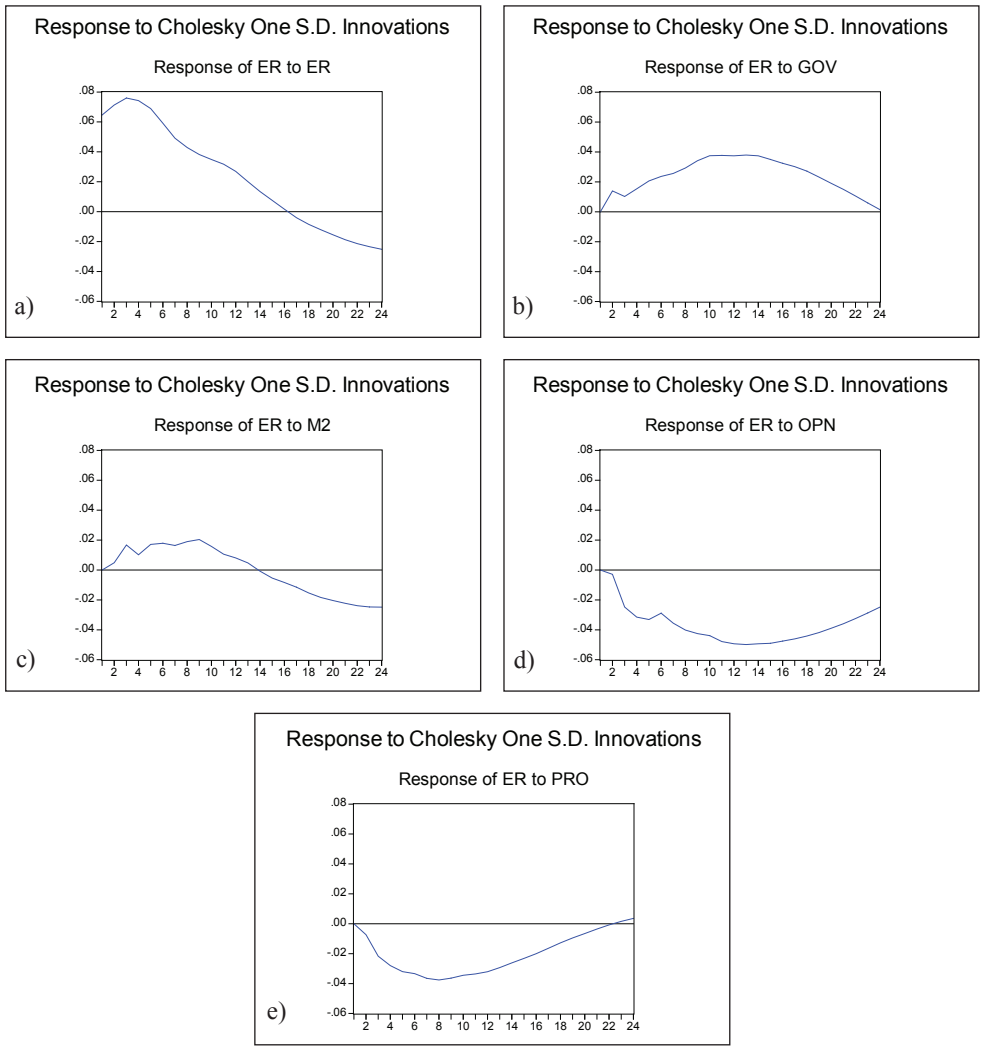
Quarter	RER	GOV	lnM2	OPN	lnPRO
(1) Variance decomposition of RER					
1	100.0000	0.000000	0.000000	0.000000	0.000000
4	84.15531	2.205182	1.665842	6.614902	5.358761
8	65.63623	6.046952	3.275342	12.74502	12.29645
12	50.54017	11.38949	3.359114	20.06971	14.64152
16	41.38982	14.72936	2.836647	26.55832	14.48586
20	37.05478	15.47627	3.586008	30.53004	13.35289
24	36.03307	14.64477	5.352617	31.59613	12.37340
(2) Variance decomposition of GOV					
1	0.120745	99.87925	0.000000	0.000000	0.000000
4	3.591676	74.65592	14.22767	4.893494	2.631241
8	2.901074	64.54820	20.51108	7.650498	4.389141
12	2.797616	58.08298	23.55175	9.517962	6.049696
16	3.298604	54.14567	24.93559	9.759419	7.860723
20	4.050558	51.81879	24.96315	9.448523	9.718986
24	4.567825	50.25237	24.13836	9.694500	11.34694
(3) Variance decomposition of lnM2					
1	1.722486	3.403476	94.87404	0.000000	0.000000
4	16.74299	20.15468	59.82913	1.237421	2.035786
8	13.28991	20.94517	38.58777	18.11746	9.059681
12	12.60666	16.64923	20.80593	29.86289	20.07530
16	10.21806	12.52156	13.62161	36.11184	27.52693
20	8.004500	9.836663	10.23552	40.42803	31.49529
24	6.333107	8.480139	8.251572	43.69007	33.24511
(4) Variance decomposition of OPN					
1	1.368611	11.91324	3.847362	82.87079	0.000000
4	4.314298	10.68602	12.37081	72.50958	0.119291
8	21.75797	8.435846	13.12203	55.47588	1.208279
12	25.06147	11.51690	12.94106	46.60578	3.874782
16	24.78571	16.69562	11.15263	41.74402	5.622020
20	22.40484	20.55946	10.00578	40.56597	6.463952
24	20.51859	22.09771	10.21254	40.30040	6.870768
(5) Variance decomposition of lnPRO					
1	3.138787	34.48477	0.269466	4.132094	57.97488
4	17.23446	24.60938	2.038037	27.87321	28.24491
8	12.23697	18.63189	2.575163	36.64809	29.90789
12	8.857700	15.38935	3.020581	42.30150	30.43087
16	7.366076	13.31881	3.586300	44.52090	31.20792
20	7.314507	12.55624	4.003036	44.02983	32.09639
24	7.890677	13.24435	4.118272	41.81063	32.93607

Note: As there are more than one common trend in the models, different ordering of the trends may affect the results of variance decompositions and impulse response if the common trends are not absolutely uncorrelated. Here, following the practice of Sims (1980), the presumably trends. Therefore, the trends are ordered a [ER GOV M2 OPN PRO]

Source: Author's calculation

In Figure 2(d), the solid line represents the impulse responses of OPN to the shock of RER and the response of OPN to the shock of RER is negative response from the first quarter. The response of OPN to the shock of RER declines till the twelfth, and then rebounds after the fifteenth quarter. In Figure 2(e), the solid line represents the impulse responses of lnPRO to the shock of RER and the response of lnPRO to the shock of RER declines from the first quarter till the eighth and then rebounds after that period. Finally, the response of lnPRO to the shock of ER turns to positive response after twenty-third quarter and never dies out after 24 quarters.

Figure 2: Response to Cholesky One S.D. Innovations response of ER to GOV, M2, OPN, PRO



Source: Author's calculation

In Figure 2(b), the solid line stands still on positive response in all 24 quarters, and its presents that GOV increase year by year make RMB exchange rate appreciate. In Figure 2(d), the solid line presents negative response, but after fourteenth quarter OPN rebounds which could be explained as OPN grow up from 1990's to recent ten years, RMB exchange rate has changed gradually from depreciation to appreciation. In Figure 2(e), the solid line goes from negative response to positive response, it presents in recent years lnPRO become one of important factors in Chinese economic environment, and it pushes RMB exchange rate forward.

The findings of this study indicate that appreciation of RMB's real exchange rate is a function of decreasing degree of openness of the economy, ratio of government expenditure to GDP, relative productivity activity differential and M2 money supply. Increase of the openness of an economy is expected to worsen the trade surplus and cause the RER to depreciate. If government expenditure falls more on tradable than non-tradable, then it raises the demand for imports which would result in trade deficit and cause the equilibrium RER to depreciate either. Appreciation of RER for the country is thought to be able to sustain the higher relative productivity gain. Increase in money supply leads to a rise in domestic aggregate demand for money and thus increases the demand for imports and worsens the current account, causing the equilibrium long-run RER to depreciate. Following the results in Table 5 and taking into account the significance of estimated coefficients, we can conclude that increases in OPN, GOV, PRO and M2 have a negative impact on exchange rate. It means if they increase, exchange rate will fall, RMB become appreciation. OPN, GOV, and PRO are basically in line with previous expectations. After the reform of RMB institution in 1994 and the Asian financial disaster in 1997, China tried to develop a new exchange rate regime, so called managed floating exchange rate regime, based on market demand and supply with reference to a basket of currencies, and aiming to improve the exchange rate system by achieving greater flexibility in 2005. In the past sixteen years, Chinese government made spectacular progress in economic development. The GDP growth rate is finely maintained with shrinking government expenditure in the proportion of GDP. On the other hand, large population in China is one of the greatest advantages. Low-cost labor attracts lots of international enterprises to set up their factories and firms in China.

These factors contribute much to growth of GDP, increase of trade volume and higher degree of openness to rest part of the world. Currently, all of these variables are exerting considerable pressure for RMB to revalue. Both the national income and foreign currency reserves in China are increasing. The rapid rise in the reserve holdings and monetary sterilization operations of People's bank of China must have checked the rapid growth of domestic money supply in China.

5. Conclusions

The empirical findings of this study are supportive of the relationship among equilibrium exchange rate of RMB and macroeconomic variables in accordance with economic theory as well as with China's national conditions. Results show that RMB exchange rate and macroeconomic variables have nonlinear relationship with each other. To be specific, degree of openness of the economy, ratio of government expenditure to GDP, relative productive activity differential and real money supply are detected to be negative and significant explanatory variables for the long-run equilibrium of RMB exchange rate. These variables may have profound impact on the future value of RMB. From the estimated model, it can readily been seen that increase of the openness, government expenditure, output and money supply in China could act as the major forces for the revaluation of RMB in near future.

The mentioned results should be taken with a restriction considering that the RMB exchange rate in China has been structurely broken with its government policy. The RMB exchange rate is usually considered undervalued and manipulated by Chinese government. Furthermore, it fails to consider information of exchange rate volatility adjusting for codependence between macroeconomic variables.

Further research could be extending the interaction of RMB exchange rate between other major currencies to test the RMB trend in the long run. Furthermore, one another issue in financial reform of China is the sequencing of capital account liberalization and more flexible exchange rate policies. The order in which financial liberalization and exchange rate system reform are implemented have profound different financial consequences.

Undoubtedly, this finding has great meaning for Chinese economy. When the macroeconomic variables are in the long-term steady situation, the government can control the behavior of the equilibrium exchange rate by adjusting the disorder exchange rate and reducing the intervention in currency markets. Enterprises and the general investors can also gain deeper understanding of the trends of equilibrium exchange rate to avoid investment losses.

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Odnos valutnog tečaja i makroekonomskih varijabli u Kini

Chi-Wei Su[1]

Sažetak

Cilj ovog istraživanja je utvrditi odnos između Renminibi (RMB) valutnog tečaja i makroekonomskih varijabli u Kini, te ponuditi smjernice za reformu RMB režima valutnog tečaja. Dugoročna ravnoteža odnosa RMB valutnog tečaja i makroekonomskih varijabli istražuje se pomoću ne-parametarskih testova (testova rangiranja) koje je predložio Breitung. Nadalje, u ovom istraživanju autori koriste TECM model korekcije graničnih vrijednosti za utvrđivanje nelinearnog odnosa između RMB valutnog tečaja i makroekonomskih varijabli nelinearnih oblika. Rezultati pokazuju da su RMB valutni tečaj i makroekonomske varijable u nelinearnom odnosu. Dugoročno ovi rezultati predstavljaju čvrst dokaz da RMB valutni tečaj i makroekonomske varijable potvrđuju hipotezu asimetričnosti procesa korekcije grešaka u Kini. Rezultati ovog istraživanja od velikog su značaja za kreiranje politike kineske vlade.

Ključne riječi: *RMB valutni tečaj, nelinearni test rangiranja, TECM model korekcije graničnih vrijednosti*

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