Equilibrium Exchange Rate and Misalignment of the Chinese Renminbi

A Research Based on Montiel's Model and the BEER Approach

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Foreword

This thesis marks the end of my two year master's degree program in Department of Economics, University of Oslo.

Throughout the period of completing my thesis, the person I would like to thank the most is my supervisor, Professor Steinar Holden, who offered generous helps which I appreciated so much. With the critical and constructive suggestions from Professor Holden, I not only got deeper insights into the research topic, but also refined the thesis to a great extent by better interpreting the theoretical framework and the empirical results. I learnt from Mr Holden what a good scholar should be like.

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Finally I want to say thanks to my dearest mother and father, and to the whole big family that is always believing in me and proud of me. I am indeed fortunate with their love, encouragement and support. Without my family, I would never have such hope, confidence and goodness. Like a stray bird I fly, like a warm nest thou wait.

There is endless to say about Norway, a beautiful country. Hugging with the mountains and lakes, sky and seas, I discover the unlimited time and space; I become able to maintain a true inner peace; I hear a poem, continuously sung deep in my heart.

The world is big, but in fact it is small;

We will depart, but in fact we never will.

Summary

The exchange rate problem of the Chinese currency, Yuan, or the Renminbi (RMB), has been at the center of the debate in international finance since the beginning of the 21st century. In view of the importance of the RMB exchange rate, and given the fact that the RMB is under the control of the political authorities, the answer to the question whether the currency is properly valued at its 'equilibrium' level is likely to be disputed across the world.

In this thesis, we try to explore three aspects of the RMB's equilibrium exchange rate.

First, we discuss what is the appropriate definition of the equilibrium exchange rate. By comparing the BEER with the alternative approaches such as the Fundamental Equilibrium Exchange Rate (FEER) approach, we argue that the Behavioral Equilibrium Exchange Rate (BEER) has important advantages.

Second, we want to develop a model for the RMB's equilibrium real effective exchange rate (REER), and discover the relationship between the RMB's REER and several economic factors. The economic factors in the model are based on Montiel (1999)'s theoretical framework.

Third, we use the model estimation to explore how the RMB's equilibrium REER has evolved over the 20 years between 1994 and 2014, and measure the extent of 'misalignment' (overvaluation or undervaluation) during the sample period.

We take the Behavioral Equilibrium Exchange Rate (BEER), which was put forward by Clark and Macdonald in 1998, as the approach of analysing the equilibrium exchange rate of the RMB. Montiel (1999)'s model for developing countries' equilibrium exchange rate is utilized in this thesis as a theoretical framework, and the basis of variable selection.

We conduct empirical research using the cointegration technology in time series econometrics. We establish a Vector Error Correction Model for the RMB's real effective exchange rate (REER) and several key economic factors such as the relative productivity, the relative government expenditure, the terms of trade, the openness of economy, as well as the relative money supply, using quarterly data from 1994Q1 to 2014Q4. We use the Stata/MP 13.0 as the software of empirical study.

We identify the equilibrium relationship between the RMB's REER and three groups of economic variables through the VECM and have the following findings:

First, we identify the equilibrium relationship between the RMB's REER and several economic variables from the error-correction term of the VECM. We find that the RMB's equilibrium REER is negatively related to the relative productivity growth in tradable sector and relative money supply, while it is positively related to the terms of trade.

Second, we discover how the equilibrium REER of the RMB has evolved throughout the sample period, based on three estimated equilibrium relationships. We find that the equilibrium REER of the RMB has been steadily appreciating since 2005, and is continuing to appreciate at present.

Third, we calculate the extent of 'misalignment' of the RMB's actual REER on a BEER sense. We find that the actual REER was overvalued in periods between 1997 and 2003, and between 2007 and now. The REER was undervalued in period between 2003 and 2007. Meanwhile, the extent of misalignment stayed within 10% on a BEER sense.

We also point out some pitfalls of our empirical research and further provide future possible research topic.

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1 Introduction

In this chapter we discuss two major issues in the according sections below. First, we provide some background information of exchange rate problems for developing countries and for China, which indicate the reason that we choose the RMB's Equilibrium Exchange Rate as our research topic; second, we introduce the problems we are trying to answer in this thesis; as well as the research framework, methodologies and software adopted in the thesis.

1.1 The exchange rate problem for developing countries and China: An overview

1.1.1 Equilibrium exchange rate problems for developing countries

The problems related to the exchange rates of developing countries' currencies emerged since as early as the 1970s. After the collapse of the Bretton Wood system, floating exchange rate regimes were established and enhanced through reforms by major industrialized countries such as Japan and the UK, etc. However, in most developing countries, the exchange rates were still under controls of the authorities even until now. One significant consequence of the active management is a divergence of the actual exchange rate from its equilibrium level (i.e. overvaluation or undervaluation), this is the so-called 'currency misalignment'. It may lead to 'disequilibrium' of the economy if a country's currency is not properly priced, since the exchange rate is related to many macroeconomic factors such as inflation, employment, international trade, and balance of payment, etc. Hence the exchange rate is critical for a country's overall competency and economic development.

The judgment of whether a currency is misaligned is based on our estimation of the equilibrium exchange rate as a benchmark. Great amount of theoretical achievements were made in the past in estimating the equilibrium exchange rate for developed countries, including the Purchasing Power Parity (PPP), Fundamental Equilibrium Exchange Rate (FEER) approach, etc. However, when adopted in the context of developing countries, these theories showed many limitations and usually provide poor estimations of the equilibrium exchange rates. The reason lays in the difficulty of defining 'equilibrium', the simultaneous attainment of internal and external balance, for developing countries, most of which countries are undergoing rapid structural changes in economy and society, and these changes implied

different characters of economic fundamentals compared to that in the industrialized countries.

This reality brought about the necessities for equilibrium exchange rate theory tailored specially for developing countries, and for the suitable empirical methodologies that facilitate theoretical studies. Edwards (1989, 1994) and Elbadawi (1992) made great innovative contributions in this direction by establishing a framework of equilibrium exchange rate for developing countries. They studied the exchange rates of 12 developing countries like India and Brazil during 1960 to 1985. In their theoretical model of a dual-exchange-rate, three-sector small open economy, the dynamic behaviour of the actual exchange rate is determined mutually by the stable status of demand, supply, government and external sectors together with people's portfolio decisions. And the equilibrium exchange rate in the long run is affected only by real disturbances such as terms of trade, government expenditure, technological progress; However, in the short run, nominal factors like monetary disturbances also exert influences on real exchange rate.

1.1.2 The exchange rate regime of RMB and related exchange rate problems

China, as the world's largest developing economy, experienced a rapid and sustained growth for several decades since the 1980s. Meanwhile, the controlled exchange rate of China's currency, the Renminbi (RMB), has been at the center of the debate in the international finance for a long time.

In 1994, China's foreign exchange market was first thoroughly reformed; this marked the beginning of the so-called managed floating exchange rate regime, and the termination of 'dual' exchange rate regime (coexistence of black and official foreign exchange markets). The official rate was devalued from 5.7yuan/US$ to 8.7yuan/US$.

In July 21, 2005, China's central bank, the People's Bank of China (PBC) announced a switch of RMB exchange rate regime from the de-facto dollar-peg to a managed floating exchange rate regime with reference to a basket of currencies, and the RMB was revalued up by 2.1% to 8.11yuan/US$ based on assessment of its equilibrium level. [1] The RMB entered a

[1] See China Monetary Policy Report, Quarter Three, 2005, published by PBC on its website: http://www.pbc.gov.cn/publish/english/990/1951/19513/19513_.html

prolonged period of appreciation ever since. Meanwhile, China has seen an average annual GDP growth rate of above 7%, and double-digit GDP growth rates for 5 consecutive years between 2003 and 2007. The current account surplus soared at an astonishing annual speed of 45% from 20.5 billion dollars in 2000 to 420.6 billion dollars in 2008, counting for more than 7% of nominal national GDP. [2] Together with the increasing amount of disputes between China and its trading partners, the Chinese authority was blamed to have artificially undervalued RMB to gain unfair advantages in international trade, thus the issue of RMB equilibrium exchange rate and its misalignment was discussed more and more throughout the world.

In June 2010, China's exchange rate regime was further reformed. The reform was designed to make the RMB exchange rate more flexible with reference to a basket of currencies and to keep it basically stable at an adaptive and equilibrium level.[3] The term 'effective exchange rate' was highlighted. Rather than the bilateral exchange rate that measures the relative currency prices of two countries, effective exchange rate is the average relative price of a given currency to several other currencies, weighted by trade shares. The real economy was affected by this reform and the following strengthen of the RMB, in a sense that the overly rapid expansion of trade surplus has moderated, and the trade-structure was improved.

Overall, the RMB has experienced a prolonged period of appreciation ever since 2005, with the real effective exchange rate accumulatively appreciated by 43%. And the momentum of appreciation seems not to reduce at present and in the foreseeable future. Under concerns of the slowdown of Chinese economy, people start to worry whether the RMB has been overvalued already; the problem of the RMB exchange rate is still a center economic and political issue currently.

The RMB's internationalization in recent years also strengthened the significance of the RMB's exchange rate problems. In 2009 the pilot program of RMB cross-border trade settlements was launched, and the RMB accounted for 25% of the total cross-border payments and receipts of Chinese entities so far; In 2011 direct investments with the RMB from both

[2] Current account data is achieved from the Time-series data of Balance of Payments of China, published by China's State Administration of Foreign Exchange (SAFE) on its website: http://www.safe.gov.cn/wps/portal/english/Data/Payments; nominal GDP is achieved from IMF's IFS database.

[3] See China Monetary Policy Report, Quarter Four, 2010, published by PBC on its website.

domestic and overseas institutions became possible; in 2010 financial investment is facilitated, overseas institutions are allowed to invest in China's inter-bank bond market, and a pilot scheme for the RMB Qualified Foreign Institutional Investors (RQFII) yuan was launched in 2011, with 86 qualified institutions from 10 countries and a total investment of 280 billion yuan until the third quarter of 2014. There're 16 RMB offshore clearing centers worldwide; direct trading is available between the RMB and 8 different currencies. And the RMB has become the 7th largest reserve currency in the world. These all point to a fact that the RMB is going to become an internationalized currency, and the question of the appropriate value of the RMB is more and more crucial.

1.2 The research of the RMB in this thesis

The background of the RMB exchange rate issues suggests the importance of understanding and properly measuring the RMB's equilibrium exchange rate. Theoretically, it requires an adoption of a suitable model of equilibrium exchange rate into China's situation, the existing achievements in measuring the equilibrium exchange rates for developing countries will be utilized as well as tested here in our research of China's RMB. Pragmatically, the estimation of the RMB's equilibrium exchange rate provides a necessary benchmark for us to judge whether the currency is, as alleged to be, kept basically at an adaptive and equilibrium level.

We are trying to answer the following three questions through our research in this thesis. First, Why the Behavioral Equilibrium Exchange Rate (BEER) approach is utilized here in measuring the RMB's equilibrium exchange rate and misalignment? And what makes the BEER approach more suitable a method for developing countries compared to the Fundamental Equilibrium Exchange Rate (FEER) approach? Second, What equilibrium relationship, if there's any, exists between the RMB's actual real effective exchange rate and different combinations of economic fundamentals? Third, how did RMB's equilibrium real effective exchange rate evolve during the past 20 years? And to what extent is the actual RMB value diverged from its equilibrium level?

It should be pointed out that the objective of our research in this thesis is the real effective exchange rate (REER) of the RMB, based on the argument that the REER is a more scientific and more appropriate measure than bilateral rates, and that it plays a more effective

role in the trade adjustments and balance of payments. Hence it's more relevant and scientific in reflecting the comprehensive international competitiveness of China.

The rest of the thesis is organized in four chapters.

In the second chapter, we rationalize our adoption of the Behavioral Equilibrium Exchange Rate (BEER) approach in measuring the equilibrium exchange rate of the RMB by analysing its advantages compared to an other most commonly used approaches, FEER; we then provide a summary of existing literatures on measuring RMB's equilibrium exchange rate and misalignment.

In the third chapter, we introduce the equilibrium exchange rate model for developing countries established by Montiel (1999). Following the theoretical model, we then introduce the empirical methodology utilized in our research to estimate equilibrium relationships between REER and other economic variables, the Vector Error Correction Model (VECM) which is a cointegration technology that makes it possible to conduct empirical research under the BEER framework.

In the fourth chapter, we conduct an empirical study of the real effective exchange rate (REER) of the RMB during period from 1995 to 2014 using quarterly data. The construction and specification of the VECM will be reported in detail by procedure, and the equilibrium relationship between the REER and fundamental economic variables such as 'relative' productivity growth will be revealed by the error correction term in the VECM. We finally estimate the RMB's equilibrium REER based on the equilibrium relationship and the permanent levels and trends of economic variables.

In the fifth chapter we summarize the research by providing some comments toward our discoveries on the dynamic behavior of the equilibrium REER and the misalignment of the RMB.

The econometric software that is used in this thesis for empirical studies is Stata/MP 13.0.

2 Behavioral Equilibrium Exchange Rate approach and literature review

In this chapter, we first discuss the Behavioral Equilibrium Exchange Rate approach in a comparative perspective; the advantages of the BEER relative to the FEER approach rationalize our adoption of the BEER approach in this thesis. Then, a review of literature is provided in the second part of this chapter.

2.1 BEER approach: a comparative analysis

The Behavioral Equilibrium Exchange Rate approach put forward by Clark and Macdonald (1998) was a significant progress in the study of the equilibrium exchange rate. Here we start with the concept of equilibrium exchange rate and follow with a comparative analysis of BEER with the Fundamental Equilibrium Exchange Rate (FEER), another frequently adopted approach.

The concept of equilibrium exchange rate was originally put forward by Ragner Nurkse (1945), who defined the equilibrium exchange rate as the exchange rate that is associated with the simultaneous attainment of both internal and external balance. The internal balance is the equilibrium status in the nontradable goods market, while the external balance stands for 'sustainable' balance between current and capital accounts. Following the original definition of the equilibrium exchange rate, some approaches of equilibrium exchange rate determination were developed. One of the most influential achievements was made by J. Williamson (1983), he put forward the framework of Fundamental Equilibrium Exchange Rate (FEER), in which the equilibrium exchange rate is defined to be the one that is formed under a sustainable, desirable current account balance under the condition of external balance expressed in the balance-of-payments equation (1), given that the internal balance is satisfied, i.e. the output is at its potential level and the inflation is kept at low and sustainable level.

$$CA^* = -KA^* \tag{1}$$

Where CA^* stands for a desirable and sustainable value of current account, and KA^* stands for a desirable and sustainable value of capital account. The equation implies that in

equilibrium, a country's current account deficit should be financed with sustainable capital inflows.

FEER is an idealized general equilibrium framework in a sense that it only considers the role of real economic factors (the 'fundamentals') in determining equilibrium exchange rate, so it is free from short-term nominal disturbances. For example, the equilibrium level of current account balance in equation (1) is mutually determined by fundamentals including the real effective exchange rate, potential levels of output of both home and foreign countries.

However, though being theoretically scientific as a general equilibrium framework, the FEER approach is not suitable for the research of developing countries like China, also it is difficult to utilize empirically.

First, the FEER's analytical framework is based on the precondition of the maintenance of a 'sustainable', 'desirable' current account balance illustrated by equation (1). For China however, the equality in equation (1) is never satisfied, as is evidenced by a sustained 'twin surplus' of current and capital account for decades. Yet this does not necessarily imply a severe currency misalignment or economic disequilibrium for China. The current account balance that should be considered as 'sustainable' and 'desirable' varies according to different specific situations of economies; we should not simplify the problem by exerting equation (1) to all countries without taking account of different status of the economies. For many emerging economies like China at present as well as most industrialized countries throughout history, a prolonged current account surplus is usually a natural outcome and a necessary phase of economic catching-up.

Second, the FEER approach contains a large amount of parameters that must be estimated and the estimations are always prone to subjective judgments. For example, the 'desirable', 'sustainable' current account balance is ultimately determined by the estimation of the economy's potential output level, i.e. the output gap, as well as the price elasticity of supply and demand in international trade. However, these parameters cannot be measured precisely in reality, especially in the context of China. Unlike industrialized economy, China's speed of economic growth is still high with plenty of technological progress and structural changes cross economic sectors and within different industries. Given the dynamic characteristic of the Chinese economy, the potential output and the output gap are difficult to measure. Also, the price elasticity of supply and demand make sense theoretically as a

microeconomic concept, in reality however, it is difficult to quantify due to the unobservable and ever-changing utility functions of economic representatives.

Starting from the limitations of FEER approach, Clark and Macdonald (1998) put forward a more inclusive and flexible approach, the Behavioral Equilibrium Exchange Rate (BEER). In BEER, the equilibrium exchange rate is determined by a group of properly selected explanatory variables, which includes the fundamental factors in the FEER approach such as productivity growth, as well as other factors that affect the behaviour of the actual exchange rate in medium or short run, such as monetary policy. In estimating the equilibrium exchange rate, the BEER approach takes advantage of great achievements of cointegration technology in time-series econometrics. It first estimates the systematic equilibrium relationships between the actual exchange rate behaviour and economic variables; the relationship is usually illustrated in a reduced-form expression, which is the cointegration equation like equation (2)

$$e_t = \beta_1 X_{1t} + \beta_2 X_{2t} + \tau T_{3t} + \varepsilon_t \tag{2}$$

Where e_t is the real effective exchange rate (REER); X_{1t} is a vector of long-run fundamentals that persistently affect the real effective exchange rate, X_{2t} is a vector of medium-term fundamentals, and T_{3t} is a vector of transitory factors that only have short-term effects on the real effective exchange rate; β_1, β_2 and τ are vectors of reduced-form coefficients. ε_t is the error term (term of random disturbances).

Then the equilibrium level of exchange rate is estimated based on the cointegration relationship and the potential trend of variables. The framework is summarized as equation (3).

$$e^* = e\left(\bar{X}_1, \bar{X}_2\right) \tag{3}$$

Where e^* stands for the equilibrium exchange rate, which is determined by the sustainable values of the long run and medium-run fundamentals $\bar{X}_1, \bar{X}_2$ through the equilibrium relationship e.

In Clark and Macdonald (1998), the long-run exchange rate is a function of 5 fundamentals including the interest differential, the risk premium, the terms of trade, the Balassa-Samuelson effect, and net foreign assets. Reduced-form models were established for the US dollars, German Marks, and the Japanese Yen using a BEER approach. Their research reached well-explained conclusions about the relationship between the variables in the system, and about the equilibrium exchange rate in a BEER sense.

BEER's advantages compared to the FEER approach can be summarized in the following two aspects.

The first advantage is bigger flexibility in variable selection. The incorporation of short-tern factors in the BEER framework makes it more capable of precisely capturing the dynamic behavior of equilibrium exchange rate, thus BEER is more realistic than FEER. Meanwhile, BEER allows people to discretionarily select different groups of economic variables according to the economic characteristic of the research objectives. This enables us to differentiate between developing countries and developed countries by adopting a more suitable theoretical framework. For example, for a country that is not open to the international financial market and capital flow is tightly controlled, the interest differential in Clark and Macdonald's original model for USD, etc. may better be excluded from the variable set in the BEER model for this country, while some other variables such as export supplements should be included given the existence of trade protectionism. Government expenditure should also be included given that the economy of the country is more government-controlled than liberalized.

The second advantage is its applicability for empirical research. As can be recognized from its name, BEER focuses more on the behavioral characteristics of the equilibrium exchange rate, rather than how the equilibrium exchange rate is determined by the equilibrium values of the predetermined real economic fundamentals. Thus it successfully avoids the overwhelming tasks to estimate a large number of parameters in FEER that might be unobservable by nature. For example, in BEER's framework there's no necessity of estimating the economy's potential output level and the output gap, and this does not hamper us from detecting the equilibrium relationship between productivity and exchange rate (using actual data), and estimating the equilibrium exchange rate based on the variables' permanent values and the equilibrium relationship. Meanwhile, the development of cointegration technology, especially the application of the Vector Error Correction Model (VECM), gives

BEER more explanatory power in an empirical sense, and makes it much more convenient to conduct empirical study.

2.2 Existing studies of the RMB's equilibrium exchange rate: a literature overview

The theoretical and empirical studies of the RMB's equilibrium exchange rate are basically divided into three groups according to different approaches adopted in measuring equilibrium exchange rate.

The first group is the studies based on the theory of Purchasing Power Parity (PPP), such as W.L.Chou et al (1997), and Sabramanian (2010), etc. most of which studies estimated the bivariate relationship of income and exchange rate and used panel regressions in the empirical studies. The results usually pointed out significant misalignments of the RMB exchange rate during the sample periods. However, although the PPP method is widely used in developed countries, it is quite problematic in the studies of developing countries, so there're actually more studies discussing the shortcomings of PPP, such as Paul. G. J. O'Connell (1998), Francisco Maeso-Fernandez et al (2006), Yin-Wong Cheung (2010), etc. These studies reasonably pointed out the limitations of PPP in explaining exchange rates of developing countries' currencies. First, the model specification of a bilateral relationship lacks consideration of other economic variables which may also influence the exchange rate level; second, data availability in developing countries is always poor and not consistent across time; third, heterogeneity of sample countries and sample periods in the panel regressions implies that the estimated income-exchange rate relationships will differ a lot from the countries and time periods selected in the empirical studies, thus the resulting judgements of the RMB exchange rate are different. Yin-Wong Cheung (2007) discovered that when sample uncertainties and serial correlation are controlled properly, there's no evidence of significant misalignment of the RMB using PPP approach. Coudert and Couharde (2007) concluded that the real exchange did not appreciate despite the rapid catching-up, by evidencing a lack of 'Balassa—Samuelson' effect[4] at work in China, since there's no perfect flow of labour between sectors and capital across countries.

[4] The Balassa-Samuelson effect points to the distortion in PPP resulting from the international differences in relative productivity between the tradable and nontradable goods sector. Given a

The second group of studies is those based on the FEER approach. These include Goldstein and Lardy (2007) who discovered a 35%-60% undervaluation of RMB in 2007, Coudert and Couharde (2007) who concluded that the RMB was undervalued based on an estimation of sustainable current account surplus of 1.5% of GDP; Chuntian Hu et al (2010) who found that the RMB has been over appreciated by end of 2008, and You and Sarantis (2011) who discovered an over 25% undervaluation of RMB against USD. Cline and Williamson from Peterson Institute for International Economics conduct estimation of fundamental equilibrium exchange rates for the world's major currencies including the RMB every year since 2010. In their consecutive studies, the current account target are estimated for each country each year, and the RMB's exchange rate was estimated to have appreciated from a 30% undervaluation in 2010 to a 3-4% undervaluation in 2012, and is finally reached its equilibrium level in 2014. As were discussed in sector 2.1, the results of the FEER approach are highly dependent on the somehow subjective estimations of parameters such as the 'sustainable' and desirable current account balance, hence the result always vary across different settings of these variables, and thus provide poor estimations of the equilibrium exchange rate of the RMB.

The third group of studies are those that adopted the BEER approach. For example, Zhichao Zhang (2001) studied the real exchange rate of RMB in the period between 1955 and 2000, they discovered that RMB was in prolonged overvaluation during the period of central-planned economy, while the economic reform taken place afterward had brought it back towards equilibrium level; Xiaopu Zhang (2002) assessed the RMB's exchange rate from 1978 to 1999 and found that the exchange rate of RMB was close to the equilibrium level in 1999, they also suggested gradual reforms in RMB exchange rate policies.

Ming and Yoonbai (2006) studied the RMB exchange rate from 1978 to 2002 based on theories developed by Edwards (1989) and Montiel (1999) for developing countries, they built a vector error correction model and estimated a reduced-form single equation of real exchange rate and economic variables using the Engle-Granger two-step method, they

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competitive labor market and a 2-sector economy, if a country's productivity in tradable sector grows faster relative to that of the non-tradable sector, compared to the foreign country, the currency of this country will appreciate against the foreign currency. Similar to the PPP theory, the B-S theory also predicts that the economic catching-up will result in a real appreciation of the currency. The assumptions are that the global market is fully competitive and the labor can flow freely between sectors. Most researches based on PPP method are actually testing the existence of the B-S effect.

discovered that the most influential factors of RMB's equilibrium exchange rate are government expenditure, openness of economy and long-term productivity growth.

Yajie Wang et al (2007) studied the long-run equilibrium exchange rate of the RMB from 1980 to 2004, they adopted the Johansen technology in establishing the VECM, and concluded that there's no prolonged severe undervaluation of the RMB relative to the USD during the past 25 years; Jinchao Chen (2007) studied the RMB's equilibrium real exchange rate from 1994 to 2006, and found that the RMB was in steady appreciation since 1994 and has been undervalued during most part of sample period while the misalignment became smaller after the 2005 reform.

Tao Peng et al (2008) empirically examine the magnitude of the exchange rate misalignment of RMB against USD and conclude that the RMB was undervalued by 15% from 2002 to 2003 while overvalued from 1997 to 2002; Ye Qian et al (2012) estimated the RMB equilibrium exchange rate between 1994 and 2010, and found that the degree of misalignment of RMB had been eased a lot during the sample period; Christopher Gan et al (2013) empirically estimated the equilibrium exchange rate and misalignment of RMB's REER from 2005q3 by a reduced-form model out of VECM and concluded that the RMB was undervalued by a modest average of 6.7%.

Generally speaking, the overall messages brought about by most of the studies can be summarized as follows: First, there existed a divergence of the RMB from its PPP level, though the divergence can theoretically be explained by the Balassa-Samuelson effect, China doesn't show enough evidence for the existence of Balassa-Samuelson effect to explain the total currency misalignment, since both international capital market and domestic labour market of China are restricted. (See e.g. Coudert and Couharde 2007) Second, there was a consensus that the RMB was undervalued in the first decade of the 21st century, associated with the reality of huge current account surplus during that period. Third, the extent of undervaluation has been eased a lot, i.e. there was a sign of convergence of the RMB exchange rate towards its equilibrium level since 2005 (in the third group of studies) and 2010 (in Cline and Williamson). And the convergence was caused by the continuing real appreciation of the RMB rather than a depreciation of the equilibrium exchange rate, since most studies estimated an appreciating equilibrium exchange rate after 2003; Forth, studies based on the BEER methodology commonly discovered sustainable relationships between the RMB's exchange rate and some fundamental economic factors, such as productivity,

government spending, openness (or commercial policy or trade policy), terms of trade, money supply, as well as net foreign assets.

However, due to the diverse methodologies adopted and different data sets and sample periods that were selected, the studies differed a lot in estimations of undervaluation, basically, the studies using the FEER approach always pointed to larger disparity than the ones using the BEER approach. Meanwhile, there are very few studies on the current status of the RMB exchange rate, yet Cline and Williamson have argued that the RMB is basically properly valued in 2014, we are still curious about whether same conclusion would be reached using the BEER approach based on variables from the equilibrium exchange rate theory for developing countries. We also suspect that the RMB has already become overvalued rather than remain at the equilibrium value. If so, we want to discover to what extent has the RMB been misaligned recently.

3 Montiel's equilibrium exchange rate model and our empirical methodology

In this chapter we describe the theoretical model, which our research of the RMB equilibrium exchange rate is based on. This model is developed by Peter J. Montiel and was introduced in his book with Lawrence E. Hinkle, 'Exchange rate misalignment: concepts and measurement for developing countries', A World Bank Publication, Oxford University Press, 1999. The second important part of this chapter is to introduce how the empirical technology of cointegration that is utilized in our research based on the idea of BEER and on Montiel's framework.

3.1 Montiel's equilibrium exchange rate model

In this section we introduce Montiel's Long-run Equilibrium Real Exchange Rate (LRER) model from four aspects: definition of 'sustainability' and LRER, behavior of economic representatives, conditions for general equilibrium and the exogenous influential factors of equilibrium.

3.1.1 Sustainability and the LRER: definition

The core of Montiel's long-run equilibrium exchange rate framework for developing countries is the term 'sustainability', which was strengthened by Montiel in view of the dynamic properties of equilibrium exchange rate.

According to Montiel (1999a), there are three types of variables that affect the economy's internal and external balance, and the real exchange rate can be expressed as a function of these variables like equation (4)

$$RER_t = F\left(X_{1,t}, X_{2,t}, X_{3,t}\right) \tag{4}$$

Where X_1 stands for endogenous or 'predetermined' variables like consumption, the exchange rate and the interest rate; X_2 stands for policy variables such as commercial liberalization policies and capital control; X_3 stands for other (external) exogenous variables related to foreign countries, such as the world interest rate, and productivity growth of foreign countries.

The endogenous variables are determined by other variables and the expectation of themselves, and can be expressed as equation (5), which is also a representation of short-term equilibrium relationship between endogenous and exogenous variables.

$$\dot{X}_{1,t} = G\left(X_{1,t}, X_{2,t}, X_{3,t}\right) \tag{5}$$

Where the dot above the variable means the change of the predetermined variables over time.

The term 'sustainability' contains the following two implications:

First, the policy variables and other exogenous variables are identified by their permanent components, i.e. at 'sustainable' values, as can be expressed by equation (6):

$$\Delta X_{i,t} = X_{i,t} - X_i^* = 0 \tag{6}$$

Where i=2, 3, X_i^* stands for the permanent value of variable i, and $\Delta X_{i,t}$ stands for the difference between actual and permanent values of policy variables and other exogenous variables, i.e. the transitory components

Second, the endogenous variables have stopped evolving overtime endogenously, i.e. at steady state values, as can be expressed by equation (7):

$$\dot{X}_{1,t} = G\left(X_1^*, X_2^*, X_3^*\right) = 0 \tag{7}$$

Where $X_1^* = X_1^*\left(X_2^*, X_3^*\right)$.

In sum, the long-run equilibrium in Montiel's context is a short-run equilibrium conditioned on particular values of the three types of "forcing" variables, specifically on the permanent values of the policy and exogenous variables. Hence the long-run equilibrium exchange rate (LRER) can be expressed as equation (8):

$$LRER = F\left[X_1^*\left(X_2^*, X_3^*\right), X_2^*, X_3^*\right] = H\left(X_2^*, X_3^*\right) \tag{8}$$

To avoid the troubles in analysing LRER based on the theoretical definition of 'sustainability', Montiel also provided practical advices on how to obtain the sustainable

values of the policy variables and the external exogenous variables. For external exogenous variables, we can take advantage of statistical technologies to identify the 'permanent' component empirically; while for policy variables, we can also substitute the 'optimal' values that depend on economic structures and the policymakers' objective functions with arbitrary values that are considered to be sustainable in principle. This method saves us troubles and may not lead to a bias, but it may be inaccurate due to the same pitfalls of the FEER approach, that is, discretionary and subjectivity. Fortunately, the development of cointegration technology makes it more empirically feasible for estimation of sustainable values in equilibrium, as was evidenced by Elbadawi (1994). We'll come closer to it later when introducing our empirical methodology.

3.1.2 Behaviors of economic representatives: An analytical framework

As is mentioned at the beginning of this chapter, we declare that the formal model follows Montiel (1999b) in his book with Lawrence E. Hinkle, 'Exchange rate misalignment: concepts and measurement for developing countries', A World Bank Publication, Oxford University Press, 1999. Chapter 6. To save space, the exposition in this thesis will be brief.

The model considers a representative small open economy, which consists of tradable and nontradable goods sector; and has fully flexible wage and price. [5] There are three groups of economic representatives: producers, households and the policymaker (in the consolidated public sector).

The exchange rate studied here is the internal real exchange rate, i.e. the relative price of tradable goods T to nontradable goods N: $e = \frac{P^T}{P^N}$. Thus an increase in e represents a relatively decrease in the price of nontradables, which is a real depreciation, and vice versa.

[5] As we'll see, though this representative model doesn't suit China's situation, where the financial market is not liberalized, and domestic labor and capital flows are to a large extent restricted; We can still take advantage of this basic analytical framework, given its ready adaptability. Economic variables will be selected according to China's reality.

a. Behavior of producers

The production sector produces both tradable and nontradable goods. Given that the labour can freely flow cross sectors, the behavior of producers is determined by the profit maximization conditions: $y'_T\left(L_T\right)=w$ and $y'_N\left(L_N\right)=we$, where y_T and y_N stand for the output in tradable and nontradable sectors respectively, in terms of tradable goods, L_T and L_N stand for the labour demand in tradable and nontradable sectors respectively, w stands for the real wage in terms of tradable goods.

The equilibrium in the labour market is represented by the equality of labour demand and supply: $L_T\left(w\right)+L_N\left(we\right)=L$, which implies a negative relationship between real wage and real exchange rate: $w=w\left(e\right)$ and $\frac{\partial w}{\partial e}=\frac{-wL'_N}{L'_T+L'_N e}<0$.

Finally we have the negative relationship between total real output in terms of tradable goods and the real exchange rate:

$$y=y_T+\frac{y_N}{e} \tag{9}$$

$$\text{i.e. } y\left(e\right)=y_T\left[L_T\left(w\left(e\right)\right)\right]+y_N\left[L_N\left(e\cdot w\left(e\right)\right)\right]/e$$

Where $\frac{\partial y}{\partial e}=-\frac{y_N}{e^2}<0$, which means that the real exchange rate appreciates (e is reduced) when real output in terms of tradable goods increases, and vice versa.

b. Behavior of households

A representative household's earns wage income for saving, investment and tax payment; assume that they can choose between foreign currency[6] f_H and domestic currency m,

[6] In Montiel's original framework, f_H was defined to be foreign bonds, however, it makes no difference if we take it as foreign currency here, since both represent the foreign assets held by households. Meanwhile, we consider foreign currency to be more suitable than foreign bonds in terms of comparison with domestic currency.

i.e. $a = f_H + m$, and that the Uncovered Interest rate Parity holds: $i = i^* + \varepsilon_t$. The behaviour of households is determined by solving the utility maximization problem:

$$\underset{c=\{C_T,C_N\}}{Max} \int u\left(C_T, C_N\right) e^{-\rho t}\, \mathrm{d}t$$

Subject to the budget constraint: $\dot{a} = y + \left(i^* + \varepsilon\right) f_H - t - \left(1+\tau\right)c - \left(\varepsilon + \pi_w\right)a$.

Where c is the total consumption in terms of tradable goods; C_T and C_N are consumptions of tradable and nontradable goods respectively, in terms of tradable goods; $c = C_T + C_N$; ρ is the parameter of time preference; $\dot{a}$ is the change in net asset, which is composed of wage income y, interest income of foreign assets $\left(i^* + \varepsilon\right) f_H$, lump-sum tax t, consumption expenditure $\left(1+\tau\right)c$ and capital income $\left(\varepsilon + \pi_w\right)a$. i^* is the foreign interest rate, ε is the depreciation of domestic currency, τ is the transaction cost related to consumption, π_w is the foreign inflation.

The households' utility function is set to be in a Constant Relative Risk Aversion (CRRA) form: $u\left(C_T, C_N\right) = \dfrac{\left(C_T^{\theta} C_N^{1-\theta}\right)^{1-\sigma}}{1-\sigma}$. Solving the utility maximization problem gives rise to the optimal consumption of tradables and nontradables:

$$C_N = \left(1-\theta\right)ec,$$

$$C_T = c - C_N = \left(1-\left(1-\theta\right)e\right)c$$

c. The consolidated public sector

The representatives of public sector are the central bank and the government. The former offers credit to the latter via monetary supply, while the latter gets credit support from the former and get tax income from households for expenditures on tradable and nontradable goods. The budget constraint can thus be expressed by $\dot{f}_c = t + rf_c + \left(\dot{m} + \pi^* m\right) - \left(g_T + \dfrac{g_N}{e}\right)$,

where f_c is the net foreign asset held by the public sector; g_T and g_N are government consumptions for tradable and nontradable respectively.

The cost of borrowing from a foreign country that is charged by creditor country contains two parts: interest i_w and the risk premium $p\left(f\right)$, which is negatively related to the net asset held by the domestic country f .

3.1.3 Equilibrium conditions

a. Short-term equilibrium

The short-term equilibrium condition represents the relationships between endogenous variables f , c , e , i and the exogenous variables π_w , i^*, g_N .

The short-term external equilibrium is represented by the relationship between i and f , and is expressed by equation (10), which is the uncovered interest rate parity condition adjusted for a risk premium, it implies that the returns of investment at home and abroad should equal:

$$i = r + \pi_w + p\left(f\right) + \varepsilon \tag{10}$$

The short-term internal equilibrium is represented by the relationship between e and c based on the condition that the nontradable goods market clears: $y_N\left(e\right) = C_N + g_N = \left(1-\theta\right)ec + g_N$, and the equilibrium is expressed by equation (13):

$$e = e\left(c, g_N\right) \tag{11}$$

Remember that $C_N = (1-\theta)ec$ is the optimal consumption of non-tradable goods underpinned by the households' utility function. $\frac{\partial e}{\partial c} < 0$ and $\frac{\partial e}{\partial g_N} < 0$, i.e. an increase in consumption and an increase in government consumption in nontradable sector both imply a real appreciation.

When g_N and c increase, the demand for y_N increase, P_N increases as a result, so the relative price of tradable goods to nontradable goods decreases, i.e. $e = \frac{P^T}{P^N}$ decreases, which is a real appreciation.

b. Long-run equilibrium

The long-run equilibrium is the relationship between different variables when endogenous variables are at their steady-state values, i.e. $\dot{c} = \dot{e} = \dot{i} = 0$. To be more specific, the long-run equilibrium is expressed as the relationship between endogenous variables e and c given particular values of exogenous variables g_N when other endogenous variables f , i , τ are at their steady-state levels: f^* , $\bar{i}$, τ^*

Figure 1 shows that the internal balance (IB) and the external balance (EB) together determine the equilibrium levels of exchange rate and consumption.

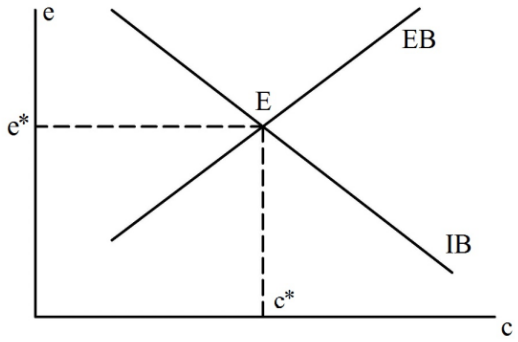


Fig. 1 The long-run equilibrium

The EB curve illustrates the equilibrium relationship between e and c under the long-term external balance represented by equation (12):

$$\pi_w f^* = y_T\left(e\right) + \left(\rho + \pi_w\right) f^* - \left(\tau^* + \theta\right) c - g_T \tag{12}$$

Which implies a positive relationship between real exchange rate and consumption given the balance of current and capital account, and a sustainable debtor or creditor position. A real depreciation (a rise in e) enlarges the current account surplus, which requires domestic absorption to raise (an increase in c) to rebuild external equilibrium. This relationship is illustrated in Figure 1 by an upward curve EB.

The IB curve illustrates the equilibrium relationship between e and c under the long-term internal balance represented by equation (12):

$$e = e\left(c, g_N\right), \text{ where } \frac{\partial e}{\partial c} < 0 \text{ and } \frac{\partial e}{\partial g_N} < 0.$$

The expression of internal equilibrium condition is the same as that of the short-term. It implies a negative relationship between private consumption and real exchange rate, as well as a negative relationship between government consumption in nontradable sector and real exchange rate, on the condition that the nontradable goods market clears. When consumption increases (a rise of c), the over-demand and under-supply of nontradable goods increase the price of nontradables. This implies the need of a real appreciation of the home currency, in order to re-establish internal equilibrium by shifting demand toward tradable goods and supply towards nontradable goods. This relationship is illustrated in Figure 1 by a downward curve IB.

The intersection of the IB and EB curves illustrates the equilibrium level of real exchange rate and total private consumption.

3.1.4 The exogenous influential factors of equilibrium exchange rate

Montiel classified the economic factors that influence the equilibrium exchange rate into four categories.

a. Supply-side factors

The supply side factors mainly include productivity growth. For example, the relative productivity of domestic country in the tradable sector compared to its nontradable sector results in a real appreciation of exchange rate by moving both curves downward as shown in Figure 2. If productivity growth in the tradable sector is higher than that in the non-tradable sector in domestic country compared to the foreign country, both curves move down.

A higher productivity growth in the tradable sector increases the real wage and capital return in tradable sector, attracting resources from nontradable sector into tradable sector for higher rate of return, thus reducing the supply of nontradable goods, increasing prices of

nontradable goods as well as the overall wage and price level. This is the well-known Balassa-Samuelson effect.

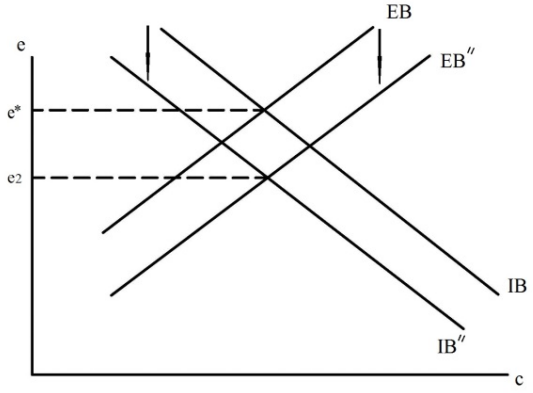


Fig. 2 supply-side factor: the Balassa- Samuelson Effect

b. Demand-side factors

In a developing country's context, the demand-side factors are mainly represented by government expenditure. An increase of government expenditures on tradable goods moves the EB curve upward from EB to EB' and leaves IB curve unchanged, thus results in a real depreciation of equilibrium exchange rate from e^* to $e1$; while an increase of government expenditures on nontradable goods moves the EB curve downward EB to $EB''$and results in a real appreciation of the equilibrium exchange rate from e^* to $e2$. These are illustrated in Figure 3.

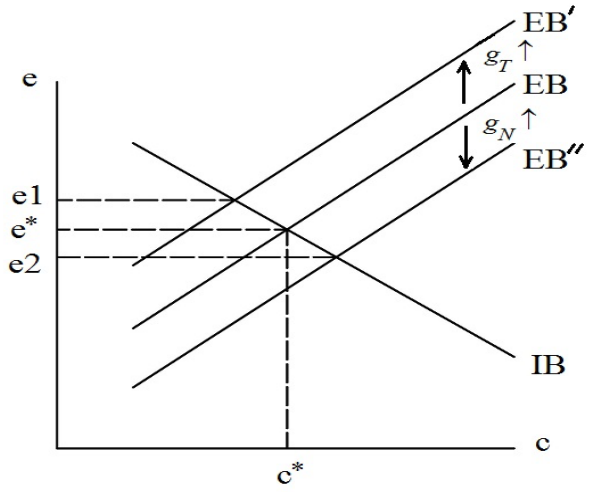


Fig. 3 Demand-side factor: Gov. expenditures on tradable and nontradable goods

c. External economic environment factors

The most common external factor is the terms of trade, an improvement of terms of trade implies an increase of exported products relative imported products, the effect is the same as that caused by a higher productivity growth in the tradable goods sector, as depicted in Figure 2.

d. Trade policy-related factors

These factors include the government's engagement promoting commercial liberalization, for example, reduction of export subsidies to facilitate foreign trade. This policy encourages the production resources to move towards nontradable sector from tradable sector and results in an over-supply in the nontradable sector; a real depreciation is required for rebuilding both internal and external balance by shifting resources back to tradable sector. Hence the effect on the equilibrium exchange rate is opposite from that of high productivity growth in the traded goods sector and that of the improvement in terms of trade.

To summarize, though the Montiel model is highly stylized and might not be good a representation of any particular developing economy, it represents a common analytical framework that can be generally adopted in such countries. It is based on the ideology of the BEER approach, in that the variables are not narrowly constrained within the supply-side of the economy, but are extended to a larger variety that includes demand-side factors, policy factors etc. Meanwhile, given the flexibility of variable selection, Montiel's framework can be reasonably adopted in different countries by incorporating varieties of phenomena and adjusting variables in the basic structure according to the particular context of the objective country, i.e. it has the virtue of ready adaptability as described by Montiel himself.

3.2 Empirical Methodology: VECM

As one significant achievement of modern time series econometrics, the cointegration technique put forward by Engle and Granger in 1987 enabled the empirical study based on the BEER approach, and also provided a feasible and reliable way to deal with the 'sustainability' problem in Montiel's theoretical framework, mitigating the concerns on the discretion and subjectivity related to unobservable 'desired' values. Elbadawi (1994) first took advantage of the cointegration technique in the research of equilibrium exchange rates for three developing

countries. He estimated the permanent components of the fundamentals and substituted them into the cointegrating equations to derive the long-run equilibrium real exchange rate. He found that the estimates fit the reality of the countries extremely well.

In this section we introduce the Vector Error Correction Model (VECM), the cointegration model that is adopted in our empirical study on the RMB's equilibrium exchange rate.

3.2.1 Model specification

As economic variables are often nonstationary, the traditional Ordinary Square method is prone to spurious regression; yet OLS regression on the stationary differenced series may also lead to misspecification. Cointegration technique provides good methodology to study nonstationary time series and their relationships. (According to Sean Becketti's book *Introduction to Time Series Using Stata*. Texas, US. Stata Press, 2013. Chapter 10.)

If n nonstationary time-series variables $y_1, y_2, \ldots, y_n$ are all non-stationary individually, there might exist certain linear combination of them that is stable, if so, the variables are found to be cointegrated.

First, n nonstationary time-series variables can be written in the Vector Autoregressive (VAR) form with order p like equation (13)

$$\begin{aligned} y_t &= u + \Phi_1 y_{t-1} + \Phi_2 y_{t-2} + \cdots + \Phi_p y_{t-p} + \varepsilon_t \\ &= u + \sum_{i=1}^{p} \Phi_i y_{t-i} + \varepsilon_t \end{aligned} \tag{13}$$

Where $y_t = \begin{bmatrix} y_{1,t} \\ y_{2,t} \\ \vdots \\ y_{n,t} \end{bmatrix}$, is a vector of n nonstationary time-series variables;

$u = \begin{bmatrix} u_1 \\ u_2 \\ \vdots \\ u_n \end{bmatrix}$ is a vector of n constants;

$\Phi_i = \begin{bmatrix} \Phi_{i,11} & \cdots & \Phi_{i,1n} \\ \vdots & \ddots & \vdots \\ \Phi_{i,n1} & \cdots & \Phi_{i,nn} \end{bmatrix}$, is an n×n matrix of cointegration parameters;

$\varepsilon_t = \begin{bmatrix} \varepsilon_1 \\ \vdots \\ \varepsilon_n \end{bmatrix}$ is a vector of n stochastic disturbances.

The VAR expression in equation (13) can be rewritten into a Vector Error Correction (VEC) form as equation (14), if there are cointegration relationships within $y_1, y_2, \ldots, y_n$.

$$\Delta y_t = \mu + \prod y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i y_{t-i} + \varepsilon_t \tag{14}$$

Where $\Pi = \sum_{j=1}^{p} \Phi_j - \mathrm{I}$ is the companion matrix, the rank of which would be any number between zero and n and this number implies the number of cointegration relationship exist in all variables; $\Gamma_i = -\sum_{j=i+1}^{p} \Phi_j$.

The VEC expression in equation (14) can be further written as a standardized and complete VEC form in equation (15) by decomposing the companion matrix Π as the inner product of the adjustment parameter vector α and the cointegration parameter vector β. β represents the cointegration relationship, i.e. equilibrium relationship.

$$\Delta y_t = \mu + \delta t + \alpha\beta' y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i y_{t-i} + \varepsilon_t \tag{15}$$

Where μ and δt stand for the linear trend and quadratic time trend respectively in the system.

Finally, we get the basic form of VECM as expressed by equation (16), where $\mu = \nu + \alpha\gamma$ and $\delta t = \tau t + \alpha\rho t$:

$$\Delta y_t = \nu + \tau t + \alpha\left(\beta' y_{t-1} + \gamma + \rho_t\right) + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-u} + \varepsilon_t \tag{16}$$

Based on equation (16), we now end up with five different model specifications depending on the different restrictions exerted on the deterministic trend μ and δt. The possible specifications are listed in Table 1, as was summarized by S. Becketti in his book *Introduction to Time Series Using Stata,* Stata Press (2013), Chapter 10.

Table 1. Model specifications of the VECM

	Specification	Restrictions
Form 1	Unrestricted trend	none
Form2	Restricted trend	τ=0
Form3	Unrestricted constant	τ=ρ=0
Form4	Restricted constant	τ=ρ=γ=0
Form5	No trend	τ=ρ=γ=ϑ=0

3.2.2 Equilibrium and adjustment in VECM

The basic form of VECM expressed by equation (15) contains two important parts that represent the long-run equilibrium and the short-term adjustment of variables.

The long-run equilibrium relationship in the system is represented by the 'error correction term': $\left(\beta' y_{t-1} + \gamma + \rho t\right)$, where β is the vector of cointegration parameters that tells us how the variables are correlated with each other systematically. Any circumstance in which the term differs from zero implies a deviation from equilibrium status, i.e. disequilibrium.

The short-run adjustment of variables in the system is represented by α, which is the vector of speed of adjustment parameters. α illustrates in which direction and at which speed different variables would adjust throughout time with the existence of present disequilibrium. Also note that if all adjustment parameters α equal zero, then no cointegration relationship

exists in this system, i.e. the rank of companion matrix $\Pi = \alpha\beta'$ equals zero. If some parameters equal zero while others don't, then the variables with zero α are weakly exogenous in the system.

3.2.3 VECM and equilibrium exchange rate of the RMB

In our empirical study, we'll establish a VECM for the real effective exchange rate (REER) of RMB and different groups of economic fundamentals based on the ideology of BEER approach and the arguments made by Montiel. The purpose is to estimate the equilibrium relationship between REER and supply-side factors, demand-side factors, international environment factors, policy factors. We'll also study the role of monetary factor in the equilibrium relationship in a relatively shorter time period. This can be illustrated in a reduced-form expression as follows:

LRER=e (supply-side factors, demand-side factors, international environment factors, policy factors)

Step 1

The first step is to know the time series properties of the variables, we should make sure whether they are stationary or not, or at which order are they integrated.

Step 2

The second step is to construct a Vector Autoregressive (VAR) model, and to determine the best number of lag basing on suggestions of information criteria such as AIC and SBC.

Step 3

The third step is to conduct trace-test under Johansen method to know the rank of companion matrix i.e. the number of cointegration relationships in the system, since the VECM can only be established properly when there's 'reduced rank' in the companion matrix. Full rank implies that the system is stable and zero rank implies no cointegration relationship. Our goal is to ensure a unique equilibrium (cointegration relationship) among the variable by testing whether the rank equals one, because the estimation of equilibrium REER will be based on a reduced-form expression of REER. Only when the equilibrium is unique, will the reduced-form expression derived from the error correction term in the VECM be reliable.

The maximum likelihood 'trace statistic' of Johansen method is $TR = T\sum_{i=r+1}^{N} \ln\left(1-\hat{\lambda}_i\right)$, a significant trace statistics implies that the null hypothesis is rejected.

Step 4

The Forth step is to estimate the VECM and analyse the equilibrium relationship and short-term adjustment that are embedded in the model.

Step 5

The final step is to estimate the equilibrium REER based on the equilibrium relationship and the permanent (smoothed) values of variables, by substituting the properly derived permanent values of variables into the equilibrium relationship. The Hodrick-Prescott filter is utilized here to separate the permanent and cyclical components of a variable. The H-P filter is the solution of the following minimization problem:

$\min_{\tau_t}\left\{\sum_{t=1}^{T}\left(y_t-\tau_t\right)^2+\lambda\sum_{t=2}^{T-1}\left[\left(\tau_{t+1}-\tau_t\right)-\left(\tau_t-\tau_{t-1}\right)\right]^2\right\}$, through which the permanent value of a variable is identified.

4 An estimation of equilibrium REER of the RMB

In this chapter we introduce the procedures and results of our empirical studies on the equilibrium real effective exchange rate of the RMB. The first section introduces the economic variables that are selected for establishing the VECM, followed by a detailed explanation of how we construct proxy variables for each of the economic indicators; the second section provides a description of the procedures by which we establish the VECM; the third section shows our discoveries. The sample period of our empirical study is the 20 years between 1995 and 2014. The period before 1995 are not considered due to the dual-exchange rate regime, and also due to the limited availability of data. We use quarterly data since this frequency is suitable for a time series analysis of 20 years' period, and for capturing the economic dynamic of China in both perspective of longer and shorter term.

4.1 Selection of variables and construction of proxies

Our selection of variables is based on Montiel's equilibrium exchange rate model, that is, the variables reflect the four types of shocks, supply-side, demand-side, international environment and policy. Meanwhile, when coming to China's reality, we make some adjustments: first, we study the real effective exchange rate of the RMB, rather than the bilateral real exchange rate of the RMB against USD, since the REER better reflects the overall competitiveness of China relative to its trading partners; Second, we don't include variables such as interest differential and capital flow, since China's capital market has not been fully liberalized so variables related to international capital would not enter the model as influential factors as described in Montiel's model of small open economy; in addition, data quality is low before 2005; Third, we incorporate monetary factors into the framework, based on the argument of Edwards (1989), that in a shorter term, the nominal factors represented by monetary disturbances exert influence on the real exchange rate, and in China's context, this is more likely to be true given strong government intervention in the market.

Another thing that may distinguish our research from the existing studies is the way in which the proxies are constructed. The proxies are expressed in a 'relative' and 'comparative'

sense, which is the ratio of China's level to the weighted average level of its trading partners. This method makes the proxies more associated with the meaning of 'effective' exchange rate. The partners are selected according to their trading volumes with China; using data from the IMF's Direction of Trade (DOT) database, we found the top three trading partners of China are the European Union (EU), the United States (US) and Japan (JP), with weights of 38%, 34% and 28% respectively (each are the average percentage from 2002 to 2014). The import and export between China and the EU, the US and JP in total count for 44% (on average between 2004 and 2013) of China's total amount of foreign trade. Yet the percentage is decreasing overtime, associated with an increasing share of trade between China and the emerging markets such as the South-eastern Asia.

Meanwhile, since some economic indices are not available for the EU, we need to calculate the value of EU as the weighted average of its major member countries. According to size of economy, we choose four countries as representative of the EU; they are Germany (GE), France (FR), the United Kingdom (UK) and Italy (IT), and their weights in the EU are 33%, 24%, 23% and 20% respectively.

The weighted average value of variable X is calculated as followed:

$$X\_p = \sum_i w_i X\_i$$

Where $i = EU, US, JP$, $w_{EU} = 38\%$, $w_{US} = 34\%$, $w_{JP} = 28\%$.

The value of the EU can be calculated by weighted average of four countries as followed:

$$X\_EU = \sum_j w_j X\_j$$

Where $j = GE, FR, UK, IT$, $w_{GE} = 33\%$, $w_{FR} = 24\%$, $w_{UK} = 23\%$, $w_{IT} = 20\%$.

a. The real effective exchange rate of the RMB

We use the Real Effective Exchange Rate Index published by the IMF's International Financial Statistics (IFS) database as proxy of the RMB's exchange rate, denoted by REER. The index is the average price of a unit of RMB expressed with a basket of foreign currencies;

it should be well noticed that the REER here is in the opposite direction of the exchange rate in Montiel's theoretical model, since a larger REER implies a higher value of the RMB.

Meanwhile, the index has been adjusted; the level in 2010 was fixed as 100.

b. Supply-side factor

We consider two types of supply-side factors.

The first is the relative productivity level of China relative to partners, represented by rltvPROD, the proxy is the ratio of China's real GDP index over its trade partners' weighted average real GDP index. We should note that theoretically, productivity should be represented by GDP per capita, in this thesis however, we use real GDP index instead, based on the argument that China's employment rate throughout the years of rapid economic growth was not so volatile, we consider the real GDP index to be a meaningful indicator of China's productivity; meanwhile, the GDP index is widely used as a proxy for China's productivity in the existing literatures.

The proxy is expressed as follows:

$$rltvPROD_t = \frac{rGDPindex\_CN_t}{rGDPindex\_P_t}$$

Where 'rGDPindex' stands for the real GDP index and $rGDPindex\_CN_t = \frac{nGDPindex\_CN_t}{GDPdeflator_t}$.

The indexes of the partners are published by IMF's IFS, which are seasonally adjusted and the value in 2010 is 100, the index of China is calculated using nominal GDP and the GDP deflator, the data are found in China's CSMAR database, to be consistent with partners, we calculate the index of nominal GDP (nGDPindex, 2010=100)

The second is the so-called Balassa-Samuelson Effect, which is China's relative productivity growth in tradable sector compared to partners ('relative relative' growth of tradable sector), represented by rltvPROD1. The proxy is China's ratio of CPI to PPI relative to the ratio of its partners. It is expressed as follows:

$$rltvPROD1_t = \frac{CPI / PPI\_CN_t}{CPI / PPI\_P_t}$$

More specifically, the overall price levels in the nontradable and tradable sectors can be proxied by the CPI and PPI indices respectively. Due to the fact that China is the world's factory that is importing raw materials from abroad and exporting its manufactures globally, while in the domestic market, residents' consumption is mainly composed of nontradable goods. Hence a relative productivity growth in tradable sector leads to a reduction in producer prices relative to the consumer prices, i.e. an increase in the CPI to PPI ratio. In short, the higher the ratio, the larger the 'relative relative' productivity level of China's tradable sector compared to its partners. The price indexes of China are downloaded from China's CSMAR database, while indexes of partners are achieved from the IMF's IFS database.

c. Demand-side factor

We choose government expenditure as the representative of demand-side factor, denoted by rltvGOVEX. The proxy is the government expenditure as percentage of the country's nominal GDP, and is calculated by the ratio of China's level to the weighted average level of its trading partners. Expressed as follows:

$$rltvGOVEX_t = \frac{GOVEX\_CN_t}{GOVEX\_P_t}$$

The higher the ratio is, the larger the size of China's government expenditure is relative to its partners. The data of government expenditure as well as the nominal GDP are from the IMF's IFS. Note that since we are not able to distinguish whether the government expenditure of China is more leaned towards tradables or non-tradables, we use total government expenditure to build up the proxy variable.

d. International economic environment factor

We use terms of trade as the representative of international economic environment factor, represented by TOT. The proxy is calculated by the ratio of China's export price index (*ExPi*) to import price index (*ImPi*), expressed as follows:

$$ToTt = \frac{ExPi_t}{ImPi_t}$$

A higher ratio implies an improvement of China's terms of trade. Both export and import price indexes are achieved from the CEIC Database of China economy.

e. Trade-related policy factor

As the trade-related policy factor reflects the government's policies to promote international trade and improve openness of commerce, it is denoted by FTPolicy. We use the proxy of total foreign trade (*Ex+Im*) as percentage of nominal GDP (*nGDP*) as a measurement of the country's degree of openness. Though this proxy is limited in fully capturing the policy behaviour, the idea is generally reasonable, that an increase of the ratio represents an increase of the economy's degree of openness and a reduction of the country's protectionism, which might in reality be caused by reduction of import taxes or trade promotions such as the setting up of free-trade zone. The expression of the variable is as follows:

$$FTPolicy_t = \frac{Ex_t + Im_t}{nGDP\_CN}$$

However, we should be well aware that the total export and import is actually a noisy measure of trade policy. It is problematic because the real exchange rate may affect both imports and exports. But a country is generally considered to be more opened (the government is more likely to be promoting foreign trade) if its total export and import counts for more of the national income.

The data of export and import, and China's nominal GDP is achieved from China's Statistical Yearbooks as well as the CSMAR database.

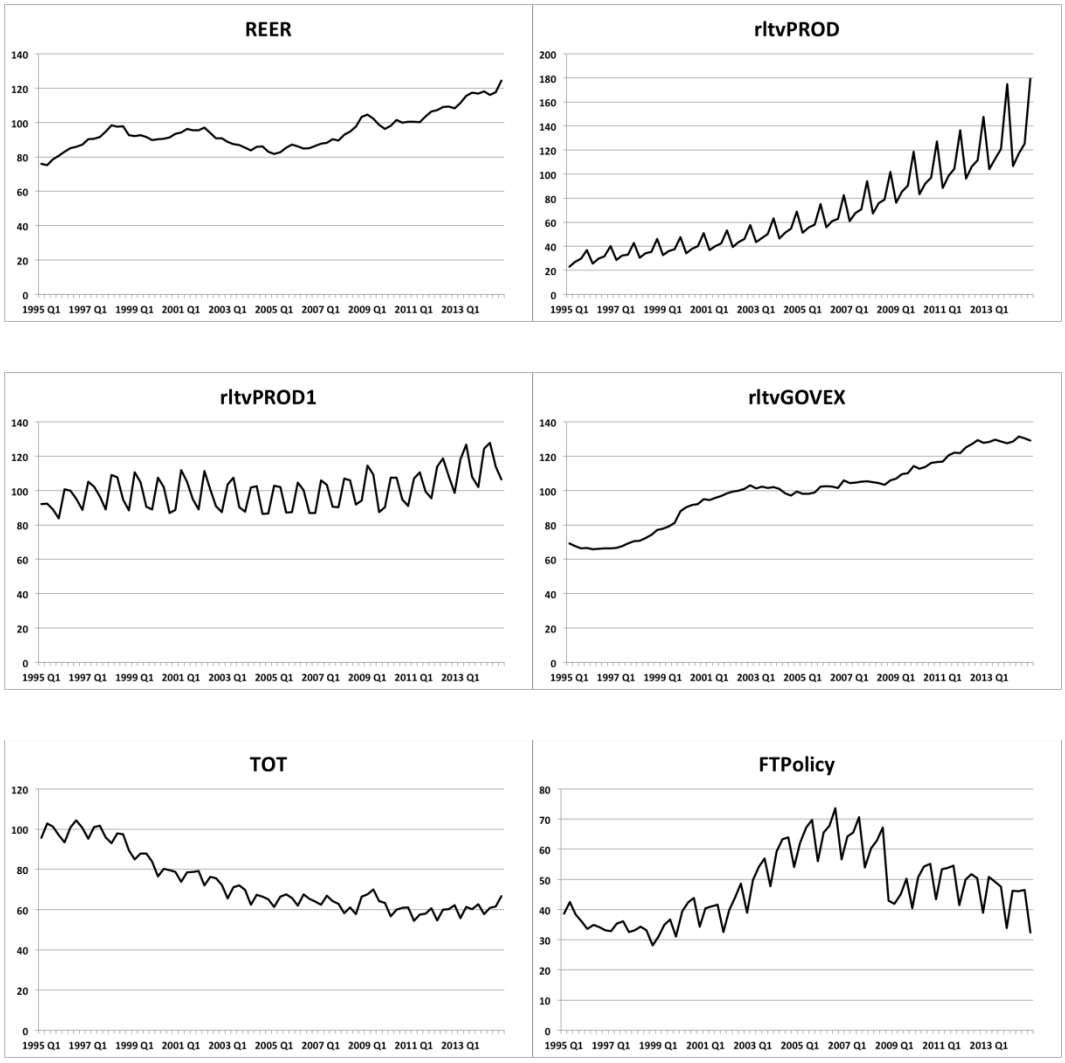
f. Monetary factor

Following the idea of Edwards (1989), we incorporate the relatively short-term but rather influential factor of monetary policy into our empirical model. The representative is China's money supply relative to that of the US, represented by rltvMONEY. We use M2 as

percentage of nominal GDP as a proxy of money supply, and the expression of this proxy is as follows:

$$rltvMONEY_t = \frac{M_2 / nGDP\_CN_t}{M_2 / nGDP\_US_t}$$

A larger ratio implies a more expansionary monetary policy of China compared to the US. The M2 data are achieved from IMF's IFS database.



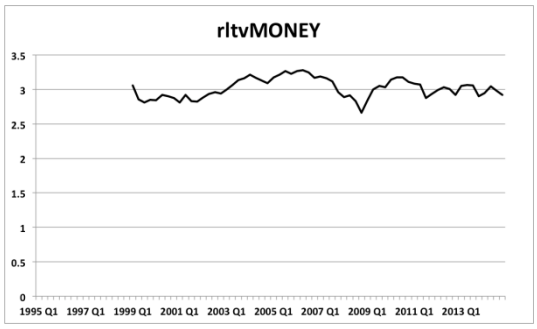


Fig. 4 A description of the evolution of variables

As is illustrated by figure 4, the RMB's REER has experienced periods of appreciation during 1995 to 1998, stable adjustment from 1999 to 2001, depreciation from 2001 to 2005, and appreciation afterwards, especially significant during the 4 years since 2010 till now. The rltvPROD as a measure of relative productivity growth of China compared to trading partners has been steadily increasing with increasing speed, meanwhile the series exhibits obvious seasonal pattern. The rltvPROD1 as a measure of China's 'relative relative' productivity growth in the tradable sector has remained relative stable and had a little increase throughout the sample period. It also exhibits obvious seasonal pattern. The rltvGOVEX as a representative of China's government expenditure as percentage of GDP relative that of its trading partners, kept increasing during the sample period. The TOT that is China's terms of trade have been deteriorating from 1995 to 2011, and kept relatively stable afterwards. It also exhibits seasonal pattern. China's foreign trade as percentage of GDP has increased from 1999 and peaked in period around 2005 to 2007, while reduced afterwards till now. It also exhibits seasonal pattern. The rltvMONEY that illustrates China's relative money supply compared to that of the US is generally stable except in period around 2008 when the financial crises took place in the US.

4.2 Estimation of VECM

We try to establish a VECM for four different combinations of variables; the potential combinations are listed in table 2.

Table 2. The groups of variables for VECM estimation

Variable	Group 1	Group 2	Group 3	Group 4
REER	✓	✓	✓	✓
rltvPROD	✓			✓
rltvPROD1		✓		✓
rltvGOVEX	✓	✓	✓	✓
TOT	✓	✓	✓	✓
FTPolicy	✓	✓	✓	✓
rltvMONEY			✓	

The ✓ in the table means that the according variable is included in the estimation.

Group 1, 2 and 4 capture the long-run fundamentals in the system, and they are differed by the proxies of productivity adopted, Group 1 only includes relative productivity growth of China, Group 2 only includes the Balassa-Samuelson Effect, while Group 4 includes both. Group 3 incorporates the medium-term nominal factor of money supply, while excluding the long-run productivity factor.

Step 1: check the time-series properties of variables

We first test the time series properties of the variables by the Augmented Dicky-Fuller (ADF) method. The ADF test for unit-root examines the following data generating process in equation (17)

$$\Delta y_t = \alpha_0 + \beta y_{t-1} + \alpha_1 t + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \varepsilon_t \qquad (17)$$

Where p is the orders of lags in the process.

The null hypothesis is the existence of unit root, i.e. $\beta = 0$, which implies that the series is nonstationary; while the alternative hypothesis is no unit root, i.e. $\beta < 0$, which implies the stationarity of the series.

Before conducting ADF test, we use different information criteria to identify the number of lags of variables the suggestions are listed in table 3. Meanwhile, as a practical

way suggested by Sean Becketti,[7] proper identification can be made according to frequency of data, which reflects the economic properties, for example, the suitable lag order for quarterly data is 4. We decide to take the suggestion by Min SC.

Table 3. Number of lags suggested by three information criteria

	Best number of lags suggested by		
Variable	Ng-Perron seq t	Min SC	Min Maic
REER	6	1	2
rltvPROD	9	9	7
rltvGOVEX	8	4	1
TOT	8	5	5
FTPolicy	5	5	5
rltvPROD1	4	4	4
rltvMONEY	6	4	2

The result of ADF test on the variables and their first order difference series (denoted with a 'd' ahead of the variable's name) is shown in table 4.

Table 4. ADF test results

Variables	No. of lags	DGP	ADF statistics	10% significance value
REER	1	trend	-1.043	-3.163
rltvPROD	9	trend	-1.634	-3.168
rltvGOVEX	4	trend	-3.025	-3.165
TOT	5	trend	-0.211	-3.166
FTPolicy	5	trend	-1.001	-3.166
rltvPROD1	4	trend	-0.285	-3.165
rltvMONEY	4	trend	-2.95	-3.175

[7] In his book 'Introduction to Time Series Using Stata'. Texas, US. Stata Press, 2013.

Table 4 cont. ADF test results

Variables	No. of lags	DGP	ADF statistics	1% significance value
dREER	1	drift	-5.531	-2.378
drltvPROD	3	drift	-3.536	-2.381
drltvGOVEX	3	drift	-2.675	-2.381
dTOT	5	drift	-3.675	-2.384
dFTPolicy	4	drift	-3.753	-2.382
drltvPROD1	4	drift	-3.807	-2.382
drltvMONEY	3	drift	-3.214	-2.397

For all original series of the variables, the ADF-test statistics are not significant at 10% significance level; we could not reject the null hypothesis of nonstationary; for all first-order difference series, the null hypothesis is rejected at 5% significance level, the series are stationary. Since there's no strong evidence to reject the conclusion that all variables are integrated of order 1, we accept that all series are I(1) as a reliable conclusion, which enables us to further conduct cointegration analysis.

Step 2: identify the number of lags in the VAR model

As is shown in table 5, Stata provides the suggestions of lag number for each of the four groups, based on four different information criteria: FPE, AIC, HQIC and SBIC, as well as the Likelihood Ratio. Almost all criteria point to a lag order of 4.

Table 5. Best lag number of VAR model

	LR	FPE	AIC	HQIC	SBIC
Group 1	4	4	4	4	4
Group 2	4	4	4	4	2
Group 3	4	4	4	4	4
Group 4	4	4	4	4	4

Step 3: identify the number of cointegration relationships in VECM

As is stated in the previous section, the goal of our empirical study is to identify the unique equilibrium relationship represented by the error correction term, and estimate the equilibrium exchange rate based on the relationship. So it's necessary to ensure the uniqueness of cointegration relationship in the VECM. Johansen test is adopted here to identify the rank of the companion matrix Π in the VECM expressed by equation (16). Stata produces the trace statistics, which are used to determine the number of cointegrating equations in a VECM; an insignificant trace statistics implies that we cannot reject the according null hypothesis.

The Johansen test shows that the rank of companion matrix in VECM constructed by variables in group 4 is not 1, indicating the existence of multi-equilibrium, while VECM constructed by variables in the first three groups satisfy our requirement of rank=1. The Johansen test results for the three VECMs are listed in table 6.

Table 6. Results of Johansen test

VECM1 (lag=4)	Trace statistics	
H_0	Unrestricted	τ=0
r＝0	91.8023	160.2269
r<=1	53.1727*	71.8663
r<=2	25.8011	38.5597*
r<=3	12.0506	20.8669

VECM2 (lag=4)	Trace statistics			
H_0	Unrestricted	τ=0	τ=ρ=0	τ=ρ=γ=0
r＝0	83.9086	94.6944	78.0265	100.0534
r<=1	45.1594*	55.9441*	45.1295*	62.5818
r<=2	19.0595	29.1367	20.7365	32.2926*
r<=3	8.2032	17.1973	8.843	13.4425

Table 6 cont. Results of Johansen test

VECM3 (lag=3)	Trace statistics		
H_0	Unrestricted	τ=0	τ=ρ=0
r＝0	89.2762	97.3574	54.3893*
r<=1	38.8277*	45.9699*	30.8695
r<=2	19.2253	26.071	13.5434
r<=3	6.5836	11.4809	4.546

The notation * represents the first test statistic is insignificant at a 10% significant level.

Due to the fact that the test results are sensitive to different specifications of VECM model, we conducted the test separately for different restrictions on the deterministic terms.

To interpret the test results, let's consider VECM1 for example. With the restriction τ=0 for the deterministic variables. Here, in the first row the null hypothesis is rank=0 against the alternative hypothesis rank>0. The critical value for this test, given 5 variables and a 10% significance level, is about 83. The test statistics is 160.2, which exceeds the critical one, hence, is significant and implies that the null hypothesis is rejected.

Based on the test results, we cannot reject that the rank of the companion matrix of the first VECM is 1, when the model is specified to be 'unrestricted', while we cannot reject that the rank is 2 when the model is specified to be 'restricted trend' (τ=0). For the second VECM, we cannot reject that the rank of its companion matrix is 1 when the model is specified to be 'constant' (τ=ρ=0), while we cannot reject that the rank is 2 when the model is specified to be 'restricted constant' (τ=ρ=γ=0). As for the third VECM, we cannot reject that the rank of its companion matrix is 1 when the model is specified to be 'restricted trend' (τ=0), while we cannot reject that the rank is 0 when the model is specified to be 'constant' (τ=ρ=0). Hence the three models are specified as 'unrestricted', 'unrestricted constant' and 'restricted trend' respectively in order to ensure the uniqueness of integrating relationship in the VECM.

Step 4: estimate the VECM

Now we are interested in three VECMs that consist of different groups of variables, we aim to identify the equilibrium relationships (represented by the error correction terms) in these VECMs that can be expressed in the following reduced-form equations (18) to (20):

$$REER = cons_1 + \beta_{11} rltvPROD + \beta_{12} rltvGOVEX + \beta_{13} TOT + \beta_{14} FTPolicy + \rho_1 t \quad (18)$$

$$REER = cons_2 + \beta_{21} rltvPROD1 + \beta_{22} rltvGOVEX + \beta_{23} TOT + \beta_{24} FTPolicy + \rho_2 t \quad (19)$$

$$REER = cons_3 + \beta_{31} rltvGOVEX + \beta_{32} TOT + \beta_{33} FTPolicy + \beta_{34} rltvMONEY + \rho_3 t \quad (20)$$

We first conduct Maximum Likelihood tests on the restrictions exerted upon the deterministic terms to see whether our model specifications are proper. Table 7 shows the test results, where we take 1% as the threshold of test statistics.

Table 7. Tests on model specification

Model 1:			
H_0	χ2 statistic	P value	Conclusion
τ=0	18.69	0.0009	Reject τ=0

Model 2:			
H_0	χ2 statistic	P value	Conclusion
τ=0	10.78	0.0291	Accept τ=0
τ=ρ=0	5.85	0.0155	Accept τ=ρ=0
τ=ρ=γ=0	17.45	0.0016	Reject γ=0

Model 3:			
H_0	χ2 statistic	P value	Conclusion
τ=0	7.14	0.1286	Accept τ=0
τ=ρ=0	27.87	0.0000	Reject ρ=0

The results show that the specification of model 1 is unrestricted trend, the specification of model 2 is restricted constant and the specification of model 3 is restricted trend.

Table 8 exhibits the VECM estimation:

Table 8. Estimation of the VECM

	Model 1	Model 2	Model 3
Cointegration Equation:			
$\chi 2$ statistic	242.9525***	508.0046***	399.443***
REER	1	1	1
rltvPROD	0.401463 (0.14)***		
rltvPROD1		-0.5775723 (0.17)***	
rltvGOVEX	-0.6818807 (0.13)***	-0.6217705 (0.17)***	0.270445 (0.15)**
TOT	-1.101308 (0.22)***	-0.468564 (0.23)**	0.270445 (0.25)***
FTPolicy	0.365122 (0.11)***	0.16 (0.11)	-0.07 (0.09)***
rltvMONEY			53.49 (5.71)***
Trend[8]	-1.07		-1.291542
constant	47.92	50.89413	-153.3766
Number of lags	4	4	3
REER's speed of adjustment parameter: α	-0.32	-0.13	-0.07
VECM stability	4 eigenvalues lie on the unit root circle	All eigenvalues lie within the unit root circle	All eigenvalues lie within the unit root circle

Where notation * represents the significance level of 10%, ** represents the significance level of 5%, *** represents the significance level of 1%.

[8] Stata doesn't provide standard errors and significance levels for either the trend or the constant terms.

From the error correction term in the estimated VECMs, we are able to exploit the following reduced-form cointegration equations (21) to (23), which represent the equilibrium relationships between REER and related economic variables:

$$REER1 = -47.92 - 0.4rltvPROD + 0.68rltvGOVEX + 1.01TOT - 0.37FTPolicy + 1.07t \quad (21)$$

$$REER2 = -50.89 + 0.58rltvPROD1 + 0.62rltvGOVEX + 0.47TOT - 0.16FTPolicy \quad (22)$$

$$REER3 = 153.38 - 0.27rltvGOVEX + 1.36TOT + 0.07FTPolicy - 53.49rltvMONEY + 1.29t \quad (23)$$

The equilibrium relationship identified through the first VECM is expressed as equation (21). The variables selected in this model are the relative output level (rltvPROD), the relative government expenditure (rltvGOVEX), terms of trade (TOT), and the openness of economy (FTPolicy). The empirical evidence shows that in equilibrium: 1). A one percent increase in rltvPROD (i.e. a one percent relative economic growth of China compared to its partners) is associated with[9] a 0.4 percent depreciation of the REER. This negative sign is opposite of what one would expect based on theory. In this model, the appreciation effect of economic growth on real exchange rate may be captured by other variables that increase over time. In addition, the time trend could capture other time-increasing economic factors that are not included in this model. 2). A one percent increase in the relative government expenditure is associated with a 0.68 percent appreciation of the REER; a one percent increase in the terms of trade is associated with a 1.01 percent appreciation of the REER. 3). A one percent increase of the total foreign trade as a percentage of nominal GDP is associated with a 1.07 percent appreciation of the REER.

The equilibrium relationship identified through the second VECM is expressed as equation (22). The variables selected in this model are the relative productivity level (rltvPROD1), the relative government expenditure (rltvGOVEX), terms of trade (TOT), and the openness of economy (FTPolicy). The empirical evidence shows that in equilibrium: 1). A one percent increase in rltvPROD1 (i.e. a one percent relative productivity growth in tradable sector compared to nontradable sector, in China relative to its partners) is associated with a 0.58 percent appreciation of the REER. This is consistent with Montiel's prediction of the influence of the Balassa-Samuelson effect on real exchange rate as a supply side factor. 2). A

[9] We are not saying 'lead to' or 'cause' here and hereafter, since the equilibrium relationship identified under the VECM framework is not an expression of causal relationship between the economic variables and the REER. Rather all variables are correlated systematically. (Co-integration relationship).

one percent increase in the relative government expenditure and in the terms of trade is associated with a 0.62 percent and 0.47 percent appreciation of the REER respectively. 3). A one percent increase of the total foreign trade as a percentage of nominal GDP is associated with a 0.16 percent appreciation of the REER.

The equilibrium relationship identified through the third VECM is expressed as equation (23). The variables selected in this model are the relative government expenditure (rltvGOVEX), the terms of trade (TOT), the openness of economy (FTPolicy), and the relative money supply compared to the US (rltvMONEY). The empirical evidence shows that in equilibrium: 1). A one percent increase in the relative government expenditure is associated with a 0.27 percent depreciation of the REER. 2). A one percent increase in the terms of trade is associated with a 1.36 percent appreciation of the REER. 3). A one percent increase of the total foreign trade as a percentage of nominal GDP is associated with a 0.07 percent appreciation of the REER. 4). A one percent higher relative money supply compared to the US at sample mean implies a 1.61 percent depreciation of the REER. (calculated as the coefficient 53,4 times the sample mean 3.02, divided by 100).

The expected sign of cointegration parameter of rltvGOVEX is ambiguous. This reflects that without data for how government expenditure is distributed between tradable and nontradable sectors, it is not possible to identify the direction of influence of total government expenditure on the real exchange rate. In our empirical results, an increase in government expenditure leads to appreciation of the REER in model 1 and 2, and depreciation in model 3.

The different signs of identified cointegration parameter before FTPolicy to some extent indicate the point that we've mentioned before: the total foreign trade as a percentage of nominal GDP is not a strong proxy variable of trade-openness policy factors, since exchange rate affects both exports and imports and the direction of influence is also complicated.

4.3 Further discussions of our empirical study

First, as is illustrated in equation (21), the economic growth in China compared to that of its partners (proxied by rltvPROD) exerts downward pressure on RMB's REER in equilibrium, given that the government expenditure, the terms of trade and the openness are controlled. This is opposite to the theoretical prediction, thus may suggest that the model is mis-specified. However, our second proxy for productivity growth, rltvPROD1 has a positive

cointegrating parameter in the model confirms the theoretical predictions by Montiel in his model. China's 'relative relative' productivity growth in tradable sector compared to its partners exerts upward pressure on RMB's REER in equilibrium, given that government expenditure, terms of trade and openness are controlled for.

Second, according to the theory, the influence of an increase of government expenditure on the real exchange rate is dependent on the composition of the government expenditure. If the government is spending more in the tradables sector, the equilibrium real exchange rate is prone to depreciate. If the government increases its spending on the nontradables, on the contrary, we expect equilibrium exchange rate to appreciate. (As is illustrated by Figure 3). However, given limited information however, we cannot decide whether the Chinese government expenditures are leaned towards the tradable goods sector or not, hence the direction of the effect on equilibrium exchange rate cannot be identified;

Third, the deterioration of terms of trade exerts downward pressure on RMB's REER in equilibrium; fifth, the improvement in trade openness exerts downward pressure on RMB's equilibrium exchange rate; finally, as predicted by Edwards (1989), an increase of China's money supply relative to that of the US has negative impact on RMB's REER in equilibrium. [10]

Finally and more importantly, we find it difficult to interpret such big disparity of the results based on three different models in our empirical research. Each model has different variable set, and some are set with time trend while some without. Following the procedures of model specification prudently in order to ensure the uniqueness of equilibrium relationship in the VECM, we end up with different variable sets and different settings of deterministic components. It would have been easier to interpret the results if all variables had been included in one model. However, it would be risky in an empirical sense even through the result would look nice with significant cointegration parameters of the variables. This means that by including more variables, the rank of the according companion matrix would no longer be one, which implies multi or none-equilibrium relationship in the system. If so, the results would not be robust and trustable.

[10] The theory predicts the effect of money supply to be in short term; but in this thesis we find a permanent effect by establishing VECM.

Nevertheless, by ensuring unique equilibrium relationship, we still cannot avoid misspecification of each model. Faced with this reality, we set up three different models with three groups of variables. Looking at estimations of three models simultaneously more or less helps us to avoid relying on a wrong result of one wrong model. Starting from this pitfall of our research, a possible future direction of research would be comparing those different models in terms of predictability etc. and end up with one best model.

4.3.1 Estimations of RMB's equilibrium REER

Starting from the reduced-form equilibrium relationship expressed by equation (21) to (23), we are able to estimate the RMB's equilibrium REER by substituting the permanent values of the variables with the help of the Hodrick-Prescott filter. The equilibrium REERs estimated by three models are REER11, REER22 and REER33 respectively, and are illustrated in Figure 5 in solid lines while the actual REER is expressed by dashed lines:

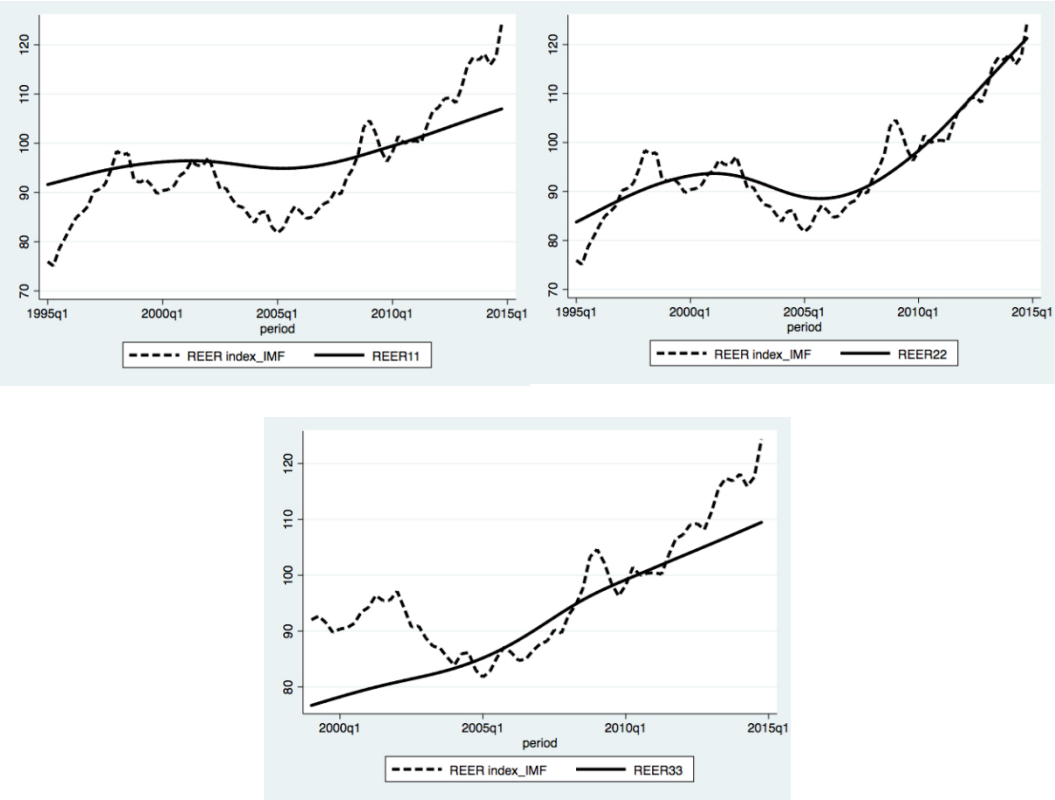


Fig. 5 estimated equilibrium REER based on three models

As is shown in the picture, the RMB's real effective exchange rate has experienced steady appreciation especially since 2005, which is captured by all three models. The possible

reasons behind the continuous appreciation are related to the relative growth of China's real economy, the monetary easing of major industrialized countries in the post-crisis era, etc.

4.3.2 Misalignment of RMB's REER

We define the term 'Misalignment' as the degree at which the actual exchange rate differs from its equilibrium value. It can be calculated as follows:

$$REERmisalignment = \frac{actualREER - equilibriumREER}{equilibriumREER} \times 100\%$$

The result of calculation is depicted in figure 6, in which the lower-right picture shows the average value of the previous three misalignments.

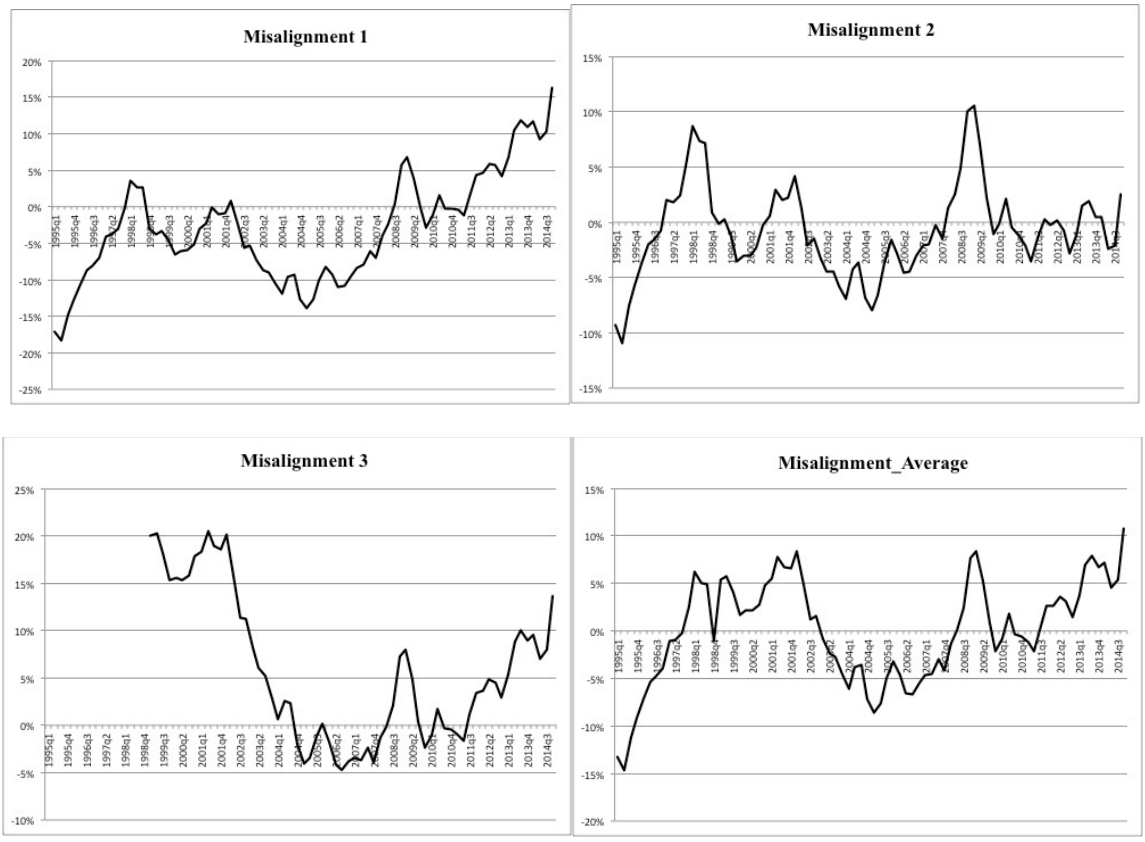


Fig. 6 three estimations of misalignment and the average misalignment

To analyze the misalignment, we are looking at the lower-right figure, which illustrates the average of three estimations. The reason of this is the same as the reason why we have three different models. By looking at the average misalignment, we can reduce the probability of relying on one wrong estimation result. As is shown in the figure, the RMB's REER was

overvalued from 1997 to 2002 within 5%, undervalued from 2003 to 2007 by approximately 5% and within 10%, overvalued during 2008 and overvalued with increasing degree from 0 in 2010 to 10% in 2014.

The following four aspects of facts from the estimations need to be noticed:

First, our empirical results are the same with previous studies in the sense that the RMB was undervalued during period between 2003 and 2007. However, the degree of misalignment in our estimation is not so severe as that of some former studies, especially the ones using the FEER method. Meanwhile, since we focus on the real effective exchange rate, the estimated misalignment will likely be reduced compared to the ones calculated out of bilateral real exchange rate towards the USD.

Second, the RMB's REER has been overvalued in recent years since 2010, and the degree of misalignment is increasing. This is different from the estimations conducted by Clark and Macdonald under the FEER approach; they conclude that the RMB is at equilibrium value at present. However, we consider it a warning sign that the RMB might has already been overvalued. Reasons of overvaluation are complicated, both the relative stable economic environment and the moderate monetary environment compared to the US, the EU as well as Japan are contributing factors that increase the popularity of the RMB.

Third, we should be cautious toward the estimation of the equilibrium exchange rate and the subsequent misalignment, since they are both on a BEER sense, and the BEER approach has limitations and pitfalls it self. Rather than a precisely defined theoretical equilibrium exchange rate that is generated under the FEER framework, the equilibrium exchange rate of BEER is more like a smoothed series of the actual exchange rate by nature. Hence the extent of estimated misalignment could become much smaller when we use BEER method. As a result, if the currency misalignment of the RMB exists on average, the BEER approach would not likely be able to detect it. Meanwhile, we should be aware of the fact that China's current account surplus is still very large although it's been declining recent years, which could still point to a possible undervaluation of the RMB. However, the BEER estimation still has its significant value of being a good benchmark that indicates the possible misalignment of actual exchange rate, also to be utilized to analyze the evolution of the exchange rate throughout time.

Forth, the consequence of a sustained appreciation and the possible overvaluation may have many influences on China's economy. At one hand, a strengthened RMB is good to the currency's internationalization process, since more people will be willing to hold a currency that is strong and stable enough to in the challenges of economic boom-and-busts. The RMB has seen a significant increase in its popularity in recent years, because of the steady appreciation and the emerge of new investment instrument denominated in the Chinese Yuan; On the other hand however, the appreciation of the RMB lowers China's trade competitiveness, and put downward pressures on China's export, which has already shown signs of declination since last year. As a consequence, China's employment and the growth target of the economy will be more difficult to maintain and reach. As can be observed clearly, China's economic growth is already slowing down, from 7.7% in 2013 to 7.3% last year. If the momentum of economic growth continues to remain sluggish, China may experience more difficulties in creating job opportunities and increasing personal income than if the RMB was cheaper than how it is now. In addition, the reduction of exports (together with a shrinking current account surplus) will hamper the RMB from staying strong and appreciating in the long run. It is a reality that shouldn't be forgotten that China is still relying upon its export as an engine and a driving force of its growth. The RMB is still far from being a fully liberalized currency, yet it is not immune to the speculations and the international financial turbulence. The appreciation of the RMB will put the central bank of China at a disadvantage when making monetary policies. The exchange rate effects the economic development, and economic power, in turn, is the ultimate determinants of the RMB's value and its goal of becoming a globally accepted currency. That is the reason why the RMB's exchange rate issue should be study more at present and in the future.

List of Literatures

[1] Bela Balassa, “The Purchasing Power Parity: A reappraisal.” Journal of Political Economy, 1964, 72(6): pp.584-596.

[2] Bénassy-Quéré, A., Duran-Vigneron, P., Lahrèche-Révil, A., V. Mignon. “Burden sharing and exchange-rate misalignments within the group of twenty.” CEPII Working Paper No. 2004-13.

[3] Christopher Gan et al. “An Empirical Analysis of China’s Equilibrium Exchange Rate: A co-integration Approach.” Journal of Asian Economics, 2013, 29: pp. 33-44.

[4] Clark, P. B., MacDonald, R. “Exchange Rates and Economics Fundamentals: A methodological Comparison of BEERs and FEERs.” IMF Working Paper, 1998, No. 67.

[5] Cline and Williamson (2012). “Estimating Fundamental Equilibrium Exchange Rates, May 2012.” No PB12-14, Policy Briefs from Peterson Institute for International Economics.

[6] Cline and Williamson (2013). “Estimating Fundamental Equilibrium Exchange Rates, May 2013.” No PB13-15, Policy Briefs from Peterson Institute for International Economics.

[7] Cline and Williamson (2014). “Estimating Fundamental Equilibrium Exchange Rates, November 2014.” No PB14-25, Policy Briefs from Peterson Institute for International Economics.

[8] Edwards, Sebastian. Real Exchange Rate, Devaluation, and Adjustment: Exchange Rate Policy in Developing Countries. Cambridge, US: The MIT Press, 1989.

[9] Edwards, Sebastian. “Real Exchange Rate in the Developing Countries: Concept and Measurement.” National Bureau of Economic Research Working Paper No, 2950, 1989.

[10] Elbadawi, Ibrahim (1994). “Estimating Long-Run Equilibrium Real Exchange Rates.” In John Williamson, ed., Estimating Equilibrium Exchange Rates. Washington, D.C.: Institute for International Economics.

[11] Francisco Maeso-Fernandez, Chiara Osbat, Bernd Schnatz. “Pitfalls in Estimating Equilibrium Exchange Rates for Transition Economies”, Economic Systems, 2009, 29: pp. 130-143.

[12] Francisco Maeso-Fernandez, Chiara Osbat, Bernd Schnatz. “Towards the Estimation of Equilibrium Exchange Rates for Transition Economies: Methodological Issue and a Panel Cointegration Perspective”, Journal of Comparative Economics, 2006, 34: pp.499-517.

[13] Hinkle, Lawrence E., Montiel, Peter J., Ed., Exchange Rate Misalignment: Concepts and Measurement for Developing Countries. A World Bank Publication. Oxford: Oxford Univ. Press, 1999.

[14] Montiel, Peter J., “The Long-Run Equilibrium Real Exchange Rate: Conceptual Issues and Empirical Research.” In Lawrence Hinkle and Peter J. Montiel, Eds., Exchange Rate Misalignment: Concepts and Measurement for Developing Countries, pp. 219-263, A World Bank Research Publication, Oxford: Oxford Univ. Press, 1999a.

[15] Montiel, Peter J., “Determinants of the Long-Run Equilibrium Real Exchange Rate: An Analytical Model.” In Lawrence Hinkle and Peter J. Montiel, Eds., Exchange Rate Misalignment: Concepts and Measurement for Developing Countries, pp. 219-263, A World Bank Research Publication, Oxford: Oxford Univ. Press, 1999b.

[16] Jinchao Chen. “Behavior equilibrium exchange rate and misalignment of renminbi: A Recent empirical study” Paper presented at the DEGIT conference 2007.

[17] Ming He Goh, Yoonbai Kim. “Is the Chinese Renminbi Undervalued?” Contemporary Economic Policy，2006，24: pp. 116-126.

[18] Nurkse, Ragnar. “Conditions of International Monetary Equilibrium.” Princeton Essays in International Finance No.4 (Spring), Princeton University Press, 1945.

[19] Paul. G. J. O’Connell. “The Overvaluation of Purchasing Power Parity.” Journal of International Economics, 1998, 44: pp. 1-19.

[20] Ronald MacDonald, Ed., Exchange Rate Economics: Theories and Evidence. New York: Routledge Press, 2007.

[21] Subramanian,A. “New PPP-Based Estimations of Renminbi Undervaluation and Policy Implications”, Policy Brief PB10-18, Washington, D. C.: Peterson Institute for International Economics, 2010.

[22] Sean Becketti, Introduction to Time Series Using Stata. Texas, US. Stata Press, 2013.

[23] Tao Peng, Minsoo Lee, Christopher Gan. “Has the Chinese Currency Been Undervalued?” Journal of Chinese Economic and Business Studies, 2008, 6, issue 1: pp. 49-66.
(http://econpapers.repec.org/article/tafjocebs/v_3A6_3Ay_3A2008_3Ai_3A1_3Ap_3A49-66.htm)

[24] V. Coudert, C. Couharde. “Real Equilibrium Exchange Rate in China. Is the Renminbi Undervalued?” Journal of Asian Economics, 2007, 18: 568-594.

[25] W. L. Chou and Y.C. Shih, “The Equilibrium Exchange Rate of the Chinese Renminbi”, Journal of Comparative Economics, 1998, 26: pp.165-174.

[26] Williamson, John. “The Exchange Rate System.” Washington: Institute for International Economics, 1983.

[27] Williamson, John. “Estimates of FEERs.” In John Williamson, Eds., Estimating Equilibrium Exchange Rates, Washington: Institute for International Economics.

[28] Xiaopu Zhang (2002). “Equilibrium and misalignment: an assessment of the RMB exchange rate from 1978 to 1999.” Stanford University Working Paper 127, Stanford, CA.

[29] Yajie Wang, Xiaofeng Hui, Abdol S. Soofi. “Estimating Renminbi (RMB) Equilibrium Exchange Rate.” Journal of Policy Modeling, 2007, 29: pp. 417-429.

[30] Ye Qian, L Dan-yan. “A Measurement of Renminbi Equilibrium Exchange Rate and Misalignment (1994-2010) Based on BEER Model.” Advances in Information Sciences and Service Science, 2012, 4: pp. 88 -97.

[31] Yin-Wong Cheung, Menzie D. Chinn, Eiji Fujii. “The Overvaluation of RMB Undervaluation.” Journal of International Money and Finance, 2007, 26: pp. 762-785.

[32] Yin-Wong Cheung, Menzie D. Chinn, Eiji Fujii. “Measuring Renminbi Misalignment: Where Do We Stand?” Hong Kong Institute for Monetary Research, Working Paper, 2010, 24: pp.

[33] Zhichao Zhang. “Real Exchange Rate Misalignment in China: An Empirical Investigation.” Journal of Comparative Economics, 2001, 29: pp. 80-94.