An Empirical Analysis of China's Equilibrium Exchange Rate: A Co-integration Approach

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The question of an equilibrium exchange rate has always been a debatable issue. Along with rapid growth of the Chinese economy over the past two decades, a number of studies have been undertaken to investigate whether or not the RMB exchange rate is at its long run 'equilibrium' level. Because the equilibrium exchange rate affects the competitiveness of a country's economy, these studies have focused on whether or not the real exchange rate is misaligned with respect to its long-run equilibrium level. One of the main reasons for this concern is that effective management of the exchange rate system could help a country's economy achieve internal and external balance. Otherwise, it could negatively influence the stability of a country's financial economy, possibly resulting in regional financial crises.

This study estimates time varying values of the equilibrium real effective exchange rate (EREER) and associated exchange rate misalignments for China in recent years (from the first quarter of 1999 to fourth quarter of 2007). The study focuses on the reduced-form equilibrium real exchange rate (ERER) model for developing countries presented by Elbadawi (1994) and follows Edwards' (1989, 1994) work on models of exchange rate determination. We identify the terms of trade, openness, government expenditure, productivity, and money supply as important explanatory variables of the RMB long-run equilibrium value. We use the Johansen-Juselius (1990) co-integration procedure to analyse our data.

Using the ERER model, our results show there is a cointegrating relationship between the real effective exchange rate and its economic fundamentals. Subsequently, compare to other previous studies discussed in Chapter 2, our restricted error-correction model suggests that the extent of the misalignment is not very large, moving in a narrow band of plus and minus 12 percent of the long-run equilibrium level during the sample period. Focusing on the RMB real exchange rate misalignment in recent years, our result shows that the RMB was undervalued by an average of 6.7 percent during the period of 2005Q:3-2007Q:4. Furthermore, our short-run empirical error correction model indicates that, on average, the real exchange rate takes over one quarter to reach its long-run equilibrium level.

Key words: Equilibrium exchange rate, Real effective exchange rate, Misalignment, Cointegration, Error-correction model, Hodrick-Prescott decomposition, RMB.

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Chapter 1

Introduction

1.1 Introduction

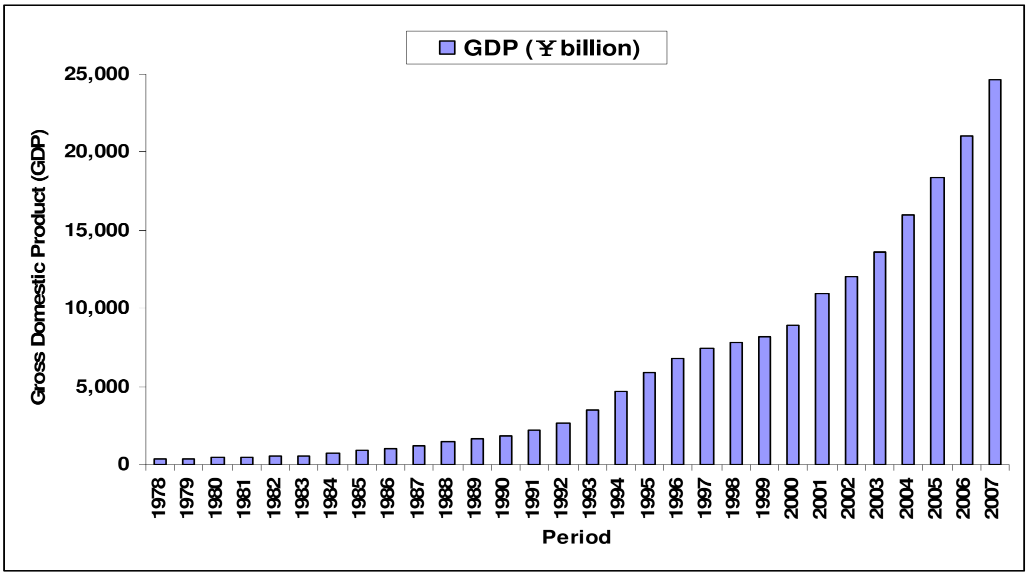
The study of the Renminbi (RMB)[1] equilibrium exchange rate has been hotly contested, disputed and discussed. With the advent of China's economic openness, along with its membership of the World Trade Organization (WTO), the RMB exchange rate policy has been faced severe challenges and attacks. For example, much of the interest has been prompted by speculation that China would revalue its currency after the end of 2000. Furthermore, the central theme for many studies in both the economics and finance disciplines over the last 20 years has been to investigate whether the RMB exchange rate is at 'equilibrium' level or not.

In late 1978, the Chinese leadership began moving the economy from a sluggish, inefficient, Soviet-style centrally-planned economy to a more market-oriented system. Furthermore, China has achieved extraordinary economic growth while maintaining price stability in the three decades since the start of the economic reforms. The rate of Chinese economic growth has been outstanding, averaging 9.8 percent growth per annum in gross domestic product (GDP) since 1979 (Tung, 2007) whilst also maintaining a relatively low inflation rate (Bouveret, Mestiri, & Sterdyniak, 2006) and large current account surpluses since 2005 (Corden, 2007). In 2006, China emerged as the world's fourth-largest economy due to this rapid economic growth. Figure 1.1 shows that China's GDP exhibited rapid growth, more than tripling in value in the last ten years. The booming economy has brought substantial benefits to people's lives, with per capita income (see Figure 1.2) rising from 379 yuan in

[1] *Renminbi*, or *RMB* in short, is China's legal tender, and *yuan* is the base unit of measurement for the RMB.

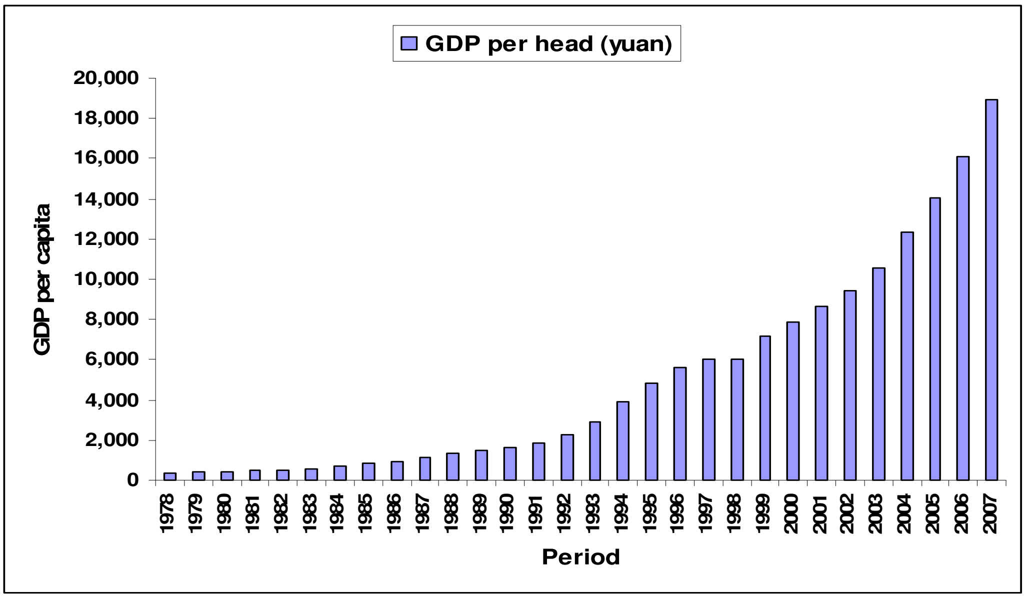
1978 to 18,934 yuan by 2007 (Chinability, 2008).

Figure 1.1 China's Gross Domestic Product (GDP) (1978-2007)



Source: *National Bureau of Statistics of China (2008)*

Figure 1.2 China's GDP Per Capita (1978-2007)



Source: *National Bureau of Statistics of China (2008)*

The main driving force behind China's economic growth has been the rapid growth in exports. China's total exports were $266.6 billion in 2001, which accounts for around 4.3 percent of the world's total. Thus, China's export growth has outpaced its import growth giving a trade surplus and a current account surplus since 2000 (Makin, 2008). By 2006 China's current account surplus was the largest in the world by a large margin. According to the data, China's current account surplus reached $360 billion in 2007, about 15 percent of GDP (McKinnon & Schnabl, 2008) and became a major point of contention between China and its trading partners, especially the United States. A surplus of this magnitude relative to its GDP is unprecedented for China's stage of development. China's trading partners' contend that much of this 'global imbalance', leading to large trade deficits, is due to the undervaluation of the RMB. Accordingly, a rise (appreciation) in the RMB real exchange rate would help to reduce China's trade surplus.

In the wake of the 1997-98 Asian financial crises, many academics deemed that China should depreciate the RMB, otherwise China's economy might undergo a sharp reversal of fortune. Nevertheless, the Chinese government absorbed the effects of the financial crisis and adopted the *de facto* peg to the USD regime, in which the RMB exchange rate was pegged to U.S. dollar at 8.28 RMB/USD. Thus, the RMB has maintained a steady state and a strong currency position since the Asian financial crises, in line with China's long-run economic interests. Subsequently, on 16 June 2003, US Treasury Secretary John Snow announced that China should adopt a more flexible exchange rate system. The purpose is to request that China gives up the pegged exchange rate system and allow the value of RMB to fluctuate freely. Thus, the debate on whether the RMB should appreciate or depreciate became a hot topic in recent years.

As people debated about whether the RMB is undervalued globally, the People's Bank of China (PBC), China's central bank, revalued the RMB by 2.1 percent to 8.11 RMB/USD on 21 July 2005. The RMB remains closely managed within narrow margins of fluctuation. The

PBC announced that the RMB would switch from a strictly dollar-peg to a basket of currencies (US dollar, euro, Japanese yen and Korean won), allowing for more flexible floating of the currency. Since then, the RMB slowly appreciated to 8.05 RMB/USD by March 2006 (Bouveret et al., 2006). On 10 April 2008, the exchange rate reached a new high of RMB 6.99 per U.S. dollar, having appreciated by more than 4 percent since the beginning of the year. As a result, China has gradually revalued the RMB. However, it is still unclear whether the current RMB exchange rate level is appropriate. To answer this question, it is important to find out where the current exchange rate lies relative to the equilibrium level. Therefore, the estimation of a long-run equilibrium exchange rate for the RMB is one of the primary objectives of this study.

Other current interest in the RMB has been motivated by the possibility that the RMB exchange rate has been misaligned over a long period of time. Misalignments occur when the actual exchange rate deviates persistently from its equilibrium path. Evidence from developing countries is often cited to support the view that the linkage between real exchange rate misalignment and economic performance is strong; for example, misalignment could result in reduced investments, plant shutdowns, declining productivity, deterioration of commercial positions and loss of established markets over a long time. Sekkat and Varoudakis (1998) emphasize that the chronic misalignment of real exchange rates are a major factor behind the weak economic performances of developing countries. In addition, misalignments can be used as a tool to evaluate the need to adjust the exchange rate. The real exchange rate misalignments (as well as its volatility) can also influence a country's economic performance (see Krueger, 1983; Edwards, 1989; Dollar, 1992; Aguirre & Calderon, 2005).

Because the equilibrium exchange rate affects the competitiveness of a country's economy, it is a major concern for all countries to determine whether the real exchange rate is misaligned with respect to its long-run equilibrium level. That is, real exchange rate overvaluation can undermine domestic goods' competitiveness and weaken the external position (such as current account deficits, etc), while an undervalued real exchange rate may induce inflationary pressures, as the increased price of imported goods will raise the consumer price index. Thus, it does not matter whether the RMB is overvalued or undervalued, the misalignment of real exchange rate can have a negative impact on China's macroeconomic performance and economic structure. Hence, as a financial tool, maintaining the RMB equilibrium exchange rate *vis a vis* other major currencies would promote further development of the Chinese economy. The issue of choosing the appropriate exchange rate has also emerged as a key concern in China's macroeconomic policy.

To quantify the degree of possible RMB real exchange rate misalignment over time, this thesis develops a reduced-form equilibrium real exchange rate model based on Edwards's (1989) and Elbadawi's (1994) developing country model, which is determined by the real "fundamental" variables that are found to affect the behaviour of the real exchange rate. Once the equilibrium exchange rate is estimated, we will be able to assess whether the RMB real exchange rate has been over- or under- valued in recent years. We will assess the equilibrium real exchange rate value of the RMB by applying the Johansen-Juselius (1990) co-integration procedure in our empirical analysis.

1.2 Study Rationale

With globalization, the real exchange rate's behaviour plays an even more important role in policy evaluation. Furthermore, most empirical estimates of equilibrium exchange rates have always been associated with important policy-related discussions in policy institutions, as well as an important responsibility of macroeconomic policymakers in maintaining exchange rate stability. Therefore, the objectives of this research are to investigate: (1) where the current RMB real exchange rate stands relative to its long-term equilibrium, and (2) whether there is a tendency for the RMB real exchange rate to move away from its long-run equilibrium level in recent years.

Against this background, this thesis seeks to address three key questions as follows:

- Does a long-run equilibrium level exist for the RMB real exchange rate and, if so, what is it?
- Are there any inherent market or policy forces that would tend to move the RMB real exchange rate toward its long-run equilibrium level?
- Following a disturbance, what is the speed at which the RMB real exchange rate reverts to its equilibrium level?

To provide a conceptual framework that addresses the above questions, we will briefly exposit the theory of equilibrium exchange rate determination. Prior to that, however, we present a concise historical review of Chinese currency and RMB exchange rate regimes to provide a background for the theoretical and empirical analyses in the main body of the thesis.

1.3 Background

1.3.1 A Brief History of Chinese Currency

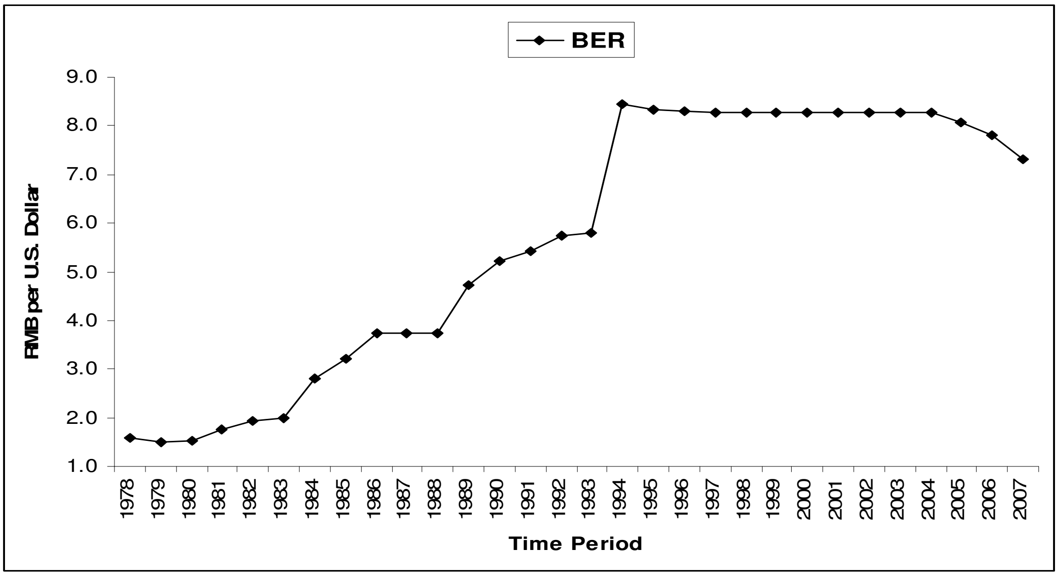
The RMB is the official currency of the People's Republic of China (PRC) that is issued and administered by the PBC. The use of money dates back to at least four thousand years. Cattle, grain, and things of daily use, such as shells, pearl, jade, bronze, as well as gold, silver and silk have all been used as money during ancient time. Furthermore, paper currencies have been in circulation for over a thousand years; the Song Dynasty (998-1022) was the first to issue true paper currency in 1023. However, the most successful historical period of paper currency in China was during the early Yuan Dynasty (1271-1368). With the rise of modern banks, banknotes became popular in recent history. The PBC - China's monetary authority began to issue RMB in 1948. Subsequently, the RMB became the sole unified legal tender in China after the founding of the People's Republic of China on 1 October 1949 (Yang, Yin, & He, 2007). However, the value of the RMB was non-tradable with other currencies during the era of the communist economy. In addition, the RMB was not fully convertible because the conversion of foreign exchange against RMB was restricted.

1.3.2 China's Exchange Rate Regimes

China had an almost completely closed economy from 1949 until the start of reforms in the late 1970s and the opening-up to the outside world in the early 1980s. Previous to that, China's economy was highly centrally controlled and China's exchange rate policy was mostly determined by the nation's strategic interests. China's centrally planned economy began in 1953 and the exchange rate was pegged to the U.S. dollar at 2.4618 RMB until 1971 (Le, 2007).

When the Bretton-Woods system collapsed in 1973, China's exchange rate system had to be adjusted in line with the rest of the world. Hence, the exchange rate rose gradually to a high of 1.5 Yuan per U.S. dollar in 1979, in an effort to lower the cost of imports. However, the RMB was considered to be highly overvalued - by 60 percent, based on China's export prices. In order to develop a better balance between exports and imports and maintain the benefits of a strong currency, China adopted a dual exchange rate system in 1981. One rate was the "internal settlement rate" introduced by China's state council on 1 January 1980, which was set at 2.80 RMB/USD; the other rate was the "official rate" that for non-trade sector. With the approval of the government, the Bank of China (BOC) started a foreign exchange swap market in several major cities in China; the swap market rate could fluctuate in a band between 5-10 percent with the internal settlement rate as the pivot (Yang et al., 2007). However, the dual exchange system did not last long - the internal settlement rate was abolished in January 1985.

Figure 1.3 China's Bilateral Exchange Rate against U.S. Dollar (1978-2007)



Source: *International Monetary Fund (2008), IMF (International Financial Statistics, IFS)*

In July 1986, the exchange rate was determined by the swap market, at 6.50 RMB/USD, but the official rate was only 3.72 and remained stable at that level until 1989. By the end of 1993, the official rate had dropped to 5.80 from the 3.20 yuan per dollar in 1985. From the first day of 1994, the Chinese government, reformed its double-track exchange rate system and adopted a unified exchange rate regime, where the exchange rate was depreciated to 8.70 RMB/USD. To get a sense of the evolving range of China's exchange rate movement, Figure 1.3 plots the bilateral exchange rate (RMB/USD) during the period 1978 to 2007. Under the double-track exchange rate system, the RMB appreciated from 8.70 to 8.45 RMB/USD at the end of 1994 and then further appreciated to RMB8.28, making the regime a *de facto* peg to the U.S. dollar in October 1997. However, this rate remained almost at 8.28 until the latest revaluation of the RMB on July 21, 2005 (Wang, Hui, & Soofi, 2007). It is to be noted that a decrease in the bilateral exchange rate (RMB/USD) reflects an appreciation of the country's currency, RMB.

At the end of June 2005, China's foreign exchange reserves totalled 711 billion U.S. dollars, a huge trade surplus (Le, 2007). In order to implement a sustainable economic development strategy, including greater independence of monetary policy and enhanced effectiveness of financial macro control, China decided to adjust the exchange rate and reform the RMB exchange rate system. On 21 July 2005, the PBC issued the *Public Announcement on Reforming the RMB Exchange Rate Regime* (People's Bank of China, 2005). On the same day, China instituted a reform of its exchange rate regime by moving into a managed floating exchange rate regime based on market demand and supply with reference to a basket of currencies, and improving the exchange rate system by achieving greater flexibility. When the official bilateral rate appreciated by 2.1 percent, moving from 8.28 to 8.11 RMB/USD at 7 p.m. local time (Le, 2007), China announced it would switch from a dollar-pegged to a basket-pegged regime, and allow for more flexible floating of the currency (Wang et al., 2007). Nonetheless, the daily fluctuation of the RMB exchange rate is restricted within 0.3 percent, which has not moved very much under the managed floating exchange rate regime. This is because of the central bank intervention conducted. The data in Table 1.1 illustrates the key events of China's exchange rate regime since the founding of the PRC in 1949.

Table 1.1 Summary of Key Events of the China's Exchange Rate Regimes

YEAR	KEY EVENTS
Before 1978	Mostly determined by the nation's strategic interests
1978	Reform and opening-up economy policy
Jan 1981 to Jan 1985	Dual exchange rate system
Jul 1986 to Jan 1994	Official rate and foreign swap market rate coexisted
On Jan 1, 1994	Unification of exchange rate regime
1997	*De facto* pegged to U.S dollar exchange rate regime
On July 21, 2005	Managed floating exchange rate regime

1.4 Research Objectives

This study aims to estimate empirically the RMB equilibrium real exchange rate and its misalignment using time series data from the first quarter of 1999 to the fourth quarter of 2007. Some studies used the bilateral real exchange rate (RMB against to U.S. dollar) to assess the RMB equilibrium rate, and others chose only a single fundamental as a variable that determine the equilibrium real exchange rate (ERER). In order to improve upon previous research, we add some relevant and real 'fundamental' variables (such as terms of trend index, money supply-M2, etc) into our study to make our research findings more reliable and robust. The major difference between our study and other studies is that we use recent quarterly data instead of annual data and the terms of trade index (see Goh and Kim, 2006). In addition, we add the money supply (M2) as a fundamental variable for the determination of the equilibrium real exchange rate.

The specific research objectives of this study include:

1) To estimate a long-run equilibrium level for the RMB real exchange rate from 1999Q1 to 2007Q4;
2) To investigate whether there is a persistent departure of the RMB real exchange rate from its equilibrium level over a long period of time;

3) To predict the extent of the RMB real exchange rate misalignment during the sample period.

1.5 Outline of the Thesis

The rest of the thesis is organised as follows: Chapter One highlights the key features of China's remarkable growth, including descriptions of the background of the study and the rationale for the research to be undertaken. Chapter Two briefly discusses the concepts of equilibrium exchange rates and reviews major real exchange rate determinants for developing countries. In addition, the chapter systematically introduces, compares and assesses current equilibrium exchange rate models. This also includes a review of the theoretical and empirical literature on the RMB exchange rate. Chapter Three presents the econometric method, variables and data sources used in the empirical application. Chapter Four analyzes and interprets the empirical results and Chapter Five presents the overview of the research and provides a summary of the main findings. This chapter also describes some implications of the findings with regard to RMB exchange rate misalignment. It then discusses some of the limitations of the study and suggests some possible directions for future research.

Chapter 2

Literature Review

2.1 Introduction

This chapter provides a literature review of relevant aspects of the equilibrium exchange rates. There is a voluminous body of theoretical and empirical literature that attempts to estimate equilibrium exchange rates and to define the long-run relationship between exchange rates and their fundamental variables. Recently, there is an increasing amount of empirical research on the RMB and some of those studies will be discussed later. Prior to this, we exposit the basic concepts of exchange rate and theory of equilibrium exchange rate determination to provide a theoretical groundwork for the empirical assessment of equilibrium exchange rates in our research.

The Chapter is structured as follows: Section 2.2 contains a review of the concepts of equilibrium exchange rates. Sections 2.3 to 2.5 discuss the theory of exchange rate determination and models of equilibrium real exchange rates. Following this, we will identify the economic fundamental variables that could be incorporated in our model in Section 2.6. Finally, Section 2.7 reviews briefly the findings of some previous studies conducted in the equilibrium exchange rate of RMB.

2.2 Basic Concepts and Definitions of Exchange Rate

In most research, the exchange rates are measured in real terms because this is considered to be more suitable for estimating the misalignment of exchange rate compared to nominal exchange rate (see Edwards, 1989). In addition, the real exchange rate also reflects a country's economic comparativeness (see, the discussion in Williamson, 1985, p. 14;

Salvatore, 2001; Driver, & Westaway, 2004).

2.2.1 Defining Real Exchange Rate (RER)

Many variants of the concept of RER have been used in the literature, but in its simplest form it is defined as the actual exchange rate adjusted for inflationary effects in the two countries of concern (Madura, 2006). To observe whether the real exchange rate is at 'equilibrium' or not, a benchmark of the equilibrium real exchange rate is necessary.

Given different research objectives, the real exchange rate can be categorized into two broad groups namely, *external RER* and *internal RER*. According to Kemme and Roy (2006), the external RER (E^e) is defined as the nominal exchange rate (E) adjusted for differences in price levels between countries - i.e. the ratio of foreign to domestic aggregate price levels measured in a common currency. This can be written as $E^e = E\left(\frac{P_f}{P_d}\right)$ where E is the nominal exchange rate, defined as the domestic price of the foreign currency, and P_f and P_d denote the foreign and domestic aggregate price indexes, respectively. The internal RER (E^i) refers to the ratio of the relative domestic price of tradable to non-tradable goods produced in the domestic economy. This can be expressed as $E^i = \frac{P_T}{P_N}$ where P_T is the domestic price index of traded goods and P_N is the home country's currency price index of non-traded goods.

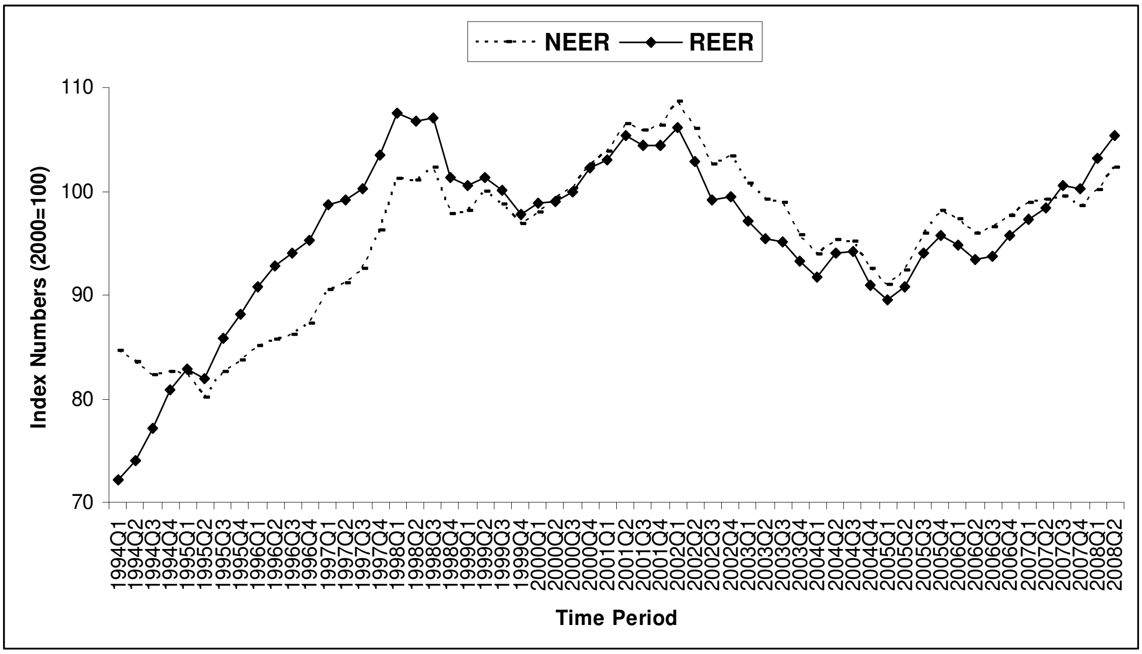
In general, the "external RER" is usually referred to as the real exchange rate used in estimating the equilibrium exchange rate of a country's currency (Salvatore, 2001). It reflects the relative price changes of a basket of domestic products and foreign goods. Furthermore, the external RER can be defined in two ways, *bilateral real exchange rate* that gives the price of foreign goods basket in terms of a domestic goods basket and is the *trade weighted real* *exchange rate* (i.e. real effective exchange rate). Note that the weights of different currencies in the basket are determined by the countries' trade volumes in the domestic economy. Following this convention, an increase in the bilateral real exchange rate (e.g. RMB/USD) represents a real depreciation of the RMB.

2.2.2 Defining Real Effective Exchange Rate (REER)

As defined in Edwards (1991), the real effective exchange rate (REER) is a key macroeconomic relative price, which plays an important role in the country's economy. A REER index is often monitored to detect possible changes in international competitiveness and used to inform monetary and exchange rate policy. Zhang (2000) also discussed that the RMB real effective exchange rate can reflect China's international competitiveness more objectively and is close to the concept of "equilibrium exchange rate". Therefore, for China's real exchange rate, we will construct a Consumer Price Index (CPI)-based REER, which is defined as the ratio of domestic consumer prices to a trade weighted index (exchange rate adjusted) of consumer prices with its trading partners (International Monetary Fund, 2006). A rise of a real effective exchange rate index usually reflects an appreciation of the domestic currency *vis-à-vis* the basket of currencies. We chose the CPI-based REER index because it is frequently used as an indicator of competitiveness of a country against its trading partners and data are readily available.

Figure 2.1 displays both the nominal and real effective exchange rates of China from 1994Q1 to 2008Q2. From the graph, it can be seen that the real effective exchange rate of RMB appreciated by 45.87 percent and the nominal effective exchange rate (NEER) by 20.78 percent from January 1994 to June 2008. Moreover, the value of RMB in 2005 was close to the value in early 1996; this was about 10 percent less than at the height of the Asian financial crisis in mid-1997.

Figure 2.1 China's Real and Nominal Effective Exchange Rates (1994Q1-2008Q2)



Source: *International Monetary Fund (2008), IMF (International Financial Statistics, IFS)*

As a cautionary note, McCown, Pollard and Weeks (2007) argue that different measures in constructing REER indices will be often result in sharply different outcomes, and the choice of nominal price measure can yield surprisingly different outcomes. In addition, the adjustments of the REER can be obtained through either price adjustments or exchange rates.

2.2.3 Defining Equilibrium Real Exchange Rate (ERER)

The equilibrium real exchange rate (ERER) is one of the more important concepts in open economy macroeconomics. Since real exchange rate misalignment refers to the sustained departure of actual REER from its equilibrium real exchange rate (ERER), an understanding of the theory of equilibrium real exchange rate is a fundamental step in any attempt to understand exchange rate misalignment.

According to the theory, exchange rates are determined in foreign exchange markets by the demand and supply for currencies, where the real exchange rate should always be at its equilibrium value. This is clearly related to the *market equilibrium exchange rate* illustrated by Williamson (1985), which defined equilibrium as equating to the supply and demand for a currency in the absence of government intervention. However, the time frame is an important point to consider when discussing equilibrium. Driver and Westaway (2004) discuss three different types of equilibrium concepts, namely, long-, medium- and short-term equilibrium. The model that will used in our study relates closely to the long-run equilibrium concepts, especially regards *movements* toward such equilibrium rate.

To calculate the extent of misalignment from equilibrium level, we must include a proxy measure of an unobserved latent variable - that is, the ERER. Following Edwards (1989), we define the equilibrium real exchange rate, which, for given sustainable values of other relevant fundamental variables, results in the simultaneous attainment of both internal and external equilibrium. However, the ERER is not an immutable value if changes in any of the other variables tend to affect the country's external and internal balance, and vary the ERER. The ERER will be affected not only by its "fundamentals" but also by the expected future evolution of these variables.

2.3 Theory of Exchange Rate Determinations

There is abundant literature and theories about the determination of the exchange rate. These theories view the exchange rate as a purely financial phenomenon for the most part. They also seek to explain the large volatility of exchange rates in the short run and have a tendency to overlook the long-run equilibrium level. Hoontrakul (1999) presents a succinct overview of exchange rate determination theories, the most popular of which are summarized below.

2.3.1 Purchasing Power Parity (PPP)

The Purchasing Power Parity (PPP) theory is perhaps the earliest and one of the most traditional exchange rate theories about equilibrium exchange rate determination. It provides the long-run framework for the monetary and portfolio approaches to exchange rate determination. According to Hoontrakul (1999), the PPP theory (sometimes called the “inflation theory of exchange rates”) can be traced back to the Salamance School in sixteenth-century Spain, and to the writing of Gerrard de Malynes in 1601 in England. Cassel (1918, p. 413) was first to name the PPP theory and he argued that without PPP, there would be no meaningful way of discussing over- or under- valuation of exchange rates.

The PPP theory can be classified into two versions, absolute and relative PPP. Basically, the absolute PPP follows the ‘*law of one price*’, which states that identical goods in two different economies, in the absence of transaction costs, taxes and transportation costs, sell for the same price when expressed in an equivalent currency. If not, arbitrage will occur. If the PPP holds in the long run then exchange rates will be adjusted to ensure the equal relative purchasing power of currencies. Mathematically, the equation of absolute PPP can be expressed as $PPP = E = \frac{P}{P^*}$, where E is the exchange rate or spot rate defined as the domestic currency price of a unit of foreign currency, and P and P^* denote the general price level in the home and foreign nation, respectively.

The relative PPP is the more commonly used version of PPP theory, as it focuses on *changes* in the price levels in two countries, which should be *proportional* to influence changes in the equilibrium exchange rate over time (Salvatore, 2001). The relative PPP theory refers to rates of change in price levels (i.e. inflation rates) and the exchange rate of a currency will be equal to the difference in inflation rates between the home and foreign country. Hence, the relative PPP can be mathematically expressed as $\frac{E_t - E_{t-1}}{E_{t-1}} = P - P^*$, where P is home country’s inflation rate and P^* is the foreign country’s inflation rate, E_t denotes the exchange rate (domestic currency per unit of foreign) at time t.

However, there are several important reasons why absolute PPP may not hold, including the existence of non-tradable goods and services in all economies whereas the "law of one price" only applies to traded goods and services. Moreover, the PPP assumes no government intervention but, in reality, there are tariffs, quotas, trade restrictions and taxes. In addition, the information on comparative prices is neither universally available nor free. Even if prices were the same in two countries, differences in income levels would cause the consumer price index to change. Moreover, tradable goods are not always perfect substitutes when they are produced in different countries (Driver & Westaway, 2004). The next paragraph considers evidence as to whether or not the PPP holds empirically.

There are numerous empirical studies to test the validity of the PPP theory after 1973, which stimulated a great resurgence of interest in this theory. Some studies argue that the *PPP does not hold* in each and every period (for example, Pippenger, 1986). Frankel (1978) argues that the PPP is not a theory of exchange rate determination, particularly in the short- to medium-run, and he provided empirical evidence on the long-run validity of the PPP theory during the high inflation years of the 1920s. Following this, Frankel (1981) found that the PPP theory collapsed during the 1970s, especially in the latter part. On the other hand, Cassel (1918) and Dornbusch (1988) both believe that the PPP remains a meaningful element of macroeconomics for an open economy. However, recent studies favour the PPP. For example, Pippenger's (1993) study confirms that the relative PPP holds in the long-run and nominal foreign exchange rates follow a random path. Becketti, Hakkio and Jones (1995) also conclude that the relative PPP holds in the long-run. In other words, neither form of PPP holds in the short to medium term, while there is some empirical evidence supporting that the relative PPP holds in the long-run.

2.3.2 Interest Parity (IP)

The theory of interest parity can be traced back to 1923 and is developed by Keynes, who links the exchange rate, interest rate and inflation. This theory also has two variations: covered interest parity (CIP) and uncovered interest parity (UIP). Empirically, the arbitrage argument based on the CIP model appears to hold in most cases (see, for example, Frankel, & Levich, 1975; Clinton, 1988).

In addition, the UIP is one of the two main arbitrage conditions in discussing exchange rates. If the condition of risk-free arbitrage exists, then the spot exchange rate should be equal to the difference in interest between assets (Rusydi & Islam, 2007). In empirical terms, the UIP has not been very successful in predicting exchange rate movements. For example, Hansen and Hodrick (1980) pointed out that the UIP *does not hold* with the simple market efficiency hypothesis (MEH) for exchange. Again, Ito (1988) found that UIP is rejected when applying the time-domain vector autoregression procedure. Furthermore, McCallum (1994) suggests that the reason for the failure of UIP might be policy behaviour; but Christensen (2000) found that McCallum's explanation no longer appears to hold after evaluating the policy response function.

2.3.3 Monetary Approach to the Balance of Payments

The monetary approach was proposed initially by Robert Mundell and Harry Johnson at end of the 1960s and became fully developed during the 1970s. It represents an extension of domestic monetarism to the international economy including the balance of payments. Money plays a crucial role in both as a disturbance and as an adjustment in the country's balance of payments in the long term (Salvatore, 2001).

The monetary approach emphasizes that under a system of determined exchange rates, movements in currency values play a primary role in restoring equilibrium between money supply and demand for money. For instance, under a managed floating exchange rate system, which is currently adopted by China, the country's monetary authorities intervene in foreign exchange markets and either accumulate or lose foreign reserves to prevent an "excessive" appreciation or depreciation of the domestic currency (Salvatore, 2001). The monetary approach has made a significant contribution to economic theory by stressing monetary factors, although there are limitations in formulating empirical tests of the monetary approach.

2.3.4 Portfolio-Balance Approach (PBA)

As given by Hoontrakul (1999), the theory of Portfolio-Balance approach determines "the exchange rate as the relative price of moneys in the short run". Kouri (1976) was the first to extend PBA from the monetary approach to the balance of payments. Unlike the monetary approach, in the portfolio-balance approach, all economic agents want to hold both domestic and foreign currencies. Under this theory, the money demand depends on the demand for financial assets, not for the currency itself. Therefore, the exchange rate is not determined primarily by the foreign currency demand, but rather on how to spread wealth over the different available assets and bonds (Hoontrakul, 1999). The PBA is similar to the Fundamental Equilibrium Exchange Rate (FEER) model in many ways and, indeed, the result of the long-run equilibrium exchange rate could be thought of as the FEER. However, the method of calculation under the PBA is quite different. According to Taylor (1995), it causes practical complications for assessing portfolio-balance models because of data issues.

2.4 Equilibrium Real Exchange Rate

The models of equilibrium real exchange rate determination can be classified into two categories: a set of studies that are based on the Purchasing Power Parity (PPP), which is discussed in a prior section, and another set that aims to estimate the equilibrium rate by using econometric models based on economic fundamentals. The latter set of models, developed at the end of the 1980s, includes FEER model, Behavioural Equilibrium Exchange Rate (BEER) model, the reduced-form Equilibrium Real Exchange rate (ERER) model, and Natural Real Exchange Rate model.

The objective of some models (such as FEER and ERER models) is to estimate an exchange rate where at the simultaneous satisfaction of internal and external balances are associated with the economic fundamental variables, and regard it as an ERER to adjust the level of actual exchange rate in the real economy. Recognizing the limitations of the PPP, a great deal of attention has focused on those fundamental exchange rate determinants. Among those models, the reduced-form ERER model is the appropriate method in assessing the equilibrium real exchange rate for developing countries. Thus, we will apply the reduced-form ERER model in our research and will discuss it later.

2.4.1 The Fundamental Equilibrium Exchange Rate (FEER) Model

The FEER model is the most popular underlying balance model. Popularised by Williamson (1985, p. 14), FEER was defined as "*the fundamental equilibrium exchange rate is that which is expected to generate a current account surplus or deficit equal to the underlying capital flow over the cycle, given that the country is pursuing "internal balance" as best it can and not restricting trade for balance of payments reason.*" Hence, the FEER approach is based on the equilibrium exchange rate consistent with a country's sustainable positions of macroeconomic balance that has both an internal and external dimension. The internal balance is said to be reached when the economy is at full employment and operating in low inflation. The external balance is characterized as a country's current account balance sustainable over the medium-term, ensuring the desired net flows of resources. Indeed, Williamson (1994, pp. 180-181) has emphasized that the FEER as the equilibrium exchange rate that would be consistent with "ideal economic conditions."

The FEER is considered a normative measurement as the equilibrium exchange rate consistent with the notion of ideal economic conditions of internal and external balances. However, the FEER approach has been criticized in the literature since the internal balance definition is somewhat less controversial, and the assumption of sustainable current account (CA) has been criticized for being too subjective in nature (Siregar & Rajan, 2006). For example, in the applying the FEER, the medium-term CA is often assumed to be at the desirable rate, which is 1 percent in the case of the US (see Bayoumi, Clark, Symansky, & Taylor, 1994). In addition, the analytical limitations of the FEER, resulting from possible fluctuations on returns from net foreign assets (see, for instance, Bayoumi et al., 1994; Driver & Westaway, 2004), make it difficult to apply in practice. Siregar and Rajan (2006) pointed out that the size of currency misalignment computed by FEER model is likely to be inaccurate. Furthermore, the key problem with the FEER method is the uncertainty surrounding the assessment of external and internal balance benchmarks, particularly for a rapidly changing economy such as China's.

However, most studies found a large undervaluation of RMB when using the FEER model. For example, Wren-Lewis (2004) used the FEER approach to estimate that the RMB was undervalued by 28 percent with a current account target of zero. Coudert and Couharde (2007) also used a FEER method to estimate the real effective exchange rate, and presented evidence that the RMB was undervalued between 16 percent and 54 percent.

2.4.2 The Behavioural Equilibrium Exchange Rate (BEER) Model

Clark and MacDonald (1998) proposed a behavioural equilibrium exchange rate model.

Unlike the FEER, the BEER approach is not a normative measure; it focuses on the real exchange rate and the medium-term equilibrium rates of the fundamental determinants (i.e. internal and external balance proxies). In contrast, the equilibrium real exchange rate is consistent with the prevailing levels of economic fundamentals in a single equation of the BEER model (Siregar & Rajan, 2006).

The starting point for the BEER analysis rests on the real UIP condition. Specifically, BEER models produce estimates of equilibrium real exchange rates based on both long-run economic fundamental variables and short-run interest rate differentials. In particular, under the UIP condition, the BEER approach can capture the sources of changes in capital accounts as well as other factors affecting the behaviour of the real effective exchange rate that the FEER cannot so easily capture.

However, BEER models in China have generally produced much lower estimates of the RMB than the FEER model. Studies such as Wang (2004) reported that the RMB was only about 5 percent undervalued in 2003 according to the BEER approach, and Funke and Rahn (2005) estimated that the RMB was undervalued by about 3 percent at the end of 2002. In short, the BEER approach is adapted to provide meaningful assessments of exchange rate values along the lines of the FEER while overcoming the limitations in the FEER approach. Clark and MacDonald (1998) declared that the use of BEER approaches in assessing real exchange rates has been more extensive for developing countries than for industrialized countries.

2.4.3 The Macroeconomic Balance (MB) Model

The macroeconomic balance approach, which has become popular in central bank policy circles, sets out to identify the medium-term real exchange rate as the rate that equilibrates the current and capital accounts balance of payments. One of the key objectives of this approach (see, for example, Isard & Faruqee, 1998; Faruqee, Isard & Masson, 1999) is to produce a more satisfactory measure of the desired capital account term. If the current account deficit is too high relative to the desired net inflow of capital, the real exchange rates have to fall, and the domestic currency will appreciate; this approach is still used by most advanced economic countries.

2.4.4 The Natural Rate of Exchange (NATREX) Approach

The BEER approach is an extension of the FEER and the model does not capture the nature of the convergence process from the actual rate to its equilibrium level. In response to this, Stein (1994) developed the "Natural Real Exchange Rate" (NATREX) approach, which is defined as "…the rate that would prevail if speculative and cyclical factors could be removed while unemployment is at its natural rate" (Stein, 1994, p. 135). According to Stein (2001), NATREX is defined as follows:

"The equilibrium value of the real exchange rate is a sustainable rate that satisfies several criteria. First, it is consistent with internal balance. This is a situation where the rate of capacity utilization is at its longer run stationary mean. Second, it is consistent with external balance. The latter is a situation where, at the given exchange rate, investors are indifferent between holding domestic or foreign assets. At the equilibrium real exchange rate, there is no reason for the exchange rate to appreciate or depreciate. Hence, portfolio balance or external balance implies that real interest rates between the two countries should converge to a stationary mean." (pp. 1-2)

On this basis, the NATREX is akin to the medium-term equilibrium concept embodied in the FEER, which allows for an explanation for the short-run dynamics. However, the short-run dynamics differentiate the NATREX from the BEER approach. Accordingly, the principal difference is that the NATREX takes its point of departure from a theoretical dynamic stock-flow model to achieve the level of ERER that depends upon the relative thrift and productivity differences (Stein, 2001, p. 5). In short, the NATREX extends the PPP and FEER models by focusing on the periods when fundamentals are not stationary.

As emphasized by McCown, Pollard and Weeks (2007), a weakness of the model summarized above is that they typically concentrate on the medium term but only assume arbitrary capital flows. However, a full understanding of a medium-term economy requires consideration of both international financial markets and capital flows. Therefore, the equilibrium international financial market position is needed to assess the ERER in the real economy.

2.5 The Equilibrium Real Exchange Rate (ERER) Model

The model of the equilibrium real exchange rate (ERER) is designed for developing countries and first developed by Edwards (1989). It estimates directly an ERER for each country based on reduced-form single equation models (see Elbadawi, 1994). Moreover, the empirical applications of Edwards' model and subsequent revisions to developing countries have yielded generally significant results. In the case of developing countries, the ERER model has been used in most of the literature (Clark, Bartolini, Bayoumi & Symansky, 1994; Chinn, 1998; Hinkle & Montiel, 1999; Lin, 2002; Goh & Kim, 2006).

In general, the ERER model has been considered sufficient to depict the characteristics of the transformation process of developing countries and suitable for the measurement of a developing country's equilibrium exchange rate. Edwards (1994) found that only real "fundamental" variables influence the ERER in the long term. Moreover, by using advanced cointegration testing techniques as developed by Johansen (1988) and Johansen-Juselius

(1990), the existence of cointegrating relationships among fundamental variables and real effective exchange rate can be effectively analyzed. For example, Montiel (1997, 1999) and Baffes, Elbadawi and O'Connell (1999) used a cointegration procedure to estimate the ERER.

Among the existing body of literature (see, for example, Zhang, 2001; Lin, 2002), many studies used only the bilateral real exchange rate (i.e. RMB against the U.S. dollar) to assess the RMB equilibrium exchange rate (Lin, 2002; Zhang 2001), and other studies (see Liu, 2004) tried to base the determination of ERER on only a single fundamental variable. Hence, the scope of such studies is limited and their reliability is questionable.

Based on the above discussion, we will conduct an empirical analysis of RMB equilibrium exchange rate based on Elbadawi's (1994) reduced-form ERER framework. The fundamental determinants in the model need to be identified if we are to use the ERER model.

2.6 The Fundamental Variables in ERER Model

Empirical analyses differ in the choice of the underlying real exchange rate fundamental variables, in part because of data availability. Following Edwards (1989, 1994) and Elbadawi (1994), the set of fundamentals affecting the ERER can be specified as, terms of trade, trade openness, government expenditure, productivity and money supply (M2). Furthermore, Montiel (1999) categorized the long-run fundamental variables into four groups, namely, fiscal policy (government spending); commercial policy (export subsidies); domestic supply side factors (productivity); and the international economic environment (e.g. terms of trade, capital flows). From Edwards' and Montiel's theories, we will determine how changes in the fundamentals affect the long-run equilibrium real effective exchange rate in our study.

- **The external terms of trade index** is defined as the ratio of the price index of a country's exports over its imports. The variable is used as a proxy for the international economy environment of a country. The price for the export primary commodities is determined in world commodity markets and subject to significant volatility affecting the terms of trade. Consider the effects of a worsening in the international terms of trade generated by an increase in the international price of imports. However, if the international price of imports is reduced, it can then lead to an appreciation of the RMB. As a result, an improvement in the terms of trade will positively affect the trade balance, and thus lead to an appreciation of the real exchange rate.

- **The degree of openness of the economy (as proxy for commercial policy)** is traditionally viewed as the degree of trade liberalization, and can be an important impact on the long-run equilibrium real exchange rate since. The ratio of total trade (imports + exports) to GDP is a commonly used measure of international trade liberalization. A rise in the openness of an economy is expected to worsen the trade balance, for example, abolishing the country's trade barriers and allowing foreign goods to enter the country more freely. Therefore, increase in openness causes the real exchange rate to depreciate.

- **Fiscal policy (the ratio of government expenditure to GDP)** measures the impact of government expenditure on real exchange rate and depends on its level and distribution between tradable and non-tradable goods. An increase in the public debt is likely to cause a rise in government expenditure on non-tradable goods, and induces a real exchange rate appreciation. However, if government expenditure falls more on tradables than non-tradables then it raises the demand for imports that result in a trade deficit, causing the equilibrium real exchange rate to depreciate. Hence, the effect of government expenditure is *a priori* indefinite on real exchange rates. Accordingly, Edwards (1989) found that increasing government expenditure induced a real exchange rate appreciation for 12 developing countries.

- **Relative productivity differential (technological progress)** is well-known as a proxy for the Balassa-Samuelson effect, which contends that productivity improvements will generally be concentrated in the tradables sector and increases in the relative price of nontraded goods (Balassa, 1964; Samuelson, 1964). If productivity grows faster in the tradables than nontradables sector, this will put upward pressure on wages in the nontradables sector and lead to higher relative price of nontradables. The result is a real exchange rate appreciation for the country, which would, therefore, be able to sustain the higher relative productivity gain without losing external competitiveness.

The Balassa-Samuelson relative productivity differential effect is proxied by the ratio of the domestic consumer price index (CPI) to the wholesale price index (WPI) relative to China's trading partners. However, the use of these proxies is problematic, because of China's unlimited supply of labour and restrictions on free movement of workers between different sectors of the economy. Furthermore, China has large numbers of unemployed and underemployed labour while components of the CPI (such as utility prices) are still under the control of the Chinese government (Dunaway & Li, 2005). For the above reasons, there may not be a strong Balassa-Samuelson effect in China. Moreover, the resulting changes in the CPI/WPI ratio were misinterpreted as changes in relative productivity since the liberalization of price controls. Nevertheless, a rise in real GDP per capita is the one proxy for productivity gain in low income countries (AIShehabi & Ding, 2008). Therefore, we will use per capita real GDP as an explanatory variable in our model (see, Drine & Rault, 2001; Goh & Kim, 2006; Yang et al., 2007) and expect a positive sign on this variable, as Balassa (1964) found that per capita real GDP is positively correlated with real appreciation.

- **Money supply (M2 to GDP)** is a proxy for financial development. An increase in money supply leads to a rise in domestic aggregate demand for money, thus increasing the demand for imports and worsening the current account, causing the equilibrium long-run real exchange rate to depreciate.

2.7 Previous Studies Relating to China

It is appropriate to review the main findings of some studies relating to China. Studies assessing RMB equilibrium real exchange rate abound, however, the view pertaining to the RMB exchange rate are agreed to by different scholars. In what follows, we present a review of main findings from some studies.

Chou and Shin (1998) formulated the purchasing power parity (PPP) model and shadow price of foreign exchange (SPFE) model using quarterly data from 1978 to 1994. They found that the long-run PPP relationship holds by using the cointegration procedure, and the estimated PPP rate indicated that the RMB was, in general, overvalued between 1978 and 1989 and was undervalued in the early 1990s. However, the value estimated by the PPP is unrealistic because prices were under Chinese government control during that period. Thus, based on the estimates of the SPFE, they concluded that the RMB official exchange rates were overvalued throughout the whole sample period of 1978-1994.

Zhang (2001) followed the BEER approach using annual data from 1952-1997 to measure the misalignment of Chinese currency, and concluded that the RMB was overvalued in China's central planning period but that economic reforms brought the real exchange rate closer to its equilibrium level. Moreover, the cumulative effect of exchange rate reform led to a real depreciation of the RMB after 1981. Zhang's result showed China had a proactive exchange rate policy using the nominal exchange rate as a policy tool to achieve real targets during that period.

In addition, Zhang (2000) also used the equilibrium real exchange rate (ERER) model to estimate the RMB exchange rate and analyze its misalignment. The author found that the RMB was overvalued significantly from 1997 to 1998 and the RMB exchange rate was closer to the equilibrium level from 1999 to 2000. Chen (2007) adopts the BEER model and the cointegration technique to assess the RMB exchange rate and its misalignment from 1994Q1 to 2006Q4. This author found that the RMB real exchange rate has been undervalued during the sample period but the degree of misalignment tended to become smaller and smaller.

In a recent paper by Chang and Shao (2004) the RMB equilibrium real exchange rate was estimated to be undervalued by 22.5 percent in 2003, but this result was not statistically significant. In addition, the Wang et al. (2007) study estimated the BEER using Johansen's Maximum Likelihood (ML) cointegration procedure and concluded that the RMB fluctuates around its long-run equilibrium level within a narrow band - i.e. the RMB had not been consistently undervalued. Cheung, Chinn and Fujii (2007) found that the RMB was undervalued under various alternative conditions, but admitted that the statistical evidence was weak.

Wang (2004) also pointed out that the RMB was undervalued by 5 percent using the extended-PPP approach. Frankel (2005) utilized the extended-PPP and concluded that the RMB was 36 percent undervalued against the USD in the year 2000. Coundert and Couharde (2005) employed both the extended-PPP and the macroeconomic balance approaches and the extended-PPP model suggest that the RMB was undervalued between 41 percent and just over 50 percent, whereas the macroeconomic balance approach showed an undervaluation of 23 percent in 2003.

However, a number of studies have failed to find significant evidence of misalignment of the RMB. For example, following Wang's (2004) study, the International Monetary Fund (2004) reported no misalignment of China's exchange rate in 2004. Funke and Rahn (2005) pointed out that neither the PPP nor the economic fundamental approach could find any significant undervaluation of the RMB. Moreover, Goh and Kim (2006), employing the reduced-form modelling developed by Edwards (1989, 1994), could not find evidence showing the RMB to be significantly undervalued.

2.8 Conclusion

This chapter reviewed the theoretical models analysing equilibrium exchange rate. The theoretical models are popular among researchers in assessing a country's equilibrium exchange rate. Section 2.2 discussed the basic concepts of exchange rate. Sections 2.3 and 2.4 presented the determinants and theoretical models of equilibrium exchange rate, in particular the PPP theoretical framework and ERER model. The final section outlined an overview of the empirical findings of the RMB exchange rate. The empirical results based on FEER models show a large degree of misalignment compared to the smaller estimates based on BEER or ERER models. On the other hand, some empirical studies have found only weak evidence of misalignment in the RMB exchange rates during their sample periods. Although the existing body of empirical evidence indicates some degree of misalignment of the RMB, it is not unanimous in regard to the direction and especially the numerical extent of any such misalignment.

The following chapter will detail the econometric methods and the data used in our study to estimate a long-run equilibrium real effective exchange rate, and evaluate the extent of its possible misalignment.

Chapter 3

Econometric Methods and Data

3.1 Introduction

This chapter discusses the econometric methods that will be used to test the reduced-form of an ERER model for China's equilibrium exchange rate. First, the Augmented Dickey-Fuller (ADF) unit root test will be performed in order to ascertain the time-series properties of individual series, i.e. whether they have a stochastic or a deterministic trend. Following this, we explain the Johansen multivariate maximum likelihood cointegration procedure that will be used to develop empirical versions of the ERER model.

In particular, we seek to determine the number of cointegrating vectors that may exist, and then perform valid statistical tests of restrictions on the estimated long-run equilibrium and "speed of adjustment" parameters. The Vector Autoregressive (VAR) and Error Correction (VEC) models will be discussed in Section 3.2.2. Following this, we will present more details of the Johansen-Juselius (1990) cointegration procedure, including the reduced rank test, determination of the cointegration vectors and deterministic components in the multivariate model. We also illustrate the testing for weak exogeneity. Section 3.2.3 describes how we use the estimated long-run parameters to determine the equilibrium level of real effective exchange rate (REER), and then discusses how the equilibrium REER is used to calculate the degree of REER misalignment. Finally, the chapter describes the sources and main properties of the data.

3.2 Econometric Methods

Before estimating an econometric model and conducting data analysis, it is crucial to investigate the dynamic properties of our time series data. In order to determine whether the time series are stationary or non-stationary, we need to test for the presence of unit roots. This is because if a series does not hold at least one unit root (i.e. non-stationary series), when it combines with other non-stationary series to form a stationary cointegration relationship, then regressions can falsely imply the existence of a meaningful economic relationship. Formally, for a time series, Y_t, if the series has constant mean and variance over time, with time-invariant autocovariance then it is said to be stationary, that is:

$$E(Y_t) = \mu \qquad \text{(constant mean)} \tag{3.1a}$$

$$\text{var}(Y_t) = \sigma^2 \qquad \text{(constant variance)} \tag{3.1b}$$

$$\text{cov}(Y_t, Y_{t-s}) = \sigma^2\rho_s \qquad \text{(covariance depends on } s\text{, not } t\text{)} \tag{3.1c}$$

where ρ_s is serial correlation of lag s.

To formally test for non-stationary time series, the most popular test is the Augmented Dickey-Fuller (DF) test devised by Dickey and Fuller (1979).

3.2.1 Testing for the Existence of Unit Roots

For any time series, Y_t, the Augmented Dickey Fuller (ADF) test equation can be written as follows:

$$\Delta Y_t = \mu + \alpha Y_{t-1} + \beta t + \sum_{j=1}^{p} c_j \Delta Y_{t-j} + \varepsilon_t \tag{3.2}$$

where Y_t is the time series tested for the existence of a unit root and the lagged first-differenced terms are added to control for the possibility that the error term is auto-correlated .

In general, Akaike Information Criterion (AIC), Hannan-Quinn Criterion (HQC) and Schwarz Info Criterion (SIC) are used to determine the optimal lag length (p) for the augmentation terms. According to Asghar and Abid (2007), their results were closed to Liew's (2004) study that compared five lag length selection criteria: AIC, SIC, HQC, FPE and BIC with true lag length fixed at 4. The results demonstrated that AIC and FPE have the highest probability of correct estimation for small sample size (60 or less); HQC has the best performance when the sample size is greater than 60 and for large sample size (120 or greater) performance of SIC is the best. Hence, we will choose the AIC, which selects the value of p to minimize:

$$-2(l/T) + 2k/T \tag{3.3}$$

where l is the log of the likelihood function value with the number of parameters (k) estimated using T observations. It is based on -2 times the average log likelihood function, adjusted by a penalty function.

Testing for a unit root means to test, $H_0 : \alpha = 0$, which implies the series, Y_t is nonstationary or has at least one unit root against the alternative $H_1 : \alpha < 0$, implying that Y_t is stationary. If the null hypothesis cannot be rejected at the chosen significance level, this suggests that Y_t is integrated of order 1 (denoted by, $Y_t \sim I(1)$), meaning that Y_t is stationary after differencing once, i.e. $\Delta Y_t \sim I(0)$. In general, a non-stationary series Y_t might need to be differenced more than once before it becomes stationary, which is denoted as, $Y_t \sim I(d)$. In other words, testing for the number of unit roots is same as testing for the order of integration. Since the Vector Autoregression (VAR) model requires that all series are integrated in the same order (Harris, 1995), determining the order of integration is an important part of the empirical analysis.

To test the unit root null hypothesis of $\alpha = 0$, Dickey and Fuller (1979) show that the usual *t*-statistic no longer has standard distribution under the null hypothesis. They computed the appropriate critical values, called tau (τ). MacKinnon (1991) further tabulated the appropriate critical values with different levels of significance for various test equation specifications. In our research, we will use the MacKinnon critical values provided in EViews.

3.2.2 The Johansen-Juselius (JJ) Multivariate Approach

In general, if the series in the model turn out to be $I(1)$ process, then the cointegration method will be used for the appropriate estimation technique. Three different types of single-equation cointegration techniques have been used to estimate long-run models - namely, the Engle and Granger (EG) two-step approach, Dynamic Ordinary Least Squares (DOLS) and the Auto-Regressive Distributed Lag (ARDL) approach. However, we will not review them here (see for example, Engle & Granger, 1987; Stock & Watson, 1993; Pesaran, Shin, & Smith, 2001) but will proceed directly to the JJ approach.

If there is evidence of more than one cointegration relationship, the single-equation approaches may not be able to detect the additional cointegrating relationships. In order to examine cointegration in systems of equations, Johansen (1988) derived a procedure which overcame this limitation by being able to identify multiple linearly independent cointegration relationships. The advantage of Johansen's procedure is that it provides not only a cointegration test but also reveals the number of cointegrating vectors. The JJ approach has become one of the standard testing procedures for investigating cointegration. In the following discussion, we will outline only the most significant and relevant parts of this procedure, referring the reader to the main literature for further elaboration[2].

3.2.2.1 The Vector AutoRegression (VAR) Model

The Johansen and Juselius (1990) procedure begins with the formulation of an unrestricted multivariate vector autoregressive (VAR) model with white noise, possibly non-stationary, *n* variables Y_t, each having *k* lags:

$$Y_t = \Pi_1 Y_{t-1} + \Pi_2 Y_{t-2} + \cdots + \Pi_k Y_{t-k} + \mu + \phi D_t + \varepsilon_t \qquad (3.4)$$

where Y_t is a vector of n variables which become stationary after first differences, *I*(1), Π_t are $n \times n$ matrices of parameters (t = 1, 2, …, k), μ is a $(n \times 1)$ vector of constants, ε_t ~ MVN $(0, \Lambda)$ --- i.e. "well behaved" random disturbances. The term D_t is a vector of deterministic terms such as (centred) seasonal and trend dummies, which are included in the model to ensure that the error terms are close to being well behaved.

3.2.2.2 Lag Length Specification and Diagnostic Tests

In implementing the JJ procedure, we must select the appropriate (optimal) numbers of lags, *k*, in our VAR model. The reason is that we expect to have Gaussian error terms (i.e. standard normal error terms that do not suffer from non-normality, autocorrelation, heteroskedasticity, etc.). In this regard, we use the Final Prediction Error (FPE), Akaike Information Criterion (AIC), Hannan-Quinn Criterion (HQ) and Sims' (1980) modified likelihood ratio (LR) test, which is performed by substituting the restricted and unrestricted maximum values into the formula as follows:

$$LR = (T - m)(\log|D_R| - \log|D_U|) \qquad (3.5)$$

[2] See Johansen (1988, 1991 and 1995) and Johansen and Juselius (1990) for further details.

where T is the number of usable observations, m is the number of parameters per equation under the unrestricted system; D_R is the matrix of residuals when the model is restricted; and D_U is the same matrix for the unrestricted model. The above test statistic has the asymptotic χ^2 distribution with degrees of freedom (which equals to the number of restrictions in the system).

In the specification of a VAR model we start with a model of arbitrary lag length and then check the values of the AIC and/or SC criteria, as well as diagnostic test results regarding autocorrelation, normality and heteroskedasticity of the residuals. If autocorrelation is present in the residuals, another lag in the subsequent estimation until the null hypothesis (of no autocorrelation) cannot be rejected at the 5% significance level. Next, the Jarque-Bera test is performed to check for normality of the residuals at all lag lengths. We choose Cholesky factor of the Residual Covariance Matrix (see Lutkepohl, 1991, pp. 155-158). Finally, we perform White's heteroskedasticity test on the residuals.

The aim of this analysis is to find a model with optimal lag length, which also passes all the diagnostic tests. Note that the lag length of the VEC model equals the lag length of the VAR model minus one, *k*-1. Once the model passes all the diagnostic checks (i.e. the residuals are reasonably close to the Gaussian assumptions) we can then develop the VEC model, as explained below.

3.2.2.3 The Vector Error-Correction (VEC) Model

The associated vector error-correction model (VECM) counterpart to the VAR(k) model, equation (3.4) given is as follows:

$$\Delta Y_t = \Gamma_1 \Delta Y_{t-1} + \Gamma_2 \Delta Y_{t-2} + \cdots + \Gamma_{k-1} \Delta Y_{t-k+1} + \Pi Y_{t-k} + \mu + \phi D_t + \varepsilon_t \qquad (3.6)$$

Where,

ΔY_t = the first difference of the series in the Y matrix

$\Gamma_i = -I + \Pi_1 + \Pi_2 + \cdots + \Pi_i$ for i = 1, 2, …, k-1

$\Pi = -I + \Pi_1 + \Pi_2 + \cdots + \Pi_k$, and

I = the identity matrix

Y_t = (Real Effective Exchange Rate, Terms of Trade, Openness, Government Expenditure, Productivity, Money supply), Γ_i contains short-run adjustment parameters, which are not our main interest. The matrix Π contains information about the long-run properties of the model, which is our main area of interest. The rank of Π, *r*, gives the number of cointegration relationships. In general, for *n* number of variables we can have only up to *n*-1 cointegrating vectors (Asteriou, 2006).

To be specific, the rank of Π is crucial in determining the number of distinct cointegrating vectors. Three possible cases are considered: (i) if the rank of Π is zero, then the system is not cointegrated and the variables in Y_t are integrated of order one or higher. In this instance, it would be appropriate to estimate the model in first differences. (ii) If Π has full rank (r = n), the variables in Y_t are stationary in levels, and (iii) if Π has reduced rank (where $0 < r \leq n-1$), where *r* stands for the number of linearly independent co-integrating vectors, and Π may be decomposed into the product of two distinct n by r matrices α and β such that $\Pi = \alpha \cdot \beta'$. Where α includes the "speed of adjustment" in the equilibrium coefficients while the β matrix contains the long-run equilibrium parameters such that the term $\beta' Y_{t-k}$ embedded in equation (3.6) comprise the *r* error-correction terms ($r \leq n-1$ co-integration vectors) which are stationary (see Harris, 1995; Johansen, 1988).

Due to the cross-equation restrictions, it is not possible to compute the maximum likelihood estimation of $\Pi = \alpha \cdot \beta'$ using ordinary least squares (OLS) regression. Thus Johansen (1988) developed a method that provides estimates of α and β and tests for the rank of Π through a procedure known as reduced rank regression that is summarised in the next two subsections.

3.2.2.4 The Reduced Rank Regression

The Johansen (1988) and Johansen and Juselius (1990) procedure of reduced rank regression is a multivariate regression model with a coefficient matrix with reduced rank. Its algorithm involves calculating eigenvectors and eigenvalues. For notational simplicity, we rewrite the VEC model (equation (3.6)) in form as:

$$\Delta Y_t = \Gamma_1 \Delta Y_{t-1} + \Gamma_2 \Delta Y_{t-2} + \cdots + \Gamma_{k-1} \Delta Y_{t-k+1} + \alpha\beta' Y_{t-k} + \varepsilon_t \qquad (3.7)$$

The maximum likelihood estimation of $\Pi = \alpha\beta'$ is based on the results obtained from two sets of OLS regressions, both of which are intended to "partial out" the lagged ΔY_{t-i} terms on ΔY_t and Y_{t-k} , respectively.

In the first instance, each of the variables in the ΔY_t vector is regressed on ΔY_{t-1}, ΔY_{t-2}, ... , ΔY_{t-k+1} , and the residual matrix R_{0t} is obtained. Secondly, each Y_{t-k} variable is regressed on ΔY_{t-1}, ΔY_{t-2}, ... , ΔY_{t-k+1} and a second residual matrix R_{kt} is obtained.

Using the series of R_{0t} and R_{kt} residuals from these regressions we compute the *residual product moment* matrices:

$$S_{ij} = T^{-1} \sum_{i=1}^{T} R_{it} R'_{jt} \qquad (3.8)$$

where, T is number of observations, and i, j = 0, k

The likelihood function has the form of a reduced rank regression as:

$$R_{0t} = \alpha\beta' R_{kt} + u_t \tag{3.9}$$

For a fixed β, equation (3.9) can be solved for α by using the regression:

$$\hat{\alpha}(\beta) = S_{0k}\beta(\beta' S_{kk}\beta)^{-1} \tag{3.10}$$

Following this, we solve equation (3.10) for its *k* eigenvalues and the corresponding eigenvectors as follows:

$$\left|\lambda S_{kk} - S_{k0}S_{00}^{-1}S_{0k}\right| = 0 \tag{3.11}$$

Let $\lambda = \hat{\lambda}_1 > \hat{\lambda}_2 > \cdots > \hat{\lambda}_n$ be the corresponding estimated eigenvalues used to solve for the corresponding estimated eigenvector $V = (\hat{V}_1, \hat{V}_2, \cdots, \hat{V}_n)$ normalized as $\hat{V}' S_{kk} \hat{V} = I$. In addition, the maximum likelihood estimators for the matrices β and α are given by $\hat{\beta} = (\hat{v}_1, \hat{v}_2, \cdots, \hat{v}_r)$ and $\hat{\alpha} = S_{0k}\hat{\beta}$, that is, these are the cointegration vectors. Because the eigenvalues are the squared canonical correlations of the 'levels' residuals R_{kt} with respect to the 'difference' residuals R_{0t} (Johansen, 1988, p. 325), the magnitude of each eigenvalue, $\hat{\lambda}_i$, indicates how strongly the linear combination Y_{t-k} is correlated with ΔY_t after correcting for the effect of the lagged differences of Y_t (i.e. the larger magnitude means that the stronger the correlation will be). Johansen and Juselius (1990) and Johansen (1992a) proposed two likelihood ratio tests for testing the null hypothesis of $\hat{\lambda}_{r+1} = \cdots = \hat{\lambda}_n = 0$, where *r* is equivalent to rank of Π or number of statistically significant $\hat{\lambda}_i$ eigenvalues.

3.2.2.5 Determining the Number of Cointegrating Vectors

As discussed previously, *r* is the rank of Π and determines the number of cointegrating vectors, which is obtained based on a method proposed by Johansen (1988). Two test statistics produced by the Johansen's maximum likelihood procedure include the Trace statistic and Maximal-eigenvalue statistic, λ_{trace} and λ_{max}. Both can be used to determine the number of cointegrating relations, and estimation of the matrix Π.

The maximized unrestricted log-likelihood function for the VAR(k) model in (3.4) is obtained from the reduced rank regression:

$$LLF_{un}(\hat{\Theta}_{un}) = -\frac{T}{2}\ln|S_{00}| - \frac{T}{2}\sum_{i=1}^{q}\ln(1-\hat{\lambda}_i) \tag{3.12}$$

Denoting the rank of $\Pi = \alpha\beta'$ as r, then the restricted likelihood function is:

$$LLF_{R}(\hat{\Theta}_{R}) = -\frac{T}{2}\ln|S_{00}| - \frac{T}{2}\sum_{i=1}^{r}\ln(1-\hat{\lambda}_i) \tag{3.13}$$

where $\hat{\Theta}_{un}$ and $\hat{\Theta}_{R}$ represent the unrestricted and restricted estimators of the parameters in equation (3.4), respectively. Thus to test $H_0 : r = 0$ (i.e. no cointegration relationship) vs $H_a : r > 0$ (i.e. at least one cointegration vector), the Trace test statistic is given by (Harris, 1995):

$$\lambda_{trace}(r) = -T\sum_{i=r+1}^{q}\ln(1-\hat{\lambda}_i) \tag{3.14}$$

where, r = 0, 1, 2…, q-1; T is the sample size and $\hat{\lambda}_i$ is the *i*th largest eigenvalue. The further the estimated eigenvalues are from zero, the more negative is $(1-\hat{\lambda}_i)$ term and the lager the λ_{trace} statistic.

In contrast, the Max-eigenvalue statistic (denoted by λ_{max}) tests the null hypothesis of at most *r* (r = 0) against the alternative hypothesis of at most *r* + 1 cointegrating vectors using the following statistic (Enders, 1995):

$$\lambda_{max}(r, r+1) = -T\ln(1-\hat{\lambda}_{r+1}) \tag{3.15}$$

The main difference between these two tests is that the trace statistic tests the null against a general alternative, whereas the max-eigen statistic tests against a specific alternative. Gu (2004) pointed out that the max-eigenvalue test has greater power when the $\hat{\lambda}_i$ are either too large or small.

A full discussion of these two test statistics is given in Johansen and Juselius (1990, pp. 169-210) and in Johansen (1988; 1991), who provide a mathematical derivation of the asymptotic distributions. However, neither of the asymptotic distributions of these two test statistics follows the standard χ^2 distribution in general, but follow the multivariate versions of the Dickey Fuller distribution. Simulated critical values are tabulated by Osterwald-Lenum (1992), as used in our case.

3.2.2.6 Selection of the Deterministic Components in the VEC Model

Before any such test statistics can be carried out it is necessary to establish the most appropriate configuration of the deterministic components in the VEC model specification (i.e. whether an intercept and/or trend exist(s) in the data or in the cointegration vectors). Following Hansen and Juselius (1995), we assume the lag length of VAR model is 2 and omit the other deterministic variables in D_t, and expanded equation (3.6) for notational simplicity as (Harris, 1995):

$$\Delta Y_t = \Gamma_1 \Delta Y_{t-1} + \alpha \begin{bmatrix} \beta \\ \mu_1 \\ \delta_1 \end{bmatrix} \tilde{Y}_{t-2} + \alpha_\perp \mu_2 + \alpha_\perp \delta_2 t + \varepsilon_t \qquad \varepsilon_t \sim NIID\ (0, \Sigma) \qquad (3.16)$$

where $\tilde{Y}'_{t\text{-}2} = (Y'_{t\text{-}2},\ 1,\ t)$ and $\alpha_\perp$ is an orthogonal matrix to α such that $\alpha'_\perp \alpha = 0$. Furthermore, if $\mu_1(\delta_1) \neq 0$ then an intercept (trend) term is included in the long-run model, whereas if $\mu_2(\delta_2) \neq 0$ it indicates that an intercept (trend) term is contained in the short-run model. On the other hand, it is possible to specify the case where, $\mu_1 = \mu_2 = \delta_1 = \delta_2 = 0$, which means there are no deterministic components either in the *data* or *cointegrating relations*, but this extreme case is not practical. The reason is that at least an intercept has to account for the units of measurement of the variables in, Y_t.

There are five possible combinations of deterministic components contained in the Johansen procedure (see Johansen, 1995). However, in practice, Cases 1 and 5 are rarely used and also implausible in economic theory (see Hansen & Juselius, 1995) because in most cases the variables in the model have non-zero means and quadratic trends. Hence, only three cases can be realistically considered:

Case 2 has no linear trends in level data so that, $\mu_2 = \delta_1 = \delta_2 = 0$. Hence the intercept is restricted to lie within the cointegration space, i.e. $\mu_1 \neq 0$.

Case 3 has linear trends in level data so it is appropriate to allow the nonstationary relationships in the model to drift, implying that, $\delta_1 = \delta_2 = 0$. However, the intercept is unrestricted, lying outside the cointegration space, i.e. $\mu_2 \neq 0$.

Case 4 assumes if there are no quadratic trends in the data, then there will be no time trend in the short-run, that is, $\delta_2 = 0$. But if there is any linear growth in the long-run model, then a linear trend will be included in the cointegration vectors, thus, $\delta_1 \neq 0$.

Since we can not certain *a priori* which case to use, it is necessary to test for the appropriate restrictions to be imposed on the μ and δ parameters. Johansen (1992b) suggested the need to carry out the joint test of both the rank of Π and the correct configuration of the deterministic components using the Pantula Principle[3]. That is, we need to estimate the eigenvalues for all three cases and then compare the computed trace or maximal-eigenvalue test statistic associated with each case to their appropriate Osterwald-Lenum's (1992) critical value (i.e. rank of Π 0 to *n*-1 and case 2 to 4). The test procedure will stop when the null is not rejected. For example, assuming that the null hypothesis of $r = 1$ under Case 3 it is accepted at the 5% significance level, then the appropriate case should be Case 3 with only one cointegration vector. As will be discussed in Chapter 4, we will use intermediate results given in EViews output to help select the appropriate case.

Once we have determined the number of cointegrating relationships, *r* and obtained a valid and appropriate case, we can proceed to examine the coefficients of β' and α, and subsequently test restrictions on them.

3.2.2.7 Testing Restrictions on the α Parameters

An interesting issue is how quickly the long-run equilibrium real exchange rate is achieved, which concerns estimating the speed of adjustment to past disequilibrium as represented by the matrix of α (i.e., the error correction or feedback parameters) in the VEC model given in (3.6). Testing restrictions on the adjustment coefficients α may be construed as tests for weak exogeneity with respect to the long-run parameters. For example, if there is only one cointegrating vector ($r = 1$), hence only one error correction term, this is equivalent to determining which of the VECM equations the error correction term should appear (see Engle, Hendry, & Richard, 1983; Johansen, 1995).

3 For a more comprehensive description of the Pantula principle, see Johansen (1992b), pp. 383-397 and Harris (1995), pp. 96-97.

Another aspect of the dynamic model is the size and statistical significance of the speed of adjustment coefficients, α_i, which measures the proportional change in the *i*-th series in response to a 1 percent deviation of the actual real exchange rate from the long-run equilibrium real exchange rate. The larger the size of adjustment, the faster the rate converges towards the equilibrium level. Computing the coefficients of speed of adjustment completes the empirical analysis. The next section explains the actual steps taken to compute the long-run equilibrium real exchange rate on which the misalignment measure is based.

3.2.3 Estimating the Long-Run Equilibrium Equation and Misalignment of RMB

3.2.3.1 Decompositions of Time-Series

Nelson and Plosser (1982) emphasize that many economic time series have an irregular and a stochastic component. Furthermore, numerous economic theories identify that it is important to differentiate between *temporary* and *permanent* movements in a series (Harris, 1995). If a series is stationary, then its movement should be inherently temporary, whereas movements in the non-stationary fundamentals are permanent. In order to obtain the "sustainable" or "permanent" components of the fundamentals, Baffes, Elbadawi and O'Connell (1997) discussed two methods that can be used, namely, the counterfactual method and the time series decomposition techniques. In practice, the second method is more widely used and includes Beveridge-Nelson decomposition, moving averages and the Hodrick-Prescott (HP) filter (see, for example, Beveridge & Nelson, 1981; Hodrick & Prescott, 1997). However, both the Beveridge-Nelson approach and centred moving averages method are problematic with small samples (Baffes et al., 1997).

The Hodrick-Prescott filter, which we adopt in our case, is widely used in macroeconomic research to obtain a smooth estimate of the long-term component of a series. Technically, it is a two-sided linear filter that computes the smoothed series μ of Y by minimizing the variance of Y around μ. Algebraically, the HP filter chooses μ to minimize as follows:

$$(1/T)\sum_{t=1}^{T}(Y_t - \mu_t)^2 + (\lambda/T)\sum_{t=2}^{T-1}\left[(\mu_{t+1} - \mu_t) - (\mu_t - \mu_{t-1})\right]^2 \qquad (3.17)$$

It is customary to set λ equal to 1600 for quarterly data, as selected in our case. The parameter λ influences the smoothness of the trend (Enders, 1995) - that is, the larger the λ, the smoother the trend. When λ becomes infinity, the trend approaches a linear time trend. So, the benefit of the HP filter decomposition is that it can extract the same time trend from a set of fundamentals.

3.2.3.2 Estimating the Long-Run Equilibrium REER and its Misalignment

Once the cointegration vector is estimated, we obtain the estimated long run equilibrium REER equation associated with the model specified in Elbadawi (1994). Therefore, the equilibrium REER can be estimated by the long-run REER equation.

In order to analyze the robustness of our empirical results, we use two measures to work out the degree of REER misalignment. First, the misalignment is obtained by subtracting the equilibrium from the observed real effective exchange rate. Second, we compute the misalignment as the REER deviations from the trend calculated using the decomposition techniques (i.e. the Hodrick-Prescott filter), as discussed above. According to Elbadawi (1994), the expressions of the REER misalignment is given as follows:

$$\text{Misalignment} = \frac{\text{REER-ERER}}{\text{ERER}} \times 100\% \qquad (3.18)$$

where REER stands for the actual real effective exchange rate, and ERER denotes the equilibrium real effective exchange rate. It is important to emphasize that the variables in our study are logarithms and it is necessary to convert them to exponential form before the measures of misalignment are obtained.

3.3 The Reduced-form ERER Model

On the basis of Edward's model, Elbadawi (1994) developed a more reasonable forward-looking ERER model (i.e., reduced-form equation). We choose the ERER model to estimate the equilibrium exchange rate of RMB because it is well suited to developing countries. The discussion of the ERER approach is based on Elbadawi (1994). Theoretically, an estimated reduced-form ERER equation is used to predict the behaviour of the real effective exchange rate associated with economic fundamentals. Indeed, Edwards (1994) found that only real "fundamental" variables influence the ERER in the long run.

As pointed out by Elbadawi, the long-run relationship is linear in simple transformations (e.g. logarithms) of the fundamentals. The reduced-form equation for the real effective exchange rate may be written as:

$$\log \tilde{e}_t = \beta' F_t + \varepsilon_t \tag{3.19}$$

where $\tilde{e}$ denotes the equilibrium real exchange rate, F stands for the vector of permanent values for the fundamentals, and ε is the random disturbance term. Following this equation, the task is to construct a time series for the equilibrium real exchange rate – using data on actual real effective exchange rate and its fundamentals to estimate the cointegration vector β of long-run parameters and choose a set of permanent values for the fundamentals appropriate to period *t*.

Once the estimated cointegration parameter vector β is considered statistically valid, then equation (3.19) is not only interpreted as a long-run equilibrium relationship, but is also consistent with a dynamic error correction model (Elbadawi, 1994). Therefore, the error-correction equation consistent with the cointegration used to model short-run fluctuations is given as follows:

$$\Delta \log e_t = \lambda \left(\log e_{t-1} - \beta' F_{t-1} \right) + \gamma_1' \Delta F_t + \gamma_2 \Delta \log E_t + \upsilon_t \qquad (3.20)$$

where $\Delta \log e_t$ indicates appropriate rate of change in the exchange rate, F_t is the vector of fundamentals, and the disturbance υ_t is a stationary random variable. The error correction term ($\log e_{t-1} - \beta' F_{t-1}$) clearly incorporates the forward-looking sources of real exchange rate dynamics. The coefficient λ governs the speed of adjustment back towards the long-run equilibrium, and we usually expect its sign to be negative, that is, for, $-1 < \lambda < 0$, the corresponding long-run equilibrium is stable.

Furthermore, the changes $\Delta \log e_t$ depend on the departure of the system from its long-run equilibrium in the previous period. The shock υ leads to a short-run departure from the cointegration equilibrium path; then, there is a tendency to correct back towards the equilibrium.

In order to carry out the cointegration analysis, we choose five economic fundamentals as the variables in the vector, F_t, thus the function of these fundamentals is given in the following:

$$\text{REER} = (\text{TOT, OPEN, GOV, PROD, M2}) \qquad (3.21)$$

The variables are selected based on whether they influence the equilibrium exchange rate of RMB in accordance with economic theory as well as with China national conditions. In equation (3.21), REER is the real effective exchange rate of the RMB. The others are determinants of the equilibrium REER, as suggested by ERER model. The variable TOT is the terms of trade, OPEN stands for the degree of openness, and GOV indicates government expenditure which captures the effect of fiscal policy. The variable PROD can be viewed as a proxy for technological progress and M2 stands for money supply (M2).

3.4 Data Sources and Construction of Variables

The dataset used in our study consists of quarterly time series. The data time period spans the first quarter of 1999 to the fourth quarter of 2007 due to limited data availability. We use a variety of econometric procedures available in EViews 6 software. In the following section we describe how we constructed these fundamentals and their sources of information. All series enter the model in natural logarithms and the data are presented in Appendix 1.

3.4.1 Real Effective Exchange Rate (REER)

Our dependent variable is the *real effective exchange rate*, which is defined as ratio of domestic price index of home country (China) *vis-à-vis* the price index of its main trading part In July 1986, the exchange rate was determined by the swap market, at 6.50 RMB/USD, but the official rate was only 3.72 and remained stable at that level until 1989. By the end of 1993, the official rate had dropped to 5.80 from the 3.20 yuan per dollar in 1985. From the first day of 1994, the Chinese government, reformed its double-track exchange rate system and adopted a unified exchange rate regime, where the exchange rate was depreciated to 8.70 RMB/USD. To get a sense of the evolving range of China's exchange rate movement, Figure 1.3 plots the bilateral exchange rate (RMB/USD) during the period 1978 to 2007. Under the double-track exchange rate system, the RMB appreciated from 8.70 to 8.45 RMB/USD at the end of 1994 and then further appreciated to RMB8.28, making the regime a *de facto* peg to the U.S. dollar in October 1997. However, this rate remained almost at 8.28 until the latest revaluation of the RMB on July 21, 2005 (Wang, Hui, & Soofi, 2007). It is to be noted that a decrease in the bilateral exchange rate (RMB/USD) reflects an appreciation of the country's currency, RMB.

ners multiplied by the nominal exchange rate of home country, and will be examined over time. We use the Consumer Price Index (CPI)-based trade-weighted REER, given as an index form and the reference base is 2000=100. We choose the CPI-based REER index because it is a frequently used indicator of competitiveness of a country (i.e. China) against its major trading partners - i.e. USA, Japan, Europe, Taiwan, and Korea. In the case of the index, an increase in REER index represents an appreciation of the RMB relative to its trading partners. China's CPI-based REER quarterly indices are obtained from *IFS Online*.

3.4.2 Terms of Trade (TOT)

TOT is defined as the ratio of the export unit value index to the import unit value index. It is the best proxy to present a country's international economy environment. The terms of trade indices are sourced from UNCTAD's *Handbook of Statistics 2008*, the base year is 2000. However, only annually data of the TOT are available in UNCTAD's database, so we converted them into quarterly data.

3.4.3 Openness (OPEN)

This variable as the proxy of commercial policy, as discussed in the literature, is defined as $\text{OPEN}=\frac{\text{IMP}+\text{EXP}}{\text{GDP}}$, where IMP and EXP refer, respectively, to importation and exportation, and GDP refers to Gross Domestic Product of China. All three quarterly series are sourced form *IFS Online*. However, this variable can normally be expected to contain substantial seasonality, and it fluctuating significantly during the 4^{th} quarter in each year. Thus, for analysis purposes the series has been de-seasonalized with dummy variables.

3.4.4 Government Expenditure (GOV)

The government expenditure variable, *GOV*, is included in the model as

$$\text{GOV}=\frac{\text{Total government expenditure}}{\text{GDP}}$$

All the data used to construct this variable are taken from the *China Statistical Yearbook 2008* and quarterly data have been interpolated from annual data when necessary.

3.4.5 Productivity (PROD)

Following Drine and Rault (2001), Goh and Kim (2006) and AlShehabi and Ding (2008), per capita real GDP may be used as a proxy for the productivity variable. It is calculated as follows:

$$\text{Real GDP} = \frac{\text{Nominal GDP}}{\text{GDP deflator / 100}}\text{, and}$$

$$\text{Per capita real GDP} = \frac{\text{Real GDP}}{\text{Population}}$$

Note that the GDP deflator is given as an index form and the reference base is 2000=100. All the data used to construct this variable are taken from the IFS *Online*.

3.4.6 Money Supply (M2)

We use M2 (i.e. money plus quasi-money) for China as one of our fundamentals, obtained from the *IFS online,* IMF and expressed as a proportion of GDP obtained from the same source. The annual GDP data were expressed in quarterly form using the linear-match last method.

3.5 Conclusion

This chapter began by describing the econometric methods relating to the unit root test and to Johansen and Juselius's (1990) multivariate cointegration procedure. It then reviewed the theoretical model for reduced-form of ERER and described the estimation of the long-run equilibrium equation. We also explained how the real effective exchange rate equilibrium is used to compute the degree of misalignment. Finally, the definitions and sources of our data are discussed. The following chapter will present and discuss the empirical results of our data analysis.

Chapter 4

Empirical Results

4.1 Introduction

This chapter discusses the empirical results of our models and data. EViews software is employed to generate the results. The chapter is structured as follows; we begin our analysis by testing the stationary properties of the time series of the individual variables used in the study using the Augmented Dickey-Fuller (ADF) unit root test. Next, we present the results of the cointegration tests and the estimates of the long-run equilibrium real exchange rate of the RMB, specify the error-correction model and filter the economic fundamentals data by the Hodrick-Prescott (H-P) filter to eliminate short-run effects on the estimated equilibrium real effective exchange rate data. The chapter then reports the result whether the RMB is undervalued during the sample period.

4.2 Testing the Order of Integration of the Variables

Before proceeding to the cointegration analysis, we first check the time series properties by testing the stationarity of each fundamental series. The selection criterion for lag length is based on the Akaike Info criterion (AIC), which has been demonstrated to have the greatest probability of correct estimation for small sample size (i.e. 60 or less). Taking the logarithms of the RMB real effective exchange rate and its fundamentals, we denote them as LREER, LTOT, LOPEN, LGOV, LPROD and LM2, respectively. A unit root test was undertaken for each of the six selected variables using the Augmented Dickey-Fuller (ADF) test equation (3.2), without a time trend. The results are presented in Table 4.1.

The results of the ADF tests indicate that the unit root null hypothesis was not rejected for all series, except for the variable LPROD where the ADF test indicates that we cannot reject the nonstationary in first difference at the 5% significance level. However, the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test indicates rejection of the non-stationary hypothesis in first difference for variable of LPROD at the equivalent confidence level. According to Harris (1995), the unit root test has the pitfall of low power, thus the evidence in favour of the series of LPROD being $I(2)$ is quite weak. Therefore, the evidence from both the ADF and KPSS tests suggest that all the variables can be considered as stationary in first difference, in other words, they are integrated of order one, $I(1)$, fulfilling the necessary criteria for estimating any long run relationships.

Table 4.1 ADF Unit Root Tests for Logarithm of Time Series

(Based on AIC criterion, maxlag = 4)

Series	Level $I(0)$			First Difference $I(1)$		
	Lags	ADF	P-value	Lags	ADF	P-value
LREER	1	-1.7380*	0.4038	0	-4.2818	0.0001
LTOT	1	-0.2025*	0.9288	0	-3.3626	0.0014
LOPEN	1	-2.1469*	0.2286	0	-7.4071	0.0000
LGOV	1	-1.1606*	0.6798	0	-2.5368	0.0128
LPROD	4	-0.3638*	0.9846	4	-0.3144*	0.9113
LM2	1	-2.5510*	0.1129	0	-3.0953	0.0030

Note: the asterisk * stands for non-rejection of the null hypothesis at the 5% significance level, and MacKinnon (1996) one-sided p-values.

We next proceed to discuss the empirical analysis of long- and short-run cointegrating relationship among the real effective exchange rate and its fundamentals.

4.3 Empirical Results for Cointegration Analysis

Once the variables have been established as $I(1)$ integrated processes, tests for cointegration are undertaken to establish a long-run equilibrium relationship among the variables. The purpose of the cointegration test is to determine whether a group of non-stationary series are cointegrated or not. The specification of a VECM requires the selection of a lag length for the VAR model, which is followed by the selection of the number of cointegration vectors and the appropriate deterministic specification.

4.3.1 Selecting the Lag Length of VAR and Performing Diagnostic Tests

As discussed in Chapter 3, before undertaking the Johansen cointegration analysis we have to first specify the lag length for the unrestricted VAR(p) model. Due to the relatively short data set (36 observations) we specify VAR(2) then test the residuals for signs of misspecification. The results of the autocorrelation, nonnormality and heteroscedasticity diagnostic tests are presented in Table 4.2.

Table 4.2 Model Evaluation Diagnostic Tests of the VAR(2) Model

Diagnostic tests (multivariate)	Test-statistic	df	P-value
Autocorrection LM test	LM 1 38.72	36	0.3478
	LM 2 37.61	36	0.3953
	No autocorrection		
Jarque-Bera normality test	$\chi^2_{(6)} = 8.79$	6	0.1857
	Normally distributed		
Heteroskedasticity test	$\chi^2_{(483)} = 489.44$	483	0.4100
(with no cross terms)	No heteroskedasticity		

Note: df stands for the degrees of freedom, and $\chi^2_{(6)}$ refers to the Chi-sq test with 6 degrees of freedom.

The summary results in Table 4.2 indicate that none of the system tests reject the null hypothesis since the p-values of the diagnostic tests are all greater than the significance level (0.05), indicating that the VAR(2) model is not misspecified. Seeking a parsimonious lag specification we also estimated a VAR(1) model, but the residuals displayed AR(2) autocorrelation and nonnormality. We conclude that the VAR(2) model shows sufficient adequacy to proceed with the cointegration analysis.

4.3.2 Determining the Rank of Π and the Deterministic Components

Since the choice of deterministic component in the multivariate model influences the asymptotic distributions of the rank test statistics, Johansen (1992b, pp. 383-397) and Harris (1995, pp. 96-97) suggested the need to consider the joint hypothesis of both the rank order and the deterministic component configuration (i.e. "case") in accordance with the Pantula Principle, which was discussed in Chapter 3. The data in Table 4.3 presents the results of Johansen's cointegration test statistics based on the Osterwald-Lenum (1992, pp. 461-472) critical values for each of the five "cases".

Table 4.3 Johansen Cointegration Test Summary

Case	1	2	3	4	5
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type:	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Max-Eigen (No. of CI)	4	1	1	2	2

Note: Selected (0.05 level*) Number of Cointegrating Relations by case, and
*Critical values based on Osterwald-Lenum (1992)

The last row in Table 4.3 shows the number of cointegrating vectors using the 95% quantiles of the asymptotic test distributions, and the first row shows the case specification selected for the deterministic components. As discussed in Chapter 3, Cases 1 and 5 are rarely used and implausible based on economic theory. Based on the Johansen cointegration test and the Pantula Principle, the appropriate deterministic specification is Case 3, since there are linear trends in the levels of the data but not in the cointegrating space. Hence, the intercept term appears only in the long-run cointegrating space and there are no deterministic trend terms. The data in Table 4.4 presents the estimated value of the max-eigenvalue test statistics using Case 3 and critical values (with both 5% and 1% levels of significance) of Osterwald-Lenum (1992) based on the estimated unrestricted VAR(2) model. The first column in Table 4.4

shows the rank order of the coefficient matrix of the VAR model, where the rank order indicates the number of cointegration vectors among all variables.

Table 4.4 Johansen Cointegration Test Statistics (Using Case 3)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	5 Percent Critical Value	1 Percent Critical Value
r = 0 **	0.738241	45.57126	39.37	45.10
r ≤ 1	0.601980	31.32256	33.46	38.77

Note: ** denotes rejection of the hypothesis at the 5% (1%) level
Max-eigen test indicates 1 cointegrating equation(s) at both 5% and 1% levels of significance

It is evident from Table 4.4 that the null hypothesis of no cointegrating vector (r = 0) is strongly rejected at both the 5 and 1 percent significance levels in the max-eigenvalue test statistic. Subsequently, the null hypothesis of at most one cointegrating vectors (r ≤ 1) is supported by the data at the 5 percent significance level, where the max-eigenvalue statistic is less than its corresponding 95 percent asymptotic critical value: $\lambda_{max} = 31.32 < c.v_{max} = 33.46$.

Because all series in our model are *I*(1) and there is only one cointegrating vector, it is appropriate to estimate the restricted VAR model that restricts the long-run behaviour of the endogenous variables to converge to their cointegrating relationship, namely, the vector error correction (VEC) model. The estimation of a VEC model is carried out in two steps. First, we estimate the cointegration equation from the Johansen procedure as used in the cointegration test. Second, we construct the error corrections terms from the estimated cointegration equation. For that purpose, we need to estimate the unrestricted VEC model first.

4.3.3 Estimating for Long-Run Equilibrium REER of RMB

After determining the number of cointegration vectors (r = 1) and the deterministic configuration (Case 3), we proceed to estimate the cointegrating coefficients. In our case, we use a lag length of 1 for the underlying the unrestricted VEC model. Because the estimated cointegrating vector is normalized on the LREER, the long-run equilibrium equation (with standard errors in parentheses and t-statistics in brackets) can be shown as follows:

$$\begin{array}{lllllll} L\hat{REER}^{LR} = -2.147 + 0.1136LTOT & - 0.7066LOPEN & + 0.5474LGOV & + 0.8290LPROD & - 1.0877LM2 & \\ (0.1984) & (0.0855) & (0.1412) & (0.1273) & (0.2780) & (4.1) \\ [0.5728] & [-8.2606] & [3.8771] & [6.5133] & [-3.9132] & \end{array}$$

We refer to equation (4.1) as the EREER (equilibrium real effective exchange rate) here. It can be seen from the equation (4.1) that all parameters of the cointegrating vector are statistically significant at the 95% significance level and correctly signed, except the terms of trade variable (LTOT) whose coefficient is small and statistically insignificant. Since, the effect of the coefficient of the variable LTOT is not even close to being statistically significant, we dropped LTOT from our estimated model.

Since the terms of trade variable (LTOT) has been dropped from our model, a new unrestricted cointegrating equation estimates provided by EViews. The cointegrating vector obtained, normalised for the value of LREER is given in equation (4.2). The output of the vector error correction estimates reports that the estimates of β are not only consistent with economic theory in regard to signs and relative sizes, they are also clearly statistically significantly different from zero at the 5% significance level.

$$\begin{array}{llllll} L\hat{REER}^{LR} = -1.9556 - 0.7474LOPEN & + 0.6512LGOV & + 0.8927LPROD & - 1.2761LM2 & \\ (0.0887) & (0.1308) & (0.1154) & (0.2256) & (4.2) \\ [-8.4276] & [4.9800] & [7.7362] & [-5.6576] & \end{array}$$

standard errors in parentheses and t-statistics in brackets

In equation (4.2), we note that the coefficients of the economic fundamentals carry the expected signs are plausible and statistically significant at the conventional level. As discussed in the theoretical section, the expectations that the degree of openness and money supply (M2) have negative effects on the equilibrium real exchange rate, while the government expenditure and productivity have positive effects on real exchange rate are borne out empirically.

The outputs of the equation indicate that an increase in trade openness is associated with a depreciation of the REER by 0.75 percent. The estimate for GOV suggests that a one percent increase in government expenditure would increase the real exchange rate by 0.65 percent in the long-run. Moreover, one unit reduction in productivity differential leads to 0.89 percent appreciation in REER. Furthermore, a one percent increase in the money supply (M2) causes 1.28 percent depreciation in the currency.

4.3.4 The Dynamic Model and Testing for Weak Exogeneity

Another interesting issue concerns the possibility of considering the economic fundamental variables (LOPEN, LGOV, LPROD, and LM2) as being weakly exogenous with respect to the long-run equilibrium parameters. If so, it then becomes statistically legitimate to model LREER conditional on these variables, in a single-equation representation. In practice, this requires tests of zero restrictions on the α_j parameters in the VEC equations for, $\Delta LTOT$, $\Delta LOPEN$, $\Delta LGOV$, $\Delta LPROD$, $\Delta LM2$.

The results of the weak exogeneity test suggest that the economic fundamentals can be considered to be "weakly exogenous" for the long-run parameters. Re-estimation of the restricted VEC model gives the equilibrium real effective exchange rate results in equation (4.3), with the standard errors in parentheses and t-statistics in brackets,

$$\hat{LREER}^{LRr} = 1.6160 - 0.4054LOPEN + 0.7495LGOV + 0.5085LPROD - 0.9687LM2 \quad (4.3)$$

	LOPEN	LGOV	LPROD	LM2
	(0.0807)	(0.1190)	(0.1050)	(0.2052)
	[-5.0238]	[6.3003]	[4.8431]	[-4.7199]

In equation (4.3), the estimated coefficients have the expected signs and are statistically significant even at less than the 5% significance level, indicating that the long-run parameters are estimated with considerable precision given the relatively small estimated standard errors for those fundamentals. Since we took the natural logarithm of all time series, the coefficients of the explanatory variables in equation (4.3) tell us the long-run elasticity of LREER with respect to the corresponding fundamentals. As expected, the negative sign for LOPEN indicates that a one unit lowering of trade restrictions (a rise in degree of openness) is likely to depreciate the real exchange rate by 0.41 percent; the result is close to Goh and Kim's (2006) estimate for China. This confirms the finding in the literature that a country's economic closeness is associated with overvaluation of its currency. The result for money supply, the variable M2, indicates a negative sign, implying that a decrease in the money supply will appreciate the real exchange rate by 0.97 percent. On the other hand, the positive sign for LGOV suggests that one unit increase in government expenditure causes a 0.75 percent appreciation in real exchange rate; the magnitude of the estimated coefficient falls within the range of 0.5-0.9 percent reported by Elbadewi (1994). Finally, the productivity variable displays a positive elasticity so that a rise in productivity will cause a 0.51 percent appreciation in the real exchange rate.

Following this, we use the results in equation (4.3) to estimate the long-run equilibrium rate and then compare its movements with those of the actual real effective exchange rate.

4.4 Examining the Extent of RMB Exchange Rate Misalignments

As we have already discussed, our primary interest is to assess the degree of misalignment of the RMB. In this sub-section we proceed as follows: first, the equilibrium real exchange rate level will be defined as the trend part of the estimated real effective exchange rate cointegrating relationships. Next, following Baffes et al. (1999), Wang (2004) and Wang et al. (2007), we extract the trend using the Hoddrick-Prescott (H-P) filter. Following this, the misalignment can be defined as the relative difference between the estimated equilibrium rate and the observed real effective exchange rate.

Figure 4.1 plots the estimated equilibrium REER derived from the restricted model (calculated from the long-run relationship using the current values of the fundamentals) against the actual REER. Note that the periods of overvaluation (undervaluation) are those when the actual REER is above (below) the equilibrium REER. The difference between the two indicates the extent of the RMB exchange rate misalignment, computed as [(actual REER-equilibrium REER)/equilibrium REER]*100 percent. For a clearer picture of the misalignments in RMB, we display the percentage deviations of the actual REER from the estimated equilibrium REER in Figure 4.2.

Recall that since we used logarithmic data in our empirical analysis in order to compute the misalignment of the RMB exchange rate, we have to convert the logarithm data to the actual values using the exponential (exp.) function. The converted equilibrium real effective exchange rate is shown in Appendix 2, namely EREER. The misalignment of the RMB exchange rate data calculated by equation (4.3) is reported in Appendix 2.

Figure 4.1 Actual REER versus Equilibrium REER (1999Q1-2007Q4)

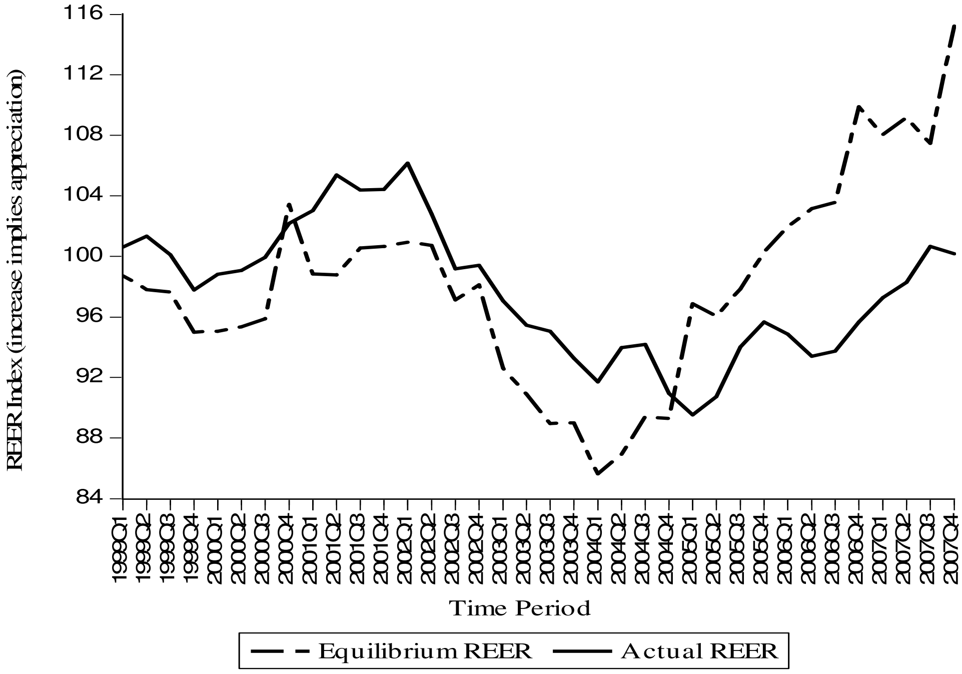
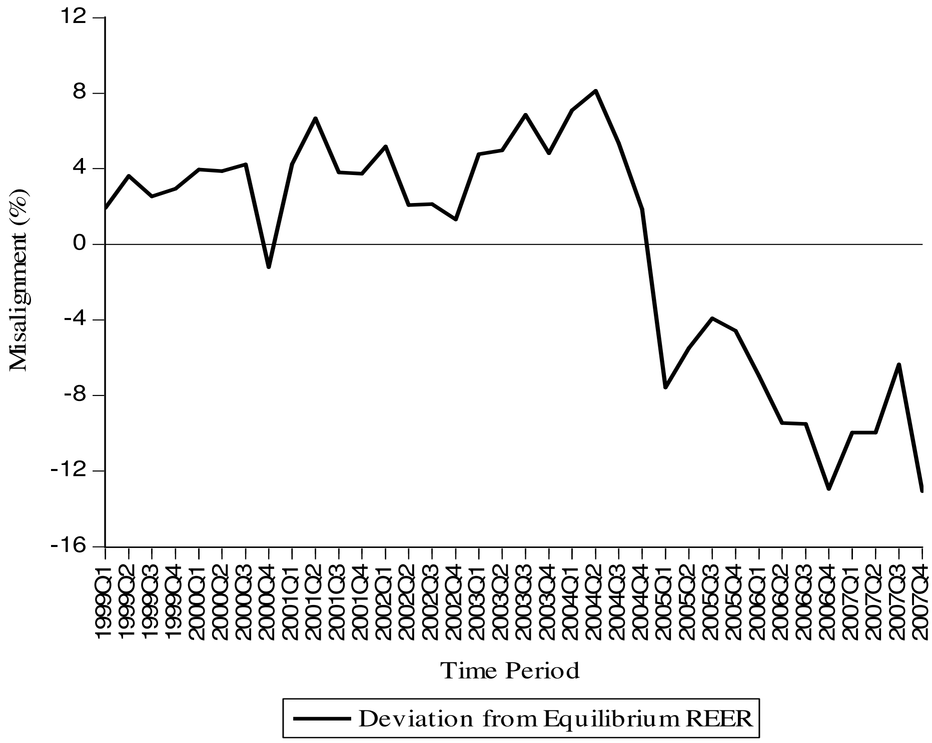


Figure 4.2 Misalignments of RMB Real Effective Exchange Rate (1999Q1-2007Q4)



As reflected in Figure 4.2 and Table 2 in the appendix, the misalignment of the RMB real exchange rate ranged between -13.06 percent to 8.14 percent during 1999Q1 to 2007Q4. According to our estimates the RMB was *over*valued for most of the 1999Q1 - 2004Q4 period. Since the start of 2005, however, the RMB started to be *under*valued and has remained so for the rest of the sample period. The extent of the undervaluation is rather modest, reaching a maximum of less than 10 percent.

As discussed in Chapter 3, it is also rational for predicting the long-run equilibrium values for the RMB using sustainable values of the economic fundamentals in order to eliminate short run fluctuations in these variables. Following Baffes et al. (1999) and Wang (2004)**,** we use the Hodrick-Prescott (HP) filter (weight = 1600) to remove the short-run variations from the explanatory variables. Figure 4.3 displays an interesting pattern of the equilibrium REER_HP (calculated using the HP filtered values of the economic fundamentals). For a clearer picture of the misalignments in the RMB, we present the percentage deviations of the actual REER from the estimated equilibrium REER_HP (based on the HP filter) given in Figure 4.4.

Both Figures 4.3 and 4.4 show that the period up to 2003Q3 was characterized by a real *over*valuation, which reached a peak of 11 percent in 2002Q1 (see Appendix 2). Then a major reversal took place after 2003Q4, as the currency became *under*valued in real terms. In summary, the main finding of the analysis presented in this section revealed that the RMB real effective exchange rate was *under*valued in recent years. The misalignment in the latter period was -6.7 percent on average since China announced a number of changes to its foreign exchange regime on July 21, 2005. Hence, these results are consistent with those obtained using the unfiltered fundamentals.

Figure 4.3 Actual REER versus Equilibrium REER_HP (1999Q1-2007Q4)

(Using the Hodrick-Prescott Filtered Values of the Fundamentals)

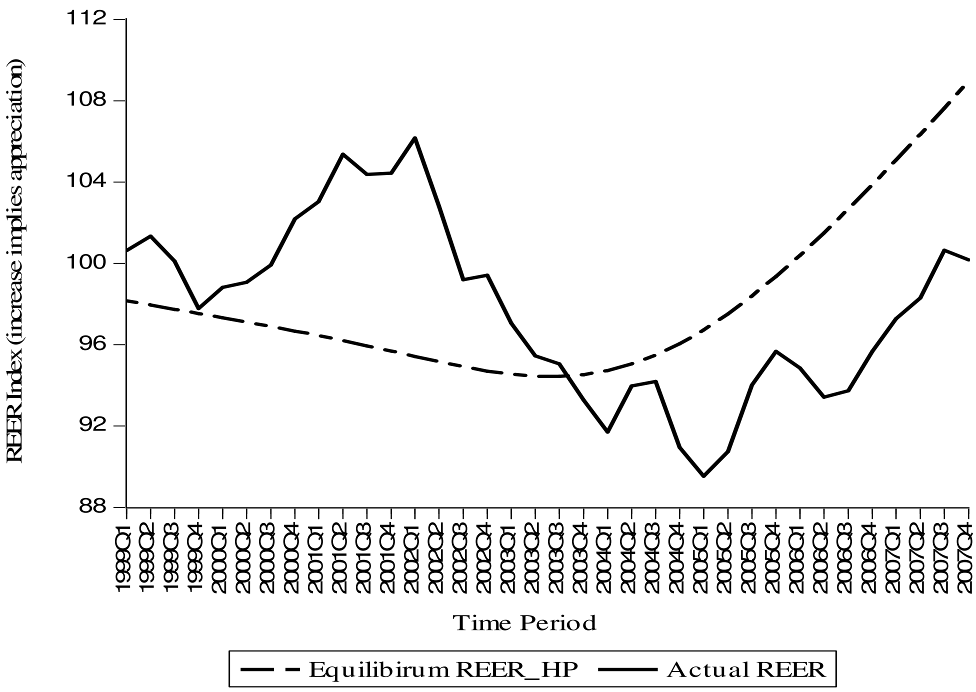
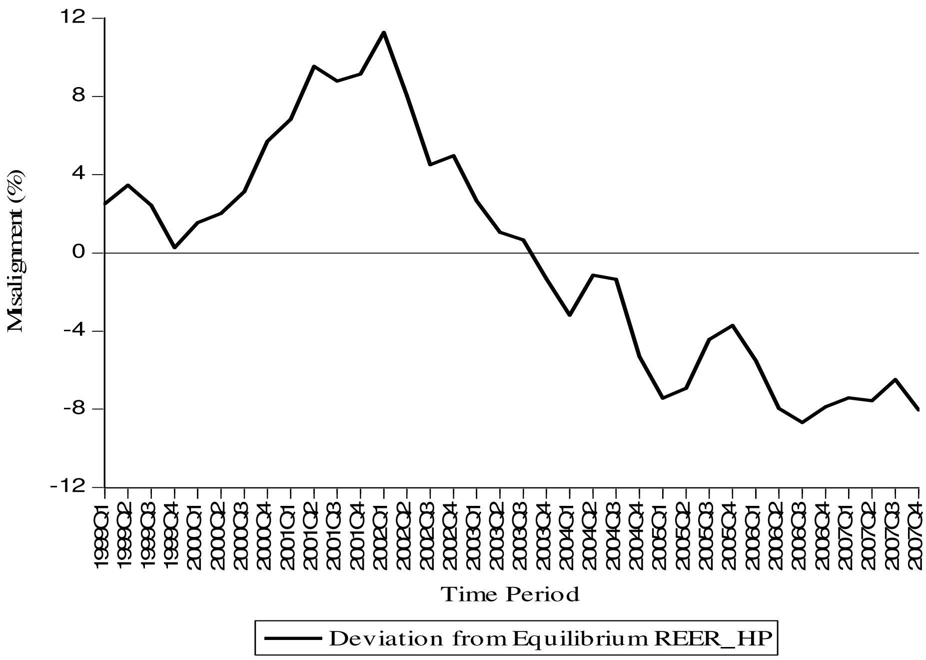


Figure 4.4 Misalignments of RMB Real Effective Exchange Rate (1999Q1-2007Q4)

(Misalignment of Actual Real Rate from the Equilibrium REER_HP)



4.5 The Adjustment of the RMB Exchange Rate

Another aspect of the dynamics is the extent and statistical significance of the adjustment coefficients. When a gap between the actual real rate and its equilibrium level arises, the actual real rate will tend to converge to its equilibrium level. Depending on the causes of the gap, the adjustment requires that the real exchange rate either moves progressively toward a new equilibrium level, or returns from its temporary deviation to the original equilibrium value (MacDonal & Ricci, 2003). The adjustment coefficient reflects the dynamic self-correcting mechanism of the error correction model. Generally, a larger (absolute value) adjustment coefficient α means that the given variable converges at a faster rate towards the equilibrium level. The speed of adjustment coefficient is given in Table 4.5.

Table 4.5 Speed of Adjustment Coefficient

Error Correction (adjustment coefficient)	
	-0.852557
D(LREER)	(0.12455)
	[-6.84513]

Note: standard error reported within parenthesis & figure in bracket is *t*-statistics.

According to the result in Table 4.5, the coefficient estimate of "speed of adjustment" suggests that the fairly large (absolute) value indicates a rather quick 'correction' of the RMB real exchange rate to lagged disequilibrium. On the "average", correction would require just over 1 quarter to complete (1/ 0.8526 = 1.1729).

4.6 Conclusion

This chapter discussed the equilibrium level of the real effective exchange rate of the RMB using the Johansen-Juselius (1990) cointegration procedure to analyze a 6-variable system. Specifically, the material focused on the following issues: estimation of the long-run equilibrium equation, assessment of the RMB exchange rate misalignments, and modelling the dynamics of the real effective exchange rate. We have found evidence that there exists a long-run cointegrating relationship amongst variables in the model. The estimated long-run equilibrium equation is acceptable, as the parameters of all explanatory variables are in accordance with the theory and, with exception of the terms of trade (LTOT) parameter, were found to be statistically insignificant. Hence, the terms of trade variable was excluded to produce a restricted version of the VECM model.

As for the misalignments of the RMB exchange rate, the estimates suggest that the extent of the misalignments is not eminently large, moving in a narrow band of plus and minus 12 percent of the long-run equilibrium level over the period of 1999-2007, when the Hodrick-Prescott filter is used. Further, the estimation of the short-run empirical model of ERER shows that the speed-of-adjustment parameter has a comparatively high value, and is highly significant, implying a quick adjustment of the actual exchange rate toward its long-run equilibrium level. Overall, the empirical results suggest that the RMB in our sample was *over*valued from 1999Q1 to 2003Q3 and, thereafter, the RMB become *under*valued since 2003Q4.

Based on the empirical results, Chapter 5 summarizes the major findings of the study, with particular reference to the research objectives stated at the outset, followed by implications of the empirical findings. In addition, it will identify some of the limitations of this research and propose some modest recommendations for future research into this topic.

Chapter 5

Summary and Conclusions

5.1 Introduction

This chapter summarizes the main findings of the thesis and evaluates the evidence regarding the empirical findings. This is followed by a discussion of the results relating to the misalignment measures and policy implications of the research findings. Finally, the chapter identifies some limitations of this investigation and also provides several recommendations for future research in this area.

5.2 Empirical Findings of the Research and Discussion

The central research question addressed in this study is whether the RMB real exchange rate has persistently departed from its equilibrium value - that is, whether there is a tendency for the RMB real exchange rate to move away from its equilibrium level over a long period. This is one of the important issues in international macroeconomics as a variation in exchange rates has a significant impact on resource allocation, as discussed in Chapter 1. In order to achieve the research objectives of this study, economic fundamentals believed to be associated with the China's real exchange rate were identified in Chapter 2. Since the real effective exchange rate (REER) is close to the concept of an 'equilibrium' real exchange rate, reflecting an international competitiveness of the country against its major trade partners, we focused on China's real effective exchange rate in this study.

This thesis examines the following research questions:

1) Does a long-run equilibrium level exist for the RMB real exchange rate and, if so, what is it?

2) Is there is a persistent departure of the RMB real exchange rate from its equilibrium

level?

3) Following a disturbance, what is the speed at which the real exchange rate tends to revert to its long-run equilibrium level?

To address these research questions directly, we reviewed different ways of identifying the equilibrium real exchange rate and discussed why the reduced-form ERER model is more applicable to a developing country case in Chapter 2. In addition, the cointegration approach was considered to be the most suitable among the many econometric methods. This method was conducted on the natural logarithm of the real effective exchange rate and its economic fundamentals for the RMB. Each time series was tested for unit roots then the Johansen-Juselius (1990) procedure was used to test for cointegration – i.e. for long-run relationships.

As for the full sample ADF and KPSS unit root tests, our results showed that all variables are non-stationary and first order integrated variables, namely variables of $I(1)$, which is consistent with the theory and literature (see, Harris, 1995; Wang et al., 2007).

This thesis found that there exists one cointegrating vector among those series at the confidence levels (5% and 1%) during the sample period of 1999-2007 (see Chen, 2007; Wang et al., 2007). This implies that the LREER variable has a long-run relationship with other economic fundamental variables, such as LTOT, LOPEN, LGOV, LPROD, and LM2.

However, the first estimated long-run equilibrium equation of this study indicates that the estimated coefficient of the terms of trade was positive, as suggested by the theory, although not statistically significantly different from zero; thus the impact of the terms of trade variable is insignificant to the real effective exchange rate. This finding is consistent with some previous studies, for example, Alexius and Nilsson (2000) found there is less to support that terms of trade affect equilibrium real exchange rate in their study. Accordingly, a key conclusion of the study is that we found weak evidence that rises in the terms of trade have led to an appreciation of Chinese currency, the RMB.

A restricted version of the model was estimated, showing that the real effective exchange rate is related to openness, money supply, productivity and government spending, with long-run elasticities of (0.41), (0.97), (0.51) and (0.75), respectively. Those findings imply that the economic fundamentals used in this study are the important determinants of long-run equilibrium real exchange rate of RMB.

Subsequently, our restricted error-correction model of REER determination showed that the RMB was *over*valued in the range of 0.27 to 11.26 percent during the period 1999Q:1-2003Q:3, then was *under*valued in the range of 1.13 to 8.69 percent for the period from 2003Q:4 through to 2007Q:4. The results reflect the "economic phenomena" that happened in the sample period. The RMB kept its value firmly while other regional Asian currencies depreciated dramatically after the Asian financial crisis in late 1997, thus the RMB was overvalued by a large degree during 1997-98. However, due to the fact that China's commodity prices gradually declined since 1999, the RMB became mildly *over*valued at that time. Based on these results, the analysis in this study shows that there are no large, persistent deviations of the actual real effective exchange rates from their long-run equilibrium level. This suggests that the actual real effective exchange rate of RMB is not too far away from its equilibrium level and more or less reflects the underlying economic fundamentals. Our misalignment measures generally accord well with the claims by other authors. For example, according to the CPI-based REER index measurement, Wang (2004) found that the estimated equilibrium real exchange rate was *under*valued about 5 percent on average during the estimation period. Moreover, Funke and Rahn (2005) also found that the RMB was *under*valued by only 3-6 percent on a real effective basis, and MacDonald and Dias (2007) found a wide range from 8-30 percent undervaluation in real effective terms.

Focusing on the extent of the RMB real exchange rate misalignment in recent years, (starting off with latest China's exchange rate regime - i.e. 2005Q3), our results show that the RMB was *under*valued by an average of 6.7 percent during the period of 2005Q3-2007Q4, which appears to be consistent with previous studies. The China Currency Coalition (2008) based upon a reduced-form real exchange rate approach to estimate the RMB exchange rate misalignment in real effective terms (CPI-based REER index), found that the RMB was undervalued by 13.6 percent on average for the period from September 2006 through February 2008. Further, Cheung, Chinn and Fujii (2009) found that their estimated undervaluation was on the order of 10 percent. In summary, it is submitted that the method followed in the computations underlying our study arrives at a reasonable and fair estimation of the extent of the RMB exchange rate misalignment in the real effective exchange rate.

Finally, the estimation of the short-run empirical model presents that the coefficient of the error correction term has a positive and highly significant value of 0.85, which is consistent with Edwards' (1994) study. This finding implies that the actual real effective exchange rates would converge relatively quickly toward their long-run equilibrium level without intervention - on average the real exchange rate takes over one quarter to reach its long-run equilibrium level.

5.3 Policy Implications of the Empirical Results

The findings of this study yield some important policy implications for the policymakers who are responsible for making exchange rate policy decisions in China. First, our results show that there is a modest undervaluation of the RMB during the latest exchange rate regime. In this regard, Crockett (2008) concluded that the RMB is both undervalued and insufficiently flexible. Consequently, it is apparent that the RMB will need to appreciate. Nevertheless, a rapid revaluation of the RMB could have catastrophic consequences for China's development and employment (i.e. lead to a decline in China's output). Indeed, a real appreciation in short-run will raise the price of the domestic goods and services, thus causing the country's exports to drop and reduce its aggregate demand. For that reason, we concluded that in the short-term the Chinese government could continue to appreciate the currency in order to reach an equilibrium exchange rate level consistent with economic fundamentals, but the appreciation should be gradual. It is a very important issue for Chinese policymakers to look into as appreciation in the exchange rate could be beneficial to the country's economy. In addition, the current exchange rate regime in China (a managed floating exchange rate based on market demand and supply with reference to a basket of currencies) is almost perfect. As we have already discussed in Chapter 1, the major currencies used to value the RMB include the US dollar, the Euro, the Japanese yen and the Korean won. Due to the reverse direction of causality in the relationship between the US dollar and two other currencies (Euro and Japanese yen), it would be advisable to include the new exchange rate system, which is viewed as a basket peg, in order to reduce the fluctuation of the RMB exchange rate in favour of stabilising the exchange rate. Besides, Frankel (2009) suggested that the China's exchange rate regime is better described as a basket peg (rather than the dollar peg), but it has recently been in effect as a basket peg with some weight on a non-dollar currency, especially weighted on the euro. Therefore, China should continue to implement the current managed floating currency regime – based on market condition with reference to a basket of other currencies.

Furthermore, here are several suggestions regarding the reform of the mechanism for setting the RMB exchange rate. First, under the regime of managed floating exchange rate, China should nurture and consummate the foreign exchange market, because the supply of foreign exchange market is the main factor that influences the RMB exchange rate level. Second, the RMB exchange rate was implemented by a managed-float regime as a dollar peg since 1994; however, the floating range was extremely small and made the exchange rate too fixed. As a whole, this is not conducive to the external balance of China's economy. Hence, the monetary authorities should expand the fluctuating range of RMB exchange rate and enhance the flexibility of RMB exchange rate policy. Finally, China should consider trying to reduce the local government intervention in exchange policy, allowing the RMB exchange rate to be determined chiefly by market forces of supply and demand.

However, China is facing issues of employment generation, pollution control, income distribution and many others domestic issues; thus dealing with those issues will require not only attention to macroeconomic fundamentals and regulatory policy but also targeted fiscal policy that will affect the China's equilibrium exchange rate.

5.4 Limitations and Recommendations for Future Research

The majority of empirical studies suffer from certain limitations or weaknesses which are specific to each study. Similarly, our study is affected by some limitations that are briefly described below.

- The sample period used in this study is relatively short, with only 36 observations available for analyzing the RMB real exchange rate misalignment. In general, the use of a longer time frame (say, from 1990Q1-2008Q2) would have been more precise and beneficial. Because this period would have also captured the years preceding Chinese government adopted the unification of exchange rate regime on 1st January 1994 that was a prominent step on the process of China's open economy reforms, and the Asian financial crisis in late 1997. The main reason a longer period was not used in this study was that the Chinese quarterly data were not available or reliable, especially prior to 1999.

- As discussed in Chapter 2, we used the real GDP per capita as a proxy for the technological progress (productivity). Usually, the relative productivity differential effect is proxied by the ratio of China's consumer price index to the wholesale price index, relative to China's trading partners. Nevertheless, this ratio is limited by incomplete data because more complete data could not be found for the China's trade-weighted index. Therefore, following some studies (Drine & Rault, 2001; Goh & Kim, 2006), the real GDP per capita has been analysed instead of the ratio of tradable to nontradable productivity in this research. This might lead to different results when we estimate the RMB equilibrium real exchange rate.
- Another limitation comes from the low power of the ADF unit root test in the short sample period; according as DeJong, Nankervis, Savin and Whiteman (1992) showed that the ADF unit root test has low power. In the unit root test for the LPROD series, there is only weak evidence to suggest that this variable is integrated of order one. Therefore, the robustness of the results obtained by the ADF test may be limited, so they have to be interpreted with caution.
- As the proxy for the international economic environment, the coefficient for the terms of trade variable appears to be statistically insignificant in our analysis. Hence, this effect on the RMB real effective exchange rate is not shown by this study. As a result of the absence of the major economic fundamental variable, the empirical results also could be less robust and precise.

The recommended future research should be mainly based on those limitations mentioned above in order to improve the results of the study.

As has been discussed previously, this lack of data could lead to less precise and robust results. It is suggested for future research that a longer sampling period could be used to analyse the equilibrium exchange rate for Chinese currency, the RMB. Next, as the proxy for the international economy environment, terms of trade variable, is not significant in this study, thus this effect on the real effective exchange rate is not shown by this study. For that reason, an alternative proxy for the international economy environment is suggested for the further research.

Furthermore, it is suggested that a dummy variable could be introduced to reflect the pre- and post- change in a VAR system. In addition, the future research should conduct the impulse response analysis of VAR to understand the dynamic behaviour of the estimated model.

Finally, different studies employed different economic fundamentals to estimate and explain the real effective exchange rate. For example, MacDonald and Ricci (2003) employed relative real interest rate, relative real GDP per capita, real commodity prices, openness, fiscal balance and net foreign assets as determinates for modelling the real effective exchange rate of the South African rand. Moreover, Li and Rowe (2007) employed terms of trade, aid flows, trade liberalization, relative productivity differentials, and government expenditures as economic fundamentals to modelling the movements of Tanzania's real effective exchange rate. Therefore, future research should indentify an expanded set of economic fundamentals (as reliable data become available) to determine the RMB long-run equilibrium exchange rate and empirically determine the relationship between these fundamentals and the real effective exchanger rate (LREER). Any new measures, however, will have to be consistent with China's specific national conditions.

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Appendices

Appendix 1 The Logarithm Data

Period	Real Effective Exchange Rate (LREER)	Terms of Trade (LTOT)	Openness (LOPEND)	Government Expenditure (LGOV)	Productivity (LPROD)	Money Supply (LM2)
1999Q1	4.6114	4.6914	-0.4963	-2.0179	8.8378	0.2129
1999Q2	4.6185	4.6764	-0.4205	-1.9820	8.8541	0.2270
1999Q3	4.6062	4.6611	-0.3823	-1.9485	8.8702	0.2474
1999Q4	4.5828	4.6455	-0.3039	-1.9169	8.8860	0.2762
2000Q1	4.5933	4.6356	-0.2419	-1.8933	8.9047	0.2771
2000Q2	4.5958	4.6256	-0.2144	-1.8713	8.9231	0.2887
2000Q3	4.6045	4.6154	-0.1899	-1.8509	8.9411	0.2985
2000Q4	4.6268	4.6052	-0.3453	-1.8318	8.9588	0.3098
2001Q1	4.6351	4.6115	-0.1851	-1.8114	8.9773	0.3145
2001Q2	4.6575	4.6176	-0.2178	-1.7924	8.9956	0.3529
2001Q3	4.6480	4.6238	-0.2115	-1.7747	9.0135	0.3553
2001Q4	4.6485	4.6299	-0.2033	-1.7580	9.0311	0.3734
2002Q1	4.6649	4.6304	-0.1784	-1.7413	9.0517	0.3834
2002Q2	4.6329	4.6309	-0.1386	-1.7255	9.0719	0.3915
2002Q3	4.5971	4.6314	-0.0393	-1.7107	9.0917	0.4096
2002Q4	4.5993	4.6319	-0.0618	-1.6968	9.1111	0.4300
2003Q1	4.5753	4.6221	0.0615	-1.6995	9.1341	0.4472
2003Q2	4.5585	4.6121	0.0815	-1.7020	9.1566	0.4677
2003Q3	4.5545	4.6021	0.1339	-1.7043	9.1786	0.4782
2003Q4	4.5356	4.5920	0.1446	-1.7066	9.2001	0.4836
2004Q1	4.5186	4.5777	0.2498	-1.7117	9.2233	0.4868
2004Q2	4.5430	4.5633	0.2620	-1.7165	9.2460	0.4746
2004Q3	4.5452	4.5486	0.2538	-1.7209	9.2682	0.4572
2004Q4	4.5103	4.5337	0.2782	-1.7250	9.2899	0.4573
2005Q1	4.4946	4.5167	0.1221	-1.7151	9.3140	0.4579
2005Q2	4.5080	4.4995	0.1898	-1.7061	9.3375	0.4578
2005Q3	4.5435	4.4819	0.1846	-1.6977	9.3605	0.4593
2005Q4	4.5609	4.4640	0.1684	-1.6899	9.3830	0.4595
2006Q1	4.5523	4.4503	0.1875	-1.6792	9.4101	0.4559
2006Q2	4.5370	4.4364	0.2135	-1.6694	9.4365	0.4542
2006Q3	4.5404	4.4223	0.2795	-1.6603	9.4622	0.4432
2006Q4	4.5609	4.4081	0.1746	-1.6519	9.4872	0.4463
2007Q1	4.5775	4.4504	0.2116	-1.6417	9.5150	0.4702
2007Q2	4.5880	4.4419	0.2136	-1.6324	9.5421	0.4796
2007Q3	4.6116	4.4334	0.2712	-1.6240	9.5684	0.4924
2007Q4	4.6069	4.4248	0.1485	-1.6163	9.5941	0.4921

Appendix 2 Misalignments of RMB Real Effective Exchange Rate

				Degree of Misalignment (%)	
Period	***Actual REER***	***EREER***	***EREER_HP***	***vs. EREER***	***vs. EREER_HP***
1999Q1	100.6200	98.7210	98.16148	1.92%	2.50%
1999Q2	101.3430	97.8047	97.94797	3.62%	3.47%
1999Q3	100.1070	97.6307	97.73527	2.54%	2.43%
1999Q4	97.7867	94.9958	97.52364	2.94%	0.27%
2000Q1	98.8167	95.0495	97.31325	3.96%	1.54%
2000Q2	99.0667	95.3614	97.10271	3.89%	2.02%
2000Q3	99.9300	95.8626	96.88919	4.24%	3.14%
2000Q4	102.1830	103.4258	96.6688	-1.20%	5.70%
2001Q1	103.0370	98.8376	96.43705	4.25%	6.84%
2001Q2	105.3700	98.7829	96.19355	6.67%	9.54%
2001Q3	104.3730	100.5403	95.93939	3.81%	8.79%
2001Q4	104.4330	100.6575	95.67726	3.75%	9.15%
2002Q1	106.1600	100.9288	95.4126	5.18%	11.26%
2002Q2	102.8130	100.7190	95.1538	2.08%	8.05%
2002Q3	99.1933	97.1165	94.91253	2.14%	4.51%
2002Q4	99.4133	98.1168	94.70369	1.32%	4.97%
2003Q1	97.0567	92.6321	94.54341	4.78%	2.66%
2003Q2	95.4433	90.9204	94.44988	4.97%	1.05%
2003Q3	95.0633	88.9611	94.44014	6.86%	0.66%
2003Q4	93.2800	88.9916	94.52916	4.82%	-1.32%
2004Q1	91.7067	85.6314	94.72871	7.09%	-3.19%
2004Q2	93.9700	86.8982	95.04741	8.14%	-1.13%
2004Q3	94.1833	89.3986	95.48842	5.35%	-1.37%
2004Q4	90.9467	89.2762	96.05003	1.87%	-5.31%
2005Q1	89.5300	96.8740	96.72689	-7.58%	-7.44%
2005Q2	90.7433	96.0249	97.50946	-5.50%	-6.94%
2005Q3	94.0200	97.8555	98.38824	-3.92%	-4.44%
2005Q4	95.6700	100.2555	99.35272	-4.57%	-3.71%
2006Q1	94.8500	101.9610	100.3917	-6.97%	-5.52%
2006Q2	93.4133	103.1559	101.4943	-9.44%	-7.96%
2006Q3	93.7300	103.5731	102.6501	-9.50%	-8.69%
2006Q4	95.6733	109.8978	103.8494	-12.94%	-7.87%
2007Q1	97.2733	108.0414	105.0824	-9.97%	-7.43%
2007Q2	98.2967	109.1832	106.3428	-9.97%	-7.57%
2007Q3	100.6500	107.4780	107.6257	-6.35%	-6.48%
2007Q4	100.1700	115.2149	108.928	-13.06%	-8.04%