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China´s Equilibrium Exchange Rate

Bachelor Thesis

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Abstract

The object of this thesis is to estimate the equilibrium exchange rate of the Chinese currency and to determine how much the actual exchange rate deviates from the equilibrium value. Throughout the China´s central planned period the currency was highly overvalued, but economic reforms have brought it closer to the equilibrium. At the present time, the common perception is that the currency is significantly undervalued. We employ the fundamental equilibrium exchange rate (FEER), which enables to measure overvaluation or undervaluation of the actual real effective exchange rate. The basic requirements for the calculating the FEER are estimated trade equations, a potential output for China and its main foreign partners and sustainable capital flows. Trade equations are estimated by the Engle-Granger two step estimator and the Johansen methodology. The modified version of trade equations is estimated by ordinary least squares. The dataset used in this study is composed of annual observations over the period 1981 and 2010.

Keywords

China, renminbi, yuan, exchange rate, real effective exchange rate, fundamental equilibrium exchange rate

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Abstrakt

Předmětem této práce je odhad rovnovážného měnového kurzu čínské měny a stanovení, jak moc se současný měnový kurz od této rovnováhy odchyluje. Čínská měna byla během centrálně plánovaného období značně nadhodnocená, nicméně ekonomické reformy ji přiblížily k rovnovážné hodnotě. V současnosti se předpokládá, že je naopak významně podhodnocena. K odhadu ekvilibria se používá model fundamentálního rovnovážného měnového kurzu (FEER). Pomocí tohoto konceptu lze zjistit nadhodnocení a podhodnocení současného reálného efektivního měnového kurzu. Základní požadavky pro výpočet FEER jsou odhady rovnic pro zahraniční obchod, stanovení potenciálního výstupu pro Čínu a její hlavní obchodní partnery a posouzení udržitelných kapitálových toků. Obchodní rovnice se odhadují pomocí Engle-Grangerova dvoustupňového odhadu a pomocí Johansenovy metody. Modifikovaná verze obchodních rovnic se odhaduje metodou nejmenších čtverců. Použitý dataset obsahuje roční pozorování v období od roku 1981 do roku 2010.

Klíčová slova

Čína, renminbi, yuan, měnový kurz, reálný efektivní měnový kurz, fundamentální rovnovážný měnový kurz

Délka

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Signature

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Acronyms

ADF Augmented Dickey-Fuller test

AIC Akaike Information Criterion

ARDL Autoregressive Distributed Lag

BEER Behavioral Equilibrium Exchange Rate

BIC Bayesian Information Criterion

CAT Current Account Target

CNY Chinese Yuan

CPI Consumer Price Index

DEER Desired Equilibrium Exchange Rate

DOLS Dynamic Ordinary Least Squares

EA Euro Area

ECM Error Correction Model

FEER Fundamental Equilibrium Exchange Rate

GDP Gross Domestic Product

HP Hodrick-Prescott filter

HQC Hanna-Quin Information Criterion

HK Hong Kong

HKD Hong Kong Dollar

IMF International Monetary Fund

JAP Japan

KPSS Kwiatkowski-Phillips-Schmidt-Shin test

LOOP Law of One Price

OLS Ordinary Least Squares

NAIRU Non-accelerating Inflation Rate of Unemployment

PBOC People´s Bank of China

PIIE Peterson Institute for International Economics

PEER Permanent Equilibrium Exchange Rate

PPI Producer Price Index

PPP Purchasing Power Parity

ROK Republic of Korea

RMB Renminbi

US United States

USA United States of America

USD United States Dollar

VAR Vector Autoregression

VECM Vector Error Correction Model

WPI Wholesale Price Index

WTO World Trade Organization

Bachelor Thesis Proposal

Author	Milan Hanousek
Supervisor	Mgr. Ing. Vilém Semerák, Ph.D.
Proposed topic	China´s Equilibrium Exchange Rate

Topic Characteristics

In this paper we investigate the equilibrium exchange rate of the Chinese currency, the renminbi. We have decided to apply the fundamental equilibrium exchange rate (FEER) approach. This concept enables to measure overvaluation or undervaluation of the actual real effective exchange rate. For estimating the FEER we use macroeconomic data mainly from the IMF International Financial Statistics, the National Bureau of Statistics of China and the People´s Bank of China.

Abstract

The object of the research is Chinese exchange rate. This paper estimates the fundamental equilibrium exchange rate (FEER) of the Chinese currency, the renminbi. The concept of the FEER enables to measure overvaluation or undervaluation of the actual real effective exchange rate. China´s central planning period was permanently overvalued. In the 1970s, the Chinese government started to reform the economic system and the adopted exchange rate policy has brought the exchange rate closer to equilibrium. In the present situation, the Chinese renminbi is undervalued, which has an impact on the global economy, especially on the United States. Finally, we discuss the consequences of Chinese real effective exchange rate misalignment and its relation to the financial crisis.

Outline

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Chapter 1

Introduction

Over the last three decades China has made a phenomenal economic progress. It has transformed from a centrally planned economy into one of the world´s largest trading countries. Chinese economy is currently the second largest in the world, with annual growth rate of 10.3%. It is growing much faster than other major economies and catching up with the leading United States. China is also the world´s largest exporter and second largest importer [1].

Of course, as China has become an increasingly important trading country, the rest of world have taken an interest in the development of its exchange rate regime. This interest was firstly apparent, when China negotiated to join the World Trade Organization (WTO). Since then the Chinese exchange rate regime has been a permanent subject of many discussions and researches. Nowadays, the knowledge of the equilibrium exchange rate of the Chinese currency is basically one of the main interests of economists, policymakers as well as market participants.

We assume that Chinese authorities keep the currency undervalued in order to promote export performance and economic growth. The current estimates of the International Monetary Fund (IMF) indicate that China´s currency is undervalued by 3-23%, depending on different approaches [2]. The most recent estimates of the Peterson Institute for International Economics (PIIE) show undervaluation by 22% against the US dollar [3]. China´s undervalued currency has serious negative implications for the global economy, therefore the IMF, the United States and other world major countries urgue the People´s Bank of China (PBOC) to revalue the currency and make the exchange rate regime more flexible.

The ambition of this thesis is to estimate the equilibrium exchange rate of the Chinese currency and to determine how much the actual exchange rate deviates from the equilibrium value. For this purpose we employ the fundamental equilibrium exchange rate (FEER), formalized by Williamson [4]. The FEER is defined as the exchange rate which is consistent with achieving internal and external balance in the medium-run. Time series used in this study are annual observations during 1981 and 2010. A calculation of the FEER includes several steps. At first, we estimate trade equations using the error correction model (ECM) and the vector error correction model (VECM). Because the results of the FEER based on trade coefficients from these two models are not convincing, we re-estimate the modified version of trade equations by ordinary least squares (OLS). Secondly, we establish the potential output for China and its main foreign partners. For this purpose we employ the Hodrick-Prescott filter. Third issue involves a determination of Chinese sustainable capital flows. Finally, we define current account model and calculate the FEER.

The study is organized as follows. Chapter 2 discusses the evolution of the Chinese exchange rate. Chapter 3 summarizes the approaches most frequently used to estimate the equilibrium exchange rate. Chapter 4 provides the empirical model, which includes data description, unit root tests, estimates of trade equations, determination of desired outputs, judgment on sustainable capital flows and finally FEER estimates. Chapter 5 presents obtained results and conclusion.

Chapter 2

Evolution of China´s Exchange Rate Regime

At the beginning, it might be appropriate to clarify a possible confusion regarding the name of the Chinese currency. The legal and official name of the currency is the "renminbi" (RMB), which literally means "the people´s currency". The denominal unit of the currency is "yuan"[1] (CNY).

The renminbi exchange rate regime has played one of the key roles in China´s growth and integration into the world economy. Its evolution, which is closely connected to the economic regime of the country as a whole, can be divided into three historical phases, i. e. a central planned mechanism, a dual system and a market-based system.

2.1 Central Planned Mechanism

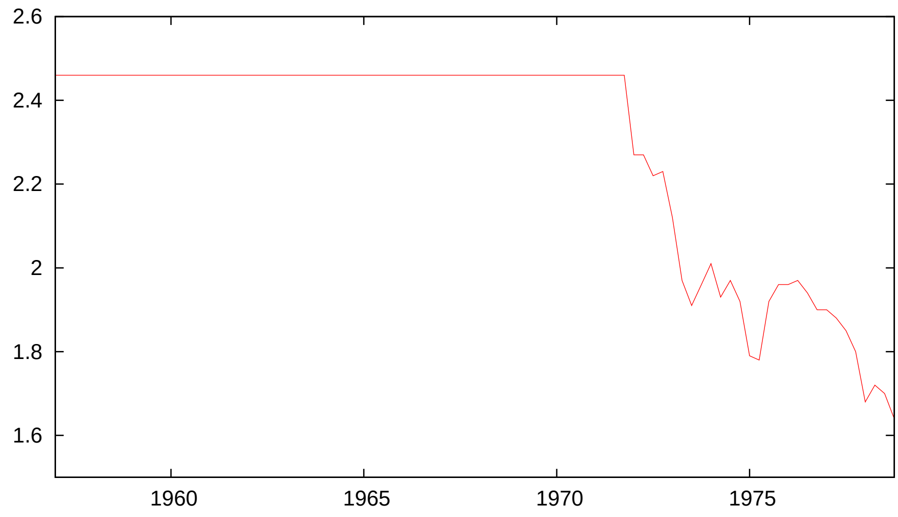
After the foundation of the People´s Republic of China in 1949, the Chinese government paid close attention to the supply of money. In fact, the country inherited a completely disordered money circulation from the old regime. Therefore, the People´s Bank of China[2] issued a new currency, the renminbi, in exchange for the old currency at rates fairly favorable to the population [5].

During the early stage of China the renminbi exchange rate was adjusted several times. The growing inflation finally led to the currency reform in 1955, which transferred the old currency for the new one at a ratio of 10000:1. This reform was the final stage in the stabilization of the Chinese monetary system.

[1] 1 yuan = 10 jiao = 100 fen

[2] The Poeple´s Bank of China is the country´s central bank.

Figure 2.1: Official rate (CNY/USD), 1957 - 1978



Note: An increase in the absolute value of the currency means a depreciation. Data are defined as the annual average.
Source: IFS

At the same time the renminbi was officially pegged to the US dollar at a rate of 2.46 CNY/USD, which was held until the early 1970s [6]. However, with the suspension of the convertibility of the US dollar into gold in 1971, the renminbi started to revalue and after the collapse of the Bretton Wood system in 1973, it was pegged to a basket of currencies [7]. The evolution of the renminbi exchange rate between the years 1957 and 1978 is illustrated in figure 2.1.

Throughout the central planned period Chinese exchange rate policy was subordinate to trade policy. The exchange rate did not reflect supply and demand relations. It served only as a translator, a mere accounting device, linking foreign trade and the domestic economy [8]. The government fixed the exchange rate at a highly overvalued level as a part of the industrialization strategy. The main target was to accelerate industrial development for a purpose of reducing country´s dependency on imported manufactured goods. The currency overvaluation allowed to import machinery and equipment to main sectors of industry at a relatively lower costs than otherwise would have been possible. On the other hand, such an overvalued exchange rate caused excess demand for foreign exchange and turned the terms of trade against the Chinese exporters. Because the foreign trade was completely controlled by state companies and all sources of foreign exchange had to be deposited in the Bank of China[3], the losses on exports were simply covered by the profits of companies, which sold imported goods at the domestic market.

The most significant progress of the exchange rate regime came after Chinese authorities adopted an economic reform in 1978. Consequently, the renminbi was placed on a dual track system, i. e. the coexistence of the official rate and the internal settlement rate and the coexistence of the official rate and the swap market rate.

2.2 Dual Exchange Rate Regime

Under the centrally planned economic system, China was not internationally competitive and lagged behind western countries. Therefore, in 1978 the government initiated the reform of the command economy towards a more market-oriented economy. The so-called "open door policy" also included a reform of the exchange rate regime. The objectives were to rationalize the level of the exchange rate, to make full use of the exchange rate as a economic lever and to establish a managed floating rate system [8].

The transition to a system in which the value of the renminbi was determined by supply and demand in a foreign exchange market took about 15 years. The most important requirement for moving the currency towards a market-determined exchange rate was an easing of the control on trade and other current account transactions. In 1979, the State Council[4] approved that exporters were allowed to retain a share of their foreign exchange profits, which was called foreign exchange quotas. By mid 1990s, about 40% of all foreign exchange earnings was in ownership of provinces and export producers. The rest was controlled by the State Administartion of Exchange Control[5], the state agency responsible for the management of Chinese foreign exchange. Further in October 1980, exporting firms were allowed to sell the excess of their foreign exchange [9].

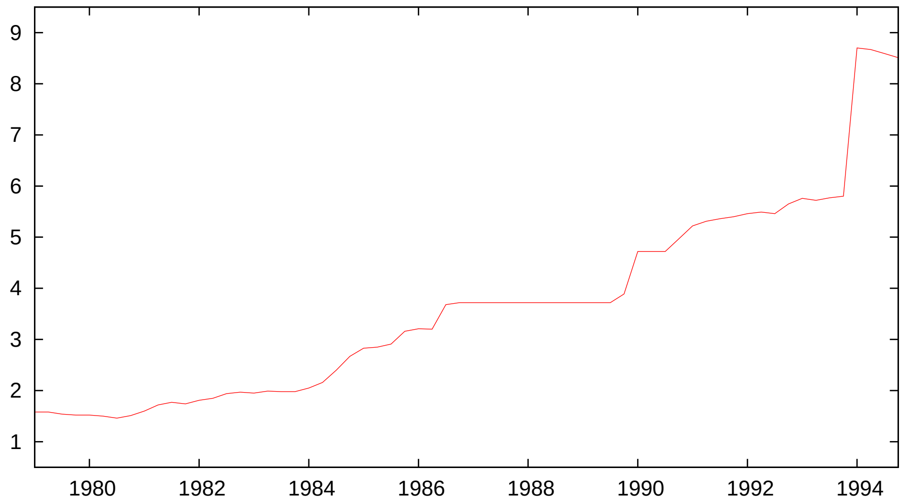
The other main policy instrument, which the government used for moving to a market-determined exchange rate, was a devaluation. In 1981, the State

[3]The Bank of China is a commercial bank owned by the state.

[4]The State Council is the name of the China´s government.

[5]The State Administartion of Exchange Control was originally subordinate to the State Council. In 1993, it came under the administration of the People´s Bank of China. In 1997, the name of the institution was changed to the State Administration of Foreign Exchange (SAFE).

Figure 2.2: Official rate (CNY/USD), 1979 - 1994



Note: An increase in the absolute value of the currency means a depreciation. Data are defined as the annual average.
Source: IFS

Council introduced a dual exchange rate system. The "internal settlement rate" of 2.8 CNY/USD was set for trade transactions, while the official exchange rate still continued to be used for non-trade transactions. At that time, the official exchange rate was 1.5 CNY/USD, which means that the new rate was a devaluation of almost 100%. In subsequent years, the government started to devalue the official exchange rate, so by the end of 1984 it achieved the same level as the internal rate of 2.8 CNY/USD. In 1985, the internal setllement rate was abolished and all international transactions were setlled at the official exchange rate [9].

However, the dual exchange rate system was used again, since foreign exchange markets, known as swap centers, were created in several cities in the mid-1980s [9]. In these markets, participants could swap the renminbi for foreign currencies at a price determined, more or less, by supply and demand. The price was known as the swap exchange rate. Initially, the government intervened in the swap markets, but the control was gradually eased. The swap markets could then enable a significant part of foreign exchange, in their last days approximately 80% of Chinese trade transactions. The Chinese rigid system of exchange control finally resulted in a relatively free flow of foreign exchange determined by supply and demand forces [8].

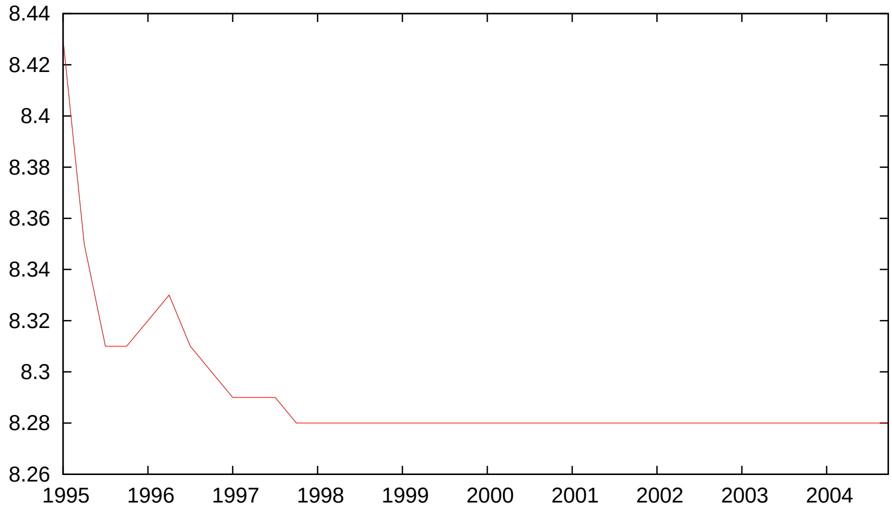
The official exchange rate was substantially lower than the swap rate, which indicated that it was highly overvalued. Hence, the government continued to devalue the currency several times between 1985 and 1993. The renminbi was firstly devalued from 3.2 CNY/USD to 3.7 CNY/USD in July 1986. The further devaluations took the rate to 4.7 CNY/USD in December 1989 and to 5.2 CNY/USD in November 1990. Over the next three years the official exchange rate was devalued continuously in small steps until it reached 5.8 CNY/USD at the end of 1993. On January 1, 1994, the government unified the official exchange rate with the swap market rate at 8.7 CNY/USD. The series of devaluations implies that the Chinese official exchange rate was systematically overvalued [10]. The devaluations are clearly visible in figure 2.2. The overvaluation of the renminbi was not only reflected in the comparison of the official rate with the swap rate, but also in the black market. In 1982, the renminbi could be exchanged for Hong Kong dollar at a rate of 0.38 CNY/HKD, which was approximately 35% higher than the official rate. In 1984, the exchange could be carried out at 0.8 CNY/HKD, more than double of the official rate [7].

The unification of the official exchange rate and the swap market rate brought the currency closer to the equilibrium. Some observers argued that the integration of the rates amounted to a devaluation of 35%, which left the currency greatly undervalued [11], but the evidence indicates that this argument is misleading. Before unification, the swap markets covered about 80% of all foreign exchange transactions and the government controlled only 20% [12]. The weighted average of the swap market rate of 8.7 CNY/USD and the official rate of 5.8 CNY/USD was 8.1 CNY/USD, which shows that the effective depreciation against the US dollar was only 7%. It also suggests that the unified rate of 8.7 CNY/USD was slightly undervalued.

2.3 Market-based System

After the termination of the dual exchange rate system in 1994, China officially adopted a market-based managed floating system. The PBOC allowed the currency to fluctuate within daily bands of 0.3% on either side of the previous day´s closing price against the US dollar. There might be a debate, how much the exchnage rate was really classified as the floating regime. The Asian authors such as Kanamori and Zhao [7] and Gang [13] think predominantly that it

Figure 2.3: Official rate (CNY/USD), 1995 - 2004



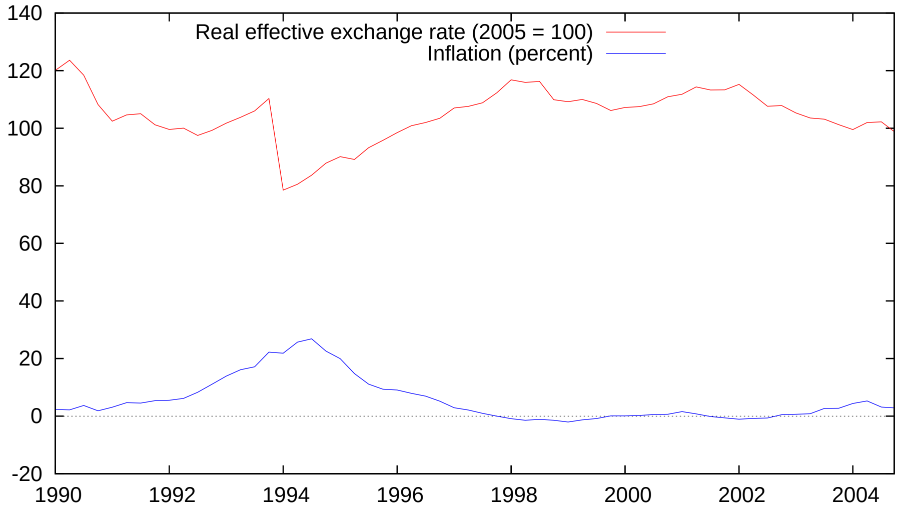
Note: An increase in the absolute value of the currency means a depreciation. Data are defined as the annual average.
Source: IFS

was. There is fairly opposite opinion among observers from western countries. Goldstein and Lardy [9] note that the renminbi was closely pegged to the US dollar. Anderson [14] describes the renminbi exchange regime as a crawling peg. For more details on the classification of exchange rate regimes we refer to the the IMF Working Papers [15] and [16]. The subsequent developmet of the exchange rate can be divided into three stages, i. e. a transition after the unification, a fixed exchange rate and an exchange rate reform.

2.3.1 Transition after Unification

Although closely managed by the government, the official exchange rate perhaps developed towards an equilibrium value during the mid-1990s. The currency was allowed to revalue up to 8.3 CNY/USD in June 1995 and then was slightly adjusted to 8.28 CNY/USD in October 1997. These revaluations signified the appreciation by 5% [9]. Since then until June 2005, the nominal exchange rate was relatively stable and fluctuated within a very narrow band around 8.28 CNY/USD (figure 2.3). But the situation was quite different in case of the exchange rate expressed in real terms. China suffered high inflation

Figure 2.4: Real effective exchange rate and inflation, 1990 - 2004



Note: An increase in the index means an appreciation. Data are defined as the quarterly average.
Source: IFS

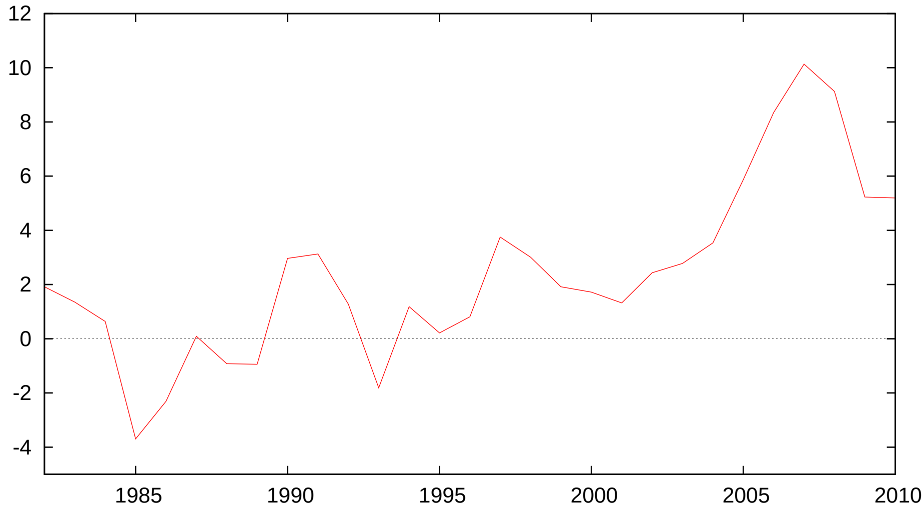
of 24% in 1994, 17% in 1995 and 8.3% in 1996 (figure 2.4), which caused the appreciation of its real effective exchange rate by 32% [1]. The evolution of the real effective exchange rate is depicted in figure 2.4.

The movement of the exchange rate closer to the equilibrium level is also indicated by other facts. Firstly, Chinese current account position was nearly balanced. Figure 2.5 shows that the current account was in modest surpluses of 1.2% in 1994, 0.2% in 1995 and 0.8% in 1996. Secondly, China accepted the obligations of IMF´s Article VIII in December 1996, meaning that it made a commitment to abide the currency convertibility on current account transactions [17].

2.3.2 De facto Pegged Nominal Exchange Rate

During Asian financial crisis in 1997 and 1998, most of the Southeast Asian currencies depreciated against the US dollar. Chinese government decided to not devalue the currency and kept it still at 8.28 CNY/USD [9]. On the one hand, Chinese exports became less competitive in Southeast Asia countries, because their goods was cheaper due to the depreciation. On the other hand, the renminbi was protected from currency speculations and became one of a few

Figure 2.5: Current account position (percent of GDP), 1992 - 2010



Note: Data are defined as the annual average.
Source: IFS

strong currencies in emerging markets, which gave positive signals to country´s foreign partners from advanced economies [7]. At the turn of the millennium the American dollar appreciated, which pulled up the value of the renminbi. The real effective exchange rate appreciated by 4% between 1997 and 2001 [1].

After very long negotiations China finally entered the World Trade Organization (WTO) in December 2001. The admission required a liberalization and deregulation of the economy, however the Chinese authorities still continued in its exchange rate policy and allowed the currency to fluctuate in a very tight band against the US dollar. In addition, the PBOC has narrowed the fluctuation bands to a level of 0.002% from 2001 and then practically to zero from late 2004 [14].

The period of the real currency appreciation terminated, when the value of the American dollar started to fall in February 2002. The real effective exchange rate of the renminbi depreciated by 10 % since 2002 to 2005 [1]. The Chinese exports grew substantially after 2001, which is surely related to joining the WTO. The combination of these two factors proposes that the Chinese currency was undervalued approximately by 23% by mid-2005. The undervaluation of the exchange rate started to increase a competitiveness of Chinese goods in the internatonal markets, which resulted in the movement of country´s trade and current account into large surplus positions [9]. From that reason China got under a massive international pressure to revalue the currency. The United States, the China´s largest trading partner, tended to think that the undervalued renminbi was the main factor behind its enormous trade deficit. Generally, the trade frictions between China and its major partners were intensified. In order to improve trade relationships, to implement a sustainable economic growth based on the domestic demand and to increase the independence of the monetary policy, Chinese government decided to reform the exchange rate regime [18].

2.3.3 Exchange Rate Reform

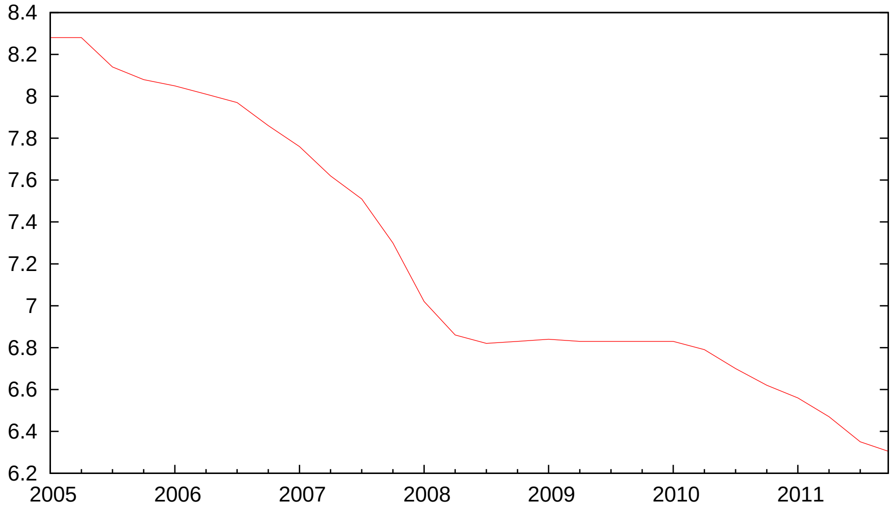
On July 21, 2005, the People´s Bank of China announced the following set of adjustments:

- China will adopt a managed floating exchange rate regime based on market supply and demand. The renminbi will be managed with reference to a basket of currencies rather than only against the US dollar.
- The exchange rate is immediately adjusted from 8.28 CNY/USD to 8.11 CNY/USD (implying the appreciation by 2.1%).
- The renminbi will be returned to fluctuate within the daily rates up to 3% of the previous day´s closing price against the US dollar. Also, the renminbi will be allowed to move within a certain band announced by the PBOC against other currencies [19].

Compared to the previous regime, the most significant change was a shift from the single peg to the exchange rate based on market supply and demand with reference to a basket of currencies. However, the PBOC has never revealed the composition of the currencies and their weights in the basket. It is widely accepted that the basket might have included the US dollar, the euro, the Japanese yen, the Korean won and other currencies of those countries with which China traded significantly, such as the Singapore dollar, the British pound, the Australian dollar, the Thai baht, the Russian rouble, the Malaysian ringgit and the Canadian dollar [18].

Here, we could again start a discussion how much the exchange rate was really managed floating regime determined by supply and demand. The PBOC actually retained the right to intervene the exchange rate band when necessary

Figure 2.6: Official rate (CNY/USD), 2005 - 2011



Note: An increase in the absolute value of the currency means a depreciation. Data are defined as the annual average.
Source: IFS

according to the market development [18]. Moreover, Frankel and Wei [20], [21] have found that there is little evidence of managing the renminbi with reference to a basket of currencies and that the renminbi has still continued to follow the US dollar.

After July 2005, China allowed the renminbi to appreciate steadily in several steps. By the end of 2008 the nominal exchange rate was 6.83 CNY/USD, reflecting the appreciation against the US dollar of 18.7% (or the cumulative appreciation of 21.2% if the initial 2.1% appreciation is included). The nominal appreciations slightly reduced the degree of the renminbi undervaluation, however the pace of the real appreciation slowed dramatically in 2006 and 2007, which finally resulted in widenning the degree of the undervaluation to 26% by November 2007 [9].

Furthermore, the government stopped the appreciation policy in July 2008, because the demand for Chinese goods dropped substantially due to the global financial crisis. Chinese exports and imports fell by 15.9% and 11.% against 2008 values [22]. From that time until June 2010, the nominal exchange rate was held reltively stable at 6.83 CNY/USD (figure 2.6). We can state that China reiterated fixing the renminbi to the US dollar. On June 19, 2010, the

Table 2.1: Evolution of the renminbi exchange rate regime

Single exchange rate (1949 - 1981)	
Dual exchange rate (1981 - 1994)	Official rate and internal settlement rate (1981 - 1985) Official rate and swap market rate (1985 - 1994)
Managed floating exchange rate (1994 - present)	Transition after unification (1994 - 1997) De facto fixed nominal exchange rate (1997 - 2005) Exchange rate reform (2005 - present)

PBOC announced that it had decided to "*further reform the RMB exchange rate regime and improve its flexibility*" [23]. Many observers claimed that the timing of the announcement was related to the G-20 summit in Torronto in June 2010. Chinese authorities prevented their currency policy from being a central focus of the summit. Since then until to November 2011, the nominal exchange rate strengthened from 6.83 CNY/USD to 6.35 CNY/USD, reflecting the appreciation by 7.6% [22].

In a conclusion of this chapter, we provide an overview of the evolution of the renminbi exchange rate regime in table 2.1

Chapter 3

Concepts of Equilibrium Exchange Rate

The knowledge of the equilibrium exchange rates has became a hot topic for economists and policymakers. What are the sources of exchange rate movements? Is a particular currency misaligned (undervalued or overvalued)? What will be the future development of a currency? What is the appropriate exchange rate to enter a monetary union? Answering these kind of questions requires some measures of the equilibrium.

Nowadays, there are many approaches how to estimate the equilibrium exchange rate. Each method defines the equilibrium in a different way, thus the choice between them must be judged relative to the question of interest. In this chapter, we review the most frequent approaches, i. e. the purchasing power parity (PPP), the fundamental equilibrium exchange rate (FEER), the desired equilibrium exchange rate (DEER), the behavioral equilibrium exchange rate (BEER) and the permanent equilibrium exchange rate (PEER).

3.1 Purchasing Power Parity

This concept is widely used to measure the equilibrium value of a currency and its misalignment. Since there is much of literature underlying the the PPP theory, we only focus on the basic concept and potential shortcomings.

The PPP theory was firstly mentioned by scholars of the Salamanca school in 16th century in Spain. The modern origins of the PPP was formulated by Gustav Cassel at the beginning of 20th century [24]. The basic building block of the PPP is the so-called "law of one price" (LOOP).

The *absolute version* of the LOOP may be defined as:

$$P_{it} = S_t P_{it}^*, \tag{3.1}$$

where P_{it} is the price of good i in terms of the domestic currency, P_{it}^* denotes the price of good i in terms of the foreign currency and S_t is the nominal exchange rate[1]. The LOOP states that the homogeneous goods should have the same price across countries, if the prices are expressed in the same currency. By summing all the trade goods in each country, we get:

$$\sum_i^n \alpha_i P_{it} = S_t \sum_i^n \alpha_i P_{it}^*, \tag{3.2}$$

where α_i denotes the weight used to aggregate the individual prices and satisfy $\sum_i^n \alpha_i = 1$. The absolute PPP condition is derived as:

$$S_t = \frac{P_{it}}{P_{it}^*} \tag{3.3}$$

Then, the absolute PPP condition in terms of the real exchange rate (Q) is:

$$Q_t = S_t \frac{P_{it}^*}{P_{it}} = 1. \tag{3.4}$$

If the absolute PPP is satisfied, the real exchange rate should equal unity. Therefore, the equation (3.4) may be viewed as a measure of the deviation from the PPP. Trying to implement the absolute PPP is in practice very complicated. At first, the trade weights (α´s) used to construct the price levels are not the same across countries. A second issue relates a discussion of the choice of the appropriate price indexes (e. g. consumer price index (CPI), producer price index (PPI), wholesale price index (WPI) and etc.).

Therefore, the *relative version* of the LOOP postulates the weaker condition:

$$S_t \frac{P_{it}^*}{P_{it}} = S_{t+1} \frac{P_{it+1}^*}{P_{it+1}}. \tag{3.5}$$

The absolute LOOP implies the relative LOOP, but not vice versa.

Obviously, there is a number of restrictions which undermine the concept of PPP. The LOOP may not hold due a presence of any sort of tariffs, transport costs, capital controls and etc. Also, the assumption of identical goods across

[1] The domestic currency per unit of the foreign currency.

countries is not mostly satisfied [25]. Finally, there are systematic differences between the PPP and the equilibrium exchange rate. One of the explanations is known as Balasa-Samuelson effect [26] and [27]. In brief, the argumentation is based on the differences in the relative productivities of tradable and non-tradable sectors. The productivity growth concentrated in the tradable goods sector leads to wage rises in the non-tradable goods sector. This results into an increase in the prices of non-traded goods, respectively the upward movement in the consumer prices. According to the definition, the growing consumer prices increases the PPP, but the nominal exchange rate remains unchanged. Hence, the PPP incorrectly indicates that the domestic currency is overvalued.

The limitations of the PPP have become the sources of motivations for developing more recent models of the equilibrium exchange rate.

3.2 Fundamental Equilibrium Exchange Rate

Nowadays, the FEER is probably the most common approach of estimating the equilibrium exchange rate. The FFER was developed by John Williamson [4], who defines it as "*the exchange rate that is consistent with macroeconomic balance, meaning simultaneous achievement of internal and external balance*". The internal balance is identified as the level of output, which is consistent with full employment (the level of unemployment given by the NAIRU[2]) and low and sustainable inflation. The external balance is then characterized as sustainable balance of payment position, i. e. desired net flows of resources between countries. A minimum criterion for the external balance is that current account outcome has to be sustainable [28].

This approach abstracts from short-run cyclical and speculative forces and focuses more on "economic fundamentals", which are expected to prevail in the medium-run. These conditions are desirable outcomes, which may never be realized in fact. In this sense, the FEER is definitely a normative concept [28]. Williamson [4] characterizes it as the equilibrium exchange rate (path), that would be consistent with ideal economic conditions.

The concept itself does not actually impose a unified methodology how to do the calculations. They can be done either using a complete macro-econometric model or using a partial equilibrium approach [30]. Further, we follow the partial approach which is particularly applied in literature. The basic identity

[2] NAIRU - non-accelerating inflation rate of unemployment

is the external balance equation, equating the current account (CA) to the capital account (KA):

$$CA = -KA. \tag{3.6}$$

Rather than to specify factors affecting the real exchange rate, the FEER approach puts emphasize on factors affecting the current account [29]. It is mostly explained as a function of the home demand (y_d), the foreign demand (y_f) and the real effective exchange rate[3] (q), which are set at their equilibrium (potential) levels:

$$CA = b_0 + b_1\overline{y_d} + b_2\overline{y_f} + b_3 q = -KA. \tag{3.7}$$

The FEER is then the real effective exchange rate (q), which brings the current account into equality with the sustainable capital account:

$$FEER = \frac{-\overline{KA} - b_0 - b_1\overline{y_d} - b_2\overline{y_f}}{b_3}. \tag{3.8}$$

The equation (3.8) can be represented by the following general form:

$$FEER = f(-\overline{KA}, \overline{y_d}, \overline{y_f}). \tag{3.9}$$

According to Wren-Lewis [31], the FEER is a "*method of calculation of a real exchange rate, which is consistent with medium-run macroeconomic equilibrium*". Through a comparison of q and $FEER$ we determine, whether the real effective exchange rate is undervalued ($q > FEER$) or overvalued ($q < FEER$).

Concretely, FEER calculation requires (1) to define the current account model and estimate relevant elasticities, (2) to determine desirable (potential) output for the domestic country and its main foreign partners and (3) to judge sustainable capital flows. The first two tasks are analytically and conceptually fairly straightforward. The third input entering the analysis is more problematic. One of the approaches is to recognize the sustainable capital flows (equilibrium current account) from the difference between desired levels of savings and investment.

Williamson [4], the godfather of the FEER, uses a theoretical framework which includes investment needs determined by debt cycle, the impacts of demographics on savings and judgment concerning sustainability and consistency to get sustainable level of the current account. The possibly more applicable solution is provided by Isard and Faruqee [33], who determine the equilibrium

[3]The domestic currency per unit of the foreign currency.

current account as the difference between desired levels of savings and investment at full employment (determinants are the output gap, dependency ratio and fiscal policy). Equation (3.9) can be then interpreted as:

$$FEER = f(\overline{S} - \overline{I}, \overline{y_d}, \overline{y_f}). \tag{3.10}$$

It is more transparent and plausible method how to estimate the sustainable capital flows (equilibrium current account) and depends less on a judgment than other implementations of the FEER approach [28].

3.3 Desired Equilibrium Exchange Rate

The normative assumptions of what would be the level of internal and external balance has led many economists to argue that the equilibrium real effective exchange rate derived from the FEER approach should be called desired equilibrium exchange rate (DEER). Williams [4] himself states that it might have been more exact, if the FEER had been called an "optimal", "appropriate" or "desirable" exchange rate.

According to Bayoumy et al. [34], the concept of "fundamental" equilibrium exchange rate would be more applicable to a long-run situation, where all underlying economic forces had worked themselves out. They literally state, "*We wish to stress that the concept of the equilibrium real exchange rate consistent with macroeconomic balance is based upon a set of desired macroeconomic objectives*" [34]. Hence, they use the term "desired equilibrium exchange rate".

The calculation of the DEER methodologically follows that of the FEER. It includes the estimation of the three elasticities, the determination desirable outputs for the domestic country and its main foreign partners and the judgment on desirable capital flows. As in the case of the FEER, different estimates of the DEER are mostly computed to generate a set of equilibrium exchange rates under different economic circumstances and policy choices. Thus, this approach is a very useful tool for policymakers [35].

3.4 Behavioral Equilibrium Exchange Rate

The BEER approach involves a direct econometric analysis to establish the behavior of the real exchange rate. The value of the equilibrium exchange rate is given by an appropriate set of explanatory variables. Hence, the underlying assumption of macroeconomic balance in the FEER approach is absent under the BEER one.

This concept is associated with Clark and McDonald [28], who estimate the BEER using the reduced-form equation:

$$q = \beta_1^{'} Z_1 + \beta_2^{'} Z_2 + \beta_3^{'} T + \epsilon, \tag{3.11}$$

where q is the current value of the real exchange rate[4], Z_1 is a vector of economic fundamentals that are expected to have persistent effects over the long-run, Z_2 is a vector of economic fundamentals that affects the real exchange rate over the medium-run, T is a vector of transitory effects over the short-run and ϵ is a disturbance term. It is useful distinguish the actual value of the exchange rate (q) and the current equilibrium value of the exchange rate ($q^{'}$), which is given by the current values of the the two sets of economic fundamentals:

$$q^{'} = \beta_1^{'} Z_1 + \beta_2^{'} Z_2. \tag{3.12}$$

Since the current values of the economic fundamentals may differ from sustainable or desirable levels (as emphasized in the FEER approach), it is useful to define the sustainable equilibrium value of the real exchange rate ($\bar{q}$), which is based on the sustainable or long-run values of the economic fundamentals:

$$\overline{q} = \beta_1^{'} \overline{Z_1} + \beta_2^{'} \overline{Z_2}, \tag{3.13}$$

To estimate reduced-form exchange rate equation it is necessary to identify the short-run factors (T), the medium-term and long-term fundamentals (Z_1 and Z_2).

The starting point is the uncovered interest parity, expressed in real terms and adjusted for the risk premium:

$$q_t = E_t[q_{t+k}] + (r_t - r_t^*) - \pi_t, \tag{3.14}$$

where $E_t[q_{t+k}]$ is the expected real exchange rate for the $t+k$, r is the domestic *ex ante* real interest rate, r^* is the foreign *ex ante* real interest rate, $\pi_t = \lambda_t + k$ is the risk premium which has a time-varying component (λ_t) and $(t+k)$ defines the maturity of the bonds. The equation (3.14) describes the current exchange rate as a function of three components: the expectation of the real

[4] The domestic currency per unit of the foreign currency.

exchange rate (long-term), the real interest deferential (short-run and medium-run) and the risk premium (time effects). The time varying component of the risk premium is considered to be a function of relative supply of the domestic to foreign government debt:

$$\lambda_t = g_1\left(\frac{gdebt_t}{gdebt_t^*}\right). \tag{3.15}$$

An increase in the relative supply of the domestic debt relative to foreign debt increases the risk premium, which implies an appreciation of the current equilibrium real exchange rate. The unobservable expectation of the real exchange rate ($E_t[q_{t+k}]$) is assumed to be determined by the long-run economic fundamentals (Z_1), thus this exchange rate can be approximated by the long-run equilibrium exchange rate ($\bar{q}_t$):

$$\overline{q_t} = E_t[q_{t+k}] = E_t[\beta_1^{'} Z_{1t}] = \beta_1^{'} Z_{1t}. \tag{3.16}$$

Clark and MacDonald [28] take into account three long-run variables, which are terms of trade (tot), Ballassa-Sammuelson effect, i. e. the relative price of non-traded to traded goods (tnt) and net foreign assets (nfa):

$$\overline{q_t} = g_2(tot_t, tnt_t, nfa_t). \tag{3.17}$$

An increase in all variables causes a depreciation of the long-run equilibrium exchange rate [28].

Combining the equations (3.14), (3.15) and (3.17), the BEER is determined by the following set of variables:

$$BEER = f(tot, tnt, nfa, r - r^*, \frac{gdebt}{gdebt^*}). \tag{3.18}$$

If the variables are in mutual long-run equilibrium relationship (they are co-integrated), the estimated BEER represents the equilibrium exchange rate in a behavior sense [12]. For estimating the equation (3.18) the methods from the co-integration framework should be used, see [36], [37] or [38]. Clark and MacDonald [28] employed the Johansen methodology, which allows the variables to be modeled as a system of simultaneous equations and the existence of more than one co-integrating vectors.

3.5 Permanent Equilibrium Exchange Rate

We have already indicated that the BEER approach identifies a behavioral link between the real exchange rate and relevant economic fundamentals. The BEER calculated using the current values of economic fundamentals corresponds to the current value of the real exchange rate. The misalignment is then referred to as the current misalignment:

$$cm = q - q^{'} = q - \beta_1^{'} Z_1 - \beta_2^{'} Z_2. \tag{3.19}$$

However, the current levels of economic fundamentals may significantly differ from their sustainable, long-term or permanent levels. Thus, the analysis of the BEER has been extended to estimate the equilibrium real exchange rate using the long-run levels of economic fundamentals. This equilibrium exchange rate is known as "permanent equilibrium exchange rate" (PEER) [35]. The difference between the actual real exchange rate and the PEER is described as the total misalignment (tm):

$$tm = q - \beta_1^{'} \overline{Z_1} - \beta_2^{'} \overline{Z_2}. \tag{3.20}$$

The Basic feature of the PEER approach is a decomposition of the real exchange rate into permanent and transitory components:

$$q = q^P + q^T. \tag{3.21}$$

where q^P is the permanent component of the real exchange rate and q^P is the transitory component of the real exchange rate. The permanent component represents a measure of the equilibrium [39]. The most used methods to decompose the non-stationary series into the permanent and transitory components are proposed by Clarida and Dali [40], Gonzalo and Granger [41] and Clark and Macdonald [42].

At the end of this chapter, we provide an overview of discussed approaches in table 3.1.

Table 3.1: Approaches for estimating equilibrium exchange rate

	PPP	**FEER**	**DEER**	**BEER**	**PEER**
Name	Purchasing Power Parity	Fundamental Equilibrium Exchange Rate	Desirable Equilibrium Exchange Rate	Behavioral Equilibrium Exchange Rate	Permanent Equilibrium Exchange Rate
Theoretical Assumptions	Constant equilibrium exchange rate	Real exchange rate compatible with both internal and external balance	As FEER, but the definition of internal and external based on desirable objectives	Real UIP with a risk premium, movements in real exchange rate determined by fundamentals	As BEER
Relevant Time horizon	Long-run	Medium-run	Medium-run	Short-run (forecast)	Medium-run/ Long-run
Statistical Assumptions	Stationary	Non-stationary	Non-stationary	Non-stationary	Non-stationary
Dependent Variable	Real or nominal	Real effective	Real effective	Real	Real
Estimation Method	Test for stationarity	Underlying balance	Underlying balance	Direct	Direct

Source: Driver and Westaway [30]

Chapter 4

Empirical Model

In this study, we estimate the fundamental equilibrium exchange rate (FEER) of the Chinese currency. The FEER is the level of the real effective exchange rate that is consistent with achieving sustainable levels of output and the current account in the medium-run. For calculating we employ the partial-equilibrium approach (e.g. [34] or [43]), which has several advantages and disadvantages. On the one hand, the calculations are simple and transparent. On the other hand, certain dynamic factors are ignored.

According to equation (3.8), there are three basic requirements to calculate the FEER. At first, we need to estimate the Chinese elasticities of the current account to the domestic output, the foreign output and the real effective exchange rate. These elasticities are derived from the trade equations. The second requirement includes the determination of the potential output for China and its main foreign partners. The third input entering the analysis is the judgment on the sustainable (equilibrium) current account. Finally, we establish the current account model and estimate the FEER over the period 1981 and 2010.

4.1 Data Sources and Definitions

It is necessary to say that we were broadly limited by data availability. Therefore, the time series used in this study are composed of annual observations during the period 1981 and 2010. The time series come from the *Direction of Trade Statistics* (DOTS), *International Financial Statistics* (IFS), *World Economic Outlook* (WEO) published by the IMF, the *World Development Indicators* (WDI) published by the WB and the *European Statistics* (ES) published by Eurostat. The base year for the series in constant prices is 2005 and the indices are for 2005 = 100. The variables are given below.

Chinese Real GDP (Y)

The Chinese real GDP is calculated by multiplying the GDP volume index (IFS) by 2005 value for GDP in the national currency (IFS). The scale is billions.

Chinese Nominal GDP (NY)

This variable represents the Chinese nominal GDP in the national currency (IFS). The scale is billions.

Foreign Real GDP (WY)

There are two possibilities how to proxy the foreign demand (GDP). Following exactly the FFER approach, the foreign demand should be represented by the demand of the country´s main foreign partners. The foreign demand is also proxied by the whole world output (e. g. [43]). Both methods have some advantages and disadvantages. The GDP of main foreign partners does not capture perfectly the demand for Chinese goods and services and may miss new opportunities for Chinese exporting firms. On the other hand, the development of the world GDP may not be fully related to the development of the Chinese foreign trade. On the basis of results, we have finally decided to proxy the foreign demand as the world GDP.

The world real GDP is computed by multiplying the GDP volume index (IFS) by 2005 value for GDP in the US dollar (WEO). The scale is billions.

Chinese Real Imports (M)

This variable represents the Chinese real exports, which is calculated by multiplying the Chinese import volume index (WDI) by 2005 value for imports of goods and services in the national currency (WDI). The scale is billions.

Chinese Real Exports (X)

In a similar manner, the Chinese real exports is obtained by multiplying the export volume index (WDI) by 2005 value for exports of goods and services in the national currency (WDI). The scale is billions.

Chinese Import Deflator (DM)

Since we need to convert the real imports to nominal values in order to formulate the current account position, we define the "import deflator". It is obtained as a ratio of the Chinese nominal imports of goods and services (IFS) and real imports of goods and services.

Chinese Export Deflator (DX)

Analogically, we define the "export deflator", which is obtained as a proportion of the Chinese nominal exports of goods and services (IFS) and real exports of goods and services.

Chinese Real Effective Exchange Rate (REER)

According to the theory of the exchange rate, we know that the real effective exchange rate can be computed as follows:

$$REER = \sum_{i=1}^{n} w_i RER_i, \tag{4.1}$$

where RER_i is the bilateral real exchange rate relative to the i-th currency, w_i is the weight of the i-th currency reflecting the foreign trade share and n is the number of countries to which the real effective exchange rate is calculated. Firstly, we have to determine the Chinese most significant foreign partners and calculate their relevant trade weights. Using merchandise exports (DOTS) and merchandise imports (DOTS) we counted Chinese total trade divided according to individual countries. The results in table 4.1 indicate that the Chinese largest trading partners are the USA, the Euro Area[1], Japan, Hong Kong[2] and the Republic of Korea.

The other inputs required for calculation are the real exchange rates between China and its foreign partners. They are obtained by multiplying the nominal exchange rate in Chinese currency per foreign currency (IFS, ES) by the ratio of the foreign consumer price index (IFS, WDI) to the domestic consumer price index (WEO). The resulted real effective exchange rate is defined in terms of

[1]The Euro Area was established on 1 January, 1999. Before that the time series are aggregated for all 17 member states (Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Slovakia, Slovenia and Spain). We further treat the Euro Area as a single country.

[2]Hong Kong is the Special Administrative Region of the People´s Republic of China.

Table 4.1: Trade weights (percent), 1981, 1991, 2001, 2010

Year	USA	EA	JAP	HK	ROK
1981	21.884	16.476	38.655	22.985	0.000
1991	14.118	13.139	20.154	49.365	3.224
2001	24.964	19.374	27.215	17.318	11.129
2010	25.850	25.143	19.879	15.263	13.864

Source: DOTS

the domestic currency per unit of the foreign currency, so that an increase in the real effective exchange rate means a real depreciation.

4.2 Trade Elasticities

The trade elasticities have always played an important role in the econometric analysis of international trade. They are estimated from the two trade equations, one for real imports and one for real exports. These equations aim at assessing the long-run relationships among the intervening variables.

The import equation is assumed to take the following form:

$$\ln M_t = \beta_{10} + \beta_{11} \ln Y_t + \beta_{12} \ln \left(\frac{PM_t}{PD_t} \right) + \epsilon_{1t}, \tag{4.2}$$

where M is the volume of imports, Y is the domestic demand, PM is the price of imports and PD is the domestic price level. The export equation is defined in a similar way:

$$\ln X_t = \beta_{20} + \beta_{21} \ln WY_t + \beta_{22} \ln \left(\frac{PX_t}{PXW_t} \right) + \epsilon_{2t}, \tag{4.3}$$

where X is the volume of exports, WY is the world demand, PX is the price of exports and PXW is the world export price. The output terms are known as income elasticities, while the price terms are called price elasticities [44].

For our purposes we employ modified versions of the trade equations, which take the form:

$$\ln M_t = \beta_{10} + \beta_{11} \ln Y_t + \beta_{12} \ln REER_t + \epsilon_{1t} \tag{4.4}$$

$$\ln X_t = \beta_{20} + \beta_{21} \ln WY_t + \beta_{22} \ln REER_t + \epsilon_{2t}, \tag{4.5}$$

where $REER$ is the real effective exchange rate. We expect the estimate of β_{11} to be positive, meaning that an increase in Chinese GDP increases a consumption of imported goods. Similarly, the estimate of β_{21} is expected to be positive, reflecting that an increases in world demand results in a rise in Chinese exports. Since the $REER$ is defined as the units of domestic currency per unit of the foreign currency, an increase in real effective exchange rate (depreciation of the currency) is expected to discourage imports and encourage exports.

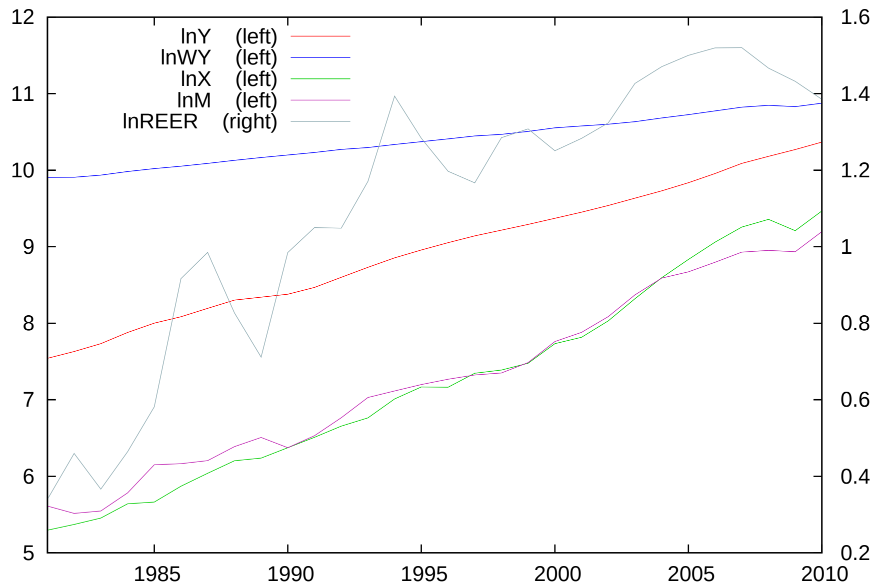
Early studies such as Warner and Kreinin [45], Bahmani-Oskooee [46] or Marquez [47] estimated trade equations using simple ordinary least squares (OLS). However, more recent development in time-series econometrics indicates that applying OLS on no-stationary time-series may lead to the spurious regression, firstly described by Granger and Newbold [48]. The possible solution provides co-integration analysis, which includes several methods of estimations. Hooper et al. [49] and Bahmani-Oskooee [50] employed the Johansen methodology. Aziz and Li [51] and Cheung et al. [52] made a use of dynamic ordinary least squares (DOLS). An alternative approach apart from the standard co-integration techniques is the autoregressive distributed lag (ARDL), which was used by Bahmani-Oskooee and Kara [53].

4.2.1 Unit Root Tests

Most of the economic time series are non-stationary, meaning that they do not meet the requirement of the time invariant mean, covariance and autocorrelation structure. These series have several specific features in a comparison with the stationary series. First of all, the impact of the shocks on the non-stationary series can be permanent, while it is only temporary in the stationary ones. As we have already mentioned, using nonstationary series can lead to the spurious regression. Finally, calculated t-statistics does not have (asymptotically) t-distribution as well as calculated F-statistics does not have (asymptotically) F- distribution [54].

It is necessary to distinguish two types of non-stationarity. The series with deterministic trend is made stationary simply by elimination of this trend. The second option to hold the assumption of stationarity is application of differences. When we differentiate the series d times, it said to be integrated of order d, denoted by $I(d)$ [36]. Equivalently, it said that the series has d unit roots. There are several tests used for testing stationarity, respectively unit roots. We employ the Augmented Dickey-Fuller (ADF) test and the Kwiatkowski-

Figure 4.1: Logarithms of Time Series



Phillips-Schmidt-Shin (KPSS) test.

ADF Test

It is an augmented version of the Dickey-Fuller test, which allows residuals to be serially correlated. Test statistics, which are known as τ-tests, are derived from the following figures according to a situation, whether constant, trend or both are present (e.g. [54]):

$$\Delta y_t = \beta y_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta y_{t-i} + \epsilon_t \tag{4.6}$$

$$\Delta y_t = \alpha_0 + \beta y_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta y_{t-i} + \epsilon_t \tag{4.7}$$

$$\Delta y_t = \alpha_0 + \alpha_1 t + \beta y_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta y_{t-i} + \epsilon_t, \tag{4.8}$$

where y_t is observed time series and p is lag order. The null hypothesis is that the series has a unit root ($\beta = 0$), whereas the alternative is that the series is stationary ($\beta \neq 0$).

Now, we perform the test for our five time series. Figure 4.1 shows that all time series have a non-zero mean and a trend, thus we make a use of the

Table 4.2: ADF test

	Specification (4.7) Constant		Specification (4.8) Constant and trend	
Variable	τ-statistic	p-value	τ-statistic	p-value
$\ln M$	1.6887	0.9997*	−1.1967	0.9103*
$\ln X$	1.5049	0.9994*	−2.7000	0.2367*
$\ln Y$	0.0969	0.9656*	−4.5955	0.0010
$\ln WY$	−0.1985	0.9363*	−0.7541	0.0010
$\ln REER$	−2.3533	0.1554*	−6.5436	0.9682*
$\Delta \ln M$	−4.3181	0.0004	−4.8921	0.0001
$\Delta \ln X$	−5.0929	0.0001	−2.5248	0.3160*
$\Delta \ln Y$	−3.3212	0.0140	−3.6830	0.0234
$\Delta \ln WY$	−5.5773	0.0000	−5.4170	0.0000
$\Delta \ln REER$	−3.3410	0.0132	−4.2377	0.0039

*The null hypothesis cannot be rejected at the 5% level.

specification (4.7) and (4.8). An important point for running the ADF test is the specification of the lag order (p). If the p is too small, the serial correlation of the residuals may bias the test. On the other hand, if p is too large, the test may suffer from the low power. In our case, the lag length was determined by information criteria, i. e. Akaike criterion (AIC), Bayesian criterion (BIC) and Hannan-Quinn criterion (HQC).

The results of tests are summarized in table 4.2. In the case of the specification (4.7), all the variables are not stationary. The differences of $\ln M$, $\ln X$, $\ln Y$ and $\ln WY$ are stationary, which means that these variables are $I(1)$. The differences of $\ln REER$ are not stationary, which reflects that this variable is at minimum $I(2)$. Taking into account the specification (4.8), if the variables $\ln M$ and $\ln X$ were stationary, we could estimate trade equations by OLS with a use of the trend. However, they are not. In general, the ADF test with the presence of the constant and trend gives worse results for the following estimates, therefore we further consider only the choice to estimate trade equations with the constant.

KPSS test

The KPSS test sets up the opposite hypothesis in a comparison with the ADF test. The null is therefore stationarity, whereas the alternative is non-stationarity. As was been said, we perform the test only for the possibility of

Table 4.3: KPSS test

Variable	Test statistic	Critical values		
		10%	5%	1%
$\ln M$	1.0821	0.354	0.476	0.711
$\ln X$	1.0792	0.354	0.476	0.711
$\ln Y$	1.0970	0.354	0.476	0.711
$\ln WY$	1.0915	0.354	0.476	0.711
$\ln REER$	0.9701	0.354	0.476	0.711
$\Delta \ln M$	0.1005*	0.354	0.477	0.710
$\Delta \ln X$	0.1681*	0.354	0.477	0.710
$\Delta \ln Y$	0.0585*	0.354	0.477	0.710
$\Delta \ln WY$	0.0704*	0.354	0.477	0.710
$\Delta \ln REER$	0.2569	0.354	0.477	0.710

*The null hypothesis cannot be rejected at the 5% level.

the constant. The results are depicted in table 4.3. The KPSS test confirms the findings of the ADF test. The variables $\ln M$, $\ln X$, $\ln Y$ and $\ln WY$ are $I(1)$. The variable $\ln REER$ is at minimum $I(2)$.

To make the series stationary we could apply their differences. This step would by statistically correct, but it does not reveal the long-run relationships between the original (undifferenced) series [54]. The possible solution of this problem is to employ the co-integration framework.

4.2.2 Co-integration Analysis

In most cases the linear combination of non-stationary series is again non-stationary. However, for economic and financial time series we are often able to make such a linear combination of originally non-stationary series that is stationary. This effect is called co-integration and can be interpreted as a long run equilibrium relationship between variables [54].

Engle and Granger [36] define the co-integration in the following way: "*the components of the vector y_t are said to be co-integrated of order d, b, denoted $y_t \sim CI(d,b)$, if (i) all components of y_t are $I(d)$; (ii) there exists a vector $\alpha(\neq 0)$ so that $z_t = \alpha' y_t \sim I(d-b), b > 0$. The vector α is called the co-integrating vector*". Consider the non-stationary time series, so that each of them has one unit root, respectively is $I(1)$. If these series are co-integrated, their non-trivial linear combination is $I(0)$, which means that this linear combination is stationary. In that case we can model the series using error correction mechanism without loosing the long-run relationships between them.

From the unit root tests we know that the variables $\ln M$, $\ln X$, $\ln Y$ and $\ln WY$ are $I(1)$. The variable $\ln REER$ is at minimum $I(2)$, however for the needs of the subsequent analysis, it is assumed to be $I(1)$. Naturally, the co-integration between the $I(1)$ variables must be examined through the tests (will be shown later).

Error Correction Model

An error correction model (ECM) is a dynamical system, which has been widely used in economics. The basic idea is that a proportion of the disequilibrium from one period is corrected in the next period. The Granger´s representation theorem shows that for any set of $I(1)$ variables the error correction and co-integration are equivalent representation [36].

The model is defined as (e. g. [54]):

$$\Delta y_t = \gamma(y_{t-1} - \beta x_{t-1}) + \delta \Delta x_t + \epsilon_t, \tag{4.9}$$

where α describes short-run relationships between variables, γ characterizes the speed of adjustment to the equilibrium, the component $(y_{t-1} - \beta x_{t-1})$ is known as the error correction term and β describes the long-run co-integrating relationships between variables. The ECM as well as the error correction term may also contain deterministic terms such as constant, trend and etc.

The single-equation ECM is estimated by the Engle-Granger two step estimator. The first step includes the estimation of the co-integration regression by OLS:

$$y_t = \beta x_t + u_t \tag{4.10}$$

In the second step, equation (4.9) is estimated by OLS, but the error correction term is replaced by the one lagged residuals from the co-integration regression (4.10) [36].

For calculating the FEER we are interested in the long-run relationships between variables in the trade equations, therefore we employ only the first

Table 4.4: Engle-Granger test

Variable	τ-statistic	p-value
u_1	-2.4242	0.5236*
u_2	-1.2130	0.9440*

*The null hypothesis cannot be rejected at the 5% level.

step of the Engle-Granger techniques:

$$\ln M_t = \beta_{10} + \beta_{11} \ln Y_t + \beta_{12} \ln REER_t + u_{1t} \tag{4.11}$$

$$\ln X_t = \beta_{20} + \beta_{21} \ln WY_t + \beta_{22} \ln REER_t + u_{2t} \tag{4.12}$$

Before own estimations we test the $I(1)$ variables for the co-integration. For this purpose we employ the Engle-Granger test, which examines the stationarity of the residuals from the co-integration regression. If the residuals are stationary, the series are co-integrated. The Engle-Granger test is basically the ADF test applied on the residuals from the co-integration regression, thus the null hypothesis is that the residuals have unit root (they are not stationary). Table 4.4 shows that we do not reject the null hypothesis, thus the variables in the import equation are not co-integrated as well as the variables in the export equation.

Since the co-integration is the main requirement for using the ECM, we should not estimate the coefficients in this way. However, table 4.6 shows that the estimates of the coefficients provided by the ECM are almost the same as their estimates obtained by the VECM, hence we consider them further for estimating the FEER.

Vector Error Correction Model

The problem of co-integration is possible to examine in the context of a vector autoregression (VAR), then it is referred to as the vector error correction model (VECM). Suppose a $m \times 1$ vector of $I(1)$ variables y_t, then the VECM take the form:

$$\Delta y_t = \Pi y_{t-1} + \Gamma_1 \Delta y_{t-1} + ... + \Gamma_{p-1} \Delta y_{t-p+1} + \epsilon_t. \tag{4.13}$$

If a rank (r) of the matrix Π is $0 < r < m$, according to the Granger´s representation theorem there exist matrices α and β (both dimension of $m \times r$), so that $\Pi = \alpha\beta'$ and each component of the vector $\beta' y_t$ is $I(0)$. In other words, there exist r co-integrating vectors [54]. The VECM as well as the error correction term may also contain deterministic terms such as constant, trend and etc.

For estimating VECM, respectively co-integration vectors, we employ the maximum-likelihood methodology developed by Johansen [37]. This technique, which is based on a full-system estimation, can eliminate simultaneous equation bias and increase the efficiency in relation to single-equation methods. On the other hand, if there is more co-integrating vectors than we need, it might be very difficult to interpret the results. In the context of the VECM, testing co-integration basically means to establish a number of co-integrating vectors. For this purpose Johansen provides two test statistics. The λ_{trace} statistic is:

$$\lambda_{trace} = -T \sum_{i=s+1}^{k} \ln(1 - \lambda_i), \tag{4.14}$$

where T is the sample size, the λ's are the eigenvalues, k is the full rank and s is the hypothesized number of co-integrating vectors. The null hypothesis is that there are $r = s$ co-integrating vectors, whereas the alternative is that $r \geq s + 1$. The λ_{max} statistic takes the form:

$$\lambda_{max} = -T \ln(1 - \lambda_{s+1}). \tag{4.15}$$

This statistic tests the null hypothesis of $r = s$ co-integrating vectors against the alternative that $r = s + 1$ [43].

Our vector of the $I(1)$ variables is $y_t = (\ln Y, \ln WY, \ln X, \ln M, \ln REER)'$. The VECM is considered to be with the constant in the error correction term (restricted constant). The lag length of the VECM is determined on the basis of relevant VAR. We have to keep in mind that if the relevant VAR is signalized to have p lags, the VECM will include $p - 1$ lags. The information criteria (AIK, BIC, HQC) indicate that the VAR for our variables should contain four lags (table C.11). Because we have relatively short time series (30 observations), it is not possible to use three lags in the VECM. We would lose the degrees of freedom, meaning that the results would be less credible. It would be probably suitable to use one lag , however in this case the λ_{trace} indicates only one co-integrating vector (table C.13). This result is not applicable for estimation, because we need two co-integrating vectors (we work with two

Table 4.5: Johansen test

H_0	Trace test	p-value	Lmax test	p-value
0	164.7600	0.0000	107.7000	0.0000
1	57.0600	0.0249	32.8480	0.0100
2	24.2120*	0.4541	10.6110*	0.7821
3	13.6010*	0.3252	9.6766*	0.3767
4	3.9245*	0.4355	3.9245*	0.4346

*The null hypothesis cannot be rejected at the 5% level.

trade equations). Finally, we have decided to use zero lag. In this case, the Johansen tests indicates two co-integrating vectors (table 4.5). We find these two co-integrating vectors by estimated VECM (table C.14). After applying normalization assumptions (linear restrictions), we get the long-run relationships between variables in the trade equations (table 4.6).

Table 4.6 shows that both methods give almost the same results. Since the assumption of the co-integration did not hold for Engle-Granger two step estimator, we interpret the trade elasticities estimated by Johansen methodology. The import elasticity to the domestic demand is 1.46, while the export elasticity to the foreign demand is 4.96. In general, we can note that the estimated income elasticities are very similar to income elasticities provided by other studies (e. g. [51] or [52]). In the case of price elasticities we do not have comparable values from another researches. We have actually modified the standard version of the trade equations (the relative price of import and the relative price of export has been replaced by the real effective exchange rate). However, we claim that the export elasticity to the real effective exchange rate has an opposite sign than expected. This findings might cause an extensive problem in the final calculation of the FEER. As will be shown later, this fear has been realized.

4.3 Desired Outputs

In this section, we need to define the sustainable or equilibrium values of domestic and world output. There are several methods how to calibrate the fundamentals at their sustainable levels. The first possibility is to place some

Table 4.6: Estimated coefficients, ECM, VECM

	Imports			Exports	
	ECM	VECM		ECM	VECM
cons	−5.2189	−6.5788	*cons*	−40.4562	−44.4740
	(0.5225)	(0.9099)		(1.8704)	(2.4494)
$\ln Y$	1.4127	1.4598	$\ln YW$	4.6280	4.9573
	(0.0777)	(0.1348)		(0.1959)	(0.2562)
$\ln REER$	−0.1427	−0.1385	$\ln REER$	−0.3418	−0.5878
	(0.1785)	(0.2987)		(0.1647)	(0.2090)

judgment on what values should have been during the sample period. Another possibility was adopted by Driwer and Wren-Lewis [43], who worked on the assumptions about the output gap in a particular year and the trend output growth. We employ the Hodrick-Prescott (HP) filter. This filter is widely used in macroeconomics, especially in the real business cycle theory, to decompose the cyclical component from the raw time series.

The coefficients from trade equations are estimated for the variables in logarithms, thus we apply the HP filter on the logarithmed Chinese GDP and world GDP. Separating the cyclical component, we get the trend (smoothed-curve) representation of these logarithmed series (figures A.1 and A.2). Because another variables, which are the import deflator, the export deflator and the nominal Chinese GDP, enter the final calculation of the FEER (equation 4.18), we must also smooth these variables. In this case, the HP filter was applied on original values (figures A.3, A.4 and A.5).

4.4 Current Account Target

As we have already said, there is no unified procedure how to establish the sustainable capital flows (the equilibrium current account). The determination of the desirable capital flows is often arrived in a fairly *ad hoc* manner.

Williamson [4] relies on a host of theoretical considerations to define current account targets for 14 countries in 1994. Williamson and Mahar [32] adopted an even wider set of theoretical considerations to get current account targets of the G-7 and East Asian countries for 2001. Bayoumi et al. [34] assumed that the targeted current account surplus for each country was equal to 1% of GDP in 1971. Isard and Faruqee [33] defined the equilibrium current account as the difference between desired savings and investment at full employment. Genoria and Kozamernik [55] employ several plausible specifications to represent the Slovenian´s equilibrium current account, i. e. the current account equal to zero, the apllication of the HP filter to smooth the actual current account and the intertemporal substitution based on an idea of borrowing at the early stages of the country´s transition.

Drawing inspiration from these studies, we have decided to adopt three scenarios of the Chinese equilibrium current account:

- Our first scenario is based on the work of Williamson and Mahar [32], who projected that the China´s current account surplus should have been 3% of GDP in 2001.
- The second natural candidate of the equilibrium current account is equal to 0%, because the country´s current account position should be balanced in the long-run horizon.
- The third specification is set to −3% of GDP in order to get a comprehensive picture of the possible misalignment of the Chinese currency.

4.5 FEER Estimates

The final step of the FEER calculation includes the establishment of the current account model. We define the current account only as the balance of goods and services. The income and net transfers are not taken into consideration, because their influence is marginal [1]. The balance of goods and services represents the nominal net exports, thus the real exports and imports are multiplied by their price deflators.

The current account model then takes the following form:

$$CA_t = DX_t X_t - DM_t M_t \tag{4.16}$$

To work in terms of the current account as a proportion of the GDP, both sides of the equation (4.16) are divided by the nominal domestic GDP:

$$\frac{CA_t}{NY_t} = \frac{DX_t X_t - DM_t M_t}{NY_t}. \tag{4.17}$$

Subsequently, the real imports and exports are substituted by trade equations:

$$\frac{CA_t}{NY_t} = \frac{DX_t \exp(\beta_{20} + \beta_{21} \ln WY_t + \beta_{22} \ln REER_t)}{NY_t} - \frac{DM_t \exp(\beta_{10} + \beta_{11} \ln Y_t + \beta_{12} \ln REER_t)}{NY_t}. \quad (4.18)$$

The FEER is calculated as the real effective exchange rate in equation (4.18), where the variables are replaced by their sustainable (equilibrium) values and the current account corresponds to the the current account target (CAT):

$$CAT = \frac{\overline{DX_t} \exp(\beta_{20} + \beta_{21}\overline{\ln WY_t} + \beta_{22} \ln REER_t)}{\overline{NY_t}} - \frac{\overline{DM_t} \exp(\beta_{10} + \beta_{11}\overline{\ln Y_t} + \beta_{12} \ln REER_t)}{\overline{NY_t}}. \quad (4.19)$$

The numerical solution of non-linear equation (4.19) with one unknown is straightforward. Using iterative algorithm called the Newton-Raphson method we get the equilibrium value of $\ln REER$ ($\overline{\ln REER}$) in a particular year. For obtaining the FEER we apply the final adjustment:

$$FEER_t = \exp(\overline{\ln REER_t}). \quad (4.20)$$

The results for selected years are depicted in table 4.7. The assumption of co-integration was not satisfied in the simple ECM, therefore we take an interest in the FEERs calculated using coefficients from the VECM. In general, we can state that the results are not satisfying. The FEER for the current account deficit of 3% in 1991 should have been 92.24 CNY/unit of the foreign currency, which is hardly believable number. Moreover, mathematical software did not find the solution for some years in the case of current account target of -3% and 3% (table B.2).

The most significant problem is that we get a quite contrary relationship in the behavior of the exchange rate relative to the current account position. The appreciation (decrease in absolute values) of the currency should reduce the current account surplus, however our findings shows that the appreciation increases the current account surplus (table 4.7). These problems are probably caused by the negative sign of the price elasticity in the export equation (already discussed), hence we have tried to re-estimate trade equations in a modified versions to reach the positive relationship between exports and the

Table 4.7: FEER (CNY/unit of f. c.), ECM, VECM, 1981, 1991, 2001, 2010

	ECM	VECM	ECM	VECM	ECM	VECM
Year	−3%		0%		3%	
1981	6.128	17.473	2.147	2.398	1.078	1.127
1991	11.253	92.237	3.133	3.301	1.439	1.472
2001	29.883	23.868	10.874	6.710	5.548	3.535
2010	12.703	12.949	6.738	6.206	4.154	3.859

real effective exchange rate.

4.6 Re-estimation

Due to the disturbing results of the FEER, we have re-calculated trade equations (4.4) and (4.5) applying several adjustments[3]. At first, we added time trends and several sorts of dummy variables. The second modification included the replacement of the world output by the output of Chinese main foreign partners. Further, we estimated the trade equations with the use of the nominal imports and exports. In that case, the oil prices was employed to capture a development of the price level. However, none of these versions did not indicated the positive relationship between exports and the real effective exchange rate.

As the last step, we have decided to model the trade equations using first differences of logarithmed original series:

$$\Delta \ln M_t = \beta_{10} + \beta_{11}\Delta \ln Y_t + \beta_{12}\Delta \ln REER_t + u_{1t} \tag{4.21}$$

$$\Delta \ln X_t = \beta_{20} + \beta_{21}\Delta \ln WY_t + \beta_{22}\Delta \ln REER_t + u_{2t}. \tag{4.22}$$

The estimated coefficients are shown in table 4.8. The real effective exchange rate has finally a positive impact on the exports. The coefficients of other three variables have expected sign just as the original estimates of trade equations.

Since we have used first differences instead of levels, we must also treat the current account equation. We proceed from the following equality:

$$\exp(\Delta \ln M_t) = \exp(\ln M_t - \ln M_{t-1}) = \frac{M_t}{M_{t-1}}. \tag{4.23}$$

[3]The results of these adjustments are not included in the study, but are available upon a request.

Table 4.8: Estimated coefficients, OLS

Imports		Exports	
$cons$	-0.0777	$cons$	-0.0290
	(0.0815)		(0.0344)
$\Delta \ln Y$	2.1341	$\Delta \ln YW$	4.9480
	(0.8072)		(0.9371)
$\Delta \ln REER$	-0.1825	$\Delta \ln REER$	0.2040
	(0.1753)		(0.1144)

Thus, the real imports is defined as:

$$M_t = \exp(\Delta \ln M_t) M_{t-1}. \tag{4.24}$$

The real exports is defined in the same manner. Then the current account equation takes the form:

$$\frac{CA_t}{NY_t} = \frac{DX_t \exp(\beta_{20} + \beta_{21}\Delta \ln WY_t + \beta_{22}\Delta \ln REER_t) X_{t-1}}{NY_t} - \frac{DM_t \exp(\beta_{10} + \beta_{11}\Delta \ln Y_t + \beta_{12}\Delta \ln REER_t) M_{t-1}}{NY_t}. \tag{4.25}$$

The FEER is calculated similarly as in the case of the variables in levels. The values of time series are replaced by their sustainable (equilibrium) values and the current account equals to current account target (CAT):

$$CAT = \frac{\overline{DX_t} \exp(\beta_{20} + \beta_{21}\overline{\Delta \ln WY_t} + \beta_{22}\Delta \ln REER_t)\overline{X_{t-1}}}{\overline{NY_t}} - \frac{\overline{DM_t} \exp(\beta_{10} + \beta_{11}\overline{\Delta \ln Y_t} + \beta_{12}\Delta \ln REER_t)\overline{M_{t-1}}}{\overline{NY_t}}. \tag{4.26}$$

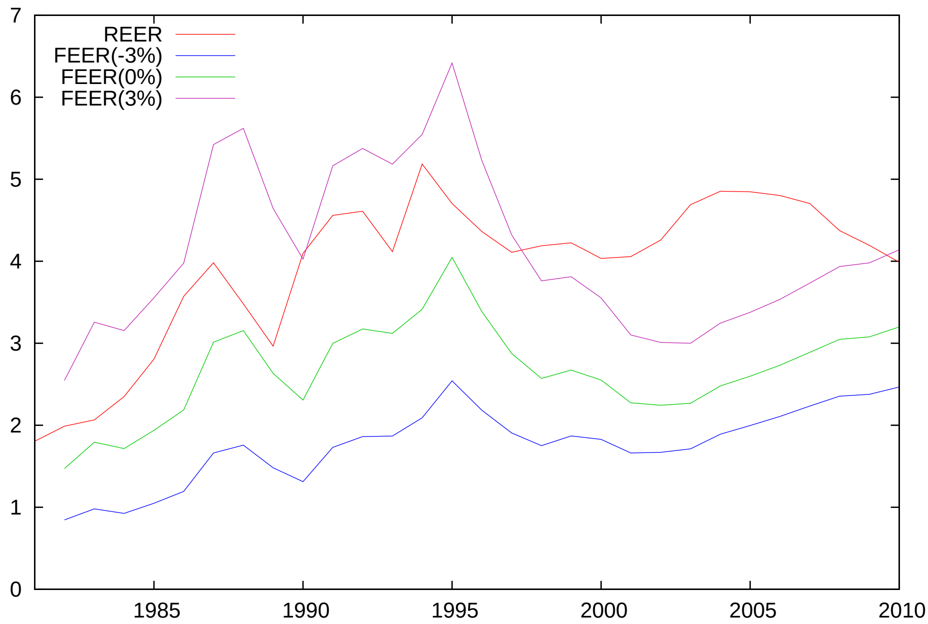
The sustainable values of $\Delta \ln Y$, $\Delta \ln WY$, M and X were obtained again by HP filter (figures A.6, A.7, A.8 and A.9). Using the Newton-Raphson method we compute the equilibrium value of $\Delta \ln REER_t$ ($\overline{\Delta \ln REER_t}$) for a given year. To get the FEER we conduct two last calculations:

$$\overline{\ln REER_t} = \ln REER_{t-1} + \overline{\Delta \ln REER_t} \tag{4.27}$$

$$FEER_t = \exp(\overline{\ln REER_t}) \tag{4.28}$$

As shown in figure 4.2, the results are more acceptable than in the previous

Figure 4.2: FEER (CNY/unit of for. curr.), OLS, 1982 - 2010

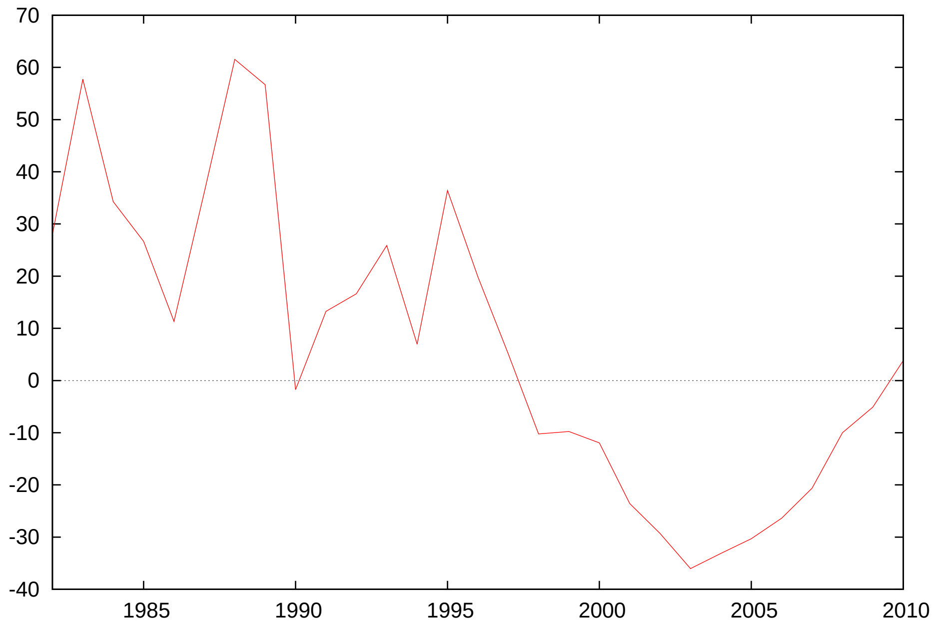


Note: The current account targets are in parenthesis.

case. It is evident that the appreciation (decrease in absolute values) of the renminbi reduces the current account surplus. We further focus on the FEER for the current account target of 3%, which most likely corresponds to Chinese sustainable capital flows. The misalignment (overvaluation and undervaluation) of the renminbi in real trade-weighted terms for this target is depicted in figure 4.3.

Nearly the whole period from 1982 up to 1995, the real effective exchange rate was significantly overvalued. The largest overvaluation, i. e. 61.5%, can be observed in 1988. Over the second half of the 1990s, the real effective exchange rate came closer to the equilibrium value. This findings is in accordance with the discussion in section 2.3.1. Since the beginning of the millenium, the real trade-weighted exchange rate started to be undervalued. During 2001 and 2007, the undervaluation was ranging from 20% up to 36%. As a consequent, the Chinese goods became much more competitive in the international markets, causing the movement of the Chinese current account into large surplus positions. From that reason advanced economies, leading the USA, has urgued China to revalue the currency. Under the pressure, Chinese government allowed the exchange rate to revalue in several small steps since 2005 to 2010.

Figure 4.3: Misalignment of the REER (percent), OLS, 1982 - 2010



Note: + indicates overvaluation, − indicates undervaluation

Our calculations indicate that the real trade-weighted exchange rate should be relatively close to the equilibrium in 2010. This result also corresponds to recent estimates of Chinese current account position. The IMF expects the surplus of only 2.3% of GDP in this year. The PIIE reckons that a surplus or deficit of less than 3% is acceptable. These figures are very close to the value of sustainable capital flows (current account target), thus the renminbi seemed to be really a reasonable approximation of the equilibrium rate.

Chinese authorities has already proclaimed that the renminbi is close to the fair value. Moreover in April of this year, the PBOC widened the renminbi´s daily trading bands against the US dollar to 1% on either side from a fixed midpoint. It is obvious that Chinese currency is approximately 30% stronger than in 2005, when its peg to the dollar was terminated [56]. In general, we can state that the China´s exchange rate regime has moved towards more market-based principles in recent times.

Finally, we provide a comparison of our results with studies showing the renminbi appreciation needed to eliminate undervaluation based on the FEER approach (table 4.9). From all the seven studies, only Wang [63] tries to show that the Chinese real effective exchange rate might be overvalued. The other

Table 4.9: Appreciation needed in the REER (percent)

Study	Year	Range		
Cline [57]	2007	11	to	18
Coudert and Couhard [58]	2002 - 2003	23	to	30
Goldstein [59]	2004	15	to	30
Goldstein and Lardy [60]	2004	20	to	35
Goldstein and Lardy [61]	2007	30	to	55
Jeong and Mazier [62]	2000		29	
Wang [63]	2003	0	to	5
		−5	to	0
Average	All		20	

Note: + indicates appreciation, − indicates depreciation

Table 4.10: Appreciation needed in the REER (percent), OLS, 2000 - 2010

Year		Year		Year	
2000	13.561	2004	49.508	2008	11.119
2001	30.834	2005	43.511	2009	5.383
2002	41.505	2006	35.839	2010	−3.677
2003	56.320	2007	26.012		

Note: + indicates appreciation, − indicates depreciation

studies indicate unanimously the substantial undervaluation. The simple average of the eight estimates of the correction needed in the real effective exchange rate is a 20% appreciation. Table 4.10 shows that we have obtained relatively similar values. In addition, the average of our estimates of the correction needed in the real effective exchange rate during the corresponding period (2000 - 2007) is a 37% appreciation. Hence, the results provided by this thesis are relatively acceptable and plausible. We can conclude that Chinese currency in real trade-weighted terms was significantly undervalued almost the whole last decade.

Chapter 5

Conclusion

In this paper, we have estimated the equilibrium exchange rate of the Chinese currency and its possible misalignment from the equilibrium value. To get a basic view of this issue, we have firstly examined the evolution of the renminbi from its establishment in 1949 up to the present. For most of the existence the renminbi was pegged to the US dollar. During central planned period it was highly overvalued in order to accelerate the industrial development. Since the China lagged behind western economies, the government decided to launch the economic reform in 1978.

Naturally, it has a large impact on the exchange rate regime. The renminbi was placed on dual track system and was gradually devalued until 1994, when it reached historically the lowest value. In that year, the dual exchange rate was terminated and China officially adopted the managed floating system. However, we can state that Chinese authorities still kept the currency closely pegged to the US dollar. During the mid-1990s, the official exchange rate moved closer to the fair value. Since 2002, the value of the US dollar began to fall, causing the real depreciation of the renminbi. By mid-2005, it was undervalued approximately by 23%.

That is the reason why China got under the international pressure to revalue its currency. In 2005, the PBOC announced a reform of the renminbi exchange rate regime. Over the next three years, the renminbi appreciated roughly by 20%. To reduce the negative effects of the global financial crises the nominal exchange rate was again fixed to the US dollar in 2008. By the mid-2010, the PBOC decided to further reform the exchange rate regime and improve its flexibility.

For estimating the equilibrium exchange rate of the Chinese currency we employed the fundamental equilibrium exchange rate (FEER). The calculation of the FEER included the estimation of trade equations, the determination of the Chinese and world output and the judgment on the sustainable current account. We have found out that the renminbi in real trade-weighted terms was really highly overvalued almost the whole period from its existence until 1994. Over the second half of the 1990s, the real effective exchange rate was relatively close to the equilibrium value. At the beginning of new millennium, it started to be undervalued. During 2001 and 2007, the undervaluation was ranging from 20% up to 36%. Our findings were relatively close to the results of another several studies. In 2010, the real trade-weighted exchange rate moved again closer to the equilibrium. This corresponds also with resent estimates of the current account position provided by the IMF and the PIIE.

Although the results of this thesis are relatively acceptable and convincing, we have to admit that we faced some problems. Firstly, we were significantly limited by data availability. Our dataset was only composed of annual observations during 1981 and 2010. It is also a question, whether the data provided by China institutions are reliable. Another problem was related to the estimates of trade equations. The export equation indicated a negative relationship between the real effective exchange rate and the volume of exports. It implied very poor and unconvincing results of the FEER. In general, we can say that the development of the Chinese export and import was not too dependent on the movements of the exchange rate, but it was rather connected to the overall economic growth. To get a better picture between the country´s trade and real effective exchange rate, we re-estimated trade equations using the first differences. In that case the real effective exchange rate had a positive effect on the export and the results of the FEER were much better. We have to also mention the problems regarding a solution of the current account equation. This equation had a non-linear character, therefore small changes in entrance numbers may have caused large differences in results. Since we obtained several sets of coefficients from trade equations, results of the FEER often varied significantly. In some cases, the solution of the equation was not even found.

Finally, we can conclude that we obtained relatively acceptable and plausible FEER estimates of the Chinese currency, but we have to keep in mind that the methodology used is not straightforward and may suffer from many problems.

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Appendix A

Figures

Figure A.1: Trend Chinese GDP

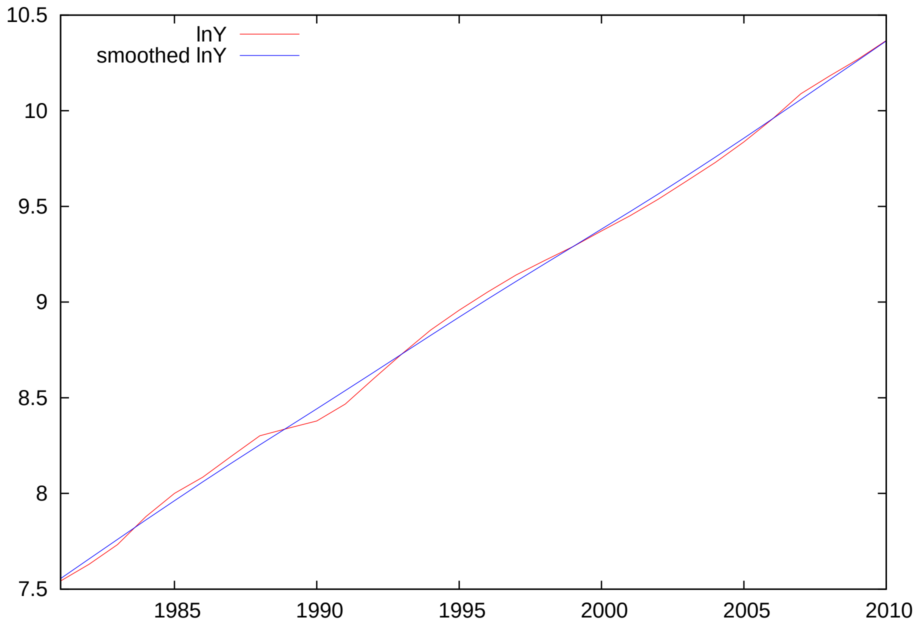


Figure A.2: Trend world GDP

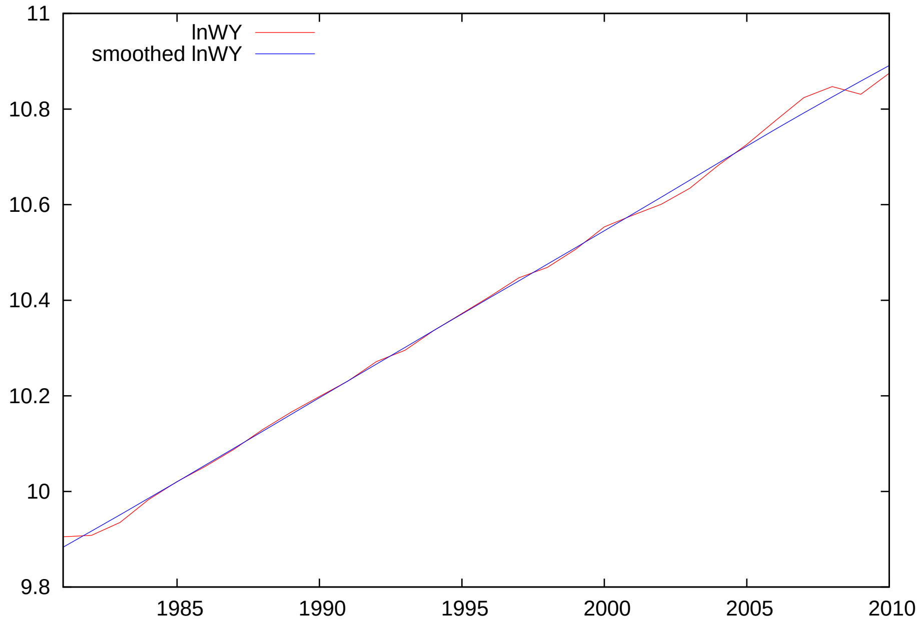


Figure A.3: Trend import deflator

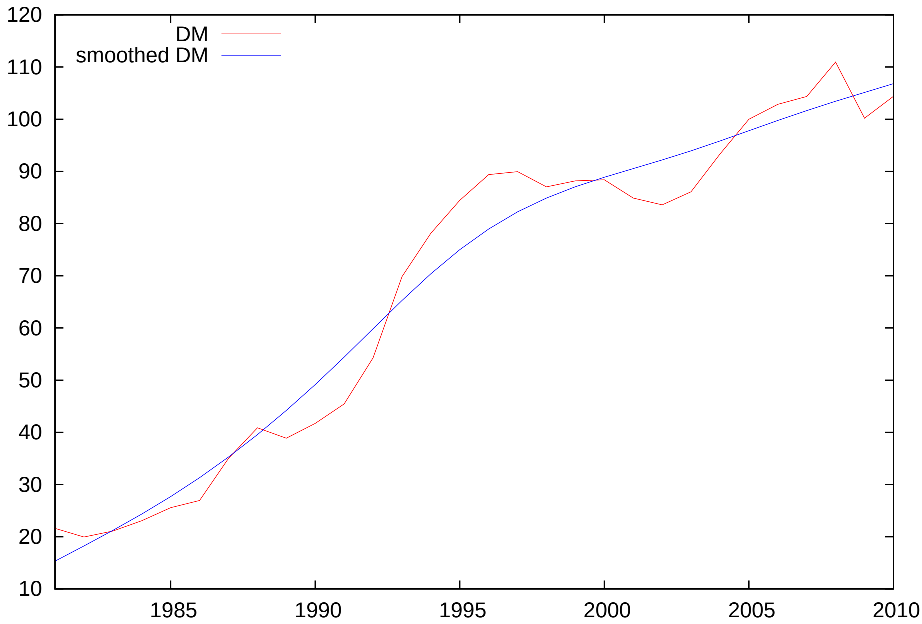


Figure A.4: Trend export deflator

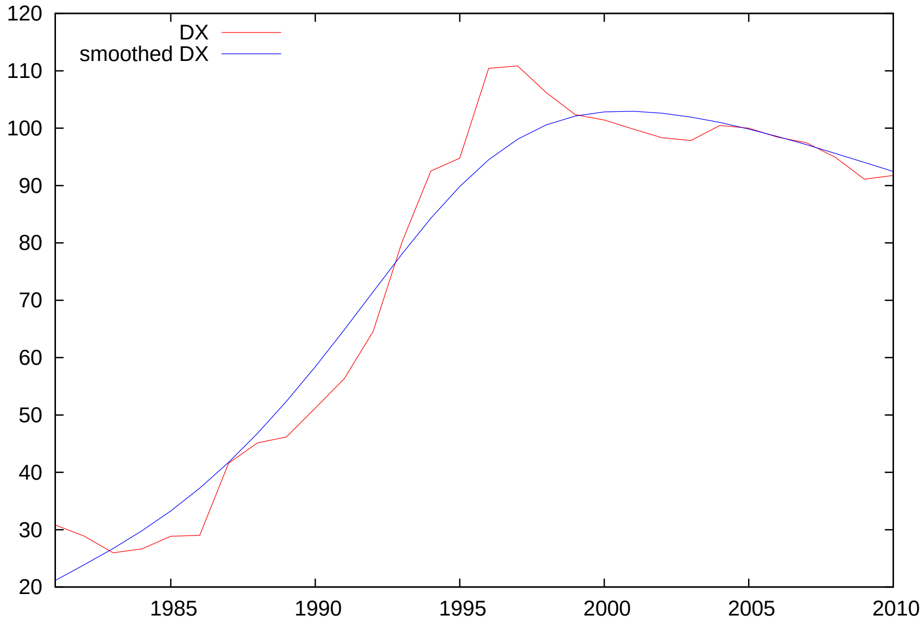


Figure A.5: Trend nominal Chinese GDP

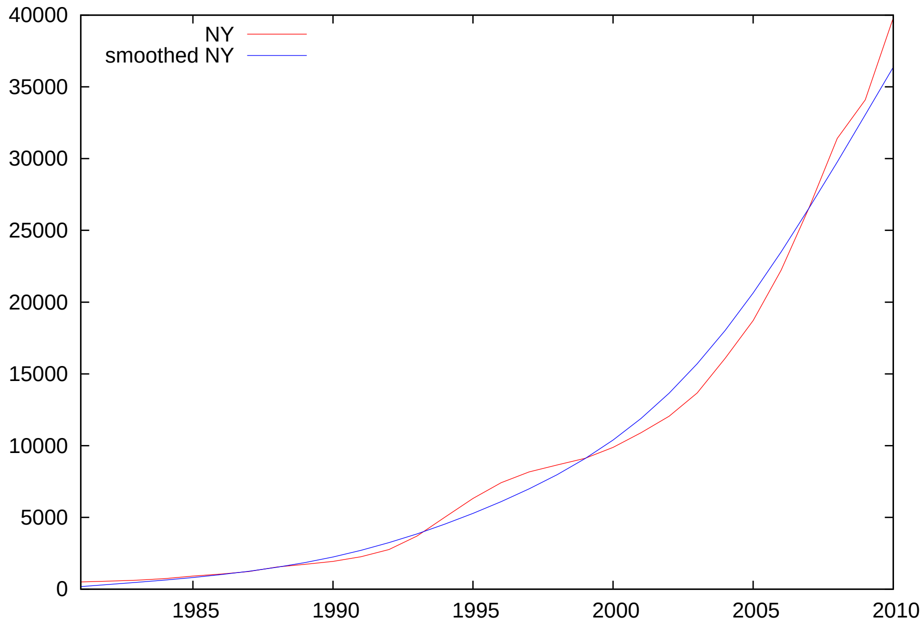


Figure A.6: Trend Chinese GDP, differences

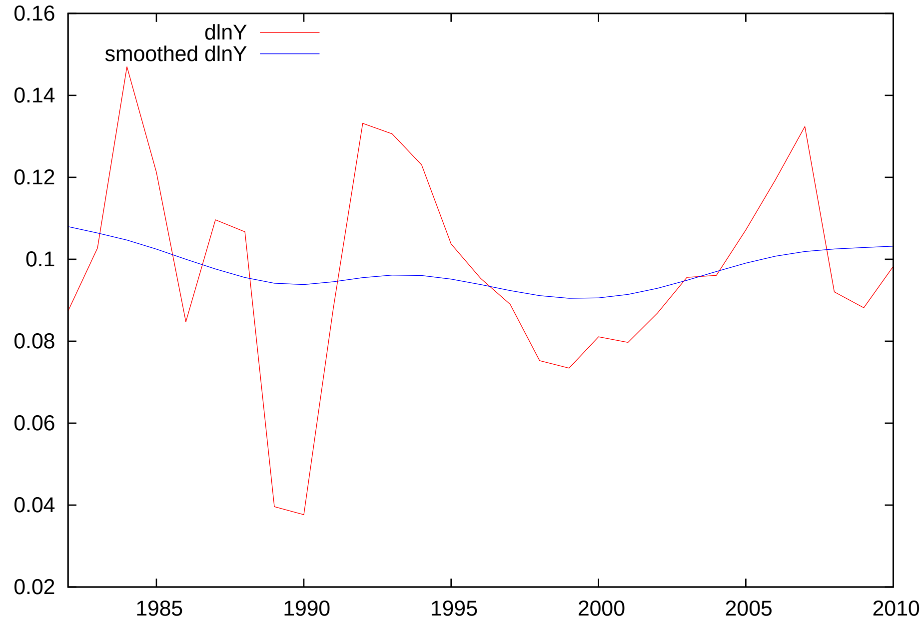


Figure A.7: Trend world GDP, differences

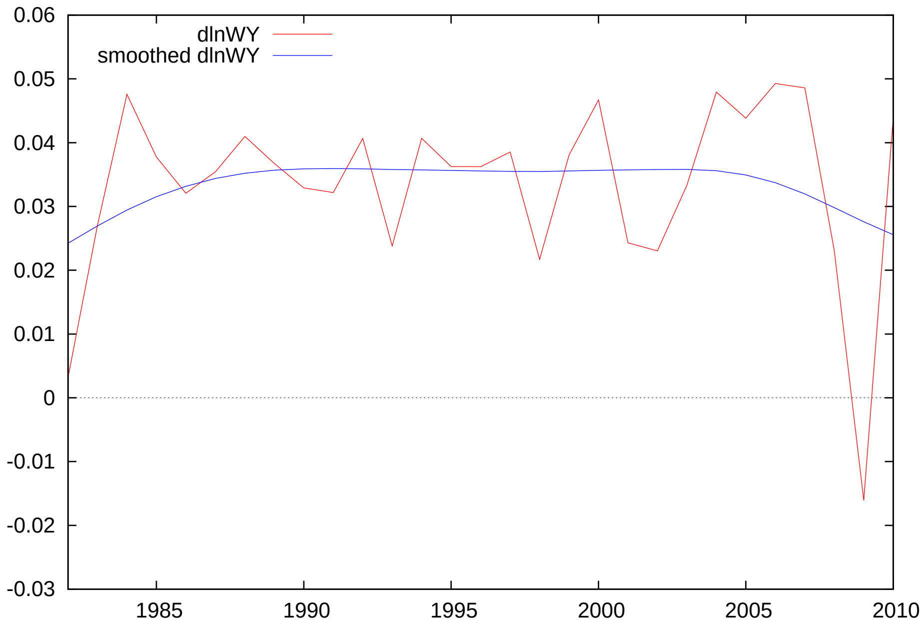


Figure A.8: Trend imports

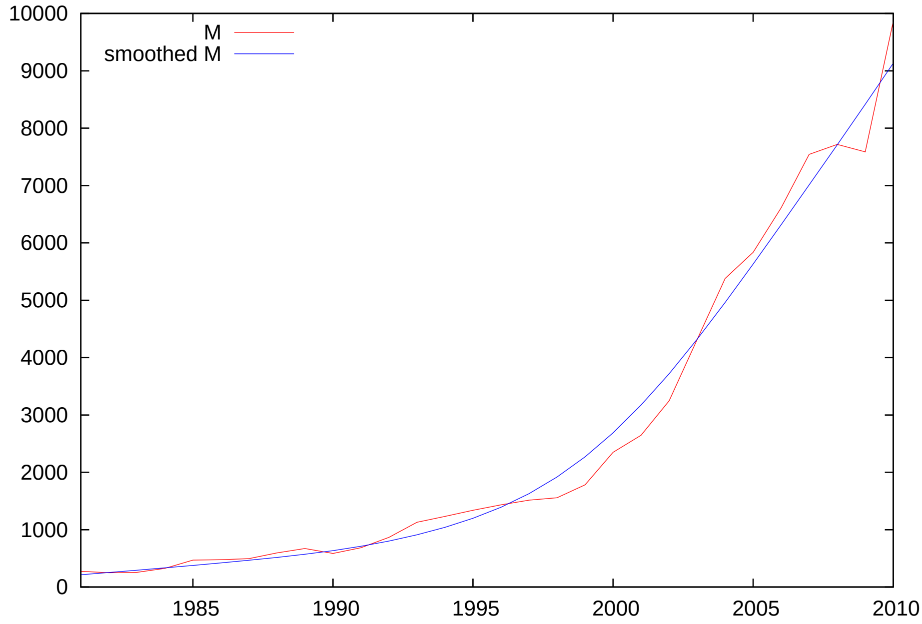
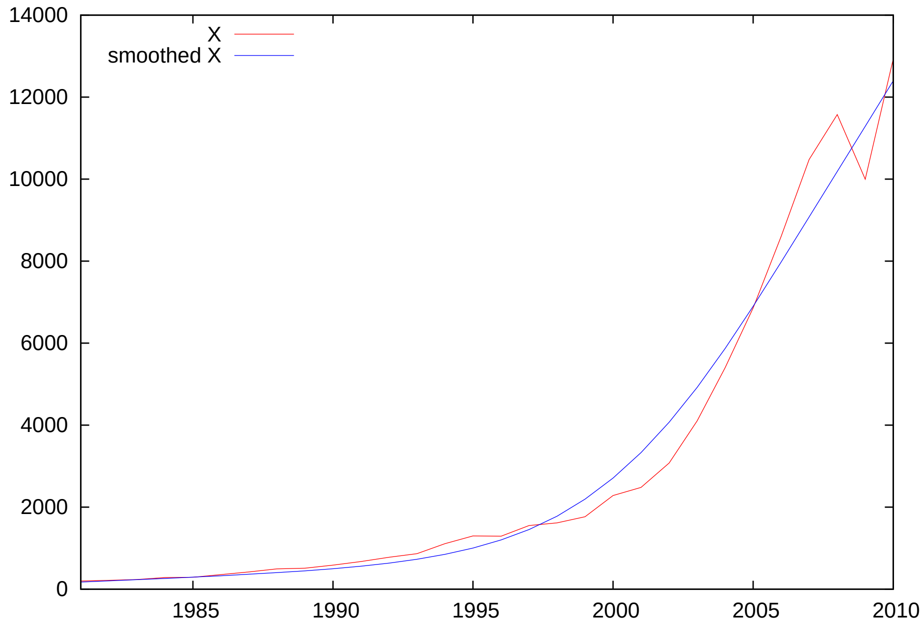


Figure A.9: Trend exports



Appendix B

Tables

Table B.1: Trade weights (percent), 1981 - 2010

Year	USA	EA	JAP	HK	ROK
1981	21.884	16.476	38.655	22.985	0.000
1982	24.470	14.237	35.108	26.185	0.000
1983	16.963	16.497	38.029	28.511	0.000
1984	18.489	13.478	39.722	28.311	0.000
1985	15.791	14.675	44.574	24.960	0.000
1986	14.928	18.278	35.624	31.169	0.000
1987	14.043	16.902	29.420	39.636	0.000
1988	14.254	15.622	27.151	42.973	0.000
1989	15.830	15.335	24.407	44.428	0.000
1990	14.300	14.515	20.259	50.122	0.804
1991	14.118	13.139	20.154	49.365	3.224
1992	14.465	12.391	20.981	47.980	4.183
1993	21.384	16.752	30.272	25.225	6.367
1994	21.725	16.071	29.341	25.686	7.177
1995	21.343	16.484	30.015	23.293	8.865
1996	22.105	15.649	30.949	20.989	10.309
1997	22.337	15.879	27.701	23.140	10.943
1998	25.135	17.846	26.519	20.771	9.728
1999	25.537	18.406	27.478	18.182	10.397
2000	24.770	18.197	27.640	17.929	11.465
2001	24.964	19.374	27.215	17.318	11.129
2002	25.291	18.745	26.502	18.003	11.458
2003	24.518	20.429	25.874	16.931	12.248
2004	24.919	20.730	24.596	16.560	13.194
2005	25.891	21.277	22.504	16.672	13.655
2006	26.617	21.995	20.991	16.809	13.588

2007	25.810	23.682	20.092	16.780	13.636
2008	25.294	25.043	20.188	15.404	14.070
2009	26.205	24.734	20.057	15.327	13.677
2010	25.850	25.143	19.879	15.263	13.864

Source: DOTS

Table B.2: FEER (CNY/unit of for. curr.), ECM, VECM, 1981 - 2010

	ECM	VECM	ECM	VECM	ECM	VECM
Year	−3%		0%		3%	
1981	6.128	17.473	2.147	2.398	1.078	1.127
1982	8.213	NA	1.751	2.222	NA	NA
1983	8.721	NA	1.536	2.127	NA	NA
1984	8.213	NA	1.440	2.097	NA	NA
1985	7.623	NA	1.438	2.127	NA	NA
1986	7.372	NA	1.520	2.214	NA	NA
1987	7.542	NA	1.687	2.354	NA	NA
1988	8.112	NA	1.938	2.544	NA	1.048
1989	9.021	NA	2.273	2.774	1.009	1.174
1990	10.122	NA	2.679	3.032	1.209	1.317
1991	11.253	92.237	3.133	3.301	1.439	1.472
1992	12.334	35.629	3.620	3.574	1.694	1.637
1993	13.417	28.039	4.146	3.855	1.979	1.812
1994	14.632	24.440	4.737	4.154	2.303	2.002
1995	16.085	22.566	5.418	4.478	2.676	2.207
1996	17.873	21.705	6.211	4.832	3.107	2.428
1997	19.983	21.507	7.103	5.210	3.587	2.659
1998	22.390	21.781	8.071	5.602	4.101	2.895
1999	25.014	22.389	9.076	5.997	4.625	3.126
2000	27.638	23.160	10.047	6.375	5.124	3.343
2001	29.883	23.868	10.874	6.710	5.548	3.535
2002	31.323	24.265	11.456	6.978	5.858	3.697
2003	31.626	24.154	11.727	7.165	6.032	3.824
2004	30.666	23.448	11.656	7.261	6.062	3.917
2005	28.535	22.178	11.252	7.261	5.950	3.975
2006	25.537	20.481	10.560	7.167	5.711	3.998
2007	22.070	18.535	9.655	6.989	5.367	3.988
2008	18.563	16.529	8.643	6.748	4.959	3.951
2009	15.382	14.634	7.644	6.476	4.542	3.904
2010	12.703	12.949	6.738	6.206	4.154	3.859

NA - mathematical software did not find a solution for the given current account target.

Table B.3: FEER (CNY/unit of for. curr.), OLS, 1982 - 2010

Year	-3%	0%	3%
1982	0.845	1.471	2.546
1983	0.981	1.794	3.257
1984	0.925	1.715	3.154
1985	1.048	1.938	3.555
1986	1.193	2.187	3.977
1987	1.662	3.013	5.422
1988	1.758	3.155	5.620
1989	1.482	2.633	4.644
1990	1.313	2.307	4.025
1991	1.730	2.999	5.164
1992	1.862	3.173	5.376
1993	1.868	3.120	5.183
1994	2.091	3.414	5.546
1995	2.542	4.048	6.417
1996	2.184	3.386	5.230
1997	1.905	2.874	4.320
1998	1.751	2.570	3.761
1999	1.870	2.673	3.812
2000	1.827	2.551	3.553
2001	1.662	2.272	3.100
2002	1.670	2.244	3.010
2003	1.712	2.268	3.000
2004	1.892	2.480	3.246
2005	1.997	2.599	3.378
2006	2,108	2.732	3.535
2007	2.234	2.890	3.733
2008	2.355	3.046	3.936
2009	2.376	3.078	3.980
2010	2.466	3.198	4.140

Table B.4: Misalignment of the REER (percent), OLS, 1982 - 2010

Year	−3%	0%	3%
1982	−57.526	−26.024	28.008
1983	−52.503	−13.111	57.740
1984	−60.620	−26.992	34.270
1985	−62.659	−30.951	26.669
1986	−66.590	−38.773	11.341
1987	−58.263	−24.329	36.177
1988	−49.475	−9.333	61.530
1989	−50.000	−11.177	56.698
1990	−67.950	−43.693	−1.737
1991	−62.063	−34.243	13.250
1992	−59.610	−31.160	16.627
1993	−54.644	−24.229	25.879
1994	−59.683	−34.165	6.961
1995	−45.966	−13.944	36.430
1996	−49.944	−22.381	19.869
1997	−53.627	−30.045	5.153
1998	−58.201	−38.650	−10.234
1999	−55.741	−36.720	−9.769
2000	−54.707	−36.771	−11.941
2001	−59.026	−43.980	−23.567
2002	−60.784	−47.308	−29.331
2003	−63.500	−51.638	−36.029
2004	−61.023	−48.901	−33.114
2005	−58.801	−46.381	−30.319
2006	−56.105	−43.114	−26.384
2007	−52.514	−38.570	−20.642
2008	−46.154	−30.339	−10.007
2009	−43.340	−26.623	−5.108
2010	−38.163	−19.819	3.817

Note: + indicates overvaluation, − indicates undervaluation

Table B.5: Appreciation needed in the REER (percent), OLS, 1982 - 2010

Year	-3%	0%	3%
1982	135.438	35.180	−21.880
1983	110.540	15.090	−36.605
1984	153.938	36.972	−25.523
1985	167.805	44.825	−21.054
1986	199.315	63.328	−10.186
1987	139.598	32.151	−26.566
1988	97.920	10.294	−38.092
1989	100.002	12.584	−36.183
1990	212.012	77.597	1.768
1991	163.595	52.076	−11.700
1992	147.587	45.264	−14.256
1993	120.477	31.977	−20.559
1994	148.037	51.895	−6.508
1995	85.069	16.203	−26.702
1996	99.778	28.835	−16.575
1997	115.642	42.948	−4.900
1998	139.238	62.998	11.401
1999	125.942	58.027	10.826
2000	120.783	58.155	13.561
2001	144.060	78.508	30.834
2002	155.000	89.782	41.505
2003	173.972	106.775	56.320
2004	156.561	95.700	49.508
2005	142.726	86.502	43.511
2006	127.814	75.790	35.839
2007	110.588	62.786	26.012
2008	85.716	43.553	11.119
2009	76.492	36.282	5.383
2010	61.716	24.718	−3.677

Note: + indicates appreciation, − indicates depreciation

Appendix C

Statement from Statistical Software

Table C.1: ADF test, levels, constant

ADF test, using observations 1981–2010 ($T = 30$) Maximum lag: 10 Unit root null hypothesis: a = 1 Case 2: Constant				
Variable	(a - 1)	τ-statistic	p-value	Lag
l_M	0.0311931	1.68873	0.9997	5
l_X	0.0780551	1.50491	0.9994	9
l_Y	0.000480523	0.0968679	0.9656	4
l_WY	−0.0018505	−0.198485	0.9363	2
l_REER	−0.179127	−2.35326	0.1554	5

Table C.2: ADF test, levels, constant and trend

ADF test, using observations 1981–2010 ($T = 30$)				
Maximum lag: 10				
Unit root null hypothesis: a = 1				
Case 3: constant and trend				
Variable	(a - 1)	τ-statistic	p-value	Lag
l_M	−0.283141	−1.19666	0.9103	5
l_X	−0.438941	−2.69967	0.2367	3
l_Y	−0.604448	−4.59552	0.001001	3
l_WY	−0.981997	−4.73492	0.0005683	1
l_REER	−0.186345	−0.754064	0.9682	5

Table C.3: ADF test, differences, constant

ADF test, using observations 1982–2010 ($T = 29$)				
Maximum lag: 10				
Unit root null hypothesis: a = 1				
Case 2: constant				
Variable	(a - 1)	τ-statistic	p-value	Lag
d_l_M	−1.62301	−4.31814	0.0004081	4
d_l_X	−1.0153	−5.09292	0.0001	1
d_l_Y	−1.63902	−3.32116	0.01399	6
d_l_WY	−1.44457	−5.5773	1.163e−006	1
d_l_REER	−1.50933	−3.34103	0.01318	4

Table C.4: ADF test, differences, constant and trend

ADF test, using observations 1982–2010 ($T = 29$)				
Maximum lag: 10				
Unit root null hypothesis: a = 1				
Case 3: constant and trend				
Variable	(a - 1)	τ-statistic	p-value	Lag
d_l_M	−1.79755	−4.89208	0.0001	4
d_l_X	−4.08724	−2.52479	0.316	8
d_l_Y	−0.826027	−3.68301	0.02341	3
d_l_WY	−1.44101	−5.41699	2.53e−005	1
d_l_REER	−2.21384	−4.23765	0.00386	10

Table C.5: KPSS test, levels, constant

KPSS test, using observations 1981–2010 ($T = 30$)				
Lag truncation parameter: 2				
Hypothesis: stationarity				
Case 1: constant				
Variable	Test statistic	Critical values		
		10%	5%	1%
l_M	1.08209	0.354	0.476	0.711
l_X	1.07921	0.354	0.476	0.711
l_Y	1.097	0.354	0.476	0.711
l_WY	1.09151	0.354	0.476	0.711
l_REER	0.970102	0.354	0.476	0.711

Table C.6: KPSS test, differences, constant

KPSS test, using observations 1982–2010 ($T = 29$)				
Lag truncation parameter: 2				
Hypothesis: stationarity				
Case 1: constant				
Variable	Test statistic	Critical values		
		10%	5%	1%
d_l_M	0.100548	0.354	0.477	0.710
d_l_X	0.168114	0.354	0.477	0.710
d_l_Y	0.0584939	0.354	0.477	0.710
d_l_WY	0.0704094	0.354	0.477	0.710
d_l_REER	0.256878	0.354	0.477	0.710

Table C.7: Co-integration regression, imports

OLS, using observations 1981–2010 ($T = 30$)				
Dependent variable: l_M				
Variable	Coefficient	Std. Error	t-ratio	p-value
const	−5.21888	0.522507	−9.9881	0.0000
l_Y	1.41271	0.0777242	18.1759	0.0000
l_REER	−0.142692	0.178534	−0.7992	0.4311

Mean dependent var	7.282509	S.D. dependent var	1.149388
Sum squared resid	0.537408	S.E. of regression	0.141082
R^2	0.985973	Adjusted R^2	0.984934
$F(2, 27)$	948.9124	P-value(F)	9.64e–26
Log-likelihood	17.76477	Akaike criterion	−29.52955
Schwarz criterion	−25.32595	Hannan–Quinn	−28.18478
$\hat{\rho}$	0.669155	Durbin–Watson	0.569885

Diagnostic test	Test statistic	p-value
RESET test for specification	3.91887	0.0330814
Breusch-Pagan test for homosked.	0.964942	0.617256
White's test for homosked.	9.11884	0.104417
Test for normality of residuals	0.0644757	0.968276

Table C.8: Engle-Granger test, imports

ADF test, using observations 1981–2010 ($T = 30$)				
Maximum lag: 10				
Unit root null hypothesis: a = 1				
Case 1: constant				
Variable	(a - 1)	τ-statistic	p-value	Lag
uhat	−0.30151	−2.42423	0.5236	1

Table C.9: Co-integration regression, exports

OLS, using observations 1981–2010 ($T = 30$)
Dependent variable: l_X

Variable	Coefficient	Std. Error	t-ratio	p-value
const	−40.4562	1.87042	−21.6295	0.0000
l_WY	4.62801	0.195915	23.6225	0.0000
l_REER	−0.341828	0.164661	−2.0759	0.0475

Mean dependent var	7.243753	S.D. dependent var	1.317610
Sum squared resid	0.461881	S.E. of regression	0.130793
R^2	0.990826	Adjusted R^2	0.990146
$F(2, 27)$	1458.050	P-value(F)	3.12e–28
Log-likelihood	20.03652	Akaike criterion	−34.07303
Schwarz criterion	−29.86944	Hannan–Quinn	−32.72827
$\hat{\rho}$	0.748604	Durbin–Watson	0.506171

Diagnostic test	Test statistic	p-value
RESET test for specification	31.1875	1.61031e-007
Breusch-Pagan test for homosked.	1.91242	0.384346
White's test for homosked.	7.08791	0.214184
Test for normality of residuals	5.73485	0.0568451

Table C.10: Engle-Granger test, exports

ADF test, using observations 1981–2010 ($T = 30$)
Maximum lag: 10
Unit root null hypothesis: a = 1
Case 1: constant

Variable	(a - 1)	τ-statistic	p-value	Lag
uhat	−0.444857	−1.21303	0.944	10

Table C.11: VAR lag selection

VAR system, maximum lag order 4
The asterisks below indicate the best (that is, minimized) values
of the respective information criteria, AIC = Akaike criterion,
BIC = Schwarz Bayesian criterion and HQC = Hannan-Quinn criterion.

Lag	loglik	p(LR)	AIC	BIC	HQC
1	258.67252		−17.590194	-16.138544	−17.172171
2	302.87178	0.00000	−19.067060	-16.405702	−18.300685
3	366.53551	0.00000	−22.041193	-18.170127	−20.926466
4	445.88640	0.00000	−26.222031*	-21.141256*	−24.758951*

Table C.12: Johansen test, 0 lag

Johansen test:
Number of equations = 5
Lag order = 0
Estimation period: 1982–2010 (T = 29)
Case 2: Restricted constant

Log-likelihood = 359.357 (including c: 277.058)

Rank	Eigenvalue	Trace test	p-value	Lmax test	p-value
0	0.97561	164.76	[0.0000]	107.70	[0.0000]
1	0.67784	57.060	[0.0249]	32.848	[0.0106]
2	0.30642	24.212	[0.4541]	10.611	[0.7821]
3	0.28371	13.601	[0.3252]	9.6766	[0.3767]
4	0.12657	3.9245	[0.4355]	3.9245	[0.4346]

Table C.13: Johansen test, 1 lag

Johansen test:
Number of equations = 5
Lag order = 1
Estimation period: 1983–2010 (T = 28)
Case 2: Restricted constant

Log-likelihood = 382.747 (including c: 303.287)

Rank	Eigenvalue	Trace test	p-value	Lmax test	p-value
0	0.76872	98.815	[0.0003]	40.995	[0.0056]
1	0.54295	57.820	[0.0209]	21.923	[0.2912]
2	0.44360	35.897	[0.0403]	16.415	[0.2802]
3	0.37571	19.482	[0.0625]	13.192	[0.1293]
4	0.20118	6.2895	[0.1752]	6.2895	[0.1749]

Table C.14: VECM

VECM system, lag order 1
Maximum likelihood estimates, observations 1982–2010 ($T = 29$)
Cointegration rank = 2
Case 2: Restricted constant

Cointegrating vectors (standard errors in parentheses)

l_Y	1.00000	0.000000
	(0.000000)	(0.000000)
l_WY	0.000000	1.00000
	(0.000000)	(0.000000)
l_X	0.161265	−0.364154
	(0.254219)	(0.0381862)
l_M	−0.833547	0.206267
	(0.301932)	(0.0453533)
l_REER	−0.194515	−0.190903
	(0.208369)	(0.0312991)
const	−4.52085	−9.18134
	(0.417940)	(0.0627789)

Table C.15: VECM, linear restrictions

Restriction set
1: b[1,2] = 0
2: b[1,3] = 0
3: b[1,4] = −1
4: b[2,1] = 0
5: b[2,3] = −1
6: b[2,4] = 0
Rank of Jacobian = 16, number of free parameters = 16
Model is fully identified
Based on Jacobian, df = 2
Switching algorithm: 40 iterations
-(T/2)log |Omega| = 467.16128, lldiff = 1.96385e-005
Weak convergence

Unrestricted loglikelihood (lu) = 264.95238
Restricted loglikelihood (lr) = 261.41519
2 * (lu - lr) = 7.07436
P(Chi-square(2) > 7.07436) = 0.0290952

Cointegrating vectors (standard errors in parentheses)

l_Y	1.4598	0.00000
	(0.13481)	(0.00000)
l_WY	0.00000	4.9573
	(0.00000)	(0.25623)
l_X	0.00000	−1.0000
	(0.00000)	(0.00000)
l_M	−1.0000	0.00000
	(0.00000)	(0.00000)
l_REER	−0.13848	−0.58779
	(0.29868)	(0.20901)
const	−6.5788	−44.474
	(0.90994)	(2.4494)

Table C.16: OLS, imports, differences

OLS, using observations 1982–2010 ($T = 29$)
Dependent variable: d_l_M

Variable	Coefficient	Std. Error	t-ratio	p-value
const	−0.0776569	0.0814604	−0.9533	0.3492
d_l_Y	2.13409	0.807175	2.6439	0.0137
d_l_REER	−0.182545	0.175331	−1.0411	0.3074

Mean dependent var	0.123643	S.D. dependent var	0.117592
Sum squared resid	0.294263	S.E. of regression	0.106385
R^2	0.239988	Adjusted R^2	0.181526
$F(2, 26)$	4.104993	P-value(F)	0.028227
Log-likelihood	25.41416	Akaike criterion	−44.82831
Schwarz criterion	−40.72643	Hannan–Quinn	−43.54365
$\hat{\rho}$	0.299969	Durbin–Watson	1.266350

Diagnostic test	Test statistic	p-value
RESET test for specification	0.589959	0.56219
Breusch-Pagan test for homosked.	0.0623908	0.969286
White's test for homosked.	3.28534	0.656087
Test for normality of residuals	1.83209	0.400098

Table C.17: OLS, exports, differences

OLS, using observations 1982–2010 ($T = 29$)				
Dependent variable: d_l_X				
Variable	Coefficient	Std. Error	t-ratio	p-value
const	−0.0289633	0.0343944	−0.8421	0.4074
d_l_WY	4.94797	0.937076	5.2802	0.0000
d_l_REER	0.203972	0.114355	1.7837	0.0862

Mean dependent var	0.143845	S.D. dependent var	0.097758
Sum squared resid	0.124581	S.E. of regression	0.069221
R^2	0.534431	Adjusted R^2	0.498618
$F(2, 26)$	14.92281	P-value(F)	0.000048
Log-likelihood	37.87720	Akaike criterion	−69.75441
Schwarz criterion	−65.65252	Hannan–Quinn	−68.46975
$\hat{\rho}$	0.171815	Durbin–Watson	1.590752

Diagnostic test	Test statistic	p-value
RESET test for specification	0.697866	0.507465
Breusch-Pagan test for homosked.	0.0296903	0.985264
White's test for homosked.	1.67788	0.891675
Test for normality of residuals	1.82227	0.402068