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Alleged Chinese currency manipulation: the case of the Yuan in relation to the USD from 2005 to 2020.

Bachelor's Thesis

Author: Bc. Sander Belon
Study program: Economics and Finance
Supervisor: Vilem Semerak, Ph.D
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Declaration of Authorship

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Prague, August 2, 2022

Sander Belon

Abstract

Currency manipulation has been an increasingly infamous studied topic especially since the US accusation of Chinese currency manipulation in the summer of 2019. Such accusations raise the question as to what extend the Chinese RMB exchange rate might be considered misaligned. This paper seeks to identify grounds of the accusation of currency manipulation by applying the Behavioural Equilibrium Exchange Rate Model (BEER) to indicate possible misalignment. Annual data from 1980 to 2019 is employed for which this paper will emphasize on the period of 2005 to 2019. The utilised Johansen co-integration test and the Vector Error Correction Model (VECM) suggest a consistent undervaluation of the RMB exchange rate from 1980 to 2019. Such undervaluation ranges from -4.623% to -2.016% with a mean undervaluation from 2005 to 2019 of -2.464%.

JEL Classification	F12, F21, F23, H25, H71, H87
Keywords	Behavioural Equilibrium Exchange Rate, Currency Manipulation, Vector Error Correction Model, China, Renminbi
Title	Alleged Chinese currency manipulation: the case of the Yuan in relation to the USD from 2005 to 2020.

Author's e-mail	`sander@belon.be`
Supervisor's e-mail	vilem.semerak@fsv.cuni.cz

Abstrakt

Manipulace s měnou je stále častěji nechvalně známým studovaným tématem, zejména od obvinění USA z manipulace s čínskou měnou v létě 2019. Taková obvinění vyvolávají otázku, do jaké míry lze čínský kurz RMB považovat za chybně nastavený. Tento článek se snaží identifikovat důvody obvinění z manipulace s měnou na základě použití Behaviorálního modelu rovnovážného směnného kurzu (BEER), aby poukázal na možnou misalignment. Jsou použity roční údaje z let 1980 až 2019, pro které je tento práce bude klást důraz na období 2005 až 2019. Použitý Johansenův kointegrační test a vektorový model korekce chyb (VECM) naznačují, že se konzistentní podhodnocení směnného kurzu RMB od roku 1980 do roku 2019. Takové podhodnocení se pohybuje v

rozmezí od -4,623% do -2,016% s průměrným podhodnocením od roku 2005 do roku 2019 ve výši -2,464%.

Klasifikace JEL	F12, F21, F23, H25, H71, H87
Klíèová slova	Behavioural Equilibrium Exchange Rate, Currency Manipulation, Vector Error Correction Model, China, Renminbi
Název práce	Údajné čínské měnové manipulace: případ vztahu Yuanu k USD v období 2005-2020
E-mail autora	sander@belon.be
E-mail vedoucího práce	vilem.semerak@fsv.cuni.cz

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Acronyms

USD United States Dollar

RMB Renminmbi

CNY Chinese Yuan

IMF International Monetary Fund

WTO World Trade Organization

EER Equilibrium Exchange Rate

BEER Behavioural Equilibrium Exchange Rate

REER Real Effective Exchange Rate

PRC People's Republic of China

PBOC People's Bank of China

GFC Global Financial Crisis

CFETS China Foreign Exchange Trade System

IEB Internal-External Balance

PPP Purchasing Power Parity

PEERs Permanent and Transitory Decomposition of Real Exchange Rate

CHEERs Capital Enhanced Measures of the Equilibrium Exchange Rate

FEER Fundamental Equilibrium Exchange Rate

NATREX Natural Real Exchange Rate

GDPC Gross Domestic Product per worker

FINVEST Gross fixed capital formation

GCON Government Consumption

OPEN Degree of openness

TOT Terms of Trade

RES Reserves

PWT Penn World Tables

ADF Augmented Dickey-Fulle

VAR Vector Autoregressive

VECM Vector Error Correction Model

ECT Error Correction Term

Bachelor's Thesis Proposal

Author	Bc. Sander Belon
Supervisor	prof. Ing. Vilem Semerak, Ph.D.
Proposed topic	Alleged Chinese currency manipulation: the case of the Yuan in relation to the USD from 2005 to 2020.

Motivation The main research question which will be addressed in this paper will concern the detailed analysis of currency manipulation in relation to the United States and the People's Republic of China.

The origin of the topic of this paper can be traced back to 1994 when China pegged its currency (Yuan) to the USD. It is thought that currently 2/3s of all countries in the world manipulate their exchange rates in such a way for which they stabilise it relative to the USD according to Hassan et al (2019). Nevertheless, in 2005 China decided to reform their exchange rate regime to a managed float from which the Yuan was allowed to fluctuate to a greater extent in comparison with the USD. Due to the further implementation and adaptation of what are thought to be "questionable" monetary policies by the People's Republic of China, many economists and public figures believe they directly harm the sustainable economic growth as well as the employment rate in developed economic areas such as the US and the Euro Area as Gagnon (2012) claims in his article.

Ever since the People's Republic of China relieved its monetary policy of pegging its currency, the Yuan (also known as the Renminbi) to the USD, there have been numerous disputes for which many widely recognized and respected public figures such as the previous US president Barack Obama, accused China publicly of currency manipulation (Cline, 2017). Many economists jumped on the accusations and researched the extent to which China was indeed manipulating its currency or not. Up until today it is still a widely discussed phenomenon for which no concrete conclusion has been drawn.

Nevertheless, the concept of currency manipulation has been widely studied from which many conclusions have been drawn. The basic concept of currency manipulation is to undervalue the domestic currency in such a way from which the domestic prices remain relatively low to enhance exports. A study conducted by Rodrik (2008) suggests that undervaluation of the currency has a seemingly positive effect on the increasing growth of the economy. The phenomenon of currency manipulation has also been widely studied from a legal perspective from which often the legal restrictions or sanctions imposed by responsible organisations such as the IMF and the WTO are lacking as Staiger et al (2010) argued in this research.

Methodology For the methodology of finding the overvaluation or undervaluation of the Chinese currency this paper will mostly utilise Dani Rodrik's (2008) methodology which he used in his own research for which he studied how undervaluation of a currency stimulates economic growth. Rodrik based his calculation on the research of Johnson et al (2007) and therefore their methodologies will be taken into consideration too. Particularly to calculate the overvaluation or undervaluation Rodrik subtracts the calculated real exchange rate by the so-called Balassa-Samuelson-adjusted rate. For this method the real exchange rate is calculated from the data given by the Penn World tables which this paper will intent to utilise too. Further the Balassa-Samuelson-adjusted rate is an effect obtained by the usage of several constants for which the essential result indicates that for example when the overall income rises by 10% the real exchange rate is estimated to naturally decline by 2.4%. Further, the research of this paper will also utilise the methodology proposed by Yahia et al (2013) from which they identified 4 main methods of foreign currency exchange rate undervaluation. These 4 methods include: equilibrium exchange rate over a relatively longer time periods, the role of PPP, the normal rate of exchange and finally is the so-called premium on the parallel exchange market. Another consideration to be made is the discussion of the sensitivity of the Chinese economy to exchange rate changes or shocks. The necessary elasticity will be based on the study conducted by Thorbecke et al (2020). Ultimately the results will then be compared to form a well-founded observation on the possible identification of currency manipulation.

Expected Contribution The research conducted in this paper aids to further illustrate the widely discussed topic of alleged Chinese currency manipulation. This paper intends to clarify to what extent the Chinese currency is undervalued or overvalued in different periods of time in relation with the USD. The time specification utilised in this paper will be from 2005 to 2020. This is due to the reason that in 2005, China changed its currency exchange rate regime to a managed floating exchange rate regime from being pegged to the USD before. Furthermore, this paper

will be studying the years up until 2020 as the US treasury department reportedly labelled China as a currency manipulator in 2019 which was widely considered to be a controversial act. The US-China currency manipulation topic has been widely discussed from mostly a legal point of view as well as studies of requirements and guidelines for being identified as a currency manipulator. Most commonly, these papers struggle to form a well-found objective model since the elements studied are often relative to one another as well as highly sensitive as they allow to be perceived in different ways. However, one of the most important and fundamental elements in the debate of identifying a currency manipulator is the degree of under- or over-valuation of the relative currency. Therefore, this study will add to the debate of possible Chinese currency manipulation through focussing specifically on the evaluation of the possible under- or overvaluation of the Chinese Yuan in relation to the USD over the specified time frame. In addition, further discussion will be applied from the utilisation of the exchange rate elasticity as this will showcase the sensitivity of the Chinese economy to exchange rate changes or shocks. This will be crucial for further discussion as well as the possible application of the results. By further studying the matter in this specified time-period, the results can be detrimental in the further discussion on whether one can accuse China of currency manipulation or not. Therefore, this paper does not argue on whether China deliberately manipulated its currency or not, but rather on the concept of whether there is a ground for which China can potentially be accused to such an extent through the potential great degree of undervaluation of its currency.

Outline

1. Abstract Introduction a. Brief overview of historical events leading up to the topic of currency manipulation b. Explaining the concept of currency manipulation c. The linkage with the China-US currency exchange rate conflict d. Short overview of conclusions drawn by other studies on the matter e. What my research will add f. The outline and organisation of the thesis Literature review and hypothesis a. Exploring existing pieces of research and its adoptability on the China-US currency exchange rate conflict b. The evidence of why the undervaluation or overvaluation of the Yuan is important in the discussion around currency manipulation c. The hypothesis explored in this paper d. The reasoning of the hypothesis and possible application and or usefulness Methodology a. Describing the data used b. Discussing the dependent and independent variables c. Showcasing the application of the methodologies Results a. Discussing the results in relation to the hypothesis b. Discuss potential differences in results from different methodologies c. Interpret the results and the explanation of what they could mean Conclusion a. Overview

of key results b. Discuss the potential implications of the research conducted c. The potential future application of the key results

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Author

Supervisor

Chapter 1

Introduction

Over the past few decades, both the Political as well as the Economic relationship between the United States and China has been at the center of numerous studies. This can be traced back to the incredible rise of China as an economic powerhouse to the extent where both China and the US make up the 2 largest economies in the world based on relative annual output according to the article by White (2021). Furthermore, the total trade value between both countries of goods and services counted a considerable 615.2 billion USD in 2020 according to the Office of the United States Trade Representative, Koopman *et al.* (2020). Due to the incredible rise of relative output of the Chinese economy and simultaneous decrease in US manufacturing employment, many economists and US officials have been studying the Currency Exchange Rate Regime of China to the extent where US officials labeled China as a Currency Manipulator in the summer of 2019, U.S. Treasury Department (2019). This allegation was found on the basis of the report to congress named, Macroeconomic and Foreign Exchange Policies of Major Trading Partners of the United States. Currency manipulation is a widely discussed policy for which the domestic government deliberately weakens their currency, hoping to increase exports and ultimately increase their trade surplus, Nouira *et al.* (2011). Currency manipulation is an infamous topic among economists as the jurisdictional boundaries are still being explored by institutions such as the WTO and IMF , Sanford (2011), Vinh *et al.* (2011). Such allocations of currency manipulation, hence, have the potential to impact the trade between both countries as well as the future developments of the currencies in question, namely the Renminmbi (RMB) as well as the US dollar (USD). Furthermore, both currencies but in particular the USD are fundamental currencies in global trade as about 59.43% of the

foreign exchange reserves are kept in USD and roughly 2.50% in the Chinese RMB, as reported by Arslanalp *et al.* (2022). Therefore one can imagine that any fluctuations of the currency exchange rate of both the USD and RMB can have significant impact on not only trade between the US and China but Global trade entirely.

The objective of this thesis is not to prove or disprove whether China participated in Currency Manipulation or not, but rather to further investigate the grounds for accusation based on potential under or overvaluation. In particular, this thesis will attempt to calculate the Chinese Equilibrium Exchange rate which will ultimately be compared with the reported exchange rates for which possible under or overvaluations will be identified. Based on given calculations one can interpret the extend to which China might or might not participate in currency manipulation. Before calculating the Equilibrium Exchange Rate (EER), a brief historical background will be provided of the Chinese exchange rate regime. In this section, a variety of topics and changes to the exchange rate regime will be touched upon as of 1980. From 1980 up until 2019 the different policies and approaches will be discussed for which potential links will be made with the estimated exchange rate misalignment. To identify such manipulation, the EER will be studied and analysed. The EER is a long-run equilibrium of what the exchange rate of the RMB in this case might be. The calculation of such a phenomenon depends on various factors. A number of models exist and have been applied in the past to come to such an equilibrium. These models were widely introduced in the 1990s by numerous economists. Over time, many variables were studied in relation to the EER as well as many different econometric models. Each one of these can have a different impact on the potential misalignment and therefore many different results have been reported in the past. Some argued that the RMB was overvalued and others undervalued due to the different approaches adopted by the given researchers. In this particular study, the Behavioural Equilibrium Exchange Rate (BEER) methodology will be utilised to come to an estimation of the RMB misalignment. The BEER model will be based on the Real Effective Exchange Rate (REER) provided by the IMF as the dependent variable from which a number of independent variables will be further analysed and compared. This analysis will be conducted through a number of Econometric techniques which this thesis will mostly focus on. Due to the nature of the EER, it is crucial for the thesis to establish a clear conduct and methodology for calculating possible

misalignment. Ultimately, the estimated exchange rate misalignment will be discussed and compared from which a possible conclusion can be drawn.

The structuring of the thesis will be organised in the following matter: Firstly, the Chinese Exchange Rate Regimes will be studied and analysed in Chapter 2 in great detail for historical context and potential application to describe the EER trends of the RMB. Furthermore, different models for calculating the EER will be discussed as well as their applications in Chapter 3. In Chapter 4, the data selection will be discussed for the independent and dependent variables. Then, the econometric methodology will be discussed in Chapter 5 and the discussion of the results will follow in Chapter 6. Finally, this thesis will conclude in Chapter 7.

Chapter 2

Development of the Chinese exchange rate regime

2.1 Foundation

Before analysing the currency exchange rate regime of China in the desired time frame, previous regimes have to be analysed to understand the bigger picture. In 1949, the People's Republic of China (PRC) was founded. It is important to note for further analysis that the "renminmbi" (RMB) is the legal currency of China. However, the "yuan" (CNY) is the unit of account. When the PRC was founded, they were experiencing a monetary crisis due to hyperinflation caused by the previous regime. Due to these circumstances, the new governing body took action by issuing the first series of RMB in 1948, 1 year before the foundation of the PRC. Throughout the years, various series of the RMB were introduced and issued. Despite the implication of the RMB, the PRC was still faced with increasing inflation rates for which an economic reform took place. As of the introduction of the currency up until 1955, no stable peg exchange was found as constant intervention was necessary. As of 1995, the RMB had a fixed exchange rate of 2.4618 yuan to 1 USD for 16 years. After the Bretton Wood System broke down in 1971, China decided to peg their currency to a basket of currencies. This basket included the USD, the British Pound, Japanese Yen, Swiss Frank and more. In 1979, China settled the exchange rate at 1.49 Yuan/USD for which the currency exchange rate was still based on a basket of currencies. The key takeaway from 1979 was that exporters could now hold foreign exchange quotas. Furthermore, this means that the exporters can hold onto a share of the foreign exchange rate earnings. This concludes the

period before the reform era. After this event, exchange rate regimes will be more aligned with the research in this thesis as the data studied will be from 1980 and on wards. Please refer to figure (2.1) for the further analysis of the RMB exchange rate. The data of figure (2.1) was retrieved from the Federal Reserve (2022).

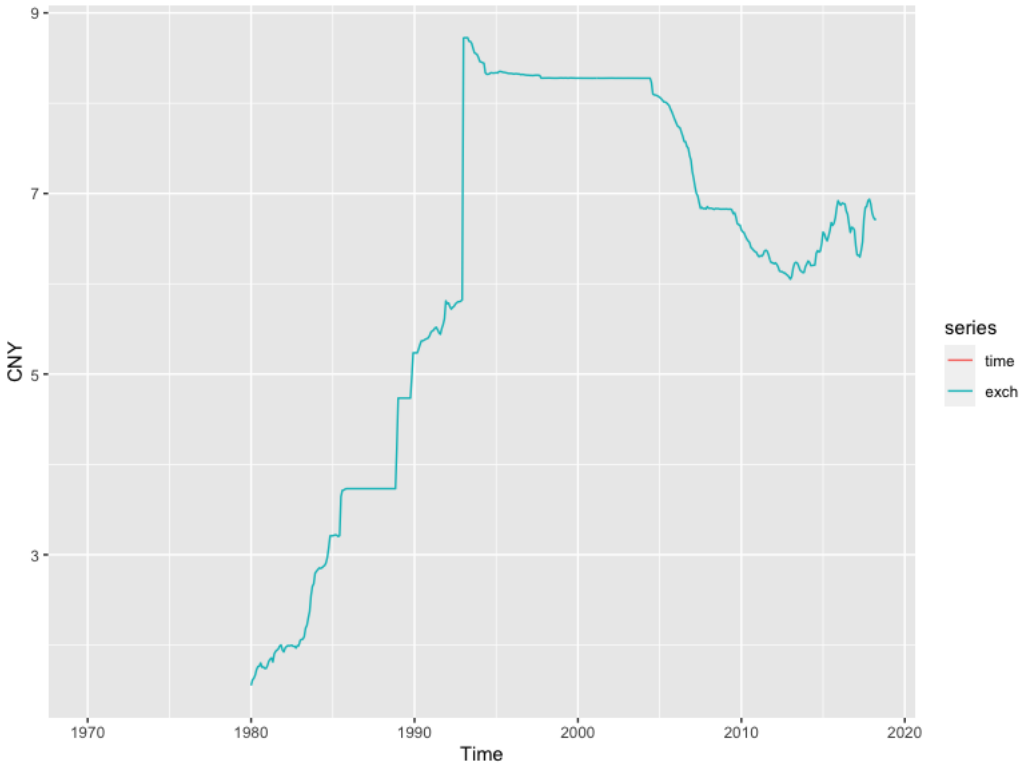

Figure 2.1: Historical USD/CNY Exchange Rate

In 1981, a new system was introduced by the name of a multiple exchange rate. In this case the exchange rate was still officially pegged to the USD at 1.55 Yuan/USD. However these counted only for transactions which did not include trade. Trade transactions had a different exchange rate dependent on the amount of USD could be earned per RMB production cost. Therefore, one could argue that a more flexible and diverse system was implemented but possibly also less transparent. Nevertheless, this seemingly had a devaluing effect on the currency as in 1984 the exchange rate gradually changed to 2.8 yuan/USD. This could possibly be explained by the nature of the multiple exchange rate regime. When lowering the exchange rate of certain import goods, the domestic production of such goods naturally will gain less sales. Another

common argument is that of black marketing. Such activity might take place when goods are imported at a favourable rate and then again exported at once again a favourable rate. Therefore profits were made based on the assigned exchange rate regimes. The year after in 1985, Chinese authorities abandoned the idea of a multiple exchange rate system as they implemented a dual exchange rate regime. This included an official exchange rate which was set at 2.8 yuan/USD and the concept of a swap exchange rate. A swap rate is a fixed rate dependent on demand and supply where mostly companies could trade with foreign companies using a swap center. These swap rates were generally much lower then the official exchange rate due to the demand of USD in Chinese trade. Nevertheless, it is important to note that the Chinese authorities were still responsible for setting the given swap rates causing the legislative body to still have most control over the exchange rate. Due to the increasingly high demand of swap rates, the dual exchange rate system took a blow as by 1993 the official exchange rate stood at 5.8 yuan/USD whereas the swap rate stood at 8.7 yuan/USD, notably much higher. This was not meant to be as the swap rates were intended for domestic businesses to enjoy a more beneficial exchange rate causing the Chinese trade balance would be impacted positively. In 1994, the Chinese authorities were forced to intervene and decided to merge both the official exchange rates as well as the swap rates to ultimately set one official exchange rate to 8.7 yuan/USD. This intervention turned out to be of great success. From hindsight, it was a good intervention as in 1994 80% of all the exchange rate transactions could be traced to the swap rate market and therefore the transition from a dual exchange rate regime to a managed floating regime went smoothly. Moreover the managed floating exchange rate regime proved to be successfully over time as the exchange rate stood at 8.28 yuan per USD by 1997. Additionally this managed floating regime allowed China to claim to have adopted an exchange rate regime dependent on demand and supply. Nevertheless, in 1997, the Asian Financial Crisis took place for which China anticipated a great deal of devaluation. This event therefore suddenly changed their regime to a pegged exchange rate to the USD. This drastic change naturally was initiated with the intention of avoiding any potential devaluation. Nevertheless, one must note that the preferred option was still the managed floating regime. Therefore, initially the Chinese authorities intended to change back to the managed floating regime as soon as the Asian Financial Crisis calmed down and therefore when the external pressure of devaluation of the RMB was elevated. However, this was never changed back to the managed

floating regime due to domestic instability of exporting businesses until 2005.

In 2005, it was decided by the People's Bank Of China to abandon the pegged system and once again adopt the managed floating regime, Cui (2014). This time a recalculation was conducted causing the original 8.28 yuan/USD to be merely changed to the new exchange rate of 8.11 yuan/USD. In this regime the exchange rate was dependent once again on a basket of currencies and was also market based. However the People's Bank Of China (PBOC) did mention that the exchange rate is allowed to fluctuate a maximum amount of 0.3$ per day. Due to this implementation, the new instigated exchange rate regime is neither pegged to a currency basked nor is it free floating. By adopting such a regime it allowed the PBOC to have enough of a margin to potentially manipulate their currency as they like. This is thus an important detail moving forward with the research conducted during this thesis. The period of 2006 until 2008 was hence, classified to be a crawling peg. In 2008 another crisis influenced the Chinese exchange rate regime. This time, it is the Global Financial Crisis (GFC). The GFC motivated China to once again change their currency exchange rate to a pegged regime to the USD from 2008. This peg was held until 2010 and described as a "stabilized arrangement" by the IMF as illustrated by Habermeier *et al.* (2009). Following the stabilized arrangement the so called "crawl-like arrangement" was implemented. This is a market based arrangement where the exchange rate must remain within a margin of 2% of a statistical trend. It is important to note that this is not a free floating regime but a crawl-like arrangement. The margin was enlarged and shortened multiple times over the period of initiation until 2014. In 2015, the PBOC introduced the infamous '8.11' regime which was based on daily central parity quote as well as the closing rate of the previous day plus a margin of roughly 2%. However, this regime was only active for about 3 days as it proved largely unsuccessfully by reaching a 3% inflation in only 2 days. Therefore shortly after, China changed their regime to another variation of the floating regime based on market trends as well as central parity quotes. Also, in 2016, China adopted the central parity rate-setting rule. This is also known for the CFETS basket as mentioned by Das *et al.* (2019). Additionally, in this period, China implemented a basket based on the CFETS which is also known as the China Foreign Exchange Trade System. In particular this is an index of a basket based on the weights of internatinal trade by the given countries. Moreover, in general, China focuses mostly on the CFETS, but also the BIS and SDR basket to determine the exchange rate.

In 2017 a Counter Cyclical Adjustment Factor (CCAF) was introduced as an addition to the CFET RMB Index. This addition was developed in order to "reduce 'irrational' depreciation expectations and 'pro-cyclical' herding behavior" as was described by Das *et al.* (2019). This component however was not explained as many banks used different methodologies to calculate the CCAF and hence one ought to question the validity of scuh a component as well as its effectiveness. This cyclical component was then made neutral in 2018 as it was deemed no longer needed. Finally, in 2018, China was considered to be taking steps to implement a floating currency exchange rate regime but despite such intentions, China was faced with great depreciation as well as indications of a recession for which no further action swere undertaken in order to accomplish a floating exchange rate regime.

For further discussion, it is important to note that from 1980 to 1994 the convertibility of RMB capital account was rather limited. The Chinese authorities set particularly high exchange rates in relation with other currencies for which limited conversions were made. After the implementation of swap centers in accordance with the implementation of the managed floating regime. From 1994 until 2005 in relation with the second implementation of the managed floating system for which the RMB was able to appreciate in comparison with the USD. In 2013 the RMB reportedly became convertible in current accounts as was mentioned by Yongding (2014). However, the Renminbi was not yet convertible in capital accounts. China aims for the RMB to be fully convertible which was aided by the announcement in 2016 by the IMF to include the Chinese Yuan into the SDR basket and therefore recognising the Chinese Yuan as a world currency.

Chapter 3

Models for calculating the equilibrium exchange rate

Calculating the EER is a widely discussed phenomenon as there are a variety of approaches for which different results can be expected. Choosing a particular model depends on a variety of factors such as data availability, the selected time horizon, Econometric applicability and the functionality of the model. Historically, the main approaches are the BEER and Internal-External Balance (IEB) as is showcased in the literature review conducted by Cline & Williamson (2007). However, many more exist. Most researches, including this one, utilises the models introduced and analysed by Macdonald (2000). Moreover, these models include the Equilibrium Under Floating Rates, Purchasing Power Parity (PPP), Capital Enhanced Measures of the Equilibrium Exchange Rate (CHEERs), Behavioural Equilibrium Exchange Rate (BEERs), Permanent and Transitory Decomposition of Real Exchange Rate (PEERs) and the Internal-External Balance (IEB) Approach. All these approaches/models can be applied and further studied to obtain an EER. For the purpose of this study the 2 most common approaches will be analysed, namely the BEER and IEB approach. In more detail the Fundamental Equilibrium Exchange Rate (FEER) which can be categorised under the IEB approach and the BEER model will be compared. Over the course of the last 20 years these 2 models were the most commonly used. It is important to note that other models were too popularly utilised such as the Natural Real Exchange Rate (NATREX) was also commonly used but for the purpose of this thesis only the BEER and FEER will be compared. Note that the descriptive functions in the analysis will be mostly adopted from MacDonald & Clark (1998).

3.1 The FEER model

The FEER model was originally developed by Williamson (1994). As mentioned before the FEER approach can be categorised under the IEB approach. This means that the FEER model bases its calculations on the macroeconomic balances which naturally include both an internal and external perspective. The internal balance can be observed as the output of a country, given low inflation rates and under full employment. The external balance is the equilibrium of net flow of resources represented as the sustainable current account. To calculate the FEER, given these conditions it usually tends to focus on 'fundamentals'. 'Fundamentals' are introduced by MacDonald & Clark (1998) to be the variables thought to have an effect on the medium-run EER for which the undesirable short-term variables are omitted. This is due to the reason that the FEER approach is meant to study the medium-term relationships which roughly means 5 years in economic terms. Due to the nature of the study, it is often argued to be normative and for it to assume an ideal economy. Furthermore the external balance approach can be identified as the following formula:

$$CA = -KA \tag{3.1}$$

Where CA denotes Current Account and KA denotes Capital Account. The FEER model is hence focusing for the most part on the factors influencing the current account rather then focusing on behavioral indications such as in the BEER model. The current account in relation to the FEER model is therefore usually explained through the following function:

$$CA = b_0 + b_1 q + b_2 \bar{y}_d + b_3 \bar{y}_f = -\bar{KA} \tag{3.2}$$

Where $b_1 < 0, b_2 < 0 and b_3 > 0$
y_d = domestic aggregate output,
y_f = foreign aggregate output,
q = real effective exchange rate,
$\bar{KA}$= equilibriium capital account,

From this function we can interpret that the current account is determined by the real effective exchange rate as well as the domestic and foreign aggregate output. From this equation we can ultimately determine, q, the real effective exchange rate by transforming equation (3.2) as a function of capital account

under the assumption of full employment.

$$FEER = (-\bar{KA} - b_0 - b_2\bar{y}_d - b_3\bar{y}_f)/b_1 \tag{3.3}$$

By this formula, it can be retrieved that equation (3.3) showcases the medium run equilibrium of the real exchange rate.

3.2 The BEER model

The BEER model was originally introduced in the late 1990s by MacDonald & Clark (1998) in a set of concepts to calculate the Equilibrium Exchange Rate. As illustrated above the BEER model estimates the effect and relationships of particular variables on the EER in the long-run. The BEER model used in this thesis can be identified as a so called "reduced-form equation" in accordance with their associated longitudinal effects. Namely, distinguishments are made between the long-term, medium-term and short-term effects. These differences are resembled by 3 different vectors in the econometric model displayed in equation (3.4). Moreover, by studying such vectors as a part of the econometric model, the behaviour of the real effective exchange rate can be analyzed accordingly.

$$q_t = \beta_t' Z_{1t} + \beta_2' Z_{2t} + \tau' T_t + \epsilon_t \tag{3.4}$$

Where:
Z_1= Economic fundamentals in the form of a vector which have long term effects,
Z_2= Economic fundamentals in the form of a vector which have medium term effects,
β_1, β_2, τ= Coefficient vectors,
T= Transitory elements in the form of a vector which have short term effects,
ϵ_t= a random disturbance term.

According to this function, one can thus estimate the real effective exchange rate using economic fundamentals and transitory elements for the long-term, medium-term and short-term. Such categorisation of variables helps us to understand the potential effect that variable might have on the real effective exchange rate. For example the economic fundamentals in the medium-term

help to explain for business cycle-type patterns. Therefore categorising these variables by the duration of the effect gives us a better understanding of the nature of the variables used in accordance to the data frame. Now to find an estimation of the current misalignment one must first note that there is a difference between the current equilibrium exchange rate value and the actual real exchange rate value. The current equilibrium rate can be denoted by q', and represented by the following formula:

$$q'_t = \beta'_1 Z_{1t} + \beta'_2 Z_{2t} \tag{3.5}$$

Note that q' does not take into consideration the transitory elements as in equation (3.4). Since we have now established q', we can define the current misalignment by the function:

$$cm_t = q_t - q'_t = q_t - \beta'_1 Z_{1t} + \beta'_2 Z_{2t} = \tau' T_t + \epsilon_t \tag{3.6}$$

Given the current misalignment, it is also important to identify the total misalignment as an important element moving forward in comparison with the FEER approach. The total misalignment can be represented by the difference of q_t by the sustainable or equilibrium medium- and long-term economic fundamentals, $\bar{Z}_{1t}, \bar{Z}_{2t}$.

$$tm_t = q_t - \beta'_1 \bar{Z}_{1t} - \beta'_2 \bar{Z}_{2t} \tag{3.7}$$

Which can also be denoted as:

$$tm_t = (q_t - q'_t) + [\beta'_1 (Z_{t1} - \bar{Z}_{1t}) + \beta'_2 (Z_{2t} - \bar{Z}_{2t})] \tag{3.8}$$

$(q_t - q'_t)$ is simply the current misalignment as denoted in (3.6). $[\beta'_1 (Z_{t1} - \bar{Z}_{1t}) + \beta'_2 (Z_{2t} - \bar{Z}_{2t})]$, however, is the difference of the economic fundamentals in their current setting and equilibrium or sustainable setting in the medium- and long-run. Ultimately when we apply the function of (3.6) to function (3.8) we obtain the final form of total misalignment which is a function of the transitory effects, random disturbances and the deviation from the economic fundamentals to their equilibrium at any point in time.

$$tm_t = \tau' T_t + \epsilon_t + [\beta'_1 (Z_{t1} - \bar{Z}_{1t}) + \beta'_2 (Z_{2t} - \bar{Z}_{2t})] \tag{3.9}$$

Overall, using the BEER approach the total misalignment can thus be represented by equation (3.9).

3.3 Analysis of BEER and FEER models

Given the fundamental elements making up the FEER and BEER models, both can now be analysed and compared in greater detail. One of the arguments overshadowing the FEER approach is that it is too idealistic. Namely, it assumes full employment as well as low inflation rates to calculate the internal balance. Additionally capital flows need to be studied at equilibrium which is dependent on the internal balance. Due to these assumptions the FEER model is thought to be an estimation of the idealistic equilibrium exchange rate and in some cases not realistic. It therefore, does not showcase the exact effect of particular variables on the real effective equilibrium exchange rate. Even though, it is a widely respected approach it is thus often argued that the FEER approach does not capture the individual effects of the economic fundamentals as well as the transitory effects.

On the other hand, one can argue that the FEER model is highly effective to map the macroeconomic shocks and imbalances. These are often not represented well by the BEER model. The FEER method is therefore, despite it's arguably idealistic approach, a very effective model to calculate the EER based on external balances. With relation to China's main trading partners, the FEER method will be more likely to represent or behave in accordance to shocks in the global market. For example, if the US would suffer from a significant economic crisis, the FEER will be very effective to interpret such data and display the possible effects on the EER.

The BEER method is a profound concept to calculate the long-run equilibrium of the EER. One of the main benefits of utilising the BEER method is that it includes the specific variables which have a statistically significant effect on the EER. The BEER method is therefore very precise to identify particular relationships of 1 or more variables and the EER in a long term setting. This is very useful with regards to currency misalignment or currency manipulation as one might study the influenced factors by the Chinese financial institutions and the extend to which it has a significant relationship with the EER as well as the degree of impact. Moreover, it could estimate whether the relationship

is positively correlated or negatively correlated. In relation to the methodlogy of the BEER method, one might identify a particular variable which can be significantly correlated with the misalignment, thus the EER, for which that variable might have been manipulated to a certain extend.

The major drawbacks of the BEER approach is that due to the direct mapping of relationships between the EER and the studied variables, the model is highly sensitive to the studied variables. If for example, any biases exist in regards to variable selection it could have a negative impact on the applicability of the research and the estimation of the EER. For example if too few or too many variables are selected, a relationship might be established which is misleading or incorrect due to the insufficient or over sufficient variables studied. In addition, the BEER model is very much dependent on the econometric approach. As Zhang (2010) was able to showcase that different econometric approaches to calculate the BEER estimations, can have large impacts on the result of the estimation. Therefore, one should take all these indications into account when analysing or interpreting the provided estimations by the BEER model.

Furthermore, one should note the differences between teh BEER and FEER model in terms of their intended terms of application. Namely, the FEER model studies the medium-term equilibrium and the BEER model is actually aimed to obtain the long-run equilibrium. Taking this into consideration, it should be made clear that the analysis of both models is not with the aim of substituting one over the other. Both approaches ought to be very well respected and compared in the sense of applicability to a particular setting. When trying to calculate the equilibrium on a macroeconomic level with a short term view, the FEER model should be more suitable. Lopez-Villavicencio *et al.* (2010) too, mentions that both models should be utilised rather as "complements" for the most comprehensive study. In the same research conducted by Lopez-Villavicencio *et al.* (2010), it was also found that there is a significant relationship between the FEER and BEER model. This too supports the idea of a complementary relationship of both models rather then a substitutional relationship. It was also found that the main differences of the BEER and FEER correlation arose in a different reaction or trend of the current account and the real effective exchange rate.

Chapter 4

Data selection

This section will discuss the variables used in the application of the BEER model. To do so, one must first analyze and consider the variables studied in previous research. The dependent variable mostly represents the exchange rate in real or nominal terms. Moreover, the exchange rate is mostly studied in the bilateral and multilateral representation. This means that it is either calculated by 2 parties and/or more in the multilateral case. Cui (2013), Iimi (2006), Feenstra *et al.* (2011), Fidora *et al.* (2021) and Alshehabi & Ding (2008) for example studied a real exchange rate based on a multiple variables or 2 variable approach. The multilateral approach is the most common approach as it represents a weighted exchange rate and therefore can be considered more accurate in the setting of the global economy. In the case of this essay, the Real Effective Exchange Rate (REER) will be adopted as the dependent variable. This variable is obtained from the IMF (2022), International Financial Statistics (IFS) database, IFS (2022), for which it represents "a measure of the value of a currency against a weighted average of several foreign currencies) divided by a price deflator or index of costs". Many researches attempting to calculate the BEER model differ in a number of aspects considering the data selection. Namely, 2 aspects are considered, both the nature of the variables as well as the number of variables. Some researchers study only 2 independent variables and others up to 6 or more. As mentioned by Zhang (2010), both aspects can have a tremendous effect on the results of the estimated misalignment. Alshehabi & Ding (2008) utilised 6 independent variables for example. These include, the productivity differential, terms of trade (TOT), Government consumption as a percentage of GDP relative to trading partners (GOV), Investment as a percentage of GDP relative to trading partners (INV), Net foreign assets as a

share of GDP (NFA), and Openness to trade (OPEN). Cui (2013) used a total of 5 independent variables, namely the Balassa-Samuelson Effect, terms of trade (TOT), level of openness, foreign reserves and Foreign Direct Investment (FDI). Iimi (2006) Used only 3 independent variables as well as a risk premium factor. These included relative price of nontradables to tradables, net capital inflows and terms of trade. Feenstra *et al.* (2011) as well as Fidora *et al.* (2021) used 6 explanatory variables.

Based on the number of independent variables used in the mentioned studies as well as the nature of those variables this research will use an updated version of the independent variables used in the study of Zhang (2010). Zhang used 5 independent variables, which consisted of real GDP per worker (GDPC), the gross fixed capital formation (FINVEST), government consumption (GCON), degree of openness (OPEN), the terms of trade (TOT), total reserves (RES) and the dependent variable REER (Real Effective Exchange Rate). For the purpose of this research an annual data frame was used dating from 1980 to 2019, therefore a total of 40 observations for each variable. Due to the nature of the studied variables as well as the annual data, one should take into consideration structural breaks. Structural breaks commonly occur in a time series data frame for which sudden shifts or changes occur over time. Such changes or shifts in our case could be explained by global trends or occurrences as well as newly implemented policies and more.

4.1 Real Effective Exchange Rate (REER)

The REER "is the real effective exchange rate (a measure of the value of a currency against a weighted average of several foreign currencies) divided by a price deflator or index of costs" according to the definition provided by the IMF. When Chinese trade is relatively larger with the US for example, the exchange rate of the US will have a higher share of the basket to which the RMB is compared to. The REER is often utilised as a representation of the current exchange rate to obtain a more applicable and realistic result in terms of the global economy relative to the domestic country's trade volumes. The REER in this thesis will be directly retrieved from the IFS database published by the IMF. More specifically, an indexed version of the REER based on CPI will be utilised. This indexation is based on 2010.

4.2 Real output per worker (GDPC)

The real GDP per worker is a variable which accounts for technology and/or productivity. The higher the GDP per worker, the higher one can assume that country's technological progress and/or productivity is. This is measured by the ratio of expenditure-side real GDP at chained PPPs and annual average hours worked by employed individuals (AVH). The data observations are obtained from the Penn World Tables (PWT), version 10.0. For further description of the used variables to calculate the GDPC, please refer to Feenstra *et al.* (2015).

4.3 Government Consumption (GCON)

Government consumption is the amount consumed by the government which displays the fiscal policies implemented by the governing institutions. This variable is calculated by the general government final consumption expenditure as a percentage of the GDP. This way, the government consumption is weighted by the GDP to have a better understanding of what the government consumption might entail in a particular year in relation to the output of China in that same year. This variable too is obtained from the World Bank.

4.4 Investment (FINVEST)

Investment is given by the gross capital formation as a ratio of the GDP. The capital formation is the net investment of in this case China which naturally has a direct link with the output of China. This variable was also obtained from the World Bank.

4.5 Degree of openness (OPEN)

Degree of openness was obtained by adding both the Chinese exports and imports and dividing this amount by the real GDP at constant national prices. This variable ought to include the commercial policy implemented by the Chinese government. One can imagine an increase in trade restrictions therefore lowers the degree of openness and the other way around. The variable of real GDP at constant national prices was obtained from the Penn World Table, PWT (2021), and the export and imports of China was derived from the IMF

IFS database. It is important to note that the imports and exports only consider goods and thus not services. Such data was not yet provided.

4.6 Terms of Trade (TOT)

Terms of trade is a variable which was obtained from the IMF, and in particular from the data published by Gruss *et al.* (2019) who in his paper developed an updated database for the commodity terms of trade for a variety of countries. In this thesis it represents the individual commodities weighted by ratio of net exports to GDP. This variable is supposed to represent changes in the international economic environment.

4.7 Total reserves (RES)

The total reserves is also included as a variable in this study. It is often thought that currency manipulation is linked with the amount of reserves a country might have. Therefore this variable is included as a ratio of the real GDP at constant national prices. This data was retrieved from the IMF IFS database.

Variable	Calculation	Source
REER	real effective exchange rate/price deflator	IMF IFS Database
GDPC	RGDP/Chained PPPs/AVH	PWT 10.0
GCON	Government consumption/GDP	World Bank
FINVEST	Gross capital formation/GDP	World Bank
OPEN	(Exports + Imports)/real GDP at constant national prices	IMF IFS database, PWT 10.0 table
TOT	individual commodities weighted by ratio of net exports/GDP	IMF IFS database, PWT 10.0 table
RES	total reserves/real GDP at constant national prices	IMF IFS database, PWT 10.0 table

Table 4.1: Data summary

Chapter 5

Econometric Methodology

This section will discuss the econometric methodology utilised to conduct the necessary calculations in accordance with the BEER model to calculate the misalignment of the Chinese currency exchange rate. All calculations are conducted through R studio, RStudio Team (2020). To do so, we must first establish the main model. The main model will be composed of the multiple data series discussed in 4. In accordance the dependent variable, reer, can be represented as a function of gdpc, finvest, gcon, open, tot and res. This will be further explored as the main model for this econometric analysis.

$$reer = f(gdpc, finvest, gcon, open, tot, res) \tag{5.1}$$

The applied methodology uses the log, denoted as "ln", of the variables at hand. The econometric regression model can heceforth be represented by equation (5.2) below:

$$\begin{aligned} lnreer = \beta_1 + \beta_2 lngdpc + \beta_3 lnfinvest + \beta_4 lngcon \\ + \beta_5 lnopen + \beta_6 lntot + \beta_7 lnres \end{aligned} \tag{5.2}$$

For further analysis, the variables will be tested for a unit root test for the extend of stationary. Furthermore the Johansen (co-integration) test will be conducted to find the number of co-integrational relationships between the given variables. Ultimately the Vector Error Correction Model (VECM) will be calculated for which the coefficients of the standard model will be estimated through the usage of the Johansen test. In accordance with the results of the estimations, the possible misalignment will be calculated and represented

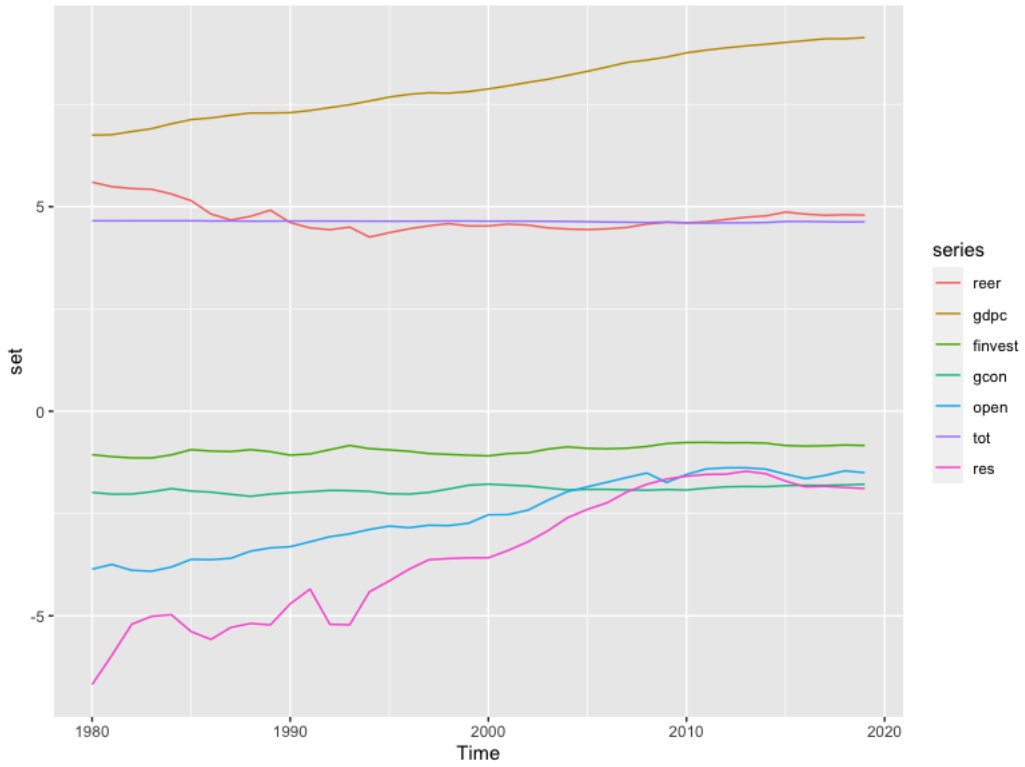

Figure 5.1: log transformation of the variables

accordingly. Finally, for the purpose of analysing our model as well as its validity and applicability a number of diagnostic tests were conducted.

5.1 Augmented Dickey-Fuller (ADF) test

The ADF test is used to study the extend of stationarity of the variables used, mostly in an econometric setting. It does so by studying the null-hypothesis of the presence of a unit root in a given time series data sample. The result of the test is negative, for which the degree of the test statistic dictates the extend to which the null-hypothesis can be rejected at a certain level of significance. When the null-hypothesis is rejected at a certain level of significance, it is normally concluded for the data to be stationary, more particularly covariance stationary. This implies that the variables have a constant mean, constant variance and the same covariance for identical intervals over different times. The degree of stationarity is important for the econometric analysis of the co-integration between a number of variables. For more detailed information about the mathematical background of the ADF test, please refer to Tam (2013). For

the sake of our thesis, the ADF test will be conducted to calculate stationarity at the 5% significance level under the form of levels and first difference. Please note that the ADF test will be conducted under a lag order of 3.

Table 5.1: ADF test of variables at levels

	reer	finvest	gcon	gdpc	open	res	tot
statistic	-3.14	-2.68	-3.11	-2.14	-1.19	-1.94	-2.61
p.value	0.126	0.307	0.138	0.518	0.890	0.599	0.332

The results of the ADF test of the non differentiated variables can be observed in table 5.1. From the given results, the null-hypothesis can not be rejected at 5% significance level for all variables. Therefore, we can conclude that at levels, reer, finvest, gcon, gdpc, open, res and tot are all non-stationary. However, since we are unable to reject the null-hypothesis for all variables, further analysis is needed.. To do so, we can take the first differential. The newly found set of variables by their first difference is illustrated in figure 5.3. Further, the ADF test will be applied to the newly transformed variables for which the results can be found in table (5.2).

Table 5.2: ADF test of variables at first difference

	reer	finvest	gcon	gdpc	open	res	tot
statistic	-2.53	-3.65	-5.44	-3.02	-2.63	-4.44	-3.22
p.value	0.366	0.042	0.01	0.173	0.327	0.01	0.098

The results of the ADF test of the differentiated variables suggest that we can now reject the null-hypothesis for finvest, gcon and res at a significance level of 5%, for all other variables we are still unable to do so. Typically, due to the unstationary nature of the displayed variables, the Vector Autoregressive (VAR) model would not be possible to conduct. However, the VECM claims that due to the concept of cointegration, an equilibrium of the variables at levels can be obtained, henceforth deeming those variables stationary without taking any differentiation.

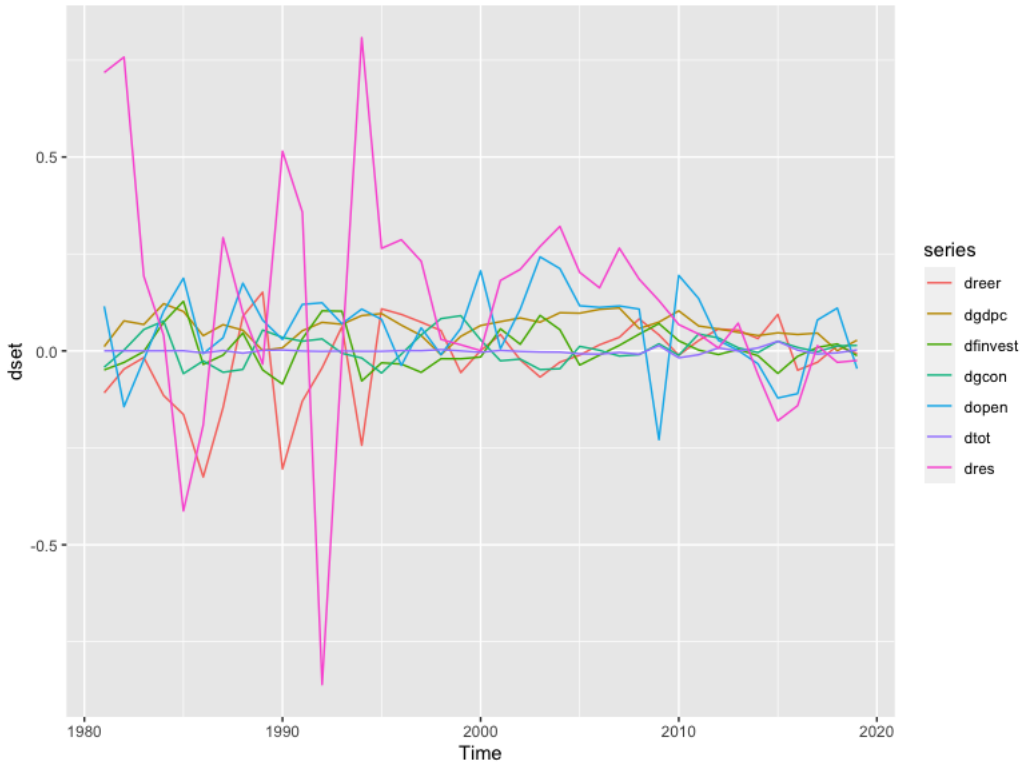

Figure 5.2: First difference transformation of the variables

5.2 Johansen test

The Johansen test is a statistic which tests for co-integration of a set of variables over a given time series interval. In more detail, there are 2 different methodologies, the trace - and eigenvalue Johansen co-integration test. One should note that both tests aim to find the number of cointegration vectors. This is denoted by r and r* for the optimal cointegration vector(s) correspondingly. This will be tested in relation with our set of data time series at levels, which is denoted by k. Moreover, for the trace johansen test, the null hypothesis (H_1) can be represented as $r = r* < k$. On the other hand H_1 can be denoted as $r = k$. The eigenvalue test is similar to the trace test as both have the same H_0 but a different alternative hypothesis which can be depicted as $r = r* + 1$. For the purpose of this thesis, the trace johansen test will be conducted at a lag order of 2. The Johansen trace test will include a constant term for cointegration. The results of the trace test can be observed in table (5.3).

For interpreting the results of table (5.3), this thesis will test for 5% signifi-

Table 5.3: Test statistic of the Johansen test

	test	10pct	5pct	1pct
r <= 6	6.93	7.52	9.24	12.97
r <= 5	16.95	17.85	19.96	24.60
r <= 4	32.02	32.00	34.91	41.07
r <= 3	48.49	49.65	53.12	60.16
r <= 2	78.98	71.86	76.07	84.45
r <= 1	122.62	97.18	102.14	111.01
r = 0	194.66	126.58	131.70	143.09

cance level. Therefore, we can observe that for r <= 3, as the 5pct significance level is greater then the test statistic. In accordance with the provided theory above, The test illustrates that there are 2 co integrating vectors for the variables used in our model. Therefore for further analysis of the Vector Error Correction Model (VECM), the assumption of 2 existing co integrating vectors will be adopted.

5.3 Vector Error Correction Model (VECM)

The VECM is a model utilised to analyse a multivariate time series model. In simple terms, it can be the case that not all variables are stationary at levels, yet the VECM suggest that in some cases even though the variables are non-stationary, their cointegrational relationships between 2 or more variables could be of a stationary nature. Therefore, the cointegrational relationships can be discussed and analysed in more detail despite some variables being non-stationary. In our case for example, all variables under levels are non-stationary and under their first difference only 3 variables (finvest, gcon, and res) can be identified as stationary. Despite it's non-stationary nature, its cointegrational relationship with any set given variables could be of a stationary nature and henceforth be of an important underlying effect on the REER. First and foremost, we have identified a contegrational relationship of 2 variables as is showcased in the Johansen test. From this information we can now attempt to derive the VECM for further analysis of which variables are identified as significant in the cointegrational relationships. This will be showcased in the form of a function of matrices shown below in equation (5.3). For detailed mathematical description on the derivation of such equation please refer to Shin *et al.*

(2000) where detailed mathematical discussion is constructed for the application of the VECM. There are 2 main methods for calculating the VECM, these include the Engle-Granger (2OLS) method or the Johansen (MLE) method. For the purpose of this thesis, the MLE method is preferred and therefore implemented. Important to note, is that the ECT denotes the Error Correction Term. This represents the rate at which the variables adjust to reach their long-run equilibrium. Moreover, the left-hand side of equation (5.3) represents the explained vector. On the right-hand side, the first term is the discussed ECT, second, the constant, third, the first lag, and finally, the second lag. In accordance with each variable a significance code is assigned for which ".", means a significance level of <10%. "*" indicates <5%, "**" means <1% and finally "***" illustrates a significance level of <0.1%.

$$
\begin{pmatrix} \Delta X_t^1 \\ \Delta X_t^2 \\ \Delta X_t^3 \\ \Delta X_t^4 \\ \Delta X_t^5 \\ \Delta X_t^6 \\ \Delta X_t^7 \end{pmatrix} = + \begin{pmatrix} -0.21^{**} & 0.51 \\ -0.02 & -0.20^{*} \\ -0.10^{***} & 0.24^{\cdot} \\ 0.04^{\cdot} & 0.03 \\ 0.01 & -0.53 \\ -0.01 & -0.03 \\ 0.31^{*} & -3.09^{***} \end{pmatrix} ECT_{-1} \begin{pmatrix} 44.15^{**} \\ 2.51 \\ 21.18^{***} \\ -6.81 \\ -4.44 \\ 0.82 \\ -81.57^{**} \end{pmatrix}
$$

$$
+ \begin{pmatrix} 0.05 & 1.53^{\cdot} & 0.16 & -0.78 & 0.06 & 3.48 & -0.00 \\ -0.05 & 0.30 & 0.02 & 0.11 & -0.13^{\cdot} & -0.71 & 0.02 \\ -0.34^{***} & 0.58^{\cdot} & 0.94^{***} & 0.87^{**} & 0.12 & 4.46^{*} & 0.04 \\ 0.14^{*} & -0.60^{*} & -0.05 & 0.20 & -0.04 & -2.10 & 0.02 \\ -0.37^{\cdot} & 1.47^{\cdot} & 0.42 & 0.32 & 0.11 & -3.38 & -0.06 \\ 0.01 & -0.15^{*} & -0.04 & -0.06 & -0.00 & 0.00 & -0.00 \\ 0.89^{*} & -1.40 & -4.87^{***} & -5.99^{**} & -1.15^{*} & -37.16^{***} & -0.45^{*} \end{pmatrix} \begin{pmatrix} \Delta X_{t-1}^1 \\ \Delta X_{t-1}^2 \\ \Delta X_{t-1}^3 \\ \Delta X_{t-1}^4 \\ \Delta X_{t-1}^5 \\ \Delta X_{t-1}^6 \\ \Delta X_{t-1}^7 \end{pmatrix} \tag{5.3}
$$

$$
+ \begin{pmatrix} -0.02 & -1.02 & 0.05 & -1.03 & -0.07 & 0.05 & 0.06 \\ 0.02 & 0.14 & -0.18 & -0.28 & -0.05 & -0.21 & 0.01 \\ -0.09 & 0.33 & -0.18 & -0.66^{*} & -0.06 & 1.89 & 0.03 \\ -0.00 & -0.05 & 0.14 & 0.31 & -0.01 & -0.15 & 0.05^{*} \\ 0.44 & -1.65^{\cdot} & -1.45^{\cdot} & -2.22^{*} & -0.44 & -4.92 & -0.14^{\cdot} \\ 0.00 & 0.07 & -0.04 & -0.04 & -0.03 & -0.22 & 0.00 \\ 1.92^{**} & -2.69 & -3.63^{*} & -2.28 & -0.76 & -25.03^{*} & -0.37^{*} \end{pmatrix} \begin{pmatrix} \Delta X_{t-2}^1 \\ \Delta X_{t-2}^2 \\ \Delta X_{t-2}^3 \\ \Delta X_{t-2}^4 \\ \Delta X_{t-2}^5 \\ \Delta X_{t-2}^6 \\ \Delta X_{t-2}^7 \end{pmatrix}
$$

After considering the results obtained from the VECM, we can now derive the estimated coefficients of the standard model using the Johansen method. Using this method we will be able to extract a simple OLS model from the restricted VECM. We can obtain such estimated coefficients by the calculated VECM equation illustrated above. The above calculations are henceforth also dependent on the cointegration rank which we found to be 2 as well as the lag order of 2 as was showcased by the Johansen test. Ultimately we can denote the simple model as follows in equation (5.4):

$$\begin{aligned} REER = &- 170.76 - 6.48 * gdpc + 12.21 * finvest + 7.85 * gcon \\ &+ 3.68 * open + 55.33 * tot + 0.49 * res \end{aligned} \tag{5.4}$$

5.4 Diagnostic tests

To test whether our model was conducted appropriately, several diagnostic tests were conducted to obtain a clear overview of the shortcomings as well as strengths of our model. These factor will hence be taken into consideration on the discussion on the results of the model. One should note that the diagnostic tests are conducted on the VAR (Vector AutoRegressive) model. Therefore the VECM was transformed into a VAR model for which the diagnostic tests can be applied. Moreover, the diagnostic tests are mostly applied to the residuals of the model as the trends and patterns observed in the residuals showcase the extend of successful application.

5.4.1 Portmanteau- and Breusch-Godfrey test

The Portmanteau- and Breusch-Godfrey test, tests for serial correlated errors. Serial correlation is the concept of correlations found between the variable at a certain time and the variable at a previous point in time. Thus, naturally this concept occurs in time series regression models. If serial correlation would take place, the assumption of independent errors in relation with OLS based regressive models does no longer hold. For detailed description of the adopted methodology please refer to Gabrys & Kokoszka (2007). This is then called the serial correlation errors. The tested statistic can be found below, in table (5.4):

Table 5.4: Test statistic of the Portmanteau Test (asymptotic)

Chi-squared	df	lags	p-value
195.05	154	5	0.01405

From the given results, we can confirm that for a maximum of 5 lags, no serial correlation errors occur in the provided model with a significance level of 0.01405. Therefore the applied model does not violate the OLS assumption.

5.4.2 Arch effects

An ARCH test is conducted to test whether the residuals of the VECM are auto correlated with one another. When this is the case, the VECM was not applied appropriately. In this thesis, the multivariate ARCH test is utilised as presented by Engle & Kroner (2015). The null hypothesis can be identified for the existence of autocorrelation in the residuals. The alternative hypothesis is when no autocorrelations of the residuals can be established. Table (5.4) showcases that the p-value equals 1 for which the null hypothesis can be rejected. This therefore means that no autocorrelation was found from the residuals of the model.

Table 5.5: Test statistic of multivariate ARCH

Chi-squared	df	lags	p-value
924	3920	5	1

5.4.3 Normality of residuals

The normality of residuals tests for 3 objects. The Jarque-Bera test, the multivariate Skewness and Kurtosis tests. Testing for normality of the residuals tests for central tendency which is important for appropriate econometric methodologies. All three tests above test for normality for which the results can be retrieved in table (5.6).

Table 5.6: Test statistic of multivariate ARCH

Chi-squared	df	p-value
47.769	14	1.435e-05
16.74	7	0.01915
31.029	7	6.141e-05

The results of all three tests in table (5.6) suggest that there is a significant normal distribution of residuals. Therefore the applied model succeeds this test. Despite, the relatively small sample size of the data sample, all diagnostic tests were successful for which one can conclude that the VECM was applied appropriately.

Chapter 6

Discussion

In this chapter, the results of the econometric model will be presented and discussed accordingly. Such results will then be discussed in accordance with the exchange rate regime discussed in chapter 2. Given trends will then potentially be established with certain events.

6.1 Results

To investigate the results we must consider equation (5.4) for which the equilibrium exchange rate can be estimated. This estimation is compared with the original REER in figure (6.1) from which the trends of misalignment are visible where 'reer' represents the provided REER and estimREER represents the estimated REER. Furthermore the misalignment can be established by equation (3.9) which is showcased in figure (6.2). Moreover the list of all the misalignment of each year can be found in appendix 1.

Table 6.1: Summary of misalignment from 1980 to 2019

Minimum	1st Quarter	Median	Mean	3rd Quarter	Maximum
-4.623	-2.649	-2.366	-2.532	-2.268	-2.016

Table 6.2: Summary of misalignment from 2005 to 2019

Minimum	1st Quarter	Median	Mean	3rd Quarter	Maximum
-4.020	-2.428	-2.347	-2.464	-2.301	-2.016

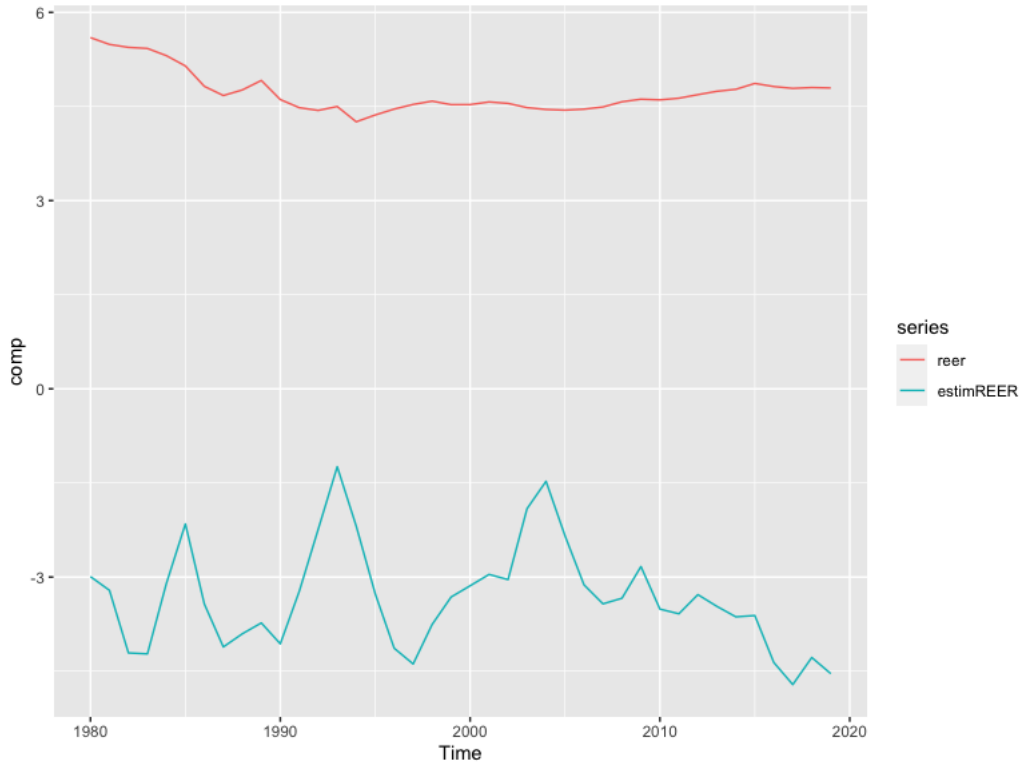

Figure 6.1: REER vs estimated REER

From the results displayed in figure (6.2), the RMB was undervalued for all years from 1980 to 2019. In addition, the minimum counts an undervaluation of -4.623% which was located in 1993. The maximum is also an undervaluation of -2.016% in 2017. Overall, from the interval of 1980 to 2019, an average undervaluation can be observed of -2.532%. Accordingly, one could suggest that throughout the reported 40 years, the RMB was undervalued. In particular when looking at the period of interest from 2005 to 2019, an average undervaluation of -2.464% is established as reported by table (6.2). One can also perceive a general upward trend from 22005 to 2019 from -4.020% in 2005 to -2.056% in 2019. Therefore, one could argue that the misalignment decreased by merely 1.964% over the 15 years of interest. A boxplot of the reported misalignment data can too be observed in appendix 2. From this boxplot, it can be observed that the misalignment empirically mostly ranged between -2% and -3%.

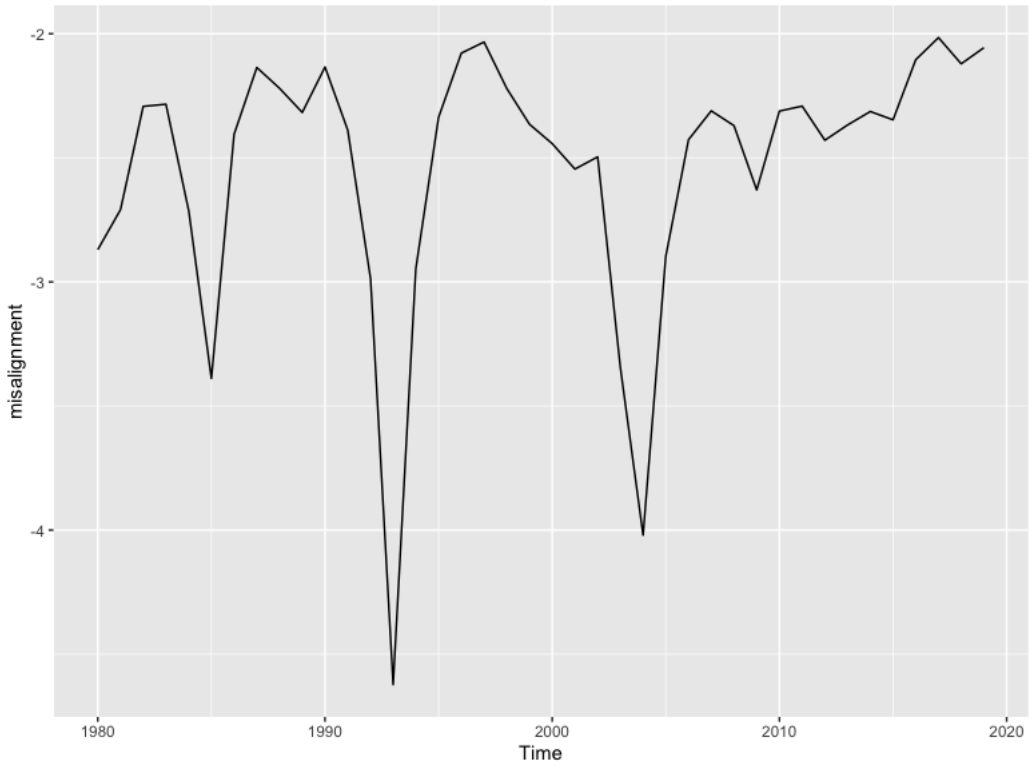

Figure 6.2: The exchange rate misalignment

6.2 Linkage of results with the implemented exchange rate regime

When comparing the results to the historical exchange rate regime, one can note that during the multiple exchange rate from 1881 to 1885 the misalignment fluctuated in the range from -2.87% to -2.28%. Most notably and interestingly from the multiple exchange rate regime is that a peak can be observed in 1985 during the transition year from a multiple exchange rate to a dual exchange rate regime counting an undervaluation of -3.39%. After the transition year, the alignment increased notably during the dual exchange rate regime until 1990. As of 1990 a significant decrease can be observed until 1993 to the overall minimum of the studied period of -4.623%. Possibly this can be traced back to the reported increasingly high demand of the swap rates for which a new managed floating exchange rate regime was introduced which immediately had an impact on the misalignment as a upwards peak can be observed in 1997 of -2.034% which is the second highest point over the studied period. In addition, the introduction of swap centers in 1994 allowed for a significant increase in

convertibility which can also aid to explaining the upward sloping alignment past 1994. However in 1997, the Asian Financial Crisis convinced China to change regime to a pegged exchange rate which gradually caused the alignment to decline until another downward sloping peak in 2004 of -4.020%. In 2005, the managed floating regime was once again adopted for which an incline can again be observed in the alignment to -2.311% in 2007. However, a small downward peak can be observed in 2009 possibly explained by the Global Financial Crisis (GFC). In 2008 until 2010 a peg was held against the USD which can too be related with the GFC. From 2010, the crawl-like arrangement until 2014 experienced no shocks or significant points as this period's misalignment ranged from -2.292% to -2.429%. Moreover, after 2014 a continued increase can be observed in relation to the central setting rate parity rule as well as the inclusion into the SDR basket. Explicitly, one can even note the highest point of alignment in 2017 of -2.016%. Finally, further developments past 2019 ought to be followed closely in particular to another global economic crisis caused by the COVID-19 pandemic.

6.3 Comparison of results with other studies

In 2007, Wang *et al.* (2007) studied the RMB misalignments by the utilisation of the BEER model as well as the VECM. Wang *et al.* (2007) obtained a misalignment ranging roughly from 4% overvaluation to -5% undervaluation. Such results can be observed in figure (6.3). 3 downward peaks were observed, in 1988, 1993 and 2004. The 3 downward slopes in this thesis were located in 1985, 1993 and 2004, thus all 3 were observably similar except for the first downward peak which was observed 3 years earlier in this thesis. Potentially this can be explained by the usage of different lags or the usage of different seasonal data used by Wang et al. However, the upward-sloping counted much less in this thesis as no overvaluation was observed. In Wang et al on the other hand overvaluation was observed on numerous observations. In genaral, this thesis resembles similar trends as the results presented by Wang et al but the numerical deviations differ.

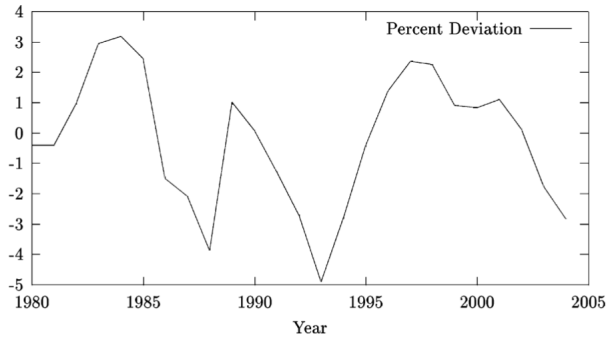

Figure 6.3: Percent misalignment of RMB REER and HPBEER by Wang *et al.* (2007)

Zhang & Chen (2013) studied the RMB misalignment by also conducting the BEER model. From 2003 to 2012 an upward misalignment trend can be observed as displayed by table (6.4):

Table 6.3: Misalignment of the RMB as reported by Zhang & Chen (2013)

year	RER misalignment (%)
2003	-29.7
2004	-30.1
2005	-31.4
2006	-27.6
2007	-21.9
2008	-5.3
2009	-1.9
2010	-0.1
2011	8.8
2012	11.4

From these given results a misalignment range was established from -31.4% to +11.4%. Such range is much greater then the established range in this thesis. However, a similar trend is once again observed. From 2003 to 2012 an upward trend is observed both in Zhang and Chen as well as the misalignment of this thesis presented in figure (6.2). However, just like with Wang et al, this thesis did not observe any overvaluation of the RMB in contrary to Zhang and Chen.

Cui (2013) too conducted the BEER model to estimate the RMB's equilib-

rium exchange rate as well as the misalignment on a data frame from 1995 to 2012. The misalignment obtained in Cui's research can be retrieved in figure (6.4) which ranges from approximately 35% overvaluation to -45% undervaluation. A downward peak can be observed in 1997 and 2005. Such peaks were not observed in this research. On the contrary, 1997 was an upward peak of misalignment in this thesis. Moreover, in 2004 a downward peak was also observed 1 year earlier then Cui. Upward peaks were observed in 2001 and 2008-2009. The main argument by Cui was that the GFC drove the misalignment to decrease (upward). Neither peaks were observed. In relation to the GFC, this thesis observed a small upward peak in 2007 but furthermore no noteworthy critical points. One must note however, that Cui utilised quarterly data which deviates from the data utilised in this thesis due to the seasonal differences. Such seasonal differences could impact the lag order, which could cause the observations to a certain degree be misaligned with reality. This factor should be taken into consideration. Moreover, ideally in the future this research should be conducted with more data, which indicates that a quarterly data set could be more effective in describing any trends.

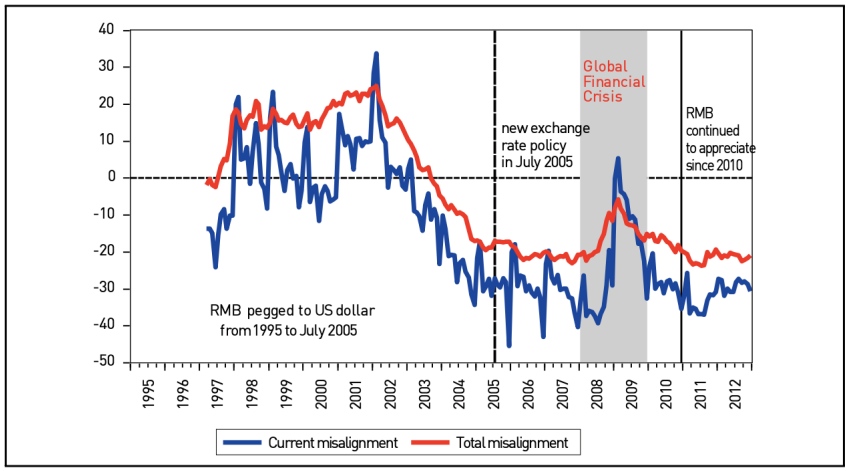

Figure 6.4: The RMB's current misalignment and total misalignment by Cui (2013)

Notably, studies such as Wang et al implement the Hodrick-Prescott (HP) filter to the obtained estimated equilibrium exchange rate. The HP filter is commonly used in a wide variety of economic research despite its controversy. The HP filter is intended to decompose the cyclical movements within a time series. Therefore, the data is represented in a more "smooth" curve. It is utilised in particular for the analysis of long-term phenomenon. One could ar-

gue that such a filter could therefore effect the misalignment to a great extend. This can also be observed when applied to the estimated REER in this paper as is showcased in the figure C.1 in Appendix C. Therefore one must consider the effect of the HP adjustment in the analysis of this research in addition to past and future studies on the matter. Please refer to Hamilton (2018), where further reasons are explained as to why one should not use the HP filter.

Overall, it can be concluded that for a number of researches, similar trends were observed. However the range of misalignment differed to a large extend. In addition, no overvaluation was observed in this research in contrast to the analysed researches which all observed a certain degree of overvaluation at a certain point in time. Nevertheless, differences were observed and discussed in methodology and data selection which could account for the differences in results.

Chapter 7

Conclusion

In conclusion, this thesis attempted to map the exchange rate misalignment in an attempt to build an underlying understanding behind the US accusation of Chinese currency manipulation. Moreover, this was attempted by focusing on the misalignment calculated by the equilibrium exchange rate. In accordance, the history of the exchange rate regimes implemented by Chinese authorities were discussed for which a number of different regimes were identified from 1980 up until 2019. These regimes include, multiple exchange rate system, dual exchange rate, swap exchange rate, managed floating regime, pegged exchange rate, crawl-like arrangement and '8.11' regime. Furthermore a brief discussion on the predominant models to calculate the equilibrium exchange rate regime was conducted from which the BEER methodology was chosen for the purpose of this essay. Furthermore the variables used to estimate the BEER model were discussed in chapter 4 for which the REER, GDPC, FINVEST, OPEN, TOT and RES were described and adopted for further analysis. The econometric models and techniques used to accomplish the purpose of the thesis include the HP filter, the ADF test, the Johansen test, the VECM as well as diagnostic tests to analyze the extend to which the model fits and applied appropriately. From the results, it can be concluded that the RMB was mostly overvalued from 1980 to 2019 for which the average misalignment counts an undervaluation of -2.532% and -2.464% from 2005 to 2019. In addition, the trends of misalignment were analysed in accordance with the exchange rate regimes as well as compared with the results of other researches.

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Appendix A

List of misalignment from 1981 to 2019

Table A.1: List of misalignment from 1981 to 2019

Year	Misalignment (%)
1980	-2.870166
1981	-2.709065
1982	-2.292833
1983	-2.284143
1984	-2.711939
1985	-3.388839
1986	-2.405066
1987	-2.136205
1988	-2.220018
1989	-2.317239
1990	-2.134356
1991	-2.388117
1992	-2.983912
1993	-4.622571
1994	-2.945068
1995	-2.336583
1996	-2.078358
1997	-2.033514
1998	-2.220702
1999	-2.364820
2000	-2.442949
2001	-2.545532
2002	-2.496190
2003	-3.345815
2004	-4.020457
2005	-2.896189
2006	-2.426961
2007	-2.310832
2008	-2.370586
2009	-2.629500
2010	-2.311838
2011	-2.291730
2012	-2.429222
2013	-2.367768
2014	-2.313474
2015	-2.346988
2016	-2.104653
2017	-2.015756
2018	-2.121305
2019	-2.056307

Appendix B

Boxplot of misalignment

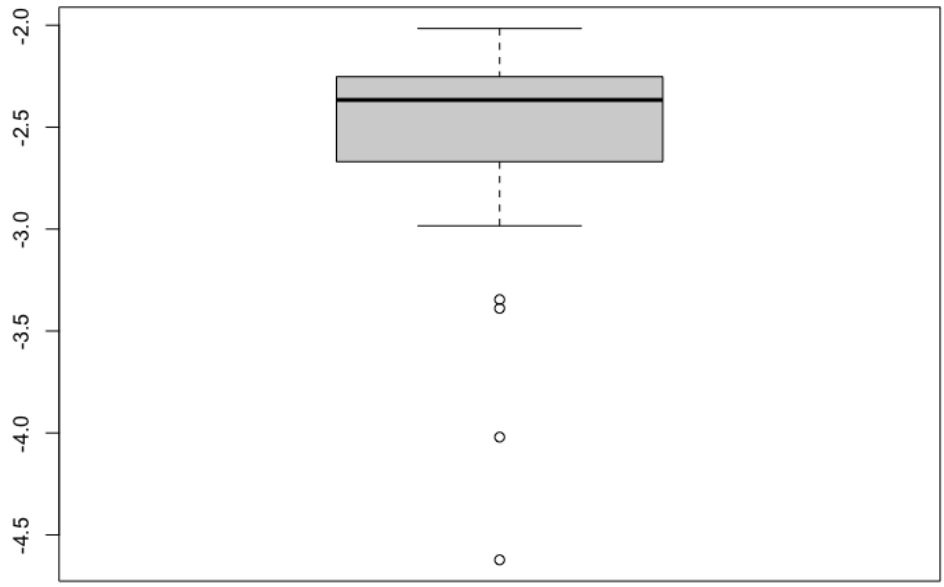

Figure B.1: Boxplot of the misalignment

Appendix C

HP adjusted REER estimation versus the 'raw' REER estimation

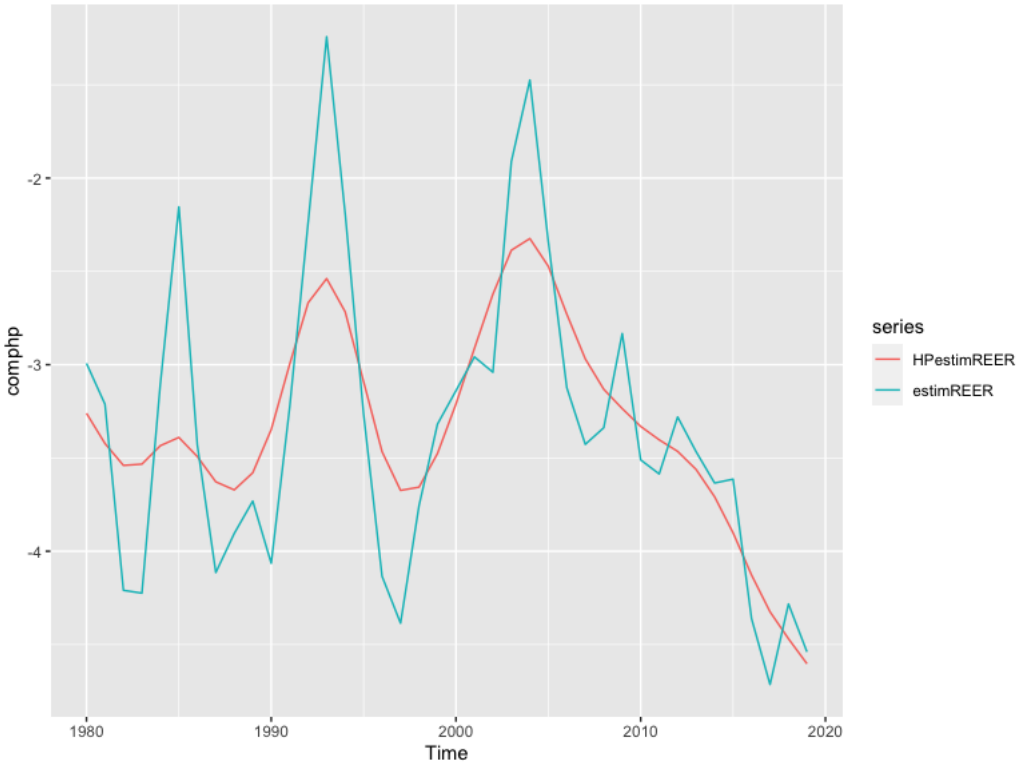

Figure C.1: HP adjusted REER estimation versus the 'raw' REER estimation