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Analysis of China's current account: Evidence based on Inter-temporal Current Account Model

Economics

Master's thesis

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2015

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Abstract

China's continuing high current account surplus during the last ten years has attracted worldwide attention. This paper aims to investigate whether China's current account surplus is reasonable based on the inter-temporal current account model, and whether GDP growth rate of China, world real interest rate, and real exchange rate of Chinese Yuan have significant effects on China's current account balance, and if it is the case, how they affect China's current account behavior.

To solve my research questions, I chose the inter-temporal current account model as the theoretical model and Vector Autoregression (VAR) model as the econometric model. Two datasets: annual dataset (1980-2013) and quarterly dataset (1994Q1-2014Q2) have been collected, and each dataset has three time series including the change of net output, current account and consumption-based real interest rate. All the time series are stationary in both Dickey-Fuller (ADF) unit root and Phillips-Perron unit root test, except that in ADF test results consumption-based real interest rate is not stationary in all different lags.

Adequate VAR model performs fairy well. VAR estimation shows that the change of net output and consumption-based real interest rate have significant effects on current account; impulse response analysis results show that consumption-based real interest rate has more sustained effects on current account compared with the change of net output, though they have similar strong cumulative effects on current account which converge to a positive constant in the long term.

Present value test results reject the theoretical model. Therefore it is difficult to determine whether China's current account surplus is reasonable merely based on the inter-temporal model. Nevertheless, combining the recent research results and China's economy itself, one can conclude that China needs a current account surplus and substantial international reserves to help maintain the stability of development of domestic capital market and ensure the success of joining into the world economy in its gradual opening process.

Keywords:

Current account	Inter-temporal CA model	National income equation
Net output	Consumption-based interest rate	
VAR model	Stationary test	Model checks
Impulse response analysis	Present value test	

Contents

1 Background introduction

1.1 History and structure of China's current account

The trend of China's current account (CA) and its share in GDP from 1982 to 2013 are described in Figure 1.1. Before 1995, China's CA surplus fluctuated and dropped to 1.6 billion US dollar (USD) in 1995; while in the later 12 years, the CA surplus kept increasing, sharply increased from 1.6 billion USD in 1995 (0.20% of GDP) to 421 billion USD in 2007 (almost 10% of GDP). After 2007, this surplus decreased and dropped steadily, but in 2013 the CA surplus was still up to 182.8 billion USD (around 2% of GDP) and accumulated CA surplus was more than 2,450 billion USD by the end of 2013.

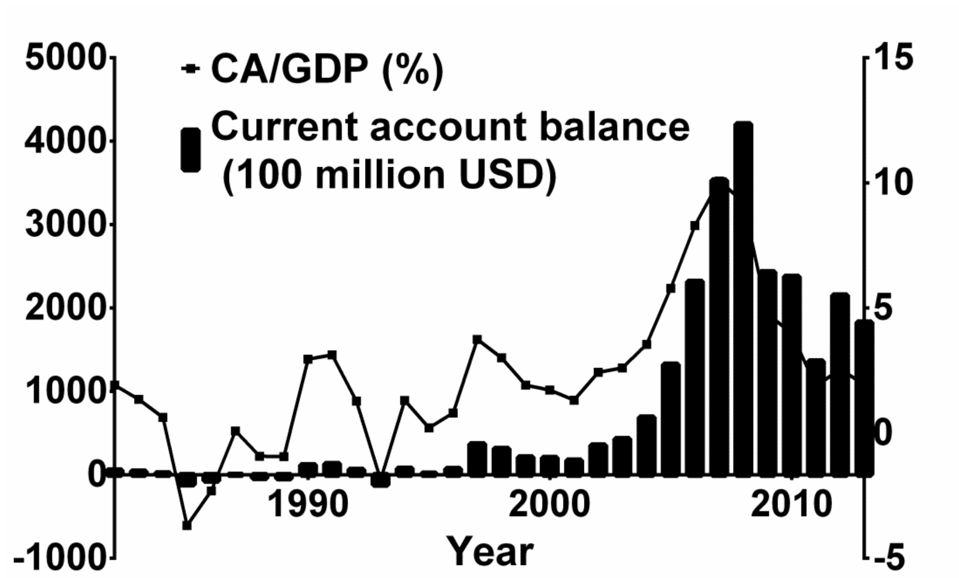

Figure 1. 1 China's current account surplus and share of CA in GDP from 1982 to 2013
Data source: National Bureau of Statistics of China and State Administration of Foreign Exchange

According to the fifth version of IMF international balance of payment, current account balance (CAB) = trade balance in goods and services + net income from abroad + net current transfers.

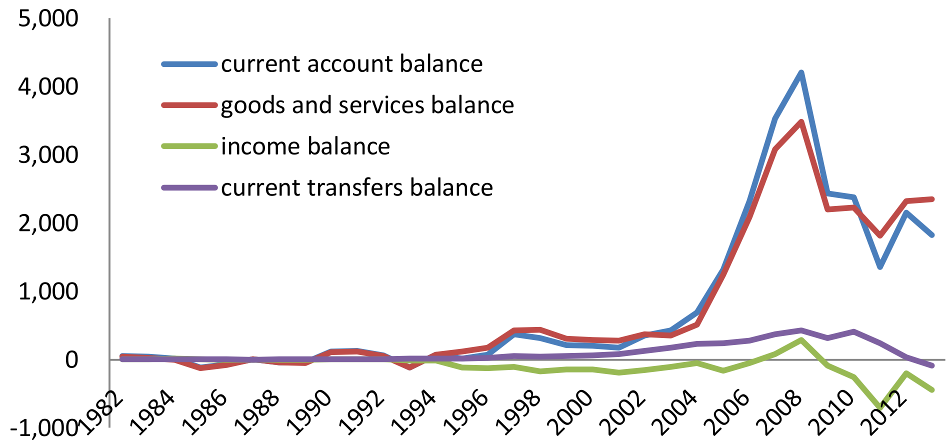

Figure 1. 2 China's current account components from 1982 to 2013 (unit: 100 million USD)
Data source: State Administration of Foreign Exchange

From 1990 to 2013, China's CA surplus mostly came from trade surplus in goods and services, for example in 2012, the trade surplus accounted for 108% of CA surplus. However, of noted, the average shares of net income in CA balance was about -11%, suggesting that the return from international investment almost kept in loss, especially during recent years, for instance in 2011 the loss from intentional investment was up to 70 billion USD (52% of CA).

Though China's CA surplus kept high in these years, the income account[1] remained negative and even went worse after 2009, which indicates that China lacked competence in international market.

1.2 Domestic effects of China's current account surplus

From China itself, during these years China's CA kept in high surplus, accompanied with this high surplus has been accumulated high foreign exchange reserves, large amount of monetary supply and high inflation.

While the value of China's foreign exchange reserves have depreciated almost 20% since 2005. The exchange rate of 1 USD for Chinese Yuan (CNY) has depreciated from 8.2 in

[1] Income account is the difference between returns from global investment and returns of foreign investment in domestic market.

2005 to 6.15 in 2014, 1 EUR for CNY also depreciated from 10 in 2005 to 7.8 in 2014. Since half of China's total foreign exchange reserves is in USD and almost one-third is in EUR, these two currencies' depreciation almost means that China's total international reserves depreciated. (http://www.pbc.gov.cn)

Furthermore, if monetary supply is measured in M2, until the end of 2008 China has issued 47.5 trillion CNY and until the end of 2013 China has issued 110.6 trillion CNY, meaning that monetary supply M2 has increased 63 trillion CNY in the last 5 years, which is larger than the total issued M2 from 1949 to 2008. Meanwhile annual growth rate of monetary supply (M1) was around 15%, which was far quicker than the annual growth rate of GDP and average salary. China has experienced high inflation since 2004. (http://www.pbc.gov.cn&http://www.stats.gov.cn&http://www.financeun.com/News/2014116/2013cfn/8330243700.shtml)

1.3 Global imbalance of current account imbalance

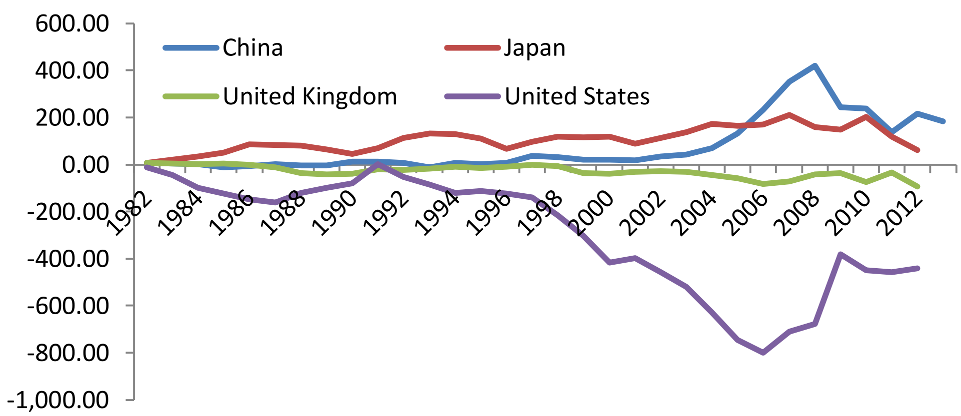

Figure 1. 3 Current account situations in some major economies (unit: 1 billion USD)
Data source: IFS

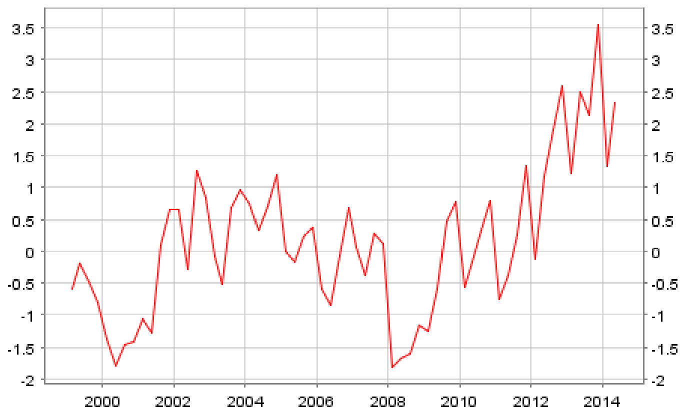

Figure 1. 4 European current account balances as % of GDP
Source: http://sdw.ecb.europa.eu/home.do

As shown in the above two figures, European CA has fluctuated and been generally in balance since 1999; while the CA of U.S. and some Asian countries, especially Japan and China, have gone to totally opposite direction since 1996. U.S. is the main CA deficit country, whereas Japan and China are the main CA surplus countries. In the meanwhile, the gap of this deficit and surplus between America and Asia has continued to widen.

There is a big global imbalance and China has been agreed as a key contributor to global imbalance with both a high CA surplus and substantial international reserves (Bacchetta et al. (2012)).

Calvo and Talvi (2006) showed that the accumulation of international reserves denominated in USD by foreign central banks accelerated significantly, increasing from 83 billion USD in 2001 to 500 billion USD in 2004, of which 29% was held by Japan, 27% by China, and 20% by rest of Asia[2]. In addition, Bernanke (2011) showed that China's CA surplus from year-end 2003 to year-end 2007, about 900 billion USD, was almost used to acquire assets in the United States, of which more than 80% were safe treasuries.

After 1997 Asian financial crisis, U.S. has become the global insurer to provide insurance to the rest of the world (Gourinchas et al. (2010)) since domestic governments of emerging countries with surplus CA accumulate reserves to ensure their own credibility

[2] Includes: Korea, Hong Kong, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan and Thailand.

(Jeanne and Ranciere (2011)) and most of international reserves are denominated in USD (Bernanke (2011))[3]. Then a modern Triffin dilemma[4] appears, since the asymmetry between American fiscal capacity and the stock of reserve assets held abroad (U.S.'s external debt) is growing, which not only threatens the solvency and credibility of US, but also the safety of the international reserves denominated in USD held by emerging countries (Gourinchas and Rey (2013)).

2 Motivations and research questions

2.1 Motivations

As we know, continued huge CA deficit of an economy means a decline in solvency and credibility of the deficit country, whereas on the other hand continued large CA surplus means that a surplus country transfers a large amount of domestic resources for foreign consumption instead of improving domestic welfare, which in turn will pose threat to the development and stability of its own economy. Therefore, we need to figure out means to adjust CA imbalance.

From the view of ordinary Chinese, China should not have a high surplus CA balance. Instead, China should consume more export products and import more from abroad since CNY has appreciated around 20% since 2005 and has more purchasing power than ever before, and importing more can prevent further depreciation of foreign exchange reserves. Meanwhile it seems that China should produce less since its domestic supply is higher than demand unless its domestic demand can be efficiently increased. In addition, most of production is labor- and resource-intensive and generates unsustainable usage

[3] Between year-end 2003 and year-end 2007, the supply of total US securities increased about 10 trillion USD, of which 4.5 trillion USD was absorbed by foreign investors; the supply of Treasuries and Agencies outstanding increased about 1.6 trillion USD and 0.9 trillion USD was taken by Asia (excluding Japan) and the Middle East (Bernanke (2011)).

[4]Triffin dilemma: In the 1960s, under Bretton Woods' system, the currencies of member countries could change at a fixed rate against the dollar while the value of the dollar was fixed against gold at $ 35/oz. Triffin observed that there is an asymmetry between American gold stocks and global liquidity demand. Since the rest of the world grew with the global economy, so the stock of dollars held abroad grew too, while the United States' gold stocks were almost constant. Therefore maintaining the gold value of the dollar became increasingly difficult, the dollar crisis happened and Bretton Woods system collapsed. Ten years before the end of the Bretton Woods system, Robert Triffin had predicted its collapse.

of natural resources, and cause severe environmental pollution problems which severely affect people's life quality.

Current policy has been rationalized from several angles. Calvo and Talvi (2006) pointed out that one main reason for China to accumulate international reserves is to ensure the stability of liberalization of banking system according to WTO rules[5]. Jeanne and Rancière (2011) showed that emerging markets accumulate reserves against capital flow volatility for precautionary reasons.

China is a semi-open economy and its true market economy started from late 1990s. Chinese Central Bank became independent after a law was passed in March 1995 and its retail prices were market-determined only since 1995[6].

China has been using relatively fixed exchange rate and fixed interest rate, and has an imperfect capital market with high restrictions on capital inflow and outflow. In addition, private sectors cannot get access to international capital markets, but Chinese Central Bank has full access to them and Chinese government is the only financial intermediary for the domestic private sector. Moreover, China's interest rate can be different from the world interest rate and undervalued real exchange rate of CNY can be maintained through capital controls and selling-buying of international reserves by the Chinese Central Bank. (Bacchetta et al. (2012), Jeanne (2012), and Song et al. (2011))

Bacchetta et al. (2012), Bacchetta et al. (2013) and Jeanne (2012) proved that China, especially when its economy is in transition, needs substantial international reserves to maintain the capital controls and exchange rate policy, thereby getting a higher welfare without capital mobility and with using a undervalued real exchange rate and an optimal interest rate different from the world interest rate, just as China has done. However, on the other hand, it causes malfunction of China's monetary policy in adjusting growth

[5] China joined WTO in the end of 2001.

[6] OECD (2009) gives the detail of China reform process.

rate, inflation rate and unemployment rate since China's monetary policy is mainly used to maintain the capital controls and exchange rate policy and to set optimal interest rate.

On one hand, it seems that China should have a CA surplus, while on the other hand it seems not, so there is a paradox.

2.2 Research questions

Should China have a CA surplus and what actually affects China's CA balance? My research questions are as follows:

- Is the China's CA high surplus reasonable or not, or is China's CA surplus too high or not?
- Whether GDP growth rate of China, world real interest rate and real exchange rate of CNY have significant effects on China's CA balance and if so, how they affect China's CA behavior?

3 Literature review on current account research

There are many theoretical models developed to analyze the current account balance. In general, these models can be classified into four categories, including elasticity approach, absorption approach, portfolio approach, and inter-temporal approach, which are widely accepted and used.

Early research on external adjustments was static analysis and mainly focused on the role of monetary and fiscal policy in order to achieve a desired level of internal and external balance, but could not ensure long-term stability. Then it is the inter-temporal model, which reflects how CA is dynamically affected by domestic shocks (change of net output), and external shocks (real interest rate and real exchange rate), but its key empirical predictions often have not worked well. (Gourinchas and Rey (2013))

3.1 Literature review on current account analysis

3.1.1 Elasticity approach

The elasticity approach is the application of elasticity theory into supply and demand of foreign money market and mainly emphasizes the role of exchange rate in adjusting current account imbalance. The change in exchange rate will affect the price of imported and exported goods and services, thereby bringing the changes in net trade and affecting the CA balance. However, the elasticity approach has not considered the capital flow and treated CA balance as trade balance. Meanwhile it uses the static analysis, which could not dynamically analyze how CA imbalance happened. (Jiang (2013), pp 36-40)

The elasticity approach was first developed by J. Robinson based on the Marshall's Microeconomics and partial equilibrium analysis. In a recent global imbalance analysis Obstfeld and Rogoff (2005) argued that the global imbalance of exchange rate is the main reason for global CA imbalance.

3.1.2 Absorption approach

The absorption approach, proposed by S. Alexander based on the Keynes' national income equation in 1952, considers that in an open economy the current account balance is the difference between income and consumption. National income (Y) = Consumption (C) + Investment (I) + Government Expenditure (G) + [Export(X) – Import (M)], then trade balance (X-M) = Y – C – I –G = [Saving(S) – Investment (I)] + [Tax(T)-G]. If domestic consumption is larger than income, then it will have deficit in CA, and vice versa. (Jiang (2013), pp 40-42)

The representatives of this approach are Kawai and Maccini(1995), Rajan(2005) and Chinn(2005), and they investigated the effect of private and government consumption, investment and saving on CA.

Kawai and Maccini (1995) analyzed the connection of the American CA deficit and "twin deficits", government deficit (T-G) and negative private saving (S-I), and pointed that the

American CA deficit mainly comes from the deficit in government and insufficient private saving. Chinn (2005) further confirmed that the worsening of the American CA is due to the government deficit and inadequate private saving.

The absorption approach analyzes the CA from a macro level, which makes the CA analysis more systematically compared with elasticity approach. Though it treats the CA as trade account, which is the same as in the elasticity approach, and has not considered the income account and transfer account. As shown in Figure 1.2, the trade account is the major part of CA while the share of income and transfer accounts is very small, therefore considering the trade account as CA is reasonable.

3.1.3 Monetary approach

CA balance = - Capital and Financial account balance (excluded international reserves) + reserve assets. The monetary approach, proposed by H. Johnson and J. Frenkel in the 1970s, analyzes the CA from the view of reserves and considers that CA is a monetary phenomenon. If CA is in surplus, which means the money demand is larger than supply, then the extra demand of money should be balanced by international reserves, and vice versa. They assumed that domestic currency and international reserve can be substituted and rational investors should choose a suitable portfolio for their reserve assets. (Jiang (2013), pp 42-44)

Gourinchas and Rey (2005) showed that one of the main reasons why the return of American international investment keeps sustainably positive regardless of CA worsening is that America mostly chooses direct investment and equity investment in foreign countries, while foreign countries mostly choose government bonds as investments in America. American investors choose the high-risk investment, therefore get high return. Hausmann and Sturzenegger (2006) had a similar conclusion and pointed out that the deficit of American CA is due to high competence of American enterprises. American can borrow at a low interest rate from other countries and invest into high-risk and high-return markets, thereby compensating the CA deficit.

3.1.4 Inter-temporal approach

The inter-temporal approach, started in early 1980s, applies the permanent income hypothesis and inter-temporal consumption smoothing theory to CA analysis and considers the CA as the outcome of forward-looking dynamic saving and investment. It, derived from absorption approach and included elasticity approach, focuses on the optimal saving decision of a representative household to smooth consumption. For example, if an open economy experiences a temporary fall in output, then the country would be expected to smooth consumption by borrowing from world capital markets and thereby to run a temporary CA deficit.

The inter-temporal model, summarized in Obstfeld and Rogoff (1995) and borrowed from the optimal growth theory of Ramsey (1928), Cass (1965) and Koopmans (1965), considers the dynamic relationship between the change of net output and current account in order to provide a foundation for open-economy policy analysis (Gourinchas & Rey (2013)). The theoretical model is a giant leap forward, but its key empirical predictions have been often rejected [7](Gourinchas & Rey (2013)). Bergin and Sheffrin (2000) extended the simple inter-temporal model further to include interest rates and exchange rates to test whether the inter-temporal with variables of external shocks can explain CA fluctuations better.

Engel and Rogers (2006) pointed out that American CA deficit may be an optimal inter-temporal choice if based on inter-temporal analysis.

3.2 The recent research on current account

Recent research on global CA is mainly focused on how to adjust global imbalance and how to share the adjustment cost during global imbalance adjustments and how to build an efficient international monetary and financial system to adjust global imbalance efficiently.

[7] Nason and Rogers (2006) find that the test results of Canada CA soundly reject the present-value-model of the current account. Aguiar and Gopinath (2007) find that the current account fluctuations in small emerging economies are consistent with the theoretical model only when taking into account productivity shocks which seem much more persistent in emerging economies.

Recent research on European CA is mainly focused on how to adjust CA imbalance of each member countries in order to reach a compromised and efficient monetary policy.

Recent research on China's CA is focused on the Chinese government's substantial international reserves, and analyzed the welfare cost for its capital control policies and exchange rate policies maintained by the accumulation of international reserves (see Bacchetta et al. (2012), Bacchetta et al. (2013) and Jeanne (2012)). Considering that the CA surplus is the main source for international reserves in Chinese Central Bank, my research topic on China's CA is very important .

4 Methodology

The methodology used in this paper is based on the inter-temporal CA model developed by Bergin and Sheffrin (2000): it considers CA as a saving account for an open economy, an economy chooses an optimal CA balance based on the present value of future income just as a representative household makes an optimal saving decision to maximize the entire-life utility. Meanwhile the model considers time-varying real interest rate and real exchange rate since they can induce substitution in consumption between periods and substitution in international traded and non-traded goods.

The vector auto regression (VAR) model is used to generate empirical research results and to answer the research questions by checking the present value test results and VAR estimated results.

4.1 Methodology (1): Theoretical model

4.1.1 Why to choose inter-temporal approach?

There are three main reasons why I choose the inter-temporal model as the theoretical model.

Firstly, inter-temporal CA model uses a dynamical methodology and was developed by Bergin and Sheffrin in 2000. The original model only considered the variable of present value of future income, and now it takes into account other two variables including world real interest rate and real exchange rate to test whether the CA can be affected not only by the domestic shocks, the change of net output, but also by external shocks, such as world real interest rate and real exchange rate.

Secondly, empirical work showed that simple inter-temporal CA model works well for large countries, and almost fails for many small open economies. The failure is mostly due to the reason that small open economy can be easily affected by external shocks. (Bergin and Sheffrin (2000))

Finally, inter-temporal model is suitable for analyzing a semi-open economy such as China too, since China can enable inter-temporal trade as well as an open economy (Bacchetta et al. (2012)). As shown in Bacchetta et al. (2012), a semi-open economy with limited capital mobility may have a higher welfare than an open economy through choosing an optimal real interest rate while an open economy cannot.

4.1.2 Inter-temporal current account model

Following Dornbusch (1983), a small open country producing traded and non-traded goods can borrow from and lend to the rest of the world at a time-varying real interest rate. A representative household chooses a path of consumption and debt to maximize their discounted lifetime utility.

$$\text{MaxE}_0 \sum_{t=0}^{\infty} \beta^t U(C_{Tt},\ C_{Nt}) \quad (1)$$

$$\text{s.t. } Y_t - (C_t + P_t C_{Nt}) - G_t - I_t + r_t B_{t-1} = B_t - B_{t-1} \quad (2)$$

Where $U(C_{Tt}, C_{Nt}) = \frac{1}{1-\delta}(C_{Tt}^{a}\ C_{Nt}^{1-a})^{1-\delta}$ (δ>0, δ=/1, 0<a<1)

C_{Tt} : Consumption of traded good, C_{Nt}: Consumption of non-traded good, $C_t = C_{Tt} + C_{Nt}$ is the total consumption expenditure in terms of traded goods.

Y_t is the GDP in current period, I_t is investment, and G_t is government consumption on goods and services, and all the values are measured in terms of traded goods. P_t is the relative price of domestic non-traded goods in terms of traded goods. B_t is the stock of external assets at the beginning of the period, and r_t is the net world real interest rate in terms of traded goods, which may vary exogenously over time. The left-hand side of (2) is the current account.

Then one can get the inter-temporal Euler equation or the optimal consumption profile:

$$1 = E_t[\, \beta^{\gamma}\, (1 + r_{t+1})^{\gamma}\, \frac{C_t}{C_{t+1}} (\frac{P_t}{P_{t+1}})^{(\gamma-1)(1-a)}] \quad (3)$$

$\gamma=\frac{1}{\sigma}$ is the inter-temporal elasticity of substitution. This derivation generally follows the well-known methods described in Dornbusch (1983) and Obstfeld and Rogoff (1996), and Appendix 1 in Bergin and Sheffrin (2000) derives it.

Here the consumption growth rate is defined as $\Delta c_{t+1} = logC_{t+1} - logC_t$, the percentage change in the relative price of non-traded goods defined as $\Delta P_t = logP_{t+1} - logP_t$, gross world real interest rate defined as $r_t = \log(1 + r_t)$, and r_t^* is the consumption-based real interest rate. It is assumed that the variances and covariance among Δc_{t+1} , ΔP_t and r_t are not time-varying.

Then (3) can be written in a log-linearized form:

$$E_t \Delta c_{t+1} = \gamma E_t (r_{t+1}^*) \quad (4)$$

$$r_t^* = r_t + \frac{1-\gamma}{\gamma} (1 - a)]\Delta P_t + \text{Constant} \quad (5)$$

The constant term in (5) will drop out in the later empirical model.

For a representative consumer in an open economy, an increase in the real interest rate which makes current consumption more expensive in terms of future consumption will induce a substitution toward future consumption with elasticity γ.

Meanwhile the temporarily low price of traded goods is expected to rise in the future, which makes the current consumption more expensive in terms of traded goods alone, will lower the current total consumption by elasticity γ(1-a) through substituting toward future consumption in non-traded goods and will rise the total current consumption by intra-temporal elasticity (1-a) through substituting toward traded goods as well.

Using the budget constraint of the optimization of consumption (2), the CA may be written:

$$CA_t = Y_t - (C_t + P_t C_{Nt}) - G_t - I_t + r_t B_{t-1} = B_t - B_{t-1} \quad (6)$$

$$CA_t = NO_t - C_t + r_t B_{t-1} \quad (7)$$

Here net output $NO_t = Y_t - G_t - I_t$.

Define R_s as the market discount factor for time s consumption, therefore

$$R_s = \frac{1}{\prod_{j=1}^{s}(1+r_j)}, \text{ then } \lim_{t\to\infty} E_0 (R_t B_t) = 0 \quad (8)$$

The inter-temporal budget constraint (7) can be rewritten as

$$\sum_{t=0}^{\infty} E_0 (R_t C_t) = \sum_{t=0}^{\infty} E_0 (R_t NO_t) + B_0 \quad (9)$$

Log linearize (9) as:

$$-\sum_{t=1}^{\infty} \beta^t \left[\Delta no_t - \frac{\Delta c_t}{\Omega} - \left(1 - \frac{1}{\Omega}\right) r_t\right] = no_0 - \frac{c_0}{\Omega} + (1 - \frac{1}{\Omega}) b_0 \quad (10)$$

Where lower case letters represent the logs of upper case counterparts, except the world real interest rate, $\Omega = 1 - \frac{\bar{B}}{\sum_{t=0}^{\infty} R_t C_t}$ is a constant slightly less than one, $\bar{B}$ is the steady state value of net foreign assets. This log linearization follows the methods described in Campbell and Mankiw (1989) and Huang and Lin (1993) and Appendix 2 in Bergin and Sheffrin (2000) illustrates it.

Next, take expectations of (10) and substitute (4) into:

$$-E_t \sum_{i=1}^{\infty} \beta^i \left[\Delta no_{t+i} - \frac{\gamma}{\Omega} r_{t+i}^* - \left(1 - \frac{1}{\Omega}\right) r_t\right] = no_t - \frac{c_t}{\Omega} + (1 - \frac{1}{\Omega}) b_t \quad (11)$$

We assume that in a steady state net foreign assets are zero, which means $\bar{B}$ is zero, and Ω=1. The right side of equation (11) is similar to the definition of the current account in (6), except that its components are in log terms. We define this transformed representation of the current account as CA^*, then (11) can be written as:

$$CA_t^* = -E_t \sum_{i=1}^{\infty} \beta^i \ [\Delta no_{t+i} - \gamma r_{t+i}^*] \tag{12}$$

$$CA_t^* = no_t - c_t \tag{13}$$

4.2 Methodology (2): Econometric method

4.2.1 Vector Autoregression model

The restriction in (12) is tested by using the approach of Sheffrin and Woo (1990b), with a consideration of an additional variable r^*(Bergin and Sheffrin (2000)). First the Vector Auto Regression (VAR) is used to get the estimation of these two present values.

$$\begin{pmatrix} \Delta no \\ CA^* \\ r^* \end{pmatrix}_t = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} \Delta no \\ CA^* \\ r^* \end{pmatrix}_{t-1} + \begin{pmatrix} u_1 \\ u_2 \\ u_3 \end{pmatrix}_t \tag{14}$$

Or written as $Z_t = AZ_{t-1} + u_t$, then $E_{t-1}(Z_t) = A\,Z_{t-1}$, then get $E_t(Z_{t+i}) = A^i\,Z_t$ [8].

Since $CA_t^* = (0 \;\; 1 \;\; 0) \begin{pmatrix} \Delta no \\ CA^* \\ r^* \end{pmatrix}_t = h^* Z_t \quad (h = (0\;1\;0))$ (a)

$$\Delta no_{t+i} = (1 \;\; 0 \;\; 0) \begin{pmatrix} \Delta no \\ CA^* \\ r^* \end{pmatrix}_{t+i} = g_1\, Z_{t+i} = g_1 A^i Z_t \quad (g_1 = (1\;0\;0)) \tag{b}$$

$$r^*_{t+i} = (0 \;\; 0 \;\; 1) \begin{pmatrix} \Delta no \\ CA^* \\ r^* \end{pmatrix}_{t+i} = g_2\, Z_{t+i} = g_2 A^i Z_t \quad (g_2 = (0\;0\;1)) \tag{c}$$

Substitution of (a) (b) (c) into (12) gives:

$$h^* Z_t = -\sum_i^{\infty} \beta^i (g_1 - \gamma g_2) A^i Z_t \tag{15}$$

For given Z_t, we can get $\widehat{CA_t^*}$ = K Z_t, Where K= - $(g_1 - \gamma g_2)\beta\, \hat{A}\, (1 - \beta \hat{A})^{-1}$ (16)

Running the given Z_t can get estimated A, then substitute the estimated A into (16) *to* test whether *K is statistically equal to (0 1 0)* significantly**.**

[8] Assumption here: u_t is white noise and estimated constant is zero in VAR model.

The test of a simple model, which holds consumption-based real interest rates constant would involve a VAR that omits the third equation and the third variable, r^*. Then h = (0 1), $g_1 = (1 \;\; 0)$, K=$-g_1'\beta\,\hat{A}\,(1-\;\beta\hat{A})^{-1}$, and it is tested whether K is equal to (0 1) significantly.

Here K Z_t is not the forecast of current account, but it is the representation of restrictions in the inter-temporal model. If the restrictions of the theory were satisfied, such that $\widetilde{CA}_t^* = \; CA_t^*$, then the vector K should equal to [0 1 0] in a significant level when lag period P = 1. Meanwhile the estimated CA can be compared graphically with the observed CA as an indication of the performance of VAR model.

If number of lags P >1, the $Z_t = A_1 Z_{t-1} + \; A_2 Z_{t-2} \; + \cdots\cdots + \; A_p Z_{t-p} + \; u_t$, and it always can be rewritten as VAR(1) form:

$$\begin{pmatrix} Z_t \\ Z_{t-1} \\ \vdots \\ \vdots \\ Z_{t-p+1} \end{pmatrix} = \begin{pmatrix} A_1 & A_2 & \cdots & A_{t-p+1} & A_{t-p} \\ 1_k & 0 & 0 & 0 & 0 \\ \vdots & 1_k & \ddots & 0 & \vdots \\ 0 & 0 & 1_k & 0 & 0 \\ 0 & 0 & \cdots & 1_k & 0 \end{pmatrix} \begin{pmatrix} Z_{t-1} \\ Z_{t-2} \\ \vdots \\ \vdots \\ Z_{t-p} \end{pmatrix} + V_t$$

$$\text{Then } \;\widehat{\boldsymbol{A}} = \begin{pmatrix} A_1 & A_2 & \cdots & A_{t-p+1} & A_{t-p} \\ 1_k & 0 & 0 & 0 & 0 \\ \vdots & 1_k & \ddots & 0 & \vdots \\ 0 & 0 & 1_k & 0 & 0 \\ 0 & 0 & \cdots & 1_k & 0 \end{pmatrix}$$

Substitute $\hat{A}$ into (16) to test whether **K** is equal to **(0 1 0 0 0….)**, and the number of lines (columns) of the vector K is p times the number of variables in the VAR model.

4.2.2 Model checks of adequate VAR model

4.2.2.1 Diagnostic test

The error items in equation (14) are assumed to be white noise. If they are not white noise, then VAR estimations may be not correct. For instance, if error items are highly correlated or do no follow normal distribution, then standard error and t statistic will not be correct; if recursive residuals are not stable, then estimated coefficient will not be consistent with the real coefficient.

Therefore, we need to test whether autocorrelation exists in residuals and whether the error items are stable and normally distributed. Here adjusted Portmanteau test statistic is applied to test autocorrelation of residuals, the uni- and multivariate Jarque-Bera test are used to test normality and rec-CUSUM test is used to test stability.

4.2.2.2 Granger-causality test

The Granger-causality is a predictive causality other than a true cause-effect relationship. The equation in (14) implies that the time series of Δno and r* should be able to predict the CA*, meaning that the times series of Δno and r*should be Granger-causal to current account CA*, otherwise the variables Δno and r* are not able to predict CA*. Therefore the Granger-causality test is necessary.

5 Data

Five variables NO (net output), C (consumption), CA*(current account), r (world real interest rate) and p (real exchange rate) need to be defined in this part in order to get the final three variables r*(consumption-based world real interest rate), Δno (difference of log net output), and CA*. Then explanations from where to collect raw data and how to refine and adjust them to get the final data of these three time series r*, Δno, and CA* will be given.

The equations of (12) and (5) show that tests of inter-temporal current model need to combine the values of the parameters β (discount factor), a (the share of traded goods) and γ (inter-temporal elasticity). Therefore, the values of three parameters including β, a, and γ, need to be known too. Bergin and Sheffrin (2000) experimented GMM estimation of equation (3) to choose parameter values, but their results were imprecise with large standard errors and the estimated share of tradable goods were even outside of the theoretical range. However, the estimations of β, a, and γ are out of the scope of this thesis research, therefore the values assigned to β, a and γ are mainly taken from the previous empirical research results.

5.1 Defining variables and parameters

a. **Net output (NO)**: According to Bergin and Sheffrin (2000), $NO_t = Y_t$ - G_t - I_t

In the annual data, net output is obtained subtracting investment (gross capital formation included gross fixed capital formation and changes in Inventories) and government expenditure from GDP.

In the quarterly data, the investment in fixed assets in most periods is even larger than GDP, so it is reasonable to adjust the investment as 'estimated investment" through subtracting the total private consumption, government expenditure and current account balance from GDP, then get net output as the same calculation as annual data.

Equation (12) uses log and difference form:

$$\Delta no_t = \log(Y_t - G_t - I_t) - \log(Y_{t-1} - G_{t-1} - I_{t-1})$$

b. **Consumption (C)**: private final consumption

In the annual data, it is the total final consumption deducting the government consumption;

In the quarterly data, it is the 'total retail sales of consumer goods' deducting the government consumption.

c. **Current Account (CA_t^*)**: Following Bergin and Sheffrin (2000), CA* is obtained subtracting the log of consumption in b from the log of net output in a, rather than logging the current account data from the balance of payments, since a big difference might occur between CA*= $\log(Y_t - G_t - I_t)$ - $\log C_t$ and log(CA) = log $(Y_t - G_t - I_t - C_t)$ especially when CA balance is in deficit.

$$CA_t^* = \log NO_t - \log C_t$$

d. **World real interest rate (r)**: following the method of Barro and Sala I Martin (1990), the world real interest rate is a time-varying weighted average real interest rate of G7 economies. Here I added China, and the world real interest rate is weighted average interest rate of G7 economies and China.

- Nominal interest rate: the annual and quarterly nominal interest rates of the G7 economies (Canada, France, Germany, Italy, Japan, United Kingdom and United States) and China.
- Expected inflation: Following Barro and Sala I Martin (1990), inflation in each country is measured using that country's consumer price index, and expected inflation is forecasted using a four-quarter auto regression in quarterly data and four-year auto regression in annual data, $E(P_t) = \widehat{\alpha_1} P_{t-1} + \widehat{\alpha_2} P_{t-2} + \widehat{\alpha_3} P_{t-3} + \widehat{\alpha_4} P_{t-4}$.

Then world real interest rate: $r_t = \sum w_i \frac{nominal\ interest\ rate_{\ t}}{1 + Expected\ inflation\ rate\ t}$

e. **Real exchange rate (p):** following Rogoff (1992), first convert the market exchange rate index of China into real terms using a consumption price index. An ex-ante expected exchange rate appreciation is computed, $E_t \Delta p_{t+1}$, using a four-quarter auto regression in quarter and four-year auto regression in annual data, logging and differencing. Finally, the consumption-based real interest rate is calculated using the common world real interest rate and the rate series derived above, as specified in (5).

$$r_t^* = r_t + [\frac{1-\gamma}{\gamma}(1-a)]\Delta P_t \qquad (\Delta P_t = \log \frac{real\ exchange\ rate_t}{real\ exchange\ rate_{t-1}})$$

β: the discount factor in consumption utility function. Following Bergin and Sheffrin (2000), $\beta = \frac{1}{1+\bar{r}}$, $\bar{r}$ is the sample mean of world real interest rate in the dataset.

a: the share of traded goods in private final consumption. a is one-half following Stockman and Tesar (1995) estimation and two-thirds following Kravis et al. (1982) based on G7 countries. Compared with G7 economies, the share of traded goods in private final consumption of China should be less. The average ratio of import to the aggregated final consumption, including private final and government consumption, is around 0.34. Surely the actual share of traded goods in private final consumption should be less than 0.34, and here the assigned a is 0.2 and 0.5, and the model tests consider both values for the share parameters.

γ: the inter-temporal elasticity. It is the most problematic of the three parameters, and the empirical estimated value ranges widely[9]. Here following Campbell and Shiller (1988) method, γ has been assigned as 0.087, 0.5 and 1 (the same series of γ values as in Bergin and Sheffrin (2000)) as reference values to check how the main results change.

5.2 Data and data sources

There are two datasets: annual data from 1980 to 2013 and quarterly data from 1994Q1 to 2014Q2. The data country is mainland China.

Due to the unavailability of some data, the periods of time series both in annual data and quarterly data are too short. There two datasets are chosen to convince the research results.

The annual and quarterly data of real interest rate and consumption-based real interest are available in the International Financial Statistics (IFS)[10].

Both National Bureau of Statistics of China (NBSC) and IFS provide the annual data for GDP, G, I, C and CA whereas most quarterly and monthly data for time series GDP, G, I, C and CA are missing in IFS, therefore the NBSC is the main source for quarterly data.

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[9] Hall (1988) estimates that the inter-temporal elasticity is might be less than 0.1 or may close to zero; Mehra and Prescott (1985) suggest that inter-temporal elasticity should be greater than 0.5; while Campbell and Shiller (1988) test the model with a range of values of the inter-temporal elasticity and suggest the γ that can fit the model best, they also call it as a method of moments estimation.

[10] If some data, especially the data after 2008, are not available in IFS, then the data sources are World Bank, European Central Bank data warehouse (ECB), World Bank or Organization for Economic Co-operation and Development (OECD).

5.2.1 Annual Data

The annual data for nominal deposit interest rates, T-bill rate or equivalent, price index, GDP and exchange rate of G7 economies and China are collected from IFS, and no adjustments are needed.

Here I use the balance sheet data of 'Gross Domestic Product by Expenditure Approach' provided by NBSC as the annual data source, showing that GDP = final consumption $(C_{private} + G)$ + gross capital formation + net export, and therefore no adjustments are needed in this part.

5.2.2 Quarterly data

The quarterly data period is from 1994Q1 to 2014Q2. The quarterly data of nominal deposit interest rates, T-bill rate or equivalent, price index, GDP and exchange rate of G7 economies and China are collected from IFS, and some data of recent quarters are missing in IFS but can be got from ECB data warehouse, World Bank or OECD Statistics, and therefore no adjustments are made in this part.

5.2.2.1 Seasonally adjusted in G and C

Seasonally adjusted time series of Δno and CA*. NBSC only provides the monthly data rather than quarterly data of total retail sales of consumption, investment in fixed assets and government expenditure, which are not available in IFS, and so I summarize the monthly data and simply calculate the quarterly data.

For missing observations (just quite few data are missing), the same method is used as in computing expected inflation, using a four-quarter auto regression to compute an *ex-ante* one as a substitution of missing observation.

5.2.2.2 Autoregression in G and CA

NBSC provides the monthly data of government expenditure from 2001Q1 and IFS provides quarterly data of government expenditure in cash for period 1999Q1 to 2000Q4, therefore true period of government expenditure is 1999Q1 to 2014Q2.

The quarterly data of CA balance can be obtained from 1998Q1 to 2014Q2 in State Administration of Foreign Exchange (SAFE) and monthly data of net trade from 1994Q1 to 1997Q1 can be obtained in NBSC.

The quarterly data of GDP are available from 1992Q1 in NBSC. Then it means that the true data of time series Δno and CA* is only available from 1999Q1 and 2014Q2, totally 62 periods, which might be too short and wastes some available data in GDP and CA balance.

Then I use a four-quarter reverse auto regression, $E(G_t) = \widehat{\alpha_1}\, G_{t+1}$ + $\widehat{\alpha_2}\, G_{t+2}$ + $\widehat{\alpha_3}\, G_{t+3}$ + $\widehat{\alpha_4}\, G_{t+4}$ to get the missing data for time series of government expenditure from 1994Q1 to 1998Q4 and time series of CA balance from 1994Q1 to 1994Q2.

5.2.2.3 The adjustments in I, CA and GDP

The data of investment in fixed assets from NBSC is quite large, and in some periods it is even larger than GDP. The sum of quarterly investment for each year might contain both public and private investment, not just only private investment. While the data of private investment is not available, I simply calculate the 'estimated investment' following the definition of Keynesian national accounting equation through subtracting the total private consumption, government expenditure and CA balance from GDP, and use the estimated data to substitute the true data provided by NBSC.

The quarterly data of CA balance provided by SAFE from 1998Q1 and 2014Q2 are only measured in USD, and need to convert into CNY, which is the same unit used for measuring GDP and expenditure, through multiplying foreign exchange rate between CNY and USD provided by IFS.

The quarterly data of GDP from NBSC is only provided in an accumulated form and there is no current period value, so the accumulated GDP needs to be transferred into current period GDP through deducting the accumulated GDP in period t from accumulated GDP in period t+1.

6 Empirical Results

6.1 Stationarity test results

The assumption of using VAR model is that the time series used in VAR should be stationary, or the VAR regressions are spurious regressions. Here both Dickey-Fuller unit root test (ADF) and Phillips-Perron unit root test (PP) were used to check the stationarity of time series Δno_t , $CA_t^* \ and \ r_t^*$. The stationarity test is performed by a range of lags, and here I choose the number of lags n equals to 1, 2 and 3 to test. Since the periods of my time series data are very short, 34 periods in annual data and 82 periods in quarterly data, and too large number of lags may be not suitable for a short time period. The trade of goods share a is assigned as 0.5 and γ as 0.087 to compute the corresponding r*.

The unit root test results of annual variables and quarterly variables are in Appendix 1. Both ADF and PP test reject the presence of a unit root at least at 5% significance level for all the above-mentioned number of lags considered, except the shaded parts in the table. The consumption-based interest rate r* in ADF test is non-stationary when number of lags equals to 2 and 3 in annual data and non-stationary when number of lags equals to 1 and 2 in the quarter data, also CA in ADF is non-stationary when number of lags equals to 2 and 3 in annual data.

6.2 VAR model

There are two VAR models, bivariate VAR and trivariate VAR, in annual data and quarterly data respectively.

The simple model which excludes the interest rate and exchange rate is bivariate VAR including only the change of net output Δno and current account CA*. While the alternative model which includes a time-varying consumption-based real interest rate is trivariate VAR including the change of net output Δno, current account CA* and consumption-based real interest rate r*. Four groups of data have been used to run in trivariate VAR model to check whether the change in a and γ can affect the prediction of current account and the four groups are (a=0.5, γ=0.087), (a=0.2, γ=0.087), (a=0.2, γ=0.5), (a=0.2, γ=1).

6.2.1 Specification of adequate VAR

For annual data, in the simple model both Akaike information criterion (AIC) and Bayesian information criterion (BIC) suggest that the adequate VAR has two lags. In the alternative model, and in all the four groups, AIC suggests that the adequate VAR has three lags, while BIC suggests only one lag, so here I use VAR (1) model for simplifying the analysis, also because my time series are short.

For quarterly data, in the simple model, four lags are used suggested by both AIC and BIC; in the alternative model, BIC suggests one lag and AIC suggest three lags in all four groups of data, and one lag is in use in all four groups according to BIC suggestions.

6.2.2 VAR estimation results

Diagram of fitted and observed CA in Appendix 2 shows that VAR model performs quite well.

6.2.2.1 Annual VAR estimation results

Appendix 2.1 is the diagram of fit and residuals for China's CA using annual data (1980 - 2013) in the simple model. Appendix 2.2 shows four group diagrams of fit and residuals for China's CA using annual data (1980 - 2013) in the alternative model with different values of a and γ, (a = 0.5, γ = 0.087), (a = 0.2, γ = 0.087), (a = 0.2, γ = 0.5) and (a = 0.2, γ = 1).

As shown in the diagrams, both bivariate and trivariate VAR models work fairly well in predicting the general direction of current account fluctuations, which captures the direction of most current account fluctuations, such as the deficit in the middle and late 1980s, and increased surplus after 2000, highest surplus around 2007 and 2008 and decreased surplus after 2008. However, the prediction slightly lags behind actual value and the fluctuation of the fitted current account is a little bit smaller than observed one.

Taking the consumption-based interest rate into consideration has not improved prediction of CA a lot, and the prediction of current account is quite similar under different values of a and γ.

But as shown in Appendix 3.1, after adding r*, the CA is positively correlated with the change of net output, while without considering r*, CA is negatively and positively correlated with the change of net output in lag one and lag two periods, respectively. In trivariate VAR(1) model, last year's change of net output Δno and last year's consumption-based interest rate r* significantly affect the CA. While last year's CA in the bivariate VAR(2) estimation and the year before last year's CA and change of net output in the trivariate VAR(1) do not significantly affect CA. Therefore, in the annual VAR estimation, CA can be significantly affected by the last period Δno and r*.

In both the bivariate and trivariate VAR models, the constant is significantly different from zero, while the trend is only significantly different from zero in the trivariate VAR(1) model but not in the bivariate VAR(2) model.

6.2.2.2 Quarterly VAR estimation results

Appendix 2.3 is the diagram of fit and residuals for China's CA using quarterly data (1994Q1 – 2014Q2) in the simple model. Appendix 2.4 are four group diagrams of fit and residuals for China's CA using quarterly data (1994Q1 – 2014Q2) in the alternative model with different values of a and γ ((a = 0.5, γ = 0.087), (a = 0.2, γ = 0.087), (a = 0.2, γ = 0.5), and (a = 0.2, γ = 1)).

Quite similar results in the quarterly data, both bivariate and trivariate VAR models do fairly well in predicting the general direction of current account fluctuations. They capture the direction of most current account fluctuations, such as the small surplus before 2004, and increased and high surplus around 2006, 2007 and 2008, high fluctuations around 2009 and decreased surplus after 2008. Same as in the annual diagrams, the prediction is a little bit lagging from actual value and the fluctuation is a little bit smaller than the observed one. Taking consumption-based interest rate into consideration has not improved the prediction of CA a lot, but the prediction of current account is quite similar under different values of a and γ.

Estimation results of quarterly data are shown in Appendix 3.2. In the simple model CA is negatively correlated with the change of net output, while after adding r*, the CA is positively correlated with the change of net output.

In the simple model, the Δno in last two and four periods has a positive effect on CA and in last three periods has no significant effect on CA. However, the CA in the last two and three periods has a negative effect on CA. In the alternative model, last year's change of net output Δno and last year's consumption-based on interest rate r* positively and significantly affect the CA, but last year's CA has not significantly affected the CA.

In the simple model, the constant and trend are significantly different from zero in. In the alternative model, the constant is significantly different from zero, while the trend is not.

6.2.3 Results of model checks

Granger causality test results and test results for autocorrelation, stability and normality of residuals are shown in Appendix 4.

In Granger-causality test, if P value was larger than 5%, then we cannot reject the null hypothesis that Δno and r* do not Granger-cause CA and we cannot reject the null hypothesis that Δno and r* do not instantaneous-cause CA under 95% confidence interval. Granger causality test results show that Δno and r* have Granger causality to CA, and shaded parts mean that there is an instantaneous causality between Δno, r* and CA, indicating that current period Δno and r* have effects on CA too, not just former period affect this period's CA. The existence of instantaneous causality suggests that structural VAR model could give out better estimation results than VAR model.

Portmanteau test results show that null hypothesis of 'no autocorrelation of residuals at lags 1… m' cannot be rejected at least at 5% significant level except in the shaded part.

There is almost no autocorrelation between error items and only error items in the annual simple model (shaded part) are correlated, therefore the adequate VAR models are good models.

If P value in Jarque-Bera normality test was less than 5%, then we cannot reject the null hypothesis and all the sample values follow a normal distribution under 95% confidence interval. The shaded parts in Appendix 4 mean that the error items of the corresponding variable follow normality and all the sample values of CA follow normality.

Under the Rec-CUSUM test results as shown in Appendix 5, the residuals of Δno, CA and r* are stable under the 95% confidence interval and only residuals of Δno in quarterly simple model do not followed stability.

Nevertheless, the VAR model performs well and results from model checks are good though the values of most samples do not follow normality. We still can use VAR to make forecast and analyze how the change of net output and consumption-based interest rate affect CA behavior.

6.2.4 Impulse response analysis

Impulse response analysis traces out the response of one variable to an impulse in another variable, for instance, what is the response of an impulse to the change of interest rate on CA immediately, the next quarter, after two quarters etc. It summarizes the dynamical effects of Δno, CA and r* and describes how these three economic variables mutually affect each other.

Appendix 6 contains only quarterly impulse response analysis using the bivariate and trivariate VAR model with ($a = 0.2$, $\gamma = 0.087$). Since the results from the VAR estimation and model checks are rather similar regardless of different values of a and γ, therefore the results in Appendix 6 are more than enough to find out whether GDP growth rate of China, world real interest rate and real exchange rate of CNY have significant effects on China's CA balance and how they affect China's CA behavior.

As shown in Appendix 6.1, in the simple model, one unit economic shocks from the change of net output Δno has positive effects on CA, which increase and decrease to zero, then increase and decrease to zero with a smaller magnitude. After repeating several periods, the effects converge to zero after around 20 periods. The cumulative effect of Δno on CA converges to a positive number, while its lower band of 95% confidence interval is below zero, so one cannot conclude that Δno has significantly positive effects on CA, but can clearly observe the trending positive effects of Δno on CA.

One unit economic shock from the CA itself has positive effects on CA too, which swiftly drop and then increase, repeating to fluctuate for many periods with smaller and smaller fluctuations, but still have not converged to zero after 20 periods. The cumulative effect from CA itself converges to a positive number, but shocks from the CA have very small effects on Δno and the cumulative effect from CA on Δno converges to a tiny negative constant.

As shown in Appendix 6.2, in the alternative model, after adding r*, economic shocks from the change of net output Δno have positive effects on CA. They severely affect CA in the present and next period, then their effects gradually decrease and converge to zero after five or six quarters, but does not fluctuate similarly as in the simple model. The cumulative effect on CA from Δno converges to a positive number and its lower band of 95% confidence interval is below zero, but one can clearly observe the trending positive effects of Δno on CA though the positive effects are not significant. Shocks from Δno almost have no effects on r*.

Shocks from r* have most sustained positive effects on CA compared with the shocks from △no and CA itself, but have the same strong cumulative effects on CA as Δno. The effects of economic shocks from r* on CA increase to the strongest after three or four periods, and then slowly drop and converge to zero at around 20 periods later. The cumulative effect on CA from r* converges to a positive number and its lower band of 95% confidence interval is below zero too, but the trending positive effects of r* on CA is very obvious though not significantly. Shocks from r* have almost no effects on Δno neither.

Shocks from the CA itself have effects on CA too, which gradually drop and converge to zero after around seven periods. However, shocks from the CA have no effects on Δno and r*.

6.3 Present value test

6.3.1 Present value test results (Theoretical model test results)

In the bivariate VAR model, in the annual data the adequate VAR model is VAR(2) model, then

$$\begin{pmatrix}\Delta no\\ CA^*\end{pmatrix}_t = \begin{pmatrix}a_{11} & a_{12}\\ a_{21} & a_{22}\end{pmatrix}\begin{pmatrix}\Delta no\\ CA^*\end{pmatrix}_{t-1} + \begin{pmatrix}b_{11} & b_{12}\\ b_{21} & b_{22}\end{pmatrix}\begin{pmatrix}\Delta no\\ CA^*\end{pmatrix}_{t-2}\ \begin{pmatrix}u_1\\ u_2\end{pmatrix}_t$$

$$\begin{pmatrix}\Delta no_t\\ CA_t^*\\ \Delta no_{t-1}\\ CA_{t-1}^*\end{pmatrix} = \begin{pmatrix}a_{11} & a_{12} & b_{11} & b_{12}\\ a_{21} & a_{22} & b_{21} & b_{22}\\ 1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\end{pmatrix}\begin{pmatrix}\Delta no_{t-1}\\ CA_{t-1}^*\\ \Delta no_{t-2}\\ CA_{t-2}^*\end{pmatrix} + \begin{pmatrix}u_{1t}\\ u_{2t}\\ 0\\ 0\end{pmatrix}$$

Here h = (0 1 0 0), g_1= (1 0 0 0), $\hat{A}$ = $\begin{pmatrix}a_{11} & a_{12} & b_{11} & b_{12}\\ a_{21} & a_{22} & b_{21} & b_{22}\\ 1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\end{pmatrix}$

Since K = - $g_1\, \beta\, \hat{A}\, (1 - \beta\hat{A})^{-1}$, substituting estimated A into K equation allows to test whether K is equal to (0 1 0 0).

Meanwhile in the bivariate VAR model, in the quarterly data the adequate VAR model is VAR(4): then h = (0 1 0 0 0 0 0 0), g_1= (1 0 0 0 0 0 0 0),

$$\hat{A} = \begin{pmatrix} a_{11} & a_{12} & b_{11} & b_{12} & c_{11} & c_{12} & d_{11} & d_{12} \\ a_{21} & a_{22} & b_{21} & b_{22} & c_{21} & c_{22} & d_{21} & d_{22} \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \end{pmatrix}$$

K = - $g_1 \, \beta \, \hat{A} \, (1 - \beta\hat{A})^{-1}$, estimated A is substituted into K equation to test whether K is equal to (0 1 0 0 0 0 0 0) in a significant level.

In the trivariate VAR model, the adequate VAR model is only VAR(1), then it is tested whether K is equal to (0 1 0) as illustrated in part 4.2.1.

The present value (PV) test results, presented in Appendix 7, soundly reject the theoretical model. The columns 1 to 5 and columns 6 to 10 are the PV test results for annual data and quarterly data, respectively.

The inter-temporal theory suggests that in the bivariate VAR(2) model the K-vector should be [0 1 0 0]. While column 1 shows that the estimated K-vector is [-0.823 0.114 0.544 -0.078]. The estimated coefficient of the current account at date t is 0.114, which is significantly different from zero and also significantly different from one suggested by the theory. Furthermore, the values on the change of net output, lagged change of net output and lagged current account are significantly different from their theoretical values of zero. Overall, the model can be strongly rejected with a p-value of zero.

The inter-temporal theory suggests that in the trivariate VAR(1) model the K-vector should be [0 1 0]. While columns 2 to 5 and columns 7 to 10 with different values of a and γ show that the estimated coefficient of the current account at date t is around 0.15, which is significantly different from zero and significantly different from one suggested by the theory. The values on the change of net output and consumption-based real interest rate are significantly different from their theoretical values of zero as well. Overall, the model can be strongly rejected with a p-value of zero too.

The inter-temporal theory suggests that in the bivariate VAR(4) model the K-vector should be [0 1 0 0 0 0 0 0]. While the column 6 shows that the estimated coefficient of the current account at date t is 0.189, which is significantly different from zero and also significantly different from one suggested by the theory, and the same the values on net output and lagged current account and net output are significantly different from their theoretical values of zero. Overall, the model can be strongly rejected with a p-value of zero.

The last row in the table shows that the model prediction is about 85% as volatile as the actual data, which is consistent with the diagram analysis in Chapter 6.2.2.

6.3.2 Possible reasons for the failure of PV test

One main reason for the failure of PV test is that some important assumptions in the inter-temporal model have not been satisfied.

For instance, the white noise assumption of error items has not been satisfied, and the residuals are not normally distributed. Also the assumption of zero constant in the VAR model has not been satisfied. VAR estimation results show that the constant in CA estimation equation is significantly different from zero. While if the constant is not zero, the illustrated present value equation (15) will be a different formula. Additionally during the theoretical illustration, it is assumed that in a steady state the net foreign assets are zero, and one can get the equation (12), but China is not in a steady state and its economy is in fast transition, thus this assumption might not be satisfied.

ADF test shows that time series of consumption-based interest rate r* is not stationary when number of lags is 1 in the quarterly data, which might be one reason for the failure of PV test in the alternative model of quarterly data.

Granger-causality test shows that there is an instantaneous causality between Δno, r* and CA, therefore Structural VAR model might give out more correct estimation results than the VAR model.

China joined the World Trade Organization (WTO) at the end of 2001, allowing China to trade with the rest of the world with less tariff barriers, especially greatly promoting the international trade between United States and China. Therefore, omitting an important dummy variable (joining WTO) which affects the correctness of estimation results may be another reason for the failure of PV test.

As discussed before China is a semi-open economy, and its true market economy started only from late 1990s and retail prices were not market-determined until 1995. While my data periods are from 1980 to 2013 and from 1994Q1 to 2014Q2, so the properties of data itself may be not so suitable for the inter-temporal theoretical model.

7 Conclusions

The paper uses the VAR model to investigate whether GDP growth rate of China, world real interest rate, and real exchange rate of CNY have significant effects on China's CA balance and how they affect China's CA behaviors. Both bivariate VAR model with 'Δno and CA' and trivariate VAR model with 'Δno, CA and r*' perform quite well and adding r* has not improved the prediction of CA a lot.

In the VAR model both Δno and r* have significant effects on CA and their cumulative effects on CA converge to positive numbers. The lower bands of their converged numbers are below zero in 95% confidence interval. Although the positive effects from Δno and r* on CA are not significant, one can clearly observe the trending positive effects of Δno and r* on CA. Consistently, one previous empirical work showed the positive correlation between growth and saving (Blanchard et al, 2014). Furthermore, impulse response analysis results suggest that r* has more sustained effects on CA compared with Δno, though their cumulative effects on CA are similarly strong in the long term. Therefore one of my research question - whether GDP growth rate of China, world real interest rate and real exchange rate of CNY have significant effects on China's CA balance and how they affect China's CA behavior is solved.

Meanwhile the paper tests whether China's CA surplus is reasonable based on the inter-temporal theoretical model. The test results reject the theoretical model. Then the paper lists some possible reasons why the theoretical model test fails. For instance, the white noise assumption of error items is not satisfied; zero assumption of constant in the theoretical illustration which is significantly different from zero in the VAR estimation is not satisfied; steady state is assumed in the theoretical model, but China is not a steady state economy and its economy is in transition; SVAR may give out better estimation than VAR; omitted dummy variable (China joined WTO in the end of 2001); non-stationary time series of consumption-based on interest rate r* in quarterly VAR model and the properties of data itself since some price indexes before 1995 were not determined by market.

Therefore my other research question – Is China's CA too high or not cannot be interpreted merely based on the inter-temporal model. However, based on the former China itself analysis, combining with recent research on China's CA account, at least it can conclude that China needs a surplus CA to maintain substantial international reserves in order to maintain the stability of development of domestic capital market and to ensure the success of joining into the world economy during its gradual opening process.

Appendices

Appendix 1 Unit Root Test Results

Unit Root Tests

no. of lags	1	2	3
Change in net output(Δno)			
ADF	-2.564*	-2.453*	-2.169*
PP	4.639**	4.639**	4.639**
Current Account (CA*)			
ADF	-2.071*	-1.597	-1.601
PP	8.282**	8.282**	8.282**
Interest rate(r*)			
ADF	-2.479*	-1.873	-1.387
PP	15.672***	15.672***	15.672***
share of traded goods a=0.5, intertemporal elasticity γ=0.087, range: 1980-2013			
Change in net output(Δno)			
ADF	-5.185***	-8.583***	-5.189***
PP	-2.444*	-2.444*	-2.444*
Current Account (CA*)			
ADF	-5.185***	-2.844**	-5.189***
PP	6.021***	6.021***	6.021***
Interest rate(r*)			
ADF	-1.475	-1.831	-2.369*
PP	34.011***	34.011***	34.011***
share of traded goods a=0.5, intertemporal elasticity γ=0.087, range: 1994Q1-2014Q2			

Notes:

1) ADF indicates the augmented Dickey-Fuller test; PP indicates Phillips-Perron test.

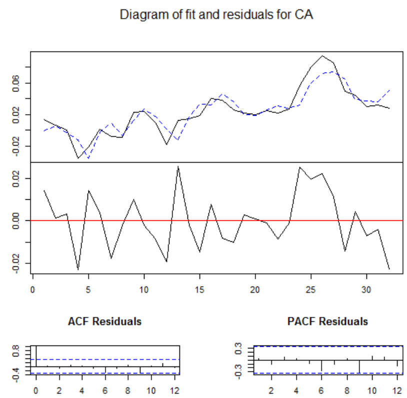
2) '*' '**' and '***' indicate the rejection of null hypothesis 'the tested variable has a unit root' at 5%, 1% and 0.1% significance level.

3) Regressions include a constant, do not include time trend.

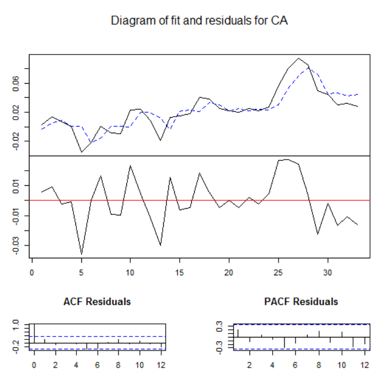
Appendix 2 Diagram of fit and residuals for China's Current Account

Range: 1980 to 2013 for annual; Range: 1994Q1 – 2014Q2 for quarterly; ------ Predicted CA

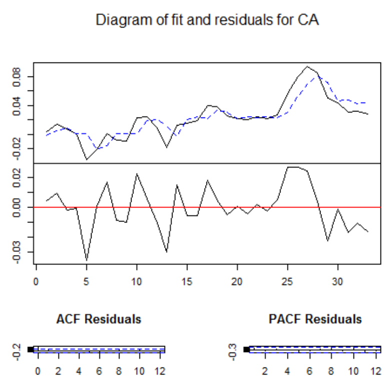
Appendix 2.1 Diagram (annual) of bivariate VAR model excluding r*



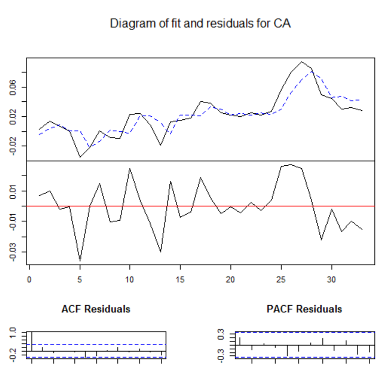
Appendix 2.2 Diagram (annual) of trivariate VAR model with different a and γ



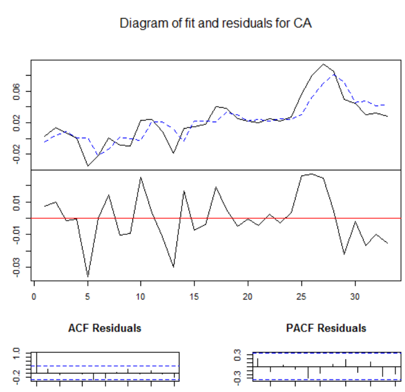
(a = 0.5, γ = 0.087)



(a = 0.2, γ = 0.087)

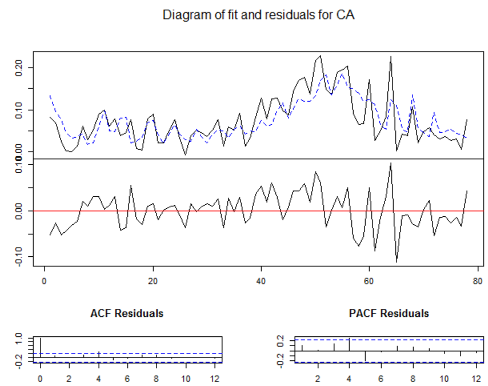


(a = 0.2, γ = 0.5)

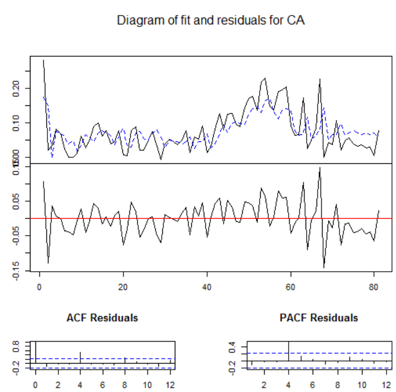


(a = 0.2, γ = 1)

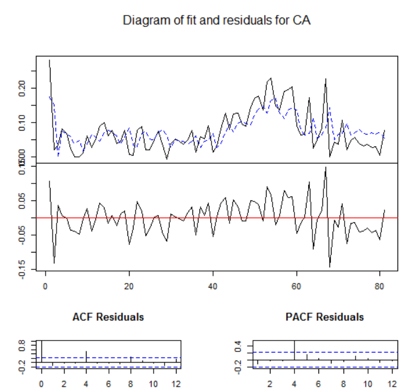
Appendix 2.3 Diagram (quarterly) of bivariate VAR model excluding r*



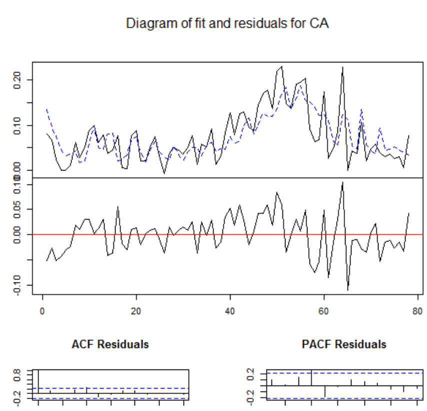
Appendix 2.4 Diagram (quarterly) of trivariate VAR model with different a and γ



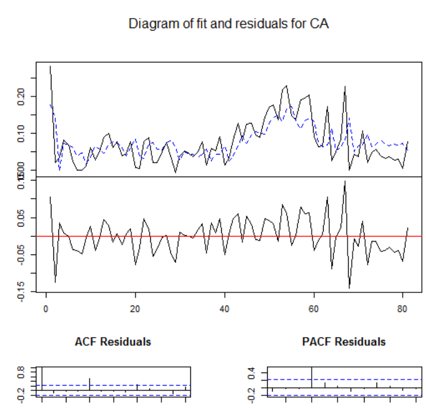
(a = 0.5, γ = 0.087)



(a = 0.2, γ = 0.087)



(a = 0.2, γ = 0.5)



(a = 0.2, γ = 1)

Appendix 3 Estimation results of equation CA

Appendix 3.1 Estimation results (annual) of equation CA

Estimation results of equation CA (annual)

Bivariate VAR(2) model *excluding r**												
	CA=	-1.8	Δno11 +	0.91	CA11 +	2.52	Δno12 -	0.51	CA12 -	0.02	+	0.00
Std.Error		*1.31*		*0.18*		*1.2*		*0.20*		*0.01*		*0.00*
P value		0.18		0.00		0.04		0.02		0.15		0.01
Trivariate VAR(1) model *including r* with different a and γ*												
(a=0.5, γ=0.087)	CA=	0.95	Δno11 +	0.60	CA11 +	0.24	r11 -	0.034 +	0.00			
Std.Error		*1.06*		*0.17*		*0.34*		*0.04*	*0.00*			
P value		0.38		0.00		0.49		0.34	0.20			
(a=0.2, γ=0.087)	CA=	0.97	Δno11 +	0.59	CA11 +	0.25	r11 -	0.035 +	0.00			
Std.Error		*1.06*		*0.17*		*0.32*		*0.03*	*0.00*			
P value		0.37		0.00		0.45		0.30	0.17			
(a=0.2, γ=0.5)	CA=	0.92	Δno11 +	0.61	CA11 +	0.20	r11 -	0.030 +	0.00			
Std.Error		*1.07*		*0.17*		*0.37*		*0.04*	*0.00*			
P value		0.40		0.00		0.59		0.43	0.27			
(a=0.2, γ=1)	CA=	0.91	Δno11 +	0.61	CA11 +	0.19	r11 -	0.029 +	0.00			
Std.Error		*1.07*		*0.17*		*0.37*		*0.04*	*0.00*			
P value		0.40		0.00		0.61		0.44	0.28			

Note:

1) The null hypothesis for each coefficient is: coefficient equals to zero, the shade part means we can't reject the null hypothesis at least at 5% significant level;

2) Annual data: 1980 -2013, observed time period: 34;

3) Regressions include constant and trend.

Appendix 3.2 Estimation results (quarterly) of equation CA

Estimation results of equation CA (quarterly)

Bivariate VAR(4) model *excluding r**												
	CA=	-0.01	Δno11 +	0.35	CA11 +	0.11	Δno12 -	0.12	CA12 -	0.00	+	0.00
Std.Error		*0.17*		*0.11*		*0.17*		*0.11*		0.01		0.00
P value		0.93		0.00		0.52		0.31		0.87		0.39
	+	0.36	Δno13 -	0.04	CA13 +	0.11	Δno14 -	0.42	CA14			
Std.Error		*0.16*		*0.10*		*0.13*		*0.09*				
P value		0.02		0.73		0.40		0.00				
Trivariate VAR(1) model *including r* with different a and γ*												
(a=0.5, γ=0.087)	CA=	0.16	Δno11 +	0.46	CA11 +	1.10	r11 -	0.026 +	0.00			
Std.Error		*0.12*		*0.09*		*0.63*		*0.03*	*0.00*			
P value		0.18		0.00		0.09		0.40	0.03			
(a=0.2, γ=0.087)	CA=	0.16	Δno11 +	0.46	CA11 +	0.98	r11 -	0.021 +	0.00			
Std.Error		*0.12*		*0.09*		*0.62*		*0.03*	*0.00*			
P value		0.17		0.00		0.12		0.48	0.03			
(a=0.2, γ=0.5)	CA=	0.16	Δno11 +	0.45	CA11 +	1.26	r11 -	0.032 +	0.00			
Std.Error		*0.12*		*0.09*		*0.65*		*0.03*	*0.00*			
P value		0.18		0.00		0.06		0.29	0.02			
(a=0.2, γ=1)	CA=	0.16	Δno11 +	0.44	CA11 +	1.29	r11 -	0.034 +	0.00			
Std.Error		*0.12*		*0.09*		*0.66*		*0.03*	*0.00*			
P value		0.18		0.00		0.05		0.28	0.02			

Note:

1) The null hypothesis for each coefficient is: coefficient equals to zero, the shade part means we can’t reject the null hypothesis at least at 5%;

2) Quarterly data: 1994Q1 - 2014Q2, observed time period: 82;

3) Regressions includes constant and trend.

Appendix 4 Results of model checks

Results of Mode Checks

	Annual data (1980-2013)					Quarterly data (1994Q1-2014Q2)				
	without r*	with r*				without r*	with r*			
a=	---	0.5	0.2	0.2	0.2	---	0.5	0.2	0.2	0.2
γ=	---	0.087	0.087	0.5	1	---	0.087	0.087	0.5	1
no. of lags=	2	1	1	1	1	4	1	1	1	1
	P value					P value				
Granger causality test										
Granger-cause CA	0.111	0.559	0.531	0.620	0.630	0.113	0.126	0.159	0.087	0.081
instantaneous causality test	0.022	0.152	0.183	0.103	0.096	0.858	0.030	0.024	0.048	0.053
Autocorrelation test (ε)										
Portmanteau Test	0.799	0.017	0.019	0.024	0.026	0.000	0.000	0.000	0.000	0.000
Normality test (ε)										
dno JB-Test	0.004	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000
CA JB-Test	0.698	0.950	0.948	0.956	0.957	0.853	0.326	0.299	0.369	0.377
r JB-Test	---	0.539	0.908	0.023	0.010	---	0.048	0.263	0.001	0.000
JB-Test (multivariate)	0.017	0.004	0.002	0.002	0.001	0.000	0.000	0.000	0.000	0.000
Skewness (multivariate)	0.125	0.071	0.082	0.022	0.016	0.306	0.001	0.003	0.000	0.000
Kurtosis (multivariate)	0.020	0.001	0.002	0.009	0.008	0.000	0.000	0.000	0.000	0.000
Stability test										
Recursive residual										
Δno	yes	yes	yes	yes	yes	no	yes	yes	yes	yes
CA	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
r*	---	yes	yes	yes	yes	---	yes	yes	yes	yes

Note:

1) Granger causality test includes: H0: Δno and (r*)do not Granger-cause CA and H0: no instantaneous causality;

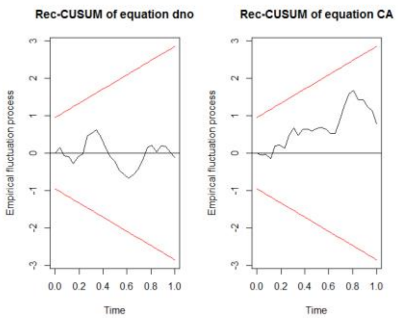
2) Portmanteau test: H0: no autocorrelation of residuals at lags 1,...,m;

3) Jarque-Bera test: H0: erro items follow normality;

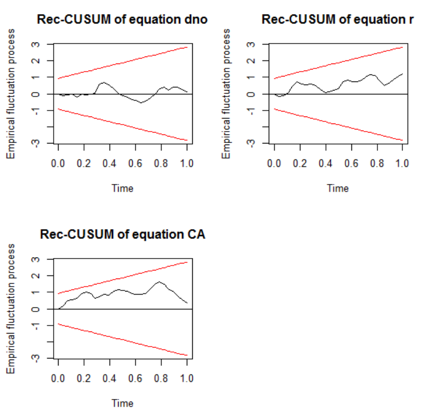
4) Stability test results summerized here, detail showed in graph.

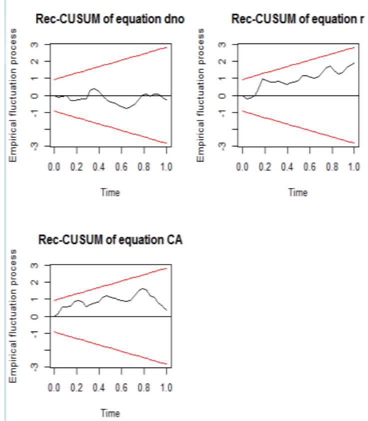
Appendix 5 Diagram of stability test

Appendix 5.1 Rec-CUSUM graph (annual) excluding r*

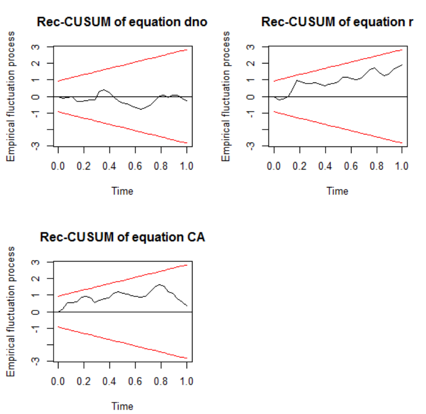


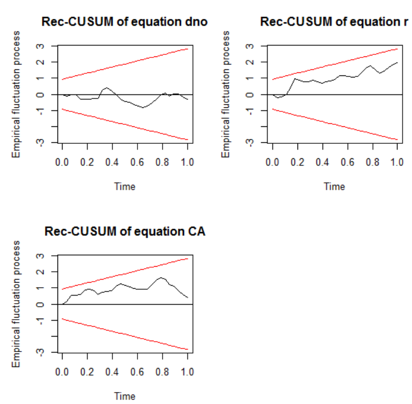
Appendix 5.2 Rec-CUSUM graph (annual) including r* with different a and γ





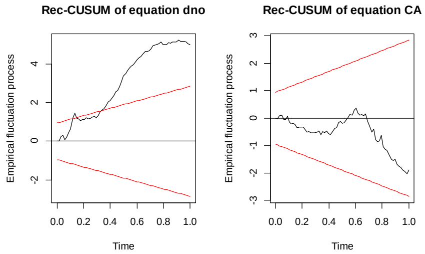
(a = 0.5, γ = 0.087) (a = 0.2, γ = 0.5)



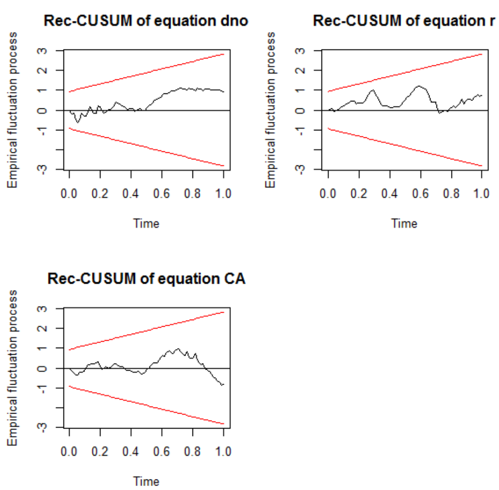


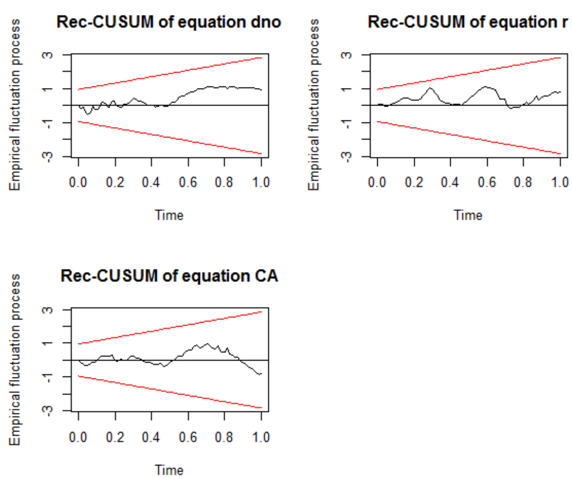
(a = 0.2, γ = 0.5) (a = 0.2, γ = 1)

Appendix 5.3 Rec-CUSUM graph (quarterly) excluding r*

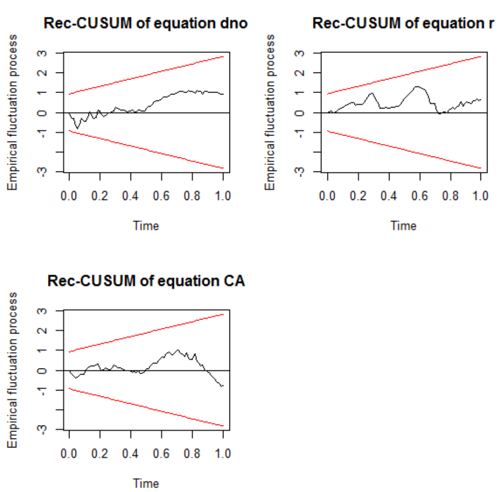


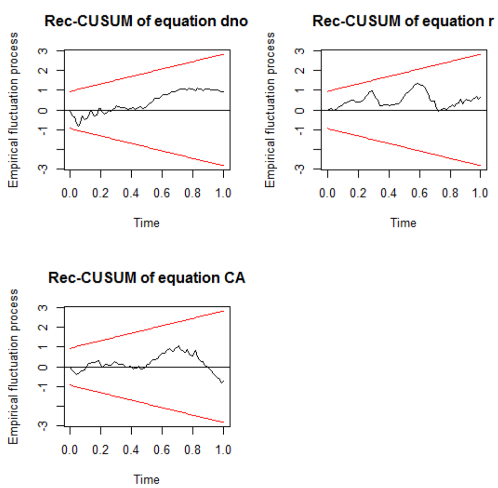
Appendix 5.4 Rec-CUSUM graph (quarterly) including r* with different a and γ





(a = 0.5, γ = 0.087) (a = 0.2, γ = 0.087)

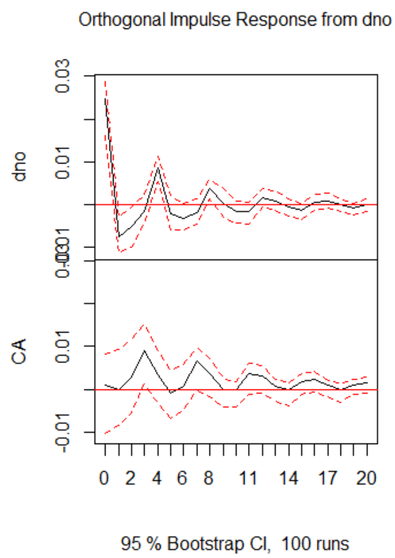


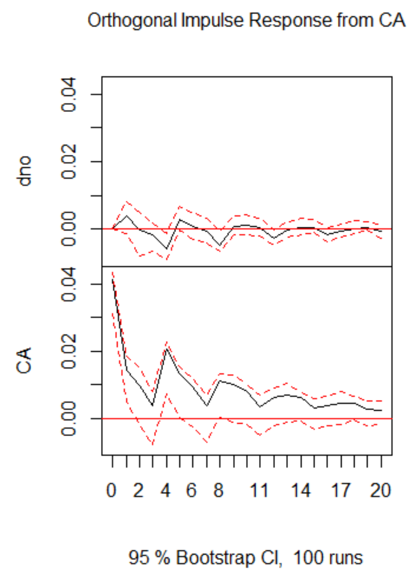


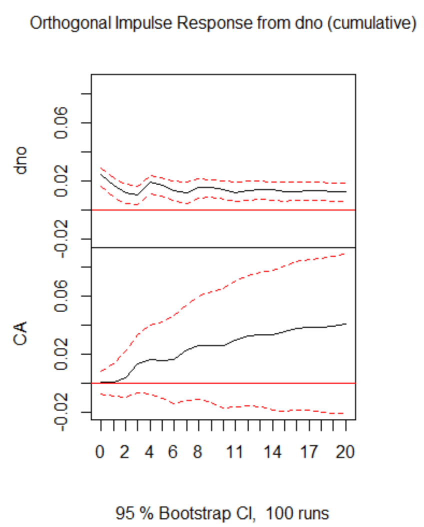
(a = 0.2, γ = 0.5) (a = 0.2, γ = 1)

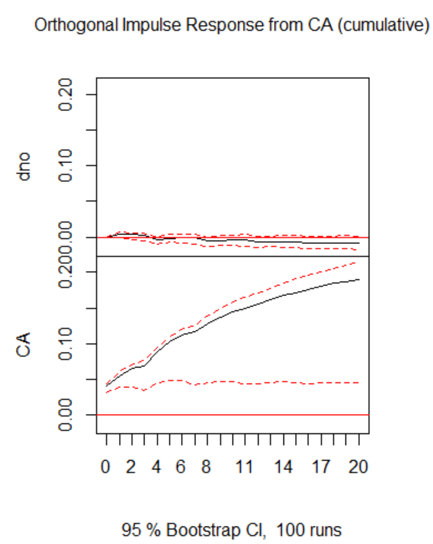
Appendix 6 Impulse Response Analysis

Appendix 6.1 Impulse response graph (quarterly) excluding r*

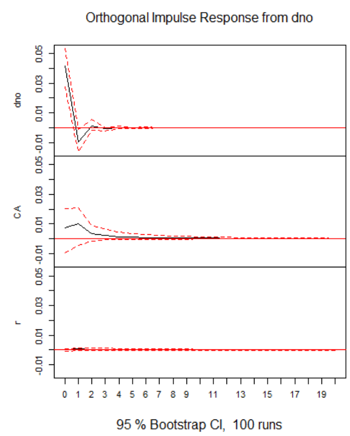


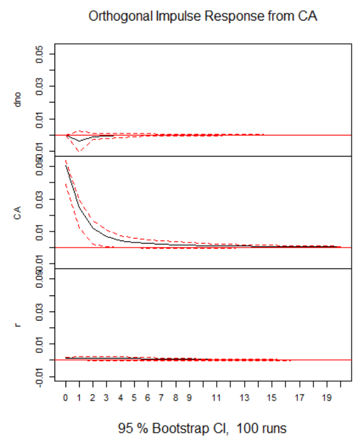


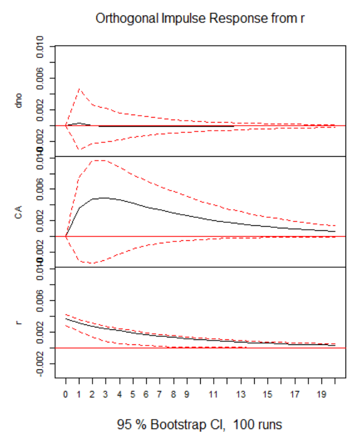


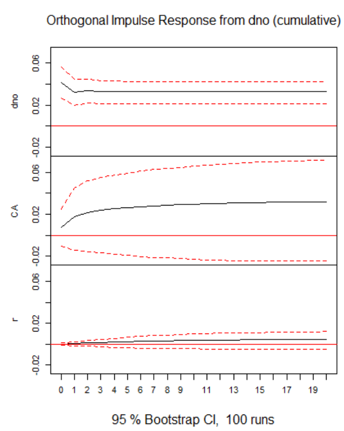


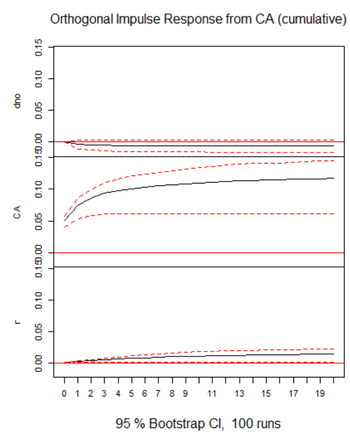
Appendix 6.2 Impulse response graph (quarterly) including r* with a = 0.2, γ = 0.087

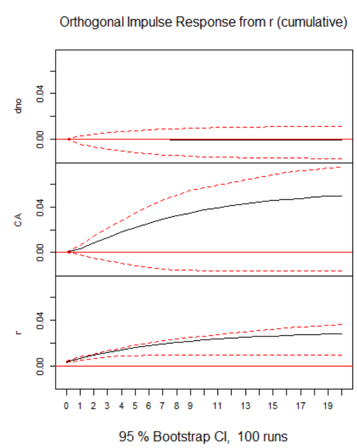












Appendix 7 Present Values test results

K-test Results

	Annual data (1980-2013)					Quarterly data (1994Q1-2014Q2)				
	without r*	with r*				without r*	with r*			
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
a=	---	0.2	0.2	0.2	0.5	---	0.2	0.2	0.2	0.5
γ=	---	0.087	0.5	1	0.087	---	0.087	0.5	1	0.087
no. of lags=	2	1	1	1	1	4	1	1	1	1
K-vector										
Δno	-0.823	-0.086	0.356	1.061	-0.217	0.462	0.196	0.188	0.181	0.191
CA*	0.114	0.154	0.190	0.226	0.155	0.189	0.123	0.123	0.120	0.119
r*	---	0.200	0.574	1.024	0.212	---	0.725	3.599	7.802	0.566
Δnol1	0.544	---	---	---	---	0.307	---	---	---	---
CA*l1	-0.078	---	---	---	---	0.180	---	---	---	---
Δnol2	---	---	---	---	---	0.128	---	---	---	---
CA*l2	---	---	---	---	---	0.156	---	---	---	---
Δnol3	---	---	---	---	---	-0.063	---	---	---	---
CA*l3	---	---	---	---	---	0.148	---	---	---	---
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Adjusted R-squared	0.748	0.683	0.906	0.679	0.906	0.499	0.326	0.336	0.338	0.330
$\sigma(\widetilde{CA*})/\sigma(CA*)$	0.898	0.853	0.851	0.851	0.853	0.622	0.769	0.764	0.763	0.767

Notes:

1) P-value is used to: null hypothesis of K value is zero, regressions include constant and trend;

2) Ajusted R-square is for the CA estimated equation;

3) Ơ(CA*)̃/Ơ(CA*): standard error of estimated current account/ standard error of observed current account.

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