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Misalignment of Renminbi Exchange Rate Revaluation: Estimation and Implications

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ABSTRACT

For the past several years, the revaluation of the renminbi has been a hot topic among policymakers and economists as well as market participants inside and outside the PRC against the background of internal and external disequilibrium of the PRC economy.

Based upon the history of the exchange rate system, current arguments made by various stakeholders, and surveys of different theoretical approaches, the authors develop a two-country general equilibrium model to determine the exchange rate, taking particular account of the implications of price rigidity for the policy independence of each country.

An empirical test is also introduced to identify the current degree of misalignment of the renminbi compared to its estimated equilibrium rate.

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Zhijun Zhao and Toshiki Kanamori[†]

Introduction

For the past few years, there have been a number of arguments about the level of the renminbi exchange rate as well as its regime. Arguments on this issue have been made not only by economists and politicians in the countries concerned, but they have also attracted the attention of ordinary people since many major developed countries, and in particular the United States, have intensified pressure on the authorities of the People's Republic of China (PRC) to revalue the renminbi and change its US dollar-pegged exchange rate regime to a more flexible one.

One important step was taken on 21 July 2005, when the People's Bank of China (PBOC) "unexpectedly" announced a 2.1 per cent revaluation of the renminbi. We can make the following observations regarding this announcement. The first relates to the timing. While many concerned experts and media saw the announcement as abrupt and surprising, careful examination shows that this was not necessarily the case. There was no doubt that the PRC authorities were constantly watching various economic indicators such as balance of payment, foreign reserves and short-term capital inflow, watching for the timing for the revaluation. Still, the PRC had difficulty revaluing the currency because it did not want to give the impression that external pressure from other industrialized countries had forced it to do so. The timing of the recent revaluation seems to have been felt to be best by the PRC authorities, because the external pressure was somewhat mitigated by the appreciation of US dollar, to which the renminbi was pegged. Considering the political and economic importance of its relationship with the United States, we could also have predicted that the PRC would demonstrate some measures to the United States before the meeting of their two leaders.

Secondly we should note that the PBOC carefully stated in its announcement that the renminbi exchange rate would be adjusted "based on market supply and demand with reference to a basket of currencies." It is not so clear yet what kind of currency basket is to be introduced and how it will be operated. In fact, the details of the basket have not yet been clarified[1] and the actual renminbi exchange rate since July 21st has

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[1] On 10 August 2005, the Governor of PBOC stated that taking account of the trade relationship with other countries, major currencies in the basket are the US dollar, euro, Japanese yen and Korean won at this stage, but that the currencies of Singapore, the United Kingdom, Malaysia, Russia, Australia, Thailand and Canada are also very important. The respective weights are not yet clear.

fluctuated within a relatively narrow range centering on the new 8.11 RMB rate (8.095–8.115). Although the announcement allows a fluctuation range of 0.3 per cent, the PBOC seems to be intervening significantly in foreign exchange and is trying to contain the fluctuation of the renminbi as much as possible. Considering this, it is interesting to note that after the announcement in July, the PBOC firmly denied the possibility of another revaluation (meaning a change from the 8.11 rate) for the time being.

The third observation relates to the second point. Although other countries and experts mostly welcomed the announcement as a first step, there is concern that compared with the previous US pegged regime, the system has become less transparent: "with reference to a basket of currencies" is rather vague and the PRC may now more freely manipulate the exchange rate by foreign exchange intervention.

Fourthly, ultimately this announcement seems to be another example of the PRC's traditional gradualist approach, starting with a very limited scope on an experimental base and then carefully examining its impact before slowly expanding the scope. Overall the core of the announcement seems to be a modest first step toward a more flexible exchange system, and the appreciation of the renminbi based on the announcement is still far from our current estimated equilibrium rate.

This research project started well before the PBOC's announcement on 21 July and most of the analyses, suggestions and conclusions in this paper were prepared under the background of the earlier USD-pegged exchange rate regime. However, we note that those analyses and suggestions basically depend on the theoretical framework and empirical studies. In addition, we note that even after the announcement, the appreciation of the renminbi has still taken place in a very narrow range, and is far from the current equilibrium rate. In view of this, the authors believe that the suggestions and analyses of this paper basically remain relevant and are not changed by the July 2005 announcement.

Of course the announcement is undoubtedly a significant first step, and it may turn out that this was a historical turning point. Therefore we must carefully follow the developments in the renminbi exchange rate and the next steps the PRC authorities take in the near future. In fact, soon after the revaluation, the PBOC issued circulars on an expansion of forward Forex trading and to allow renminbi and foreign currency swap transactions. Also, in late September 2005, the PBOC announced, on the occasion of the G7 summit, that it would widen the renminbi's trading band against non-USD currencies from a maximum plus or minus 1.5 per cent to 3 per cent (although this is just a technical adjustment and only has the impact of limiting arbitrage opportunities between currencies). These measures clearly indicate that the PBOC envisages greater fluctuation of the renminbi exchange rate in the foreseeable future and feels the need to provide market participants with more risk hedge instruments or at least trigger speculation by market participants on further policy changes.

1. The General Equilibrium Exchange Rate Model

The shortcomings of existing theories[2] in explaining the phenomenon occurring in the PRC prompts us to make efforts to build a more general framework. To analyze the factors that influence the exchange rate and exchange rate regime, in this part we create a general equilibrium model, which includes two countries and three sectors, namely final product producers, consumers and import firms. The first section deals with the equilibrium of the firm producing the final product firm, the second section deals with the equilibrium of intermediate import business and the third section deals with the equilibrium of consumer behavior. In the fourth section, the general equilibrium conditions for the import goods market equilibrium, export goods equilibrium and equilibrium of international payments are investigated. Finally, we summarize the main policy implications of the model.

1.1 The Behavior of Final Product Producers

Unlike a closed economy in which capital input is formed from domestic investment only, in an open economy, the capital input can be formed either from domestic investment or from foreign investment. Taking this into consideration, we assume that a representative final goods producer uses two kinds of capital, one from domestic investment and the other from foreign investment. They differ in quality (one of the reasons for the PRC to introduce more FDI from foreign countries is perhaps because it is better in quality than that from the PRC itself) and thus they cannot be perfectly substituted[3] without a loss of generality. We adopt Cobb-Douglass production technology, in which foreign capital goods is treated as intermediate goods produced and processed by an import company to embody the role that tariffs, transport costs and monopolistic import power plays in final product pricing. We will see that the price of intermediate goods is jointly determined by their price in foreign currency, transport costs, tariffs, and monopolistic power.

The production function of a representative domestic final good producer is defined as:

$$Y_{h,t} = A_{h,t}(K_{hh,t}{}^{\alpha} K_{hf,t}{}^{\phi}) L_{h,t}{}^{1-\alpha-\phi} \tag{1.1}$$

Where the lowercase *t* stands for time, *h* represents the home country and *f* represent the foreign country. The meanings of the symbols in function (1.1) are defined as follows:

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[2] We have reviewed various existing exchange rate theories, including absolute PPP, Relative PPP, CIP, UCIP, and B_S model, Fleming-Mundell model, F-M-Dornbusch model, Redux model, and PTM model. This review provided help for us in creating a new theoretical framework. (Kanamori and Zhao 2006 [47]).

[3] Because of the product quality difference, FDI enjoys some preferential tax treatment. The United States also imposes various restraints on the export of high technology, also indicating the importance of the difference in goods quality.

$Y_{h,t}$: domestic final aggregate output,

$K_{hh,t}$: demand for capital goods by home firms produced by home firms,

$K_{hf,t}$: demand for capital goods by home firms produced by foreign firms,

$L_{h,t}$: labor force used in production,

$A_{h,t}$: total factor productivity of domestic production,

α: The share of home capital

ϕ: The share of foreign capital

Dividing both sides of equation (1.1) by $L_{h,t}$ and letting $y_{h,t} = Y_{hh,t} / L_{h,t}$, $k_{hh,t} = K_{hh,t} / L_{h,t}$, $k_{hf,t} = K_{hf,t} / L_{h,t}$, which represent variables in per capita terms, we have

$$y_{h,t} = A_{h,t}(k_{hh,t}{}^{\alpha} k_{hf,t}{}^{\phi})$$

Since our main focus is mainly on the goods and capital flow across countries, the labor forces of both domestic and foreign firms are assumed to be inelastic and to grow exogenously at a constant rate:

$$\left(A_{h,t} - A_{h,t-1}\right) / A_{h,t-1} = a_h \text{, } \left(A_{h,t} - A_{h,t-1}\right) / A_{h,t-1} = a_h \text{, and } \left(L_{h,t} - L_{h,t-1}\right) / L_{h,t-1} = n_h \tag{1.2}$$

The objective of the firm is to maximize profits:

$$\Pi_t = \left[P_{h,t+1} A_{h,t}(k_{hh,t}{}^{\alpha} k_{hf,t}{}^{\phi}) - P_{h,t} k_{hh,t} r_{h,t} - P_{hf,t} k_{hf,t} r_{f,t} - W_{h,t}\right] L_{h,t} \tag{1.3}$$

Where $W_{h,t}$ is the nominal wage rate, $r_{h,t}$, $r_{f,t}$ denotes respectively nominal interest rate controlled by the central bank[4]; $P_{h,t}$ is the price of home goods in the home currency, and $P_{hf,t}$ is the price of foreign goods in the home currency. Different capital returns to domestic capital goods and foreign capital goods are assumed because the required returns for foreign and home investors are different. The first order conditions for the firm to maximize its profits are expressed in (1.4) and (1.5):

$$\alpha P_{h,t+1} A_{h,t}(k_{hh,t}{}^{\alpha-1} k_{hf,t}{}^{\phi}) = P_{h,t} r_{h,t} \tag{1.4}$$

$$\phi P_{h,t+1} A_{h,t}(k_{hh,t}{}^{\alpha} k_{hf,t}{}^{\phi-1}) = P_{h,t} r_{h,t} \tag{1.5}$$

[4] Here we ignore the difference between the lending rate and deposit rate for simplicity. If we take monopolistic competitive commercial banks into consideration, the lending rate and deposit rate will be different (Zhao and Ma etc, 2002). But this may not influence the conclusion of the paper.

From (1.4) and (1.5), the domestic demand for per capita capital, output and the wage rate are:

$$y_{h,t} = A_{h,t}^{\frac{1}{1-\alpha-\phi}} \left(\frac{\alpha \pi_{h,t+1}}{r_{h,t}} \right)^{\frac{\alpha}{1-\alpha-\phi}} \left(\frac{\phi P_{h,t+1}}{r_{f,t} P_{hf,t}} \right)^{\frac{\phi}{1-\alpha-\phi}} \tag{1.6}$$

$$k_{hh,t} = A_{h,t}^{\frac{1}{1-\alpha-\phi}} \left(\frac{\alpha \pi_{h,t+1}}{r_{h,t}} \right)^{\frac{1-\phi}{1-\alpha-\phi}} \left(\frac{\phi P_{h,t+1}}{r_{f,t} P_{hf,t}} \right)^{\frac{\phi}{1-\alpha-\phi}} \tag{1.7}$$

$$k_{hf,t} = A_{h,t}^{\frac{1}{1-\alpha-\phi}} \left(\frac{\alpha \pi_{h,t+1}}{r_{h,t}} \right)^{\frac{\alpha}{1-\alpha-\phi}} \left(\frac{\phi P_{h,t+1}}{r_{f,t} P_{hf,t}} \right)^{\frac{1-\alpha}{1-\alpha-\phi}} \tag{1.8}$$

$$w_{h,t} = \frac{W_{h,t}}{P_{h,t}} = (1-\alpha-\phi)\pi_{h,t+1} y_{h,t} \tag{1.9}$$

Where the new symbol $\pi_{h,t+1} = P_{h,t+1} / P_{h,t}$ represents one plus the expected inflation rate at time *t*. Equation (1.6)–(1.9) indicate that from the angle of producers, the output of final goods and the demand for domestic and foreign capital decrease when the domestic and foreign nominal interest rates increase. The output of final goods and the demand for domestic and foreign capital increases when expected prices increase or the present price level decreases.

By symmetry, assuming the foreign production function to be

$$Y_{f,t} = A_{f,t} (K_{ff,t}^{\alpha'} K_{fh,t}^{\phi'}) L_{f,t}^{1-\alpha'-\phi'} \tag{1.10}$$

The foreign demands for per capita capital, foreign wage rate and output can be expressed as:

$$k_{ff,t} = A_{f,t}^{\frac{1}{1-\alpha'-\phi}} \left(\frac{\alpha' \pi_{f,t+1}}{r_{f,t}} \right)^{\frac{1-\phi'}{1-\alpha'-\phi'}} \left(\frac{\phi' P_{f,t+1}}{r_{h,t} P_{fh,t}} \right)^{\frac{\phi'}{1-\alpha'-\phi'}} \tag{1.11}$$

$$k_{fh,t} = A_{f,t}^{\frac{1}{1-\alpha'-\phi'}} \left(\frac{\alpha' \pi_{f,t+1}}{r_{f,t}} \right)^{\frac{\alpha'}{1-\alpha'-\phi'}} \left(\frac{\phi' P_{f,t+1}}{r_{h,t} P_{fh,t}} \right)^{\frac{1-\phi'}{1-\alpha'-\phi'}} \tag{1.12}$$

$$w_{f,t} = \frac{W_{f,t}}{P_{f,t}} = (1-\alpha'-\phi')\pi_{f,t+1} y_{f,t} \tag{1.13}$$

$$y_{f,t+1} = A_{f,t}^{\frac{1}{1-\alpha'-\phi'}} \left(\frac{\alpha' \pi_{f,t+1}}{r_{f,t}} \right)^{\frac{\alpha'}{1-\alpha'-\phi'}} \left(\frac{\phi' P_{f,t+1}}{r_{h,t} P_{fh,t}} \right)^{\frac{\phi'}{1-\alpha'-\phi'}} \tag{1.14}$$

Where the implications of the new symbols in equation (1.11)–(1.14) are given as follows:

$k_{ff,t}$: per capita capital goods used and produced in foreign firms at time *t*,

$k_{fh,t}$: per capita capital goods used in foreign firms and produced by home firms at time *t*,

$w_{f,t}$: real term of foreign wage rate at time *t*, and

$y_{f,t}$: per capita foreign output at time *t*.

$\pi_{f,t+1} = P_{f,t+1} / P_{f,t}$: one plus the inflation rate of the foreign economy.

A parameter with the uppercase symbol $'$ represent the corresponding foreign production parameter. For example, α' is the foreign capital share corresponding to home firm parameter α.

1.2 The Behavior of Import Firms

In order to make clear the roles played by transport costs, tariffs and import monopolistic power in exchange rate determination, we introduce import firms with monopolistic power in the pricing of imported capital goods. Since our main purpose in this part is to build a theoretical framework to elucidate the variables and channels by which the variables influence the exchange rate, rather than accurate relations between the variables, we ignore the pricing of consumption goods. Given demand functions for domestic final goods, import firms decide the quantity and price of domestic demand for import goods according to the demand curve. We can rewrite (1.8) as the inverse demand function for capital goods in (1.15):

$$P_{hf,t} = A_{h,t}^{\frac{1}{1-\alpha-\phi}} \left(\frac{\alpha \pi_{h,t+1}}{r_{h,t}} \right)^{\frac{\alpha}{1-\alpha-\phi}} \left(\frac{\phi P_{h,t+1}}{r_{f,t}} \right) \left(\frac{K_{hf,t}}{L_{h,t+1}} \right)^{-\frac{1-\alpha-\phi}{1-\alpha}} \tag{1.15}$$

This is the foreign demand curve faced by foreign import firm with constant demand elasticity with respect to the interest rate, implying that if prices increase by 1%, the demand for capital goods $K_{hf,t}$ will decrease by $(1-\alpha)/(1-\alpha-\phi)$ %. We further assume the domestic tariff rate to be τ_h and the coefficient for transport costs to be $\theta > 1$, which means that transport costs take a $\theta - 1$ part of the import goods price. The objective function of the import firm can be written as:

$$\begin{aligned} \Pi_m &= P_{hf,t} K_{hf,t} - \varepsilon_t P_{f,t} (1+\tau) \theta K_{hf,t} \\ &= A_{h,t}^{\frac{1}{1-\alpha}} \left(\frac{\alpha \pi_{h,t+1}}{r_{h,t}} \right)^{\frac{\alpha}{1-\alpha}} \left(\frac{\phi P_{h,t+1}}{r_{f,t}} \right) \left(L_{h,t+1} \right)^{\frac{1-\alpha-\phi}{1-\alpha}} \left(K_{hf,t} \right)^{\frac{\phi}{1-\alpha}} - \varepsilon_t P_{f,t} (1+\tau_h) \theta K_{hf,t} \end{aligned} \tag{1.16}$$

Where ε_t is the nominal exchange rate, or the domestic currency price of foreign currency. According to the first order condition for optimization problem (1.16), the domestic price of imported foreign capital goods is

$$P_{hf,t} = \frac{\varepsilon_t P_{f,t}(1+\tau_h)\theta(1-\alpha)}{\phi} = \varphi\varepsilon_t P_{f,t} \tag{1.17}$$

where $\varphi = \frac{(1+\tau_h)\theta(1-\alpha)}{\phi} > 0$. (1.17) indicates that the domestic price of import capital goods depends on four factors: their price in the foreign country, the transport costs, the level of tariffs and the capital share ratio $\phi/(1-\alpha) < 1$. Thus, after taking into account transport costs, tariffs and monopolistic power, the domestic price of imported goods is greater than their foreign price.

Substituting (1.17) into (1.6)–(1.9), we obtain:

$$k_{hh,t} = A_{h,t}^{\frac{1}{1-\alpha-\phi}} \left(\frac{\alpha\pi_{h,t+1}}{r_{h,t}} \right)^{\frac{1-\phi}{1-\alpha-\phi}} \left(\frac{\phi\pi_{h,t+1}}{r_{f,t}} \frac{1}{\varphi q_t} \right)^{\frac{\phi}{1-\alpha-\phi}} \tag{1.18}$$

$$k_{hf,t} = A_{h,t}^{\frac{1}{1-\alpha-\phi}} \left(\frac{\alpha\pi_{h,t+1}}{r_{h,t}} \right)^{\frac{\alpha}{1-\alpha-\phi}} \left(\frac{\phi\pi_{h,t+1}}{r_{f,t}} \frac{1}{\varphi q_t} \right)^{\frac{1-\alpha}{1-\alpha-\phi}} \tag{1.19}$$

$$w_{h,t} = \frac{W_{h,t}}{P_{h,t}} = (1-\alpha-\phi) y_{h,t} \tag{1.20}$$

$$y_{h,t+1} = A_{h,t}^{\frac{1}{1-\alpha-\phi}} \left(\frac{\alpha\pi_{h,t+1}}{r_{h,t}} \right)^{\frac{\alpha}{1-\alpha-\phi}} \left(\frac{\phi\pi_{h,t+1}}{r_{f,t}} \frac{1}{\varphi q_t} \right)^{\frac{\phi}{1-\alpha-\phi}} \tag{1.21}$$

Similarly, the demand for capital, the wage rate and the output supply for foreign firms can be deduced from (1.12)–(1.14) as follows (1.21)–(1.25).

$$k_{ff,t} = A_{f,t}^{\frac{1}{1-\alpha'-\phi}} \left(\frac{\alpha'\pi_{f,t+1}}{r_{f,t}} \right)^{\frac{1-\phi'}{1-\alpha'-\phi'}} \left(\frac{\phi'\pi_{f,t+1}}{r_{h,t}} \frac{q_t}{\varphi'} \right)^{\frac{\phi'}{1-\alpha'-\phi'}} \tag{1.22}$$

$$k_{fh,t} = A_{f,t}^{\frac{1}{1-\alpha'-\phi'}} \left(\frac{\alpha'\pi_{f,t+1}}{r_{f,t}} \right)^{\frac{\alpha'}{1-\alpha'-\phi'}} \left(\frac{\phi'\pi_{f,t+1}}{r_{h,t}} \frac{q_t}{\varphi'} \right)^{\frac{1-\phi'}{1-\alpha'-\phi'}} \tag{1.23}$$

$$w_{f,t} = \frac{W_{f,t}}{P_{f,t}} = (1-\alpha'-\phi')\pi_{f,t+1} y_{f,t} \tag{1.24}$$

$$y_{f,t+1} = A_{f,t}^{\frac{1}{1-\alpha'-\phi'}} \left(\frac{\alpha'\pi_{f,t+1}}{r_{f,t}} \right)^{\frac{\alpha'}{1-\alpha'-\phi'}} \left(\frac{\phi'\pi_{f,t+1}}{r_{h,t}} \frac{q_t}{\varphi'} \right)^{\frac{\phi'}{1-\alpha'-\phi'}} \tag{1.25}$$

In (1.22)–(1.25), the real exchange rate is introduced to reflect the impact of the exchange rate on output and investment. They indicate that the real appreciation of foreign currency has a negative impact on domestic investment and output, but a positive impact on foreign investment and output, if other things are held equal. The increase of domestic transport costs and tariffs raises domestic investments and output as well.

1.3 The Behavior of Consumers

We assume that a representative household has two generations at time *t*. Each generation lives for two periods: youth and old age. The generation born at *t* is denoted with a subscript *t*. the young work and earn a wage, and decide how much to deposit for their old age. The old do not work, but spend the money they deposited and the interest on the deposit when they are old. In an open economy, the consumption goods of a home consumer consist of two parts: one produced in the home country, the other imported from the foreign country. The aggregate consumption at time *t* is the sum of consumption of the young generation and old generation.

Since the quality of foreign and domestic goods is different, we assume that they are imperfect substitutes. The imperfect substitution between consumption goods originates from their different physical utility, liquidity, preferential tax treatment, preferences, and so on. Actually, some exchange rate models have already adopted imperfect substitution between assets and consumption goods (Chen, 2004; Zhao and Liu, 2002). In this model, we allow different consumption goods to go into the utility function to deal with the current account and capital account more practically, making the model more persuasive.

Following Calvo (1980), Chen (2004) and Zhao and Liu et al. (2002), the representative consumer in the home country with rational expectations is assumed to maximize the present value of his life utility $U_{h,t}$:

$$U_{h,t} = \frac{\left(C_{hh,t}^{\delta} C_{hf,t}^{1-\delta}\right)^{1-\sigma}}{1-\sigma} + \beta \frac{\left(C_{hh,2t+1}^{\delta} C_{hf,2t+1}^{1-\delta}\right)^{1-\sigma}}{1-\sigma} \tag{1.26}$$

Subject to

$$P_{h,t} C_{hh,t} + \varepsilon_t P_{f,t} C_{hf,t} + D_{h,t} = W_{h,t} L_{h,t} \tag{1.27}$$

and

$$P_{h,t+1} C_{hh,2t+1} + \varepsilon_{t+1} P_{f,t+1} C_{hf,2t+1} = (1 + r_{h,t}) D_{h,t} \tag{1.28}$$

Where $W_{h,t} L_{h,t}$ is the aggregate income for the young generation at time *t*, $C_{hh,t}$ stands for the home consumption demand for home produced goods of the young generation at time *t*; $C_{hh,2t}$ stands for the home consumption demand of the old generation for home-produced goods at time *t*; $C_{hf,t}$ stands for the home consumption

demand of the young generation for imported goods at time t, and $C_{hf,2t}$ stands for the home consumption demand for imported goods of the old generation at time t. $D_{h,t}$ is the deposit balance at time t. β is the subjective time discount rate. Combining equation (1.27) and (1.28), the budget constraints for the young and old generation at time t can be rewritten as:

$$P_{h,t}C_{hh,t} + \varepsilon_t P_{f,t}C_{hf,t} + \left(P_{h,t+1}C_{hh,2t+1} + \varepsilon_{t+1}P_{f,t+1}C_{hf,2t+1}\right)/(1+r_{hD,t}) = L_{h,t}W_{h,t} \tag{1.29}$$

Solving this optimization problem, we obtain the following consumption function:

$$C_{hh,t} = \frac{\delta L_{h,t}w_{h,t}}{1+\beta^{\frac{1}{\sigma}}\left(\frac{\pi_{h,t+1}}{(1+r_{h,t})}\right)^{1-\frac{1}{\sigma}}\left(\frac{q_{t+1}}{q_t}\right)^{\frac{(1-\delta)(\sigma-1)}{\sigma}}} \tag{1.30}$$

$$C_{hf,t} = \frac{(1-\delta)L_{h,t}w_{h,t}}{q_t+\beta^{\frac{1}{\sigma}}q_t\left(\frac{\pi_{h,t+1}}{(1+r_{h,t})}\right)^{1-\frac{1}{\sigma}}\left(\frac{q_{t+1}}{q_t}\right)^{\frac{(1-\delta)(\sigma-1)}{\sigma}}} \tag{1.31}$$

$$C_{hh,2t+1} = \frac{\delta L_{h,t}w_{h,t}}{\frac{\pi_{h,t+1}}{(1+r_{h,t})}+\beta^{-\frac{1}{\sigma}}\left(\frac{\pi_{h,t+1}}{(1+r_{h,t})}\right)^{\frac{1}{\sigma}}\left(\frac{q_{t+1}}{q_t}\right)^{\frac{(1-\delta)(1-\sigma)}{\sigma}}} \tag{1.32}$$

$$C_{hf,2t+1} = \frac{(1-\delta)L_{h,t}w_{h,t}}{q_{t+1}\left(\frac{\pi_{h,t+1}}{(1+r_{h,t})}\right)+\beta^{-\frac{1}{\sigma}}q_{t+1}\left(\frac{\pi_{h,t+1}}{(1+r_{h,t})}\right)^{\frac{1}{\sigma}}\left(\frac{q_{t+1}}{q_t}\right)^{\frac{(1-\delta)(1-\sigma)}{\sigma}}} \tag{1.33}$$

$$\frac{D_{h,t}}{P_{h,t}} = \frac{L_{h,t}w_{h,t}}{1+\beta^{-\frac{1}{\sigma}}\left(\frac{\pi_{h,t+1}}{(1+r_{h,t})}\right)^{\frac{1}{\sigma}-1}\left(\frac{q_{t+1}}{q_t}\right)^{\frac{(1-\delta)(1-\sigma)}{\sigma}}} \tag{1.34}$$

By symmetry, foreign consumer's consumption can be expressed in (1.35)–(1.38) as:

$$C_{ff,t} = \frac{\delta' L_{f,t}w_{f,t}}{1+\beta^{\frac{1}{\sigma'}}\left(\frac{\pi_{f,t+1}}{(1+r_{f,t})}\right)^{1-\frac{1}{\sigma'}}\left(\frac{q_{t+1}}{q_t}\right)^{\frac{(1-\delta')(1-\sigma')}{\sigma'}}} \tag{1.35}$$

$$C_{fh,t} = \frac{(1-\delta')L_{f,t}w_{f,t}}{\frac{1}{q_t} + \beta'^{\frac{1}{\sigma'}} \frac{1}{q_t}\left(\frac{\pi_{f,t+1}}{(1+r_{f,t})}\right)^{1-\frac{1}{\sigma'}}\left(\frac{q_{t+1}}{q_t}\right)^{\frac{(1-\delta')(1-\sigma')}{\sigma'}}} \tag{1.36}$$

$$C_{ff,2t+1} = \frac{\delta' L_{f,t}w_{f,t}}{\frac{\pi_{f,t+1}}{(1+r_{f,t})} + \beta'^{-\frac{1}{\sigma'}}\left(\frac{\pi_{f,t+1}}{(1+r_{f,t})}\right)^{\frac{1}{\sigma'}}\left(\frac{q_{t+1}}{q_t}\right)^{\frac{(1-\delta')(\sigma'-1)}{\sigma'}}} \tag{1.37}$$

$$C_{fh,2t+1} = \frac{(1-\delta')L_{f,t}w_{f,t}}{\frac{1}{q_{t+1}}\left(\frac{\pi_{f,t+1}}{(1+r_{f,t})}\right) + \beta'^{-\frac{1}{\sigma'}}\frac{1}{q_{t+1}}\left(\frac{\pi_{f,t+1}}{(1+r_{f,t})}\right)^{\frac{1}{\sigma'}}\left(\frac{q_{t+1}}{q_t}\right)^{\frac{(1-\delta')(\sigma'-1)}{\sigma'}}} \tag{1.38}$$

Which is derived from the foreign utility function

$$U_{f,t} = \frac{\left(C_{ff,t}^{\delta'}C_{fh,t}^{1-\delta'}\right)^{1-\sigma'}}{1-\sigma'} + \beta'\frac{\left(C_{ff,2t+1}^{\delta'}C_{fh,2t+1}^{1-\delta'}\right)^{1-\sigma'}}{1-\sigma'} \tag{1.39}$$

Subject to

$$P_{f,t}C_{ff,t} + \left(P_{h,t}/\varepsilon_t\right)C_{fh,t} + D_{f,t} = W_{f,t}L_{f,t} \tag{1.40}$$

and

$$P_{f,t+1}C_{ff,2t+1} + \left(P_{h,t+1}/\varepsilon_{t+1}\right)C_{hfh,2t+1} = (1+r_{f,t})D_{f,t} \tag{1.41}$$

1.4 Equilibrium Conditions

The above studies on the behavior of consumers, producers and imported firms produce the functions of consumption, investment, output supply, import demand and supply of both home and abroad, from which related variables are further defined as follows:

Export goods supply of home firms:
$X_{h,t} = Y_{h,t} - \left(C_{hh,t} + C_{hh,2t} + K_{hh,t}\right)$
Import goods demand of home firms:
$M_{h,t} = C_{hf,t} + C_{hf,2t} + K_{hf,t}$
Export goods supply of foreign firms:
$X_{f,t} = Y_{f,t} - \left(C_{ff,t} + C_{ff,2t} + K_{ff,t}\right)$
Import goods demand of home firms:
$M_{f,t} = C_{fh,t} + C_{fh,2t} + K_{fh,t}$

To reach the general equilibrium for a two-country open economy model, three equilibrium conditions, i.e., the equilibrium of the import goods market, equilibrium of the export goods market and international payment equilibrium, should be fulfilled:

1. *Export goods market equilibrium:* Under this equilibrium, the domestic supply of export goods (the left-hand-side of the following formula) and the foreign demand for these export goods (the right-hand-side) are made equal.

$$X_{h,t} = M_{f,t} \tag{1.42}$$

2. *Import goods market equilibrium:* This equilibrium condition implies that the foreign supply of import goods (the left-hand-side of the following formula) and domestic demand for these import goods (the right-hand-side) are identical:

$$X_{f,t} = M_{h,t} \tag{1.43}$$

3. *International payment equilibrium*[5]*:* Under a flexible exchange rate regime, equilibrium in the balance of payments is attained when the trade balance, balance of services account and capital account add up to zero:

$$\begin{aligned} &C_{fh,t} + C_{fh,2t} + K_{fh,t} - q_t\left(C_{hf,t} + C_{hf,2t} + K_{hf,t}\right) \\ &+\left(q_t K_{hf,t} - K_{fh,t}\right)+\left(K_{fh,t} r_{h,t} - q_t K_{hf,t} r_{f,t}\right) \\ &= C_{fh,t} + C_{fh,2t} + K_{fh,t} r_{h,t} - q_t\left(C_{hf,t} + C_{hf,2t} + K_{hf,t} r_{f,t}\right) = 0 \end{aligned} \tag{1.44}$$

Where $CA = \left(X_{h,t} - M_{h,t}\right) = \left(C_{fh,t} + C_{fh,2t} + K_{fh,t}\right) - q_t\left(C_{hf,t} + C_{hf,2t} + K_{hf,t}\right)$ represents net exports or the current account balance; $KA = \left(q_t K_{hf,t} - K_{fh,t}\right)$ is the net capital flow or capital account balance; and $\left(K_{fh,t} r_{h,t} - q_t K_{hf,t} r_{f,t}\right)$ is the net gain from foreign investment.

1.4.1 Short Run Equilibrium

Under our model, "short-run" equilibrium refers to the situation where the current exchange rate price or interest rates are adjusted to equalize the demand to supply in the goods and deposit markets, given the previous and future variables, including policy variables, fixed at exogenous levels. Equations (1.42), (1.43) and (1.44) are combined into a complex nonlinear dynamic difference equation system including five types of variables, i.e., domestic and foreign inflation, interest rates and exchange rates of the past, present and future. Generally, the solution of this system cannot be expressed clearly in elementary mathematical functions. However, in the short run, the equations

[5] Consider the reality of the PRC where the capital accounts are strictly controlled and the government prefers a positive trade surplus, an acceptable positive trade surplus can be seen as an equilibrium state. In coming empirical studies we will consider the actual situation of the PRC.

imply that current interest rates and the real exchange rate should be functions of the past, present or expected value of inflation rates, exchange rates and interest rates:

$$r_{h,t} = f_1(\pi_{h,t-1}, \pi_{h,t}, \pi_{h,t+1}; \pi_{f,t-1}, \pi_{f,t}, \pi_{f,t+1}; r_{h,t-1}, r_{f,t-1}; q_{t-1}, q_{t+1}; \tau_h, \tau_f; \theta\Lambda) \quad (1.45)$$

$$r_{f,t} = f_2(\pi_{h,t-1}, \pi_{h,t}, \pi_{h,t+1}; \pi_{f,t-1}, \pi_{f,t}, \pi_{f,t+1}; r_{h,t-1}, r_{f,t-1}; q_{t-1}, q_{t+1}; \tau_h, \tau_f; \theta\Lambda) \quad (1.46)$$

$$q_t = f_3(\pi_{h,t-1}, \pi_{h,t}, \pi_{h,t+1}; \pi_{f,t-1}, \pi_{f,t}, \pi_{f,t+1}; r_{h,t-1}, r_{f,t-1}; q_{t-1}, q_{t+1}; \tau_h, \tau_f; \theta\Lambda) \quad (1.47)$$

Where "$\theta\Lambda$" denotes θ and other exogenous parameters. From (1.45)–(1.47), the real exchange rate as well as domestic and foreign interest rates are endogenously determined given past and expected future inflation rates, interest rates and exchange rates, and especially the current inflation. Like under the Tailor rule (Tailor, 1993), monetary policy needs to respond to the inflation rate and other variables, but the form is not necessarily the same. Since $q_t = \frac{e_t P_{f,t}}{P_{h,t}}$, rewriting (1.47), we have:

$$e_t = \frac{f_3(\pi_{h,t-1}, \pi_{h,t}, \pi_{h,t+1}; \pi_{f,t-1}, \pi_{f,t}, \pi_{f,t+1}; r_{h,t-1}, r_{f,t-1}; q_{t-1}, q_{t+1}; \tau_h, \tau_f; \theta\Lambda) P_{h,t}}{P_{f,t}} \quad (1.48)$$

Thus, expression (1.48) implies that the nominal exchange rate is determined by past and expected future inflation, interest and exchange rates, and especially the current inflation. This indicates that the exchange rate is endogenously determined and that a floating exchange regime in both countries is desirable to clear the markets.

Taking an extreme case in which the prices are constant (the viewpoint of the Keynesian school), and where the inflation rates are all zero, (1.45)–(1.47) can be rewritten as:

$$r_{h,t} = f_1(r_{h,t-1}, r_{f,t-1}; q_{t-1}, q_{t+1}; \tau_h, \tau_f; \theta\Lambda) \quad (1.49)$$

$$r_{f,t} = f_2(r_{h,t-1}, r_{f,t-1}; q_{t-1}, q_{t+1}; \tau_h, \tau_f; \theta\Lambda) \quad (1.50)$$

$$q_t = f_3(r_{h,t-1}, r_{f,t-1}; q_{t-1}, q_{t+1}; \tau_h, \tau_f; \theta\Lambda) \quad (1.51)$$

This demonstrates that the real exchange rate and interest rates and other variables interact, and that neither country can perform monetary policy independently.

Another case is where the interest rates in both countries are controlled by monetary policy. In this case, the interest rates of both countries are regarded as exogenous variables. Under this circumstance, prices have to be adjustable to clear the markets, so we can derive:

$$\pi_{h,t} = f_1(\pi_{h,t-1}, \pi_{h,t+1}, \pi_{f,t-1}, \pi_{f,t+1}; r_{h,t-1}, r_{h,t}, r_{f,t-1}, r_{f,t}; q_{t-1}, q_{t+1}; \tau_h, \tau_f; \theta\Lambda) \quad (1.52)$$

$$\pi_{f,t} = f_2(\pi_{h,t-1}, \pi_{h,t+1}; \pi_{f,t-1}, \pi_{f,t+1}; r_{h,t-1}, r_{h,t}, r_{f,t-1}, r_{f,t}; q_{t-1}, q_{t+1}; \tau_h, \tau_f; \theta\Lambda) \quad (1.53)$$

$$e_t = \frac{f_3(\pi_{h,t-1}, \pi_{h,t+1}, \pi_{f,t-1}, \pi_{f,t+1}; r_{h,t-1}, r_{h,t}, r_{f,t-1}, r_{f,t}; q_{t-1}, q_{t+1}; \tau_h, \tau_f; \theta\Lambda)\ P_{h,t}}{P_{f,t}} \tag{1.54}$$

(1.52)–(1.53) imply that if both countries control interest rates independently to realize market equilibrium, the inflations and nominal exchange rate have to adjust endogenously. In other words, under a pegged exchange rate regime, market equilibrium will not realized in general unless at least one of the countries gives up its monetary policy independence.

Generally speaking, the PRC, as a bigger country, may be reluctant to give up the independence of its monetary policy. In this connection, no matter how price levels change, general equilibrium may not be reached in the absence of a flexible exchange rate regime.

Under general conditions, a clear analytical expression of (1.51) is not available and the real exchange rate is not constant. Thus, we have actually demonstrated that purchase power parity and interest rate parity do not hold in the short run.

To see how the exchange rate affects the balance of international payments, we write the balance of international payment-output ratio into

$$\frac{BP_{h,t}}{Y_{h,t}} = \frac{(1-\alpha-\phi)}{1+\beta^{-\frac{1}{\sigma}}\left(\frac{\pi_{h,t+1}}{(1+r_{hD,t})}\right)^{\frac{1}{\sigma}-1}\left(\frac{q_{t+1}}{q_t}\right)^{\frac{(1-\delta)(1-\sigma)}{\sigma}}} - \frac{(1-\alpha-\phi)/(1+g_{h,t})}{1+\beta^{-\frac{1}{\sigma}}\left(\frac{\pi_{h,t}}{(1+r_{hD,t-1})}\right)^{\frac{1}{\sigma}-1}\left(\frac{q_t}{q_{t-1}}\right)^{\frac{(1-\delta)(1-\sigma)}{\sigma}}},$$

We have $\frac{\partial q_{t+1}}{\partial\left(\frac{BP_{h,t}}{Y_{h,t}}\right)} < 0,$ $\frac{\partial \pi_{t+1}}{\partial\left(\frac{BP_{h,t}}{Y_{h,t}}\right)} < 0,$ $\frac{\partial \pi_t}{\partial\left(\frac{BP_{h,t}}{Y_{h,t}}\right)} > 0,$

$\frac{\partial\left(\frac{BP_{h,t}}{Y_{h,t}}\right)}{\partial g_{h,t}} < 0,$ $\frac{\partial\left(\frac{BP_{h,t}}{Y_{h,t}}\right)}{\partial r_{h,t}} < 0,$ when $\sigma < 1$[6]. This demonstrates that with an increase in the ratio of the balance of payments to output, more pressure will be put on current home inflation, as well as expected real appreciation of the home currency and future deflation. For the home country, whether or not to maintain a fixed exchange rate depends on if it can tolerate a high inflation rate. Presently, the PRC inflation rate is not so high, and the PRC government may be willing to take the pressure. In addition, raising the interest rate may also help to lower the balance of international payments. The balance of payments may benefit from rapid growth. Once the economy cools down, the balance of payments may fall and even disappear.

[6] $\sigma < 1$ is a condition for the existence of a saddle point equilibrium in the case of a fixed exchange rate. When $\sigma > 1$, the steady state is not stable.

A great deal of evidence has shown that the exchange rate is flexible. Theoretically, it is likely that the exchange rate is determined by conditions (1.42), (1.43) and (1.44). Chen (2004) studied a special case of the framework here qualitatively, in which the output is assumed to be constant, and concluded that the exchange rate may move explosively away from its balance track when the parameters of the model fail in some specific regions. This implies that it is necessary to impose some control on the fluctuation of the exchange rate.

1.4.2 The Long-Run Steady State

As we have stated previously, some economists have worked out some schemes to revalue the renminbi to a certain level by a sufficient appreciation to prevent speculative attacks. Is this kind of scheme practicable? This question is related to whether the long-run steady state exchange rate exists and what conditions are needed to maintain exchange rate stability. A long-run steady state means that the exchange rate and price levels change at a constant speed, but that the growth rate of and the ratio between aggregate economic variables are constant. If a steady-state exchange rate exists, a fixed exchange rate regime can be maintained for long; if not, one cannot expect that the issue of renminbi revaluation can be resolved by just once appreciation. To answer this question, let us focus on the international payment equilibrium condition (1.44), from which the exchange rate at time *t* can be determined.

Substituting the domestic and foreign consumption and investment function into (1.44), the international payment equilibrium condition can be rewritten as:

$$\begin{aligned}
&\frac{(1-\delta')(1-\alpha'-\phi')(1+g_{f,t})}{\frac{1}{q_t}+\beta'^{\frac{1}{\sigma'}}\frac{1}{q_t}\left(\frac{\pi_{f,t+1}}{(1+r_{f,t})}\right)^{1-\frac{1}{\sigma'}}\left(\frac{q_{t+1}}{q_t}\right)^{\frac{(1-\delta')(1-\sigma')}{\sigma'}}} \\
&+\frac{(1-\delta')(1-\alpha'-\phi')}{\frac{1}{q_t}\left(\frac{\pi_{f,t}}{(1+r_{f,t-1})}\right)+\beta'^{-\frac{1}{\sigma'}}\frac{1}{q_t}\left(\frac{\pi_{f,t}}{(1+r_{f,t-1})}\right)^{\frac{1}{\sigma'}}\left(\frac{q_t}{q_{t-1}}\right)^{\frac{(1-\delta')(\sigma'-1)}{\sigma'}}}+\phi' q_t \pi_{f,t+1}(1+g_{f,t}) \\
&=\left(\frac{(1-\delta)(1-\alpha-\phi)(1+g_{h,t})}{1+\beta^{\frac{1}{\sigma}}\left(\frac{\pi_{h,t+1}}{(1+r_{h,t})}\right)^{1-\frac{1}{\sigma}}\left(\frac{q_{t+1}}{q_t}\right)^{\frac{(1-\delta)(\sigma-1)}{\sigma}}}\right. \\
&\left.+\frac{(1-\delta)(1-\alpha-\phi)}{\left(\frac{\pi_{h,t}}{(1+r_{h,t-1})}\right)+\beta^{-\frac{1}{\sigma}}\left(\frac{\pi_{h,t}}{(1+r_{h,t-1})}\right)^{\frac{1}{\sigma}}\left(\frac{q_t}{q_{t-1}}\right)^{\frac{(1-\delta)(1-\sigma)}{\sigma}}}+\phi\pi_{h,t+1}(1+g_{h,t})\right)\frac{Y_{h,t-1}}{Y_{f,t-1}}
\end{aligned} \tag{1.55}$$

Since the inflation rate, interest rate and exchange rate do not change with time in a steady state, (1.55) implies that the existence of a steady state exchange rate (q_t is

constant) requires that $Y_{h,t}/Y_{f,t}$ does not change with time *t*, that is, $\frac{Y_{h,t}}{Y_{f,t}}=\frac{Y_{h,t-1}}{Y_{f,t-1}}$ for any *t*. According to (1.20), (1.21) and (1.25), we have

$$\frac{Y_{h,t}}{Y_{f,t}}=\frac{A_{h,t}^{\frac{1}{1-\alpha-\phi}}\left(\frac{\alpha\pi_{h,t+1}}{r_{h,t}}\right)^{\frac{\alpha}{1-\alpha-\phi}}\left(\frac{\phi\pi_{h,t+1}}{r_{f,t}}\frac{1}{\varphi q_t}\right)^{\frac{\phi}{1-\alpha-\phi}}L_{h,t}}{A_{f,t}^{\frac{1}{1-\alpha'-\phi'}}\left(\frac{\alpha'\pi_{f,t+1}}{r_{f,t}}\right)^{\frac{\alpha'}{1-\alpha'-\phi'}}\left(\frac{\phi'\pi_{f,t+1}}{r_{h,t}}\frac{q_t}{\varphi'}\right)^{\frac{\phi'}{1-\alpha'-\phi'}}L_{f,t}}$$

$$=\frac{\left(A_{h,0}\right)^{\frac{1}{1-\alpha-\phi}}\left(\frac{\alpha\pi_{h,t+1}}{r_{h,t}}\right)^{\frac{\alpha}{1-\alpha-\phi}}\left(\frac{\phi\pi_{h,t+1}}{r_{f,t}}\frac{1}{\varphi q_t}\right)^{\frac{\phi}{1-\alpha-\phi}}L_{h,0}\left[(1+n_h)(1+a_h)^{\frac{\alpha}{1-\alpha-\phi}}\right]^t}{\left(A_{f,0}\right)^{\frac{1}{1-\alpha'-\phi'}}\left(\frac{\alpha'\pi_{f,t+1}}{r_{f,t}}\right)^{\frac{\alpha'}{1-\alpha'-\phi'}}\left(\frac{\phi'\pi_{f,t+1}}{r_{h,t}}\frac{q_t}{\varphi'}\right)^{\frac{\phi'}{1-\alpha'-\phi'}}L_{f,0}\left[(1+n_f)(1+a_f)^{\frac{\alpha'}{1-\alpha'-\phi'}}\right]^t},$$

then,

$$\left[\frac{(1+n_h)(1+a_h)^{\frac{\alpha}{1-\alpha-\phi}}}{(1+n_f)(1+a_f)^{\frac{\alpha'}{1-\alpha'-\phi'}}}\right]^t=\left[\frac{(1+n_h)(1+a_h)^{\frac{\alpha}{1-\alpha-\phi}}}{(1+n_f)(1+a_f)^{\frac{\alpha'}{1-\alpha'-\phi'}}}\right]^{t-1} \tag{1.56}$$

and

$$(1+n_h)(1+a_h)^{\frac{\alpha}{1-\alpha-\phi}}=(1+n_f)(1+a_f)^{\frac{\alpha'}{1-\alpha'-\phi'}} \tag{1.57}$$

The left side of (1.57) is the home economic growth rate and the right side is the foreign economic growth rate. Thus, (1.57) indicates that the two economic growth rates are equal. We denote them with *g*.

Defining $M_h=\beta^{\frac{1}{\sigma}}(1+r_h)^{\frac{1}{\sigma}-1}$ and $M_f=\beta^{\frac{1}{\sigma}}(1+r_f)^{\frac{1}{\sigma}-1}$, in a steady state where $\pi_{f,t}=\pi_{h,t}=1; r_{h,t}=r_h; r_{f,t}=r_f; q_t=q_{t+1}=q$, for all *t*, the exchange rate can be expressed as:

$$q^{1+\frac{\phi}{1-\alpha-\phi}+\frac{\phi'}{1-\alpha'-\phi'}}=\left\{\left[\frac{\left(A_{h,0}\right)^{\frac{1}{1-\alpha-\phi}}\left(\frac{\alpha}{r_h}\right)^{\frac{\alpha}{1-\alpha-\phi}}\left(\frac{\phi}{r_f}\frac{1}{\varphi}\right)^{\frac{\phi}{1-\alpha-\phi}}L_{h,0}}{\left(A_{f,0}\right)^{\frac{1}{1-\alpha'-\phi'}}\left(\frac{\alpha'}{r_f}\right)^{\frac{\alpha'}{1-\alpha'-\phi'}}\left(\frac{\phi'}{r_h}\frac{1}{\varphi'}\right)^{\frac{\phi'}{1-\alpha'-\phi'}}L_{f,0}}\right]\right.$$
$$\left.*\left[\frac{\frac{(1-\delta)(1-\alpha-\phi)(1+g\ )}{1+M_h}+\frac{(1-\delta)(1-\alpha-\phi)}{\left(1+r_h\right)^{-1}\left(1+M_h^{-1}\right)}+\phi(1+g\ )}{\frac{(1-\delta')(1-\alpha-\phi)(1+g\ )}{1+M_f}+\frac{(1-\delta')(1-\alpha-\phi)}{\left(1+r_f\right)^{-1}\left(1+M_f^{-1}\right)}+\phi'(1+g\ )}\right]\right\} \tag{1.58}$$

Where the implication of some of the variables are as follows:

q : real exchange rate at steady state

r_h : home interest rate at steady state

r_f : foreign interest rate at steady state

π_h : one plus the inflation rate of the home country at steady state

π_f : one plus the inflation rate of the foreign country at steady state

From (1.58) we conclude that a necessary condition for the existence of a steady-state exchange rate is that the two economies have identical long-run economic growth rates. This implies that only in the long run can relative PPP (q is constant) hold, and that absolute PPP, (equivalently q=1) requires even stronger conditions, that is, every variable concerned at home must be equal to its counterpart abroad, for example, $\alpha=\alpha', \beta=\beta', r_h=r_f, \Lambda$, and so on.

A necessary condition for (1.58) to hold is that the two economies concerned have identical long-run economic growth rates[7] (as indicated in (1.57)). In other words, there will be no long-run steady-state exchange rate between two countries that have different long-run steady-state economic growth rates.

The PRC, US, Japan and other developed countries lie in different development phases, and their long-run economic growth rates are generally viewed as different. Thus, there is no long-run constant exchange rate between the US dollar and the renminbi, and we have reason to say that it is impossible to resolve the issue of the renminbi through only one appreciation. To the contrary, to keep an independent monetary policy and balance of international payments, a flexible exchange rate regime is needed.

[7] Although this conclusion may be obtained from some simple existing models, we have not seen that such conclusion can be obtained from a more general and complicated system like this.

This model can explain why both absolute and relative purchase power parity do not receive support from empirical studies, but that relative power parity does in the long run. From (1.58), only if the interest rates, economic growth rates, starting period labor and technology levels and all parameters in the production and utility functions between the two countries concerned are equal can the real exchange rate be equal to one, or equivalently, can absolute PPP hold. In addition, given exogenous variables and the steady-state growth rate of the two countries being equal, (1.58) implies that relative purchase power parity holds in the long run.

1.5 Implications of the Model

We have created a two-country general equilibrium model in which each country has three sectors. The inclusion of import firms allows us to examine the roles that transport costs, tariffs and monopoly power play in the determination of the exchange rate. The model also allow us to consider exchange rate determination in a framework for a "large" country, which differs from a small country model in that a small country model takes foreign monetary policy and prices as given, as it is too small to affect foreign policy and economic variables, whereas big countries can influence one another. Thus, conclusions gained from a small country model may not hold for a large country model. Then, what can we draw from the model?

1) The equilibrium condition derived from the model is a complex nonlinear dynamic second order difference equation system based on the inflation rate, exchange rate, interest rate, transport costs, tariffs, monopoly power and some of their lag values. Considering that big countries like the PRC and US are reluctant to give up monetary policy (represented by the interest rate) independence, the system tells us that prices and the exchange rate are endogenously determined by production and preference parameters and interest rate when both exchange rate and prices are flexible. If both countries want to maintain the independence of their monetary policy and internal and external balance, a floating exchange regime is desirable.
2) On the other hand, under circumstances where prices are preset (such as in the Mundell-Fleming model) or sticky (such as in the Dornbusch model), it is difficult to achieve a general equilibrium without changing the interest rate; This means that the monetary policy of each country cannot be performed independently, and the exchange rate fluctuates endogenously. Otherwise, a general equilibrium cannot be realized.
3) Under a fixed exchange rate regime, at least one of the two countries cannot carry out an independent monetary policy, in contrast to the small country model in which small countries cannot perform independent policies.
4) One necessary condition for the existence of a long-run steady-state exchange rate is that the two economies have identical economic growth rates. In other words, if the two countries have different long-run economic growth rates, the long-run steady-state exchange rate does not exist. Since there are different economic growth rates among the PRC and US, Japan and other developed countries, it is difficult for

the PRC to maintain the renminbi's exchange rate stable in the long run. Thus, it is impossible to resolve the issue of the renminbi by a single revaluation.

5) We show theoretically that under general conditions, neither absolute nor relative purchase power parity holds. Relative purchase power parity may hold only in the long run if the two economies have identical economic growth. The condition for PPP is that everything concerned in the model be equal between home and abroad.

6) Considering that the exchange rate may move explosively under external shocks, it is necessary to allow the exchange rate to float in a relatively narrow band around its equilibrium level.

2. Misalignment of the Renminbi Exchange Rate and Its Adjustment

2.1 Introduction

In the first part of this paper, a general theoretical equilibrium model of exchange rate determination has been created to show how the exchange rate interacts with the inflation rate, interest rate and balance of payments, as well as some other exogenous technical and preference parameters. This model is nonlinear, and clear expressions of the model's solutions are usually not available. However, some special forms of the model have been studied qualitatively. For example, in the case of small countries and constant output (ignorance of the production sector), Shi Kuan Chen (2004) demonstrated that the exchange rate is endogenously determined and the fluctuation of the exchange rate depends on the preference parameter of consumers. Under some specific conditions, exchange rates perform smoothly and a long-run steady state can be achieved, but at a certain time the exchange rate may change explosively. However, the theory itself does not tell us where the preference parameters are. Thus, whether exchange rate becomes explosive is an issue of empirics rather than theory. However, the results of empirical studies are usually more or less removed from theoretical studies. A general way to handle a nonlinear mode is the linearization of a nonlinear model. The linearized model forms the basis for the Behavioral Equilibrium Exchange Rate (BEER). Based on the BEER, one can estimate BEER and the misalignment of the renminbi exchange rate. This allows an assessment of the consequences of external shocks to exchange rates, which obviously has implications for the revaluation of renminbi and can be a useful reference for policymakers.

The rest of this part is organized as follows: section 2.2 is a description of the model and the data of relevant variables. Section 2.3 presents the empirical results. Finally, the implications are discussed in Section 2.4.

2.2 Model Selection and Data

Through linearization, the nonlinear theoretical general equilibrium model can be transformed into a Vector Auto Regression (VAR) model that includes five variables: the exchange rate, domestic and foreign inflation rates, and domestic and foreign interest rates. Taking into consideration the institutional feature of the PRC, that capital flows are controlled rigorously and that mercantilism – the tendency to accumulate trade

surpluses and related foreign reserves – dominates the ideas of the PRC government, a lasting positive trade surplus can be an acceptable condition for the external balance. Thus we put the trade surplus-GDP ratio of the PRC with the rest of the world into the model. As a result, six macroeconomic variables (the nominal exchange rate, domestic inflation rate, foreign inflation rate, domestic interest rate and foreign interest rate, and trade balance-GDP ratio) are incorporated into the VAR, where the change of the domestic interest rate and foreign interest rate represent changes of monetary policies.

The deposit rate of the PRC is viewed to be exogenous, just because the deposit rate has not been liberalized and is controlled by the PBOC. As for foreign interest rates, there is no unified world interest rate policy, but the United States, the biggest economy in the world, has an exceptional impact on other economies, especially those of small countries or regions whose currencies are pegged to the US dollar. Thus, we think that US federal interest can be viewed as a benchmark and as a substitute for foreign interest rate and put into the model as a policy instrument.[8]

We take the GDP deflators of the PRC and US as indexes of inflation indicators. Generally, the GDP deflator is a better index than the change of consumer prices, since it is a more comprehensive price indicator of various goods. Another reason for us to choose the GDP deflator as an index of inflation indicators is that other indicators, such as export and import price and consumer price of the PRC before 1985 are either unavailable or too short-term for this study. The data used in this study are yearly data from 1980 to 2004. Most of them are from International Financial Statistics (IFS) June 2005 edition and China Statistical Yearbook 2004.

Before setting the Vector Error Correction (VEC) model, we define the relevant variables as below:

- C_NEER: nominal effective exchange rate.
- C_DEFG: per cent change of PRC deflator.
- C_DRATE: deposit interest rate.
- US_ DEFG: per cent change of US deflator.
- US_FRATE: US federal funds interest rate.
- C_TRADE: trade balance of the PRC versus the rest of world.

$Y_t = \left(NEER_t \quad C\_DEFG_t \quad US\_DEFG_t \quad C\_TRADE_t\right)'$: an endogenous variable vector.

$X_t = \left(C\_DRATE \quad US\_FRATE\right)'$: an exogenous variable vector.

[8] Though the PRC deposit rate and US federal interest rate are viewed by some as endogenous variables, with the federal interest rate being seen to follow Taylor's rule, for example, this proposition is still controversial. In our view, they are at most partly endogenously determined because they are controlled by the government and do not respond very flexibly to inflation and other variables. For the sake of simplicity and the constraints on the length of data in the PRC, we regard them as exogenous variables.

Unrestricted VAR (k) can be expressed as:

$$Y_t = \sum_{i=1}^{k} A_i Y_{t-i} + \sum_{i=1}^{l} B_i X_{t-i+1} + \mathrm{E}_t \text{ [9]},\ U_t = iid(\mathrm{O}, \Omega) \tag{2.1}$$

Where, $A_1, A_{2,\Lambda,} A_k$ are all 4×4 parameter matrices, B_i is a 4×2 parameter matrix, U_t is a 4×1 random residual vector, O is a 4×1 zero vector, and Ω is a 4×4 covariance matrix. If necessary, the shifts and trends and dummy variable can also be included in this model. Since the specific VAR here is derived from the linearization of the nonlinear general equilibrium model around its equilibrium, in fact we have already assumed that there is an equilibrium force that pulls the economic variables toward their equilibrium state. In other words, there are integration relationships among the endogenous variables. However, the existence of the integration has to be studied empirically, or the integration equations have to be tested, and the distance of the economic variables from their equilibrium level has to be estimated. An efficient tool for dealing with this issue is the restricted VAR model or VEC model. Rewriting the VAR model (2.1), we have the standard form of the VEC model (2.2):

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \sum_{i=1}^{l} B_i X_{t-i+1} + U_t \tag{2.2}$$

where $\Gamma_i = -\sum_{i=j+1}^{k} A_i,\ \ i = 1,2,\Lambda\ , k-1$, $\Pi = \left(\sum_{i=1}^{k} A_i - I \right)$, I is a unit 4×4 matrix.

Statistically, to avoid spurious regressions, one need to test if the relevant time series in (2.2) are stationary or cointegrated. If Y_t is not stationary, and is say, $Y_t \sim I(1)$ without loss of generality, we have $\Delta Y_t \sim I(0)$. This means all of the endogenous terms in (2.2) except ΠY_{t-1} are stationary. If ΠY_{t-1} is not stationary, there are no cointegrations among the elements of Y_t. If ΠY_{t-1} is stationary, there are cointegrations among the elements of Y_t. Granger's representation theorem asserts that if the coefficient matrix Π reaches reduced rank $\tau < 4$, then there exist matrices α and β each with rank τ such that $\alpha\beta' = \Pi$ and $\beta' Y_{t-1} \sim I(0)$. τ is the number of cointegrating relations (the cointegrating rank) and each column of β is the cointegrating vector (Hamilton, 1994).

2.3 Empirical Study and Results

The empirical study include five steps: (1) unit root test of level variables, (2) unit root test of first order difference, and second order difference of level variables if necessary, (3) cointegration test, (4) estimation of cointegration and VEC relations, and (5) impulse-response analysis. The unit root test is used to test if a time series is stationary to determine if a regression is spurious. If the test confirms that a series has a unit root,

[9] Theoretically, the lag k of the model in this paper should be 2.

the series is nonstationary. Different nonstationary series may have cointegrating relations. Thus, an integration test is needed. If integration relations exist, the next step is a VEC model estimation, which estimates both the long-run integration equations among endogenous variables and the short-run fluctuations. The purpose of impulse and response analysis is to investigate how one variable responds to the impulse of another variable. In the case of the renminbi, we want to understand what takes place once a one-time exchange rate adjustment is made under the pressure of the United States and other countries.

2.3.1 Unit Root Test

The results of the unit root tests listed in Table 1–4 demonstrate that the Augmented Dickey-Fuller (ADF) test cannot reject any of the null hypotheses that the endogenous variables C_NEER, C_DEFG, C_TRADE or US_DEFG, has a unit root. Thus, these time series cannot be viewed as stationary.

Secondly, we test if the first differences of these time series are stationary under the Augmented Dickey-Fuller (ADF) tests. The test outcomes are shown in Table 5–8. The null hypothesis that the first difference of each variable tested has unit root is rejected. This indicates that the first difference of C_NEER, C_DEFG, US_DEFG and C_TRADE can be viewed as a stationary process.

2.3.2 Cointegration Test

Since the level endogenous variables are not stationary, we need to conduct further cointegration tests. The results are shown in Table 9 and 10. Table 9 contains two kinds of cointegration rank tests, the trace test and maximium eigenvalue test, with domestic and foreign interest rates as exogenous variables. Both show that there are four cointegration relations. We also conduct an integration rank (trace) test without exogenous variables (see Table 10), which shows that this series has two cointegrations. In any case, all the tests demonstrate that cointegrating relations exist among the variables.

2.3.3 Vector Error Correction and Cointegration Estimation

Before conducting VEC analysis, it is necessary to judge the order of the system. The theoretical model shows that the order should be two. The VEC with more than two lags is not available due to data limitations. In addition, a comparison of the statistic of first and second order VEC shows that the second order VEC is better than the first.

There is more than one cointegration statistically, but the cointergation with maximum eigenvalue is generally believed to be more meaningful. The cointegration corresponding to maximum eigenvalue according to a computation with the EVIEWS software is listed in Table 11, and represents the equilibrium relation between C_NEER and other factors concerned.

The estimation of the misalignment of C_NEER is shown in Chart 1. It indicates that the renminbi has gone through two phases of overvaluations and three phases of undervaluations since 1979. The two phases of overvaluations were before

1986 and during 1998 to 1999. In the period from 1983 to 1986, the renminbi was severely overvalued, from 29 to 66 per cent. Before the East Asia financial crisis broke out in 1997, the renminbi was nearly at its proper level, or was at most slightly overvalued. After the East Asia Financial crisis, most of East Asia currencies depreciated greatly and the renminbi was still pegged to the US dollar, so it was found to be overvalued by 13 per cent and 32 per cent, respectively, in 1998 and 1999.

The three phases of undervaluations happened during 1989 to 1990, 1993 to 1994, and after 2000. During 1986 to 1988, the renminbi was relatively properly valued, but with the market oriented price reform of 1988, high inflation appeared, at the same time, the renminbi was undervalued by about 28 in 1989 and 33 per cent in 1990. This is the first time it was found to be undervalued. The second time it was undervalued was between 1993 and 1994, following Deng Xiaoping's South China Tour speech of 1992. His speech indicated that a new round reform and opening up policy to the outside world was being launched. As a result, demand for foreign exchange increased rapidly, FDI was introduced on a greater scale, and speculative attacks on the renminbi grew in the black and swap market. Under this circumstance, the exchange rate became distorted at a much higher than the official rate. With the shock of reform and opening up, the official exchange rate was finally unified with the market rate in 1994, and the nominal effective exchange rate was considerably undervalued, by approximately 18 per cent in 1993 and 44 per cent in 1994. The issue was eventually resolved through long-time inflation. The third and latest undervaluation started from 2000 and has lasted for five years. The magnitude of the undervaluation has been between 7 per cent and 25 per cent, or 17 per cent on average.

2.3.4 Impulse-Response Analysis

Though the VEC model analysis shows that the renminbi has been undervalued by 17 per cent on average, this does not mean that the nominal exchange rate has to be sharply revalued by 17 per cent to recover its equilibrium. A series of consequences of one time adjustment of exchange rate should also be taken into consideration. The magnitude of the adjustment should take into account the capacity of the PRC economy to bear a sudden adjustment. Chart 2 shows that a one-time innovation to the nominal effective exchange rate of the renminbi will be followed by a consecutive appreciation of the nominal effective appreciation if other things are equal, though the appreciation will weaken with time.

Then C_NEER will experience a period of depreciation followed by another appreciation. In summary, it seems that C_NEER has to experience a business cycle before approaching a steady state. Chart 2 also shows that the appreciation of the renminbi will cause the inflation rate to experience an increasing cycle and the foreign inflation rate a decreasing cycle. Its impulse on PRC inflation is much larger than on US inflation[10].

[10] Theoretically, it is difficult to show if an appreciation of the renminbi will cause inflation or deflation. From the viewpoint of trade balances, an appreciation of the renminbi will hurt Chinese exports and benefit imports, so net import or foreign demand will decrease, which may cause deflation. But from the

From the impulse-response analysis, we also find that the exchange rate adjustment can't be passed through for 100 per cent to the price adjustment. Similar evidence is also observed in Japan (Kanamori and Zhao, 2005 [46]), and other countries or regions (Engle and Devereux, 2003). In addition, the positive impulse on the exchange rate lowers the PRC trade surplus, though not by very much.

Policymakers have to consider the accumulated effect that follows a one-time nominal exchange rate shock. According to Table 12, the accumulated effects of one unit innovation to C_NEER may reach about three units in three years, and the ratio of the trade balance to GDP is about 0.18 units. On average, the C_NEER is undervalued by 22 units (equivalent to 17 per cent) and the trade balance-GDP ratio is about 2 per cent. Thus, we estimate that the PRC economy could endure as much as a 7 per cent to 11 per cent revaluation without suffering an overvaluation and trade deficit.

2.4 Policy Implications and Exchange Rate Reform

Theoretically, the undervaluation of the renminbi distorts resource allocations across countries. An appreciation of the renminbi helps to correct the distortion. However, there are different views on how much the renminbi should be revaluated. This indicates how difficult it is for an economy to achieve consensus on where the equilibrium level is.

The empirical study in this part shows that in terms of the nominal effective exchange rate, the renminbi has been undervalued between 7 per cent and 25 per cent, and on average, 17 per cent, since 2000. Comparing this estimation with the announcement made on 21 July 2005 by the PBOC that the renminbi would be appreciated by some two per cent, we can conclude that a two per cent revaluation is evidently not enough to relieve the pressure of appreciation. This means that the renminbi will continue to face upward pressure and may experience a process of slow appreciation.

On 21 July 2005, the PBOC announced a two per cent revaluation of the renminbi, and allowed it to fluctuate by 0.3 per cent, up or down, in daily trading starting at 19:00 on 21 July 2005, with the closing price becoming the opening price of the following day. It also stated that the PRC would carry out a managed floating exchange rate regime in which the exchange rate would be determined by market supply and demand and adjusted with reference to a basket of currencies. The renminbi would be no longer be pegged to the US dollar only. This reform soon earned positive reply from outside, with both the US, Japan and European governments expressing support for the decision. Comparing this announcement with our estimation, we have the following comments.

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viewpoint of capital flow, the appreciation of the renminbi will cause foreign investors to hold more renminbi assets, causing more capital inflow. This will result in an increase in investment demand and inflation. Thus, in the appreciation process, the forces that cause deflation and inflation coexist, and the final result will depend on which force is stronger. Japan experienced an inflation process in the early period of appreciation, which was different from what was expected by most economists according to traditional theory.

First, the direction of the adjustment is clearly in accordance with the findings of this paper and many others. It is helpful for the exchange rate to move from disequilibrium toward equilibrium. Though the adjustment is not sufficient to make up for our estimated misalignment, it is definitely a positive step toward marketization.

Second, the two per cent revaluation falls below market expectations and our own estimation, and is not enough to remove the pressure of the trade surplus. However, this reform is in line with the gradualist strategy adopted regularly in the past by the PRC. This strategy has been confirmed as successful in comparison to the big bang reform adopted by Russia (Kanamori and Zhao, 2005 [45]). Without precisely knowing the consequences of the reform, it is understandable that the PRC government has taken a prudential step.

Third, when making policy decisions, the government has to take into consideration the lagged accumulated effect of the revaluation on the economy. We estimate that a 7–11 per cent appreciation would be acceptable, given that the PRC does not want to suffer from an overvaluation and trade deficit. Since the exchange rate is endogenously determined and may change explosively under certain conditions, it is necessary to keep the exchange rate within a narrow band. This reform allows the exchange rate to fluctuate within 0.3 per cent, helping to prevent excessive speculative action.

Fourth, our estimation shows that the renminbi still faces pressure toward appreciation and may experience a process of slow appreciation. The magnitude of the appreciation will depend on how much the US dollar appreciates against other currency, changes in the domestic and foreign interest rates and domestic and foreign inflation rates. We expect that a rise of inflation in the PRC and a fall of inflation in the US will alleviate the pressure on the renminbi.

Finally, traditional wisdom may also be helpful. The gradualist strategy toward marketization adopted regularly in the past by the PRC has been confirmed as successful to some extent compared to the big bang reform adopted by Russia (Kanamori and Zhao, 2005 [45]). Because of the flexibility and without precisely knowing the consequences of the revaluation, it is understandable for the PRC government to take prudential steps and give firms and individuals time to adjust their behavior patterns. From this angle, the adjustment, though not sufficient, is definitely a positive step toward marketization.

Table 1. Stationary Test of C_NEER

Null Hypothesis: C_NEER has a unit root

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		–1.98902	0.2893
Test critical values:	1% level	–3.73785	
	5% level	–2.99188	
	10% level	–2.63554	

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(C_NEER)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C_NEER(–1)	–0.076042	0.038231	–1.98902	0.0599
D(C_NEER(–1))	0.488354	0.164517	2.96841	0.0073
C	7.288577	7.595707	0.959565	0.3482
R-squared	0.378795	Mean dependent var		–10.0013
Adjusted R-squared	0.319633	S.D. dependent var		21.58285
S.E. of regression	17.80248	Akaike info criterion		8.713021
Sum squared resid	6655.493	Schwarz criterion		8.860278
Log likelihood	–101.5563	F-statistic		6.402631
Durbin-Watson stat	2.071225	Prob (F-statistic)		0.006745

* MacKinnon (1996) one-sided p-values.

Table 2. Stationary Test of C_DEFG

Null Hypothesis: C_DEFG has a unit root

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		–2.33355	0.1706
Test critical values:	1% level	–3.75295	
	5% level	–2.99806	
	10% level	–2.63875	

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(C_DEFG)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C_DEFG(–1)	–0.34985	0.149921	–2.33355	0.0302
D(C_DEFG(–1))	0.357364	0.211831	1.687024	0.1071
C	1.897115	1.131156	1.677148	0.1091
R-squared	0.237914	Mean dependent var		0.035456
Adjusted R-squared	0.161705	S.D. dependent var		4.240477
S.E. of regression	3.882515	Akaike info criterion		5.671951
Sum squared resid	301.4784	Schwarz criterion		5.820059
Log likelihood	–62.2274	F-statistic		3.121875
Durbin-Watson stat	2.046963	Prob (F-statistic)		0.066076

* MacKinnon (1996) one-sided p-values.

Table 3. Stationary Test of US_DEFG

Null Hypothesis: US_DEFG has a unit root

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		–2.58452	0.1110
Test critical values:	1% level	–3.7696	
	5% level	–3.00486	
	10% level	–2.64224	

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(C_DEFG)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
US_DEFG(–1)	–0.27136	0.104995	–2.58452	0.0187
D(US_DEFG(–1))	0.299398	0.134186	2.231218	0.0386
D(US_DEFG(–2))	–0.18085	0.113971	–1.58684	0.13
C	0.591988	0.284672	2.079544	0.0521
R-squared	0.582767	Mean dependent var		–0.1815
Adjusted R-squared	0.513228	S.D. dependent var		0.666632
S.E. of regression	0.465103	Akaike info criterion		1.469849
Sum squared resid	3.893772	Schwarz criterion		1.668221
Log likelihood	–12.1683	F-statistic		8.380456
Durbin-Watson stat	1.819931	Prob (F-statistic)		0.001067

* MacKinnon (1996) one-sided p-values.

Table 4. Stationary Test of C_TRADE

Null Hypothesis: C_TRADE has a unit root

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		–2.32629	0.1720
Test critical values:	1% level	–3.72407	
	5% level	–2.98623	
	10% level	–2.6326	

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(C_ TRADE)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C_TRADE(–1)	–0.37919	0.163004	–2.32629	0.0292
C	0.467093	0.359459	1.299434	0.2067
R-squared	0.190472	Mean dependent var		0.112816
Adjusted R-squared	0.155275	S.D. dependent var		1.771337
S.E. of regression	1.628017	Akaike info criterion		3.889221
Sum squared resid	60.96011	Schwarz criterion		3.986731
Log likelihood	–46.6153	F-statistic		5.411619
Durbin-Watson stat	1.799235	Prob (F-statistic)		0.029173

* MacKinnon (1996) one-sided p-values.

Table 5. Stationary Test of D(C_NEER)

Null Hypothesis: D(C_NEER) has a unit root

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		–2.54956	0.0132
Test critical values:	1% level	–2.66485	
	5% level	–1.95568	
	10% level	–1.60879	

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(C_NEER,2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(C_NEER(–1))	–0.422	0.165517	–2.54956	0.0179
R-squared	0.218193	Mean dependent var		–1.12292
Adjusted R-squared	0.218193	S.D. dependent var		21.83163
S.E. of regression	19.30349	Akaike info criterion		8.799222
Sum squared resid	8570.367	Schwarz criterion		8.848308
Log likelihood	–104.591	Durbin-Watson stat		1.904161

* MacKinnon (1996) one-sided p-values.

Table 6. Stationary Test of D(C_DEFG)

Null Hypothesis: D(C_DEFG) has a unit root

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		–3.89009	0.0004
Test critical values:	1% level	–2.66936	
	5% level	–1.95641	
	10% level	–1.6085	

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(C_DEFG,2)

Included observations: 23 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(C_DEFG(–1))	–0.82427	0.211889	–3.89009	0.0008
R-squared	0.407107	Mean dependent var		0.142037
Adjusted R-squared	0.407107	S.D. dependent var		5.423217
S.E. of regression	4.175854	Akaike info criterion		5.739019
Sum squared resid	383.6306	Schwarz criterion		5.788389
Log likelihood	–64.9987	Durbin-Watson stat		1.924077

* MacKinnon (1996) one-sided p-values.

Table 7. Stationary Test of D(US_DEFG)

Null Hypothesis: D(US_DEFG) has a unit root

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		–4.96267	0.0000
Test critical values:	1% level	–2.67429	
	5% level	–1.9572	
	10% level	–1.60818	

Dependent Variable: D(US_DEFG,2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(US_DEFG(–1))	–0.68501	0.138032	–4.96267	0.0001
D(US_DEFG(–1),2)	0.191319	0.123559	1.548399	0.1372
R-squared	0.552063	Mean dependent var		0.162385
Adjusted R-squared	0.529666	S.D. dependent var		0.763033
S.E. of regression	0.523295	Akaike info criterion		1.629166
Sum squared resid	5.476759	Schwarz criterion		1.728352
Log likelihood	–15.9208	Durbin-Watson stat		2.23884

* MacKinnon (1996) one-sided p-values.

Table 8. Stationary Test of D(C_TRADE)

Null Hypothesis: D(C_TRADE) has a unit root

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		–5.16479	0.0000
Test critical values:	1% level	–2.66936	
	5% level	–1.95641	
	10% level	–1.6085	

Augmented Dickey-Fuller Test Equation

Dependent variable: D(C_TRADE, 2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(C_TRADE(–1))	–1.48704	0.28792	–5.16479	0
D(C_TRADE(–1),2)	0.411751	0.198563	2.073657	0.0506
R-squared	0.608117	Mean dependent var		–0.01857
Adjusted R-squared	0.589455	S.D. dependent var		2.688374
S.E. of regression	1.722542	Akaike info criterion		4.008421
Sum squared resid	62.31019	Schwarz criterion		4.107159
Log likelihood	–44.0968	Durbin-Watson stat		2.098737

* MacKinnon (1996) one-sided p-values.

Table 9. Cointegration Test of Related Variables (with exogenous variables)

Series: C_NEER C_DEFG C_TRADE US_DEFG
Exogenous series: C_DRATE US_FRATE
Warning: Critical values assume no exogenous series
Lag interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.994913	207.3066	47.85613	0.0000
At most 1 *	0.883717	91.12402	29.79707	0.0000
At most 2 *	0.701511	43.78609	15.49471	0.0000
At most 3 *	0.542169	17.18763	3.841466	0.0000

Trace test indicates 4 cointegrating eqn(s) at the 0.05 level
* Denotes rejection of the hypothesis at the 0.05 level
** MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.994913	116.1825	27.58434	0.0000
At most 1 *	0.883717	47.33793	21.13162	0.0000
At most 2 *	0.701511	26.59845	14.26460	0.0004
At most 3 *	0.542169	17.18763	3.841466	0.0000

Max-eigenvalue test indicates four cointegrating eqn(s) at the 0.05 level
* Denotes rejection of the hypothesis at the 0.05 level
** MacKinnon-Haug-Michelis (1999) p-values

Table 10. Cointegration Test of Related Variables (without exogenous variables)

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.972657	79.18477	27.58434	0
At most 1 *	0.718115	27.85762	21.13162	0.0049
At most 2	0.421581	12.04404	14.2646	0.109
At most 3 *	0.162643	3.905095	3.841466	0.0481

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* Denotes rejection of the hypothesis at the 0.05 level
** MacKinnon-Haug-Michelis (1999) p-values

Table 11. Cointegration Equation with Maximum Engenvalue

Variable	C_NEER	C_DEFG	C_TRADE	US_DEFG	Constant
Cointegration coefficient	1.000000	3.591663	21.20970	–30.4883	–115.969
Standard deviation		(0.19814)	(0.91071)	(0.98153)	
T-statistic		[18.1273]	[23.2891]	[–31.0619]	

Table 12. Accumulated Effects on Response to Nonfactorized One-Unit Innovations to the Nominal Effective Exchange Rate

Period	C_NEER	C_DEFG	US_DEFG	C_TRADE
1	1	0	0	0
2	1.800366	0.148614	–0.01659	–0.08008
3	2.759604	0.191728	–0.04879	–0.1417
4	3.267964	0.255582	–0.0796	–0.17726
5	3.493285	0.342185	–0.10834	–0.25966
6	3.356211	0.498616	–0.13618	–0.35076
7	3.214566	0.666273	–0.15691	–0.40297
8	3.120856	0.838798	–0.17214	–0.45877
9	3.155389	0.985485	–0.18879	–0.5247
10	3.300548	1.112996	–0.20626	–0.57166

Chart 1. Misalignment of the Renminbi NEER (%)

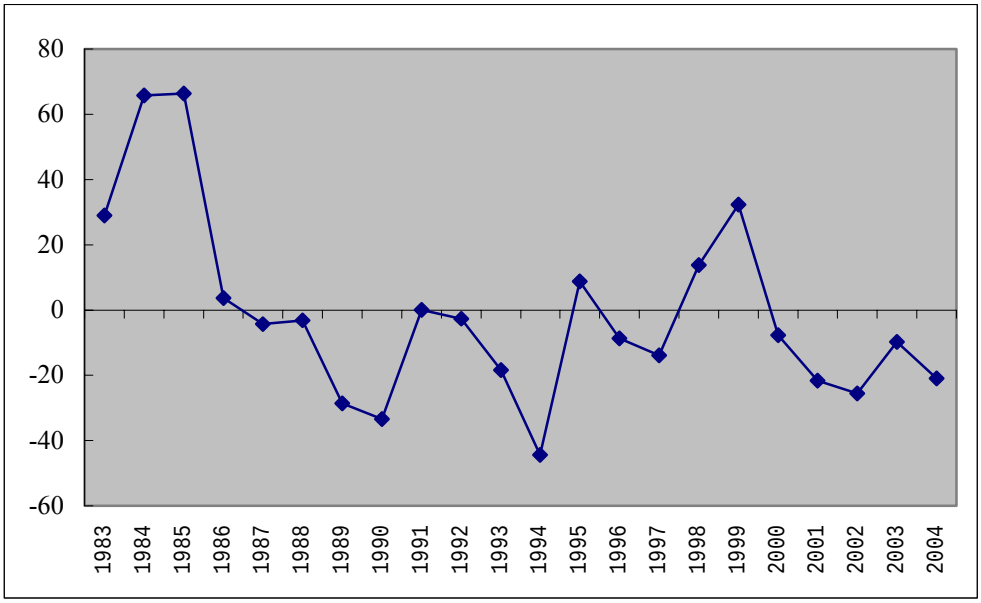
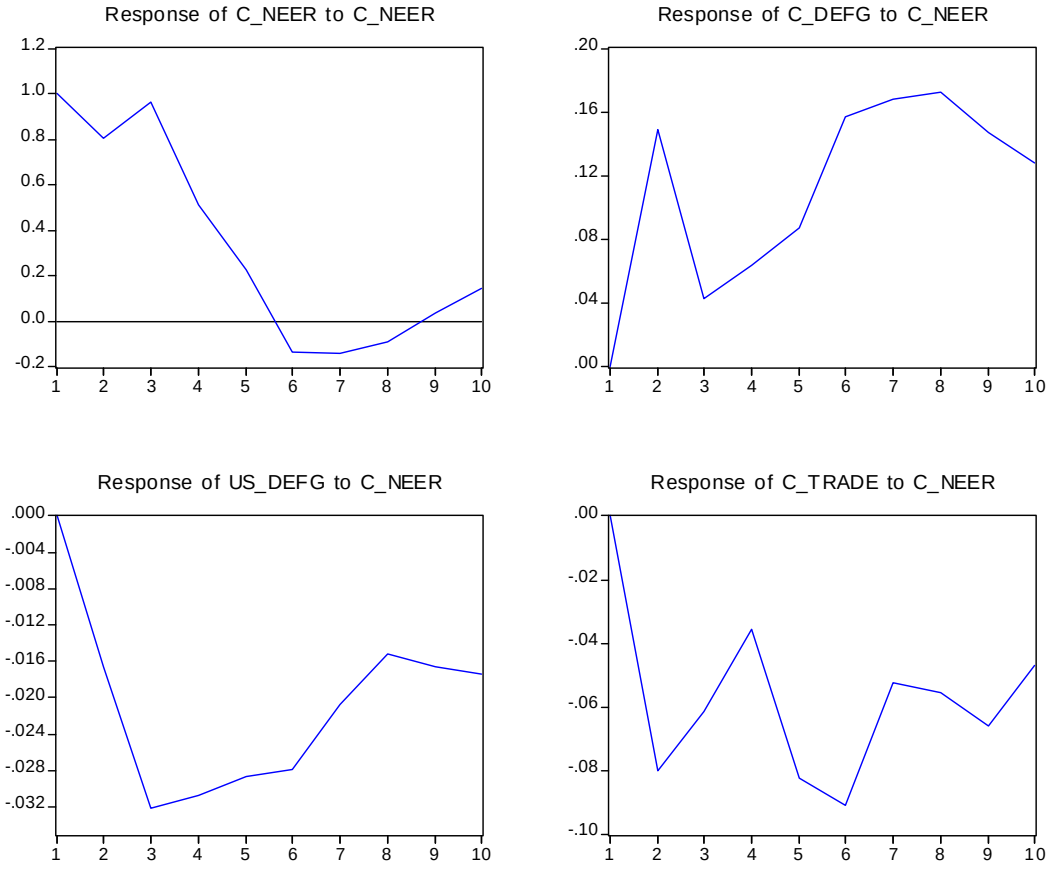


Chart 2. Responses to One-Unit Innovations to the Nominal Effective Exchange Rate



Conclusion

Since 2001, the revaluation of the renminbi has been a hot topic and many papers have been published. But their conclusions are very different, because they are based on different models, data, and econometric techniques, as well as political considerations. Given the fact that so many differing views have been presented by so many economists, it is very difficult for the PRC monetary authorities to take any action. This encourages us to work on this interesting and challenging topic, in order to put forward something useful for policymakers and market participants.

We have reviewed various existing exchange rate theories, including absolute PPP, Relative PPP, CIP, UCIP, and B_S model, Fleming-Mundell model, F-M-Dornbusch model, Redux model, and PTM model. This review provided help for us in creating a new theoretical framework (Kanamori and Zhao 2006 [47]).

To overcome some shortages of the existing models and to investigate what and how variables impacted exchange rate, in part 1, "A General Equilibrium Model of the Exchange Rate," we created a general equilibrium model with two countries (home and foreign) and three sectors (consumers, firms, and intermediate importers).

By solving the profit maximizing problem, we can obtain the product supply function, investment demand function, export function, import function of each country, and obtain the three equilibrium conditions.

The model shows that the difference between small open countries and big countries is that small countries do not have the ability to carry out an independent monetary policy and control prices, and has to give up control and let the market decide, while a big country is able to carry out an independent monetary policy and to influence prices and usually is reluctant to give up this power. Given the fact that both the PRC and US maintain an independent policy, according to the model, a fixed exchange rate would be desirable. Otherwise, the economy may often be in a state of disequilibrium.

Another theoretical finding relates to the necessary conditions for the existence of a long-run steady-state exchange rate, which states that if the two countries have different long-run economic growth rates, there is no long-run steady-state exchange rate. Since there are different economic growth rates among the PRC, US, Japan and other developed countries, it is difficult to maintain a stable renminbi exchange rate in the long run. Thus, it is impossible to resolve the issue of the renminbi through a one-time revaluation.

The third theoretical finding is that for the first time, we show theoretically that under general conditions, neither absolute nor relative purchasing power parity holds. Relative purchase power parity may hold only in the long run if the two economies having identical economic growths. The condition for PPP to hold is that all elements concerned in the model between home and abroad must be equal.

Considering that the exchange rate may change explosively under external shocks, it is necessary to allow the exchange rate to float in a relatively narrow band around its equilibrium level.

Since the original model is a second order nonlinear difference equation system and clear expressions of the model's solutions are not available, a restricted six-variable

VAR (VEC) model is developed in part 2, considering the PRC's preferences regarding the trade surplus, foreign exchange reserve and inconvertibility of the renminbi.

One of the most important findings of our empirical study is the degree of undervaluation from 2000, which is estimated to be between 7 per cent and 25 per cent, and on average, 17 per cent.

The other finding of the empirical study is that moderate appreciation has a weak inflation effect in PRC and deflation effect in the US, and little negative effect on the trade surplus of the PRC.

Thus, policymakers should not only consider the direct effect of revaluation, but also the accumulated effect on the economy, when making nominal exchange rate revaluation policies. In terms of the NEER, we estimate that a 7–11 per cent revaluation would be acceptable, given that the PRC hopes to avoid an overvaluation and trade deficit.

Thus, it can be seen that the two per cent revaluation made on 21 July 2005 is in line with the direction of the estimates, although it is less than our estimates and market expectations, and may not be large enough to remove the pressure of the trade surplus. Considering that the PRC must try to avoid speculative attacks by controlling the fluctuation range, and that the undervaluation can be also corrected by inflation and the interest rate, as well as fiscal policy, we expect that an annual appreciate rate of 3 per cent might be allowed in the coming three years. This would allow each market participant to adjust his or her behavior, and eventually act as a major tool to explore the equilibrium.

Of course, the exchange rate is not the only way to adjust the external balance. The freedom of monetary policy is important. Japan, for instance, could have mitigated inflationary pressure by taking monetary measures in a more timely manner and by leaving the external balance basically to the adjustment of the exchange rate. This point perhaps is particularly important for the PRC (Kanamori and Zhao 2006 [47]).

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