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1 September 2012

International Research Journal of Finance and Economics
ISSN 1450-2887 Issue 97 September, 2012

http://www.internationalresearchjournaloffinanceandeconomics.com

A Comparison of the Beer and Penn Effect Models via Their Applications in the Renminbi Valuation

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Abstract

The behavioral equilibrium exchange rate (BEER) and the Penn effect models are compared via their applications on the valuation of the Renminbi (RMB). Considering the two models' bases and applications, I conclude that, in time-series and cross-section data settings, the Penn effect model is the more reasonable or more robust model for currency valuation. In a panel data setting, the Penn effect model can be viewed as a special form of the BEER model; however, the latter includes many other forms that are different from the former. The criteria and methods of comparing different model findings are given and used to compare typical misalignment results on RMB derived from the two models. According to the misalignment classification comparison, each model's findings from the BEER model are only partly reasonable but each model's findings from the Penn effect model are wholly reasonable. Thus, the latter is more reasonable than the former.

Keywords: Behavioral Equilibrium Exchange Rate, Penn effect, Purchasing Power Parity, Chinese Renminbi
JEL Classification Codes: F31, F41

1. Introduction

As China's presence in the world economy has risen dramatically in recent years, focus has increased on its exchange rate arrangement as an important factor in explaining the country's competitiveness. Consequently, the valuation of the Chinese currency, the renminbi (RMB), has been the subject of extensive discussion. At issue is the RMB's equilibrium value. A number of studies employing various methodologies have attempted to answer the question by estimating the RMB's equilibrium value. Most notable among these are the behavioral equilibrium exchange rate (BEER) model and the Penn effect model. The BEER model has been employed by Zhang (2001), Funke and Rahn (2005), Goh and Kim (2006), Wang et al. (2007), and Lopez-Villavicencio et al. (2012). Conversely, the Penn effect model has been employed by Chang and Shao (2004), Frankel (2005), Coudert and Couharde (2007), Cheung et al. (2007, 2010), and Garroway et al. (2012).

Our interest is focused on the following two issues. One is on the difference and relationship, if any, between the two models in theory. Clark and MacDonald (1998) have compared the BEER model and the fundamental equilibrium exchange rate (FEER) model, but no one has compared the BEER model with the Penn effect model. The other focus is finding which model can provide a more reasonable result given their seemingly great differences. For example (see Table 2 in Section 5.3.1), Zhang (2001) and Goh and Kim (2006) use the BEER model and respectively conclude that the Renminbi (RMB) was undervalued by 60% and 13% in 1978. However, Chang and Shao (2004) and Cheung et al. (2007) use the Penn effect model and respectively conclude that the RMB was overvalued by 51.3% and 90% in the same year. As we know, there are few relevant studies on the comparison of the model findings derived from exchange rate models. These two issues have led me to write this paper. I expect this study to be useful in the theory of exchange rate economics and in understanding the valuation of the RMB.

The remainder of the paper is structured as follows. Section 2 describes the two models, namely, the BEER model and the Penn effect model. The differences between the two models in time-series and cross-section data settings are listed and explained in Section 3. The comparisons between the two models in a panel data setting are given in Section 4. In Section 5, the general criteria and concrete methods of comparing different model findings are given. The criteria and methods are used to compare four typical misalignment results on RMB derived from the two models. Section 6 presents the conclusion.

2. Descriptions of the BEER and Penn Effect Models

In this section, I introduce the BEER model in a time-series setting and the Penn effect model in a cross-section data setting. These two models are mostly widely in the valuation of RMB in these settings. After the two models in these settings are discussed in detail, they can easily be extended into a panel data setting.

2.1. The BEER Model

The theoretical and econometric framework of the BEER model are described by Baffes et al. (1997), Clark and MacDonald (1998), and Zhang (2001). Clark and MacDonald (1998) in describing the BEER model believe that the actual real exchange rate (*RER*) is in equilibrium in a behavioral sense when its movements reflect changes in the economic fundamentals that are found to be related to the actual real exchange rate in a well-defined statistical manner.

The equilibrium real exchange rate of the BEER model can be calculated using the following equation:

$$RER_t^* = \beta' F_t \tag{1}$$

where RER^* is the equilibrium real exchange rate, and F is a vector of the economic fundamentals that determine or affect the actual real exchange rate. The values for the economic fundamentals in F can either be permanent or not, and the permanent values can be obtained from the data using a filter procedure, such as the Hodrick-Prescott filter procedure.[1]

β in Equation (1) is a vector of coefficients for the economic fundamentals and it can be obtained from a cointegration equation of the form:

$$RER_t = \beta' F_t + u_t \tag{2}$$

where RER is the actual real exchange rate, and u_t is a stationary random variable with zero mean. This indicates that the actual real exchange rate and the economic fundamentals are cointegrated. If this cointegration equation holds, the cointegration parameters can be used as the estimates of the parameter vector β in Equation (1) and the equilibrium real exchange rate RER^* can be derived.

The subscript t in Equations (1) and (2) denotes the time-series dimension.

1 Filter procedure and permanent values are used by Wang et al. (2007), but are not used by Zhang (2001) and Goh and Kim (2006). The only difference between the BEER model and the so-called permanent equilibrium exchange rate (PEER) model in Funke and Rahn (2005) is whether or not the filter procedure is used. Some economists argue that the use of filters to determine permanent values creates unnecessary complication in determining the equilibrium exchange rate.

2.2. The Penn Effect Model

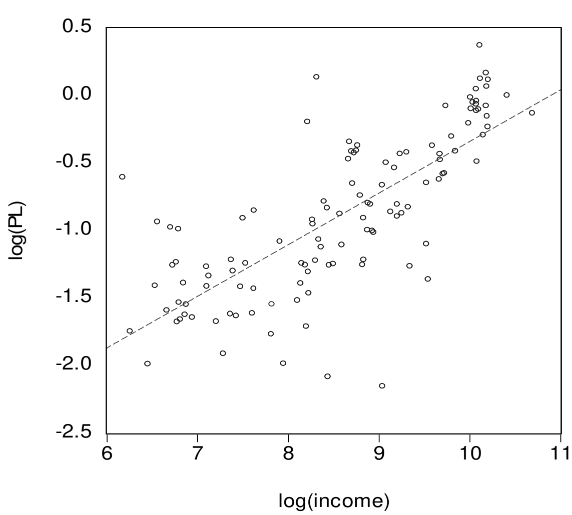
Samuelson (1994, p.201) describes the Penn effect, "This K-H-S effect or Penn effect states that a rich country, in comparison with a poor one, will be estimated to be richer than it really is if you pretend that the simplified Cassel version of purchasing power parity (PPP) is correct and if you use crude exchange rate conversions to deflate the nominal total per capita incomes of the two countries. The greater their per capital real-income differentials truly are, the greater tends to be the resulting coefficient of bias."

Although the term "Penn effect" is coined originally by Samuelson (1994) in the context of international income comparison, in essence, it refers to the international price level differences caused by the different income levels of different countries. Let P be a country's domestic price level, P^* the specified foreign country's price level (in this case, the US's price level), and E the nominal exchange rate expressed as the national currency units per US dollar. Consequently, the price level (PL), defined in Equation (3), measures the ratio of domestic price level against the foreign (the US) price level, which is also called the relative price level between the country and the US. It can be seen that the PL defined in Equation (3) is one of the two often-used definitions of real exchange rate (RER). The definition is the same as the definition of Frankel (2005, p.20 and p.22) and Cheung et al. (2007, p.768).

$$PL = \frac{P}{EP^*} (= RER) \tag{3}$$

Given the definition of countries' price level, the Penn effect can be easily obtained by comparing price levels across the world or across a group of the countries which can represent the world (in terms of income level or economic development stage). The Penn effect is illustrated in Figure 1. When converted by one common currency, the price levels of different countries with different income levels are very different, and the price level defined by Equation (3) is a rising function of the income level. In other words, when all countries' price levels are translated to dollars at prevailing nominal exchange rates, rich countries tend to have higher price levels and poor countries tend to have lower price levels. The Penn effect has been proved and confirmed (Balassa, 1964; Kravis and Lipsey, 1982; Summers and Heston, 1991; Rogoff, 1996; Frankel, 2005).

Figure 1: Price Levels and Income Levels of 118 Countries in 2000



Notes: PL and income are the variables of price level of GDP and real GDP per capita (Constant price: Chain series) from the PWT version 6.1, respectively. Log means taking nature logarithm. The Figure is same as that of Frankel (2005, p.22).

Source: Alan Heston, Robert Summers and Bettina Aten, Penn World Table Version 6.1, Center for International Comparisons at the University of Pennsylvania (CICUP), October 2002.

The empirical Penn effect model is either the linear regression Equation (4) or the log-linear regression Equation (5); where *PL* is the price level defined by Equation (3), *income* is the income level or economic development stage which may be represented by the absolute or relative real GDP per capita, and the subscript *i* denotes the cross-section data dimension. Considering that the price level defined in Equation (3) is also the real exchange rate, the variable *PL* in Equations (4) and (5) can also be substituted by the variable *RER*.

$$PL_i = \beta_0 + \beta_1 income_i + u_i \tag{4}$$

$$\log(PL)_i = \beta_0 + \beta_1 \log(income)_i + u_i \tag{5}$$

Although the Penn effect exists, there are different explanations for its existence. The most influential explanation is from Balassa (1964) and Samuelson (1964), who explain the Penn effect from the perspective of inter-country differences in the relative productivity of tradable and non-tradable sectors. This is also called the Balassa-Samuelson effect. Another different influential explanation is credited to Kravis and Lipsey (1982) and Bhagwati (1984), who explain the Penn effect from the view of capital-labor ratios. There are other explanations aside from these two influential ones.[2] In a word, there is a consensus among economists on the existence of the Penn effect; however, the reasons for the occurrence of the Penn effect have not been addressed. Therefore, I use the term "the Penn effect model" rather than "the Balassa-Samuelson model" in order to avoid any misunderstanding.

3. The Differences between the Two Models in Time-Series and Cross-Section Data Settings

The "time-series and cross-section data settings" in the title means that the BEER model is used in a time-series econometrics setting (Zhang, 2001; Funke and Rahn, 2005; Goh and Kim, 2006; Wang et al., 2007) and the Penn effect model is used in a cross-section data econometrics setting (Chang and Shao, 2004; Frankel, 2005). In these settings, there are six main differences between the two models: theoretical or empirical basis, explained variable, explanatory variable, econometric method, equilibrium real exchange rate, and misalignment result. The differences are listed in Table 1 and then are analyzed one by one.

Table 1: Differences between the BEER and Penn Effect Models

	The BEER model	**The Penn effect model**
Theoretical or empirical basis	No direct theoretical or empirical basis	The Penn effect
Explained variable (real exchange rate)	In various forms	In a consistent form
Explanatory variable (and the number)	A set of economic fundamentals (usually more than two)	Income level (a single one)
Econometric method	Unit root and co-integration analysis, using one single country's data	Cross-sectional data method, using many countries' data
Equilibrium real exchange rate	Is determined by a systemic relationship, and appears from one country only	Is determined by a binary relationship, and appears from the comparison between one country and other countries
Misalignment result	The RMB must be under- and overvalued in turn in the whole sample period	No any prior information about the RMB's misalignment

[2] Two related studies can be found in Bergin et al. (2006) and Broda (2006).

3.1. Theoretical or Empirical Basis

According to Baffes et al. (1997, Section 2. The Equilibrium Real Exchange Rate), the BEER model is based on the theory of internal and external balance. Internal balance holds when the markets for labor and non-traded goods are clear. External balance holds when the country's net creditor position in world financial markets has reached a steady equilibrium state. In practice, the equilibrium real exchange rate consistent with internal and external balances can be solved from the econometric Equations (1) and (2). However, different opinions exist. Clark and MacDonald (1998, p.34) say, "More specifically, the BEER approach does not directly involve considerations of internal and external balance, which are identified in the FEER approach as sustainable positions of macroeconomic equilibrium." Égert et al. (2006, p.281) say, "The BEER approach of Clark and MacDonald is not based on any specific exchange rate model."

In my opinion, we cannot say definitively that the BEER model has no theoretical basis: when choosing the economic fundamentals, the BEER model indeed needs some guidance from relevant economic theories or empirical studies. The internal and external balance theory, the Balassa-Samuelson effect, and other relevant empirical studies are often used in the process of choosing economic fundamentals. The essential thing is that after entering the econometric analysis process, all relationship between economic fundamentals and their economic theory or empirical study basis is ended, or broken. The equilibrium exchange rate in the BEER model is given and decided directly by an econometric analysis, rather than by an economic theory.[3] Thus, the BEER model has no direct theoretical basis beyond the indirect theoretical basis for the selection of its economic fundamentals.

According to the above discussion in Section 2, the Penn effect model is based on the Penn effect, which stipulates that rich countries usually have higher price levels than poor countries. The empirical studies have provided enough evidence to show that the Penn effect does exist. Constrained by the Penn effect, many economic fundamentals that may affect the price and income levels of a country directly or indirectly, such as monetary and fiscal policies, are not specified in the Penn effect model. The Penn effect model appears to view the impact of the economic fundamentals on the real exchange rate as already embodied in the price and income.

3.2. The Explained Variable

In the BEER model, the explained variable (real exchange rate) can be in various forms. For example, Zhang (2001) constructs real exchange rate using the nominal exchange rate multiplied by a fraction consisting of the foreign (US) wholesale price index in the numerator and the domestic (China) retail price index in the denominator. Funke and Rahn (2005) and Goh and Kim (2006) both use trade-weighted real effective exchange rate indexes; however, their constructions are different. Wang et al. (2007) uses a real effective exchange rate, albeit its definition was not given clearly.

In the Penn effect model, constrained by the Penn effect, the explained variable (real exchange rate) must be defined by Equation (3), in addition to permitting its reciprocal. This definition of the real exchange rate ensures that it measures the differences in price levels between two countries. Many forms of real exchange rates used in the BEER model, including $E(WPI^{*}/CPI)$ (Zhang, 2001) and the trade-weighted real effective exchange rate index (Funke and Rahn, 2005; Goh and Kim, 2006), cannot be used in the Penn effect model because these defined real exchange rates are not intended to measure the differences in price levels between two countries.

3.3. The Explanatory Variable

In the BEER model, the explanatory variables may be very different. Zhang (2001) uses investment, government consumption, terms of trade, and the degree of openness. Funke and Rahn (2005) use the

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[3] This is markedly different from the PPP or ratio model (Zhang, 2012), in which the equilibrium exchange rate is decided by macro-economic conditions, rather than mainly relying on an econometric analysis.

productivity levels and net foreign asset position while Goh and Kim (2006) use government expenditure, the rate of gross fixed capital formation to GDP, terms of trade, capital controls, technological progress (real GDP per capita), and macroeconomic policies. Wang et al. (2007) use terms of trade, the relative price of the trade goods to non-trade goods (Balassa-Samuelson effect), foreign exchange reserve, and the change of money supply. The number of explanatory variables may be very different accordingly. From the above list, it can be seen that the number of the explanatory variables varies from two to six.

In the Penn effect model, the explanatory variable *income* in Equations (4) and (5) must represent the sample countries' income level or economic development stage, and their proxies are usually absolute or relative real GDP per capita. Furthermore, other explanatory variables are not permitted. That is, the number of explanatory variables in the Penn effect model must be one.

On the other hand, the variable real GDP per capita can either be included in the explanatory variables of the BEER model or not. For example, Goh and Kim (2006) include the real GDP per capita in their BEER model, but Zhang (2001) and Funke and Rahn (2005) do not include the variable in their BEER models. It should be noted that the real GDP per capita in the BEER model is different from that in the Penn effect model because the former is obtained from different time periods of one country while the latter is obtained from different countries (see Section 3.4). The two cannot be the same in time-series and cross-section data settings; they can be the same only in a panel data setting (see Section 4.1). Likewise, the variable representing technological progress or the Balassa-Samuelson effect used in the BEER model, such as the variable *FINVEST* in Zhang (2001) and the variable *PROD* in Funke and Rahn (2005), do not have the same meaning as the variable *income* in the Penn effect model.

3.4. The Econometric Method and the Derived Equilibrium Exchange Rate

The BEER model uses a non-stationary time-series (unit root and co-integration) analysis and derives the equilibrium exchange rate only from the economic data of China (one country). Thus, two issues arise. The first issue is whether the equilibrium real exchange rate exists is decided by the co-integration relationship. That is, when the co-integration relationship between the actual real exchange rate and economic fundamentals holds, the equilibrium real exchange rate exists; however, when the co-integration relationship does not hold, the equilibrium rate does not exist. In the latter situation, the model cannot be applied validly to the valuation of RMB. Is this a fault of the BEER model? The second issue deals with the derived equilibrium exchange rate that (when it exists) is derived from the comparison of China's actual real exchange rate and economic fundamentals at a certain time with those at another other time. The concept of "equilibrium" and "misalignment" reflects how the actual real exchange rate and economic fundamentals move (or behave) with time. The model is concerned only with how China changes with time.

In contrast, the Penn effect model uses a cross-section data analysis and derives the equilibrium real exchange rate from the economic data of multiple countries. The equilibrium real exchange rate can always be obtained because the regression analysis can always be applied in any situation. Second, the equilibrium real exchange rate is derived from the comparison between China and other countries. The concept of "equilibrium" and "misalignment" reflects how the actual real exchange rate of China is far from the average value of that of all the sample countries that are used in the model at a given income level.[4] The model is concerned with how China is different from the other countries.

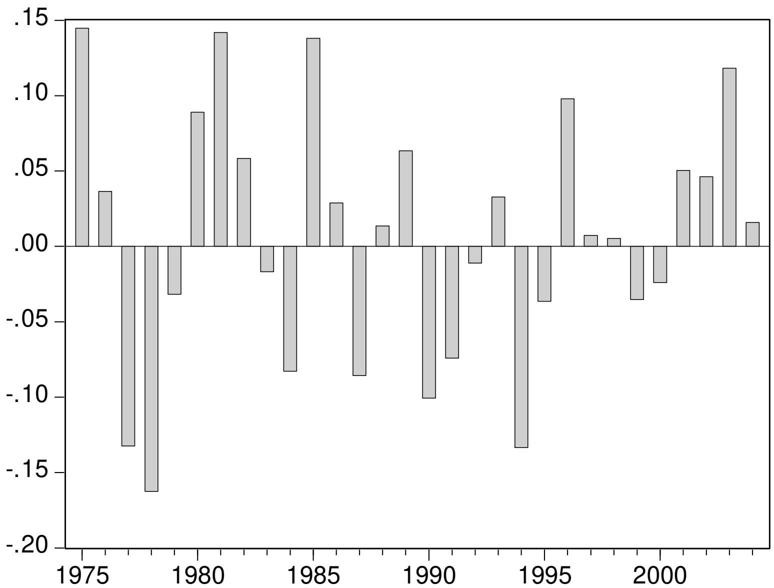
[4] According the theory of regression analysis, the fitted value of *PL* in Equation (4) or (5) is roughly equal to the average value (or expected value) of *PL* of all the sample countries given *income*.

3.5. The Misalignment Result

The calculation of currency misalignment in the BEER and Penn effect models is both derived from the residual from the corresponding equation. Nonetheless, the two types of residuals and their meanings for the RMB's misalignment are very different.

In the BEER model, the RMB's misalignment is derived from u_t of Equation (2).[5] The residual u_t must be stationary if the cointegration equation (Equation (2)) holds. The stationary residual means that its negative and positive values lie on two sides around the zero line. In other words, the residual line must cross the zero line multiple times. As a result, positive and negative values appear in turn. Figure 2 shows such a residual derived from my econometric work for this use. It means that the RMB must be under- and overvalued in turn in the whole sample period no matter how the Chinese economy is in the sample period. To generalize, when using the BEER model to value any currency, such as the US dollar, the Japanese yen, the Euro, or any other currency, the used currency must be under- and overvalued in turn in the whole sample period regardless of the country's economy during that period. It is difficult to supply a reasonable economic explanation to this phenomenon.

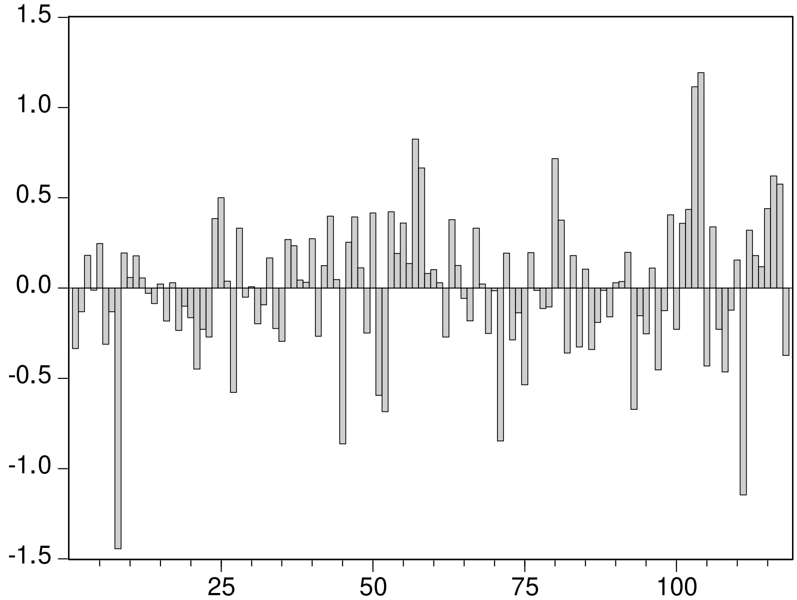
Figure 2: A Residual from the BEER Model



In the Penn effect model, the RMB's misalignment is derived from u_i of Equation (4) or (5). A residual from the Penn effect model can be seen from Figure 3, which is similar to Figure 2, except that there are countries instead of years in the horizontal axis. According to the regression theory, the residual u_i must also be both negative and positive in the entire sample countries; therefore, there must be both under- and overvaluation in the countries. However, we cannot determine beforehand whether RMB is among the currencies that are undervalued or overvalued. In other words, when using the Penn effect model, some currencies are inevitably undervalued (or overvalued), but which currencies are undervalued (or overvalued) is unknown beforehand. In contrast, when using the BEER model, the RMB being undervalued (or overvalued) is evitable; what is unknown beforehand is only wherein which observation the RMB is undervalued (or overvalued).

[5] The RMB's misalignment derived from Equation (2) is roughly equal whether a filter procedure for the economic fundamentals is used or not.

Figure 3: A Residual from the Penn Effect Model



Note: The residual is same as that of the cross-country regression for year 2000 in Frankel (2005, p.22)

The following reasons account for the different residuals and their different meanings for the RMB's misalignment: for the BEER model, the RMB's misalignment is derived from a single residual from one cointegration equation which uses only China's data; for the Penn effect model, it is derived from many residuals from the regression equations which use China's and many other countries' data.[6]

3.6. Which Model is More Appropriate for Currency Valuation?

The BEER model appears to be more robust than the Penn effect model because it uses more than two economic fundamentals that may affect the real exchange rate. However, the theoretical basis for the BEER model is only the theoretical guide for the choice of its economic fundamentals, and the theory guide ends when the econometric analysis is used. That is, the BEER model has no direct theoretical basis, which leads to very different choices for the real exchange rate and its economic fundamentals. In contrast, the Penn effect model has a solid empirical observation basis in which the explained and explanatory variables are both constrained.

In application, the BEER model uses a non-stationary time-series method (unit root and co-integration analysis). This particular econometric method sometimes causes the non-existence of the equilibrium real exchange rate and inevitably causes the RMB to be misaligned regardless of the reality (when the equilibrium rate exists). Generally, when using the BEER model to value any currency, the currency must be under- and overvalued in turn in the whole sample period regardless of the economic reality of the country being studied. In contrast, when the Penn effect model is used, the equilibrium rate can always be obtained, and we do not have any prior information regarding the misalignment of the RMB. The BEER model derives the equilibrium exchange rate from China alone (one single country), whereas the Penn effect model derives the equilibrium exchange rate from the comparison between China and other countries. As is known, a traditionally defined exchange rate, whether nominal or real, is mainly an international comparison concept.[7] Assessing the valuation of a currency implies that we want to determine whether an exchange rate is priced lower or higher

[6] Using the Penn effect model to obtain the RMB's misalignments in the two years 1990 and 2000 (Frankel, 2005), for example, we should run two Penn effect regressions, and one is for 1990 and the other is for 2000.

[7] Égert et al. (2006, p.260–262) classify real exchange rate into internal real exchange rate and external real exchange rate. They view the external exchange rate, which is just the traditionally defined real exchange rate as given by Equation (3) in this paper, to be more useful than the internal one in the analysis of currency valuation.

compared with others. From this view, the cross-section data dimension of the Penn effect model is more reasonable than the time-series dimension of the BEER model.

Considering the two models' bases and applications, we can conclude that, in time-series and cross-section data settings, the Penn effect model is the more reasonable or more robust model for the valuation of RMB.

4. Comparisons of the Two Models in a Panel Data Setting

In Section 3, we discussed the differences between the BEER and Penn effect models from the view that the former is used in a time-series setting while the latter is used in a cross-section data setting. In this section, the two models are compared from the view that they are used in the same panel data setting. Cheung et al. (2007) used the two models in this setting.

Given the common panel data setting that combines the time-series with the cross-section data dimension, the different econometric methods between the two models discussed in Section 3.4 now disappears automatically. Furthermore, the different equilibrium real exchange rate and misalignment result between the two models in time-series and cross-section data settings, which are derived from different econometric dimensions and are discussed in Sections 3.4 and 3.5, also disappear or are reduced. In other words, in the common panel data setting, the disadvantages of the BEER model compared with the Penn effect model in time-series and cross-section data settings no longer exist (or become unobvious).

In a panel data setting, the differences in the theoretical basis and the explained and explanatory variables between the two models continue to exist and are the characteristics that can be used to differentiate them. In this setting, the Penn effect model remains in a constrained form: the basis is the Penn effect, and the explained and explanatory variables remain specified strictly by Equation (4) or (5) (in the equation's panel data form). However, the BEER model has various forms: the basis can either be the Penn effect or otherwise; the explained variable (real exchange rate) can either be defined by Equation (3) or not; the explanatory variable can represent income level of countries or otherwise, and its number can exceed 1. In particular, the Penn effect model can be viewed as a special form of the BEER model (1) when the BEER is based on the Penn effect, and (2) when the commonly used explanatory variables, which are commonly more than two variables, are reduced to only one variable that represents the income level of countries. But the BEER model also includes several other forms that are different from the Penn effect model. If we use a model that is not based on the Penn effect, or where the explained variable (real exchange rate) does not measure the price level of countries, or where the explanatory variable does not represent the income level of countries, or where the number of the explanatory variables exceeds one, then the model is a BEER model but must not be a Penn effect model.

Based on the above discussion, the model used in Cheung et al. (2007, Section 3. Absolute purchasing power parity) is classified as a Penn effect model, but the model used in Cheung et al. (2007, Section 5. Beyond the bivariate framework) is classified as a BEER model because other explanatory variables such as demographics, policy, and financial development are used in the latter case. Similarly, the model used in Coudert and Couharde (2007, Section 3.2. Estimations for RER levels) in a cross-section data setting is the Penn effect model, but the model used in the same reference but in panel data estimations (Section 3.3. Panel data estimations) is the BEER model. In Coudert and Couharde (2007, Section 3.3. Panel data estimations), the explanatory variable used is the relative price index, calculated as the ratio of the consumer price index to the producer price index in difference between the home country and the United States, which is deviated from the variable *income* specified in the Penn effect model Equations (4) and (5).[8]

[8] Dunaway and Li (2005, p.8) point out that the link between changes in productivity and changes in the CPI/ PPI ratio may be less apparent in China.

5. Which Model Finding is More Reasonable?

After comparing the BEER and Penn effect models in theory, we now turn to the second issue put forward in the Introduction: determining the model that can provide a more reasonable result. Given that there are few relevant studies on the comparison of the model findings derived from exchange rate models, I will also provide concrete criteria and methods.[9]

5.1. Criteria of Comparison

Given that the two models are used to study an economic fact (Chinese real exchange rate) and that we cannot judge whether a model finding is reasonable or not from the model itself, I will use relevant economic facts to value the model findings.

First, the particular Chinese economic fact to be used as the criterion has to be determined. Given the different economic fundamentals used in the BEER and Penn effect models, and the different economic fundamental choices in the BEER model, the use of a particular economic fundamental fact (such as real GDP per capital, government expenditure, terms of trade) as the criterion would again lead to the argument of whether the chosen economic fundamental fact is true or important. Thus, all the economic fundamental facts should not be treated as criteria. On the other hand, both the models are used to measure the level of actual real exchange rate of RMB. That is, both models have a common goal: the actual real exchange rate of RMB, which can be and should be used as the relevant Chinese economic fact. Therefore, the relevant Chinese economic fact used as criterion in the comparison is (single) the actual real exchange rate of RMB. I am not able to find a better Chinese economic fact than this one.

Second, given that the equilibrium real exchange rate is not observable and is not defined in the actual real exchange rate, whether a misalignment result is reasonable should also be determined. This is a difficult problem because, as is known, appreciation (of an actual real exchange rate) may not necessarily mean that the currency is overvalued, and depreciation may not necessarily mean that the currency is undervalued. In my opinion, if an actual real exchange rate depreciates and the concluded degree of undervaluation (overvaluation) increases (decreases), then the misalignment result can be said to be reasonable. Likewise, when an actual real exchange rate appreciates and the concluded degree of undervaluation (overvaluation) decreases (increases), then the misalignment result can be said to be reasonable. In other words, in a reasonable misalignment result, the increase in the degree of undervaluation (overvaluation) of a currency corresponds to the depreciation (appreciation) of the currency, and the decrease in the degree of undervaluation (overvaluation) corresponds to the appreciation (depreciation). For example, since the RMB depreciated greatly from late 1970s to mid-1990s (see Table 2 in Section 5.3.1), a misalignment result that "the RMB was overvalued in 1978 and undervalued in 1996" is more reasonable than another misalignment result that "the RMB was undervalued in 1978 and overvalued in 1996." Whether a result for RMB misalignment is consistent with Chinese economic fact is decided by this criterion.

Third, the (actual) real exchange rates and their equilibrium values used in different studies are not allowed to be compared directly. As stated in Section 3.2, the real exchange rates used in the BEER and Penn effect models (Zhang, 2001; Funke and Rahn, 2005; Goh and Kim, 2006; Chang and Shao, 2004; Frankel, 2005; Cheung et al., 2007) are not all consistent. Zhang (2001), Funke and Rahn (2005) and Goh and Kim (2006) construct their own real exchange rates; Chang and Shao (2004) and Cheung et al. (2007) use the real exchange rates from the WDI database; and Frankel (2005) uses the real exchange rate from the PWT database. Furthermore, even for the real exchange rate defined by the same equation, different databases may also give different values. For example, the values for RMB real exchange rate in the PWT are different from those in the WDI. The inconsistent real exchange rates that economists use mean that they cannot be compared directly. To solve this issue, I compare

[9] Meese and Rogoff (1983) compared the out-of-sample forecasting accuracy of various structural and time series exchange rate models. But the method and criterion given in this paper are markedly different from theirs.

each model finding with the real exchange rate used in the same paper, and indirectly compare these different model findings (see Sections 5.2 and 5.3 for details).

5.2. Constructing Real Exchange Rates and Deriving Misalignments Used

Since each model finding is compared with the real exchange rate used in the same paper, for the real exchange rates that are constructed by the economists themselves (Zhang, 2001; Goh and Kim, 2006), I have constructed real exchange rates using similar methods (see Appendix). For consistency and convenience, I use the reciprocals for the values of the real exchange rate of Zhang (2001) and define the value in 1975 to be equal to 100 in order that the bigger values also imply the appreciation of RMB as the real exchange rates used in other models (Goh and Kim, 2006; Chang and Shao, 2004; Cheung et al., 2007). The real effective exchange rate index constructed according to Goh and Kim (2006) is normalized, with its value in 1978 being 100. The real exchange rate obtained from the WDI can be directly compared with the model findings from the two Penn effect models (Chang and Shao, 2004; Cheung et al., 2007) because this rate is used in the two Penn effect models.

Chang and Shao (2004, p.370, Table 2) provide their RMB misalignment result in a table to show the concrete degree of misalignment of the RMB in each year clearly. For the misalignment results given in the figures (Zhang, 2001, p.90, Figure 1; Goh and Kim, 2006, p.125, Figure 2; Cheung et al., 2007, p.772, Figure 4), the concrete degree of misalignment of the RMB in each year is obtained through my manual measurement from their relevant figures.[10] Zhang (2001, p.90, Figure 1) and Cheung et al. (2007, p.772, Figure 4) both use the actual and equilibrium real exchange rates in log forms; thus, the degree of misalignment can be approximated by the difference between the actual and equilibrium real exchange rates. Although the degrees of misalignments from Zhang (2001), Goh and Kim (2006), and Cheung et al. (2007) through the manual measurement are not precise, they can be used to determine whether the RMB was over- or undervalued and how the misalignment changed; they can also satisfy the demands of the comparison.

The real exchange rates used and the misalignment of RMB derived from the BEER and Penn effect models are listed in Table 2 (see Section 5.3). In Table 2, only four model findings are used: the model findings from Zhang (2001) and Goh and Kim (2006) for the BEER model, and the model findings from Chang and Shao (2004) and Cheung et al. (2007, p.772, Figure 4) for the Penn effect model. Funke and Rahn (2005) use quarterly data, whereas Wang et al. (2007) do not specify the real exchange rate used; and Frankel (2005) only provides two misalignments (RMB's misalignments in 1990 and 2000); thus, the three model findings are not used. Although the BEER and Penn effect models have also been used in other currencies, the studies that used these models, although numerous, differ greatly from the focus of this paper. Thus, they are not discussed here.

5.3. Concrete Comparisons between the Findings of the Two Models

According to the criteria of comparison introduced in Section 5.1, two concrete comparison methods are used below: the real exchange rate classification comparison and the misalignment classification comparison.

5.3.1. Real Exchange Rate (RER) Classification Comparison

The result for the RER classification comparison is listed in Table 2. As evident from the upper and main block of Table 2, the RERs of RMB from different sources (Zhang, 2001; Goh and Kim, 2006; WDI) change similarly. All the RERs depreciated greatly from the 1970s to the 1990s, with the mid-1980s viewed as a watershed.[11] Thus, each RER can be divided into two periods: 1975–1985

[10] As discussed in Section 4.2, the panel data model that accounts for serial correlation in Cheung et al. (2007, Section 3.3. Controlling for serial correlation, p.770-773) is classified as a Penn effect model.

[11] For more details on the RMB' RER and China's RER policy, see Xu (2000).

(relatively high-priced period) and 1986–2002 (relatively low-priced period). Two concrete comparison methods are used for the model findings in the two periods.

Table 2: The RERs and Misalignments of the RMB in Different Model Findings

	Zhang (2001)		**Goh and Kim (2006)**		**WDI**	**Chang and Shao (2004)**	**Cheung et al. (2007)**
	RER (1975=100)	**Misalign-ment**	**RER (1978=100)**	**Misalign-ment**	**RER (US=100)**	**Misalign-ment**	**Misalign-ment**
1975	100.00	100%			77.85	66.7%	
1976	92.07	270%			70.39	64.8%	85%
1977	92.13	50%			69.94	65.5%	85%
1978	94.94	-60%	100.00	-13%	73.10	51.3%	90%
1979	94.37	-75%	102.74	-7%	75.56	50.8%	90%
1980	91.50	-45%	110.88	4%	74.65	44.9%	90%
1981	49.78	-130%	91.46	-4%	61.36	40.2%	70%
1982	48.08	60%	84.88	1%	52.08	36.8%	45%
1983	47.72	90%	83.75	6%	48.63	38.5%	40%
1984	46.84	-80%	75.27	1%	41.91	33.8%	20%
1985	46.50	160%	63.07	-3.5%	35.30	33.3%	0%
1986	42.50	0%	51.72	-19%	30.64	19.7%	-10%
1987	41.45	-190%	44.64	-22%	29.04	-8.9%	-20%
1988	36.20	-90%	44.88	-20.5%	31.49	-13.6%	-15%
1989	40.47	45%	51.15	-9%	32.66	-4.4%	-10%
1990	37.18	-50%	39.66	2%	26.22	-5.0%	-30%
1991	35.41	-20%	35.18	0%	24.28	-11.2%	-40%
1992	34.13	-70%	35.21	-14%	24.68	-19.7%	-40%
1993	32.55	0%	37.03	-29%	26.38	-35.2%	-40%
1994	31.99	-190%	28.04	-17%	20.71	-24.3%	-70%
1995	37.19	-20%	32.51	-11%	23.36	-12.6%	-60%
1996	38.62	400%	37.38	-2%	24.42	-7.4%	-55%
1997	38.90	0%	65.90	4%	24.36	-6.1%	-60%
1998			45.87	13%	23.42	-8.9%	-65%
1999			41.99	-3%	22.65	-14.3%	-70%
2000			45.96	-5.5%	22.40	-18.4%	-70%
2001			47.53	0%	22.08	-20.1%	-75%
2002			42.00	-1.5%	21.80	-23.2%	-80%
Averages in two periods							
1975-1985	**73.08**	**31%**	**89.01**	**-1.9%**	**61.89**	**47.9%**	**62%**
1986-2002	**37.22**	**-15%**	**42.74**	**-7.9%**	**25.33**	**-12. 6%**	**-48%**
Most types (overvalued, equilibrium, or undervalued) of observations and their ratios in two periods							
1975-1985		**Over., 54.5%**		**Over., 50%**		**Over., 100%**	**Over., 90%**
1986-2002		**Under., 58.3%**		**Under., 70.6%**		**Under., 94.1%**	**Under., 100%**

Notes: In the misalignments, the blank cells denote that there are no results in those years in the related papers; the positive (negative) values represent overvaluation (undervaluation). The period "1986–2002" is actually 1986–1997 for Zhang (2001); the period "1975–1985" is actually 1978–1985 for Goh and Kim (2006) and is actually 1976-1985 for Cheung et al. (2007). In each period (1975–1985 or 1986–2002), the sum of ratios of overvalued, equilibrium, and undervalued observations is 100%. The smaller ratios of misalignment observations in each period are omitted.

Sources: Relevant papers, WDI database and the author's calculations

The first method is a comparison among the averages in the two periods. The average of Zhang (2001)'s real exchange rate is 73.08 in 1975–1985, approximately twice of that in 1986–1997 (37.22). The average of Goh and Kim (2006)'s real exchange rate in 1978–1985 (89.01) is also approximately twice that in 1986–2002 (42.74). The average of WDI's real exchange rate in 1975–1985 (61.89) is more than twice that in 1986–2002 (25.33). Given the huge depreciation of RMB from 1975–1985 to 1986–2002, the reasonable misalignment result should correspond to the decrease in the degree of overvaluation or the increase in the degree of undervaluation according to the criteria of comparison (see Section 5.1). Seen from the average misalignments in the two periods, all the model findings are reasonable. Zhang (2001), Chang and Shao (2004), and Cheung_et al. (2007) all conclude that RMB was on average overvalued in 1975–1985 (31%, 47.9% and 62%, respectively) and undervalued in 1986–2002 (-15%, -12.6% and -48%, respectively). Goh and Kim (2006) conclude that the degree of undervaluation of RMB increases (in absolute value) from an average of -1.9% to an average of -7.9%. However, this comparison cannot determine which model findings are more reasonable. That is, whether the changes in the RMB from being overvalued on average in 1975–1985 to being undervalued on average in 1986–2002 (Zhang, 2001; Chang and Shao, 2004; Cheung et al., 2007) is more reasonable or whether the RMB's change from being slightly undervalued on average in 1978–1985 to being fairly undervalued on average in 1986-2002 (Goh and Kim, 2006) is more reasonable cannot be determined.

The other method is a comparison among the ratios of different types of observations in the two periods. The findings from the Penn effect model and from the BEER model are compared from the ratios of overvalued, equilibrium, and undervalued observations in the two periods, as listed at the bottom of Table 2. All the four model findings regarding the ratio of overvalued observations in 1975–1985 and the undervalued observations in 1986–2002 indicate that RMB was mostly overvalued in its high-priced period (1975–1985) and mostly undervalued in its low-priced period (1986–2002). This further indicates that all the model findings are reasonable according to the criteria of comparison. However, the ratios among different model findings have slight differences. Zhang (2001) and Goh and Kim (2006) conclude that the overvalued observations occupy approximately 50%–55% in 1975–1985 and the undervalued observations occupy approximately 60%–70% in 1986–2002, whereas Chang and Shao (2004) and Cheung et al. (2007) conclude that the overvalued observations occupy 90%–100% in 1975–1985 and the undervalued observations also occupy 90%-100% in 1986-2002. This shows that the tendency of overvaluation in 1975–1985 to undervaluation in 1986–2002 in Chang and Shao (2004) and Cheung et al. (2007) is more obvious than that in Zhang (2001) and Goh and Kim (2006). Given that we cannot determine the true misalignment, we also cannot decide which model findings are more reasonable from this comparison.

In conclusion, according to the RER classification comparison using either the averages or the ratios, all the model findings are reasonable; however, which findings are more reasonable cannot be determined.

5.3.2. Misalignment Classification Comparison

In addition to the above RER classification comparison in two (sub-)periods, the model findings can also be compared using different types of misalignment observations in the whole period, as listed in Table 3.

Table 3: The Misalignments and RERs of the RMB in Different Model Findings

Zhang (2001)		Goh and Kim (2006)		Chang and Shao (2004)		Cheung et al. (2007)	
Misalign-ment	**RER (1975=100)**	**Misalign-ment**	**RER (1978=100)**	**Misalign-ment**	**RER (U.S.=100)**	**Misalign-ment**	**RER (U.S.=100)**
400%	38.62	13%	45.87	66.7%	77.85	90%	73.1
270%	92.07	6%	83.75	65.5%	69.94	90%	75.56
160%	46.5	4%	110.88	64.8%	70.39	90%	74.65
100%	100	4%	65.9	51.3%	73.1	85%	69.94
90%	47.72	2%	39.66	50.8%	75.56	85%	70.39
60%	48.08	1%	84.88	44.9%	74.65	70%	61.36
50%	92.13	1%	75.27	40.2%	61.36	45%	52.08

Table 3: The Misalignments and RERs of the RMB in Different Model Findings - continued

45%	40.47	0%	47.53	38.5%	48.63	40%	48.63
0%	42.5	0%	35.18	36.8%	52.08	20%	41.91
0%	38.9	-1.5%	42	33.8%	41.91	0%	35.3
0%	32.55	-2%	37.38	33.3%	35.3	-10%	30.64
-20%	37.19	-3%	41.99	19.7%	30.64	-10%	32.66
-20%	35.41	-3.5%	63.07	-4.4%	32.66	-15%	31.49
-45%	91.5	-4%	91.46	-5.0%	26.22	-20%	29.04
-50%	37.18	-5.5%	45.96	-6.1%	24.36	-30%	26.22
-60%	94.94	-7%	102.74	-7.4%	24.42	-40%	24.28
-70%	34.13	-9%	51.15	-8.9%	29.04	-40%	24.68
-75%	94.37	-11%	32.51	-8.9%	23.42	-40%	26.38
-80%	46.84	-13%	100	-11.2%	24.28	-55%	24.42
-90%	36.2	-14%	35.21	-12.6%	23.36	-60%	24.36
-130%	49.78	-17%	28.04	-13.6%	31.49	-60%	23.36
-190%	41.45	-19%	51.72	-14.3%	22.65	-65%	23.42
-190%	31.99	-20.5%	44.88	-18.4%	22.4	-70%	22.65
		-22%	44.64	-19.7%	24.68	-70%	22.4
		-29%	37.03	-20.1%	22.08	-70%	20.71
				-23.2%	21.8	-75%	22.08
				-24.3%	20.71	-80%	21.8
				-35.2%	26.38		
Averages in overvalued, equilibrium, and undervalued observations in order							
147%	63.20	4%	72.32	45.5%	59.28	68%	63.07
0%	37.98	0%	41.36			0%	35.30
-85%	52.58	-11%	53.11	-14.6%	25.00	-48%	25.33

Notes: This table is obtained from Table 2. The corresponding years are already shown in Table 2 and are thus omitted.
Sources: The relevant papers, WDI database and the author's calculations.

Table 3 is obtained from Table 2 by sequencing the misalignments of each model's findings from overvaluation to undervaluation. Concretely, the misalignments of each model's findings are first classified into three types (overvalued, equilibrium, and undervalued observations) and then the corresponding averages of misalignments and of real exchange rates are calculated. Evidently, there are obvious differences between the findings from the BEER models (Zhang, 2001; Goh and Kim, 2006) and those from the Penn effect models (Chang and Shao, 2004; Cheung et al., 2007). In Zhang (2001), the average real exchange rate in overvalued observations (63.2) is bigger than that in equilibrium observations (37.98) and in the undervalued observations (52.58), indicating that the overvaluation corresponds to a higher priced real exchange rate than the equilibrium and the undervaluation. This observation is reasonable according to the criteria of comparison. However, the average real exchange rate in equilibrium observations (37.98) is smaller than that in undervalued observations (52.58), indicating that the equilibrium corresponds to a lower priced real exchange rate than the undervaluation, making it unreasonable. The similar phenomenon can also be found in the model findings of Goh and Kim (2006), which are also partly reasonable and partly unreasonable. In the model findings of Chang and Shao (2004), the overvaluation (45.5% on average) corresponds to a higher priced real exchange rate (59.28 on average) and the undervaluation (-14.6% on average) corresponds to a lower priced real exchange rate (25 on average), which is reasonable. In Cheung et al. (2007), the overvaluation (68% on average), the equilibrium (0% on average) and the undervaluation (-48% on average) corresponds to a higher priced (63.07 on average), a middle priced (35.30 on average) and a lower priced (25.33 on average) real exchange rate, respectively, which is also reasonable.

In conclusion, according to this misalignment comparison, each model's findings from the BEER model are partly reasonable and partly unreasonable, whereas each model's findings from the Penn effect model are wholly reasonable; thus, the latter model is more reasonable than the former.

Considering that the real exchange rates used in the two Penn effect models (Chang and Shao, 2004; Cheung et al., 2007) are both from the WDI, we also simulate a BEER model in which the real exchange rate is also from the same database. However, no new findings are obtained when the simulated BEER model is added to the above comparisons; thus, the simulation work is omitted.

5.4. Further Discussion

It should be noted that the conclusion on the comparison of the model findings from the BEER and Penn effect models, which is derived in Section 5.3 in this paper, is limited. Dunaway et al. (2006) have proven that, at least for China, small changes in model specifications, explanatory variable definitions, and periods used in estimation can lead to very substantial differences in the equilibrium real exchange rate. This can also be seen from Table 2 in Section 5.3.1, in which the RMB misalignments in each same year derived by different economists are different. Thus, if other or more model findings from the BEER and Penn effect models are used, the conclusion derived in Section 5.3 may change. Thus, my conclusion on the comparison of the four particular model findings cannot be generalized easily and further relevant studies are required.

6. Conclusion

In time-series and cross-section data settings, the BEER and Penn effect models are basically different. In these settings, there are six main differences between the two models: theoretical or empirical basis, explained variable, explanatory variable, econometric method, equilibrium real exchange rate, and misalignment result. Given these differences, compared with the Penn effect model, the BEER model has a weaker basis, uses an improper econometric method, and derives a misalignment result that is known beforehand to some degree. Thus, the BEER model is the less reasonable (or a less robust) model in terms of the valuation of RMB in time-series and cross-section data settings.

In a panel data setting, the differences in the econometric method, the equilibrium real exchange rate, and the misalignment result between the BEER and Penn effect models automatically disappear or are reduced. In this setting, the differences in the theoretical basis and explained and explanatory variables between the two models continue to exist and are the characteristics that can be used to differentiate them. In this setting, the Penn effect model is still in a constrained form; however, the BEER model can have many various forms. Concretely, the Penn effect model can be viewed as a special form of the BEER model; however, the latter also includes many other forms that are different from the former.

Finally, a criterion to compare different model findings and to determine a more reasonable model is given using the corresponding real exchange rate as the relevant economic fact. If the increase in the degree of undervaluation (overvaluation) of a currency corresponds to the currency's depreciation (appreciation), and the decrease in the degree of undervaluation (overvaluation) corresponds to the appreciation (depreciation), the misalignment result is said to be reasonable. According to this general criterion of comparison, two concrete methods, the real exchange rate classification comparison and the misalignment classification comparison, are used in four typical model findings on RMB valuation. According to the real exchange rate classification comparison, including the comparison among the averages in the high-priced and low-priced periods and the comparison among the ratios of different types of observations in the two periods, all the four model findings (Zhang, 2001; Goh and Kim, 2006; Chang and Shao, 2004; Cheung et al., 2007) are reasonable; however, which one is more reasonable cannot be determined. According to the misalignment classification comparison, each model's findings from the BEER model are only partly reasonable but each model's findings from the Penn effect model are wholly reasonable. Thus, the latter is more reasonable than the former.

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Appendix

1. Constructing Zhang (2001)'s Real Exchange Rate Index

The nominal exchange rate of RMB against the US dollar and the US wholesale price index for finished industrial goods are from the IFS online database of the IMF. The swap rate and internal rate for trade settlements during China's dual exchange rate period are from Wu and Chen (2002, p.80, p.167–168). The retail price index of China is from the Scientific Database published by the Institute of Geographical Sciences and Natural Resources Research under the Chinese Academy of Sciences.

2. Constructing Goh and Kim (2006)'s Real (Effective) Exchange Rate Index

Each original bilateral nominal exchange rate is measured by domestic currency per US dollar, so its conversion to RMB is calculated. The exchange rate of the New Taiwan dollar against the US dollar and Taiwan's CPI index are from the CEIC Data of the Information Sciences Institute in which both the exchange rate and the CPI values are indicated monthly. Thus, we average the rates and values to obtain the annual rates and values. China's CPI index before 1998 is from the Scientific Database and that after 1998 is from IFS online database. All the other data related with exchange rates and CPI indices are from IFS online database. For Germany's CPI index, prior to 1991, the CPI of West Germany is used; after 1992, that of united Germany is used (the two indices are reconciled). The same weights used in the weighted real effective exchange rate index of Goh and Kim (2006, p.119), including Japan (0.34), U.S. (0.32), South Korea (0.13), Taiwan (0.12), and Germany (0.09), are used. Notably, mainly because the nominal exchange rate of Korean Won (series 542..AE.ZF… in IFS) depreciated greatly from 844.2 Korean Won per US dollar in 1996 to 1569.0 Korean Won per US dollar in 1997, the constructed real effective exchange rate index suddenly changes from 37.38 in 1996 to 65.90 in 1997.