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***Abstract*—A regular phenomenon of the behavioral equilibrium exchange rate (BEER) model is analyzed. The result derived by the model is proved to contradict the economic fact and that by the Balassa-Samuelson model. The BEER model cannot be used, therefore, to calculate equilibrium exchange rate.**

Keywords-Behavioral equilibrium exchange rate; Chinese currency; Valuation

I. INTRODUCTION

Estimating the degree of exchange rate misalignment is one of the most important tasks in open-economy macroeconomics. The behavioral equilibrium exchange rate (BEER) model is one of the most widely used models for this purpose. Some of the other models are the purchasing power parity model (Chou and Shih, 1998), the fundamental equilibrium exchange rate model (Clark and MacDonald, 1998), and the Balassa-Samuelson model (Chang and Shao, 2004; Frankel, 2005). The BEER model has been used by Clark and MacDonald (1998), Baffes et al. (1999), and many other economists. In recent years, this model has been used to calculate equilibrium value of the Chinese currency, the renminbi (RMB) [see Zhang (2001), Wang (2004), Funke and Rahn (2005), Goh and Kim (2006), Wang et al. (2007)].

In an approach different from the economists who use the BEER model to calculate the equilibrium exchange rate, the model itself is the focus of this study. In this article, the working of the BEER model is studied from its application to the valuation of the RMB. A study about the BEER model is useful for both understanding the equilibrium value of currencies and the development of economics.

The remainder of the paper is structured as follows. Section II describes the BEER model and Section III presents the analysis of a regular phenomenon of the BEER model. Section IV presents the investigation results of the model by combining them with Chinese economic fact and the Balassa-Samuelson model and Section V concludes.

II. THE BEER MODEL

The theoretical and econometric framework of the BEER model are described by Baffes et al. (1999), 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 (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 (1) and the equilibrium real exchange rate RER^* can be derived.

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

III. A REGULAR PHENOMENON IN THE BEER MODEL

A. What is a Regular Phenomenon?

When examining the RMB's misalignment derived by the BEER model (Zhang, 2001, p.90; Funke and Rahn, 2005, p.484; Goh and Kim, 2006, p.124; Wang et al., 2007, p.425), one can find a regular phenomenon: the actual real exchange rate line crosses its equilibrium line many times; more than two equilibrium values appear; undervaluation mixes overvaluation more than two times (see Table 1 and Figure 1).

The regular phenomenon can be seen more clearly when the BEER model is compared with the Balassa-Samuelson model (Chang and Shao, 2004). For the latter, one can see that the actual real exchange rate line crosses its equilibrium line only once and that only one equilibrium value appears.

[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).

TABLE I. THE RMB'S MISALIGNMENTS DERIVED BY THE BEER MODEL AND THE BALASSA-SAMUELSON MODEL

	The BEER Model				The Balassa-Samuelson Model	
	Zhang (2001)		Goh and Kim (2006)		Chang and Shao (2004)	
	RER(1975=100)	Misalignment	RER (1978=100)	Misalignment	RER(US=100)	Misalignment
1975	100.00	100%			77.85	66.7%
1976	92.07	270%			70.39	64.8%
1977	92.13	50%			69.94	65.5%
1978	94.94	-60%	100.00	-13%	73.10	51.3%
1979	94.37	-75%	102.74	-7%	75.56	50.8%
1980	91.50	-45%	110.88	4%	74.65	44.9%
1981	49.78	-130%	91.46	-4%	61.36	40.2%
1982	48.08	60%	84.88	1%	52.08	36.8%
1983	47.72	90%	83.75	6%	48.63	38.5%
1984	46.84	-80%	75.27	1%	41.91	33.8%
1985	46.50	160%	63.07	-3.5%	35.30	33.3%
1986	42.50	0%	51.72	-19%	30.64	19.7%
1987	41.45	-190%	44.64	-22%	29.04	-8.9%
1988	36.20	-90%	44.88	-20.5%	31.49	-13.6%
1989	40.47	45%	51.15	-9%	32.66	-4.4%
1990	37.18	-50%	39.66	2%	26.22	-5.0%
1991	35.41	-20%	35.18	0%	24.28	-11.2%
1992	34.13	-70%	35.21	-14%	24.68	-19.7%
1993	32.55	0%	37.03	-29%	26.38	-35.2%
1994	31.99	-190%	28.04	-17%	20.71	-24.3%
1995	37.19	-20%	32.51	-11%	23.36	-12.6%
1996	38.62	400%	37.38	-2%	24.42	-7.4%
1997	38.90	0%	65.90	4%	24.36	-6.1%
1998			45.87	13%	23.42	-8.9%
1999			41.99	-3%	22.65	-14.3%
2000			45.96	-5.5%	22.40	-18.4%
2001			47.53	0%	22.08	-20.1%
2002			42.00	-1.5%	21.80	-23.2%

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).
Sources: Relevant papers, WDI database and our calculations.

B. Why does the Regular Phenomenon Occur?

The regular phenomenon appears whenever the BEER model is used. This is because it is relative to the residual from the cointegration equation and can be derived from the theory of the BEER model.

In the BEER model, the RMB's misalignment is derived from u_t of (2). The residual u_t must be stationary if (2), the cointegration equation, 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 1 shows such a residual derived from our 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 China's economic reality is in the sample period.

Why does the Balassa-Samuelson model not have the phenomenon? This is because the BEER model is based on time-series analysis and the Balassa-Samuelson model on cross-section analysis. The RMB's misalignment for the BEER model is derived from comparing different observations within China itself and for the Balassa-Samuelson model from comparing between China and other countries. For the BEER model, the RMB's misalignment is derived from a single residual from the cointegration equation and for the Balassa-Samuelson model, from many residuals. For example, to obtain the RMB's misalignments in 1990 and 2000, one should run two Balassa-Samuelson regressions (Frankel, 2005), and so on.

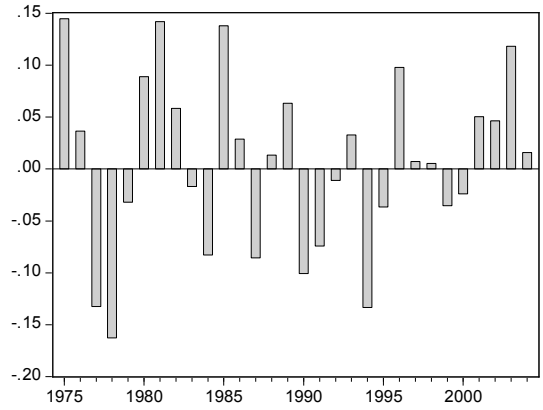

Figure 1. A residual from the BEER model.

C. An Inference Derived

The regular phenomenon's existence is equivalent to giving an assumption and then applying the BEER model. The assumption is that the RMB will have both undervaluation and overvaluation over each (entire) 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 economic reality during that period. It is necessary to examine possible economic explanations to this.

IV. CAN THE RESULT OFFER A REASONABLE ECONOMIC EXPLANATION?

This question will be discussed from two perspectives: one is the Chinese economic fact and the other is the comparison between the BEER and the Balassa-Samuelson models.

A. The Criteria and Method

First, the particular Chinese economic fact to be used as the criteria has to be determined. Given the different economic fundamentals used in the BEER and Balassa-Samuelson 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 criteria 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. Therefore, 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. That is, the relevant Chinese economic fact used as criterion in the comparison is (single) the actual real exchange rate of RMB. We were not able to find a better Chinese economic fact than this one.

Second, given that the equilibrium real exchange rate is not observable, whether a misalignment result is reasonable should also be determined. This is a difficult problem because we have not found relevant studies up till now. In our 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 mid-1970s to mid-1990s (see Table 1), a misalignment result that "the RMB was overvalued in 1975 and undervalued in 1994" is more reasonable than another misalignment result that "the RMB was undervalued in 1975 and overvalued in 1994." Whether a result for RMB misalignment is consistent with Chinese economic fact is decided by this criterion.

Third, the method of comparing the different model findings should be determined. On one side, the real exchange rates used in the BEER and Balassa-Samuelson models (Zhang, 2001; Funke and Rahn, 2005; Goh and Kim, 2006; Chang and Shao, 2004; Frankel, 2005) 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) use the real exchange rates from the WDI database; and Frankel (2005) uses the real exchange rate from the PWT database. On the other side, 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, we compare each model finding with the real exchange rate used in the same paper, and indirectly compare these different model findings.

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), we have constructed them using similar methods. The concrete constructions are omitted to save space. For consistency and convenience, we 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). 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 Balassa-Samuelson model (Chang and Shao, 2004) because this rate is used in the Balassa-Samuelson model.

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), the concrete degree of misalignment of the RMB in each year is obtained through our manual measurement from their relevant figures. Zhang (2001, p.90, Figure 1) uses 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) and Goh and Kim (2006) through our 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 Balassa-Samuelson models are listed in Table 1.

B. Comparison with Chinese Economic Fact

As evident from Table 1, the real exchange rates of RMB from different sources (Zhang, 2001; Goh and Kim, 2006; Chang and Shao, 2004) change similarly. All the real exchange rates depreciated greatly from the 1970s to the 1990s, with the mid-1980s viewed as a watershed. Thus, each real exchange rate can be divided into two periods: 1975–1985 (relatively high-priced period) and 1986–2002 (relatively low-priced period). For example, according to

Chang and Shao (2004), the real exchange rate in 1978-1979 was about 75, which meant China's price level was about 75% of the U.S. price level (U.S.=100). But in 1996-1997, the China's price level was only one fourth of the U.S. price level. For more details on the changes of the RMB' exchange rate, see Xu (2000) and Frankel (2005).

But, Zhang (2001) uses the BEER model and concludes that the RMB was undervalued (by 60-75%) in 1978-1979 and overvalued (by 400%) in 1996. Similarly, Goh and Kim (2006) use the BEER model and conclude that the RMB was undervalued (by 7-13%) in 1978-1979 and overvalued (by 4%) in 1997. Their results thus contradict the economic fact of the RMB's great depreciation from 1978-1979 to 1996-1997.

Furthermore, based on the inference that the RMB must have both undervaluation and overvaluation over each (entire) sample period, one can arrive at the following conclusion. If the BEER model is used over a relatively high-valued period, for example 1975 to 1980, in any case one will get the RMB's undervaluation at some observations in this period. If the BEER model is used over a relatively low-valued period, for example 1995 to 2000, one will get the RMB's overvaluation at some observations in this period. Are these results reasonable?

C. Comparison with the Balassa-Samuelson Model

The Balassa-Samuelson model, also called the Balassa-Samuelson regression (Frankel, 2005), is based on the results of Balassa (1964) and Samuelson (1964). According to this model, a developing country's currency tends to appreciate with increase in the rate of economic growth. The results derived by the BEER model in Table 1 do not, however, support this theory.

As is known, the economic growth of China, as measured by its GDP per capita, was fast after the late 1970s when China unleashed market-oriented reform and open policy. According to the theory of Balassa-Samuelson model, the equilibrium real exchange rate must have appreciated after the late 1970s. But the actual real exchange rate has depreciated greatly in the same time. So Chang and Shao (2004), using the Balassa-Samuelson model, obtained that the RMB was all overvalued before 1986 and all undervalued after 1987.

Here one can see the big difference between the results of the two models: before 1986 (after 1987), as per the Balassa-Samuelson model, the RMB was all overvalued (undervalued); but as per the BEER model, it was (still) mixed up under-valuation and overvaluation. Therefore, the result from the Balassa-Samuelson model, rather than the BEER model, is more in conformity with the economic reality of the RMB's great depreciation from 1975 to 2002, an observation of common economic knowledge.

So the result of the BEER model may contradict the economic fact, and also may differ from that of the Balassa-Samuelson model.

V. CONCLUSION

In an approach different from the economists who use the BEER model to calculate the equilibrium exchange rate, the working of the BEER model is studied from its application to the valuation of the RMB in this paper.

When using the BEER model, the RMB must be under- and overvalued in turn in the whole sample period, regardless of China's economic reality. This regular phenomenon lacks a reasonable economic explanation and is proved to obviously contradict the economic fact. In addition, the result of the BEER model may differ from that of the Balassa-Samuelson model. The BEER model cannot be used, therefore, to calculate a currency's equilibrium exchange rate.

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