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Zhang, Zhibai

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A Simple Model and its Application in the Valuation of Eleven Main Real Exchange Rates

Zhibai Zhang
Economics & Management College, Zhaoqing University
Zhaoqing City 526061, Guangdong Province, China
E-mail: zhibai.zhang@gmail.com, zzhang5678@163.com
Tel: +86 13620351106

Abstract

A simple currency valuation model is given. The model is based on the Penn effect but reduces the uncertainty of the econometric specification that the Penn effect and many other models have. I use the model to valuate eleven main currencies' bilateral real exchange rate against the US dollar from 1980 to 2010. In the model finding, a seeming convergence phenomenon is found.

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

Currency valuation, or calculating a currency's equilibrium exchange rate, has been a hot topic in international finance. The models for such use are the absolute or relative purchasing power parity (Isard, 2007; Sidek et al., 2011), the Penn effect (Frankel, 2005; Cheung et al., 2010), the behavioral equilibrium exchange rate (BEER) (Clark and MacDonald, 1998; Wang et al., 2007), the macroeconomic balance (Isard, 2007; Lopez-Villavicencio et al., 2012), and so on. In this study, I will develop a new model, which is simple, easy to use, and is expected to give some meaningful misalignment results.

1. Some Existing Models and their Faults

The basic and most influential model for assessing a bilateral nominal exchange rate (NER) is the absolute purchasing power parity (PPP). It uses Eq. (1), where P_i is country i's price level, P^* is the specified foreign country's price level (the US's price level, in this paper), and E_i is the bilateral NER expressed as the national currency units per US dollar. According to Eq. (1), whether the real exchange rate (*RER)* is equal to 1 gives a result that E is equilibrium or not. But there exists an empirical regularity that the RERs (in this definition) in rich countries are bigger and those in poor countries are smaller, which makes the deviation of the PPP common. This regularity is similar to the term "Penn effect" coined by Samuelson (1994) (Isard, 2007, p.10), which is also adopted in this paper. But the PPP and Peen effect, as the tools for currency valuation, had seldom developed till the early 2000s.

$$RER_i = \frac{PPP_i}{E_i} = \frac{P_i / P^*}{E_i} = \frac{P_i}{E_i P^*} \tag{1}$$

In the early 2000s, some economists (Takeuchi, 2003; Chang and Shao, 2004; Frankel, 2005) began to combine the PPP with the Penn effect, and use the cross-section data regression, Eq. (2) or its log-linear, to value a currency's RER. In Eq. (2), *RER* is defined by Eq. (1), and *income* is the income level, which is often represented by the relative GDP per capita. Since Eq. (2) regresses the countries' RERs on their income levels, deviations from the regression line represent the over- or undervaluation of the RERs when the Penn effect is taken into account. Following Cheung et al. (2010, p.274), I call this the Penn effect model. The Penn effect model's influence is growing; see Cheung et al. (2007), Subramanian (2010), Reisen (2010), and Garroway et al. (2012).

$$RER_i = \beta_0 + \beta_1 income_i + u_i \tag{2}$$

But the Penn effect model has a fault in that different econometric specifications in the model always give different misalignment results. For example, I find that using the same 118 countries as Frankel (2005) gives the RMB's undervaluation 36% against the regression line and 55.9% against the US dollar in 2000; but when the country number is reduced to 60, the RMB's undervaluation changes to 22.4% against the regression line and 26.5% against the US dollar in the same year. The uncertainty of econometric specification for the Penn effect model was also confirmed by Cheung et al. (2010). Besides the Penn effect model, the fault also appears in all other models that use an econometric method, such as the BEER and the macroeconomic balance models; see Dunaway et al. (2009).

2. The New Model (the Ratio Model)

Let $GDPP_i$ and $GDPP^*$ be country i's and the US's GDP per capita (GDPP) respectively, RER_i be defined by Eq. (1), then the index $Ratio_i$ measures the difference of country i's RER and GDPP (both relative to the US). If the value of $Ratio_i$ is 1, the RER is equal to the GDPP, and I say the RER is equilibrium. And if the value of $Ratio_i$ is more (less) than 1, the RER is concluded to be overvalued (undervalued). That is, A RER should stay at the same level as the country's GDPP, otherwise it is misaligned. For example, in 2010, China's RER, China's GDPP, and the US's GDPP were 0.583, 4428.5 US dollar and 47198.5 US dollar respectively; so $Ratio_{\text{China}}$ was 6.21 (=0.583/(4428.5/47198.5)) and the RMB was overvalued by 521%.[1] For convenience, I call this model "the ratio model".

$$Ratio_i = \frac{RER_i}{\frac{GDPP_i}{GDPP^*}} = \frac{\frac{P_i}{E_i P^*}}{\frac{\mathrm{GDPP_i}}{GDPP^*}} \qquad Misalignment = Ratio_i - 1 \tag{3}$$

From the above definition, we can see that: (1) the ratio model is based on the Penn effect model but uses a simple digital calculation, rather than an econometric method, so it reduces the fault of the uncertainty of econometric specification that the Penn effect and many other models have. (2) Since the PPP model is based on the PPP theory which holds only between two similar-income-level countries, while the ratio model is based on the Penn effect which holds between an arbitrary pair of two countries, the ratio model extends the Penn effect model's application range.

3. The Application

Then I use the model and the World Bank's WDI database to valuate some currencies. In the WDI, the RER and GDP per capita (current US$) can be directly obtained. For countries, the 12 biggest ones (except some Euro countries because of their inconsistent currencies during the period) are used, which are the US and the other eleven countries listed in Table 1. The time period is 1980-2010 because some relevant data before 1980 can't be obtained.

1. This degree of misalignment from the ratio model seems to be too big. Comparatively speaking, in the Penn effect or BEER model, the degree of misalignment is obtained from a residual of a regression equation and the regression theory insures the residual's value being smaller (near zero). But the ratio model has not such an adjustment mechanism.

3.1. Each Currency's Misalignment against the US Dollar

Each currency's misalignment against the US dollar, measured by the *ratio*s, can be directly calculated using Eq. (3), which is listed in Table 1.

Table 1: The *ratio*s (defined by Eq. (3)) for eleven main countries' currencies

Obs.	Brazil	Canada	China	India	Indonesia	Japan	Korea	Mexico	Russian	Turkey	UK
1980	3.13	1.10	43.07	25.20	17.06	1.45	5.13	3.15	NA	5.64	1.46
1981	3.71	1.10	47.60	27.90	18.52	1.42	4.94	3.00	NA	5.59	1.50
1982	3.58	1.11	42.99	26.77	18.19	1.35	4.52	3.00	NA	5.36	1.42
1983	3.95	1.13	40.73	26.40	17.75	1.36	4.23	3.31	NA	5.42	1.42
1984	4.09	1.15	38.07	27.59	17.98	1.39	4.15	3.46	NA	5.52	1.47
1985	4.00	1.14	35.09	27.62	18.30	1.36	4.03	3.54	NA	5.58	1.47
1986	3.88	1.15	33.54	27.60	18.05	1.36	3.72	3.85	NA	5.45	1.45
1987	3.90	1.14	31.23	27.73	17.87	1.35	3.43	3.94	NA	5.19	1.42
1988	4.11	1.14	29.41	26.65	17.65	1.30	3.20	3.85	NA	5.34	1.40
1989	4.15	1.16	29.43	26.34	16.90	1.27	3.11	3.87	2.76	5.56	1.41
1990	4.45	1.18	28.98	25.65	15.88	1.22	2.89	3.78	2.87	5.21	1.41
1991	4.38	1.20	26.48	25.48	14.59	1.16	2.61	3.63	2.99	5.16	1.41
1992	4.56	1.23	23.94	25.09	14.11	1.17	2.54	3.63	3.56	5.03	1.44
1993	4.49	1.23	21.56	24.77	13.56	1.19	2.45	3.68	3.96	4.81	1.43
1994	4.46	1.22	19.83	24.32	13.17	1.22	2.34	3.68	4.65	5.32	1.41
1995	4.39	1.21	18.32	23.33	12.49	1.22	2.21	4.05	4.91	5.12	1.40
1996	4.48	1.24	17.26	22.64	12.08	1.22	2.13	4.02	5.20	4.97	1.37
1997	4.54	1.24	16.48	22.86	12.08	1.25	2.11	3.96	5.29	4.84	1.35
1998	4.76	1.24	15.94	22.62	14.55	1.32	2.35	3.97	5.77	3.65	1.36
1999	4.99	1.23	15.49	22.21	15.17	1.37	2.22	4.02	5.60	4.04	1.37
2000	5.00	1.23	14.84	22.37	15.09	1.37	2.04	3.89	5.13	3.79	1.35
2001	5.01	1.23	13.81	21.62	14.76	1.37	1.98	3.95	4.88	4.13	1.30
2002	4.99	1.23	12.85	21.35	14.43	1.37	1.87	3.95	4.58	4.21	1.27
2003	5.08	1.22	11.95	20.31	14.17	1.39	1.89	3.58	4.13	4.31	1.28
2004	4.99	1.23	11.20	19.53	14.02	1.39	1.86	3.57	3.93	3.94	1.27
2005	5.00	1.21	10.34	18.50	13.71	1.40	1.87	3.49	3.59	3.71	1.30
2006	4.94	1.21	9.38	17.45	13.37	1.40	1.84	3.35	2.98	3.45	1.28
2007	4.75	1.21	8.33	16.26	12.83	1.38	1.77	3.28	2.76	3.33	1.30
2008	4.51	1.20	7.57	15.55	12.12	1.39	1.75	3.19	2.32	3.13	1.28
2009	4.38	1.21	6.67	13.82	11.20	1.43	1.69	3.32	2.42	3.22	1.30
2010	4.21	1.21	6.21	13.17	10.91	1.40	1.63	3.26	2.38	3.08	1.31

Sources: WDI database and the author's calculations.

From Table 1 we can see that all the *ratio*s are more than 1, which means that all the currencies are overvalued relative to the US dollar, or the US dollar was undervalued against all the others, from 1980 to 2010. This can be explained roughly using an income-consumption relationship comparison between China and the US. According to a news report and the author's investigation, in China, the common monthly wage for an associate professor of economics is 5000 yuan, a meal in KFC costs 30 yuan, a meal (for 2-3 persons) in a restaurant costs 100 yuan, a pair of Levis jeans costs 400 yuan, and a BMW X1 costs 300000 yuan (60 times the monthly wage). While in the US, the common monthly wage for an associate professor of economics is 10000 US$, a meal in KFC costs 4 US$, a meal in a restaurant costs 40 US$, a pair of Levis jeans costs 20 US$, and a BMW X1 costs 40000 US$ (4 times the monthly wage).[2] Meanwhile the current nominal exchange rate is 6.3 yuan per US$, far from the 1:1 ratio. The wage for the same kind of work in the US can buy more commodities than in China, which reflects, to some degree, the US's undervaluation or the RMB's overvaluation.

2. But some costs, such as housing tax, or fees for insurance, medical treatment and education, in the US are more expensive than in China. For details, see http://news.ifeng.com/mainland/detail_2011_07/14/7682276_0.shtml.

3.2. The Currencies' Misalignment against Each Other

Table 1 gives the misalignment of each currency against the (common) US dollar, from which the misalignment of one currency against the others can be obtained. Let Mis_A and Mis_B be the misalignments of currencies A and B against the US dollar respectively, then the misalignment of currency A against currency B, noted by $Mis_{A/B}$, can be obtained by using Eq. (4). Or $Mis_{A/B}$ can be directly calculated in the same idea as in Eq. (3); see the part in the bracket of Eq. (4), where RER_A (RER_B) and $GDPP_A$ ($GDPP_B$) still have the same meanings as in Eq. (3). The two methods will give the same result, which can be proven if we use a simple algebraic transformation.

$$Mis_{A/B} = \frac{Mis_A - Mis_B}{1 + Mis_B} = \left(\frac{\frac{RER_A}{RER_B}}{\frac{GDPP_A}{GDPP_B}} - 1 \right) \qquad (4)$$

For example, in 2010, the misalignments (*ratio*s-1) for the Brazilian real, Canadian dollar and the RMB were 3.21, 0.21 and 5.21 respectively. So the Brazilian real and Canadian dollar were undervalued by 32.2% and 80.5% against the RMB, respectively.[3]

4. Does the *Ratio* Converge to 1?

From Table 1 we can see that there is an obvious difference between the developing countries and the developed ones. The *ratio*s for all the currencies of the developing countries were greater than 2 in 1980-2010, and over 3 for the currencies in the period except the Russian ruble in some years; for example the Brazilian real's 3-5 and the RMB's 6-48. Meanwhile the *ratio*s for all the currencies of the developed countries except Korea in the period are all 1.1-1.5, very near 1. This seems to show a regularity that in a global view the *ratio*s converge to 1 as countries' income levels rise. The seeming regularity is also confirmed by the time-series data of some countries. An example is Korea, a newly developed country. The *ratio* for the Korean won decreased steadily from 5.13 in 1980 to 1.63 in 2010. Before 1990, its *ratio* was above 3, which is an obvious character of a developing country; but after 2000, it already decreased to 1.6-2, very near that of the other developed countries. Another example is China, which showed fast growth in the period. The *ratio* for the RMB also plunged from more than 40 in the early 1980s to about 6 in 2010, an obvious convergence trend to a smaller value.

This convergence phenomenon is interesting. As we know, the PPP model says that the RER should converge to 1 in the long run. But after including the income level difference (the Penn effect), the *ratio* also seems to converge to 1 (or a narrow range of 1-1.5). This needs relevant further studies.

5. Conclusion

All the currency valuation models that use an econometric method have a serious fault in that different model specifications always give different misalignment results. A simple model given in this paper can reduce this fault. The new model is based on the Penn effect model and extends the PPP model. When applied, it gives an unusual finding that the US dollar was undervalued against all other currencies from 1980 through 2010, which can be roughly explained by an income-consumption relationship. Finally, in the model finding a seeming convergence phenomenon is found, which is similar to that of the PPP model.

[3] It is wrong to think that the Brazilian real and Canadian dollar were undervalued by 200% (=3.21-5.21) and 500% (=0.21-5.21) against the RMB, respectively.

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