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Equilibrium Exchange Rate of Asian Currencies: the Chinese Renminbi*

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Abstract

We estimate the equilibrium exchange rate (EER) of the Chinese renminbi (RMB) vis-à-vis the U.S. dollar from 1992 to 2009~~8~~. In contrast to the recent empirical studies on the EER employing a large cross-country analysis, we focus on the supply side real factors in estimating the EER by extending the Yoshikawa (1990) model. To better reflect China's processing exports in the context of growing intra-regional trade in Asia, we incorporate in the empirical analysis the source country breakdown data on import prices and input coefficients of intermediate inputs by constructing an annual new International Input-Output (IIO) table for the period from 1992 to 2009~~8~~. The results show that the EER of Chinese RMB appreciates sharply from 2005 to 2009~~8~~, suggesting that the current RMB exchange rate has been substantially undervalued and should be revalued by 46~~65~~ percent as of 2009 compared to~~from~~ the year 2009~~4~~ level. Such sharp appreciation of the EER corresponds to the dramatic increase in China's current account surplus from the mid-2000s, especially against the United States, which is ascribed to the significant improvement of both labor and intermediate input coefficients in China.

JEL Classification: F31, F33, F15

Keywords: Equilibrium exchange rate; purchasing power parity (PPP); International Input-Output Table; Chinese renminbi

1. Introduction

In recent years the exchange rate policy of Mainland China (henceforth, China) has attracted a great deal of attention in academic, industrial and political arena. With the emerging Chinese economy as the largest reserve country and the largest "world factory", the renminbi (RMB) exchange rate issue has been at the centre of ongoing debate over the source of global current account imbalance, especially with the United States. Although China relinquished the US dollar peg policy in July 2005, the RMB got re-pegged to the US dollar after the global financial crisis occurred in fall 2008. In June 19, 2010, the People's Bank of China (PBOC) announced that it would enhance the flexibility of the RMB exchange rate again. However, it is still debatable whether and to what extent the current level of the RMB exchange rate is overvalued or undervalued.

There have so far been a large number of studies that analyze the equilibrium exchange rate (henceforth, EER) of the RMB. Most of the existing empirical studies typically conduct a large cross-country (panel) analysis to estimate the EER by using the dataset of macroeconomic fundamentals. This approach, however, tends to mask the country-specific factors in determining the EER. Specifically, ~~T~~these studies fail to incorporate into their analysis the rapid upgrading of China's export competitiveness in the context of growing intra-Asian trade in the recent years. Koopman, Wang and Wei (2008) emphasize that China is now well integrated into a global production chain and has become a top supplier of manufacturing outsourcing for multinational companies in the world. It is observed that processing trade accounts for more than 50 percent of China's exports which normally has a very low value added, thanks to China's preferential tax policy towards imported intermediate inputs and lower labor costs.[1] Such characteristics of China's export and import structure must be taken into account when analyzing the EER of the RMB.

While most of the existing studies seldom focus on the supply side real factors, Yoshikawa (1990) develops a model of the nominal EER of the yen vis-à-vis the US dollar by taking into account labor and intermediate input coefficients for production. Given the growing intra-regional trade and production network in Asia, we advance the Yoshikawa (1990) model by estimating the nominal EER of the RMB vis-à-vis the US dollar using the industry and source country breakdown data on imports of intermediate inputs for production.

The novelties of this study are three-fold. First, in marked contrast to the recent

[1] Chinn and Wei (2008) also demonstrate that the share of foreign contents in China's exports is around 50 percent.

studies on EER that emphasizes the trade/current account balance and/or net foreign assets, we focus on China's production structure and its export competitiveness as the main determinant of EER. Second, we construct a new trade dataset based on the International Input-Output (IIO) framework by making maximum use of the United Nations Commodity Trade Statistics Database (UN Comtrade database). Specifically, we make an external transaction part of the IIO table for China and the United States annually from 1992 to 2008. By using the IIO table, we distinguish between imports of intermediate goods and those of finished/capital goods, and compute the source country breakdown data of intermediate import prices. Input coefficients of intermediate inputs are also calculated under the IIO framework. Taking into account China's procurements of intermediate inputs from overseas and the technological upgrading of its production, our empirical strategy of utilizing the IIO data will provide new insights on the EER of the RMB. Third, it has been a long debate concerning the reliability and measurement problem of China's domestic price data such as CPI,[2] a result of which would be an inaccurate calculation of the real exchange rate. In this study we estimate the nominal EER of the RMB vis-à-vis the US dollar in contrast to the existing studies which typically estimate the real (effective) EER of the RMB. To avoid such measurement issue of domestic prices, we use the trade data obtained from the UN Comtrade database to calculate the export and import price (unit value) of each commodity.

The rest of the paper is structured as follows. Section 2 overviews of the actual RMB exchange rate and the recent empirical studies on the EER of RMB. Section 3 discusses the analytical framework of the EER. The estimated EER of the RMB is presented and the underlying factors determining equilibrium level of RMB exchange rate are discussed in Section 4. Finally, Section 5 concludes.

[2] The measurement issue of the China's domestic price level is often pointed out in the literature on EER, such as Cline and Williamson (2007) and Wong, Hui and Soofi (2007). See also Heston (2001).

2. Overview of the RMB Exchange Rate and Existing Literature

Purchasing power parity theory (PPP) is arguably the most popular approach to measure the long-run equilibrium exchange rate. However, the "simple" PPP approach is not in practice considered appropriate in analyzing an equilibrium level of the exchange rate. Figure 1 shows the annual series of the nominal exchange rate (NER) of the RMB vis-à-vis the US dollar and the PPP exchange rate that is calculated by dividing the Chinese CPI by the US CPI from 1990 to 2009. It is noteworthy that, if the year 2000 is chosen as a base year, the PPP exchange rate follows closely the movement of the nominal exchange rate over the sample period, especially before 2007. Although the nominal RMB exchange rate exhibits an appreciation vis-à-vis the US dollar from 2005 to 2009, the PPP rate shows a slight trend of depreciation during the same period. Based on the PPP, one may interpret the result as that the exchange value of the RMB was undervalued, but only slightly, during period in 2000-2007 and became overvalued only since then.[3] However, as shown in Figure 2, China started to experience a rapid increase in its current account surplus only from the mid-2000s. There is therefore a diverse relation between the change of the exchange rate and China's current account balance. This raises an interesting question if the RMB exchange rate is the main cause to the current account imbalance and whether the RMB is overvalued or undervalued.

Figure 1. The Nominal Exchange Rate of the RMB vis-à-vis the US Dollar and the PPP Exchange Rate (2000=100).

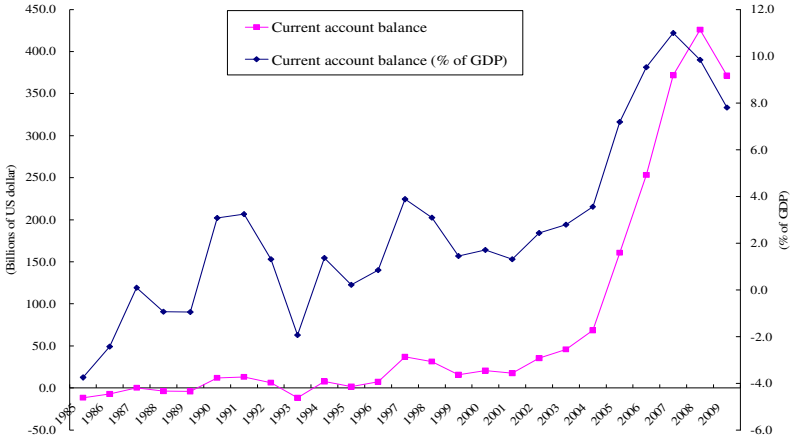
Note: All data are annual and the index number the base year of which is 2000.

[3] This interpretation is based on the assumption that the year 2000 is the base year. If choosing the different base year, we will have different interpretation.

NER denotes the nominal exchange rate of the RMB vis-à-vis the US dollar, and the PPP rate the ratio of the China's CPI to the US CPI.

Source: Authors' calculation based on the data taken from the IMF, *International Financial Statistics*, CD-ROM.

Figure 2. China's Current Account Balance (billion of US dollars)



Source: IMF, *International Financial Statistics*, CD-ROM.

In recent years there are a number of studies assessing the equilibrium level of the RMB exchange rate by employing the following three approaches, namely: (1) PPP enhanced by the Balassa-Samuleson effect (henceforth, "enhanced PPP"); (2) the behavioral equilibrium exchange rate (BEER); and (3) the fundamental equilibrium exchange rate (FEER) or the macroeconomic balance (MB) approach.[4] Table 1 summarizes their major findings. Interestingly, most of the studies report an average undervaluation of 21% to 45% for the Chinese currency measured in the real exchange rate and even higher if measured bilaterally.

Coudert and Couharde (2005) analyze the equilibrium level of the RMB real exchange rate vis-à-vis the US dollar by using the above three approaches and find large RMB undervaluation in all three cases ranging from 18 to 50 percent. In contrast, by using the enhanced PPP approach, Cheung, Chinn and Fujii (2007) conduct panel estimation on the relationship between the real exchange rate and the relative per capita

[4] Cline and Williamson (2007) consider these three as the main measurement approaches to EER. See also Isard (2007) who summarizes the six methodologies for an assessment of EER. Driver and Westaway (2004) classified the previous studies in terms of the relevant time horizon, such as short-run, medium-run and long-run.

GDP with a large data set covering up to 160 countries over the 1975-2004 period, and find little statistical evidence on the RMB undervaluation. The mixed results can also be observed in the studies based on the BEER, which is typically specified as a function of the macroeconomic fundamentals, such as (relative) productivity, net foreign assets, openness index.[5] Wong, Hui and Soofi (2007) argue that the degree of deviation between the actual real effective exchange rate of the RMB and the estimated BEER is rather small over the period of 1980-2004, which contradicts the finding of Coudert and Couharde (2005) that the RMB real exchange rate is undervalued by almost 18 percent as of 2002.

Table 1. Summary of the Previous Studies on the EER of Chinese RMB

	Approach	Estimated Year	Estimated Undervaluation	
			Effective ER	Bilateral ER vs USD
Coudert and Couharde (2005)	FEER	2003	23%	44%
	E-PPP	2003		43-50%
	BEER	2002		17.80%
Bénassy-Quéré, Lahrèche-Révil and Mignon (2006)	BEER	2004	31-45%	30-59%
Yajie, Xiaofeng and Soofi (2007)	BEER	1980-2004	REER fluctuates around its long-run equilibrium rate within a narrow band.	
Cheung, Chinn, and Fujii (2007)	E-PPP	2004	There is little statistical evidence that the RER is undervalued.	
Cline and Williamson (2009)	FEER	March 2009	21.4%	40.2%

Note: E-PPP denotes the enhanced PPP; ER exchange rate; RER real exchange rate; and REER real effective exchange rate.

The FEER or MB approach is probably the most widely used approach in the literature on EER.[6] The FEER is considered as the exchange rate that achieves internal and external balances simultaneously in every country.[7] Existing studies typically

[5] The BEER is not based on any specific model of the exchange rate determination but considered as a general approach to modeling the EER. For a good survey of the BEER approach, see MacDonald (2007) and Cline and Williamson (2007).

[6] See also IMF (2006) and Lee, et al. (2008) for the details of the CGER (Consultative Group on Exchange Rate Issues).

[7] An appreciation of the RMB, however, will not always lead to the adjustments of China's current account surplus. For example, Chinn and Wei (2008) find no robust evidence that the speed of current account adjustment increases with the degree of flexibility of an exchange rate regime by

employ the normative current account balance that is obtained by panel estimation using a set of macroeconomic fundamentals. Recent studies, such as Cline and Williamson (2009), present the estimates of large RMB undervaluation against the US dollar by about 40 percent, which is consistent with Coudert and Couharde (2005). Although the empirical studies based on FEER tend to find the RMB undervaluation,[8] it is still arguable how to set up a normative level of external balance.[9]

Hence, the current studies suggest that there is neither a strong consensus over the methodology for estimating~~used to estimate~~ the EER nor the results affirming whether the RMB is overvalued or undervalued. However, most of the existing studies employ a large cross-country analysis which tends to mask country-specific factors in determining the EER. Moreover, the supply side real factor is missing ~~from~~in these studies. Given that the intra-Asian trade has been accelerating in the recent years and China has emerged to be the largest exporting country with rapid increasing in its trade surplus especially against the United States, the impact of the supply-side real factor on the equilibrium exchange rate of the RMB should not be ignored. As discussed by Koopman, Wang and Wei (2008), China has now been well integrated into a global production chain and more than 50 percent of China's exports are processing exports with active imports/procurements of intermediate input goods. Such characteristics of the China's export and import structure need to be considered when assessing the EER of the RMB.

A notable exception in the literature on EER is Yoshikawa (1990) who develops a model for nominal EER determination with labor and intermediate input coefficients in the production function and estimates the EER of the Japanese yen vis-à-vis the US dollar from 1973 to 1987.[10] Here PPP is assumed to hold in the tradable goods sector, so the EER is determined when the export price competitiveness between the home and foreign countries is held constant. We extend the Yoshikawa (1990) model to better reflect the rapid upgrading of the China's export competitiveness.

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using a large data set spanning 170 countries over the 1971–2005 period.

[8] For further details, see Table 1 in Cline and Williamson (2007).

[9] Isard (2007) also suggests that the FEER or MB approach is based on an accounting framework that imposes an identity between the current account and either the capital account or the IS balance. Accordingly, MB or FEER approach may not be very helpful for countries that have bright prospects for economic growth and are attracting large volumes of capital inflows like China.

[10] de Carvalho (2002) also analyze the EER of the yen from 1976 to 1991 by emphasizing the supply side real factors with an assumption of PPP for traded goods. Dekle and Fukao (2009) find that while the yen was undervalued before 1985, it was significantly overvalued after 1985, and especially since 1995.

3. Analytical Framework

3.1 Basic Model of the Equilibrium Exchange Rate

This section elaborates the basic model of the long-run nominal EER, which is developed by Yoshikawa (1990), by emphasizing the supply-side real factors. In contrast to the previous studies where only labor and natural resources are used for production,[11] we assume that the tradable goods sector uses imported intermediate inputs for production and sells its products to foreign customers. This assumption appears to be reasonable in the context of growing intra-regional trade in Asia, where intermediate inputs, such as parts and components, are actively traded for processing exports. A fixed-coefficient production function is assumed in our model where labor and intermediate inputs are used to produce one unit of the tradable good. Under the assumption of perfect competition, we have the following condition for the home country (China):

$$wa + p_M b = p_{EX}\,, \qquad (1)$$

where p_{EX} and p_M denote the home currency (RMB) prices of export products and intermediate inputs, respectively; w the nominal wage rate; and a and b the input coefficient of labor and intermediate inputs, respectively.[12] Similarly, we can derive the following condition for the foreign country (the United States):

$$w^* a^* + p_M^* b^* = p_{EX}^*\,, \qquad (2)$$

where a single asterisk (*) denotes a foreign (US) variable that is in terms of the foreign currency (US dollar).

The basic assumption of our EER model is that PPP holds in the long-run in the tradable goods sector:[13]

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[11] Yoshikawa (1990, 1995) and Miyagawa, Toya and Makino (2004) allow for only labor and natural resources as a factor of production.

[12] Zero profits are assumed in equation (1). Yoshikawa (1990, 1995) discusses the case of allowing for a normal rate of profit, which will not affect an analysis of this paper as long as the normal rate of profit is constant.

[13] There are a large number of studies that empirically show that the law of one price and PPP does not hold in manufacturing exports (see *inter alia* Knetter (1989, 1993), Marston (1990), Takagi and Yoshida (2001), and Parsons and Sato (2008) for an analysis of the pricing-to-market (PTM)

$$p_{EX} = sp_{EX}^{*}, \qquad (3)$$

where s denotes the bilateral nominal exchange rate of the RMB vis-à-vis the US dollar.[14]

Since $p_{EX} = sp_{EX}^{\$}$ and $p_M = sp_M^{\$}$ where $p_{EX}^{\$}$ and $p_M^{\$}$ denote respectively the US dollar price of China's exports and imports, we can rewrite Equation (1) as:

$$wa + bsp_M^{\$} = sp_{EX}^{\$}. \qquad (4)$$

By rearranging equation (4), we obtain:

$$s = \frac{wa}{p_{EX}^{\$}(1 - b\tau)}, \qquad (5)$$

where $\tau = p_M^{\$} / p_{EX}^{\$}$ can be considered as the inverse of the terms of trade for China. By using equations (2), (3) and (5), we obtain:

$$EER = s = \left(\frac{w}{w^*}\right)\frac{a/(1 - b\tau)}{a^* + b^*\left(p_M^* / w^*\right)}. \qquad (6)$$

The above condition, which is identical to Yoshikawa's (1990) long-run EER formula, indicates that the EER is conditional on the three factors: the relative nominal wage level that may capture the simple PPP effect; the terms of trade, i.e., the relative price of home country's imports of intermediate inputs to its export prices in the foreign currency (US dollar) terms ($\tau = p_M^{\$} / p_{EX}^{\$}$); and the technological parameters (labor and intermediate input coefficients).

behavior of exporting firms). Although Yoshikawa (1990) allows for the deviation from PPP in the short-run, the derived formula of EER is the same as ours because PPP is assumed to hold in the long-run in his model.

[14] As shown in Koopman, Wang and Wei (2008), processing exports account for more than 50 percent of China's exports and there are fast growing similarities between the China's export structure and that of developed countries. Accordingly, the above assumption of the PPP in the tradable goods sector appears to be reasonable in the context of China's rapid development.

3.2 Extension of the Model: Industry and Source Country Breakdown

The basic model of the nominal EER differs markedly from the recent EER model discussed in Section 2. First, unlike the FEER or MB approach, our model does not assume a normative level of the trade/current account balance. Second, we focus on China's production structure and its export competitiveness by incorporating the technological parameters (labor and intermediate input coefficients) into the model. To better reflect China's processing exports, we then extend the model into a multi-sourcing country and multi-industry model to incorporate the effect of China's imports of intermediate inputs from various source countries on the EER. Thus, we rewrite Equation (6) as follows:

$$EER = \frac{\dfrac{\sum_{i=1}^{m} \sigma_i w_i a_i}{1 - \sum_{i=1}^{m} \sum_{j=1}^{n} \sigma_i \delta_j \left(b_{ij} p_{Mij}^{\$} / p_{EXi}^{\$} \right)}}{\sum_{i=1}^{m^*} \sigma_i^* w_i^* a_i^* + \sum_{i=1}^{m^*} \sum_{k=1}^{n^*} \sigma_i^* \delta_k^* b_{ik}^* p_{Mik}^*}, \qquad (7)$$

where subscript i, j, and k identify each sector, home country's (China's) trading partner and foreign country's (US) trading partner, respectively. σ and δ denote the weight of each sector and that of each trading partner, respectively. The details of variables and parameters are explained in Appendix.

4. Empirical Analysis

4.1 Estimation Strategy and Data

Based on equation (7), we estimate the nominal EER of the RMB vis-à-vis the US dollar. Although we use a two-country framework where PPP holds for the export products in the long-run between the two countries, China and the United States are assumed to procure intermediate inputs from different source countries.[15] To better reflect such import/procurement structure of intermediate inputs, we construct a new data set, i.e., an external transaction part of the IIO table for China and the United States

[15] Miyagawa, Toya and Makino(2004) also apply the Yoshikawa (1990) approach to several Asian currencies. In their analysis, only natural resources are regarded as intermediate inputs and various source countries are not taken into consideration.

every year from 1992 to 200~~8~~9 by using the UN Comtrade database. A notable advantage of using the IIO table is that we can distinguish between intermediate inputs and finished goods in both domestic and external transactions. Although the domestic transaction part of the IIO table has not yet been constructed, we compute the source country breakdown data on intermediate imports and the input coefficients based on the external transaction parts of the IIO table.

For both China and the United States, we first collect 3,121 categories of export and import commodities at a 4- or 5-digit SITC3 level obtained from the UN Comtrade database, and then select the intermediate input goods from the 3,121 SITC3 commodities by matching the SITC3 code with the BEC (Broad Economic Categories) code. The selected SITC3 intermediate input goods (1,933 commodities) are then converted into the 4-digit ISIC3 level with 145 categories, and finally classified into 22 sectors in the IIO classification. We make this data conversion and classification for each source country and for every year from 1992 to 200~~8~~9. There are in total 21 source countries for China and 18 countries for the United States.[16] In the above data conversion/classification process, the unit value of each SITC3 commodity is calculated and the weighted average of these unit values is finally computed for the export and import prices of 22 IIO sectors. In addition, our IIO table enables us to compute the intermediate input coefficients by sector and by source country. The details of the data conversion/classification and the calculation of intermediate input coefficients are presented in Appendix.

Another point worth mentioning is the data on wage and labor input coefficient. Since the industry breakdown wage data is not available for China, we use the wage of the total manufacturing industry for both China and the United States to estimate the EER. The labor input coefficient is computed for each IIO sector of both countries.

Thus, the nominal EER of the RMB vis-à-vis the US dollar is estimated by the following equation:

$$EER_{RMB/\$} = \frac{w\sum_{i=1}^{22}\sigma_i a_i \Big/ \left\{1-\sum_{i=1}^{22}\sum_{j=1}^{21}\sigma_i\delta_j\left(b_{ij}p_{Mij}^{\$}/p_{EXi}^{\$}\right)\right\}}{w^*\sum_{i=1}^{22}\sigma_i^* a_i^* + \sum_{i=1}^{22}\sum_{k=1}^{18}\sigma_i^*\delta_k^* b_{ik}^* p_{Mik}^*}. \qquad (8)$$

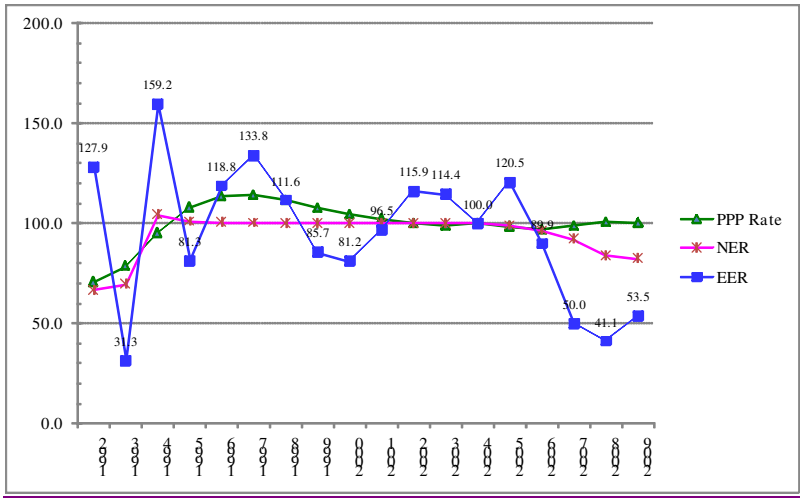
Further explanation on our estimated IIO table as well as the details of variables and parameters is presented in Appendix.

[16] These source countries account for one percent or more in the total imports of China and the United States, respectively, as of 2005.

4.2 Results of EER Estimation

The estimated EER of the RMB vis-à-vis the US dollar is shown in Figure 3, where the year 200~~0~~4 is chosen as the base year.[17] For comparison purpose, both the nominal exchange rate (NER) of the RMB vis-à-vis the US dollar and the PPP rate based on CPI are also reported in Figure 3.[18] It is interesting to note that there is a striking difference between the estimated EER, the actual NER and the PPP rate.

Figure 3. Nominal Equilibrium Exchange Rate (EER) of the Chinese Renminbi (RMB) vis-à-vis the US Dollar: 1992-2009~~8~~



Note: All data are annual and the index number the base year of which is 200~~0~~4. EER denotes the equilibrium exchange rate; NER the nominal exchange rate of the RMB vis-à-vis the US dollar; and the PPP rate the relative price of the China's CPI to the US CPI.

Sources: Authors' estimation and IMF, *International Financial Statistics*, CD-ROM.

First, the estimated EER of the RMB shows ~~a~~ large fluctuations ~~but clear downward (appreciation) trend~~ from 1992 to early 2000s. Such a large fluctuation may be attributed to the smaller volume of China's external trade transactions during that period. To estimate the EER, we calculate the import unit values by sector and by source

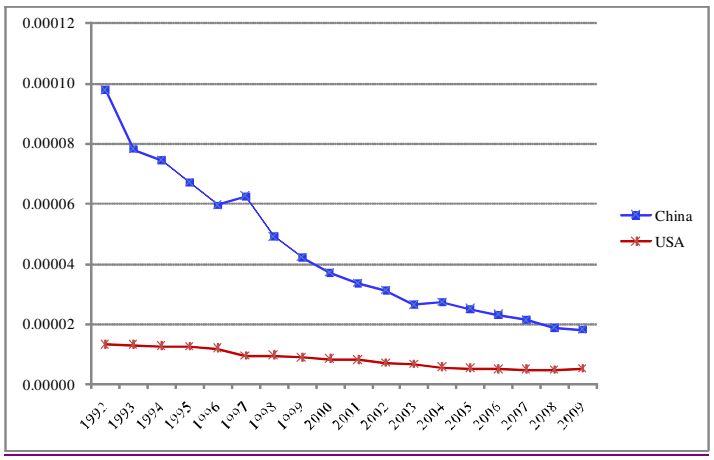
[17] The interpretation of the estimated EER is subject to the choice of the base year. We choose the 200~~0~~4 base year, because China's current account started to increase sharply after 2004~~was relatively balanced from 1999 to 2001~~ as shown in Figure 2, although we do not impose any restrictions on the current account balance in the model.

[18] Like Figure 1, the PPP rate is defined as the relative price of the China's CPI to the US CPI.

country. The calculated unit value series tend to show either extremely large or small number if the volume of imports is small. As the volume of China's trade increased from around 2000, the estimated EER became less volatile and started to exhibit a ~~much~~ smoother line in Figure 3.

Second, the estimated EER started to appreciate sharply from 2005 to 2008 after a relatively stable period in the first half of 2000s~~from 2000 through 2005~~ within a narrow range from 81.2~~100~~ to 120.5~~1~~. More noteworthy is the sharp appreciation of the EER since 2005, which corresponds closely to the rapid increase in China's current account surplus shown in Figure 2 and the move toward a more flexible exchange rate regime in China.[19] Although the NER of the RMB vis-à-vis the US dollar started to appreciate from 2005, the degree of the NER appreciation is far smaller than what our estimated EER suggests. The EER in Figure 3 implies that the RMB needs to be revalued around by about 59~~65~~ percent in 2008 and by about 46 percent in 2009 from the 2004~~0~~ year level; otherwise, China's export sector would continue enjoying the excessive export price competitiveness against the US counterpart.

Figure 4. Labor Input Coefficient (Weighted Average): 1992-2009~~8~~



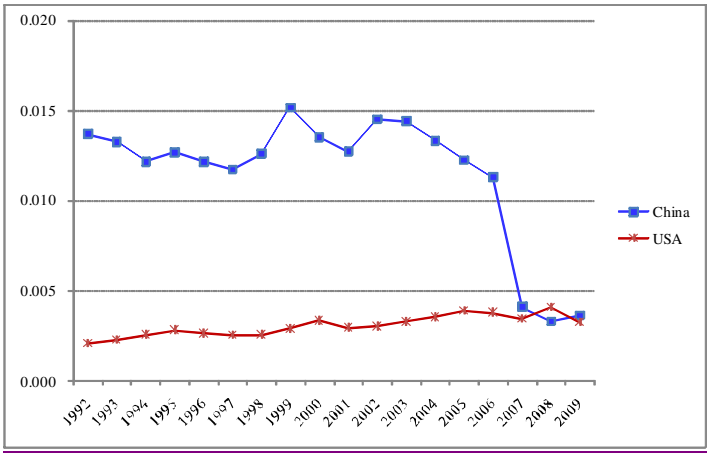
Source: Authors' calculation.

To make further investigation of the factors in driving down (appreciating) the EER of the RMB, we compute the average input coefficients for labor and intermediate inputs. The weighted average labor input coefficients for China ($\sum_{i=1}^{22} \sigma_i a_i$) and for the

[19] This is a surprising correspondence because, in contrast to the FEER or MB approach, our estimated EER is not conditional on any level of trade/current account balances.

United States ($\sum_{i=1}^{22} \sigma_i^* a_i^*$) are shown in Figure 4. It is noted that the Chinese labor input coefficient declines to a far larger extent than that of the US counterpart from 1992 to 2009~~8~~, which indicates the continuous improvement of labor productivity in China. Although the wage level has increased considerably in China in the recent years,[20] the steady and substantial decline of the labor input coefficient is found to be responsible for the appreciation of the EER of the RMB.

Figure 5. Intermediate Input Coefficient (Weighted Average): 1992-2009~~8~~



Source: Authors' calculation.

The difference of intermediate input coefficients between China and the United States is more interesting. Figure 5 shows the weighted average intermediate input coefficient for China ($\sum_{i=1}^{22} \sum_{j=1}^{21} \sigma_i \delta_j b_{ij}$) and for the United States ($\sum_{i=1}^{22} \sum_{k=1}^{18} \sigma_i^* \delta_k^* b_{ik}^*$). While ~~From around 2000, China's intermediate input coefficient~~increased only slightly from 1992 to 2002, China's intermediate input coefficient has started to decline gradually since then and fell sharply from 2006. The level of the China's intermediate input coefficient reached almost the same level as the US counterpart in 2007-2009. ~~shows similar movements to the estimated EER in Figure 3. The intermediate input coefficient started to decline gradually from around 2003 and fell sharply from 2006 to 2008.~~ This result suggests that the Chinese exporting sectors have experienced a

[20] China's average manufacturing wage rose by 818 percent over the period of 1992 through 2008. The wage data is taken from the CEIC database.

significant improvement in productivity and, hence, enhanced rapidly the export price competitiveness. In contrast, the US intermediate input coefficient increased gradually over the sample period, which shows the relative deterioration~~ shows an upward trend during the same period, which indicates the deterioration~~ of productivity in the US export sectors.

The result of our EER estimation of the RMB has several important implications. First, the rapid appreciation of our EER estimation can be ascribed to the significant productivity improvement of China's export sectors. This result may imply that the revaluation of the RMB exchange rate toward the EER level will be conducive to the adjustment of current account imbalance between China and the United States. Second, the labor input coefficient improved greatly in China over the sample period. Based on the Balassa-Samuelson hypothesis, the improvement of labor input coefficient and, hence, of the productivity of the tradable goods sector in China would drive up the relative price of the non-tradable to the tradable goods. However, the ratio of China's CPI to the US one does not show clearly an increasing trend from around the mid-1990s (Figure 1). This finding may imply that there exists a measurement problem for China's domestic prices, and hence real exchange rate of RMB based on CPI needs to be carefully interpreted.

5. Concluding Remarks

Most of the existing studies on the EER of the RMB typically employ a large cross-country analysis to estimate the EER of the RMB and fail to take into consideration the supply side real factors such as the China's productivity improvement and the procurement structure of intermediate inputs. By constructing an IIO table for China and the United States for every year from 1992 to 200~~8~~9, we have estimated the nominal EER of the RMB vis-à-vis the US dollar and generated some promising results. It is found that the EER of Chinese RMB has appreciated sharply from 2006~~5~~ to 2009~~8~~, suggesting that the current RMB exchange rate is substantially undervalued and should be revalued by about ~~65~~46 percent in 2009 from the year 2004~~0~~ level. Such sharp appreciation of the EER corresponds to the dramatic increase in China's current account surplus from around 2004~~the mid 2000s~~, especially against the United States, and is associated with the significant improvement of both labor and intermediate input coefficients in China. This finding associated with our empirical strategy of utilizing the IIO data will provide new insights on the current debate about the EER of the RMB.

Our analysis can be further extended in the following way. First, we use a simple model and focuses on the external transactions in this study. Domestic transactions, such as the procurements of intermediate inputs from domestic producers, are not incorporated in our analysis, because we have not yet constructed the domestic transaction part of the IIO table. To estimate and construct the complete IIO table for each year will significantly broaden the scope of our research. Second, we need to estimate the EER of other Asian currencies vis-à-vis the US dollar. We will then be able to test whether the EERs for the East Asian countries share a long-run relationship between the regional countries by employing time series technique, which is believed to make a new contribution to the literature on the regional monetary arrangements. Moreover, once the bilateral EER vis-à-vis each of the other major trading partners' currencies is calculated, we will then be able to calculate the effective EER. These are left for our future research.

Appendix: Data Description for Empirical Estimation

A1. Construction of IIO Data Set

To estimate the EER of the RMB, we use the industry and source country breakdown data on import prices and input coefficients of intermediate inputs. The trade data obtained from the United Nations Commodity Trade Statistics Database (UN Comtrade database) is based on the Standard International Trade Classification, Revision 3 (SITC3) and contains 3,121 commodity categories from 1992 to 2009~~8~~.[21] Our objective is to convert the SITC3 trade data into the IIO classified trade data for 31 sectors (Table A1).[22] Since the service trade data is not available from the UN Comtrade database, we choose 22 manufacturing sectors of our IIO classification for the data conversion. The details of the data conversion process are as follows.

First, we collect the SITC3 data on imports for China and the United States. We assume that as a major source country, it has to account for 1 percent or more in the total imports of China and the United States as of 2005. Then, 21 and 18 countries are chosen accordingly as the major import partners for China and the United States, respectively (Table A2).[23]

Second, the SITC3 data needs to be converted into the industrial classification data compatible with the IIO table that distinguishes between intermediate inputs and final goods to allow for the effect of industrial production on the EER. For this conversion, we follow the data code concordance rule provided by the United Nations[24] which relates the SITC3 code to the BEC (Board Economic Categories) code and also to the ISIC3 (International Standard Industrial Classification, Revision 3) code. Matching the SITC3 code with the BEC code enables us to classify the SITC3 commodity data into the three categories: intermediate inputs, final consumption goods

[21] The final trade data set have been adjusted for re-export (export of foreign goods) and re-import (import of domestic goods). See http://comtrade.un.org/kb/Article.aspx?id=10152 for the details.

[22] This IIO classification is compatible with the IDE IIO and OECD IO classification in terms of the sectoral aggregation.

[23] It is important to mention that UN does not provide Taiwanese data. However, the trade with 'Other Asia, nes' in UN Comtrade can be considered as the Taiwan data. See the web site of UN Comtrade (http://comtrade.un.org/kb/Article.aspx?id=10043) for the UN's explanation on the Taiwanese trade data.

[24] UN web pages, http://unstats.un.org/unsd/cr/registry/regdnld.asp?Lg=1 and http://unstats.un.org/unsd/cr/registry/regsale.asp?Lg=1, provide the code conversion rules from SITC3 to BEC and from SITC3 to ISIC3, respectively.

and capital goods.[25] Finally, we obtain 1,933 SITC3 commodities as intermediate inputs that are converted into the ISIC data.

Table A1. IIO Classification

IIO Code	Description
I_01	Agriculture, hunting, forestry and fishing
I_02	Mining and quarrying (energy)
I_03	Mining and quarrying (non-energy)
I_04	Food products, beverages and tobacco
I_05	Textiles, textile products, leather and footwear
I_06	Wood and products of wood and cork
I_07	Pulp, paper, paper products, printing and publishing
I_08	Chemicals Products
I_09	Coke, refined petroleum products and nuclear fuel
I_10	Rubber and plastics products
I_11	Other non-metallic mineral products
I_12	Iron & steel
I_13	Non-ferrous metals
I_14	Metal Products
I_15	Machinery and equipment
I_16	Electronics and electronic products
I_17	Other Electrical machinery and apparatus
I_18	Precision machines
I_19	Motor Vehicles
I_20	Other transport equipment
I_21	Shipbuilding
I_22	Other manufacturing products
I_23	Electricity, gas and water supply
I_24	Construction
I_25	Wholesale and retail trade
I_26	Transportation
I_27	Post and telecommunications
I_28	Finance and insurance
I_29	Education and research
I_30	Other services
I_31	Public administration and unclassified

Third, the SITC3 intermediate input goods are classified into 145 categories of ISIC3 following the UN rule of concordance between SITC3 and ISIC3. Since both ISIC3 and IIO data are based on the industrial classification, we can easily convert the 145 ISIC3 intermediate inputs data into the 22 IIO classification.[26] Thus, the IIO sector breakdown data is constructed for 21 trading partner countries for China and for 18 countries for the United States. The conversion process is summarized in Figure A1.

[25] See http://comtrade.un.org/kb/Article.aspx?id=10180 for the details on BEC code and the type of goods.

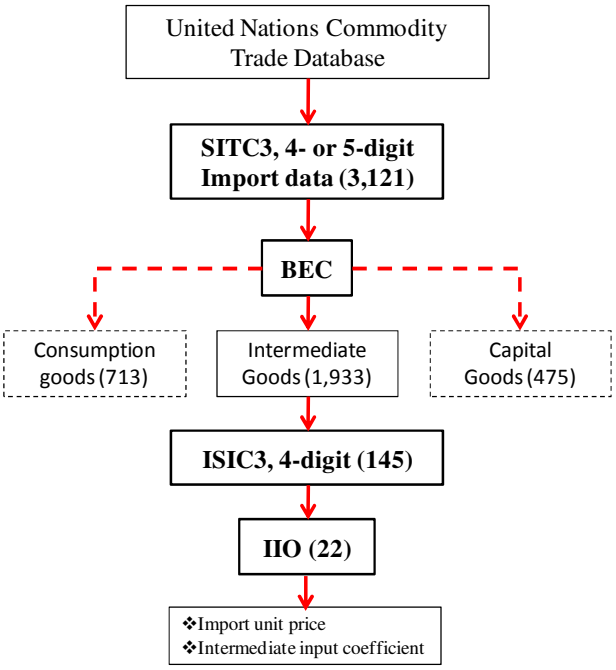
[26] Among the 24 sectors of the IIO classification (I_01 through I_22, I_30 and I_31 in Table A1), unspecified items are included in the two sectors, I_30 and I_31. We finally use the 22 IIO sectors for data conversion.

Table A2. Major Partner Countries: China's and US Imports

Rank	Import partner: (China)	Import partner: (USA)
1	Japan (16.6%)	Canada (16.8%)
2	Korea (12.7%)	China (15.0%)
3	Taiwan (12.3%)	Mexico (10%)
4	USA (8.1%)	Japan (8.2%)
5	Germany (5.1%)	Germany (5.0%)
6	Malaysia (3.3%)	UK (3%)
7	Singapore (2.7%)	Korea (2.6%)
8	Australia (2.7%)	Taiwan (2.1%)
9	Russia (2.6%)	Venezuela (2.0%)
10	Thailand (2.3%)	France (2.0%)
11	Philippines (2.1%)	Malaysia (2.0%)
12	Saudi Arabia (2.0%)	Italy (1.9%)
13	Hong Kong (2.0%)	Saudi Arabia (1.7%)
14	Brazil (1.7%)	Ireland (1.7%)
15	India (1.6%)	Brazil (1.5%)
16	France (1.5%)	Nigeria (1.4%)
17	Indonesia (1.4%)	Thailand (1.2%)
18	Canada (1.2%)	India (1.1%)
19	Italy (1.1%)	
20	Iran (1.1%)	
21	Angola (1.1%)	

Source: UN Comtrade Database and the authors' calculation.

Figure A1. Data Conversion from SITC3 to IIO



A2. Description of the Variables

The following variables are calculated from the above IIO data set for China and the United States.

Intermediate input coefficient, b:

Intermediate input coefficient is defined as the ratio of imported intermediate goods to the total export. In other words, it is a value of the imported intermediate goods necessary to produce a unit dollar worth export goods. The intermediate input coefficients have a dimension of 22 industries and 21 trading partners for imports of China and 18 trading partners for imports of the United States.

Export unit price, p_{EX}, and import unit price, p_M:

Export unit price is expressed as the ratio of export value to export quantity. The export unit price for each IIO sector is calculated as a weighted average of the export price of corresponding SITC3 commodities, where the weight is computed in terms of the total export amount of each commodity. Calculation of the import unit price is the same as that of the export unit price.

Industry weight, σ, and import partner (source) country weight, δ:

Industry weight is defined as the ratio of a particular industry trade to the total trade. The import partner (source) country share in imports of each intermediate good is calculated by dividing the amount of imported intermediate goods from the partner country by the corresponding amount of import from the world.

The following variables are obtained from other data sources.

Labor input coefficient, a:

Labor input coefficient is defined as the ratio of the number of employees multiplied by the price level (CPI) to the nominal GDP~~amount of exports~~, a proxy for the total output~~, corresponding to each industry~~. In other words, labor input coefficient refers to the labor input necessary to produce one ~~dollar~~ unit of output~~export~~. The data on the number of employees for the manufacturing industries (ISIC3 classification) is obtained from the UNIDO Industry Database. For other industries, the employment data is taken from the Institute of Developing Economy's (IDE's) Asian International

Input-Output (AIO) table. Nominal GDP and CPI are obtained from the CEIC Database and IMF, *International Financial Statistics*, CD-ROM.

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Wage rate, *w*:

Wage rate is defined as the average manufacturing wage rate. These data for China and the United States are obtained from the CEIC Database and IMF, *International Financial Statistics*, CD-ROM, respectively.

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