# RMB UNDERVALUATION AND APPRECIATION

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## ABSTRACT

*The bilateral real exchange rate between Chinese renminbi (RMB) and the US dollar is studied. The panel Penn effect model shows that the RMB was undervalued after 1994 when China reformed its exchange rate system. It was undervalued by 64% in 2013. RMB was undervalued not only relative to the US dollar, but also relative to the currencies of all other developing and emerging countries. An examination of the appreciation of 17 currencies of the countries and areas that experienced the Penn effect shows that the RMB should appreciate at an annual speed of 3.4%. At this rate, the RMB misalignment in 2013 will be reduced by half by 2020. In the future, if the interests of both China and the US are considered, RMB appreciation should be realized totally from the nominal exchange rate, not partly from the nominal exchange rate and partly from the relative price level as it did in the past.*

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**Keywords:** Chinese renminbi, The US dollar, Real exchange rate, Penn effect, Undervaluation, Appreciation.

**JEL Classification:** F31; F41.

## Contribution/ Originality

This study contributes in the existing literature on how RMB appreciation meets the interests of both China and the US. This study is one of very few studies which analyze the speed and path of RMB appreciation.

## 1. INTRODUCTION

Since 2003, whether Chinese currency, the renminbi (RMB), is undervalued and should be appreciated has been a continuing topic of debate in both political and academic circles between the US and China. On the cover of his book, Evenett (2010) cites famous persons' opinions as below.

Timothy E. Geithner says on 21 January 2009, "President Obama—backed by the conclusions of a broad range of economists—believes that China is manipulating its currency." Paul Krugman says on 14 March 2010, "China's policy of keeping its currency, the renminbi, undervalued has become a significant drag on global economic recovery. Something must be done." Karel De Gucht, Europe's new trade commissioner, says on 23 March 2010, "I'm of the opinion that yuan is underpriced and that it should be revalued. It certainly has an impact on their exports and trade patterns. The complaint is legitimate." However, China invariably insists that the RMB is not undervalued.[1] Cline (2010) says (p. 3), "An undervalued renminbi is widely considered to have contributed to large Chinese current account surpluses in recent years and, correspondingly, to large US current account deficits"; and (p. 6), "Decisions on China's exchange rate policy thus do matter for the objective of reducing international imbalances, rather than being irrelevant because of supposed structural peculiarities that cause the exchange rate to have no impact on either China's global trade or its bilateral trade with the United States." However, other economists argue that forcing China to appreciate its currency will not solve US problems, nor will it be constructive to world economic recovery.[2]

In terms of the undervaluation of the RMB, various models are used; the three main ones are as below: the Balassa-Samuelson (BS) regression or the Penn effect model, the behavioral equilibrium exchange rate (BEER) model, and the fundamental equilibrium exchange rate (FEER) model. Chang and Shao (2004) use the BS regression and conclude that the RMB was undervalued in 1987–2003 and undervalued by 22.5% in 2003. Frankel (2006) also using the BS regression, concludes that the RMB was undervalued by about 35% in 1990 and 2000. Coudert and Couharde (2007) use the FEER model and conclude that the RMB real effective exchange rate was undervalued by about 30% and the bilateral real exchange rate between China and the US was undervalued by about 55% in 2003. Wang et al. (2007) use the BEER model and conclude that RMB fluctuated around its long-run equilibrium rate within a narrow band in 1980–2004, suggesting that the misalignment of RMB was rather small. Cline and Williamson (2009) use the FEER model and conclude that the RMB real effective exchange rate was undervalued by 21.4% and the bilateral real exchange rate between China and the US was undervalued by 40.2% in March 2009. Garroway et al. (2012) use the BS regression and conclude that the RMB was undervalued by about 15% in 2008. In terms of the RMB appreciation that is obviously less studied compared with the RMB valuation, Frankel (2006) suggests that the RMB real appreciation can be better achieved through nominal appreciation than through inflation. Xu (2009) examined some economies that have experienced real currency appreciation against the US dollar in 1985–2005, and finds that the mode of faster wage growth and inflation is as common as nominal appreciation,

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[1] Jiabao Wen (the former prime minister of China): The renminbi is not undervalued. (In Chinese) Available at: http://money.163.com/10/0314/10/61NRAQDM002547T3.html. Accessed on December 20, 2014.

[2] Forcing yuan appreciation benefits nobody. Available at: http://www.chinadaily.com.cn/business/2011-10/10/content_13862934.htm. Accessed on December 20, 2014.

and asserts that the real appreciation of RMB will contribute to restructuring China's economy toward a domestic demand-based growth track. Tyers and Zhang (2011) discuss the reasons for RMB appreciation and offer two scenarios for its short-term unilateral appreciation. This paper discusses the RMB RER's undervaluation and appreciation to add a new understanding as below. (1) Popular papers as listed above only calculate the RMB misalignment (over- or undervaluation) in some years. In this paper, however, besides the RMB misalignment, we also calculate the misalignments of other developing countries' currencies, and analyze why China makes its currency undervalued. (2) Frankel (2006) only mentions, but does not formally analyze, the speed of RMB appreciation. Xu (2009) and Tyers and Zhang (2011) do not involve the speed of RMB appreciation. In contrast, we compare the appreciation speed of RMB with those of other currencies in similar economic development stages, and discuss which appreciation speed is feasible in the future. (3) Frankel (2006) and Tyers and Zhang (2011) discuss the path of RMB appreciation in a subjective manner (and do not conduct an empirical analysis.) However, we first decompose the RER into two parts (the NER and the relative price level) and then discuss the path of RMB appreciation empirically. In addition, our empirical method is different from and more formal than that used by Xu (2009). (4) Finally, we discuss which appreciation path—through the nominal exchange rate or through the relative price level—is better for RMB appreciation if both China's and the US's interests are considered. This issue is important to policymakers, but is not discussed in the above references. This paper is organized as follows. Section 2 calculates the RMB misalignment in 1990–2013 using the panel Penn effect model. Section 3 discusses which appreciation speed of RMB is better in the context of international comparison. Section 4 discusses which path of RMB appreciation is better from an international comparison and empirical analysis. The conclusion is given in Section 5.

## 2. HOW IS RMB UNDERVALUED

Among many models used in calculating RMB misalignment, the most appropriate one for the purposes of this study is the Penn effect model, because this model can be used not only to assess how RMB is undervalued (in this section) but also to analyze the speed and path of RMB appreciation (Sections 3 and 4).

### 2.1. Model and Data

The Penn effect model is based on absolute purchasing power parity (PPP), the most basic model for assessing bilateral nominal exchange rates (NER). The PPP model uses Eq. (1), where *RER* is real exchange rate, $P$ is a country's domestic price level, $P^*$ is the specified foreign country's price level (in this paper, the US's price level), $PPP$ $(= P / P^*)$ is the purchasing power parity exchange rate, and *NER* is the bilateral nominal exchange rate expressed as home currency units per US dollar. Given this definition, a greater *RER* value implies its appreciation, whereas a smaller *NER* value implies its appreciation. In the PPP model, whether a NER equals its PPP rate

is decided by the value of *RER*. If *RER* is equal to 1, the NER is equal to its PPP rate and is at equilibrium; otherwise, it is over- or undervalued.

$$RER = \frac{P}{P^* \times NER} = \frac{P/P^*}{NER} = \frac{PPP}{NER} \tag{1}$$

However, the RERs (in this definition) in rich countries are higher and those in poor countries are smaller, making deviation from the PPP common. This empirical regularity was documented in a series of studies by economists in the University of Pennsylvania, hence the term "Penn effect" (Isard, 2007). This regularity is also called the BS effect, (long-run) deviations from PPP, or others. Given that the Penn effect essentially refers to this empirical regularity and that the BS effect is only one of its explanations, with the BS effect being an invalid explanation in some cases, the Penn effect should be the more suitable name. Based on the Penn effect, the Penn effect model uses Eq. (2) to value a currency's RER. In Eq. (2), *RER* is defined by Eq. (1), *GDPP* is GDP per capita representing income level, and subscripts *i* and *t* denote panel data dimensions. Eq. (2) regresses the RERs on the income levels, so deviations from the regression line represent the over- or undervaluation of RERs when the Penn effect is taken into account (Chang and Shao, 2004).

$$\log(RER_{i,t}) = b_0 + b_1 \log(GDPP_{i,t}) + u_{i,t} \tag{2}$$

In this section, all data are from the International Monetary Fund's (IMF's) World Economic Outlook (WEO) database (October 2014 version). We first sequence all the available countries and areas by their GDP (in current US dollars) and choose the 40 largest: Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China (mainland), Colombia, Denmark, France, Germany, Hong Kong SAR, India, Indonesia, Iran, Israel, Italy, Japan, Korea, Malaysia, Mexico, the Netherlands, Nigeria, Norway, Philippines, Poland, Russia, Saudi Arabia, Singapore, South Africa, Spain, Sweden, Switzerland, Taiwan (province of China), Thailand, Turkey, the United Arab Emirates, the United Kingdom, and the United States. The NER for the Euro countries has been adjusted to be consistent in the WEO database, thus the Euro countries are not excluded.

The PPP exchange rates for Argentina before 1987, Brazil before 1991, Russia before 1991, and Turkey before 1987 are not obtained. For the other countries, all the data in 1980–2013 can be obtained. Repeatedly, the sample periods for Argentina and Turkey are 1988–2013, those for Brazil and Russia are 1992–2013, and those for all the other countries are 1980–2013. The NER is obtained from the gross domestic product per capita (GDPP) measured in the national currency and the GDPP measured in the US dollar, both in current prices. The PPP exchange rate can be directly obtained. Thus, the RER can be obtained from the NER and PPP based on Eq. (1). The GDPP measured in the US dollar in a current price is used in Eq. (2).

### 2.2. Panel Estimation and RMB Misalignment

Table 1 gives results of the redundant fixed effect tests. The associated *p*-values of the statistics strongly reject the null hypothesis that the cross-section effects, period effects, or both of the effects are redundant. Thus, the two-way fixed effects estimation is appropriate and is used.

**Table-1**. Redundant fixed effects tests

| Effects test | Statistic | Degree of freedom | P-value |
|---|---|---|---|
| Cross-section F | 100.47 | (39, 1246) | 0.000 |
| Cross-section Chi-square | 1876.86 | 39 | 0.000 |
| Period F | 37.61 | (33, 1246) | 0.000 |
| Period Chi-square | 912.39 | 33 | 0.000 |
| Cross-section / Period F | 74.74 | (72, 1246) | 0.000 |
| Cross-section / Period Chi-square | 2206.13 | 72 | 0.000 |

**Source:** The WEO database and the authors' calculations.

The main estimation result is given in Eq. (3). Values in parentheses below the coefficients are their t-statistics (second line) and associated p-values (third line). The slope coefficient is highly significant, confirming the existence of the Penn effect. The slope value (0.52) is close to that in the similar regression by Frankel (2006). $R^2$=0.94, which means the regression is a good fit.

$$\text{Log}(RER_{i,t}) = -5.15 + 0.52\log(GDPP_{i,t}) + u_{i,t} \tag{3}$$

$$(-39.17)\ (35.62)$$

$$(0.00)\ (0.00)$$

$$R^2 = 0.94;\ \text{Observations} = 1320$$

The equilibrium *RER*, the fitted value of *RER*, can be solved from Eq. (3). Subsequently, the needed appreciation or depreciation, which is interpreted as misalignment in this paper, can be calculated using (*RER* – equilibrium *RER*) / *RER*.[3] For example, in 2013, the RMB RER was 0.586 (US = 1) and the equilibrium RMB RER was 0.962, so the RMB RER should appreciate by 64% [the absolute value of (0.586 – 0.962) / 0.586] to its equilibrium value. In this case, RMB RER was undervalued by 64%. This undervaluation (64%) is relative to the regression line; it may not be the undervaluation relative to the US dollar, as the US dollar may also be misaligned (Xu, 2009; Chang, 2012). Concretely, in 2013, the US dollar is slightly undervalued by 2% (relative to the regression line), thus the RMB RER is undervalued by 62% (= 64% – 2%) relative to the US dollar. The misalignment of RMB RER (relative to the regression line) in the whole period is depicted in Fig. 1.

According to Fig. 1, RMB was overvalued in 1980–1993, and the overvaluation declined from about 55% in 1980–1981 to about 6% in 1992–1993. Then RMB became undervalued after the exchange rate reform in 1994 when China united its multiple exchange rates into a single exchange rate and depreciated the exchange rate both in nominal and real terms (from 1993 to 1994, the NER

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[3] The other misalignment is measured by (RER – equilibrium RER) / equilibrium RER, as in Frankel (2006).

depreciated from 5.76 yuan per US dollar to 8.62 yuan per US dollar, and the RER depreciated from 0.38 to 0.30 (with the US = 1)). To our surprise, even China repeatedly reformed its exchange rate system in 2005 and obviously appreciated the exchange rate after 2005 (from 2005 to 2013, the NER appreciated from 8.19 yuan per US dollar to 6.20 yuan per US dollar, and the RER appreciated from 0.35 to 0.59), the degree of RMB undervaluation increased in 1994–2013.

In 1994–2004, RMB was invariably undervalued by less than 35%. After 2005, RMB was undervalued by more than 40%. Till 2013, RMB had been undervalued by 64%.

The evolution of RMB misalignment can be explained by the changes in RMB RER and China's economic growth. Eq. (3) suggests that the equilibrium RER will increase as the GDPP increases and that a RER higher (lower) than its fitted value will be overvalued (undervalued). In 1980–1993, RMB RER was priced higher, and it decreased from more than 0.85 (US=1) in 1980–1981 to less than 0.40 in 1990–1993.
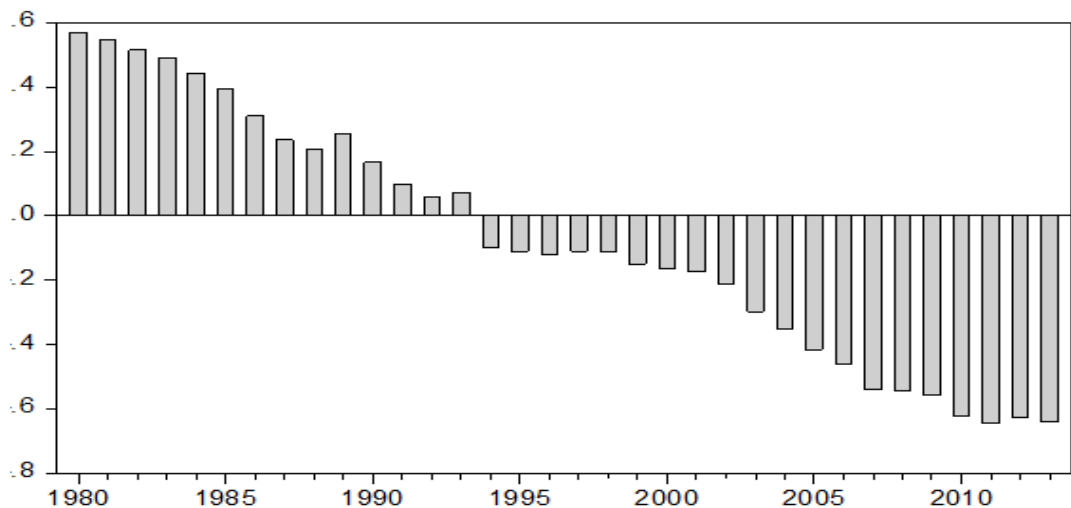


**Figure-1**. Misalignment of RMB RER in 1980–2013
**Note:** Negative (positive) values represent undervaluation (overvaluation).

Meanwhile, China's GDPP was mostly less than 500 (current) US dollars in the same period. These two factors led the RER to be higher than its fitted value (overvalued) but the degree of undervaluation decreased. In 1994–2004, RMB RER fluctuated at around 0.35, but China's GDPP tripled (from about 500 US dollars to about 1500 US dollars), thus the RER changed to be lower than its fitted value and was undervalued. In 2005–2013, though the RER increased from 0.35 to 0.59, the GDPP increased almost fourfold, from 1749 US dollars to 6959 US dollars, resulting in an increasing and higher degree of undervaluation.

### 2.3. Further Discussion on RMB Undervaluation

For comparison, we also examine the misalignments of other currencies. We find that the undervaluation in developing and emerging countries is common. Concretely, in 2013, the

currencies of Argentina, Chile, Hong Kong, India, Korea, Malaysia, Poland, Singapore, Taiwan, and Thailand were also undervalued, by 13%, 4%, 24%, 38%, 31%, 11%, 5%, 13%, 43%, and 14%, respectively. Though all these currencies were undervalued, the degree of the undervaluation of RMB was greatest. Actually, RMB was the most undervalued of all the 40 sample countries. That is, RMB was not only undervalued relative to the regression line or the US dollar, but also relative to the currencies of all the other sample countries and areas.

Then we wonder why RMB was undervalued. Does undervaluation stimulate economic growth, as argued by Rodrik (2008) and thus did China deliberately set its exchange rate to a low price for the sake of its economic growth? For this purpose, we run the regression, Eq. (4), following Rodrik (2008). In Eq. (4), *GDPP* is the GDP per capita defined in Eqs. (2) and (3), and *Misalignment* is the misalignment derived from Eq. (3).

$$GDPP_{i,t} = b_0 + b_1 \, Misalignment_{i,t} + u_{i,t} \qquad\qquad (4)$$

We first apply Eq. (4) to China in a time series dimension. The ADF test indicates that *GDPP* and *Misalignment* are not stationary, but the Johansen test indicates that they are cointegrated, thus we use FMOLS. $b_1$ is equal to -3911.62 and is significant at the 0.01 level. This means that RMB undervaluation is good for China's economic growth and overvaluation is bad for China's economic growth. Thus there may be a causality as below. China depreciated its exchange rate to be undervalued, the undervalued RMB gained a competitive advantage in exports, and the export-led growth mode stimulated China's economic growth. The examples for China to learn from, in its development after the reform and policy of openness, are the four newly industrialized Asian countries (NICs)—Korea, Taiwan, Hong Kong, and Singapore—whose economies took off before China. When we apply Eq. (4) to the four Asian NICs in a panel data dimension, $b_1$ is equal to -38171.48 and is significant at the 0.01 level; which tells the same story of undervaluation stimulating economic growth. Thus, in RMB undervaluation China may learn from its neighbors, the four Asian NICs.

## 3. SPEED OF RMB APPRECIATION

Given that RMB RER was undervalued by 64% in 2013, we now focus on how it should appreciate to reduce the undervaluation. We analyze this issue from two views: speed of appreciation (in this section) and path of appreciation (Section 4).

### 3.1. Appreciation Speed of 18 Currencies

To understand the speed of RMB RER appreciation, we analyze RMB appreciation in a comparative manner. China's economy has been rapidly growing since its reform and openness, so 17 other countries and areas in their fast economic growth stages, such as Japan in 1950–1991 and Korea in 1965–1996, are chosen; see Table 2. Fast growth is measured by the (compound) annual growth rate of the country's GDPP relative to that of the US, where an annual growth rate greater than zero means that the country's GDPP grew faster than that of the US. The 18 countries and

areas in their respective periods all showed faster GDPP growth compared with the US, with most having GDPP growth rates greater than that of the US by more than 1.5%. Most of the 18 countries and areas began their fast economic growth before 1980, but the WEO includes only RERs after 1980. Thus, we use another database, the Penn World Table (PWT) 7.0, which provides RERs (defined by Eq. (1), and normalized to US = 1) and GDPPs (PPP converted, and normalized to US = 1) for 189 countries and areas for some or all of the years in the period 1950–2009.

Table 2 lists the annual RER growth rates (RER's annual appreciation speed) and GDPPs of the 18 countries and areas in their fast economic growth stages. The countries and areas are sequenced in descending order by the annual RER growth rates. China's exchange rate was reformed greatly in 1994 and 2005, so two periods are considered, one beginning in 1994 and the other beginning in 2005.

**Table-2**. Changes in RERs and GDPPs of 18 countries and areas in their fast economic growth stages

| Country and area | Period (first, last) | RER (US = 1) | | GDPP (US = 1) | |
|---|---|---|---|---|---|
| | | Value (first, last) | Annual growth rate | Value (first, last) | Annual growth rate |
| Russia | (1999, 2009) | (0.207, 0.622) | 11.6% | (0.195, 0.344) | 5.8% |
| Romania | (1999, 2009) | (0.327, 0.649) | 7.1% | (0.146, 0.257) | 5.8% |
| China | (2005, 2009) | (0.372, 0.489) | 7.1% | (0.111, 0.178) | 12.5% |
| Korea | (1965, 1996) | (0.268, 0.812) | 3.6% | (0.106, 0.523) | 5.3% |
| Japan | (1950, 1991) | (0.308, 1.285) | 3.5% | (0.237, 0.964) | 3.5% |
| Netherlands | (1951, 1975) | (0.423,0.968) | 3.5% | (0.667, 0.980) | 1.6% |
| China | (1994, 2009) | (0.298, 0.489) | 3.4% | (0.061, 0.178) | 7.4% |
| Poland | (1991, 2009) | (0.398, 0.668) | 2.9% | (0.235, 0.403) | 3.1% |
| Germany | (1970, 1992) | (0.711, 1.202) | 2.4% | (0.774, 0.870) | 0.5% |
| Thailand | (1985, 1996) | (0.394, 0.510) | 2.4% | (0.111, 0.207) | 5.8% |
| Finland | (1959, 1989) | (0.675, 1.319) | 2.3% | (0.553, 0.814) | 1.3% |
| Taiwan | (1965, 1996) | (0.438, 0.784) | 1.9% | (0.137, 0.600) | 4.9% |
| Spain | (1953, 1975) | (0.432, 0.652) | 1.9% | (0.290, 0.639) | 3.7% |
| Norway | (1953, 1982) | (0.629, 1.041) | 1.8% | (0.679, 1.038) | 1.5% |
| Singapore | (1965, 1996) | (0.551, 0.913) | 1.6% | (0.252, 0.972) | 4.5% |
| Sweden | (1952, 1964) | (0.749, 0.860) | 1.2% | (0.758, 0.940) | 1.8% |
| Italy | (1952, 1982) | (0.476, 0.671) | 1.1% | (0.410, 0.781) | 2.1% |
| Hong Kong | (1960, 1993) | (0.681, 0.918) | 0.9% | (0.198, 0.868) | 4.6% |
| France | (1951, 1982) | (0.745, 0.873) | 0.5% | (0.522, 0.848) | 1.6% |

**Notes:** The first (last) values of the RER and GDPP are in the first (last) year. The (compound) annual growth rate x is obtained from $a \cdot (1+x)^n = b$ [or $x = (b/a)^{1/n} - 1$], where a and b are values in the first and last year, respectively, and n is the number of years examined.

**Sources:** PWT 7.0 and the authors' calculation.

We can see that the annual growth rates (annual appreciation speed) of the RERs vary greatly, from 11.6% (in Russia) to 0.5% (in France). For Asian countries, the RER's annual appreciation speeds also vary considerably. The fastest appreciation in Asian happened in China in the period 2005–2009 when the RER appreciated 7.1% per year. Then Korea in 1965–1996, Japan in 1950–1991, and China in 1994–2009 appreciated at a roughly equal speed: 3.6%, 3.5%, and 3.4%

respectively. For Thailand, Taiwan, and Singapore, the RER appreciated at about 2% per year. The Hong Kong dollar appreciated at less than 1% per year, being the slowest in the Asian group. Thus, two conclusions can be obtained. First, in all the 18 currencies or compared with other Asian currencies, the appreciation speed of RMB (7.1% or 3.4%) is in the front row, with China's economic growth speed being the greatest. Second, for all the Asian developing and emerging countries except China, though their RER appreciations were very different, their GDPPs (relative to the US) all increased at roughly 5% per year. This means that, for a given country, the appreciation speed of the RER may have little relationship with the speed of economic growth.

### 3.2. Appreciation Speed of RMB

The RMB appreciation speed of 7.1% per year in 2005–2009 is more than twice the rate in 1994–2009 (3.4%), which is the result of the political pressure of the foreign countries (especially the US and Japan). Then, we wonder which appreciation speed (3.4% or 7.1%) is more feasible in the future. The annual appreciation speed of 3.4% is a bit smaller than that of the Japanese yen (3.5%) and Korean won (3.6%) but nearly twice of that of Taiwan dollar (1.9) and Singapore dollar (1.6%). Xu (2008) reviews Taiwan's experience of currency appreciation and finds that Taiwan dollar appreciation caused the painful short-run consequences of declining export production and employment.

To overcome these difficulties, Taiwan introduced many changes to its economic structure. In Section 2.3, we have shown that RMB undervaluation is good for China's economic growth and that overvaluation is bad for China's economic growth. We think that China can hardly handle the greater challenge (given the annual RMB appreciation speed of 3.4% versus Taiwan dollar's 1.9%) as freely as Taiwan, whose economy is more flexible and robust. In addition, the appreciation of the Japanese yen at a rate of 3.5%, especially after 1985 (the RER appreciated at an annual rate of 8% in 1985–1991), is often viewed as a typical unsuccessful example. Considering the experiences of Taiwan and Japan, an appreciation speed of 3.4% may be enough, perhaps more than enough, for China to afford. Furthermore, an annual appreciation speed of 7.1%, which is about twice that of the Japanese yen and nearly four times that of the Taiwan dollar, seems quite unfeasible. That is, the annual appreciation speed of 3.4% realized in 1994–2010 is more feasible than the 7.1% realized in 2005–2010. The appreciation speed of 3.4% or less should be mainly referenced by China's policymakers in the future exchange rate level adjustment.

In Section 2.2, we have shown that in 2013, the RMB RER was 0.586, its equilibrium value was 0.962, and its undervaluation was 64%. If RMB appreciates at a speed of 3.4% per year (and the equilibrium RER is not changed), in 2020, the RER will be 0.741 [= $0.586 \times (1 + 0.034)^7$], and the undervaluation will be 30% (misalignment = 1 – 0.962 / 0.741). In other words, the undervaluation of RMB RER in 2013 (64%), if adjusted at an appreciation speed of 3.4% per year, can be corrected by half in 2020. The undervaluation of 30% is roughly equal to the undervaluation

of the Korea Won in 2013 (31%), and is already overvalued relative to India and Taiwan, whose undervaluations were 38% and 43%, respectively, in 2013.

## 4. PATH OF RMB APPRECIATION

Having discussed the appreciation speed, we now turn to the second issue, the path of RMB RER appreciation. We analyze the path of RMB RER appreciation from the two components of RER: NER and relative price level.

### 4.1. Path of RMB Appreciation in the Past and an International Comparison

According to Eq. (1), changes in *RER* can be divided into two parts: change in bilateral *NER* and change in relative price level ($P/P^*$). All variables in Eqs. (5)–(7) have the same meanings as in Eq. (1).

$$\textbf{At time 0: } RER_0 = \frac{P_0 / P_0^*}{NER_0} \Rightarrow \log(RER_0) = \log(P_0 / P_0^*) - \log(NER_0) \qquad \textbf{(5)}$$

$$\textbf{At time t: } RER_t = \frac{P_t / P_t^*}{NER_t} \Rightarrow \log(RER_t) = \log(P_t / P_t^*) - \log(NER_t) \qquad \textbf{(6)}$$

Thus, the difference in log (*RER*) from time 0 to time t can be written as:

$$\text{Log } (RER_t) - \log (RER_0) = [\log (P_t / P_t^*) - \log (P_0 / P_0^*)] - [\log (NER_t) - \log (NER_0)]$$

$$= [\log (P_t / P_0) - \log (P_t^* / P_0^*)] - [\log (NER_t) - \log (NER_0)] \qquad (7)$$

A variable's percent change is roughly equal to its natural logarithm's difference, so the percent change of *RER*, $(RER_t - RER_0) / RER_0$, can be measured by the difference of its natural logarithms, $\log (RER_t) - \log (RER_0)$. Further, the percentage change of *RER* is roughly equal to the two components, the change of relative price level $[\log (P_t / P_0) - \log (P_t^* / P_0^*)]$, and the change of *NER* $\{-[(\log(NER_t) - \log(NER_0)]\}$. From the two components, we can determine how changes in relative price level and NER contribute to changes in RER. The decomposition of RER changes for the 18 countries and areas are calculated and given in Table 3, where the countries and areas are sequenced by each NER's contribution. In addition, as the sum of $[\log(P_t / P_0) - \log(P_t^* / P_0^*)]$ / $[\log(RER_t) - \log(RER_0)]$ and $\{- [\log(NER_t) - \log(NER_0)]\}$ / $[\log(RER_t) - \log(RER_0)]$ is 100%, we only list the NER's contribution (in the last column).

Based on Table 3, there are three kinds of paths.

(1) The first kind includes Germany and Singapore. In the two countries, the RER appreciation was realized totally from the NER, with the relative price level giving a negative effect. That is, as the NER appreciated, their price level relative to the US decreased. The NER appreciated so much that it not only offset all the negative effect of the relative price level but also led to a RER appreciation.

(2) The second kind includes Japan, China, Taiwan, the Netherlands, Thailand, and Norway. In these countries and areas, the RER appreciation was realized partly from the NER and partly from the relative price level, though the contributions from changes in the NER and the relative price level differ. For Japan and Taiwan, each RER appreciation was realized mostly (about two-thirds) from the NER appreciation and a little (about a third) from an increase in relative price level. For the Netherlands, Thailand, and Norway, however, the contribution of the relative price level to the RER appreciation was greater than that of the NER appreciation. For China, in the period 2005–2009, the NER appreciation accounted for 67% of the RER appreciation and the increase in relative price level accounted for 33% (similar to Japan and Taiwan). In the period 1994–2009, 47% of RER appreciation was accounted for by the NER appreciation and 53% by the increase in relative price level (similar to the Netherlands).

**Table-3**. Decomposition of RER changes for 18 countries and areas

| Country and area | Period (0, t) | $(RER_0, RER_t)$ (US = 1) | $log(RER_t) - log(RER_0)$ | $(NER_0, NER_t)$ (per USD) | $-[log(NER_t) - log(NER_0)]$ | Column (6) / Column (4) |
|---|---|---|---|---|---|---|
| Germany | (1970, 1992) | (0.711, 1.202) | 0.525 | (1.87, 0.80) | 0.849 | 162% |
| Singapore | (1965, 1996) | (0.551, 0.913) | 0.505 | (3.06, 1.41) | 0.775 | 153% |
| Japan | (1950, 1991) | (0.308, 1.285) | 1.428 | (361, 135) | 0.984 | 69% |
| China | (2005, 2009) | (0.372, 0.489) | 0.273 | (8.19, 6.83) | 0.182 | 67% |
| Taiwan | (1965, 1996) | (0.438, 0.784) | 0.582 | (40.0, 27.5) | 0.375 | 64% |
| Netherlands | (1951, 1975) | (0.423, 0.968) | 0.828 | (1.72, 1.15) | 0.403 | 49% |
| China | (1994, 2009) | (0.298, 0.489) | 0.495 | (8.62, 6.83) | 0.233 | 47% |
| Thailand | (1985, 1996) | (0.394, 0.510) | 0.258 | (27.2, 25.3) | 0.072 | 28% |
| Norway | (1953, 1982) | (0.629, 1.041) | 0.504 | (7.14, 6.45) | 0.102 | 20% |
| Sweden | (1952, 1964) | (0.749, 0.860) | 0.138 | (5.17, 5.17) | 0.000 | 0% |
| Russia | (1999, 2009) | (0.207, 0.622) | 1.100 | (24.6, 28.8) | -0.158 | -14% |
| Finland | (1959, 1989) | (0.675, 1.319) | 0.670 | (0.54, 0.72) | -0.288 | -43% |
| Spain | (1953, 1975) | (0.432, 0.652) | 0.412 | (0.24, 0.35) | -0.377 | -92% |
| Romania | (1999, 2009) | (0.327, 0.649) | 0.685 | (1.53, 2.94) | -0.653 | -95% |
| Korea | (1965, 1996) | (0.268, 0.812) | 1.109 | (266, 804) | -1.106 | -100% |
| Hong Kong | (1960, 1993) | (0.681, 0.918) | 0.299 | (5.71, 7.74) | -0.304 | -102% |
| Poland | (1991, 2009) | (0.398, 0.668) | 0.518 | (1.06, 2.85) | -0.989 | -191% |
| Italy | (1952, 1982) | (0.476, 0.671) | 0.343 | (0.32, 0.70) | -0.783 | -228% |

| Country and area | Period (0, t) | $(RER_0, RER_t)$ (US = 1) | $log(RER_t) - log(RER_0)$ | $(NER_0, NER_t)$ (per USD) | $-[log(NER_t) - log(NER_0)]$ | Column (6) / Column (4) |
|---|---|---|---|---|---|---|
| France | (1951, 1982) | (0.745, 0.873) | 0.159 | (0.53, 1.00) | -0.635 | -399% |

**Source:** PWT 7.0 and authors' calculation.

(3) All the other countries and areas belong to the third kind. In these countries and areas, each RER appreciation was totally realized from the increase in relative price level because the NER depreciated during the period. However, for some countries (Poland, Italy, and France), the negative effect of the NER was about 200% or even more; the increase of these countries' price levels relative to the US's price level (and its contribution to the RER appreciation) was striking.

### 4.2. Which Path of RMB Appreciation is Desirable in the Future

China is free to choose an appreciation path. However, Table 3 shows that China has chosen the path of realizing its RER appreciation partly from the NER appreciation and partly from an increase in relative price level. Then we wonder whether the path is expected by the US and China.

We analyze this issue from the effect of the appreciation path on the US and China. Although the effects of RMB RER appreciation are comprehensive, with effects on exports, imports, investment, and employment, the most direct and pressing effect (especially from the view of government) is on exports. Hence, we analyze the effect of RMB appreciation on exports.

Following Thorbecke and Zhang (2009) we use RER and the foreign country's income to explain the effect of RER appreciation on bilateral exports. To increase the sample size and reflect the current situation, we use monthly data. Monthly data on the relative price level ($P/P^*$) of RER and GDP of China cannot be obtained, so we use the consumer price index with fixed base and the industrial production as proxies, respectively. All data are from IMF's International Financial Statistics (IFS) and DOTS online databases. Although other data can be traced back to the early 1980s, the monthly industrial production data of China are only available after 1994. Thus, the sample begins from January 1994.

Eq. (8) describes how China's exports ($EXP_{CH}$) to the US are affected by US industrial production ($IND_{US}$) and the RMB RER, in terms of its three components, NER (expressed in RMB yuan units per US dollar), China's consumer price index ($CPI_{CH}$), and US consumer price index ($CPI_{US}$). Similarly, Eq. (9) describes how US exports ($EXP_{US}$) to China are affected by China's industrial production ($IND_{CH}$) and the RMB RER. The ADF unit root tests reveal that most of the variables are I(1) in each group. Furthermore, Johansen tests prove that there are cointegration relationships among the variables in each group. FMOLS gives the regression results in Eqs. (8) and (9). The values in parentheses below the coefficients are their *t*-statistics (second line) and associated *p*-values (third line).

Log $(EXP_{CH})$ = -12.40 – 0.10 log$(IND_{US})$ +1.28 log$(NER)$ –0.99 log$(CPI_{CH})$ + 8.51 log$(CPI_{US})$   (8)

(-7.37)  (-0.37)          (3.61)          (-5.37)          (23.06)

(0.00)   (0.71)          (0.00)          (0.00)          (0.00)

Adjusted $R^2$=0.98, sample=January 1994 to October 2014, observations=249

Log $(EXP_{US})$ = 16.11 + 0.95 log$(IND_{CH})$ –0.57 log$(NER)$ –1.30 log$(CPI_{CH})$ + 1.72 log$(CPI_{US})$   (9)

(3.99)  (4.42)          (-1.81)          (-5.15)          (1.74)

(0.00)  (0.00)          (0.07)          (0.00)          (0.08)

Adjusted $R^2$=0.97, sample=January 1994 to October 2014, observations=249

Eqs. (8) and (9) show that RMB NER appreciation will lead to a decrease in China's exports (1% *NER* appreciation will lead to a 1.28% decrease in China's exports, given other variables being unchanged) but to an increase in US exports (1% *NER* appreciation will lead to a 0.57% increase in US exports), which is consistent with the economic theory. An increase in China's price level will lead to a decrease in China's exports (1% increase in $CPI_{CH}$ will lead to a 0.99% decrease in China's exports) and to a decrease in US exports (1% increase in $CPI_{CH}$ will lead to a 1.30% decrease in US exports). There are two explanations. First, when China's price level increases, the production cost of China's export enterprises will increase. This will increase the price of export production and then reduce the exports. Second, when China's price level increases, the dispensable income of local citizens will decrease, leading them to reduce their consumption, including their consumption of imported goods from the US.

As RMB NER appreciation hurts China but helps the US, but the increase of China's price level hurts both China and the US. If the interests of both China and the US are considered, the desirable path of RMB RER appreciation is totally from the NER. Meanwhile, the increase in China's price level should be slow. The appreciation of RMB NER and slow increase in China's price level (at a smaller rate, even smaller than that of the US) will not only help US exports but also reduce the negative effect of the RER appreciation on China. The above analysis combined with findings in Section 3.2 suggest that the recommended annual RMB RER appreciation speed of 3.4% or less should be realized totally from the NER, as in the cases of Germany and Singapore (see Table 3), rather than partly from the NER and partly from the relative price level as China earlier experienced.

Note that, if a NER appreciation coincides with an increase in relative price level, the RER will appreciate at a compound rate. This is the case in the period from November 2006 to July 2008, when RMB NER appreciated by 13.1%, China's CPI increased by 20.8%, and the US's CPI increased by 9.2%, all of which gave an RER appreciation of 24.7% (= 13.1% + 20.8% − 9.2%). This high degree of RMB RER appreciation, through both the NER and relative price level channels, was one of the main factors that forced many of China's offshore export enterprises to close shop at that time. Had China controlled the increase in its price level at a smaller rate at that time, the negative effect of RER appreciation would have been greatly reduced. For example, had China's CPI been kept the same as that of the US, RER appreciation would have been reduced by

11.6% (= 20.8% − 9.2%). Thus, in RMB RER appreciation, China's policymakers should focus on controlling the price level instead of always resisting the US pressure on RMB appreciation. As long as China's policymakers control the price level well, the negative effects of RMB RER appreciation may be not as catastrophic as imagined.

## 5. CONCLUSION

This paper has discussed three issues of RMB RER (relative to the US dollar): how it was undervalued, which speed of appreciation is feasible, and which path of appreciation is desirable.

Using the panel Penn effect model, we find that the RMB was overvalued in 1980–1993 but showed a decline trend. Then it turned to be undervalued in 1994–2013. In 2013, the RMB was undervalued by 64%. The change in RMB misalignment during this period can be explained by the changes in RMB RER and China's economic growth. RMB was undervalued not only relative to the regression line or the US dollar, but also relative to the currencies of all the other developing and emerging countries. The econometric analysis shows that China may deliberately undervalue its exchange rate for its economic growth. An examination of 18 currencies of countries and areas in an economic development stage similar to that of China shows that the annual appreciation speeds differ greatly and they do not have a close relationship with the economic growth status. RMB RER appreciated 7.1% in 2005–2009 and 3.4% in 1994–2009, which is in the front row compared with that of the other 17 currencies. Considering the experiences of other Asian economies, especially Japan and Taiwan, the annual appreciation speed of 3.4% is more feasible. At this rate, RMB's undervaluation in 2013 can be corrected by half by 2020. An examination of the appreciation of the 18 currencies reveals that there are three kinds of RER appreciation paths: totally through the NER, totally through the relative price level, and partly through the NER and partly through the relative price level. For RMB, past RER appreciation was realized partly from the NER appreciation and partly from the increase in the relative price level. The econometric analysis shows that RMB NER appreciation will have a negative effect on China's exports and a positive effect on the US's exports, whereas an increase in relative price level will have a negative effect on the exports of both China and the US. Thus, considering the interests of both China and the US, the desirable path of RMB appreciation in the future is totally from the NER while making the increase in the price level slow.

## 6. ACKNOWLEDGEMENT

## REFERENCES

Chang, G., 2012. Theory and refinement of the enhanced-PPP model for estimation equilibrium exchange rates—with estimates for valuations of Dollar, Euro, Yuan, etc. Available from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1998477.

Chang, G. and Q. Shao, 2004. How much is the Chinese currency undervalued? A quantitative estimation. China Economic Review, 15(3): 366–371.

Cline, W.R., 2010. Renminbi undervaluation, China's surplus, and the US trade deficit. Peterson Institute for International Economics Working Paper No. PB10-20.

Cline, W.R. and J. Williamson, 2009. 2009 estimates of fundamental equilibrium exchange rates. Peterson Institute for International Economics Working Paper No. PB09-10.

Coudert, V. and C. Couharde, 2007. Real equilibrium exchange rate in China: Is the renminbi undervalued? Journal of Asian Economics, 18(4): 568–594.

Evenett, S., 2010. The US-Sino currency dispute: New insights from economics, politics and law. (EBook.) A VoxEU.org Publication. London: Centre for Economic Policy Research.

Frankel, J., 2006. On the Yuan: The choice between adjustment under a fixed exchange rate and adjustment under a flexible rate. CESifo Economic Studies, 52(2): 246–275.

Garroway, C., B. Hacibedel, H. Reisen and E. Turkisch, 2012. The renminbi and poor-country growth. World Economy, 35(3): 273–294.

Isard, P., 2007. Equilibrium exchange rates: Assessment methodologies. IMF Working Paper No. 296, Washington, DC.

Rodrik, D., 2008. The real exchange rate and economic growth. Brookings Papers on Economic Activity, 39(2): 365–412.

Thorbecke, W. and H. Zhang, 2009. The effect of exchange rate changes on China's labour-intensive manufacturing exports. Pacific Economic Review, 14(3): 398–409.

Tyers, R. and Y. Zhang, 2011. Appreciating the renminbi. World Economy, 34(2): 265–297.

Wang, Y., X. Hui and A.S. Soofi, 2007. Estimating renminbi (RMB) equilibrium exchange rate. Journal of Policy Modeling, 29(3): 417–429.

Xu, Y., 2008. Lessons from Taiwan's experience of currency appreciation. China Economic Review, 19(1): 53–65.

Xu, Y., 2009. Relevant international experience of real exchange rate adjustment for China. China Economic Review, 20(3): 440–451.