

# Law of Yuan Price: Estimating Equilibrium of the Renminbi

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## Abstract

This study seeks to estimate an equilibrium value for the Chinese currency, the Renminbi. While existing literature puts forth various measures of equilibrium value, there exists a gap in reconciling historical trends with current estimates, which vary from 60% undervaluation to 5% overvaluation. I perform several Purchasing Power Parity (PPP) studies of the Renminbi vis-à-vis the U.S. Dollar, the Euro, and the Yen. The tests presented represent an estimate of the market equilibrium value given the relevant macroeconomic data available. There are different methods to interpret the available data, which result in different estimations of equilibrium. In order to present a complete picture using all relevant data, I perform 14 empirical tests. They show the effect of changes in: base year (1978 through 2005), Absolute versus Relative PPP and the use of CPI versus PPI. I compare my findings to three macroeconomic estimates of equilibrium: Fundamental Equilibrium Exchange Rate (Williamson 1994), Behavior Equilibrium Exchange Rate and Permanent Equilibrium Exchange Rate (Funke and Rahn 2006). This comparison suggests the macroeconomic studies are generally in line with PPP comparisons from the early 1990s. The results also show a considerable effect on the exchange rate from the 1994 appreciation of the Renminbi by Chinese monetary authorities. The summation of evidence suggests an equilibrium exchange rate around 4.0 RMB/USD, which implies a 37.5% undervaluation. For all measures of undervaluation, I use the exchange rate from the time of publication (April 2011), 6.5 RMB/USD. Lastly, I examine how China has recently allowed Renminbi appreciation. Assuming similar actions going forward, I propose it could take at least five years of steady appreciation for the Renminbi to reach equilibrium.

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## I. Theory

Because the Chinese Renminbi is not traded in a free market, there exists no clear market equilibrium value of the exchange rate. The objective of this research is to estimate what an equilibrium rate might be using other macroeconomic data, such as inflation. Generally, economists use two methods to estimate equilibrium exchange rates. First is the Purchasing Power Parity (PPP) method, which assumes that exchange rates will come to equilibrium at the rate which aligns prices between countries. I use various empirical tests using two types of PPP methods: Relative Purchasing Power Parity (RPPP) and Absolute Purchasing Power Parity (APPP). With RPPP, equilibrium is assumed to hold in a certain base year, and then inflation differentials between two countries drive the difference in the estimate for equilibrium going forward. APPP, however, goes further in assuming that the price of a given good will reach equilibrium through a change in the exchange rate.

The second method of calculating exchange rates involves finding macroeconomic balance, which seeks an exchange rate that would allow for an equilibrium balance of payments. The macroeconomic balance approach is more complex; it draws on more data and requires more subjective assumptions (Dunaway and Li 2005). While PPP uses less data as input, it also has the advantage of theoretical consistency in making fewer assumptions. While I present empirical evidence with only the PPP framework, I explain in the third section some of the leading macroeconomic balance estimates for the equilibrium value of the Renminbi.

Evidence under the PPP framework show how currencies change relative to the inflation rates in the countries. The theory is based on arbitrage and the Law of One Price. If there is free access to trade markets (no trade barriers, transaction or transportation costs) and exchange rates are determined by supply and demand, then rational agents will buy and sell goods and currency until the price of goods across the world reaches equilibrium. The price cannot depart from equilibrium because that would provide an arbitrage opportunity to buy the cheaper good, sell the more expensive good and earn a risk-free profit. Therefore, there will be one, and only one, price of any given good. Practically, there are barriers to this type of arbitrage, such as price stickiness, transportation costs and transaction costs. However, the theory still holds, albeit with variance in the data (Froot, Kim and Rogoff 1995).

There are two ways to apply PPP. First, in its “strongest” form, PPP is an affirmation of the Law of One Price. Also called Absolute Purchasing Power Parity (APPP), this interpretation of PPP suggests that arbitrage will drive the price levels to equal each other. This assumption is difficult to prove, espe-

cially in the short term, because it assumes easy trading (no transportation or transaction costs) and free markets. The “weaker” form of PPP is Relative Purchasing Power Parity (RPPP), which assumes equilibrium in a base year and then uses the difference in inflation from one country and another to predict the expected change. RPPP suggests that “the proportionate change in the home country’s price level is equal to the proportionate change in the product of the foreign price level and the exchange rate.” Thus, RPPP does not claim that price levels equal each other (which APPP claims), but rather uses inflation differentials to show relative change between currencies. (Krueger 1983)

In general, PPP has been shown empirically as a weak predictor of future currency changes, and it holds especially weak in the short run. There is a significant effect, however, of mean reversion in the long run (MacDonald and Stein 1999). This is the theoretical basis behind the empirical tests in the paper. The reason that PPP holds in the long run is that exchange rates are the macroeconomic tool by which prices among countries adjust to allow for the Law of One Price to hold. If prices are not at equilibrium between two countries, the action of buying in one country and selling in another requires similar trades in the currencies of the two countries. That market activity drives the exchange rate to equilibrium in the long run. For an economy with a fixed exchange rate, such as China, PPP estimates suggest an estimate of the equilibrium exchange rate based on the inflation differentials and an assumption of equilibrium in the base year. Because it is so difficult to know when (if ever) there was equilibrium, I show tests using a variety of the base years to provide a range of equilibrium points as the start of RPPP comparisons.

#### ***(A) Relative Purchasing Power Parity***

This study uses inflation data and RPPP to find estimates of the RMB/USD exchange rate. For each test, a base year is selected, and the exchange rate is assumed to be at equilibrium in that year. Assuming the base year represents equilibrium, the difference of inflation rates between the two currencies is used to estimate what the exchange rate should be. If the base year in fact represents equilibrium, then the inflation-adjusted exchange rate represents equilibrium at every given date. Most importantly, the inflation-adjusted exchange rate today gives the estimate of equilibrium today, which can be used to calculate the current under- or overvaluation of the Renminbi.

For example, suppose the U.S. Dollar and the Renminbi are at an equilibrium exchange rate of 5.0 RMB/USD in the base year. Then suppose inflation for a year in the U.S. is 5% while inflation in China is 10%. The new inflation-adjusted exchange rate implied by RPPP is  $5 * 1.10/1.05 = 5.24$  RMB/USD. This implies that the U.S. Dollar will appreciate. As inflation in China out-

paces U.S. inflation, goods become relatively more expensive in China. The exchange rate adjusts for this so that one U.S. Dollar can buy the same goods in China at the end of the year as it could at the start of the year. An “inflation-adjusted exchange rate” (IAXR) line is included in each figure below to illustrate the exchange rate that PPP would predict for any given year.

To provide a full picture of the current Renminbi exchange rate, this study compares Renminbi inflation with that of three other currencies: the U.S. Dollar, the Japanese Yen, and the Euro. These three countries comprise a majority of Chinese trade, and show how the Renminbi has changed vis-à-vis individual trade partners. The U.S. and Japan are China’s two largest trade partners. Countries from the European Union constitute an additional 13% of China’s trade. Taken together, the U.S., Japan and Europe account for more than 40% of China’s exports and imports (The U.S.-China Business Council 2011) (European Commission 2011).

This study attempts to use as many base years as possible to show the changing effect of inflation differentials over time. In each figure, the exchange rate is assumed to be at equilibrium at the base year. By using various base years, the study aims to provide a complete picture of exchange rate changes with different starting point assumptions. However, the lack of data on China makes it difficult to compare inflation rates starting from different base years. Producer Price Index (PPI) data is only available from late 1998 for China. Therefore, this study uses 2000 and 2005 for base years of RPPP comparison with PPI data between China and the U.S., Japan, and Europe.

Additionally, consumer price index (CPI) rates between the U.S. and China are compared. For CPI, there is data from China dating back to 1978, 1980, 1985, and annually from 1989. CPI data is normally less optimal to use in PPP than PPI data because PPI more accurately represents costs associated with tradable goods. In this case, however, CPI is used when it is the only inflation data available.

### ***(B) Absolute Purchasing Power Parity***

As compared with RPPP, APPP makes stronger assumptions. APPP does not assume equilibrium in the base year. Instead, it estimates the equilibrium exchange rate in each year by applying the Law of One Price. APPP dictates that the equilibrium exchange rate will make one price for goods between currencies. The exchange rate is the rate at which the price of a good or service is equal in the two currencies.

To estimate APPP equilibrium exchange rates, this study uses two “baskets” of goods. One is the World Bank GDP PPP rates. This is using GDP as the basket of goods, to which the World Bank applied a factor to adjust

for PPP. Secondly, this study uses the Big Mac Index from *The Economist* as a basket of goods to apply APPP. *The Economist* collects data on the price of one McDonald's Big Mac hamburger in countries around the world. By treating the Big Mac as a basket of goods, this study finds the exchange rate at which a Big Mac would carry the same price between the U.S. and China. While the Big Mac may not seem to be a useful basket, it is attractive because of the availability of data and uniformity of the basket. The Big Mac Index as an indicator of PPP is discussed further with the corresponding data.

### ***(C) Estimates of the Balassa-Samuelson Effect***

When calculating PPP equilibrium exchange rates, it is important to note the effect of productivity changes and their effect on the real exchange rate equilibrium. This concept – known since its discovery in 1964 as the Balassa-Samuelson effect – argues that relative productivity discrepancies between countries affect the way that prices must be interpreted. Countries experience productivity gains through various means: increased infrastructure, reduced barriers to international trade and advances in the technology of production.

Productivity gains, however, progress at different rates between tradable and non-tradable products, made up of goods and services. The tradable products are able to capture more productivity increases, and cause wages in tradable product sectors to increase because of labor scarcity and workers' increased power. These wage increases affect all labor markets, and wage increases extend to non-tradable products. In tradable product sectors, wage increases are balanced by productivity gains. In non-tradable sectors, there are also wage increases (the labor is from the same pool). However, there are no corresponding productivity gains along with the increase in prices in non-tradable sectors. This causes prices in the non-tradable sector to increase at a faster rate, which leads to inflation. When a country experiences inflation more than the rest of the world, its currency appreciates (Dunaway and Li 2005). This study does not calculate productivity differences as part of the equilibrium estimates. There already exist several studies that estimate the Balassa-Samuelson effect in China over the past decade. After presenting PPP estimates of the Renminbi equilibrium, this study summarizes some of the articles that have focused on the Balassa-Samuelson effect on the Renminbi exchange rate.

While the pure PPP estimates presented in this study show no significant shift in the value of the Renminbi between 2000 and 2010, many economists feel productivity changes have caused the Renminbi to be significantly undervalued, and that this undervaluation has grown over this time period. The undervaluation is consistent with the PPP estimate that uses 1978 as an assump-

tion of equilibrium, but the change from 2000 to 2010 cannot be explained by prices alone. Several studies have found a Balassa-Samuelson effect in China, which implies that the Renminbi is more undervalued than a simple PPP estimate would predict (Dunaway and Li 2005).

However, the magnitude of the Balassa-Samuelson effect in China is not clear. Specifically, the size of the effect varies based on the number of countries included in the comparison and whether the country set is made up of developed or developing countries. In the case of China, rapid growth and high inflation make comparisons with other developing countries more applicable (Dunaway and Li 2005). There are various reasons why the Balassa-Samuelson effect may not hold in modern China. First, the effect relies on accurate price data, and there is a lack of quality price surveys in China (which also presents a limitation of PPP estimates). Prices in China are very low, which can cause models to underestimate the degree of undervaluation of the Renminbi. (Cline and Williamson, *Estimates of the Equilibrium Exchange Rate of the Renminbi* 2007)

Additionally, the Balassa-Samuelson effect assumes that the economy is at or close to full employment. That is a necessary condition for increases in wages in tradable sectors to cause increases in wages in non-tradable sectors. In China, this may not be the case, as the past decade has seen new workers migrate from the rural areas to new jobs in the cities. While many of these workers may have worked in rural areas, they were not part of the formal work force in the cities. Their abundance and recent entrance into urban work forces has had the effect of adding new workers to the cities without requiring employers to increase wages. Non-tradable sectors have been able to maintain low wages, and have not caused significant price increases or the resulting appreciation of the currency. Therefore, the Balassa-Samuelson effect may be minimal in China over this time period (Dunaway and Li 2005).

## II. Findings

### (A) Relative Purchasing Power Parity

#### a. RMB/USD Comparisons

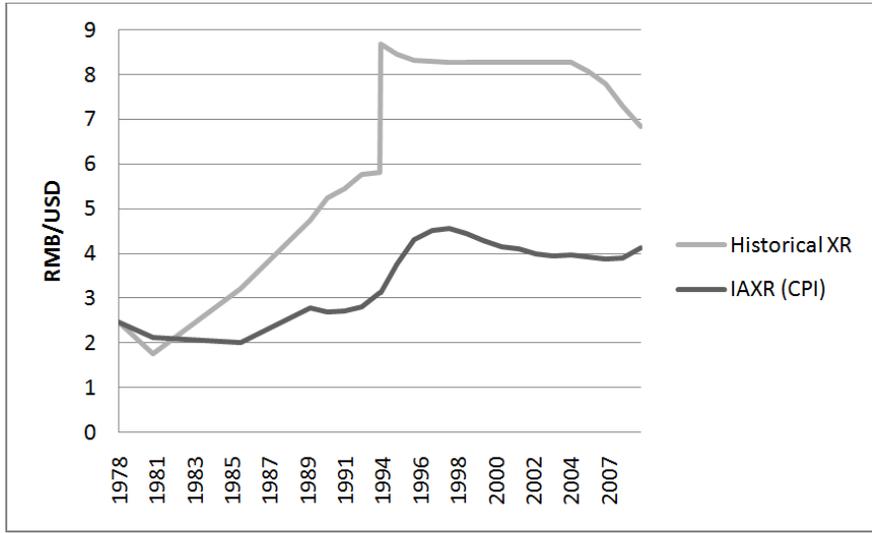


Figure 1: RMB/USD CPI (1978)

This figure demonstrates how the historical exchange rate has depreciated significantly more than the inflation adjust exchange rate would have predicted. Starting with an assumption of an equilibrium exchange rate of 2.46 RMB/USD in 1978, the inflation-adjusted exchange rate predicts a stronger Renminbi than how the exchange rate actually changed. The exchange rate predicted by inflation would be **4.13 RMB/USD** (assuming equilibrium in 1978). This translates to a **36% Renminbi undervaluation** off the current value of 6.5 RMB/USD.

Using 1978 as a base year for China is not arbitrary. On a global scale, it was only a few years after the fall of the Bretton Woods system. The price of gold was no longer fixed, and currencies were trading on floating markets. In China, Deng Xiaoping came to power in 1978 and was a strong proponent in opening up the country economically to the rest of the world. Part of this economic liberalization was allowing for greater flexibility in currency conversion. Previously, from 1949 until 1978, China's exchange rate had been pegged at 2.46 RMB/USD (Cheng 1998).

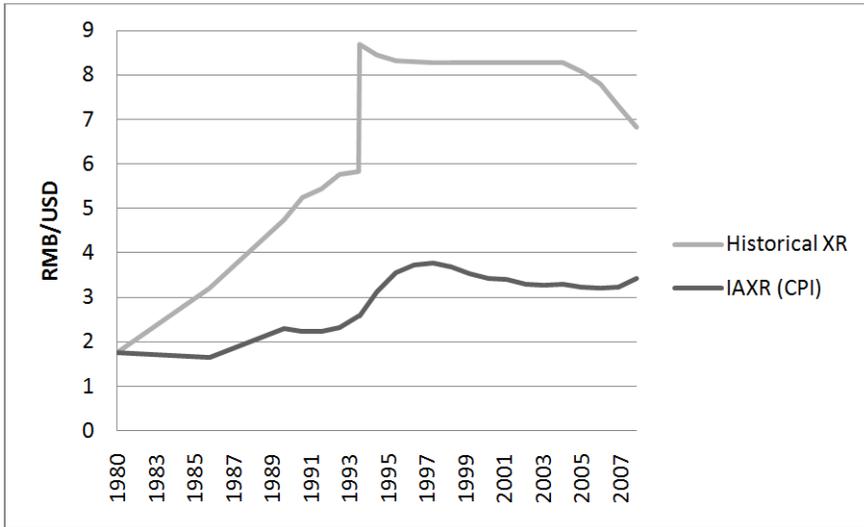


Figure 2: RMB/USD CPI (1980)

In 1980, the government began to allow 10 “swap centers” around the country, and China began a trend of a long-term, slow depreciation of the currency (Cheng 1998). From 1978 to 1980, the Renminbi had been depreciating vis-à-vis the U.S. Dollar, and the nominal exchange rate was 1.74 RMB/USD in 1980.

Figure 2 appears similar to the one that uses 1978 as a base year, but Figure 2 uses an even lower assumption of equilibrium in 1980. Using this baseline assumption of 1.74 RMB/USD from 1980, the inflation differentials suggest a current inflation-adjusted exchange rate of **3.41 RMB/USD**, which implies a **48% undervaluation**. This is greater than the 36% implied by using 1978 as starting equilibrium. It is not clear which, if either, is a good estimate of the fair equilibrium exchange rate. It is important to note, however, that both show an estimate of equilibrium significantly lower than the nominal exchange rate today. These both imply that if 1978 and 1980 represent equilibrium, inflation differentials suggest Renminbi undervaluation today.

When 1985 is used as equilibrium, the model predicts an inflation-adjusted exchange rate relatively close to where the exchange rate is trading currently. Assuming the 1985 equilibrium, the inflation-adjusted exchange rate today is **6.63 RMB/USD**, which implies a **2% overvaluation**. The rise in the inflation-adjusted rate between 1985 and 2008 was due to high inflation rates in China. This inflation came along with strong economic growth of China through the 1990s and 2000s, driven in large part by economic liberalization

and strong Chinese exports.

The fact that this figure arrives at an estimate close to the current rate shows that the exchange rate since 1985 has tracked fairly closely with the change in inflation. In Figure 2, 1985 is used as equilibrium, and then equilibrium is shown again today. But this is just one figure, and there may not have been equilibrium in 1985. Therefore, the relative under- or overvaluation of the Renminbi with the U.S. Dollar in 1985 is consistent with the current valuation of the Renminbi.

Using 1989 as a base year produces an estimate of equilibrium consistent with the estimate that uses 1985 as a base year. They both end with estimates of an exchange rate close to where current rate. In this case, using 1989 as equilibrium, inflation differential would suggest a current inflation-adjusted exchange rate of **7.05 RMB/USD**. This implies an **8% overvaluation** today. In the figure, the sharp depreciation of the Renminbi and ensuing inflation in China between 1993 and 1994 is apparent. In fact, on January 1, 1994, China officially changed its exchange rate to 8.68 RMB/USD, effectively entering the “Unified Rate Phase” (Cheng 1998).

In Figure 10, which uses the end of 1994 as equilibrium, there is no change nearly as dramatic as the devaluation in January 1994 that produces such strong inflation in China. In this figure, the increase in Chinese inflation can be noticed through the rise in the inflation-adjusted exchange rate through 1998. Assuming the exchange rate was at equilibrium in 1994, the figure suggests a current inflation-adjusted exchange rate of **9.24 RMB/USD**, which translates to a **42% overvaluation**.

This demonstrates why 1994 probably does not provide a useful base year to assume equilibrium. After the shocking devaluation of January 1994, inflation began to take hold in China, and took a few years to increase Chinese prices. The devaluation itself is evidence that equilibrium is not likely at this time. Assuming equilibrium directly after a sharp devaluation, as this figure does, can lead to misleading analysis that should not form the basis of sound conclusions about equilibrium.

Using 2000 as the base year for equilibrium shows an even more concentrated view of the exchange rate and inflation changes. Since then, there have not been significant differences in inflation, which lead to a flat inflation-adjusted exchange rate line ending at an equilibrium estimate of **8.24 RMB/USD**, above the current exchange rate. That translates to a **27% overvaluation**. The historical exchange rate was steady until July 2005, when China unpegged the Renminbi, and began to allow it to appreciate. That it now sits above the current exchange rate implies Renminbi overvaluation, but this is likely a cause of the choice of 2000 as equilibrium. It is unlikely that the currency was effec-

tively at equilibrium in 2000. Therefore, Figure 11 – along with the following figures that use 2000 as equilibrium – serves merely to demonstrate how inflation rates between the U.S. and China have differed since 2000, but are likely inaccurate as predictors of equilibrium exchange rates today.

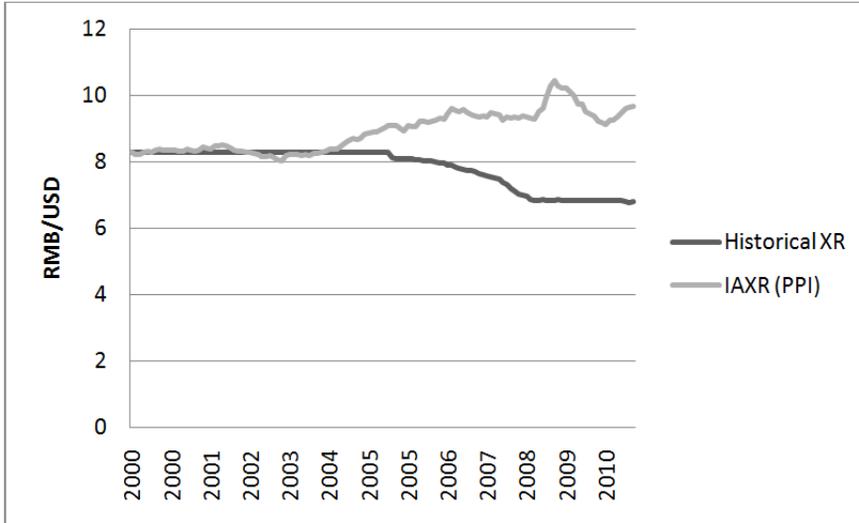


Figure 3: RMB/USD PPI (2000)

Figure 3, which uses producer price indices (PPI) and a base year of 2000, is included here to establish a similarity between CPI and PPI data, because all figures comparing the Euro and Yen use PPI data. Additionally, Figure 12 in the appendix shows the PPI test with a base year of 2005. The PPI charts are in fact similar to their CPI counterparts. Inflation in China slightly outpaced U.S. inflation in this time period, but the inflation-adjusted exchange rate line remains relatively flat. The previous figures showed the same trend with CPI data. The CPI data showed less of a difference in inflation rates between the U.S. and China using 2000 as equilibrium. The historical exchange rate appears to slope downwards more than it does in the CPI figure because this figure uses monthly rather than annual data, and this figure extends to 2010.

The PPI estimate that uses 2000 as a base year shows the inflation-adjusted exchange rate equal to the historical exchange rate around 2004, whereas the rates equal one another around 2006 in the CPI estimate. This is to be expected, as PPI is a leading indicator of CPI: Consumer goods tend to have sticky price and vary based on producer costs. The PPI estimate that assumes 2000 as equilibrium suggests an inflation-adjusted exchange rate today of **9.66 RMB/USD**, which implies a **49% overvaluation**. The PPI figure that as-

sumes 2005 as equilibrium shows less of an overvaluation of the Renminbi, and suggests a current equilibrium of **9.02 RMB/USD**, which implies a **39% overvaluation**.

#### b. RMB/EUR Comparisons

While the RMB/EUR estimate, using 2005 as a base year (Figure 14), appears similar to the RMB/USD graph from 2005 (Figure 12), the Euro comparison from 2000 (Figure 15) shows a marked difference from its USD counterpart, Figure 3. The Renminbi depreciated vis-à-vis the Euro from 2000 to 2005, which is consistent with larger currency moves at the time. The Euro was appreciating vis-à-vis the U.S. Dollar at that time, and the Renminbi was pegged to the U.S. Dollar. With an assumption that the Renminbi and Euro were at equilibrium in these figures, the tests produce estimates of **9.80 RMB/EUR** using the 2000 base year, which implies **51% overvaluation**. Using 2005 as a base year produces an estimates of **12.14 RMB/EUR** which translates to **87% overvaluation**.

#### c. RMB/JPY Comparisons

Figures 15 and 16 in the appendix show the Renminbi against the Japanese Yen in the same format as the previous figures. While the standard convention is to quote currencies against the Yen as JPY/FC, the currency is quoted in this paper as RMB/JPY to be able to visually compare the Figures 15 and 16 with previous figures. Otherwise, the movements would be inverted.

In comparing the Yen analysis with the others, it is clear that the inflation-adjusted exchange rate line appears different than it did in the Euro and U.S. Dollar figures. This is consistent with expectations because Japan has experienced such low levels of inflation. Therefore, it appears to have gained purchasing power against the Yuan. In addition, the historical exchange rate remains flat across both time periods. While the Renminbi has appreciated vis-à-vis the U.S. Dollar, the Yen has also appreciated, so the two currencies have maintained a fairly stable cross-rate. With an assumption of 2000 as equilibrium, the figure suggests an inflation-adjusted exchange rate of **0.13 RMB/JPY** (7.50 JPY/RMB). This translates to **15% overvaluation**. While that shows a significant discrepancy from the current exchange rate, the exchange rate suggested by using 2005 as equilibrium is **0.11 RMB/JPY** and **45% overvaluation** (9.42 JPY/RMB), which closer to the current exchange rate of 0.08 RMB/JPY (12.37 JPY/RMB).

*(B) Absolute Purchasing Power Parity*

## a. World Bank GDP Implied PPP Exchange Rates

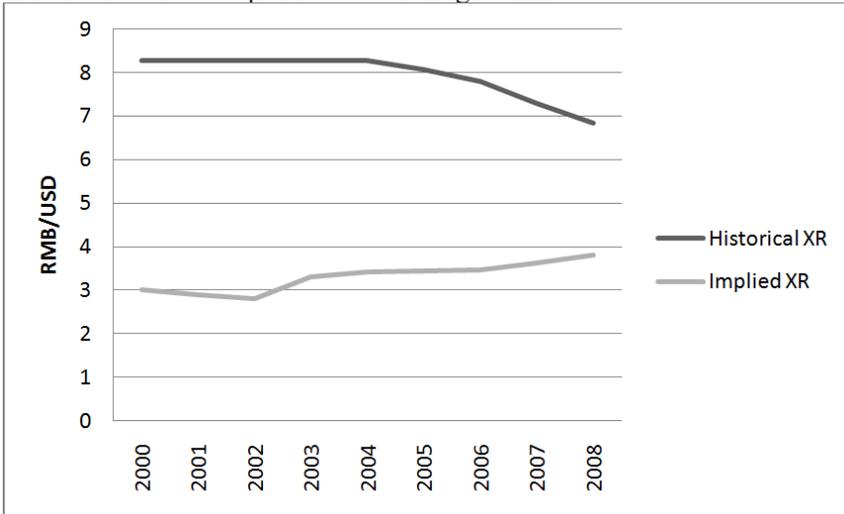


Figure 4: RMB/USD World Bank Implied Rate (2000)

This rate is based on GDP figures published by the World Bank. The World Bank publishes PPP-adjusted GDP estimates, which are the World Bank's estimate of what a country's GDP would be if it had the purchasing power of the U.S. Dollar. The number is published as GDP/capita in U.S. Dollars. To find the RMB/USD exchange rate, I multiply the PPP GDP rate by population, and divide the actual Renminbi GDP by that number. As a check on the population number, I multiply the World Bank's GDP/capita by population, and it in fact is in line with total GDP figures. The APPP estimates from these rates imply significant undervaluation of the Renminbi. In 2008, the implied exchange rate is **3.80 RMB/USD**, which implies **42% undervaluation** of the Renminbi.

## b. The Economist Big Mac Index

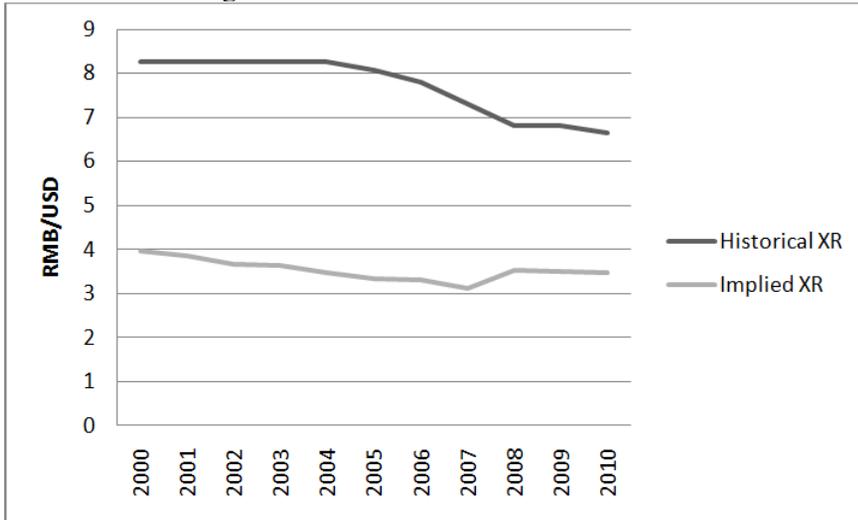


Figure 5: RMB/USD Big Mac Index (2000)

*The Economist* has compiled the Big Mac index since 1986, reporting the price of one Big Mac hamburger in many of the 110 countries where it sold around the world. While it is not an actual basket of goods, the Big Mac Index has been gaining attention among academics and media outlets over the last few decades. Economists agree that the Big Mac Index produces a number of problems. First, it is only one product, and a food product, which is exposed to highly cyclical price shifts that are not indicative of prices in the rest of the economy. Second, the Big Mac itself is marketed as a different product in different countries. In some countries, such as the U.S., the Big Mac hamburger is inexpensive and could be an inferior good compared with other food items. In other economies, including China, the Big Mac can be expensive for much of the population, and may even be seen as a higher-end food product. This discrepancy limits the effectiveness of the Big Mac Index.

Nonetheless, there are certain undeniable advantages to the Big Mac Index. Practically, it is cheap and easy to administer, and the data has been reliably gathered annually in many countries for almost 25 years. Also, the idea of the Big Mac “basket” encompasses all of the inputs into a Big Mac, including raw food costs, transportation costs, marketing and labor production costs. Regardless of the reason, several academic studies “generally find the Big Mac is surprising accurate in tracking exchange rates over the long run.” (Funke and Rahn 2006). Using the Big Mac Index, an equilibrium exchange rate for October 2010 is estimated to be **3.48 RMB/USD**, or **46% undervaluation**.

### *(C) Summary of Findings*

This section presented five figures and referred to nine more from the appendix. They all demonstrate various measures of the equilibrium Renminbi exchange rate. First, Relative Purchasing Power Parity presents evidence supporting the claim that the Renminbi is undervalued. Specifically, the devaluation in 1994 appeared to have significantly shifted the effective exchange rate. The increase in Chinese inflation relative to U.S. inflation suggests that the 1994 devaluation resulted in an exchange rate that undervalued the Renminbi.

The use of several years as the equilibrium starting points demonstrates the level of inflation differentials over time. From the data, it's clear that inflation since 2000 has been relatively similar in the U.S. and China. Therefore, the level of over- or undervaluation of the Renminbi is likely similar today to its level in 2000. Before that, from 1985 to 2000, inflation in China outpaced inflation in the U.S (see Figure 1). While the two countries experienced similar levels of inflation from 1990 to 1994, the significant disparity in inflation rates occurred from 1985 to 1990 and 1994 to 2000.

The comparison of the Renminbi with the Euro and Yen show that the trends vis-à-vis the U.S. Dollar are not specific to the Renminbi-Dollar relationship. The graphs are not the same because they reflect the unique nature of the Euro and Yen during these time periods. The Euro experiences significant appreciation against other currencies in during the first part of the decade, and that accounted for much of the changes in Figures 13 and 14. The Yen has historically experienced very low levels of inflation, which accounted for the large inflation differentials in Figures 15 and 16.

With Absolute Purchasing Power Parity, the demonstrated effects of undervaluation are stronger. Both the implied World Bank rate and the Big Mac Index would predict an exchange rate below 4 RMB/USD, significantly below the exchange rate in April 2011 of 6.5 RMB/USD. These predictions assume that their basket of goods is an accurate representation of prices within the country. While both the Big Mac Index and the World Bank PPP rate are not perfect baskets, they are still relevant and provide a baseline of comparison between the U.S. Dollar and Renminbi.

### **III. Other Methodology**

In addition to the PPP estimates presented in the previous section, this study reviews some of the leading estimates of Renminbi equilibrium found in recent academic studies. The most relevant to compare to the previous section are those which use the more complex macroeconomic balance approach. Besides for macroeconomic balance, almost all methods are variants of PPP and

draw on similar data sets. There are three such methods described in this study: the Fundamental Equilibrium Exchange Rate (FEER), the Behavioral Equilibrium Exchange Rate (BEER), and the Permanent Equilibrium Exchange Rate (PEER). John Williamson of the Institute for International Economics developed the FEER approach, and has updated his models as of January 2010. A 2006 paper by Michael Funk and Jörg Rahn of Hamburg University evaluated the Renminbi with the BEER and PEER methods.

In addition to the methods described here, there has been other significant research on the value of the Renminbi. One recent article analyzed 130 empirical estimates of the value of the Renminbi. It found that estimates were wide-ranging, from -66.70% to 161.70% misalignment of the Renminbi (Bineau 2010). The average is currently around 13%, but has changed significantly over time, as illustrated in Figure 6.

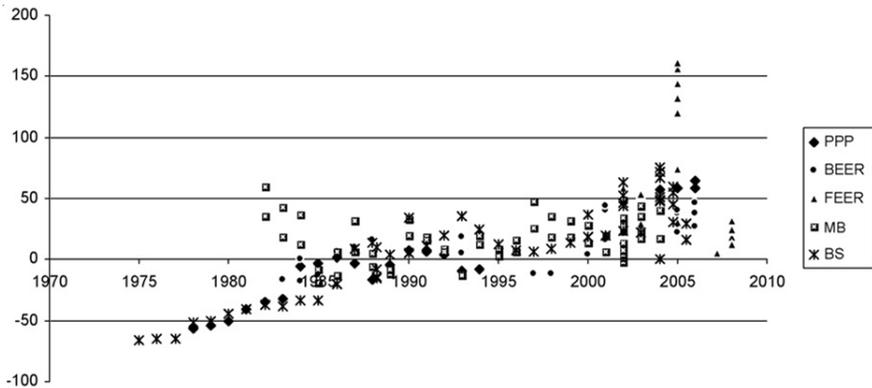


Figure 6: Estimates of Renminbi Misalignment over Time (Bineau 2010)

#### *a. Fundamental Equilibrium Exchange Rate*

This method aims to find an equilibrium exchange rate so that a country simultaneously achieves internal and external balance. For the purposes of this method, Williamson describes internal balance as “acceptance of the historically determined wage rate and achievement of a level of effective demand such as to sustain the highest level of activity consistent with the control of inflation.” External balance is a target current account large enough that it is sustainable and does not rely on capital inflows attracted by high interest rates. The target current account balance should also be small enough to avoid the domestic political pressure of a postponement of consumption and foreign political pressures (such as the political pressures the U.S. is currently applying to China in hopes of reducing China’s large current account balance) (Wil-

Williamson 1994).

The FEER is a medium term equilibrium concept (Bineau 2010). To arrive at a final value, the method uses values the exchange rate based on a number of real factors, the “fundamentals.” These variables include taxes, international terms of trade, commercial policy, capital flows, aid flows, and technology. Because this method is a function of so many factors, its value depends not only on the current values but also on the expectations of policy changes and economic shifts in the future (Elbadawi 1994).

In January 2010, Williamson published updated Fundamental Equilibrium Exchange Rates, and included an estimate for the Renminbi at **4.9 RMB/USD**, implying a **28% undervaluation** from the rate at which it was trading, 6.8 RMB/USD. This estimate, however, relied on the IMF’s expectations for China’s current account surplus through 2012, which was around 10%. This figure appeared to be too high, as recent data suggest the current account surplus may be closer to 5-6%. A lower current account surplus has a dramatic effect on the FEER. For example, if the current account surplus is 7%, the FEER implies a 25% (rather than 28%) undervaluation vis-à-vis the U.S. Dollar (Cline and Williamson, Notes on Equilibrium Exchange Rates 2010).

### ***b. Behavioral and Permanent Equilibrium Exchange Rates***

The Behavioral Equilibrium Exchange Rate (BEER) is based on fundamentals of an economy surrounding internal and external balance, similar to the FEER. The difference, however, is that the BEER does not require equilibrium. It avoids the subjective assumptions involved with selecting a sustainable current account rate. Instead, the BEER is a “data-determined systematic component of the exchange rate in the medium and long run” (Funke and Rahn 2006).

The Permanent Equilibrium Exchange Rate (PEER) attempts to address the problem with BEER and FEER that they rely on fundamentals in the rest of the macroeconomy that are not at equilibrium. In order to arrive at values for these fundamentals, the PEER starts with a Hodrick-Prescott or bandpass filter to account for the effect of the business cycle in the data. Then, the PEER extends this notion to create a time series for fundamentals that breaks the variables into permanent and transient components. The PEER uses the permanent components in a series of equations to find an equilibrium exchange rate.

The results of the evidence suggest that there is only modest undervaluation of the Renminbi. The BEER implies that the Renminbi has been undervalued by 6-15% at different points between 1999 and 2006. The PEER suggests that the Renminbi is undervalued by about 12%. Considered together, these estimates show that the undervaluation may be less than other estimates

suggest. The study also assumes a Balassa-Samuelson effect, which may not be significant in modern China (see Findings section).

#### **IV. Significance of Study**

The Chinese exchange rate has become increasingly important in past years as it has affected trade balances, the Sino-U.S. diplomatic agenda and currency policies in other countries. In each of these areas, the value at which the Renminbi trades has been important in determining how other countries set policy and interact with each other. An exchange rate has ripple effects throughout the world economy and global political environment.

##### ***(A) Current Account Balance***

There is no doubt that China has experienced massive economic growth in the past decade. In fact, a recent working paper from the World Bank estimates that Chinese GDP grew by 10% or greater every year from 2003-2008 (Kuijs 2009). A strong driver of this growth has been Chinese exports, which approximately doubled between 2005 and 2009. These exports mostly comprise manufactured goods, and their export price depends on the Renminbi exchange rate (World Bank 2010). With a weak Renminbi, exports are made relatively inexpensive, and foreign consumers demand more Chinese goods.

Simple macroeconomic theory dictates that a weak currency encourages exports (and decreases imports). The question is to what extent the current account balance depends on the exchange rate. To test this link, William R. Cline from the Institute of International Economics conducted analysis on exchange rate and trade data to determine the statistical significance of the effect of the Chinese exchange rate vis-à-vis the U.S. Dollar on China's global trade balance and its bilateral trade balance with the U.S.

The empirical evidence at first glance seems to suggest a weak link. From July 2005 to August 2008, China allowed its currency to appreciate 21%, yet the U.S. bilateral trade deficit with China remained largely unchanged during the period. Yet Cline shows that China's current account surplus is greatly influenced by the real exchange rate and the growth differential. The relationship shows an adjusted R<sup>2</sup> correlation of 0.89. The coefficient in the equation, which is statistically significant, shows that a 1% rise in the real exchange rate leads to a 0.30%-0.45% fall in the current account balance as a percent of GDP (Cline, Renminbi Undervaluation, China's Surplus, and the US Trade Deficit 2010).

Then why didn't the current account balance fall during the 21% appreciation of the Renminbi? The historical evidence shows a significant effect of the real exchange rate of the Renminbi on China's global current account

balance and the bilateral trade balance with the U.S. The effect is significantly lagged, however. This can be attributed to the time it takes for manufacturers to interpret an exchange rate change as a long-term realignment rather than a short-term fluctuation. Also, assuming companies often hedge much of their foreign currency exposure, they may not feel the effects of immediate fluctuations in exchange rates. These factors contribute to a lag of about two years in the effect of exchange rates on a trade balance (Cline, Renminbi Undervaluation, China's Surplus, and the US Trade Deficit 2010).

The data start in 2000, at a time when the Renminbi was pegged to the U.S. Dollar. Therefore, until the Renminbi was unpegged in mid-2005, the U.S. Dollar vis-à-vis other world currencies was the sole determinant of the value of the Renminbi against non-U.S. trading partners.

In 2003, China had a modest current account surplus of 2.8% of GDP. In the period of 2002-2005, the U.S. Dollar depreciated against other major world currencies. With that the Renminbi linked to that depreciation, its exports benefited from the relative weak currency. The effect was shown in 2007 (consistent with the two year lag), when China experienced a current account surplus of 11% of GDP (Cline, Renminbi Undervaluation, China's Surplus, and the US Trade Deficit 2010).

In the following years, the U.S. Dollar saw a sharp appreciation. This occurred during the financial crisis, when investors fled from risky emerging markets to assets in safer countries such as the U.S. and Japan. The result was an appreciation of the U.S. Dollar during the crisis. Concurrently during the crisis, China effectively re-pegged its currency to the dollar and stopped its recent trend of appreciation to minimize the negative impact on exports. Therefore, the U.S. Dollar appreciation in this period affected the Renminbi in a way similar to the U.S. Dollar appreciation during 2002-2005. Following the crisis, and a two-year lag, China's current account surplus has declined to around 6% of GDP in 2010 (Cline, Renminbi Undervaluation, China's Surplus, and the US Trade Deficit 2010).

From this data, we can conclude that the Renminbi exchange rate has a significant effect on the current account balance. The effect is about 30-45%. This means that, using 2010 data, a 10% appreciation of the Renminbi would reduce China's global current account surplus by \$170 billion to \$250 billion (Cline, Renminbi Undervaluation, China's Surplus, and the US Trade Deficit 2010).

### ***(B) Sino-U.S. Political and Diplomatic Agenda***

Since the strong growth China exhibited in the 1990s, the Renminbi exchange rate has been a closely watched and highly contentious issue in politics

and diplomacy between the U.S. and China. From 1994 to 2002, the Chinese economy doubled while the trade-weighted value of the Renminbi increased by 30%. Then, from 2002 to 2005, China experienced even stronger growth, but not as much appreciation because the U.S. Dollar, to which the Renminbi was pegged, had been depreciating. China's rapid growth could be largely attributed to exports; its export-GDP ratio was close to 40%. Over half of these exports were sold to consumers in the U.S. Politically, the issue arose as a major point of contention between the U.S. and China. There are two tools that the U.S. has used to pressure China on this issue: tariffs on imports and the characterization of currency manipulation in an annual report by the Treasury Department (Goldstein, *Renminbi Controversies* 2005).

On July 21, 2005, China announced that it would end its decade long peg to the U.S. Dollar. This followed a bill that was then in the U.S. to impose a 27.5% tariff on all goods imported from China. The Senate Finance Committee had scheduled hearings on the Chinese currency regime for July 23, 2005 (*The Economist* 2005). Shortly after the announcement, in November 2005, the U.S. Treasury acknowledged that "a rigid exchange rate hinders China's ability to move away from its current dependence on exports." It went on to report, "President Hu told President Bush that China would unswervingly press ahead with reform of its exchange rate mechanism. The Chinese authorities should do so by the time this report is next issued." The report labels certain countries as "currency manipulators," but left China off the list, at least in part because of its steps taken in July 2005 (Department of the Treasury 2005). Since then, the Treasury Department has still not labeled China as a currency manipulator.

After the initial 2.1% appreciation, China met this expectation and allowed gradual appreciation of the Renminbi each year until 2008 (Goldstein and Lardy, *The Future of China's Exchange Rate Policy* 2009). Then, in light of the global economic crisis, the Chinese authorities began to scale back the rate of appreciation. From September 2008 to early June 2010, the Renminbi was essentially fixed at 6.83RMB/USD (Cline, *Renminbi Undervaluation, China's Surplus, and the US Trade Deficit* 2010). Yet the political pressure did not immediately return. Other countries had been taking protectionist measures, and there was no strong pressure on China to appreciate its currency during a global recession.

In 2010, however, the issue re-emerged. As the world began to recover from the recession, politicians in the U.S. and around the world once again felt the negative effects of Chinese exports. The U.S. began to consider measures to label China as a "currency manipulator" in the annual report from Treasury to Congress. A G-20 meeting in Toronto in July of 2010 provided a forum

where many world leaders were expected to pressure China to allow the Renminbi to appreciate.

On July 21 2010, exactly 5 years after the initial un-pegging, China announced that it would once again begin to allow the Renminbi to appreciate. China followed the same strategy of trying to preempt political pressures by appreciating its currency. Yet, in the months following the announcement, the Renminbi appreciated less than 2%. The appreciation has been disappointing for U.S. lawmakers (Beattie 2010).

In response, two U.S. Congressmen introduced a bill treating currency manipulation as an illegal export subsidy. This bill would have given the U.S. more authority to impose tariffs on Chinese goods, but it did not pass. Responding to U.S. pressures, a spokesperson for the Chinese Foreign Ministry, Jiang Yu, said, “I would point out that appreciation of the Renminbi will not solve the US deficit and unemployment problems.” In addition, the Senate Committee on Banking, Housing, and Urban Affairs and the House Ways and Means Committee called Treasury Secretary Timothy Geithner to testify on September 16, 2010. The committees spoke about the annual Treasury report to Congress, and asked Secretary Geithner whether China may be labeled as a currency manipulator in the report that is due to Congress on October 15th. Although he generally agreed that action was needed, he questioned the usefulness of labeling China as a currency manipulator in the Treasury’s report: “Wishing something does not make it so – and issuing a report that requires me to go and consult – changes nothing” (Beattie 2010).

The effect of the Chinese exchange rate on the U.S.-Chinese bilateral relations is clear. In 2006, the U.S. Treasury appointed a full-time Financial Attaché to represent U.S. interests in this area and other (Department of the Treasury 2005). The Renminbi exchange rate will continue to be a significant part of the bilateral diplomatic agenda between the U.S. and China.

### ***(C) Domino Effect on Other Countries***

If the Renminbi is in fact undervalued, that would create a competitive advantage for China’s exports. In a global economy desperate for growth, many other countries have begun to consider currency interventions to depreciate the value of their own currencies and help their export economies. In many ways, this resembles the devaluations of fixed currencies under Bretton Woods that led to the eventual collapse of the gold standard in 1971. However, most of the major world currencies are floating, not fixed as they were under Bretton Woods. Even though they are floating, there are other ways that countries can influence the value of their currency. Central banks can take steps to intervene in currency markets to buy foreign currency. This increases demand, and thus

price, of foreign currencies, effectively depreciating the home currency. The perceived undervaluation of the Renminbi and corresponding competitive advantage have contributed to decisions by Japan and South Korea to lower the value of their own currencies.

On September 15, 2010, Japan spent roughly two billion Yen in the largest currency intervention in history. It came at a time the Yen was at a 15 year high against the dollar, and the Japanese government was facing intense pressures from its domestic producers to take action against the high value of the Yen (Garnham 2010). The intervention had the intended effect of depreciating the Yen and – more importantly – signaling to investors the government’s willingness to intervene in currency markets.

In addition, other countries, such as South Korea, have attempted to depreciate the value of their currency. Even the recent U.S. program of quantitative easing has to depreciation of the Dollar. In light of all of these shifts, some countries are left with strong currencies. One such country is Brazil, which appreciated about 25% vis-à-vis the U.S. Dollar from January 2009 to September 2010. Brazil’s Finance Minister, Guido Mantega, recognizes the challenges faced by these recent interventions, “We’re in the midst of an international currency war, a general weakening of currency. This threatens us because it takes away our competitiveness” (Wheatley and Garnham 2010).

However, not all interventions are meant to depreciate exchange rates for an advantage in trade. For years, Japan bought U.S. dollars with yen, and accumulated reserves exceeding \$893 billion in June of 2007. Japan largely stopped its currency interventions in 2004 (Nanto 2007). Yet while they were actively intervening, the U.S. did not object to these Japanese actions in the same way it objected to China’s intervention in currency markets. This is due to the motivations behind Japan’s actions. An April 2005 Government Accountability Office (GAO) report found that although Japan had made significant interventions in currency markets in 2003 and 2004, “Japan did not meet the criteria [of a currency manipulator] in 2003 and 2004 in part because its exchange rate interventions were considered to be part of a macroeconomic policy to combat deflation” (Government Accountability Office 2005). In addition, the interventions had little lasting effect on the exchange rate (Nanto 2007).

Even so, most currency interventions in today’s economy carry with them the intent to depreciate the value of a country’s currency. China has led the way in preventing the appreciation of its currency, and other countries have followed suit to protect their export industries. The key question going forward will be how likely China is to appreciate its currency. The question is political in the way that China makes its decisions, but clearly has important

ramifications on the current account, Sino-U.S. relations and on the likeliness of other countries to devalue their own currency.

## V. Conclusion

Almost all the relevant data show an undervaluation of the Renminbi. The magnitude of the undervaluation is unclear, but some RPPP studies and both APPP studies suggest an inflation-adjusted exchange rate of 4 RMB/USD and below. When compared with other methodology, 4 RMB/USD appears to be a lower bound within the academic estimates of the value of the Renminbi.

First, the relevant RPPP estimates in this paper seem to be from before the 1994 Renminbi devaluation. After that devaluation, Chinese inflation was relatively high (possibly itself a result of the devaluation and effect on exports), and it's unlikely that the exchange rate has been at equilibrium since 1995. Using a base year of 1978 and 1980, the inflation-adjusted exchange rate is around 4RMB/USD. This is significantly lower than the current rate of 6.50, and implies 38% undervaluation. With later base years of 1985 and 1989, the inflation-adjusted exchange rates are 6.63 RMB/USD and 7.05 RMB/USD, much closer to the current value of 6.50 RMB/USD.

The APPP estimates of from the World Bank implied GDP calculation and *The Economist* Big Mac Index are generally in line with the RPPP estimates from 1994 and earlier. The World Bank implied rates show a current value of the Renminbi at 3.80 RMB/USD, with an implied undervaluation of 42%. The Big Mac Index suggests a fair value for the Renminbi even lower than the World Bank, 3.48 RMB/USD, which corresponds to 46% undervaluation. These appear to be high estimates of undervaluation when compared with other academic studies.

While it is difficult to say conclusively what a fair value is for the Renminbi, it is useful to consider possible thresholds and how long it would take to reach those levels. China maintains control over its currency, and it is unclear what rate China will choose to appreciate the Renminbi, if it allows appreciation at all. A relevant benchmark comes from the period of 2005 to 2008, when China allowed steady appreciation of the Renminbi after strong U.S. political pressures. During that period, China averaged 6.4% annual appreciation of the Renminbi. It also did so fairly evenly throughout the year. After 2008, China stopped Renminbi appreciation, and effectively repegged the Renminbi to the U.S. Dollar. In August 2010, however, China resumed appreciation. The figure below shows 6.4% appreciation starting in November 2010.

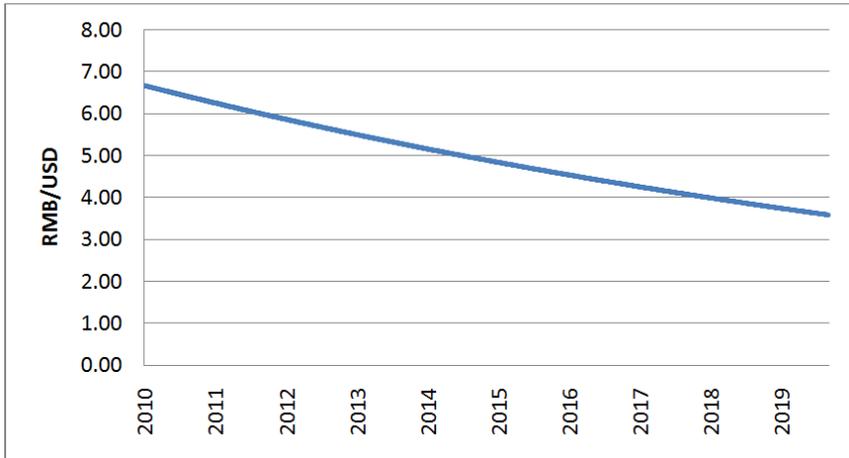


Figure 7: 6.4% RMB/USD Appreciation

This graph shows how the Renminbi would change assuming China allows 6.4% appreciation. In this scenario, it would take until April 2015 (approximately 4 years) to reach 5.0 RMB/USD. The exchange rate would then reach 4.5 RMB/USD in December 2016, which would be about 5.5 years. Finally, if China chooses to continue appreciation, the Renminbi will get to 4.0 RMB/USD in October 2018, almost eight years after the start point of appreciation. It is impossible to predict the level to which China will allow the Renminbi to appreciate and the rate at which it will take place. But if China cedes to international pressure, it may be a long time until the Renminbi reaches a value close to equilibrium.

Appendix

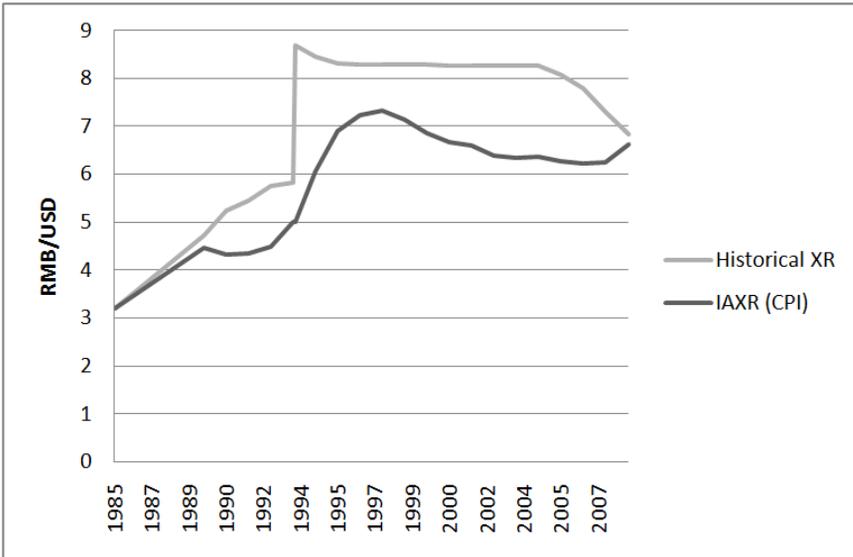


Figure 8: RMB/USD CPI (1985)



Figure 9: RMB/USD CPI (1989)

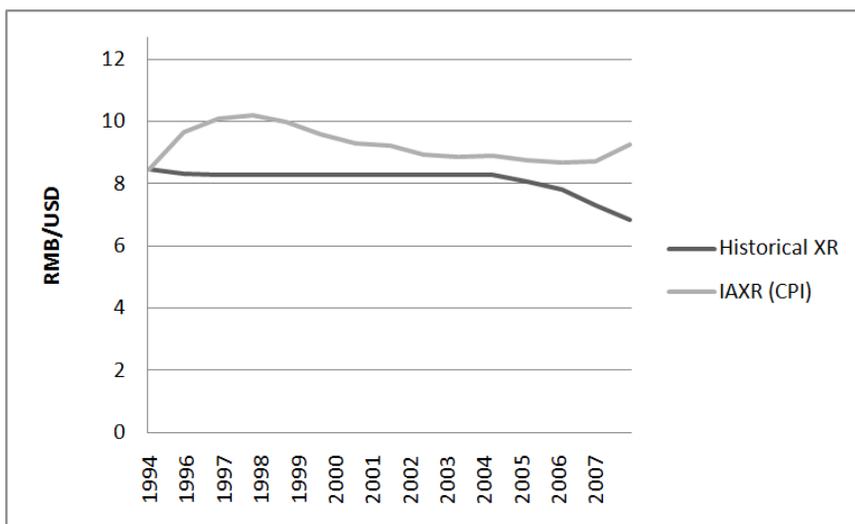


Figure 10: RMB/USD CPI (1994)

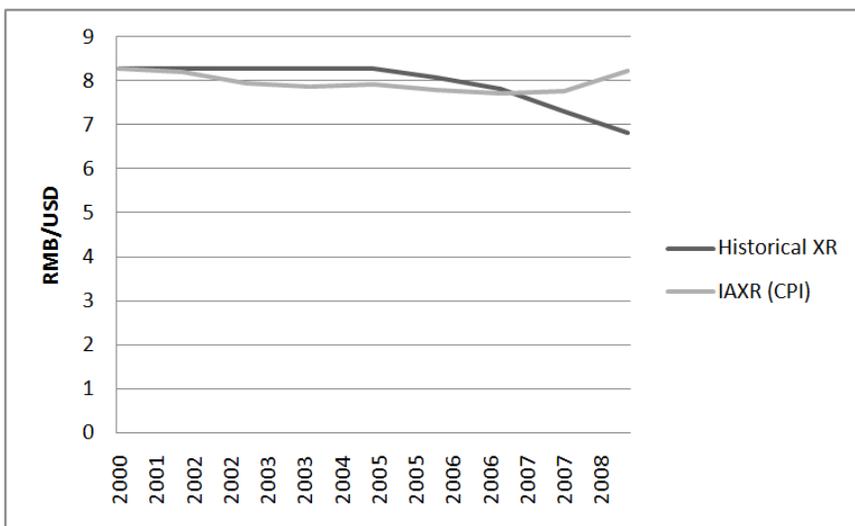


Figure 11: RMB/USD CPI (2000)

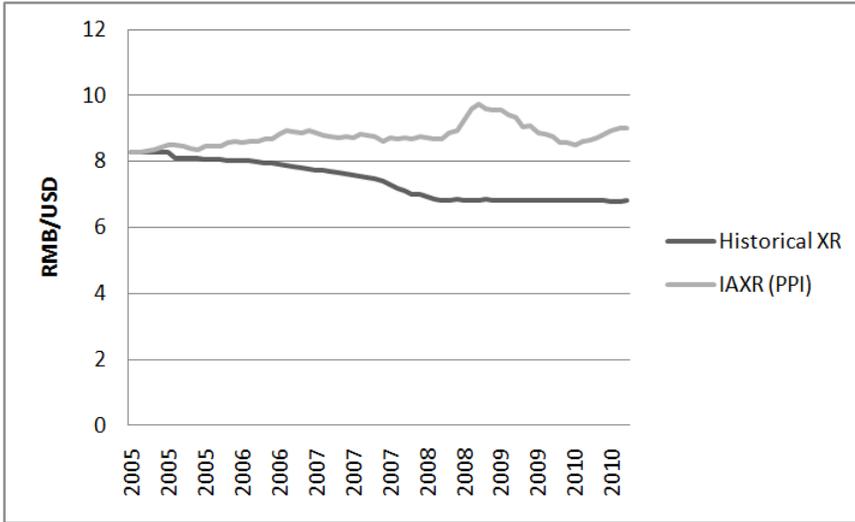


Figure 12: RMB/USD PPI (2005)

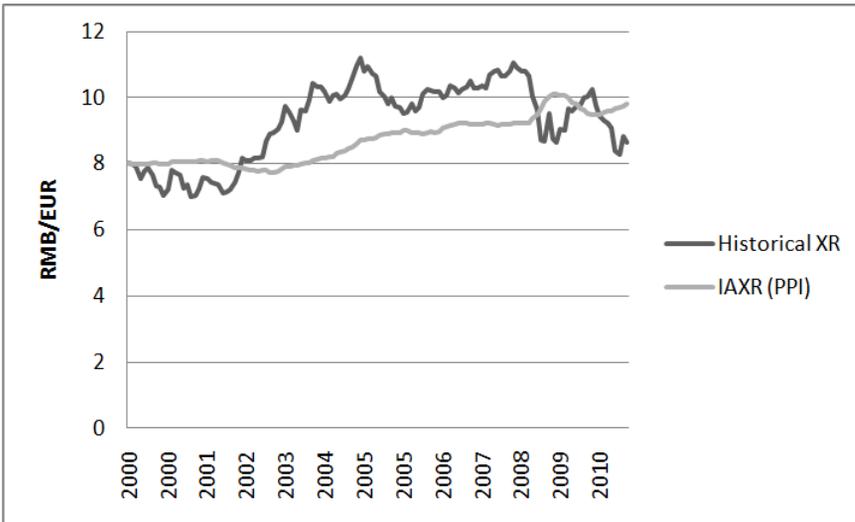


Figure 13: RMB/EUR PPI (2000)

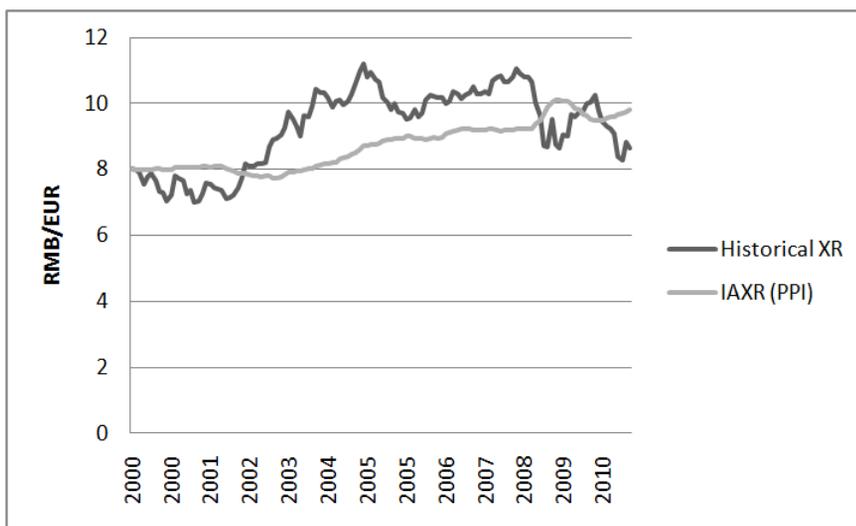


Figure 14: RMB/EUR PPI (2005)

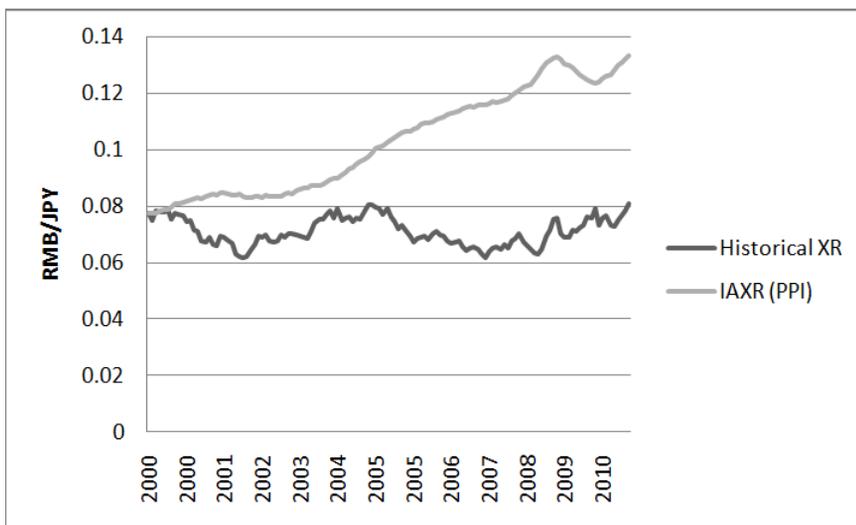


Figure 15: RMB/JPY PPI (2000)

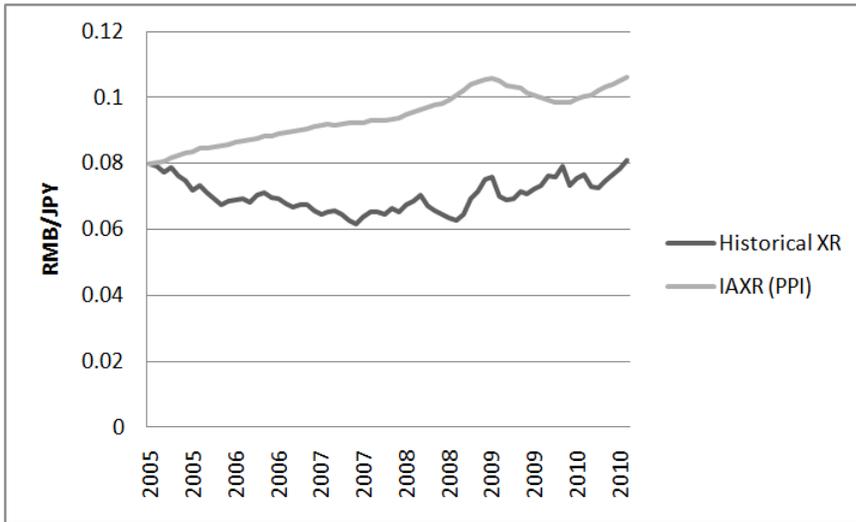


Figure 16: RMB/JPY PPI (2005)

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