# Assessment on Valuation of RMB

*– a triangular analysis approach*

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***Abstract*** – While RMB is pegged to the US dollar, the exchange rate between RMB and the euro[1] is not fixed, due to that the exchange rate between the euro and the US dollar is not fixed. Since RMB is not a small currency, its peg to the US dollar would exert a profound effect on the foreign exchange market, assuming that market forces are working to a certain extent. It is the effect on the exchange rate between the US dollar and the euro that the peg of RMB to the US dollar would force the exchange rate between the US dollar and the euro to depart from a "fair" market determined rate if the exchange rate between the US dollar and RMB is not set right. A reflective implication follows that the RMB monetary authority can neither "achieve" overall undervaluation nor "suffer from" overall overvaluation of RMB against its major trading partners' currencies by undervaluing or overvaluing RMB against the US dollar. Our analysis suggests that when RMB is overvalued relative to the US dollar, the euro would tend to be overvalued relative to the US dollar too, and vice versa. Inversely and likewise, an overvalued euro currency vis-à-vis the US dollar would imply a kind of overvaluation of RMB vis-à-vis the US dollar. The study makes an empirical assessment with supporting results.

**Key words:** exchange rate, RMB, US dollar, euro

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[1] It can be other currencies. The euro is used to represent all convertible currencies in a sense, but primarily because it has a similar size to the US dollar and RMB.

## 1. Introduction

Exchange rates and exchange rate arrangements have always been associated with balance of payments issues ever since international trade took place between nations. The exchange rate, together with its determination, valuation and adjustments, has always been one of the major factors that are perceived to have an effect on the improvement or deterioration in trade balance. In this paper, we pay attention specifically to the assessment of the right level of the exchange rate between RMB and the US dollar under the present arrangements and existing circumstances. Our starting point is an emphasis on the plain fact that RMB is a big currency, which rarely fits into any prevailing models that treat the currency under consideration in such a way that the currency and the associated economy do not influence the rest of world but are influenced by the rest of the world. Specifically, we bring the euro into play, developing a triangular analytical framework encompassing three currencies of comparable size, RMB, the US dollar and the euro. One of the arms of the triangle, the one between RMB and the US dollar, is rigid if not fixed, and the other two arms are flexible to change, mimicking the exchange rate arrangements between them. Interactions amongst them can be contemplated and assessed in this framework.

The peg of RMB to the US dollar, in a sense, creates a "basket" of two currencies of the US dollar and RMB. It would not have mattered if the pegging currency were a small currency, as the basket would have remained predominantly the US dollar's. But here the US dollar and RMB are of comparable size. Under such circumstance, the market force, if it ever works, and the economic fundamentals of the euro, would shift the euro and place it in an overall "fair" position against this "basket" of two

currencies, when RMB is undervalued/ overvalued against the US dollar. Likewise, the market force and the economic fundamentals of the US dollar, constrained by the peg of RMB, may also shift the US dollar's position against those freely floating currencies, including the euro. That is, RMB won't be kept undervalued/ overvalued against the euro at the same extent as RMB's undervaluation/ overvaluation against the US dollar. The extent to which RMB is undervalued/ overvalued to the euro would be smaller than that to which RMB is undervalued/ overvalued against the US dollar, albeit at the expense of distorting the euro dollar exchange rate. In a metaphor to a triangle, all the three arms may differ from their respective "right" lengths, because one of the arms, the one between the US dollar and RMB, is made too short (RMB overvalued against the US dollar) or too long (RMB overvalued against the US dollar), but the relationships between them are always consistently preserved. Given the above reasoning and analytical framework, the issue of whether RMB is undervalued or overvalued vis-à-vis the US dollar can then be established ultimately via scrutinizing the exchange rate of the US dollar vis-à-vis the euro.

Against the backdrop of the volume and growth in Sino-Euro trade, the study is particularly relevant empirically beyond the issue of undervaluation/ overvaluation of RMB vis-à-vis the US dollar. There are at least two affairs worthwhile being drawn attention to. First, due to the size of RMB, an undervalued/ overvalued RMB against the US dollar does not unconsciously translate to an undervalued/ overvalued RMB against the euro. Thus the peg of RMB to the US dollar that undervalues RMB vis-à-vis the US dollar won't help promote China's overall trade balance or export even if undervaluation of currencies can ever help improve nations' terms of trade. Second, no stability in RMB exchange rates can be claimed by pegging RMB to the US dollar,

as the exchange rate of RMB vis-à-vis currencies other than the US dollar would be as volatile as that between the US dollar and the euro and other convertible currencies. This kind of volatility does not matter much to the RMB monetary authority as long as the US is the predominant trading partner of China, but the US is not anymore. With the continual growth in Sino-Euro trade, which has overtaken Sino-US trade in volume, the peg becomes increasingly unsustainable and pointless except for providing ammunition for tactful and misguided argument beyond economic reasoning.

A brief review of what happened in the 19th century is relevant to contemporary studies of international trade, the balance of payments and international monetary systems, as to why there has been heated debate on the valuation of RMB in the last decate. The industrial revolution, starting in Britain and soon spreading to Germany, France, America and other western countries, took place and got an accelerating momentum earlier in the 19th century at a time that witnessed so many famous inventors and engineers whose names are still influential in our everyday life now: James Watt (1736-1819), Isambard Kingdom Brunel (1767-1849), Werner von Siemens (1816-1892), Gottlieb Daimler (1834-1900), Karl Benz (1844-1929), and Rudolf Diesel (1858-1913), to mention a few. The industrial revolution greatly increased productivity through inventions and the use of engines in production, and later, in mass production. A substantial portion of manufactured goods had to find foreign markets. Consumption and production were no longer confined within national borders. Consequently and subsequently, international trading rules and methods of settlements took their initial shape at the time, and continued to evolve over time. History seems to repeat itself in international trade and the associated

activities, though the directions of flows of manufactured goods, capital and labor have substantially changed. When there is a revolutionary change in productivity and/or a "sudden" increase in mass production in one country, frictions between trading partners is inevitable, which may or may not lead to a satisfactory new settlement in international trading rules and international monetary systems. A new round of such revolutionary change and increase has taken place since the last quarter century in the 20th century with its impacts being felt gradually and increasingly, which requires and prompts us to study an old issue with contemporary attributes.

The rest of the paper is organized as follows. The next section provides a brief review of the exchange rate determination literature with remarks, based on which a new approach that fits into the background and circumstances of this study is introduced. Section 3 presents the framework for the triangular analysis of exchange rate determination and adjustments. Section 4 describes the data and presents a general outlook of the movements and developments in the three pairs of exchange rates. Section 5 and 6 scrutinize the exchange rate between the US dollar and RMB with the triangular analytical framework developed earlier. While the former performs causality and influence analysis, which estimates the weight of influence parameter in the meantime, the latter assesses whether RMB is undervalued or overvalued against the US dollar with the derived weight of influence parameter. Finally, Section 7 summarizes the study.

## 2. Models of exchange rate determination and adjustments

### *2.1. Brief review of the literature*

This section provides a brief review of traditional models of exchange rate determination and the recent empirical literature. The Mundell-Fleming model works with the assumption that prices are fixed. The model has been originated in a series of papers and collections by Mundell (1960, 1961, 1962, 1963 and 1964) and Fleming (1962 and 1971). The background, history and development of the Mundell-Fleming model can be found in Mundell (2001) and Obstfeld (2001), which the interested reader may refer to. In contrast to the Mundell-Fleming model, the flexible price monetary model proposed by Frenkel (1976), as suggested by the name, works with the assumption that all prices are flexible. Recent studies include Rapach and Wohar (2002) who test the long-run monetary model of exchange rate determination for 14 industrialized countries using data spanning the late nineteenth or early twentieth century to the late twentieth century. Groen and Kleibergen (2003) find evidence for the validity of the monetary model within a panel for three major European countries, while the results based on individual models for each of these countries separately are less supportive. The portfolio balance approach to exchange rate determination is largely attributed to Branson (1972, 1976), McKinnon (1969) and Dornbusch (1975), with follow-ups of Branson et al. (1977, 1979), Girton and Henderson (1977) and Branson and Henderson (1985). The Dornbusch model (Dornbusch 1976) has the mixed features of the Mundell-Fleming model and the monetary model, though it stems from the former and, is sometimes called the Mundell-Fleming-Dornbusch model. Mussa (1982) also works on exchange rate dynamics in the early days of the recent float, which can produce the results of the Dornbusch model almost exactly if

the exogenous monetary factor is assumed to be observable and follow a random walk and expectations about the behavior of this factor is assumed to be formed and revised rationally. The real interest rate differential model of exchange rate determination by Frankel (1979) is an attempt to reveal how and why the differences arise as well as to reconcile the two approaches. Pierdzioch (2005, 2007), Borgersen and Gocke (2007), Bahmani-Oskooee and Panthamit (2006) and Villanueva (2005) have all tested the Dornbusch model with mixed findings.

### *2.2. Remarks*

As can be observed in the empirical literature, the test results produced by the above models are mixed – unconvincing or controversial sometimes. They include the economic fundamentals of relevance from various perspectives, which is valid as long as the fundamentals are rightly represented by the chosen variables and their behavior is correctly predicted and modeled. This has been proven hard and is further compounded by the quality of data and the capability of econometric procedures. There are at least three reasons why a new approach is required for analyzing the value of RMB. First, the majority of the models and empirical studies assume a small country stance that the currency and the associated economy can only be influenced by the rest of the world but won't influence the rest of world, which can hardly fit into the case of RMB. Second, whilst determining the right or fair exchange rate is important, detecting the deviation of the exchange rate from the right or fair exchange rate is paramount. Conversely, the former has attracted much attention over many decades, but the latter has barely been investigated, and when investigated, is investigated as a sideline matter rather than a principal issue. Third, almost all the models and empirical studies have been set up, implemented and curried out between

pairs of currencies, usually between the US dollar and the currencies under investigation and, to a less extent, between the Deutsche mark and the currencies under investigation, the euro and the currencies under investigation, and so on. The influence of a "third" currency has not been considered.

### *2.3. A new approach*

What we adopt in the analysis in this paper is a simple, straightforward but reliable relationship between three currencies. It is a triangular relationship between them that one exchange rate cannot be arbitrarily set without affecting the other two pairs of exchange rates or without being constrained by the other two pairs of exchange rates. This sounds too simple without taking the complex relationship between the three currencies into account. RMB is pegged to the US dollar, so the exchange between them can be at the wrong level, i.e., RMB can be undervalued or overvalued against the US dollar. The exchange rate between the US dollar and the euro is floating and is supposedly fair; and if so, the extent to which RMB is undervalued or overvalued against the US dollar would be translated to the undervaluation or overvaluation of RMB against the euro to the same extent. However, RMB is not a small currency, its peg to the US dollar would have a profound effect on the floating exchange rate between the US dollar and the euro, forcing the exchange rate between the US dollar and the euro to depart from a "fair" market determined rate if the exchange rate between the US dollar and RMB is not set right. Therefore, whether RMB is undervalued or overvalued against the US dollar and the extent of undervaluation or overvaluation can be deduced from the degree of distortion in the dollar euro exchange rate. We pursue this line of inquiry in this study.

## 3. Triangular analysis of exchange rate determination and adjustments

The setting of our model is as follows. The exchange rate of RMB (¥) vis-à-vis the US dollar ($) is 1$ for α¥; the exchange rate of the euro (€) vis-à-vis the US dollar is 1€ for β$; and the exchange rate of RMB vis-à-vis the euro is therefore 1€ for γ¥ ($\gamma = \alpha\beta$). The analytical framework and the relationships are illustrated by Figure 1, with three vertexes of ¥, $ and € and three arms of α, β and γ linking the three vertexes.

**{Figure 1 here}**

While RMB is pegged to the US dollar, the exchange rate between RMB and the euro is freely floating, in much the same way as the exchange rate between the US dollar and the euro. When RMB is undervalued/ overvalued against the US dollar, the market force and the economic fundamentals of the euro would shift the euro and place it in an overall "fair" position against a "basket" of two currencies of RMB and the US dollar. The rationale for such a scenario can be illustrated as follows. For example, suppose RMB is undervalued against the US dollar by 20 percent. If RMB were a small currency and the exchange rate between the US dollar and the euro were fair, there would have been a 20 percent overvaluation of the euro against RMB too. But as RMB is not a small currency and the two arms of the triangle, $\beta$ and $\gamma$, are changeable, it could turn out to be a case where the euro's overvaluation against RMB is smaller than that in the RMB dollar exchange rate, say, at 10 percent and, in the meantime, the euro becomes undervalued against the US dollar by 10 percent. Overall, the euro enjoys a "fair" exchange rate against the "basket" of RMB and the US dollar. Indeed, the market force and economic fundamentals may not only place the floating

euro, but also the fixed RMB, in such a "fair" position, with further distortions on the foreign exchange market involving other currencies. Moreover, the US dollar may achieve such an overall "fair" position too, though as the anchor currency for RMB its 20 percent overvaluation against RMB remains; in a sense, the anchor can be moved as the ship fastened to it is too big. Formal analysis follows.

Denote $\bar{\alpha}$ the fair exchange rate of ¥ vis-à-vis $; denote $\bar{\beta}$ the fair exchange rate of $ vis-à-vis €; and denote $\bar{\gamma}$ the fair exchange rate of ¥ vis-à-vis €. Further let $\frac{\alpha}{\bar{\alpha}} = \lambda_1$, $\frac{\beta}{\bar{\beta}} = \lambda_2$, and $\frac{\gamma}{\bar{\gamma}} = \lambda_3$. The ratios are indications of undervaluation or overvaluation of one currency relative to the other currency, which can be summarized as follows:

¥ is undervalued vis-à-vis $ when $\lambda_1 > 1$, overvalued otherwise;

$ is undervalued vis-à-vis € when $\lambda_2 > 1$, overvalued otherwise;

¥ is undervalued vis-à-vis € when $\lambda_3 > 1$, overvalued otherwise.

For example, if $\lambda_2 = 1.2$, then € is overvalued against $ by 20 percent. The following relationship between the three ratios holds:

$$\lambda_1 \lambda_2 = \lambda_3 \tag{4}$$

Specific to the circumstances examined in this study, if RMB were a small currency without any influence on other exchange rates, $\lambda_2$ would have been one and $\lambda_3 = \lambda_1$ would have hold. As RMB is not a small currency, the undervaluation/ overvaluation of RMB against the US dollar would tend to cause the dollar euro exchange rate to

depart from its "fair" market determined rate, and to reduce the distortion in the RMB euro exchange rate. Let's introduce a weight of influence function:

$$f(RMB, w) = \left(\frac{1}{\lambda_1}\right)^w \tag{5}$$

so that:

$$\lambda_3 = \left(\frac{1}{\lambda_1}\right)^w \cdot \lambda_1 \tag{6}$$

and

$$\lambda_2 = \frac{\lambda_3}{\lambda_1} = \left(\frac{1}{\lambda_1}\right)^w \cdot 1 \tag{7}$$

If $w = 0$, the influence of RMB is nil, then $\lambda_3 = \lambda_1$ and $\lambda_2 = 1$. That is, the distortion in the RMB euro exchange rate is of the same extent as that in the RMB dollar exchange rate, and the dollar euro exchange rate remains its fair market determined rate. $w$ increases with the influence of RMB, with $\lambda_3 = 1$ and $\lambda_2 = \frac{1}{\lambda_1}$ at $w = 1$. That is, the RMB euro exchange rate becomes fair, and all the distortion in the RMB dollar exchange rate has shifted to impact the dollar euro exchange rate that the distortion in the dollar euro exchange rate is as great as that in the RMB dollar exchange rate. $w$ should usually be confined between zero and one, though it is possible for $w$ to be greater than one. Under the circumstances that $w$ is greater than one, an overvalued/ undervalued RMB vis-à-vis the US dollar makes the euro be overvalued/ undervalued to such a great extent that it is overvalued/ undervalued against not only the US dollar but also RMB. The distortion sharing and re-distribution, and the resulting valuation profiles are summarized as follows, with o indicating overvaluation and u indicating undervaluation).

a) $0 < w < 1$

RMB's overvaluation vis-à-vis the US dollar, or $\lambda_1 < 1$, results in:

The US dollar's undervaluation vis-à-vis the euro, or $\lambda_2 > 1$;

RMB's overvaluation vis-à-vis the euro to an extent smaller than that of RMB's overvaluation vis-à-vis the US dollar, or $\lambda_1 < \lambda_3 < 1$.

(Valuation profiles: RMB, o, o; dollar: u, u; euro: o, u)

RMB's undervaluation vis-à-vis the US dollar, or $\lambda_1 > 1$, results in:

The US dollar's overvaluation vis-à-vis the euro, or $\lambda_2 < 1$;

RMB's undervaluation vis-à-vis the euro to an extent smaller than that of RMB's overvaluation vis-à-vis the US dollar, or $\lambda_1 > \lambda_3 > 1$.

(RMB, u, u; dollar: o, o; euro: u, o)

b) $w > 1$

RMB's overvaluation vis-à-vis the US dollar, or $\lambda_1 < 1$, results in:

The US dollar's undervaluation vis-à-vis the euro, or $\lambda_2 > 1$, to a great extent;

RMB's undervaluation vis-à-vis the euro, or $\lambda_3 > 1$.

(RMB, o, u; dollar: u, u; euro: o, o)

RMB's undervaluation vis-à-vis the US dollar, or $\lambda_1 > 1$, results in:

The US dollar's overvaluation vis-à-vis the euro, or $\lambda_2 < 1$, to a great extent;

RMB's overvaluation vis-à-vis the euro, or $\lambda_3 < 1$.

(RMB, u, o; dollar: o, o; euro: u, u)

Only one of the three currencies can be undervalued against the second while overvalued against the third currency, which stands in a relatively fair position and a much smaller distortion in its overall valuation against the other two currencies. In the case of $0 < w < 1$, it is the euro. When the euro is overvalued/ undervalued against the US dollar, it is undervalued/ overvalued against RMB; and under such circumstances, the US dollar is undervalued/ overvalued against both the euro and RMB, and RMB is overvalued/ undervalued against both the US dollar and euro. If $w > 1$, RMB has shifted to this fairer position ironically. That is, when RMB is undervalued/ overvalued against the US dollar, it is overvalued/ undervalued against the euro, and on average the distortion in its overall valuation against the US dollar and the euro is much smaller, as its undervaluation/ overvaluation against the US dollar compensates to a certain extent for its overvaluation/ undervaluation against the euro; whereas under such circumstances, the euro is undervalued/ overvalued against both the US dollar and RMB, and the US dollar is overvalued/ undervalued against both the euro and RMB.

One of the implications from the above analysis is that the euro tends to be overvalued/ undervalued against the US dollar when RMB is overvalued/ undervalued against the US dollar. This conveys a very useful message and provides us with a powerful means for assessing the valuation of RMB. That is, the extent to which RMB is overvalued/ undervalued vis-à-vis the US dollar can be deduced from the extent to which the euro is overvalued/ undervalued vis-à-vis the US dollar. i.e.:

$$\lambda_1 = \left(\frac{1}{\lambda_2}\right)^{\frac{1}{w}} \tag{8}$$

Like any other studies in economics or social sciences, human beings' judgment can never be detached from theoretical analysis and inference – we won't know $\lambda_1$ if we don't know $\lambda_2$ and the above formula becomes powerless. However if a consensus can be formed on whether the euro is overvalued/ undervalued against the US dollar and the extent of the euro's overvaluation/ undervaluation against the US dollar, the extent of RMB's overvaluation/ undervaluation against the US dollar can be determined with a given weight of influence $w$ . This estimation procedure is presented and demonstrated in the following.

A distorted RMB exchange rate against the US dollar distorts the exchange rate between the euro and the US dollar. This effect of the fixed/pegged RMB dollar exchange rate on the currencies adopting a floating exchange rate regime can be called the RMB effect. To evaluate this effect on the euro, which also justifies the functional form of the weight of influence function of equation (5), we take a logarithm of equation (7), yielding:

$$Ln(\lambda_2) = -wLn(\lambda_1) \tag{9}$$

which also means:

$$Ln\left(\frac{\beta}{\overline{\beta}}\right) = -wLn\left(\frac{\alpha}{\overline{\alpha}}\right) \tag{10}$$

With rearrangements, the following is reached:

$$\begin{aligned} Ln(\beta) &= wLn(\overline{\alpha}) - Ln(\overline{\beta}) - wLn(\alpha) \\ &= c - wLn(\alpha) \end{aligned} \tag{11}$$

$w$ measures the RMB effect on the dollar euro exchange rate and is also the parameter in the weight of influence function. Moreover $w$ is the parameter of the error correction term or the cointegration vector in an error correction model, which will be explained in Section 5 and can be empirically implemented and tested for a range of hypotheses.

## 4. Data and general outlook

Applying the triangular analytical framework developed in the previous section and implementing its corresponding econometric testing procedures, the exchange rates between the three currencies of the euro, the dollar and RMB and their changes are inspected and scrutinized in this section and the next. Our data set starts in April 2002 and ends in March 2010 at the monthly frequency. The three pairs of exchange rates are plotted in Figure 2. Relevant summary statistics are reported in Table 1.

**{Figure 2 here}**

**{Table 1 here}**

The world's economy enjoyed one of the remarkable prosperous periods since the new Millennium until the financial crisis and the western economies grew more or less at the same pace and performed similarly well in this period. So we would expect no large changes in the euro dollar exchange rate. The euro was launched on the first day of January in 1999 at par with the US dollar. The euro swung greatly on the

currency market, fell to 0.8 dollars briefly and then rose to 1.2 dollars in its first four years. It shot at 1.36 dollars before dropping and stabilizing around the level of 1.2 dollars again in the middle of 2005. Following several years' price discovery and allowing a wide margin, one euro for 1.2 dollars can be deemed as a ceiling for a fair exchange rate between the US dollar and the euro. However and since the end of 2005, the euro rose steadily, reaching a historic echelon of 1.58 dollars in the spring of 2008. What do these patterns of euro dollar exchange rate movements tell us about the effect on the euro dollar exchange rate of the valuation of the RMB dollar exchange rate? What happened in 2005? It was the RMB effect. The PBC announced/ adopted managed floating in July 2005[2]. Regardless whether the regime is managed floating, crawling peg or fixed peg, the plain fact is that RMB dollar exchange rate was adjusted up from ¥8.27-8.28/$, which had been maintained for years, to ¥8.11/$ in July 2005; RMB had steadily and consistently appreciated against the US dollar until the middle of 2008, and has then been kept at ¥6.82-6.83/$. Observing the movements of the three pairs of exchange rates in Figure 2 and inspecting the actual exchange rates, the RMB effect on the euro started being undergone some two years after the launch of the euro. The effect had been rather fully exerted by the time of 2004, i.e., the distorted euro dollar exchange rate stabilized at that level, albeit the exchange rate appeared distorted. An appreciating RMB during the period of 2005 – 2008 caused the euro to become increasingly overvalued against the dollar, climaxing in April 2008, coinciding with Bear Stearn's collapse and sale to JP Morgan Chase and triggering the correction or reversion in the dollar euro exchange rate.

[2] The IMF classification of the RMB de facto exchange rate regime is crawling peg dated February 25, 2009 with data as of April 2008, and conventional fixed peg dated December 22, 2006 with data as of July 2006 and dated July 18, 2006 with data as of December 2005. However, the date for changeover ought to be July 2005 according to changes in fluctuations in the exchange rate. Although the range of fluctuations was narrower than that defined by the IMF for another two years, it was much greater than that (zero standard deviation) of pre July 2005.

## 5. Causality and influence analysis

Now we turn to formal testing procedures, which implement the economic analysis in Section 3 with econometric modeling, and determine the weight of influence in the meantime. Let us express the exchange rates in equation (11) explicitly with currency symbols and a time subscript, which gives:

$$e_{\$/€,t} = c - w \cdot e_{Y/\$,t} \qquad (11')$$

where $e_{\$/€,t}$ is the exchange rate between the US dollar and the euro in logarithm, and $e_{Y/\$,t}$ is the exchange rate between RMB and the US dollar in logarithm. Equation (11) or equation (11') amounts to testing cointegration between the dollar euro exchange rate and the RMB dollar exchange rate and estimating cointegration vector parameters. Prior to cointegration tests, it has to be verified that the two exchange rates are I(1) series, i.e., they are non stationary in levels and stationary after taking a first difference operation, which is confirmed and reported in Table 2. We then apply the Johansen cointegration test procedure, which indicates that there is one and only one cointegration vector between the two exchange rates. Table 3 summarizes the results. Further the cointegration parameters are estimated to be $[-2.0070 \quad 1 \quad 0.8530]$, or the error correction term is $[-2.0070 \quad 1 \quad 0.8530][1 \quad e_{\$/€,t} \quad e_{Y/\$,t}]'$ = $(-0.20070 + e_{\$/€,t} + 0.8530\, e_{Y/\$,t})$, which indicates $w = 0.8530$.

**{Table 2 here}**

**{Table 3 here}**

Next, we implement an error correction model as follows:

$$\begin{aligned}\Delta e_{\$/€,t} &= \mu_1 + \theta_1 ecm_{t-1} + \sum_{i=1}^{p} \rho_{11i} \Delta e_{\$/€,t-i} + \sum_{i=1}^{p} \rho_{12i} \Delta e_{Y/\$,t-i} + \varepsilon_{1t} \\ \Delta e_{Y/\$,t} &= \mu_2 + \theta_2 ecm_{t-1} + \sum_{i=1}^{p} \rho_{21i} \Delta e_{\$/€,t-i} + \sum_{i=1}^{p} \rho_{22i} \Delta e_{Y/\$,t-i} + \varepsilon_{2t}\end{aligned} \tag{12}$$

In the above model, $ecm_t = \left(-0.20070 + e_{\$/€,t} + 0.8530\, e_{Y/\$,t}\right)$ is the error correction term, $\mu_1$ and $\mu_2$ are intercepts, $\theta_1$ and $\theta_2$ are the coefficients for the error correction term, and $\varepsilon_{1t}$ and $\varepsilon_{2t}$ are residuals; subscript 1 indicates coefficients for the variables in the $\Delta e_{\$/€,t}$ equation, and subscript 2 indicates coefficients for the variables in the $\Delta e_{Y/\$,t}$ equation. $\rho_{11i}$ is the coefficient for $\Delta e_{\$/€,t}$ at lag $i$ in the $\Delta e_{\$/€,t}$ equation, $\rho_{12i}$ is the coefficient for $\Delta e_{Y/\$,t}$ at lag $i$ in the $\Delta e_{\$/€,t}$ equation, $\rho_{21i}$ is the coefficient for $\Delta e_{\$/€,t}$ at lag $i$ in the $\Delta e_{Y/\$,t}$ equation, and $\rho_{22i}$ is the coefficient for $\Delta e_{Y/\$,t}$ at lag $i$ in the $\Delta e_{Y/\$,t}$ equation. A statistically significant $\theta_1$ indicates that the dollar euro exchange rate is Granger caused by the RMB dollar exchange rate in the long run; while a statistically significant $\theta_2$, if it happens, indicates that the RMB dollar exchange rate is Granger caused by the dollar euro exchange rate in the long run. Likewise, significant $\rho_{12i}$ implies causality of the RMB dollar exchange rate to the dollar euro exchange rate in the short term, and significant $\rho_{21i}$ implies causality of the dollar euro exchange rate to the RMB dollar exchange rate in the short term.

**{Table 4 here}**

Results from estimating equation (12) are reported in Table 4, with part (a) for the $\Delta e_{\$/€,t}$ equation and part (b) for the $\Delta e_{Y/\$,t}$ equation. Lag length of 12 is chosen for

monthly data and with compromise between the different information criteria. Under the current exchange rate arrangement, it is obvious that the RMB dollar exchange rate won't be Granger caused by the dollar euro exchange rate, and indeed, anything else. Table 4 (b) confirms this. All the coefficients involving the dollar euro exchange rate are statistically insignificant, including the long run parameter, $\theta_2$ and the short term parameters, $\rho_{211}$ to $\rho_{2112}$. What interest us are the results in Table 4 (a). $\theta_1$ is significant at the 5 percent level with the right sign, indicating that an appreciating RMB causes the euro to appreciate against the US dollar in the long run. With regard to short term causality, at lag 1 $\rho_{121}$ is significantly negative at the 1 percent level, and at lag 6 $\rho_{126}$ is significantly negative at the 5 percent level. That is, an appreciating RMB causes the euro to appreciate against the US dollar in the short term as well.

Essentially, we can now formally designate $w$ the weight of influence parameter for measuring the effect of RMB's influence on the dollar euro exchange rate, not the other way round, after a significant $\theta_1$ and insignificant $\theta_2$ have been confirmed. Otherwise, this weight of influence parameter $w$ can measure either the effect of RMB's influence on the dollar euro exchange rate or the effect of RMB being influenced by the euro in terms of the dollar euro exchange rate; and the weight of influence function can be the weight of influence function of RMB on the dollar euro exchange rate as well as the weight of influence function of the euro on RMB. Although we believe it is RMB that influences the dollar euro exchange rate not the vice versa, and our theoretical analysis, coupled with the actual exchange rate arrangements of the three currencies, also suggests so, it is not until the confirmation of a significant $\theta_1$ and insignificant $\theta_2$ can we formally declare that the weight of

influence parameter *w* measures the effect of RMB's influence on the dollar euro exchange rate. The empirical analysis and estimation in this section has duly fulfilled this task.

## 6. Is RMB undervalued vis-à-vis the US dollar? Or is it overvalued?

Applied the weight of influence parameter $w = 0.8530$ estimated and derived from the previous section to equation (8), assessment of RMB's valuation vis-à-vis the US dollar is carried out with various and a wide range of assumptions of a fair exchange rate between the US dollar and the euro, stretching from \$1.1/€ to \$1.7/€. Table 5a presents the assessment of relative overvaluation/ undervaluation of the three currencies in March 2008 and Table 5b presents the assessment for March 2010. Figure 3a and Figure 3b plot the assessment graphically for the two time points respectively.

**{Table 5 here}**

**{Figure 3 here}**

Let us inspect Table 5a and Figure 3a first. At the time in March 2008, the dollar euro exchange rate reached the pike of \$1.58/€, which does not look fair at all. If we assume conservatively the fair dollar euro exchange rate was \$1.4/€ at the time, then RMB was overvalued by 13 percent against the US dollar with a $\gamma_1$ of 0.87. The lower the fair exchange rate of the US dollar vis-à-vis the euro, the greater the

overvaluation of RMB vis-à-vis the US dollar. e.g., with the fair dollar euro exchange rate being assumed to be $1.3/€, which was also fairly reasonable and likely, RMB would have been overvalued by 20 percent against the US dollar with $\gamma_1$ being 0.80. Whether it coincided with the pike of the last financial crisis or there was a kind of linkage is beyond the scope of this study, but the dollar euro exchange rate did start the correction and revision course then, which witnessed the exchange rate falling to around $1.3/€ a year later. It can be inferred that by any conventional wisdom RMB was overvalued vis-à-vis the dollar as in March 2008, as was the euro. Then we assess the value of RMB relative to the US dollar two years later in March 2010 with Table 5b and Figure 3b. Depending on one's belief in the fair euro dollar exchange rate, RMB could be considered to be overvalued vis-à-vis the US dollar by some 4 percent to 13 percent in March 2010 if the fair exchange rate between the euro and the dollar is in the range of $1.2-1.3/€; or about right if one thinks a fair dollar euro exchange rate is about $1.3-1.4/€.

To conclude this section's analysis, RMB appeared to be overvalued against the US dollar in certain periods since the last half of 2005, especially around the spring and summer in 2008. RMB is unlikely to be significantly undervalued or overvalued in the medium to long terms though, due to the flexible arms between the US dollar and the euro and between RMB and the US dollar, unless the euro dollar exchange rate is also significantly distorted.

## 7. Conclusion

A triangular analytical framework for exchange rate determination and adjustments has been developed in this study involving three currencies of comparable size, RMB, the US dollar and the euro, mimicking the exchange rate arrangements between them. The influence of RMB and the effect of an overvalued/ undervalued RMB against the US dollar on the foreign exchange market have been analyzed. Our theoretical analysis suggests that the peg of RMB to the US dollar has a profound effect on the floating exchange rate between the US dollar and the euro, forcing the exchange rate between the US dollar and the euro to depart from a "fair" market determined rate, which has been confirmed by causality tests. A consistent relationship of the triangular analytical framework dictates that when RMB is overvalued relative to the US dollar, the euro would tend to be overvalued relative to the US dollar too, and vice versa. Applying this analytical framework, the study has then examined the exchange rate between the US dollar and RMB via scrutinizing the exchange rate of the US dollar vis-à-vis the euro.

The study has two findings, one direct and one implied, to report; both of them are of high market and strategic implications globally. It has been found that the movements in the RMB dollar exchange rate do influence the dollar euro exchange rate and the former do have a causality effect on the latter, in both the long run and the short term. This causality has resulted in an increasingly and incredibly overvalued euro against the US dollar, which peaked in March 2008 and coincided with the accumulation of the last financial crisis. By any conventional measures the euro appears to be overvalued vis-à-vis the US dollar, implying that RMB is also overvalued vis-à-vis

the US dollar. The RMB dollar exchange rate and the dollar euro exchange rate are not two detached variables. It is worthwhile reiterating here that it is impossible for the dollar euro exchange rate remains fair at the same time when RMB is undervalued/ overvalued against the US dollar, which violates the consistent relationships of the triangle. These consistent relationships dictate that the euro is overvalued against the US dollar only when RMB is overvalued against the US dollar too; and if the dollar euro exchange rate is fair, the RMB dollar exchange rate must be fair too.

While it is self evident that the RMB monetary authority can achieve no stability in RMB exchange rates by pegging RMB to the US dollar, one of the implications of the study is that the RMB monetary authority can neither "achieve" overall undervaluation nor "suffer from" overall overvaluation of RMB against its major trading partners' currencies by undervaluing or overvaluing RMB against the US dollar, which only creates and leads to distortions on the foreign exchange market. With Sino-Euro trade overtaking Sino-US trade in volume, the peg becomes increasingly unsustainable and pointless except for providing ammunition for tactful and misguided argument beyond economic reasoning. That floating RMB on the foreign exchange market does no harm to all the players is a logical deduction.

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**Tables**

**Table 1.** Summary statistics of exchange rates

| | Time period | $/€ | ¥/$ | ¥/€ |
|---|---|---|---|---|
| Average | 07/2005-03/2010 | 0.24% | -0.34% | -0.10% |
| | 07/2005-03/2008 | 0.83% | -0.50% | 0.33% |
| | 04/2008-03/2010 | -0.57% | -0.11% | -0.70% |
| Cumulative | 07/2005-03/2010 | 13.63% | -19.18% | -5.91% |
| | 07/2005-03/2008 | 27.42% | -16.50% | 10.80% |
| | 04/2008-03/2010 | -13.79% | -2.68% | -16.71% |

**Table 2.** Augmented Dickey-Fuller unit root tests

| | Level | First difference |
|---|---|---|
| ¥/$ | -2.2037 | -3.3736** |
| $/€ | -2.1693 | -3.4662** |

Asymptotic critical values are from Davidson and Mackinnon (1993). Lag length is chosen with a compromise between the Akaike and Schwarz information criteria.
* significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

**Table 3.** Johansen cointegration tests

| $\lambda_{max}$ | | Trace | | Trace-95% |
|---|---|---|---|---|
| r = 1 | 3.0707 | r = 1 | 3.0707 | 3.8400 |
| r = 2 | 16.9358 | r = 2 | 20.0065 | 15.4100 |

**Table 4.** Error correction model results

(a)

| $/€ | Coef | std err | *t*- stat |
|---|---|---|---|
| $\mu_1$ | -0.0395** | 0.0179 | -2.2045 |
| $\theta_1$ | -1.1189** | 0.4752 | -2.3549 |
| $\rho_{111}$ | 0.7207* | 0.3953 | 1.8233 |
| $\rho_{112}$ | 0.6358 | 0.3862 | 1.6465 |
| $\rho_{113}$ | 0.8528** | 0.3425 | 2.4902 |
| $\rho_{114}$ | 0.4621 | 0.3079 | 1.5007 |
| $\rho_{115}$ | 0.4390* | 0.2489 | 1.7641 |
| $\rho_{116}$ | 0.4629* | 0.2331 | 1.9861 |
| $\rho_{117}$ | 0.2807 | 0.2275 | 1.2341 |
| $\rho_{118}$ | 0.1908 | 0.2194 | 0.8697 |
| $\rho_{119}$ | 0.0781 | 0.2043 | 0.3826 |
| $\rho_{1110}$ | 0.1457 | 0.1962 | 0.7425 |
| $\rho_{1111}$ | 0.1560 | 0.1829 | 0.8531 |
| $\rho_{1112}$ | 0.0685 | -0.1712 | 0.4003 |
| $\rho_{121}$ | -3.3862*** | 1.2333 | -2.7456 |
| $\rho_{122}$ | -1.9539 | 1.2497 | -1.5636 |
| $\rho_{123}$ | -1.0101 | 1.2441 | -0.8119 |
| $\rho_{124}$ | 0.5106 | 1.1854 | 0.4307 |
| $\rho_{125}$ | -1.6675 | 1.1978 | -1.3922 |
| $\rho_{126}$ | -2.6194** | 1.2180 | -2.1506 |
| $\rho_{127}$ | 1.8435 | 1.2385 | 1.4885 |
| $\rho_{128}$ | 0.8295 | 1.2787 | 0.6487 |
| $\rho_{129}$ | -0.3163 | 1.2820 | -0.2467 |
| $\rho_{1210}$ | -1.6166 | 1.3430 | -1.2037 |
| $\rho_{1211}$ | -0.4094 | 1.2705 | -0.3223 |
| $\rho_{1212}$ | 0.3350 | 1.2507 | 0.2679 |

(b)

| Y/$ | coef | std err | *t*- stat |
|---|---|---|---|
| $\mu_2$ | -0.0017 | 0.0023 | -0.5562 |
| $\theta_2$ | -0.0351 | 0.0607 | -0.5792 |
| $\rho_{211}$ | 0.0330 | 0.0505 | 0.6536 |
| $\rho_{212}$ | 0.0203 | 0.0493 | 0.4109 |
| $\rho_{213}$ | -0.0198 | 0.0437 | -0.4523 |
| $\rho_{214}$ | -0.0194 | 0.0393 | -0.4938 |
| $\rho_{215}$ | 0.0184 | 0.0318 | 0.5799 |
| $\rho_{216}$ | 0.01682 | 0.0298 | 0.5653 |
| $\rho_{217}$ | 0.0083 | 0.0290 | 0.2855 |
| $\rho_{218}$ | 0.0098 | 0.0280 | 0.3514 |
| $\rho_{219}$ | 0.0022 | 0.0261 | 0.0832 |
| $\rho_{2110}$ | 0.0152 | 0.0251 | 0.6087 |
| $\rho_{2111}$ | 0.0074 | 0.0234 | 0.3158 |
| $\rho_{2112}$ | 0.0016 | 0.0219 | 0.0754 |
| $\rho_{121}$ | 0.2996* | 0.1575 | 1.9026 |
| $\rho_{122}$ | 0.2270 | 0.1595 | 1.4230 |
| $\rho_{123}$ | 0.0703 | 0.1588 | 0.4426 |
| $\rho_{124}$ | -0.1358 | 0.1513 | -0.8971 |
| $\rho_{125}$ | 0.0134 | 0.1529 | 0.0872 |
| $\rho_{126}$ | 0.0253 | 0.1555 | 0.1626 |
| $\rho_{127}$ | 0.0054 | 0.1581 | 0.0340 |
| $\rho_{128}$ | 0.0286 | 0.1633 | 0.1754 |
| $\rho_{129}$ | -0.2177 | 0.1637 | -1.3299 |
| $\rho_{1210}$ | -0.0189 | 0.1715 | -0.1100 |
| $\rho_{1211}$ | 0.2847 | 0.1622 | 1.7552 |
| $\rho_{1212}$ | -0.0126 | 0.1597 | -0.0781 |

* significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

**Table 5a.** Assessment of currency valuation: March 2008

| $\overline{\beta}$ | 1.10 | 1.20 | 1.30 | 1.40 | 1.50 | 1.60 | 1.70 |
|---|---|---|---|---|---|---|---|
| $\gamma_1$ | 0.65 | 0.72 | 0.80 | 0.87 | 0.94 | 1.01 | 1.09 |

**Table 5b.** Assessment of currency valuation: March 2010

| $\overline{\beta}$ | 1.10 | 1.20 | 1.30 | 1.40 | 1.50 | 1.60 | 1.70 |
|---|---|---|---|---|---|---|---|
| $\gamma_1$ | 0.79 | 0.87 | 0.96 | 1.04 | 1.13 | 1.22 | 1.31 |

**Figures**

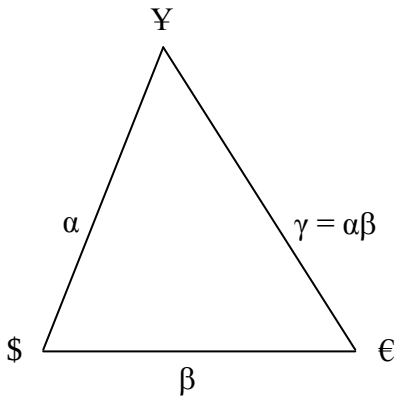



**Figure 1.** Triangular presentation of exchange rates and relationships between €, $ and ¥

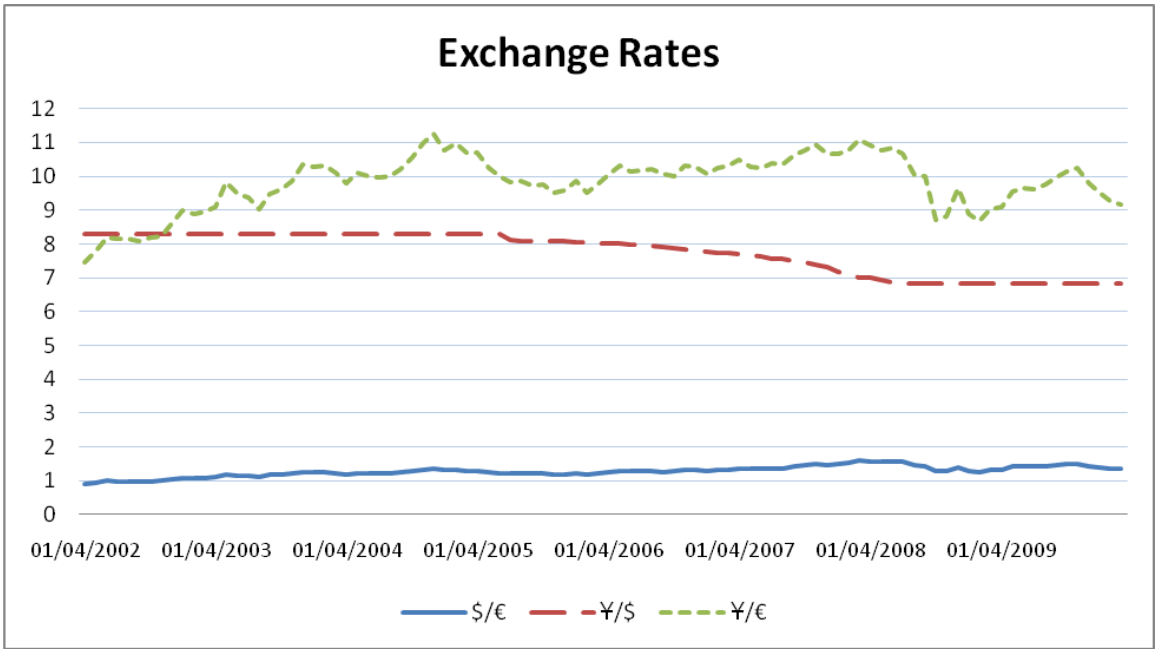
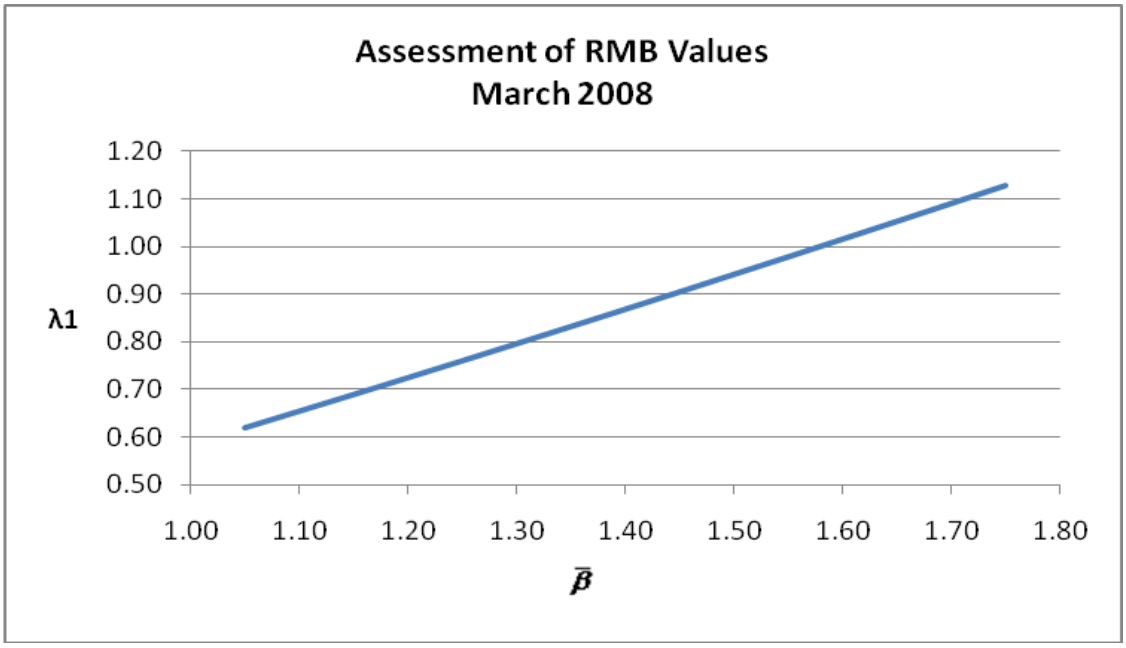
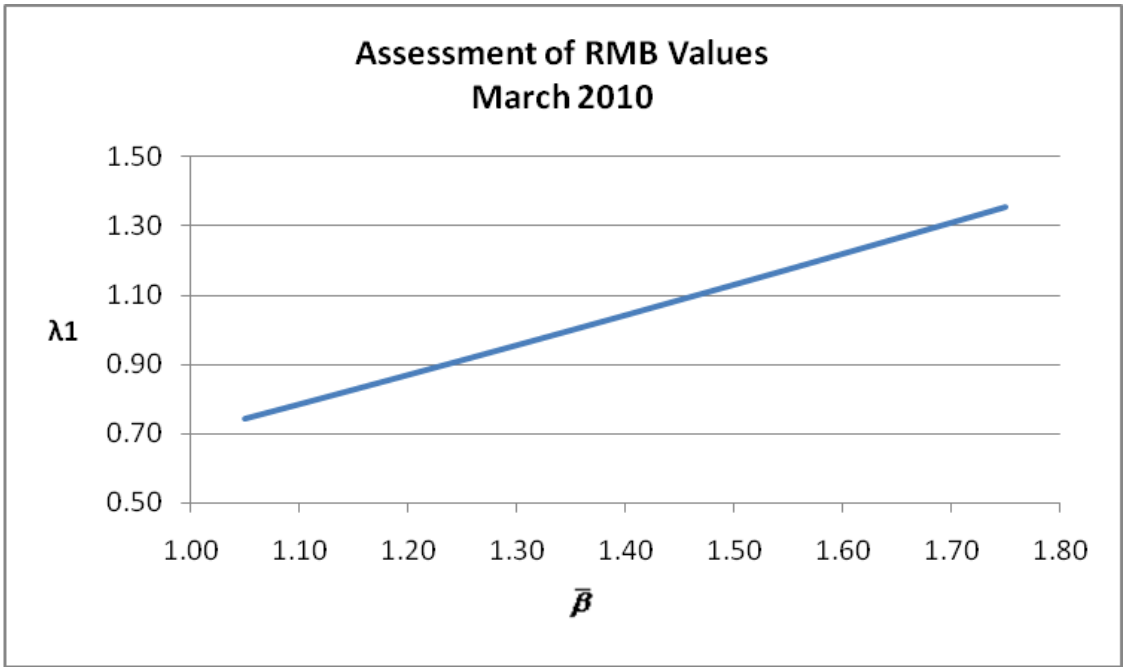



**Figure 2.** Movements of exchange rate pairs between €, $ and ¥: 2002-2010




(a)




(b)

**Figure 3.** Assessment of RMB values