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ABSTRACT

We build an optimising framework to analyse a class of economies that adopt an ECU-type basket currency while in transition to increased flexibility of the exchange rate regime. Instead of conventional basket pegging, such an economy uses an ECU-type currency index as a benchmark for monitoring and assessing exchange rate movements. This provides an anchoring device for the nation's exchange rate regime and allows the home currency's exchange rate to fluctuate. Under the assumption that the central bank is chiefly interested in maintaining stability, the optimal structure of the basket currency is based on its contribution to minimizing the volatility of the country's external account. A currency invariance index is applied to capture the effect of the country's exit from exclusive linkage with the US dollar. The approach is illustrated by Chinese exchange rate policy. We find it advisable and viable for China to form a basket currency with a diversified portfolio of currencies. While the portfolio's weighting scheme could favour the dollar, euro and Japanese yen, we show that the composition of the basket is open to a wide range of possibilities. Moreover, contrary to general fears, there is considerable potential for China to engage in currency diversification, which will not necessarily affect the dollar's position.

Key words: Exchange rate regime; Basket currency; Currency diversification

JEL classification: E58, F31, P45

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1. Introduction

This paper deals with a class of emerging economies that institute a regime switch in their exchange rate arrangements, typically aimed at greater flexibility. For these economies, while it may be feasible to articulate the end goal of a regime change, handling the transition invariably proves more challenging. In this regard, China' recent experiment with reform of its exchange rate regime provides an interesting case study.

China's exchange rate policy has become a focal point of international concerns in recent years (Williamson, 2000, 2005; Eichengreen, 2004; McKinnon, 2006; Frankel and Wei, 2007; Goldstein and Lardy, 2008; Laurenceson, 2008; Evenett, 2010). Several contentious matters concerning China's exchange rate regime have emerged as particularly salient for their likely global repercussions. Chief among these are the renminbi's exchange rate and the leeway for change. Albeit, whether the level of renminbi is undervalued remains disputable, there is nearly unanimous agreement that the Chinese exchange rate regime should be changed to allow for greater flexibility (Chinn and Wei, 2008, Eichengreen and Rose, 2010).

For a good part of the past two decades, the Chinese currency was hard-pegged to the dollar. In that context, the Chinese government strictly regulated the level and variability of the renminbi's exchange rate, which resulted in an outright denial of market forces in the country's exchange rate system, and critically contributed to the renminbi's misalignment. Against this backdrop, there are rising calls, internationally and domestically, for the Chinese government to take action.

In a measured move, the monetary authority in China announced on 21 July 2005 and reiterated on 19 June 2010, the adoption of a Chinese version of a managed floating rate system under which the renminbi exchange rate is to be administered by the government but allowed to move within a fluctuation band specified by the authority. In managing the rate movements, market conditions are to be taken into account and reference made to a basket of currencies (PBOC, 2005, 2008).

A striking feature of the new system is the use of a basket currency. The new-policy announcement has been widely interpreted as China's adoption of a basket pegging system. We argue that this is not the case. That policy change actually comprises a complex package that reconfigures the Chinese exchange rate system. There are three pillars for the new regime: a central parity that administered by the central bank; a basket currency used as a reference unit and anchoring mechanism; and a fluctuation band that specifies the allowed range for daily currency variation around the central parity. The core of the system is the central parity, between the renminbi and the dollar. This parity provides a benchmark price for the prices of other currencies in the market; subsequent market transactions are based on this price, with fluctuations allowed within a designated band, 0.5% each way for the renminbi/dollar rate. Exchange rates for the renminbi against other currencies are calculated from their cross rates with the dollar, and the bands for permissible fluctuations around parity are wider: 3% each way (SAFE, 2009).

The central parity is based on three factors: the weighted average of market makers' pre-session quotes, movements of selected international currencies included in the basket, and the central bank's assessment of macroeconomic conditions (SAFE, 2009). While the Chinese foreign exchange market formally opens at 9.30am every working day, at 9.15am market markers for renminbi/dollar spot trading, 26 in all as at end-2010 (CFETS, 2010), are convened by the monetary authority for a fixing meeting in which they submit their offers for the day. The highest and lowest quotes are eliminated and the rest are averaged by the authority. The government then exercises discretion in aligning the mean rate from the market makers with the rate implied by the basket currency and changes in macroeconomic variables (Zhu and Zhao, 2009)[1]. The monetary authority finally arrives at a central parity rate for the day, which is published before the market opens[2]. All subsequent transactions on the market are conducted on the basis of this central parity (SAFE, 2009). The microstructure of the Chinese foreign exchange market makes it evident that China is not operating a conventional basket peg, since the renminbi is not directly pegged to a currency basket. Instead, the current Chinese system can be broadly defined as a flexible rate regime in which the exchange rate for the Chinese currency is adjusted according to a set of indicators. In this system, a basket currency, among other things, has been deployed by the Chinese central bank as a reference unit for judging the necessity for rate adjustment and as an anchoring device for managing exchange rate movements by setting the central parity.

A basket currency is a group of currencies, each of which is allotted a certain number of currency units or weights (Girardin and Steinherr, 2008). A distinct feature of a basket currency is that it provides a measure of the value of a theoretical currency calculated from the weighted average of a selected group of currencies. For the Chinese monetary authority, a basket currency works in several ways in the process of parity formation. The primary function is to enable the authority to monitor the formation process of the central parity. For the Chinese central bank, having received the proposals for the parity rate from individual market makers, it is straightforward to compare the proposed rates with international currency developments, using the basket value as a reference. In addition to the level, the

[1] From 21 July 2005 to 4 January 2006, the central parity rate was determined by the previous day's closing renminbi/dollar rate (SAFE, 2009).

[2] The central parity rates of the renminbi against other currencies, i.e. the euro, Japanese Yen, Hong Kong dollar and pound sterling are arrived at via the cross rates of these currencies against the dollar, at the 9.00am prices on major international currency markets (Lu, 2010).

proposed growth of the central parity can also be compared to the growth of the value of the basket currency to assess whether the proposed change is excessive, given the changes in international market conditions. In this way, the basket currency serves as a benchmark for the monetary authority to evaluate the parity rate in relation to international currency developments (Li, 2006, SAFE, 2009).

This in turn means that the basket currency provides a mechanism that helps the monetary authority constrain the variation in the parity rate. Although a value for the basket currency can be derived using the basket construction formula, one can invert the process by working out the permissible maximum change of the basket currency, given that the weights of the component currencies are known and the allowable band for rate variations is fixed. The monetary authority is in a unique position to do so, as it knows the component currency weights and any bands kept internally for desirable rate fluctuations. This feature was deployed in Europe to develop a divergence indicator for the ECU system, and China could develop a similar mechanism for managing the central parity. For every parity rate proposed by the market makers, the Chinese monetary authority can first calculate the change from the previous day's official parity rate that it could effect and plug that change into the basket formula to get the implied movement in the metrics and hence the deviation from the allowed range. Discretion can then be used to bring the suggested rate changes back into line if needed. Compared to the nominal effective exchange rate, which is in the form of an index and is calculated monthly (being usually based on monthly bilateral trade weights), a basket currency can be expressed in terms of a particular currency and its value can be calculated daily. These advantages render it more practical for the monetary authority to use the basket currency as an anchoring devise for managing the central parity.

Another means that the Chinese exchange authority may deploy to stabilize the exchange rate is the basket construction. By choosing relevant currencies in the basket and designing an appropriate weighting scheme, one can filter out exchange rate variations in the international marketplace that are not relevant for the domestic economy. By designing an appropriate weighting scheme that reflects the true extent of a country's exposure to currency risks, a country can mitigate the effects of undesirable international currency fluctuations on trade and capital accounts. This proves particularly useful when China strives to increase the flexibility of its exchange rate system.

The effects of the basket currency are not restricted to the area of exchange rate policy. For instance, the creation of a basket currency as a reference unit also means that China is likely to phase out the dollar as the reference currency for other financial activities. The implication of this shift could be profound. An immediate effect is China's decoupling from the dollar and shift towards currency diversity, which may affect China's practice of managing foreign reserves. International research has long confirmed that the exchange rate regime is a critical determining factor of currency composition of a country's foreign reserves (Dooley, 1986; Dooley, Lizondo and Mathieson, 1989; and Eichengreen and Mathieson, 2000). In this regard, the composition of the Chinese basket currency may well affect China's management of foreign reserves. For example, a diversified basket currency may be applied to the appraisal of China's investment of reserves. More importantly, the weighting scheme of the basket may be used by Chinese reserve managers as a benchmark for currency diversification. Given the country's colossal amount of reserves, a shift away from dollar instruments could have global repercussions.

China's new exchange rate regime has prompted a growing interest among international researchers (Frankel and Wei, 2008; Funke and Gronwald, 2008; Frankel 2009; Fidrmuc, 2010; Frankel and Xie, 2010). Given that little is known about the content or construction of the Chinese basket currency and that the Chinese government has been tight-lipped regarding basket details, the previous research has focused largely on empirically estimating the weights of the Chinese basket currency. The current study seeks to better our understanding of the Chinese exchange rate policy from a normative perspective. Using an optimising method, we develop a balance of payments model to generate an optimal weighting scheme as a benchmark for deciphering the structure of China's basket currency. Because information on composition of the basket is not publically available, this normative study is not intended to point directly to possible improvement. However, the optimal composition determined by this study could provide an approximation to a desirable policy target around which the actual composition of the basket currency may fluctuate. In this sense, this study sheds light on the setting of and changes in China's exchange rate policy. By deriving the optimal composition of the basket currency using the Chinese data, we also intend to set out policy implications of the optimal weighting scheme as regards currency diversification, which is crucial for instance to the management of China's huge foreign reserves.

Derivation of an optimal basket currency is a challenging task. To avoid distorting the basket currency as a benchmark for the Chinese exchange rate policy, it is crucial to design a basket that embodies sensible criteria for selecting a potpourri of currencies and an optimal weighting scheme for calculating the value of each component currency. Flanders and Tishler (1981) detail the costs of using a "wrong" currency basket. Han (2000) demonstrates that a poorly designed weighting scheme for the currency basket could easily invite speculative attacks on the home currency.

Essentially, this is a task of deriving a formula for a theoretical currency unit that can best perform its assigned roles. In this regard, the mission can be informed by the development of the optimal currency basket theory and the methodology thereof. The literature on optimal currency basket has two broad strands. One comprises the trade models that use static and partial equilibrium analyses to determine the optimal shares of constituent currencies in the basket. The currency weights are typically proportionate to the respective trade shares with respect to the country whose currency is used as the numeraire (Flanders and Helpman, 1979; Flanders and Tishler, 1981; Branson and Katseli-Papaefstratiou, 1981, 1982; Lipschitz and Sundararajan, 1980, 1982; Connolly, 1982; Connolly and Yousef, 1982; Bhandari, 1985; Edison and Vardal, 1987, 1990; Shi and Xu, 2008). The second branch analyzes the optimal currency basket in a general equilibrium framework. In these models, the optimal composition and weightings of the currencies in the basket are determined by interaction with the macro economy and often in the presence of multiple stochastic shocks (Turnovsky, 1982; Horne and Martin, 1989; Han, 2000; Daniels et al., 2001; Habib and Strasky, 2008).

Bird and Rajan (2002) maintain that it is not satisfactory for conventional trade models to focus solely on external imbalances. They recognize the importance of domestic macroeconomic policies and argue that, in addition to trade, currency composition of external debt and foreign inflation must also be considered in determining the optimal basket. But, rather than applying a complete general equilibrium framework, they set up a game-theoretic model that focuses on export competitiveness, foreign currency debt and imported inflation as determinants of optimal basket weights.

Recently, Hovanov, Kolari and Sokolov (2004, 2007) show that choice of the base currency is critical, since using a different base currency would lead to a different optimal currency basket. They propose a stable aggregate currency index to calculate the optimal currency basket, which is invariant with respect to the chosen base currency. This method is applied to derive a stable common currency for Mercosur countries (Viale, Kolari, Hovanov and Sokolov, 2008). Pontines (2009) applies the currency invariance index to obtain an optimal common currency basket for East Asia.

We extend the existing literature by developing a balance of payments model that considers both the trade and the capital accounts. In the model, the trade balance is captured by net exports, and we deploy net international investment position to represent the capital account. The basket currency is optimally constructed to minimize the effects of international exchange rate movements on China's external accounts. This is based on the proposition that the composition of a basket currency depend on its purpose, which in turn is conditioned by the goal of exchange rate policy. China has repeatedly made it clear that the mission of its exchange rate policy is to maintain the stability of renminbi. We assume that the choice of optimal weights is driven by this goal, implying that the optimality of the composite currency is defined for its contribution to minimizing fluctuations of the balance of payments.

We then develop a theoretical model to underpin the estimation of an optimal set of currency weights. In the model setting, the nexus of relationships in the system is subject to stochastic shocks to the exchange rate and international capital movements. The theoretical model is solved numerically, and the solution is used to calibrate the optimal weights for China. To capture the effect of China's de-pegging from the US dollar, we introduce the currency invariance index to overcome the problems relating to the choice of base currency. The currency invariance index was originally developed by Hovanov, Kolari and Sokolov (2004, 2007), but we apply the method to the case where the optimizing objective is not limited to minimizing the variance of the basket value per se, but to minimizing fluctuations in trade, foreign debt and foreign direct investment (FDI).

We find that it is best for China to form a composite currency that favours the dollar, euro and Japanese yen, with the dollar accounting for about 40% of the total weight. This optimal dollar weight, which is stable over all of our constructions, is much less than generally expected. Beyond the three major currencies, we show that there is potential for China to engage in extensive currency diversification. We demonstrate that it is possible to construct a diversified basket of 20 currencies, which will considerably expand China's opportunity set while enabling the country to achieve stability of its external accounts. In contrast to general fears, the diversification would not affect the dollar's position since evidence shows that the effects of the diversification can be offset by reducing the weights of, for example, the euro and Japanese yen. Our sensitivity analysis further suggests that increasing economic ties between China and America also contribute to a stable dollar weight. We also find it advisable for China to diversify into the pound sterling, Swiss franc, and other currencies such as resource currencies, BRIC country currencies and particularly Asian currencies.

The research sheds light on the core plank of Chinese exchange rate policy. The findings confirm that a fairly large set of currencies can be included in China's optimal composite currency of which the USD, euro, JPY and Korean won are clearly the first tier constituent currencies in terms of importance. In addition to currency selection, our research offers insight into the plausible mixture of the Chinese basket currency. The optimal shares found in this study may be viewed as a yardstick for gauging possible construction of China's basket currency. Given the importance of exchange rate policy in influencing the currency composition of a country's foreign reserves, this research can also provide an indicator for the currency composition and shares of China's international reserves. For example, the 40% dollar weight unearthed in this study may be used as a guide for China's management of foreign reserves.

The rest of the paper is organized as follows. In Section II, we develop the formal model in a framework similar to Bird and Rajan (2002), incorporating the influences of trade, external debt and foreign inflation. In addition to these factors, we also consider the influence of composition of external debt as in their exposition. While also considering the influence of foreign inflation, like Bird and Rajan (2002), we extend their work by adopting the price-to-market approach, in which analysis of the inflationary effect and its pass-through to the domestic economy depends on the invoicing currency used in exports and imports, as in the contribution of Shi and Xu (2008). To overcome the bias introduced by the choice of the base currency, we incorporate the currency invariance index suggested by Hovanov, Kolari and Sokolov (2004, 2007).

2. Theoretical Model

In this section, we develop a formal model to characterize the derivation of the optimal weights for the currencies in a basket. With the Chinese case in mind, we assume that a country that creates a basket currency chooses the weights of component currencies so as to stabilize the trade balance and international investment position (IIP) in the presence of fluctuating foreign exchange rates. We further assume that the country adopts asymmetric currency pricing for exports and imports. That is, its exports and imports are priced in the currencies of its trade partners, i.e. according to so-called local currency pricing (LCP) for exports and producer currency pricing (PCP) for imports. The country faces stochastic shocks to its exchange rates against international currencies and to its international investment position. In this setting, export incomes and import payments, as measured in the home currency, are both affected by changes in exchange rates. Consequently, home and foreign demand also change. Furthermore, its international investment position fluctuates with movements in exchange rates, and flows of international investment may be correlated with exchange rate changes.

We consider two scenarios, one in which the Chinese basket currency includes 11 currencies and the other 20. The selection of component currencies is based on trade relations and international investment position vis-á-vis China at end-2004 and end-2008. The choice of denominator currency is critical as regards the correlation and variances of foreign exchange rates. To increase the robustness of our numerical results, we apply the Hovanaov, Kolari and Sokolov (2004) method to normalize the exchange rates. The author's Normalized Value in Exchange does not depend on the choice of denominator and is able to separate the movements of each currency from those of its counterparts.

2.1 Policy goal

Determination of optimal basket weights is shaped by the policy goal. The Chinese monetary authority has stated explicitly that the general objectives of the recent renminbi exchange rate reforms are to establish and improve a managed floating rate regime and to stabilize the renminbi's exchange rate at a realistic and equilibrium level (PBOC, 2005, 2008, SAFE, 2009). Corden (2008) concludes that keeping the renminbi exchange rate stable is one of China's main policy objectives. Economists from the Chinese exchange authority have indicated that the rationale for the stable nominal renminbi rate goal is to safeguard the stability of the external accounts (Wang and Ma, 2005). Recently, the governor of the Chinese central bank stated that formation of the basket currency will require comprehensive consideration of the currencies of China's major partners in external trade, foreign debts and FDI, suggesting that the trade and financial transaction accounts are the main factors in China's policy decision regarding the basket currency (Zhou, 2006). In this light, we assume that the China's policy goal for the composite currency is to ensure stability of its balance of payments in the face of international currency movements. Given the data availability, we will examine China's balance of payments by focusing on the main part of its BOP financial account - its trade balance and international investment position.

We assume that China creates a basket currency consisting of N currencies. Movements of exchange rates affect the country via both the demand for exports and values of export proceeds and import payments. The net international investment position (IIP) varies in response to exchange rate movements. The IIP may also change because of changes in investment flows, which may also correlate with exchange rate shocks. Putting these effects together, we define our task as that of determining the optimal basket currency, which will minimize fluctuations in net trade and net IIP due to shocks to exchange rates and investment positions.

The total effects of these shocks on trade and net IIP in the current period can be expressed as

$$Z = \Delta NX + \Delta NA \tag{1}$$

where NX is net exports, NA is net international investment position at end-period, and Δ indicates a change in the corresponding variable. We normalize the total effects by GDP in the initial period, Y_0. We assume that the initial-period ratios of net exports and net IIP to GDP Y_0 are α_1 and α_2, respectively:

$$NX_0 = \alpha_1 Y_0 \tag{2}$$

$$NA_0 = \alpha_2 Y_0 \tag{3}$$

We express our target objective as

$$z = \frac{Z}{Y_0} = \alpha_1 nx + \alpha_2 na \tag{4}$$

where lower case variables denote changes in corresponding capital-letter variables, e.g. nx denotes $d \log NX$. Given that the country chooses basket weights to stabilize net exports and IIP, the optimization problem is expressed as

$$\begin{aligned} &\min_{\omega_1, \omega_2, \ldots, \omega_N} \mathrm{Var}(z) \\ &\text{s.t.} \sum_{j=1}^{N} \omega_j = 1 \end{aligned} \tag{5}$$

In the process of resolving the optimal basket currency, we express the variance of this target, z, in terms of exchange rate and investment position shocks.

2.2 Trade balance

The trade balance is defined as the difference between total exports X and total imports I. When the value of the balance is denominated in the domestic currency, we obtain

$$NX = X - I \tag{6}$$

Let the initial ratio of total exports to total imports be β:

$$X_0 = \beta I_0 \tag{7}$$

Movements of the net export are then given by

$$nx = \frac{\beta}{\beta - 1}x - \frac{1}{\beta - 1}i \tag{8}$$

We assume that in the Chinese context, exports to and imports from a foreign country are all transacted in the currency of the respective country. That is, domestic exporters use local currency pricing (LCP) and foreign exporters producer currency pricing (PCP). The proceeds from and exports to country j, denominated in home currency, are $X(j)$. The proportion of total exports going to country j is γ_j:

$$X_0(j) = \gamma_j X_0,\ j = 1, ..., N \text{ and } \sum_{j=1}^{N} \gamma_j = 1 \tag{9}$$

Furthermore, total exports is the sum of exports to all foreign countries, in terms of the domestic currency:

$$X = \sum_{j=1}^{N} X(j) \tag{10}$$

Linearization of the growth of total exports around changes in exports to individual markets yields

$$x = \sum_{j=1}^{N} \gamma_j x(j) \tag{11}$$

Exports to foreign countries are all priced according to local currency pricing (LCP). For tractability, we assume that export prices are fixed by the producers or exporting traders of the goods. This is reasonable since we focus on the effects of exchange rate shocks on the trade balance in the short run, a timeframe in which price movements are likely to be limited. It is also plausible that, due for example to nominal rigidities, prices are sticky in China. Since exports are priced in the foreign currency $P^X(j)^*$, exchange rate variations do not affect the demand $D(j)$ from foreign country j, while exporters' revenues in home currency are affected. Given that the bilateral exchange rate $E(j)$ between home country and foreign country j is defined as units of domestic currency per foreign currency unit, export incomes are given by

$$X(j) = E(j)P^X(j)^* D(j) \tag{12}$$

where $P^X(j)^*$ is the foreign price of home exports, and $D(j)$ is foreign country j's demand for home exports. With such settings, changes in export revenues due to exchange rate movements are

$$x(j) = e(j) \tag{13}$$

Combining equations (11) and (13), the change in total exports becomes the average of movements in exchange rates, each weighted by the country's share in total exports:

$$x = \sum_{j=1}^{N} \gamma_j e(j) \tag{14}$$

Home consumers have constant elasticity of substitution (CES) preference over different import goods. The consumption index of import goods C can be expressed in Dixit-Stiglitz form as

$$C = \left[\sum_{j=1}^{N} C(j)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{15}$$

where $\eta > 0$ is the elasticity of substitution,. When $\eta = 1$, the index is of the Cobb-Douglas form in the limit. Foreign firms set prices according to producer currency pricing (PCP), e.g. prices of imports from country$j$, $P^I(j)^*$, are set in the currency of country j. With the same consideration as for export prices, we assume that foreign prices of imports are also fixed. Therefore imports of home country goods are associated with full exchange rate pass-through. The price index of imported goods P^I is the aggregation of prices of imports from each country:

$$P^I = \left[\sum_{j=1}^{N} \left(E(j) P^I(j)^* \right)^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{16}$$

Home country demand for import goods from country j satisfies:

$$C(j) = \left(\frac{E(j) P^I(j)^*}{P^I} \right)^{-\eta} C \tag{17}$$

Further, total imports are the sum of imports from each foreign country; and if the initial share of imports from country j is δ_j, then fluctuations of total imports can be viewed as a function of exchange rate movements:

$$i = \sum_{j=1}^{N} \delta_j i(j) = \sum_{j=1}^{N} \left[(1-\eta)\, \delta_j e(j) \right] \tag{18}$$

Substituting total exports and total imports in the net export equation of (8) with equations (14) and (18) yields

$$nx = \sum_{j=1}^{N} \left[\frac{\beta}{\beta - 1} \gamma_j - \frac{\delta_j (1-\eta)}{\beta - 1} \right] e(j) \tag{19}$$

2.3 Net international investment position

To consider the impact of the capital account, we define the net international investment position of the home country as the sum of net IIPs with respect to each foreign country:

$$NA = \sum_{j=1}^{N} NA(j) \tag{20}$$

External assets and liabilities of the home country vis-à-vis foreign country j are denominated in the currency of the partner country j:

$$NA(j) = \exp\left(\epsilon^a(j)\right) E(j) NA(j)_0^* \tag{21}$$

where $\epsilon^a(j)$ is a stochastic process of change in home-country IIP vis-à-vis country j. We assume that $\epsilon^a(j)$ has zero mean and constant variance of $(\sigma_j^a)^2$ and is correlated with exchange rate shocks. In addition to the exchange rate shocks, the net IIP is also subject to its own shocks, i.e. exogenous shocks other than exchange rate movements that impact the external investment position. The correlation matrix of all such investment shocks is assumed to be

$$\rho^{aa} = \{\rho_{ij}^{aa}\}_{N\times N},\ \rho_{jj}^{aa} = 1 \text{ and } \rho_{ij}^{aa} = \rho_{ji}^{aa} \tag{22}$$

where ρ_{ij}^{aa} is the correlation of investment shock to the net IIPs of country i and country j. If the initial share of net IIP with country j in total net IIP is λ_j, the total effect on net IIP due to exchange rate and investment shocks is

$$na = \sum_{j=1}^{N} \left[\lambda_j \left(\epsilon^a(j) + e(j)\right)\right] \tag{23}$$

Finally, we express z as a function of shocks to the exchange rate and investment position:

$$z = \sum_{j=1}^{N} \left\{\alpha_1 \left[\frac{\beta}{\beta-1}\gamma_j - \frac{\delta_j(1-\eta)}{\beta-1}\right] + \alpha_2\lambda_j\right\} e(j) + \alpha_2\lambda_j\epsilon^a(j) \tag{24}$$

In what follows, we derive the variance of z in terms of both variances and correlations of all shocks, to find the optimal weighting scheme for the basket currency.

2.4 Weights of component currencies

Given the initial level of exchange rates, the country determines the methods for valuing the basket with respect to that initial level. When the quantity of each foreign currency in the basket u_j is set, the initial value of the basket currency V_0 in terms of home currency is given by

$$V_0 = \sum_{j=1}^{N} E_0(j)u_j \tag{25}$$

Once set, the quantity of each currency in the basket is assumed to be fixed, unless units of each currency in the basket are periodically adjusted by the exchange authority. The value of the home currency with respect to country k can be calculated as

$$\frac{1}{E(k)} = \frac{\sum_{j=1}^{N} u_j E^k(j)}{V_0} \tag{26}$$

where $E^k(j)$ is the exchange rate between country k and country j, k being the reference country. We will shortly demonstrate that the setting of the reference currency can be made so as not to affect the value of the basket currency. For a basket currency, exchange rates of home currency with foreign currencies should satisfy the relationship

$$\sum_{j=1}^{N} \omega_j e(j) = 0 \tag{27}$$

Note that the basket currency weights are not necessarily positive. A negative weight for a certain foreign currency in the basket realistically reflects its negative correlation with the home currency (Edison and Vardal, 1990).

2.5 Optimal currency weights

Given the total effects of exchange rate shocks and investment shocks on the external accounts, we substitute for exchange rates of home country against foreign countries the shocks to the values of foreign currencies. The relation between the exchange rate of home country against country j and that of the reference country against country j is

$$E(j) = E(k)E^k(j) \tag{28}$$

Hence, the exchange rate movements are

$$e(j) = e(k) + e^k(j) \tag{29}$$

Furthermore, we assume exchange rate shocks $\epsilon^e(j)$ to have zero mean and variances of $\sigma^e(j)^2$. Country k's exchange rate with country j is subject to stochastic shocks to the currencies of both countries:

$$e^k(j) = \epsilon^e(k) - \epsilon^e(j) \tag{30}$$

where a positive $\epsilon(j)$ means depreciation of the currency j with respect to all other currencies. A positive $\epsilon(k)$, or a negative $\epsilon(j)$ means depreciation of the exchange rate of currency k against j. The correlation matrix of all exchange rate shocks is defined as

$$\rho^{ee} = \{\rho_{ij}^{ee}\}_{N\times N},\ \rho_{jj}^{ee} = 1 \text{ and } \rho_{ij}^{ee} = \rho_{ji}^{ee} \tag{31}$$

Using equations (29) and (30) to eliminate $e^k(j)$ and combining with (27) we obtain the exchange rates in terms of exchange rate shocks:

$$e(j) = -\epsilon^e(j) + \sum_{i=1}^{N} \omega_i \epsilon^e(i) \tag{32}$$

With equation (32) we can substitute exchange rates in equation (24) for z:

$$z = \begin{pmatrix} \Psi' & \Xi' \end{pmatrix} \begin{pmatrix} \epsilon^e \\ \epsilon^a \end{pmatrix} \tag{33}$$

where ϵ^e and ϵ^a are vectors of shocks to exchange rates and investment:

$$\epsilon^e = \{\epsilon^e(j)\}_{N\times 1},\ \epsilon^a = \{\epsilon^a(j)\}_{N\times 1} \tag{34}$$

Ψ and Ξ are the coefficient matrices:

$$\Psi = \left\{ \omega_j \sum_{i=1}^{N} \left[\alpha_1 \left(\frac{\beta}{\beta - 1}\gamma_i - \frac{\delta_i(1-\eta)}{\beta - 1} \right) + \alpha_2 \lambda_i \right] - \left[\alpha_1 \left(\frac{\beta}{\beta - 1}\gamma_j - \frac{\delta_j(1-\eta)}{\beta - 1} \right) + \alpha_2 \lambda_j \right] \right\}_{N\times 1} \tag{35}$$

$$\Xi = \{\alpha_2 \lambda_j\}_{N\times 1} \tag{36}$$

We write the correlation between all shocks in the form of a block matrix:

$$\rho = \begin{Bmatrix} \rho^{ee} & \rho^{ea} \\ \rho^{ae} & \rho^{aa} \end{Bmatrix} \tag{37}$$

where $\rho^{ea} = \{\rho^{ea}_{ij}\}$ denotes the correlation between the exchange rate shocks of country i and the shocks to IIP of country j, and $\rho^{ae} = \{\rho^{ae}_{ij}\}$ is the correlation matrix between shocks to IIP of country i and the exchange rate of country j. The correlations satisfy

$$\rho^{ea} = (\rho^{ae})' \tag{38}$$

In addition, we write the standard deviations of all shocks in matrix form:

$$\sigma = \{\sigma_j\}' = \{(\sigma^e)', (\sigma^a)'\}' = \{\sigma^e_1, ..., \sigma^e_N, \sigma^a_1, ..., \sigma^a_N\}' \tag{39}$$

Finally, we derive the variance of z:

$$\mathrm{Var}(z) = \Phi' \cdot \rho \cdot \Phi \tag{40}$$

where

$$\Phi = \begin{pmatrix} \Psi_1 \sigma^e_1 \\ \vdots \\ \Psi_N \sigma^e_N \\ \Xi_N \sigma^a_1 \\ \vdots \\ \Xi_N \sigma^a_N \end{pmatrix} = \begin{pmatrix} \Phi^e \\ \Phi^a \end{pmatrix} \tag{41}$$

The optimal solution can be derived numerically using data on the trade balance, IIP and the exchange rates. In the next situation we simulate an optimal basket currency for China according to its trade balance and investment positions.

3 Optimal Currency Weights for China

In this section, we use the solutions in the previous section to calibrate the optimal weights of the basket currency for China. Then, we examine the robustness of the model by performing sensitivity test.

3.1 Data

On 10 August 2005, shortly after its announcement of the new reform to the exchange rate regime, the Chinese central bank revealed that selection of the component currencies in the basket is mainly determined by the shares of the each countries' trade with China (Zhouo Xiaocun, 2005). In addition, the selection takes into consideration international capital movements, particularly the structure of external debt and FDI. According to these criteria, the USD, euro, Japanese yen and Korean won become the major currencies in China's construction of the basket currency. Other important currencies include those of Singapore, UK, Malaysia, Russia, Australia, Thailand and Canada. Currencies of countries whose bilateral trade with China exceeds 5 billion USD are also considered for inclusion in the basket. However, no further details have been given as to the structure of China's basket currency.

Based on a statement by China's central bank, we first choose 11 currencies for inclusion: Australian dollar, Canadian dollar, euro, Japanese yen, Korean won, Malaysian ringgit, Russian rouble, Singapore dollar, Thai baht, GBP and USD. The selection basis is that in 2004 these countries traded more than 15 billion USD with China, as measured by the sum of exports and imports in goods and services vis-à-vis China. Later, we will form a second basket according to individual countries' bilateral trade volumes with China. This alternative basket contains 20 currencies, selected according to the criterion that in 2004 the countries had bilateral trade with China exceeding 5 billion USD, which is consistent with the PBOC statement. Four other countries exceed our threshold, namely Iran, Saudi Arab, United Arab Emirates and Vietnam, but they are excluded from our basket because China has no IIPs with these countries. Table 1 reports the component currencies of the two baskets. The trade data are from IMF Direction of Trade Statistics.

In our model calibration, it is desirable to use shocks to exchange rates that are invariant with respect to denominator currency. However, the correlations between different currencies calculated using exchange rate data directly would be affected by the choice of the base currency. Hovanov, Kolari and Sokolov (2004, HKS hereafter) develop an indicator of value in exchange called the Normalized Value in Exchange (NVal). They derive the NVal by using geometric average to normalize the exchange rates, as shown in the following equation:

$$NVal(j) = \frac{E^i(j)}{GMean(E^i(1), ..., E^i(k))} = \frac{E^i(j)}{\sqrt[N]{\prod_{k=1}^{N} E^i(k)}} \tag{42}$$

where $NVal(j)$ refers to the Normalized Value in Exchange of currency *j*, $E^i(j)$ is the exchange rate of currency *j* defined relative to a base currency *i* and GMean stands for geometric average. HKS (2004) show that this normalized value in exchange is independent of the base currency (Proposition 2, p. 1487).

HKS (2004) use the important property of NVal being invariant to the choice of base currency to derive the reduced (to the moment t_0) normalized value in exchange of the *j*th currency and then construct a basket currency that has minimum variance of basket value. We use their construction of the invariant currency value index but apply it to a different policy objective in the Chinese context, i.e. to stabilize the external account including trade, foreign debts and FDI. With this invariant currency value index, one can express the exchange rate shocks in our objective function (24) as

$$\epsilon^e(j) = d \log NVal(j) \tag{43}$$

Monthly exchange rate data from January 1999 to June 2010 are collected from IMF International Financial Statistics to calculate NVals, and in turn the correlation between the currencies and exchange rate variances. Table 2 displays our calculation of correlations between the 11 currencies in the first basket. The two panels report our calculations using the base currency invariant index and exchange rates denominated in SDR, respectively. For example, the correlation between the Canadian dollar and USD using the two methods are -0.08 and 0.13, respectively. From this example, one can see that using different methods can lead to very different results. Table 3 displays our calculation of variances of exchange rate movements.

To calculate the correlation between exchange rate shocks and investment shocks to IIP, we assume $\rho^{ea} = (\rho^{ae})' = 0_{N\times N}$. The effect of exchange rate movements on IIP depends on the structure of the home country making the external investment. In China's case, a prominent factor is that the Chinese external investment position is overwhelmingly dominated by the country's huge foreign reserves, which accounted for more than 70% of total foreign assets at the end of 2009. But the Chinese decision on foreign reserve accumulation is unlikely to be driven by renminbi exchange rate movement. Given this, it is reasonable to assume that for China, at least in the short run, shocks to the renminbi exchange rates and to investment are orthogonal. Therefore, in selecting the optimal currency weights for China, one need not consider the correlation between exchange rate shocks and investment shocks. The variance of the objective function is therefore

$$Var(z) = (\Phi^e)' \cdot \rho^{ee} \cdot \Phi^e + (\Phi^a)' \cdot \rho^{aa} \cdot \Phi^a \tag{44}$$

The second term on the right hand side of the equation does not depend on ω_j.

Tables 4 and 5 display our calculation of the coefficients for the two baskets. η is the elasticity of substitution between different imports, set at 2, which is common in the literature. α_1 is the ratio of balance of trade in goods and services to GDP, α_2 the ratio of net IIP to GDP, and β the ratio of total exports to total imports. Data on the trade balance are denominated in USD and are from IMF Direction of Trade Statistics. GDP data (current price, in USD) are from IMF International Financial Statistics and net IIPs (in USD) are from IMF Balance of Payments Statistics. γ and δ are the weights of exports and imports of each country in the basket, respectively. λ is our calculation of IIP currency share. Since there are no detailed data available on the currency composition of China's IIP, we use two methods to proxy. λ^* is based on the currency composition of foreign debt of China, as disclosed in various issues of the Annual Report on International Payments of China published by the State Administration of Foreign Exchange. However, these reports provide only the USD, JPY and euro shares in China's foreign debt. We then allocate the shares to other countries. The second method λ^{**} uses the currency composition of PPG debt from the World Bank's Global Development Finance Database. The World Bank discloses the share of euro, JPY, GBP, USD and Swiss franc in China's PPG. Similarly, for the rest, we calculate the shares of these countries according to their IIPs levels relative to other countries.

3.2 Calibration

The trade and IIPs shares of different currencies are crucial in the calculation of optimal currency weights. Given China's rapid growth in recent years, the choice of base year for the calculation is also important. We calibrate our baskets based on China's 2004 and 2008 trade and investment data, respectively. These base years are chosen because it is reasonable to assume that before Chinese policymakers made the reform announcement on 21 July 2005 they would have consulted the 2004 data, and similarly before the policy move on 19 June 2010 they would have consulted the 2008 data.

The optimal weights obtained from our calibration are displayed in Table 6. We report the weights for the two baskets with different base years. The columns marked * use the currency composition of external debt disclosed by the State Administration of Foreign Exchange (SAFE). Those marked with ** use the PPG shares for currency composition. Generally, use of the two proxies does not lead to sizeable differences in the calibration results.

For the 11-currency basket (Basket I), our calibration confirms that the USD, euro, Japanese yen and Korean won are of first tier importance in terms of their weights in the basket. The weights of the other 7 currencies in Basket I are also important.

For the alternative 20-currency basket (Basket II), it is found that the nine additional currencies in this expanded basket get a total share of 8.5% using the 2004 data and account for 11% of the total weight using the 2008 data. Generally speaking, of the additional 9 currencies, those countries whose trade with China exceeds 15 billion USD would have a substantial influence in Basket II. The calibration implies that it is not only desirable but also feasible for China to engage in currency diversification.

It is interesting to observe the dollar's weight and its changes following the currency diversification. Our calibration results show that it is best for China to form a basket currency that leans toward the dollar, euro and JPY, with the dollar having the largest weight. In different constructions of the optimal basket currency, our calculations all point to a combined weight of two-thirds for the USD, euro and Japanese yen. Of these three big currencies, the dollar accounts for roughly a half, and the other two for the remaining half.

However, a closer inspection of the calibration result finds that the weight of the USD in all our baskets is surprisingly low, considerably less than expected. For the 11 currency basket, the dollar weight is 33.6% using the 2004 Chinese official foreign debt statistics from SAFE, or 34.5% using the World Bank PPG data. The 2008 data produce a slight increase in the dollar weight in the 11-currency basket, to 40% according for the SAFE data and 45% for the World Bank PPG data. For the more diversified Basket II, the dollar weight has a similar pattern. Based on 2004 SAFE statistics, the dollar in the 20-currency basket has an optimal weight of 31.9% and a weight of 32.8% based on the World Bank PPG data. The corresponding weights for 2008 are 38.3% and 43.6%, respectively.

Taking the arithmetical average of the figures on the Chinese SAFE and World Bank data, the average optimal dollar weight for the 11-currency basket is 34% using the 2004 data, while the corresponding average dollar weight for the 20-currency basket is 32.4%. Based on the 2008 data, the optimal dollar weight in the 11-currency basket is 42.6% on average, and in the 20-currency basket 40.9%. These results imply that the dollar weights are stable across the basket constructions. It follows that currency diversification will not fundamentally change the dollar weight as generally feared. In general, the optimal dollar weight for China is around 40%.

The effect of diversification seems to be largely absorbed by other currencies such as the euro and JPY. The average weight of the euro in the 11-currency basket on 2004 data was 17.2%, but it was only 15.7% in Basket II. On the 2008 data, the euro accounted for 16.4% on average in Basket I, and 14.5% in Basket II. The average weight of JPY declines even more. In the 11-currency basket, its optimal weight on average was 21.5% on the 2004 data but in Basket II it fell to 19.6%. On the 2008 data, its average weight in Basket II shrinks further, to only 13.7%. This indicates that the decline of the JPY weight is not only a result of currency diversification, but is also due to Japan's declining economic importance to China.

Our calculations further indicate that several other currencies can play important roles in China's basket currency. In Basket II, the first interesting group includes the British pound and Swiss franc. In all of our basket simulations, the pound sterling takes a weight of about 2 - 4%, which echoes the importance of the pound as a major reserve currency. The Swiss franc has a unique property. Based on the SAFE data its weight is negative, reflecting the fact that it is a safe haven currency, less prone to international currency fluctuations led by the dollar, and can even move in the opposite direction to the dollar. The next group of interest in Basket II comprises the currencies of the so-called BRIC countries, such as the Brazilian real, Indian rupee, and Russian rouble. They each have an optimal weight of around 2%, close to that of the UK currency. Another important group consists of the resource currencies, such as the Australian dollar, Canadian dollar, and Chilean peso. But perhaps the most prominent group involves the currencies of China's Asian neighbours, including the Malaysian ringgit, Singapore dollar, Thai baht, Indonesia rupiah, and Philippine peso, in addition to the Japanese yen and South Korean won in Basket I. Their weights in the more diversified Chinese basket currency are generally more than 1% each, suggesting that inclusion of these currencies can help China create a well diversified basket currency while conforming to the reality of China's economic involvement in the region.

We now compare the calibration results for the basket based on 2004 data with those for the basket based on the 2008 data. Evidence shows that rebasing our estimation on the 2008 data leads to some interesting weight changes. The currencies that undergo a weight change of more than 5% from their weights for the 2004 data are the Australian dollar, Japanese yen, Russian rouble and USD. Because of its relatively low weight in all the basket scenarios, we do not look into the changes to the rouble here. The weight change for the Australian dollar is the most pronounced, increasing by more than 11% after rebasing from 2004 to 2008. This seems to be related to Australia's rising importance for China's IIP; its investment share increased from 4% to 31.57% during the interim. The weight of the Japanese yen fell more than 5%, while both its exports to China and its investment in China's overall IIP steadily declined during the period. The USD weight however rose from 33.6% to 40.02% after the rebasing. This rise is puzzling since during the period China's exports to the US as a proportion of total exports actually decreased by about 3%, while China's IIP with respect to the US remained stable. One possible explanation could be the volatile movements in international foreign exchange markets, which enhanced the dollar's standing as a safe haven currency. Another reason might be the decline of other major currencies, such as the Japanese yen. However, it is helpful to conduct a formal sensitivity analysis to find the causes from interactions within the system. Table 7 reports the parameter values and the testing ranges for the sensitivity tests.

Given the particular importance of the USD, we focus on testing the changing weights of the USD in the system. For simplicity, we consider the case where there are only two countries. In the process, two experiments are performed. Table 7 reports the values of parameters and the ranges of sensitivity analysis that we set in the two tests, Test (a) and Test (b). In Test (a), we let α_2, the ratio of IIP to GDP, vary from 0% to 40%, while λ_1, country 1's net IIP in total net IIP, which here refers to China's IIP with the US as a proportion of China's total IIP, moves from 0% to 100%, with all the other parameters remaining fixed. We also performed the tests for other pairs of coefficients, but no strong evidence was found as regards the USD weight changes and so they are not reported here.

Figure 1 plots the optimal weights for USD while the corresponding parameters λ, the currency composition of China's IIP, and α_2, the net IIP/GDP ratio, are changing. The two solid lines are the optimal weights when α_2 is equal to 14.53% and 33.05%. The dashed line records optimal weights when λ for USD is 67%. When α_2 increases from 14.53% to 33.05 between 2004 and 2008, the optimal weight of USD in the basket currency changes along the broken line, leading to an increase in USD weight by about 5%.

In Figure 2, an increase in the ratio of exports relative to imports, i.e. β, from 1.11 to 1.34, moves the optimal weight along the dashed line, causing the weight of the USD in the basket to rise by about 4%. In both cases, the share of IIP remains large, with little change. From the graphs, it can be seen that the increase in the USD weight from 2004 to 2008 is driven by a combination of forces including a rise in the ratio of China's IIP to GDP, an increase in the ratio of China's exports to imports, and the high currency share of USD in China's IIP during the period.

In summary, to form an optimal basket currency for China, the weighting scheme should lean towards the dollar, the euro and JPY, with the dollar having the greatest weight. Meanwhile, there is room for several other currencies to play an important role in China's basket currency. Given the close links between the exchange rate regime and other policies, these findings regarding currency diversification for China could be instrumental. For example, the 40% rule for the dollar weight may serve as a guideline for China's management of foreign reserves.

4 Conclusion

China's new exchange rate system embodies an experiment in instituting a flexible exchange rate based on market relations in such a way as to save the external accounts from excessive rate fluctuation. A new exchange rate regime is introduced under which the renminbi exchange rate is allowed to move in a narrow band around a central parity set by the authority through the interaction of three factors: domestic market supply and demand represented by orders from market makers, reference to international rate movements drawn from a basket of foreign currencies, and indicators of domestic and international macroeconomic conditions.

A critical element of the system is the adoption of a basket currency, which is a theoretical composite currency created to supply a summary of international currency movements. Using the basket currency as a reference point, proposed changes to the central parity by market participants can be compared to the weighted average change of international currencies. The exchange authority can then use that information to gauge whether domestic pressure for a price change is warranted in terms of changes in international marketplace. Discretion then can be allowed for the authority to go with the proposed rate changes of the market makers or modify the proposal according to the changing value of the basket currency. In this way, China would be able to have a flexible exchange rate based on market forces while modifying excessive rate movements.

The working of this mechanism hinges on the optimal construction of the basket currency so that it will properly reflect movements in international currencies while minimising the impact on external trade and capital transactions. We estimate the possible structure of this composite currency in an optimising framework. In line with Chinese exchange authority's policy objective, we derive the optimal composite currency in terms of its contribution to minimizing the variation in China's external accounts. To capture the effect of China's de-pegging from the US dollar, currency invariance indices are introduced to nullify the problems relating to the choice of the base currency.

Our results show that for the basket currency to be optimal, the weighting scheme should lean towards the dollar, euro and JPY, with the dollar having the greatest weight. Our calculation of the optimal weighting scheme in different constructions all point to a design in which these currencies should be combined to make up approximately two-thirds of the weight and, of the three big currencies, the dollar should take roughly half and the other two currencies should share the remaining half.

The study finds a strong potential for currency diversification for China. In both the 11 and 20-currency baskets, the optimal dollar weight is around 40%, suggesting that currency diversification will not fundamentally change the (generally-feared) dollar weight. The effect of diversification seems to be largely absorbed by other currencies such as the euro and JPY. There is room for several other currencies to play an important role in China's basket currency. These include some European, but non-euro, currencies like the British pound and Swiss Franc, the BRIC country currencies, resource currencies and the currencies of China's Asian neighbours. Given the close linkage between exchange rate regime and foreign reserves, these findings regarding the possibility of diversification may also prove instrumental to China's management of foreign reserves.

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Table 1 Component Currencies of Baskets I and II

(2004, Billion US Dollars)

	Composition of the basket currency		
	Partner country	Sum of exports and imports	
Basket 1	United States	169.93	Basket 2
Basket 1	Japan	167.89	Basket 2
Basket 1	Euro area	141.36	Basket 2
Basket 1	Korea	90.07	Basket 2
Basket 1	Singapore	26.68	Basket 2
Basket 1	Malaysia	26.26	Basket 2
Basket 1	Russia	21.23	Basket 2
Basket 1	Australia	20.39	Basket 2
Basket 1	United Kingdom	19.73	Basket 2
Basket 1	Thailand	17.34	Basket 2
Basket 1	Canada	15.52	Basket 2
	India	13.60	Basket 2
	Indonesia	13.48	Basket 2
	Philippines	13.33	Basket 2
	Brazil	12.36	Basket 2
	Mexico	7.11	Basket 2
	South Africa	5.91	Basket 2
	Chile	5.36	Basket 2
	Sweden	5.20	Basket 2
	Switzerland	5.16	Basket 2

Source: IMF Direction of Trade Statistics, annual series

Table 2 Correlation Coefficients of Currencies in Basket I

Correlation of exchange rates

A. Calculation based on base currency invariant index

	Australia	Canada	Euro Area	Japan	Korea	Malaysia	Russia	Singapore	Thailand	UK	US
Australia	1.00	0.26	0.25	-0.45	0.06	-0.51	-0.13	-0.42	-0.28	0.08	-0.64
Canada	0.26	1.00	-0.20	-0.30	-0.09	-0.12	-0.21	-0.31	-0.18	-0.06	-0.08
Euro Area	0.25	-0.20	1.00	-0.13	-0.19	-0.41	-0.05	-0.20	-0.26	0.24	-0.44
Japan	-0.45	-0.30	-0.13	1.00	-0.12	-0.02	-0.26	0.23	0.17	-0.26	0.18
Korea	0.06	-0.09	-0.19	-0.12	1.00	-0.13	-0.16	-0.07	-0.14	-0.32	-0.36
Malaysia	-0.51	-0.12	-0.41	-0.02	-0.13	1.00	0.16	0.44	0.11	-0.27	0.76
Russia	-0.13	-0.21	-0.05	-0.26	-0.16	0.16	1.00	-0.06	-0.26	0.03	0.07
Singapore	-0.42	-0.31	-0.20	0.23	-0.07	0.44	-0.06	1.00	0.25	-0.32	0.40
Thailand	-0.28	-0.18	-0.26	0.17	-0.14	0.11	-0.26	0.25	1.00	-0.16	0.27
United Kingdom	0.08	-0.06	0.24	-0.26	-0.32	-0.27	0.03	-0.32	-0.16	1.00	-0.11
United States	-0.64	-0.08	-0.44	0.18	-0.36	0.76	0.07	0.40	0.27	-0.11	1.00

B. Calculation based on exchange rates (SDR as the base currency)

	Australia	Canada	Euro Area	Japan	Korea	Malaysia	Russia	Singapore	Thailand	IK	US
Australia	1.00	0.49	0.40	-0.32	0.34	-0.01	0.18	0.19	0.10	0.30	-0.34
Canada	0.49	1.00	-0.07	-0.22	0.25	0.25	0.12	0.23	0.16	0.15	0.13
Euro Area	0.40	-0.07	1.00	-0.40	0.00	-0.51	-0.01	-0.27	-0.29	0.14	-0.80
Japan	-0.32	-0.22	-0.40	1.00	0.00	-0.16	-0.25	0.06	0.10	-0.43	-0.03
Korea	0.34	0.25	0.00	0.00	1.00	0.29	0.16	0.44	0.22	-0.03	-0.05
Malaysia	-0.01	0.25	-0.51	-0.16	0.29	1.00	0.38	0.59	0.30	-0.19	0.72
Russia	0.18	0.12	-0.01	-0.25	0.16	0.38	1.00	0.28	0.02	0.16	0.18
Singapore	0.19	0.23	-0.27	0.06	0.44	0.59	0.28	1.00	0.46	-0.15	0.36
Thailand	0.10	0.16	-0.29	0.10	0.22	0.30	0.02	0.46	1.00	-0.05	0.31
United Kingdom	0.30	0.15	0.14	-0.43	-0.03	-0.19	0.16	-0.15	-0.05	1.00	-0.23
United States	-0.34	0.13	-0.80	-0.03	-0.05	0.72	0.18	0.36	0.31	-0.23	1.00

Table 3 Variances of Exchange Rate Changes

Variances based on NVal index										
Australia	Canada	Euro Area	Japan	Korea	Malaysia	Russia	Singapore	Thailand	UK	US
0.000615	0.000424	0.000396	0.000671	0.000681	0.000139	0.0004	0.000074	0.000234	0.000346	0.000237

Table 4 Coefficients for Calibration of Basket I

	Basket I (2004)				Basket I (2008)			
	η	2	α_1	2.55%	η	2	α_1	7.72%
	α_2	14.53%	β	1.11	α_2	33.05%	β	1.34
Currency of	γ	δ	λ*	λ**	γ	δ	λ*	λ**
Australia	2.35%	3.40%	4.00%	2.59%	2.63%	5.89%	31.57%	9.30%
Canada	2.17%	2.16%	1.68%	1.09%	2.58%	2.07%	-0.35%	-0.10%
Euro area	21.80%	17.45%	8.10%	9.02%	25.97%	18.05%	6.00%	6.62%
Japan	19.55%	27.73%	14.10%	15.92%	13.76%	24.47%	12.00%	9.14%
Korea	7.40%	18.29%	0.89%	0.58%	8.75%	18.20%	7.15%	2.11%
Malaysia	2.15%	5.34%	0.36%	0.23%	2.53%	5.21%	-2.44%	-0.72%
Russia	2.42%	3.56%	0.11%	0.07%	3.91%	3.86%	-16.16%	-4.76%
Singapore	3.37%	4.11%	-1.15%	-0.75%	3.83%	3.26%	-12.10%	-3.57%
Thailand	1.54%	3.39%	0.57%	0.37%	1.84%	4.16%	0.88%	0.26%
United Kingdom	3.98%	1.40%	4.54%	0.10%	4.27%	1.55%	5.46%	0.04%
United States	33.27%	13.16%	66.80%	70.77%	29.93%	13.26%	68.00%	81.68%

Table 5 Coefficients for Calibration of Basket II

	Basket II (2004)				Basket II (2008)			
	η	2	α_1	2.55%	η	2	α_1	7.72%
	α_2	14.53%	β	1.11	α_2	33.05%	β	1.34
Currency of	γ	δ	λ*	λ**	γ	δ	λ*	λ**
Australia	2.16%	2.97%	2.74%	0.99%	2.32%	4.92%	10.76%	1.06%
Canada	1.99%	1.89%	1.15%	0.41%	2.27%	1.73%	-0.12%	-0.01%
Euro area	20.03%	15.27%	8.10%	9.02%	22.87%	15.09%	6.00%	6.62%
Japan	17.96%	24.28%	14.10%	15.92%	12.12%	20.47%	12.00%	9.14%
Korea	6.80%	16.02%	0.61%	0.22%	7.71%	15.23%	2.44%	0.24%
Malaysia	1.98%	4.68%	0.24%	0.09%	2.23%	4.36%	-0.83%	-0.08%
Russia	2.22%	3.12%	0.08%	0.03%	3.44%	3.23%	-5.51%	-0.54%
Singapore	3.10%	3.60%	-0.79%	-0.28%	3.37%	2.73%	-4.12%	-0.41%
Thailand	1.42%	2.97%	0.39%	0.14%	1.62%	3.48%	0.30%	0.03%
United Kingdom	3.66%	1.22%	3.10%	0.10%	3.76%	1.30%	1.86%	0.04%
United States	30.58%	11.52%	66.80%	70.77%	26.37%	11.09%	68.00%	81.68%
Brazil	0.90%	2.23%	2.17%	0.78%	1.96%	4.02%	6.01%	0.59%
Chile	0.41%	0.95%	0.22%	0.08%	0.64%	1.54%	0.65%	0.06%
India	1.45%	1.98%	0.31%	0.11%	3.29%	2.76%	1.74%	0.17%
Indonesia	1.53%	1.86%	0.85%	0.31%	1.80%	1.95%	3.15%	0.31%
Mexico	1.22%	0.55%	2.23%	0.80%	1.44%	0.50%	8.74%	0.86%
Philippines	1.04%	2.33%	0.28%	0.10%	0.95%	2.65%	0.58%	0.06%
South Africa	0.72%	0.76%	0.15%	0.05%	0.90%	1.25%	0.23%	0.02%
Sweden	0.45%	0.86%	0.69%	0.25%	0.53%	0.68%	1.23%	0.12%
Switzerland	0.37%	0.94%	-3.44%	0.10%	0.41%	1.00%	-13.09%	0.03%

Table 6 Optimal Weights for Chinese Basket currency

Currency of	Basket I (2004)		Basket I (2008)		Basket II (2004)		Basket II (2008)	
	*	**	*	**	*	**	*	**
Australia	3.11%	2.79%	14.52%	6.04%	2.59%	2.19%	6.24%	2.52%
Canada	2.05%	1.92%	1.33%	1.42%	1.76%	1.59%	1.21%	1.25%
Euro area	17.07%	17.28%	16.26%	16.50%	15.56%	15.77%	14.35%	14.59%
Japan	21.29%	21.71%	15.93%	14.84%	19.39%	19.80%	14.27%	13.18%
Korea	9.89%	9.82%	10.64%	8.72%	8.75%	8.66%	7.67%	6.83%
Malaysia	2.91%	2.88%	1.35%	2.00%	2.57%	2.53%	1.62%	1.91%
Russia	2.31%	2.30%	-3.75%	0.59%	2.06%	2.05%	-0.05%	1.86%
Singapore	2.61%	2.70%	-2.39%	0.86%	2.39%	2.51%	0.33%	1.75%
Thailand	1.99%	1.95%	2.09%	1.85%	1.75%	1.69%	1.60%	1.50%
United Kingdom	3.17%	2.15%	4.00%	1.94%	2.64%	1.95%	2.38%	1.69%
United States	33.60%	34.51%	40.02%	45.23%	31.91%	32.82%	38.31%	43.56%
Brazil					1.68%	1.36%	4.06%	1.98%
Chile					0.56%	0.53%	0.88%	0.65%
India					1.38%	1.34%	2.56%	1.95%
Indonesia					1.49%	1.37%	2.36%	1.27%
Mexico					1.21%	0.88%	3.99%	0.97%
Philippines					1.34%	1.30%	1.26%	1.06%
South Africa					0.60%	0.58%	0.74%	0.65%
Sweden					0.65%	0.55%	0.84%	0.41%
Switzerland					-0.29%	0.52%	-4.61%	0.42%

Table 7 Parameter Values for Sensitivity Tests

Fixed value of parameters			
α_1	2.55%	α_2	14.53%
β	1.11	η	2
γ_1	0.5	γ_2	0.5
δ_1	0.5	δ_2	0.5
λ_1	0.5	λ_2	0.5
σ_1	0.025	σ_2	0.025
ρ_{11}	1	ρ_{12}	0.2
ρ_{21}	0.2	ρ_{22}	1
Ranges for testing parameters			
Test (a)		Test (b)	
α_2	[0%, 40%]	β	[1.05, 1.45]
λ_1	[0%,100%]	λ_1	[0%,100%]

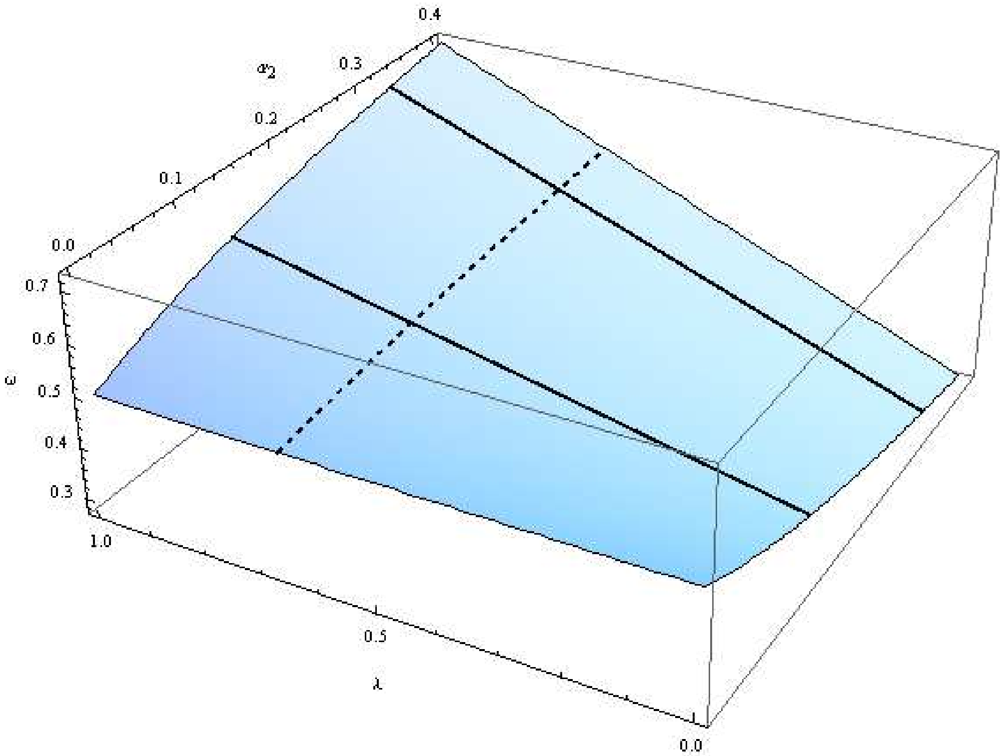

Figure 1 Results of Sensitivity Test (a) (Vertical axis shows weights, and two horizontal axes λ and α_2)

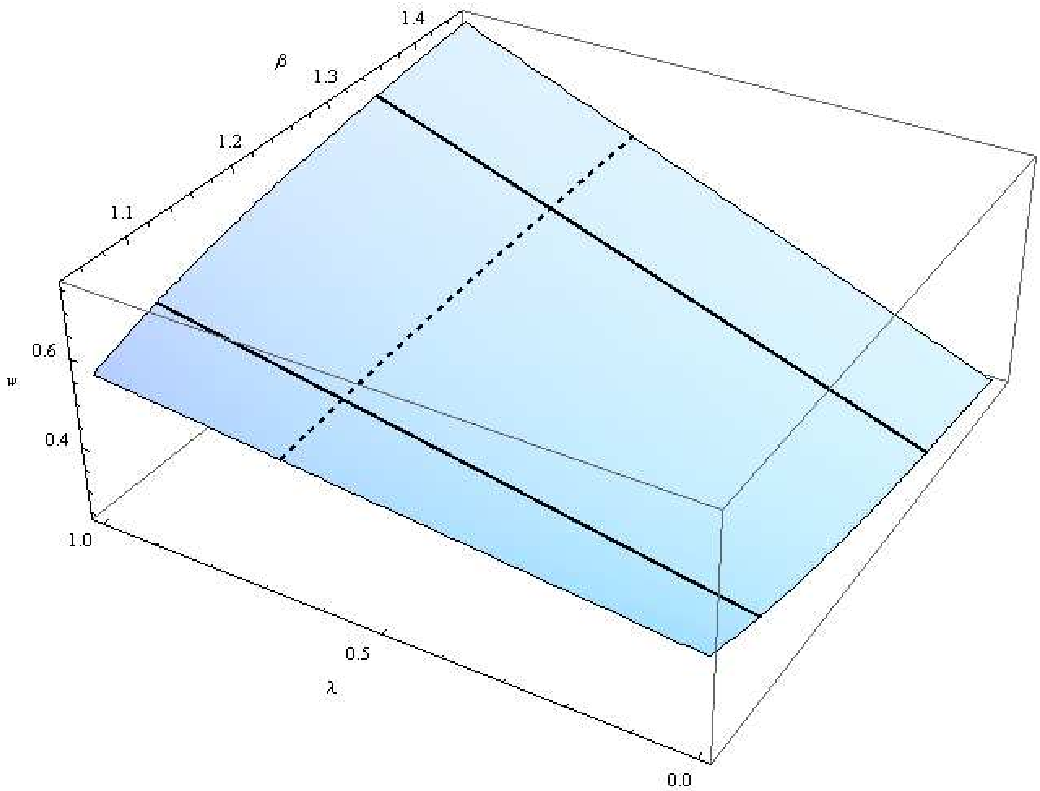

Figure 2 Results of Sensitivity Test (b) (Vertical axis shows weights, and two horizontal axes β and λ)