Measurement and Inference in International Reserve Diversification

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Abstract: This paper analyzes international reserve diversification by examining changes in quantity shares of currencies held in foreign exchange reserves. It discusses alternative methodologies for constructing quantity shares and applies the preferred methodology to three sets of data on the currency composition of foreign exchange reserves: quarterly aggregate International Monetary Fund's Composition of Foreign Exchange Reserves (IMF COFER) data, quarterly IMF COFER data for industrial- and developing-country groups, and annual data for 23 individual countries that disclose the currency composition of their foreign exchange reserve holdings. What can one infer from available data about the diversification of foreign exchange reserves since 1999? The analysis suggests four conclusions: (1) The behavior of the quantity shares of the US dollar and the euro in total reserves is consistent with net stabilizing intervention; their quantity shares tend to rise when these currencies are declining and vice versa. (2) The principal driver of this stabilizing diversification over the period 1999Q1–2005Q4 is Japan. (3) The industrial countries as a group but excluding Japan do not indicate stabilizing diversification. (4) The nonindustrial countries as a group display stabilizing diversification over short periods of only a few quarters. In summary, the aggregate data conceal much diversity in the practices of individual countries.

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INTRODUCTION

Recent media headlines echo concerns of policymakers and private-sector participants about official reserve diversification from dollars and its impact on the value of the US dollar. Reserve diversification, as noted by Truman and Wong (2006), can be differentiated between that which does not exert or relieve pressure on foreign exchange markets—passive diversification—and that which exerts pressure on foreign exchange markets—active and stabilizing diversification. Under passive diversification, monetary authorities do not take actions but allow exchange rate changes to alter the allocation of their reserve portfolio. Under active diversification, monetary authorities alter their portfolio allocation in the direction of the market trend, further adding pressure on foreign exchange markets toward the direction of the trend. On the other hand, under stabilizing diversification, monetary authorities intervene in foreign exchange markets against the market trend. Because the latter two types of reserve diversification exert different pressures (supporting for stabilizing and not supporting for active) on foreign exchange markets, they constitute the primary public concern about the impact of dollar reserve diversification on the dollar.¹

Available aggregate data on the currency composition of countries' foreign exchange reserves are reported on a value basis, which reflects all three types of reserve diversification. These value data include changes caused by variations in the relative exchange rates among the reserve currencies as well as by changes due to actual official transactions in the foreign exchange market.² Thus, to differentiate between passive and the other two types of reserve diversification, one needs to differentiate between price and quantity effects. The relevant variable for looking at active or stabilizing diversification is the change in the quantity share, which would be adjusted for price effects.

The first part of this paper examines issues related to the methods of constructing these quantity shares. The second part applies the estimation method revealed to be the most appropriate to calculate reserve currency shares from data at three levels of aggregation: (1) the International Monetary Fund's Composition of Foreign Exchange Reserves (COFER) aggregate data for global reserves, (2) IMF COFER aggregate data for industrial and nonindustrial country groups, and (3) data for 23 individual countries that disclose the currency composition of their reserves.³ Discussion of reserve diversification based on aggregate data shows only the share of reserves held in the currency by all countries as a group but does not reveal the dominant trend defined as the direction of changes by the largest

1. See Truman and Wong (2006) for further details on the three types of diversification.

2. The quantity of a reserve currency is defined as the amount of currency held in that particular reserve currency, denominated and measured in that currency.

3. The IMF's COFER database is available at www.imf.org/external/np/sta/cofer (accessed February 25, 2006).

number of countries. For example, if one large holder of dollar reserves has been increasing its reserves rapidly even though most of the other countries, which are much smaller reserve holders, have been reducing their dollar exposure, the aggregate data may still show a large increase in the dollar's share. This paper attempts to address these problems of inference by examining data on decreasing aggregation levels. This analysis shows that isolating Japan from industrial-country data provides a different picture from that in the aggregate data about the dominant diversification trend in the dollar reserve share. The last section concludes with a summary of the findings and cautions about their interpretation.

QUANTITY SHARES

When reporting the currency composition of foreign exchange reserves, national authorities typically convert their reserves held in different currencies into a base, or numeraire, currency at the present market exchange rate and report the percentage breakdown of each foreign currency in its total foreign exchange reserves denominated at the base currency. In the case of data submitted to the IMF by individual countries, the IMF aggregates the total amounts held in each currency by all reporting countries and publishes the value levels in its quarterly release of its COFER data. The value share of a currency is obtained by dividing the amount held in that currency by the total global reserves. However, the construction and interpretation of quantity shares from this information on values is not entirely straightforward. The process raises questions about (1) derivation of quantity shares and (2) implications of the derivation method for quantity levels and shares.

Derivation of Quantity Shares

Consider the value share of reserve currency k at two periods t and $t+1$, where the value share at period t is given by:

$$VS_t^k = \frac{V_t^k}{\sum_{j=1}^n V_t^j} \quad (1)$$

where

VS_t^k is the value share of currency k at time t

$\sum_{j=1}^n V_t^j$ is the sum of reserves held in all $j=1, 2, \dots, n$ reserve currencies in a particular numeraire.

Expressed in terms of VS_t^k , the value share at time $t+1$, VS_{t+1}^k , can be written as

$$VS_{t+1}^k = VS_t^k \cdot \frac{1 + \Delta V_{t+1}^k}{1 + \sum_{j=1}^n (VS_t^j \cdot \Delta V_{t+1}^j)} = \frac{V_t^k}{\sum_{j=1}^n V_t^j} \cdot \frac{1 + \Delta V_{t+1}^k}{1 + \sum_{j=1}^n \left(\frac{V_t^j}{\sum_{j=1}^n V_t^j} \cdot \Delta V_{t+1}^j \right)} \quad (2)$$

where ΔV_{t+1}^k is the percentage change in the value of reserves held in currency k in the particular numeraire, which can be further broken down into two factors:

$$\Delta V_{t+1}^k = \left(1 + \Delta \frac{N}{k}_{t+1}\right) \cdot (1 + \Delta Q_{t+1}^k) - 1 \quad (3)$$

where $\Delta \frac{N}{k}_{t+1}$ is the percentage change in the exchange rate of the numeraire currency N vis-à-vis currency k from time t to $t+1$ and ΔQ_{t+1}^k is the percentage change in the quantity of holdings of k in the numeraire from period $t+1$ to t .

Equation (3) shows that changes in the value of reserves in levels and shares can be decomposed into a price effect and quantity effect. The price effect arises from changes in the exchange rate of the reserve currency vis-à-vis the numeraire. Quantity effects come from changes in official demand for the reserve currency and, to a less important degree, accrued returns on existing investments. As equation (2) shows, the change in the value share of reserve currency k at period t depends on the rate of growth of the value of reserves held in that currency relative to the growth rate for all other currencies. If the weighted sum of the combined price and quantity changes in the reserves held in each reserve currency is higher (lower) than the combined price and quantity change in the reserves held in currency k , then currency k 's value share of global reserves falls (rises).

To obtain the quantity shares, exclude the price effects from equation (3):

$$QS_t^k = \frac{Q_t^k}{\sum_{j=1}^n Q_t^j} \quad (4)$$

where QS_t^k is the quantity share of currency k at time t

$\sum_{j=1}^n V_t^j$ is the sum of the quantities of reserve levels of all $j=1, 2, \dots, n$ reserve currencies.

Expressed in terms of QS_t^k , the quantity share at time $t+1$ can be written as:

$$QS_{t+1}^k = QS_t^k \cdot \frac{1 + \Delta Q_{t+1}^k}{1 + \sum_{j=1}^n (QS_t^j \cdot \Delta Q_{t+1}^j)} = \frac{Q_t^k}{\sum_{j=1}^n Q_t^j} \cdot \frac{1 + \Delta Q_{t+1}^k}{1 + \sum_{j=1}^n \left(\frac{Q_t^j}{\sum_{j=1}^n Q_t^j} \cdot \Delta Q_{t+1}^j \right)} \quad (5)$$

where ΔQ_{t+1}^k is the percentage change in the quantity of reserves in the numeraire held in currency k from period t to $t+1$.

The quantity share for reserve currency k will rise at time $t+1$ if its rate of growth is higher than the weighted rate of growth in global reserves in quantity terms.

The delicate part in the estimation of quantity shares is the representation of the quantity of reserves held in different reserve currencies in a single numeraire currency but excluding the effects of changes in exchange rates relative to the numeraire. This involves choosing an exchange rate that converts quantity changes in each reserve currency to the numeraire value but reasonably minimizes the effects on the quantity changes of swings in the numeraire value of the reserve currency at market exchange rates. Currently, the only agencies in the world that undertake these calculations are the IMF and the Bank for International Settlements (BIS), which are the guardians of the confidential data on currency composition of foreign exchange reserves.⁴ Each of them uses a different estimation method for calculating quantity shares.⁵

Conversion by a Base Year Numeraire Exchange Rate

The most straightforward approach to excluding numeraire price effects on the measurement of the quantity of reserves is to value the quantity of those reserves by the base year numeraire value of each currency. The BIS staff appears to favor this approach (Galati and Wooldridge 2006, Rogers 1993). This approach is intuitively attractive because it excludes the time-series and cross-currency variation in the numeraire value of each currency.

The calculation of the quantity shares for each currency involves four steps: (1) choosing a base year to fix the numeraire value of each reserve currency, (2) obtaining the numeraire value of annual quantity changes (or any frequency for which the data are available), (3) obtaining the quantity levels by adding

4. The IMF publishes the quantity changes of reserves every year in the appendix section of its annual report. The BIS occasionally publishes the quantity share of each reserve currency in its working papers.

5. Below I will also calculate quantity shares for the individual countries that report the currency composition of their reserves.

the constant numeraire value of quantity changes derived from each estimation interval to the value level at the base year, and (4) obtaining the shares by dividing the quantity level of the particular currency by the sum of the quantity levels of all currencies.

The change in the quantity of reserves in currency k in the numeraire is defined as the change in the value of reserves multiplied by a constant (base year) exchange rate of the numeraire price of the reserve currency:

$$\Delta Q_t^k = e^k \cdot \Delta R_t^k \quad (6)$$

where

e^k is the constant numeraire price of reserve currency k .

ΔR_t^k is the change of the level of reserves in reserve currency k between time t and $t-1$, valued in reserve currency k .

The quantity of reserves held in currency k at period t is the sum of the initial value level of reserves in k and all the subsequent numeraire value of quantity changes up to time t . Let the initial quantity level be $Q_{t=0}^k = V_{t=0}^k$, where Q is the quantity level and V is the value level. Consider the quantity level Q_t^k for periods $t=1, 2, 3, \dots, n$:

$$\begin{aligned} Q_1^k &= Q_0^k + e^k \cdot (R_1^k - R_0^k) \\ Q_2^k &= Q_0^k + e^k \cdot (R_1^k - R_0^k) + e^k \cdot (R_2^k - R_1^k) = Q_0^k + e^k \cdot (R_2^k - R_0^k) \\ &\vdots \\ Q_n^k &= Q_0^k + e^k \cdot (R_1^k - R_0^k) + e^k \cdot (R_2^k - R_1^k) \dots + e^k \cdot (R_n^k - R_{n-1}^k) \\ &= Q_0^k + e^k \cdot (R_n^k - R_0^k) \end{aligned} \quad (7)$$

Equation (7) shows that the differences in the numeraire value of quantity levels of reserves across periods are directly comparable due to the common denominator in the base year numeraire (for example, the US dollar). It also shows that the choice of e^k affects the quantity levels calculated for each currency k , implying that the choice of the base year of the exchange rate determines quantity levels. Because quantity shares are calculated by dividing the quantity level of individual currency by the sum of the quantity levels of all reserve currencies, the calculation of quantity shares also depends on the base year exchange rate in terms of the numeraire e^k . In this case, e^k can be interpreted as the individual currency's weight on its own quantity reserve level changes in the denominator of the share calculation in equation (5). Therefore the year to which the exchange rates are fixed determines the distribution of the weights.

But the ability of this method to filter cross-currency exchange rate value changes across time may also be its potential shortcoming. Recall that quantity levels in the long run are calculated by an accretion of quantity changes. As the numeraire value of the currency as well as the implicit cross-currency values increasingly deviate from the base year values, conversion of the quantity changes from subsequent estimation intervals using the obsolete exchange rate value will tend to understate or overstate the currency's quantity.⁶

For example, suppose that there are two reserve currencies, $k = \text{usd}, \text{euro}$. e^{usd} (the numeraire value of US dollar) tends to be high when e^{euro} is low. Furthermore, suppose that the year where e^{usd} is highest is fixed as the reference year, implying that the indexed exchange rate for the euro, e^{euro} , is low by the standard of the currency's own sample time period. As the dollar depreciates in the subsequent years, the quantity changes in the estimated intervals would be converted at the higher value, thus building up at the end of several periods later to a quantity level that is much higher than its value levels. Meanwhile, the accretions of quantity changes in the euro would lead to a much smaller quantity level than its value levels.

In the calculation of quantity shares, the dollar quantity levels would progressively take up a higher weight in the denominator, and the euro quantity levels would take up a smaller weight. As a result, the weight on the quantity changes of the depreciating US dollar is larger than would be if the exchange rate is indexed to the year with the lowest e^{usd} ; similarly, the weight on the quantity changes of the appreciating euro is smaller than would be if the exchange rate is indexed to the year with the highest e^{euro} . The quantity share of the US dollar, as a result, will be higher than would be for other index years and that for the euro will be lower than would be for other index years. It does not matter how frequently a currency fluctuates as long as the changes are white noise—what matters is if e^k contains a trend in the time period. If such a trend exists, the indexation of the conversion rate to one base year will either overstate or understate the reserves in currency k over a long period.

Although the quantity shares vary with the indexed year, the share changes do not. Thus, the choice of the indexed year does not affect the results in the context of studying reserve diversification from an arbitrary base year.

Conversion by a Moving Average Exchange Rate

This approach, favored by the IMF staff, avoids the long-run comparison problem of reserve shares arising from a fixed base year exchange rate by converting the initial quantity levels by a moving

6. An analogy can be drawn to the problems statisticians encounter with chain price index versus constant price index in the compilation of national output statistics. See Landefeld and Parker (1997).

average exchange rate in terms of the numeraire taken at the end points of each estimation interval.⁷ In effect, the exchange rate at each end point is given equal weight in the valuation of quantity reserve change.⁸

$$\Delta Q_t^k = \frac{e_t^k + e_{t-1}^k}{2} \cdot \Delta R_t^k \quad (8)$$

where

ΔQ_t^k is the quantity change in reserve currency k in terms of the numeraire at time t .

ΔR_t^k is the change of the level of reserves in reserve currency k between time t and $t-1$, valued in that reserve currency k .

e_t^k is the numeraire price of reserve currency k at time t , and e_{t-1}^k at $t-1$.

The quantity level of reserves in currency k at time $t=1, 2, \dots, n$ is then defined as:

$$\begin{aligned} Q_1^k &= Q_0^k + ae_1^k \cdot (R_1^k - R_0^k) \\ Q_2^k &= Q_0^k + ae_1^k (R_1^k - R_0^k) + ae_2^k (R_2^k - R_1^k) \\ &\vdots \\ Q_n^k &= Q_0^k + ae_1^k \cdot (R_1^k - R_0^k) + ae_2^k \cdot (R_2^k - R_1^k) \cdots ae_n^k \cdot (R_n^k - R_{n-1}^k) \end{aligned} \quad (9)$$

where $ae_t^k = \frac{e_t^k + e_{t-1}^k}{2}$.

Unlike the constant base year exchange rate method, the quantity level changes for each currency from time t to n periods later is the sum of all the quantity changes from each estimation intervals between t and $t+n$. The smaller the estimation intervals, the more closely the set of conversion rates for a currency captures the long time trend of its value against the numeraire.

Base Year Versus Moving Average: Implications for Quantity Levels and Shares

The basic idea of both methods is to isolate the price effects caused by exchange rate movements of the reserve currency vis-à-vis the numeraire. Both procedures also convert each currency's quantity changes in the estimation interval by a common exchange rate.⁹

7. See the foreign exchange currency composition tables in the appendix section of IMF annual reports.

8. An average of the market exchange rate is taken because the quantity reserves could have been added or reduced at any time during the estimation interval.

9. The two methods also do not identify quantity additions due to interest payments and dividends, for the reason that the data needed to exclude this effect is beyond the scope of this paper. But it is reasonable to assume that the quantity additions attributable to interest

The two methods differ only in the choice of the common conversion rate. Using time-varying exchange rates, as in the IMF method, more adequately measures long-run changes in the quantity shares without suffering from a distortion of weights. On the other hand, using base year exchange rates, as in the BIS method, allows a ready comparison of quantity levels across time. It is also a more convenient conversion method to apply. Appendix A provides more details on differences in the quantity shares calculated by the two methods.

This paper employs the IMF quantity share estimation method because the objective is to examine changes in the quantity shares over the long run, defined as more than five years. All the ensuing discussion of quantity shares and levels will be based on the moving average conversion.

The previous subsections have emphasized the important role of the numeraire in the estimation of quantity shares. Recall that the objective of calculating quantity shares is to exclude the numeraire price effects. Thus, the choice of numeraire determines the magnitude of these effects to be eliminated.

Currently, the US dollar is the dominant numeraire currency for international financial data. The IMF COFER database, which is the most reliable source of aggregate data on the currency composition of international reserves, currently reports the aggregate data of 115 countries in US dollars. Gross international reserve levels in the IMF's *International Financial Statistics* are also published in US dollars, as well as in special drawing rights (SDR) but not euro.

What is the effect of using a different numeraire on the value and quantity estimations?

Switching the numeraire will affect the calculated growth in value levels but not value shares. It does not affect value shares because the conversion rate of the numerator cancels out that of the denominator. Since it does not affect the value shares, the problem of changing value levels due to different numeraires is not immediately relevant to considerations of reserve diversification.

However, the choice of the numeraire will affect both quantity levels and shares (see appendix B). Since quantity shares have the most immediate relevance to inference in reserve diversification, it is worthwhile to examine their estimation based on different numeraires. The three numeraires chosen for this exercise are the top contenders for the numeraire currency status: SDR, US dollar, and euro. The difference is insignificant. The series of charts in figure 1 demonstrate these numeraire differences for the dollar, euro, and yen.

Over 1981–94 and 1995–98, the change in the dollar quantity shares using the dollar as the numeraire on average is 0.1 percentage points lower than using SDR as the numeraire. The methodological difference due to choice of numeraire for the yen quantity share averages to be trivial

and dividend payments for individual reserve currencies do not constitute enough of a magnitude to lead to a change in quantity shares, which is the variable of interest.

for all three periods. The difference between using dollar or euro as the numeraire also turns out to be insignificant, with quantity share changes based on the dollar numeraire averaging 0.1 percentage points lower than with euro as the numeraire.

The conclusion from this exercise is that the choice of numeraire can affect the measurement of levels and shares. Value and quantity *levels* would vary depending on the choice of the base currency in which they are measured. Quantity share changes measured in different numeraires also differ, albeit insignificantly. In the context of reserve currency composition, we are primarily interested in shares, thus the numeraire problem does not constitute a big concern for the purposes of this paper.

Despite its marginal influence on the variable of interest, the numeraire should be chosen in a reasonable way that at least eases interpretation. The SDR is the obvious and suitable currency unit to examine the value of a reserve currency in aggregate data. Currently, 115 countries report their reserve currency composition to the IMF COFER database. The size of these countries' reserves varies, and their purposes for holding reserves also vary for a combination of reasons, which may include financing current account deficits, intervening to achieve exchange rate and monetary policy objectives, cushioning against capital inflows and outflows, and improving terms of external financing. By construction, the SDR is a weighted sum of the world's four major reserve currencies' shares in trade, finance, and reserves (IMF 2005). Thus it seems to be a reasonable numeraire for representing the international basket of goods and services that is used to judge the international purchasing power of a reserve currency, at least for countries on average even if it is not perfect for each individual country.

Although the SDR is an appropriate numeraire for examining aggregate world reserves, it may not be the optimal numeraire when the country composition of a sample is known. The numeraire that a country chooses, as reported in their monetary authority's annual report, may be chosen as a byproduct of their reserve management objectives or national law. Thus, the best numeraire for use in analyzing the currency composition of reserves of individual countries is the one that these countries choose for themselves. An appropriate choice of numeraire in this case would be the numeraire currency used most frequently in the sample. This is the logic underlying the choice of the numeraire for calculating the quantity shares of the 23-country dataset, which consists of 7 industrial Western European countries, 7 transition countries in Eastern Europe, 4 Asia-Pacific countries, 3 Latin American countries, and 2 industrial countries from North America. The numeraires of each of the 23 countries are shown in table 1.

Out of this group of 23 countries, 11 countries report the reserve currency composition data denominated in their domestic currency, 7 non-US countries report in US dollars, and 1 non-euro area country reports in euro. Altogether, the number of different numeraires in this sample totals 18 (excluding the United States reporting in dollars and Finland in euros). The most prevalent numeraire

currency in this sample is the dollar. Thus, the quantity shares in the following discussion will be based on US dollars.

One advantage of the US dollar over the SDR as the numeraire is the convenient interpretation of its quantity levels, i.e., one dollar is always one dollar, and all quantities of other reserve currencies are measured in an actual circulating currency. Furthermore, the best case one can make for using the US dollar as the numeraire is simply that most presentations are in terms of the US dollar. The IMF COFER data as well as its international reserves template data are reported in US dollars. At an operational level, there is strong inertia supporting the use of the US dollar as the numeraire, sustained over years by accounting and transaction conventions. Using the dollar as the numeraire in this paper, therefore, simply conforms to the conventions and also facilitates easy comparison with other related studies in which currency shares are also denominated in US dollars.

THE DEVIL IS IN THE DISAGGREGATE DATA

This section applies the moving average exchange rate conversion methodology discussed in previous sections to calculate the reserve currency quantity shares estimated from three sets of data of increasing disaggregation: the COFER aggregate data series for the currency composition of global reserves, the COFER aggregate data series for the currency composition of industrial- and developing-country reserves, and the Truman-Wong data series for 23 countries that disclose the currency composition of their reserve holdings. The frequency of the COFER data used in the analysis is quarterly with the earliest data point being for 1999Q1, whereas the Truman-Wong data is annual and the time series begins in 2000.¹⁰ When examined alone, the quantity shares for the COFER data are based in 1999 and those for the Truman-Wong data are based in 2000.

This section examines the trend of global reserve currency shares from an aggregate to a less aggregate perspective. For each set of data, two contemporaneous relationships are considered: (1) the sensitivity of changes in a reserve currency's share to changes in the exchange rate value of that currency, and (2) the degree of substitutability among reserve currencies.

World Aggregate

The IMF COFER data series for world reserves consists of 115 reporting countries. Since 1999, holdings of global reserves in five major reserve currencies (US dollar, euro, yen, pound sterling, and

10. The reason for this period selection is data quality. The IMF staff revised the methodology for recording and estimating its COFER series in the 2005 Annual Report. The new methodology applies to the years after 1995. Also, quarterly data are available only beginning in 1999. The data examined in this section are based entirely on these newly revised quarterly data.

Swiss franc) as well as a category denoted as “Others” are reported. At the end of 2005, 66.5 percent of global reserves were held in dollars, 24.4 percent in euros, 3.6 percent in yen, 3.7 percent in pound sterling, and 0.1 percent in Swiss francs.

Reserve Currency Share Versus Exchange Rate Value

For a typical reserve manager, the change in the value of a reserve currency relative to other currencies is an important factor in the consideration of its share in the country’s reserve portfolio. Truman and Wong (2006) put forth a hypothesis regarding the connection between changes in the dollar’s global share in reserves to its exchange rate value: In the short run, the share of a depreciating reserve currency that is also an intervention currency may increase because countries increase their holdings of the currency to suppress appreciation of their own currencies against it, resulting in a pattern of stabilizing diversification in this depreciating currency. But the global share of this reserve currency may also eventually decrease (increase) due to the decreased (increased) attractiveness of its external purchasing power, thus resulting in a pattern of active diversification over the medium term. This hypothesis might in particular be true for the dollar, which is the principal intervention and reserve currency in the world today.

In an examination of five episodes of sustained dollar depreciation and four episodes of dollar appreciation from 1973 to 2005, chosen based on end-period exchange rates, Truman and Wong (2006) observe a pattern of stabilizing diversification in all five depreciation episodes and two of the appreciation episodes. One could also make the case for using average exchange rates to identify these episodes on account of exchange rate changes and interventions throughout the year. Table 2 presents six dollar depreciation and three appreciation episodes that result from this identification. The date and duration of the episodes differ from using end-period exchange rates by plus or minus a year but overall are not significantly different. With average exchange rates, 4 out of 6 depreciation episodes and 2 out of 3 appreciation episodes indicate a pattern of stabilizing diversification.

One of the identification differences between the two methods is the duration of the most recent period of sustained dollar depreciation that began in 2002. The end-period exchange rate method identifies 2004 as the end of this episode, while the average annual rate method identifies 2005 as the end of the episode. While many observers would remember 2005 as the year when the dollar made a comeback after three consecutive years of depreciation, one could not fully reject the reasonableness of identification by average annual rates. Because of this difference in the duration of this period, the observed diversification pattern for this episode differs. In the dollar depreciation period 2002–04, the dollar’s quantity share climbed by 2 percentage points as its value share decreased by 5.6 percentage points. However, in the period 2002–05, the dollar’s quantity share dropped by 0.5

percentage points as its value share also declined by 4.9 percentage points. The period identified by end-year exchange rate data would support considerable stabilizing diversification, and the period identified by annual average data would support some active diversification.

Which is the more accurate portrayal of reality?

With quarterly aggregate data for 1999–2005, we can examine this latest episode of dollar depreciation with higher frequency data. Figure 2 displays the aggregate value and quantity shares for the dollar, as well as the other four reserve currencies, with their corresponding end-of-period real effective exchange rate values.¹¹

Two simple tests can be applied to evaluate the contemporaneous relationship between changes in a currency's share and changes in that currency's value. The first is the correlation between the value and quantity shares of each reserve currency. Since the value share of a reserve currency already incorporates the price effects arising from changes in the value of the reserve currency against the numeraire (dollar in this case), the degree of positive correlation or lack thereof between the value share and the quantity share of a currency may suggest whether changes in quantity shares—interpreted as changes in official demand for the reserve currency relative to other reserve currencies as a reserve asset—follow changes in its external value, measured as the quantity of US dollars the currency could purchase. A cursory glance at figure 2 would appear to suggest a clear positive correlation between the value shares and quantity shares of yen, pound sterling, and Swiss franc. But the quantity shares of the US dollar and euro seem to move in the opposite direction from their value shares.

The correlation matrix between quarterly changes in each currency's value and quantity shares, as presented in figure 3, confirm the observations from figure 2. The data show that the US dollar and euro have a much smaller degree of positive correlation than Swiss franc, pound sterling, and yen. Furthermore, the correlations for the US dollar and euro are insignificant, whereas the positive correlations for the other currencies are all highly significant. The lack of significance may be an indication of the stabilizing diversification characteristics of the two currencies. These results are consistent with the observation from figure 2.

However, the degree of positive correlation between the value and quantity share is not enough to establish a relation between changes in reserve shares and the external value of the reserve currency. A decrease in the quantity share at a time of exchange rate depreciations as well as a decrease in the quantity share that exceeds the exchange rate appreciation would both result in a net negative change in the value shares, recording a positive correlation. Thus a higher degree of positive correlation

11. The exchange rate for the US dollar is the real broad effective dollar value calculated by the staff at the Federal Reserve Board. The real effective exchange rates for other currencies are taken from the IMF's *International Financial Statistics*.

may not necessarily indicate the lack of an inverse contemporaneous relationship between quantity shares and exchange rate changes. Furthermore, this first test evaluates the external purchasing power of a reserve currency in terms of the number of dollars it can buy.

A second test of sensitivity to exchange rates supplements the first test by measuring the correlation between the real trade weighted exchange rate changes and the quantity share changes. Although the results as shown in figure 4 are insignificant, it does show that the dollar and euro quantity shares are negatively correlated with their real exchange rate value, whereas the yen and pound are positively correlated with their respective real exchange rate value. The negative correlation for the Swiss franc is driven by a sharp decrease in Swiss franc's role as a reserve currency since 2002Q4 (which coincided with the increase in the dollar's share) and again in 2004Q2 (which coincided with the pound's sudden rise in reserve share) despite its strengthening currency.¹² These results match the observations from figure 2 and the results from figure 3.

The conclusion from the two tests of sensitivity of a currency's reserve share to movements in its foreign exchange value is that changes in the reserve share of both the dollar and euro appear to bear an inverse relationship with the external value of their currency; this can be supporting evidence of stabilizing diversification characterizing the intervention function of these two major reserve currencies. On the other hand, the changes in the share of yen and pound in global reserves appear to be positively correlated with their exchange rate value, which may support the case that these currencies do not function as intervention currencies and thus are managed by active diversification by reserve managers who place a high priority on their external purchasing power. The case is mixed for the Swiss franc.

Degree of Substitutability among the Reserve Currencies

On the degree of substitutability among reserve currencies, figure 5 shows the cross-correlations of currency quantity shares. The euro is the closest substitute to the dollar with a negative 0.87 correlation, followed by the pound and the yen.

Since the shares of all the reserve currencies have to sum to 1, a rise in one currency's share has to be matched by a decline in the share of at least one other currency. Over the estimation period, it would appear that the euro has served as the principal substitute for the US dollar. On both value and quantity bases, the dollar and euro shares are negatively correlated. From 1999Q1 to 2005Q4, the dollar's value share dropped by 4.6 percentage points; in the meantime, the euro's value share went

12. Wooldridge (2006) writes that the similarity between the Swiss franc/US dollar exchange rate and the euro/US dollar exchange rate combined with euro assets' favorable yield over Swiss franc assets contribute to the declining role of the Swiss franc as a reserve currency.

up by 5.3 percentage points. The dollar's quantity share decreased by 3.2 percentage points while the euro quantity share increased by 4.7 percentage points. Both quantity shares change in the same direction as their value share but much less. Yet this negative correlation is not perfect and appears to be dependent on the period of measurement—for instance, from 2000Q4 to 2004Q4, the quantity shares of the dollar and euro both increased by 1.3 and 0.3 percentage points, respectively.

Industrial Versus Developing Countries

The usual caveat applies for drawing conclusions from aggregate data: Appearances may deceive. Is the potential stabilizing diversification observed between changes in quantity shares and changes in the dollar's foreign exchange value observed in the aggregate data for the US dollar and euro caused by the actions of one large dollar holder or many dollar holders? If the large holder is the principal driver of the stabilizing diversification trend, then the moment this holder terminates this type of behavior, the dollar would be further under pressure than it used to be. With the availability of a separate IMF COFER data series for industrial and nonindustrial countries as groups, the source of these observed trends in world aggregate data can be examined further.¹³

Figures 6 and 7 display the value and quantity shares for the reserve currencies in industrial- and developing-country reserves, along with the reserve currency's own real effective exchange rate in the backdrop. These figures suggest that there are some distinct differences in the reserve currency share distribution as well as reserve management style between the industrial and developing countries as a group.

Difference in the Distribution of Reserve Currency Shares

The group of industrial countries in aggregate held a larger share of reserves in dollars than developing countries. At the end of 2005, the dollar's share in industrial-country reserves was 73.7 percent, compared with 60.5 percent for developing-country reserves. The latter group also in aggregate held a larger share in euro (29 percent compared with 19 percent) and pound sterling (5 percent compared with 2 percent). One reason is the fact that the group of industrial countries contains the countries of all five of the major global reserve currencies, especially euro area countries; since a country does not hold its own currency in its reserves, the euro share should be smaller in industrial-country reserves. However, the most important reason is that the industrial-country group

13. The IMF COFER industrial-country group contains all 24 countries classified by the *International Financial Statistics* as industrial countries. The developing-country group consists of 91 developing countries.

contains Japan, which has more than four times the total foreign exchange reserves of the euro area.¹⁴ As shown below, Japan has a disproportionate share of dollars in its reserves. For these reasons, the dollar's share in the reserves of the industrial-country group is higher and the euro's share is lower than in the non-industrial country group.

Difference in Exchange Rate Value Sensitivity of Reserve Shares

There is a salient difference in the strength and direction of the sensitivity of the dollar and euro reserve shares to changes in their foreign exchange values between the two groups of countries. For industrial countries, changes in the dollar's quantity share exhibit a significant and inverse contemporaneous relationship with changes in its exchange rate value; the correlation of the changes in the euro's share with changes in its exchange rate value is also negative though insignificant (see figures 8 and 9). This relationship is not obvious for the developing countries, where both dollar and euro shares indicate positive correlation with their exchange rate values (see figures 11 and 12). These results suggest that the data for the industrial-country group is the driving force behind the observed negative correlation between the dollar's quantity share and exchange rate value in the aggregate data for the world.

Despite differences in the exchange rate sensitivity of the dollar's share, both industrial and nonindustrial countries share some similarities. Looking at the significant results in figures 8 and 11, one can see that the degree of positive correlation between value and quantity shares for both country groups is the lowest for the dollar and euro out of the five reserve currencies. These results suggest the functioning of both currencies as intervention currencies in the larger context of stabilizing diversification. Other similarities across the country groups are that (1) the quantity shares of the yen, pound, and Swiss franc remain as highly positively correlated with their own value shares in both country groups and (2) the dollar and euro are the closest substitute for each other (see figures 10 and 13).

A surprising aspect of the nonindustrial countries' data is the weak indication of stabilizing diversification. One would have hypothesized that a negative relationship between changes in the dollar's reserve share and changes in the dollar's foreign exchange value would more likely be observed in nonindustrial countries than in industrial countries as the former tend to either have more rigid exchange rate objectives or prioritize other objectives over profit-making. Instead, the obvious trend in the dollar's share, measured on both value and quantity bases, has been declining since 1999, dropping by 10 and 9 percentage points, respectively, by the end of 2005. Despite the

14. In addition, euro area reserves, including dollars but not euros, are larger than US reserves, which do not include dollars.

lack of sustained periods of stabilizing diversification, three brief periods of stabilizing diversification in favor of the dollar can be identified in figure 7a. They are (1) 2002Q3–2003Q2, where the dollar’s quantity share increased by 1.1 percentage points as the dollar index decreased by 11.7 percent; (2) 2004Q3–2004Q4, where the dollar’s quantity share increased by 1.2 percentage points, as the dollar index decreased by 7.3 percent; (3) 2004Q4–2005Q2, where the dollar’s quantity share decreased by 4 percentage points, as the dollar index increased by 7.4 percent. These three periods seem to suggest that the bias is toward larger reduction of the dollar shares during periods of dollar appreciation rather than vice versa.

In the industrial-country data, two significant stabilizing diversification episodes that likely drive the aggregate negative relations between exchange rate and quantity shares can also be identified in figures 6a and 6b. From the third quarter of 1999 to the first quarter of 2002, the US dollar’s quantity share dropped by 3 percentage points as the trade-weighted dollar index rose by 19 percent. At the same time, the euro’s quantity share increased by 4 percentage points as the trade-weighted euro depreciated by 9 percent. From 2002Q1 to 2004Q4, a similar pattern of stabilizing diversification is apparent. The dollar’s quantity share increased by 6 percentage points as the dollar declined by 27 percent, and the euro’s quantity share decreased by 5 percentage points as the euro rose by 23 percent.

During this period of a 6 percent rise in the dollar share from 2002Q1 to 2004Q4, dollar reserves recorded by the IMF increased by \$315 billion. By comparing the individual industrial country’s reserve changes during this period with the COFER industrial-country data on dollar holdings, it can be reliably concluded that the source of this large jump in the dollar’s share reflects Japan’s reserve accumulation over 2002Q4–2004Q1 (see Truman and Wong 2006 for details). As the largest reserve holder among industrial countries, Japan holds four times as much reserves as the euro area, which is the second largest industrial-country reserve holder. Thus, it is possible that the driving force behind the stabilizing diversification trend found in the US dollar reserve share from both the aggregate and the industrial-country IMF data series is attributable to Japan alone.

This tentative conclusion from the aggregate data that the dollar and euro series indicate a degree of stabilizing diversification requires a cautious further examination to see if it is due to the dominant influence of Japanese reserve purchases in the aggregate. This issue is explored in the next subsection.

Individual Disclosing Countries

The third set of data on the currency composition of reserves is from the 23 countries that currently disclose the currency composition of their reserves.¹⁵ The data for these countries for the period

15. After December 2005, Italy and the European Central Bank also began to publish the data, expanding the total number

2000–2005 are shown in table 3. Of the 23 disclosers, 11 are industrial countries and 12 are developing countries. The 23 countries are 7 industrial Western European countries, 7 transition countries in Eastern Europe, 4 Asia-Pacific countries, 3 Latin American countries, and 2 North American industrial countries. An annual time series from 2000 to 2005 is available for most of these countries. The aggregate dollar value share of reserves in 2005 for the 23-country data was 50.7 percent, compared with 66.5 percent in the global IMF COFER data. The dollar's quantity shares are 53.5 and 68.8 percent, respectively. Both shares are lower in the 23-country group because the group underrepresents large Asian and oil-exporting countries, which tend to hold a larger share of dollars in their reserves.

Resemblance to the COFER Aggregate Data

Despite the differences in the share levels, the trends in the shares of the dollar, euro, and yen in the 23-country data show a striking resemblance to those in the IMF COFER data in both value and quantity terms. The panels in figure 14 display the currency shares calculated from each of these two datasets, for the years from 2000 to 2005 for the dollar, euro, and yen.¹⁶

Consider the similarity in the direction and magnitudes of change between the IMF COFER aggregate data and the 23-country data in the dollar's value and reserve shares. From 2000 to 2005, the dollar share in global reserves as indicated by the IMF COFER data has decreased by 4.4 percentage points on a value basis and 2.2 percentage points on a quantity basis; the corresponding numbers for the aggregate data for 19 of the 23 countries where complete data for this six-year period are available are declines of 4.4 and 1.5 percentage points, respectively. By imputing the missing values for the other 4 countries (Uruguay, Peru, Iceland, and Sweden) for which a complete time series is not available, the resulting corresponding numbers for the 23-country aggregate are negative 5.1 and negative 2.3 percentage points, respectively.¹⁷ During 2004–05, the dollar value share of total reserves recorded by the IMF COFER data indicates a 0.7 percentage point increase while the 19-country data show a 1.7 percentage point increase. The corresponding number for the 23-country data with imputed missing values is an increase of 0.8 percentage points. On a quantity basis, the former indicates a drop of 2.8 percentage points compared with a drop of 2.2 percentage points for the 19-country data and a drop of 3.1 percentage points for the 23-country data.

of disclosers to 25.

16. For comparability with the 23-country data, the IMF COFER data here are presented at annual frequency using end-of-year observations instead of the quarterly frequency portrayed in figure 6. The quantity share is also rebased to 2000 to match the period for the 23-country data.

17. The assumptions are (1) Uruguay's 2000–2002 data are the same as 2003, the earliest where its data are available, (2) Peru 2000–2001 data are the same as in 2002, (3) Iceland 2000–2002 data are the same as in 2003, and (4) Sweden's 2000–2003 data are the same as in 2004.

The similarities between the aggregate 23-country data and the IMF aggregate data allow one to simulate the effects of changes in the country sample in the IMF aggregate data on reserve shares. With the knowledge of the data for a substantial number of the industrial countries that generate aggregate data that broadly resemble the IMF data, we can test the effects on the series of dropping or adding certain countries to identify outlier effects.

One question we want to explore in the disaggregate data for the 23 countries is whether the stabilizing diversification trend in the dollar share observed in the aggregate data, including in the data for the industrial-country group, can be traced to individual countries and not heavily influenced by data from a large dollar holder and active intervener such as Japan.

Estimating the Currency Composition of Japan's Reserves

It turns out there is a way to filter the currency composition of Japan's reserves from the aggregate industrial-country COFER data. By combining information from the 11 industrial countries in the 23-country dataset and the industrial-country series from the IMF COFER database, one can obtain an interval estimate of the US dollar's share in Japan's foreign exchange reserves.¹⁸ Truman and Wong (2006) estimated Japan to hold 82 to 89 percent of its reserves in dollars in 2005. The same method can be applied back to as early as 2000 to construct an interval for the US dollar value share in the Japanese reserve portfolio. The estimates are 80 to 88 percent in 2000 and 2001, 72 to 83 percent in 2002, 77 to 85 percent in 2003, and 80 to 87 percent in 2004. Judging from the midpoints of each interval, it appears that Japan began to expand its share of dollar reserves in 2002. Coincidentally, the 4 percent decrease in the dollar's value share of Japan's reserves from 2000 to 2002 coincides with the 3 percent decrease in the dollar's quantity share indicated by the IMF COFER industrial-country data.

Simulating IMF COFER Industrial-Country Series with Disclosing-Country Data

Incorporating the Japanese currency composition approximated by the midpoints of each interval estimates into the aggregate data on 11 disclosing industrial countries yields a series that matches the IMF COFER industrial series reasonably well (see figure 15). The simulated value share for the dollar for industrial countries in 2005, as measured by the 11 disclosing industrial countries plus Japan, is

18. The key to the estimation are the following conditions: (1) Every industrial country reports the currency composition of its international reserves to the IMF for aggregate publication in the subcategory of industrial countries in the COFER series. (2) A substantial number of these industrial countries also individually disclose the currency composition of their reserves. (3) Those individual countries that do not individually disclose are primarily Japan, holding no yen in its reserves, or in the euro area, holding no euros. See Truman and Wong (2006).

now 73.1 percent, in comparison to 73.7 percent measured by the IMF industrial-country aggregate data. The dollar's quantity share for industrial countries as measured by the 11 disclosing industrial countries plus Japan is 76 percent in 2005, a 7.3 percentage point increase from 2000. Measured by the IMF aggregate industrial-country data, the dollar's quantity share is 76.6 percent, a 4.1 percentage increase from 2000.

What would the industrial-country series look like excluding Japan? Having broadly simulated the IMF aggregate data with data from the 11 disclosing industrial countries and Japan, we can be comfortable that excluding the unavailable disaggregate data from some euro area industrial countries and Denmark does not significantly diminish the 11-country sample's representation of the aggregate share of the industrial countries. Deducting Japan's reserves from all the reserve currencies will then eliminate the outlier and reveal the predominant behavior of the remaining industrial countries as a group. Figure 16 shows the US dollar's value and quantity shares of the 11 disclosing industrial countries, which should be approximately representative of the entire industrial-country group excluding Japan; they are also shown along with the shares of the IMF industrial-country data series minus the estimated Japan reserve holdings, which include Denmark and several euro area countries along with the 11 disclosing industrial countries.

A comparison of figures 15a and 16 shows that excluding Japan significantly lowers the share of industrial-country reserves held in dollars. In the dataset for the 11 disclosing industrial countries, the value share of the dollar was 40.9 percent in 2005 compared with 73.1 percent including Japan. This share is also much lower than the 60.5 percent share of developing-country reserves held in dollars. Furthermore, the share of the euro and yen in the reserves of the 11 industrial countries is 40.8 and 9.8 percent, respectively, compared with 21.8 and 2.7 percent including Japan.

The changes in the dollar's shares also have been different in the past few years. The data for the 11 industrial countries plus Japan indicated a 4.4 percentage point increase in the dollar's value share and 7.3 percentage point increase in the dollar's quantity share of reserves from 2000 to 2005. The same numbers without Japan would indicate a drop by 7.2 percentage points in value terms and 4 percentage points in quantity terms. Note a caveat: With Japan not in the sample and the euro area in it, one would expect a larger percentage change in the yen share as the euro area countries cannot hold euro in their reserves.

The dataset for the 11 disclosing industrial countries allows us partially to identify the source of the negative trend in the dollar's share of industrial countries' reserves. Table 4 shows the dollar's share for each of the 11 disclosing industrial countries in their total reserves in 2005, as well as changes in the individual country's value and quantity shares for the period 2000–2005. The industrial country that indicates the most substantial diversification away from dollar reserves during this period is

Canada, having reduced the dollar's share by 15 percentage points on a quantity basis and 21 percentage points on a value basis. Sweden also has reduced the dollar's value and quantity share by 16 and 17 percentage points, respectively, since 2004.

The IMF industrial-country series minus Japan is consistent with the downward sloping trend in the 11 industrial-country value share for the dollar (figure 16). Without Japan, the IMF industrial-country data would have indicated the value share of the dollar to be 52.6 percent rather than 73.7 percent (with Japan) in 2005. The share of the euro would be much higher at 27.3 percent (without Japan) compared with 19.2 percent (with Japan). The IMF industrial-country data, excluding Japan's reserves, show that the net aggregate behavior of the rest of the industrial countries is active diversification, shedding the dollar share when the dollar depreciated.

Figure 17 shows the world version of figure 16, where the global dollar share data series has filtered out Japan and the other 23 countries with known reserve currency composition. This annual series, like the filtered industrial-country series, also indicates that the net aggregate trend is active diversification.

What is important from the perspective of thinking about policy implications is whether there exists net stabilizing diversification—not whether one or many parties is/are doing it—but having the knowledge of the latter gives us a condition on which we base our current observations and predictions about the dollar's share in global reserves. If the large holder is the principal driver of the stabilizing diversification trend, it would be of concern that if this holder terminates this type of behavior, the dollar would be under further pressure. Knowing that stabilizing diversification is a practice supported by several central banks, not just one, may give a policymaker a more peaceful sleep at night.

Combining IMF COFER Non-Industrial Country Series with Disclosing-Country Data

We have looked at annual COFER data for industrial countries and found that combining the aggregate and national data allows us to learn information about Japan. What new information can we reap from similarly combining aggregate and individual-country data for the nonindustrial countries (see table 5 for the individual data)?

Figure 18 compares the IMF COFER non-industrial country data with data from the 12 known nonindustrial countries for the dollar, euro, and yen. Unlike the comparison of all countries in figure 14, which had shown that the IMF COFER data and the 23-country data are similar, the comparison of the IMF COFER non-industrial country data and national data shows some large differences. For the dollar share, data from the 12 individual countries show an increase in the quantity share of 3.6 percentage points from 2002 to 2003, even as the IMF quantity share of the dollar decreases

by 0.5 percentage points. This is the first strike against applying the exercise for the industrial-country group to the nonindustrial group.

Among the 12 nonindustrial disclosers of foreign reserves, only Hong Kong can be considered a large holder. But unlike the case of industrial countries, there are more than a few large and active dollar holders in the non-industrial country group that do not disclose the currency composition of their reserves. The one developing country that has the magnitude of Japan's total reserve holdings and possibly share in dollars—China—is not currently included in the IMF developing-country data.¹⁹ While China's absence from the aggregate COFER data for nonindustrial countries substantially reduces the likelihood of bias due to the presence of a single large holder, the large number of developing countries in the IMF developing-country database—currently at 91 out of 160 developing countries in the world—allows for the inclusion of a few large holders.²⁰ Thus, being able to filter out Hong Kong will not present any generalizable picture of trends in the net aggregate reserve diversification.

The identification of the currency shares of large holders, as was done for Japan in the industrial-country group, might be feasible for the non-industrial country group in the future if the following conditions are present: First, a couple of the Asian countries among the large holders other than Hong Kong begin to publish reserve currency composition. Second, China's yuan becomes convertible and is held by some Asian countries as a reserve currency (and these holdings are recorded in the IMF COFER data). This development would be highly useful for deducing the currency composition of China's reserves.

Although we cannot utilize the data from the 12 individual nonindustrial countries to identify the currency composition of a large holder as we could for Japan in the industrial-country group data, we can, however, reduce the IMF aggregate data on nonindustrial countries into a smaller set of aggregate data. The two panels of figure 19 show the dollar and euro reserve share among nonindustrial countries, with data for the 12 known nonindustrial countries subtracted from the IMF non-industrial country group aggregate. The result is a series similar to the original IMF aggregate series. This exercise makes obvious the point that the information on individual-country currency composition for nonindustrial countries is not sufficient to permit meaningful transformations off the original IMF data.

19. From 2004 to 2005, the allocated reserves for developing countries as a group, according to the IMF COFER data, increased by \$204 billion, whereas the total foreign exchange reserves of China increased by \$208 billion during the same time. The next largest developing-country holder, Taiwan, increased its reserves only by \$12 billion during this period.

20. See Ewe-Ghee (2006) for facts about the COFER database.

Qualifying the Interpretation

The finding that stabilizing diversification is not the common trend in the data for the individual industrial countries warrants some important caveats. First, the simulation exercise uses annual data. In the aggregate quarterly data for the developing-country group, we see short periods of stabilizing diversification that may be absent in data of lower frequency but might be observed in data of higher frequency.

Despite a long-run trend of active diversification, three brief periods of stabilizing diversification can be observed in the quarterly data for developing countries in the aggregate. This observation can be related to an explanation given by Truman and Wong (2006) that countries tend to add to or subtract from their foreign exchange reserves in their intervention currency and only subsequently rebalance the currency composition of their portfolios. Thus, the fact that stabilizing diversification cannot be found in the annual data for the industrial countries, excluding Japan, in the simulation exercise does not mean that it is not present in data of higher frequency.

Furthermore, the individual-country data for most of the 23 countries extend back to only 2000, and in these six years there is only one major episode of dollar depreciation. These findings would be more robust if the same exercise could be applied to check for consistency in other dollar depreciation episodes, thus constructing a pattern of behavior of industrial countries during multiple periods of dollar depreciation and appreciation.

Lastly, aggregate data, even excluding the large holders, conceal quite a lot of diversity in the type of diversification: There are some cases of stabilizing diversification and some of active diversification but mostly of passive diversification. For example, individual data of the industrial countries in table 4 show that while Canada, Switzerland, and the United Kingdom have actively diversified from the dollar, Australia and Norway have followed stabilizing diversification. Even with the aggregate series filtered of large holder bias, considerable variation among individual-country practices still exists. The filtered series gives us only an additional perspective to look at the aggregate data.

A filtered series, in any case, is still an aggregate series, disguising the heterogeneous reserve management behavior of industrial countries. The lesson that this exercise confers is that the available data do not allow us to make credible conclusions about the extent of reserve diversification. Aggregate data as reported by the IMF conceals large holder effects. The individual data also displays much diversification in practice. Filtered series offer researchers additional perspectives in making conclusions about the behavior of small undisclosed holders.

CONCLUSION

This paper discusses methodological aspects of the construction of quantity shares of currencies in foreign reserve holdings. It applies the preferred methodology to three sets of data.

In the methodological section, it finds that different choices of the numeraire do not create significant empirical discrepancies among the estimated changes in quantity shares. The paper experiments with combining aggregate IMF data with national data to create additional perspectives on the aggregate series. Using the preferred method, the paper first infers from the aggregate data that net stabilizing diversification characterizes the dollar share in global reserves. Then it examines the question of who is responsible for this trend and finds that the data for the industrial-country group is the driving force behind the inverse relationship between the dollar's quantity share in global reserves and its exchange rate value. Using a combination of aggregate and disaggregate data, the paper further finds that Japan was the source of the large stabilizing diversification found in the aggregate data.

This finding, however, still leaves room for doubt about the extent of the prevalence of stabilizing diversification in the management of dollar foreign exchange reserves. Data of higher frequency, as exemplified by the quarterly data on the dollar's share in developing-country reserves, suggest the possibility that stabilizing diversification for the dollar takes place in the aggregate albeit in short periods, while active diversification is a medium- to longer-run phenomenon. But more importantly, the individual-country data show that patterns across countries are different even when speculation of dollar demise is widespread; thus one cannot generalize from the aggregate data any particularly robust trend, just as one cannot generalize from disaggregate data about the aggregate trend.

This paper leaves many interesting questions unanswered, but its foremost goal and what is hoped to be a contribution is to present a way to think about changes in the currency composition of foreign exchange reserves. With higher-quality aggregate data and an increasing number of countries disclosing the currency composition of their reserves, inferences from data on the currency composition of international reserves would be more direct and precise, and more questions about reserve management practices could be answered.

Table 1 Numeraire currency of 23 disclosing countries

Country	Numeraire currency	Source
Australia	Domestic	IMF template
Bulgaria	Domestic	Annual report
Canada	Quantity terms	Annual report
Colombia*	US dollar	Annual report
Croatia*	Domestic	Annual report
Finland*	Domestic	Annual report
Germany	Both domestic currency and quantity	Annual report
Hong Kong*	Domestic	Annual report
Iceland*	Domestic	Annual report
Latvia	US dollar	IMF template
Lithuania	Domestic	Annual report
New Zealand	Domestic	Annual report
Norway*	Domestic	Annual report
Peru*	US dollar	Statistical release
Philippines*	US dollar	Annual report
Romania	Euro	Annual report
Slovak Republic	US dollar	IMF template
Slovenia	Domestic	Annual report
Sweden*	Domestic	Press release
Switzerland	Both domestic currency and quantity	Statistical release
United Kingdom	US dollar	Statistical release
United States	Domestic	Statistical release
Uruguay	US dollar	Reserve template

* = The reserve currency composition is reported in percentages, so the numeraire of the gross reserves is taken as the numeraire for the currency composition reporting.

Table 2 Period of real dollar depreciation**A. Identified by average exchange rates**

Year	Depreciation	Quantity change	Value change
1974–75	–3.5	0.0	0.5
1977–78	–10.4	–1.3	–7.5
1986–88	–31.2	7.0	0.3
1990–92	–7.0	4.7	4.1
1994–1995	–4.9	4.4	0.1
2002–05	–19.3	–0.5	–4.9
<i>Average</i>	–12.7	2.4	–1.2

Year	Appreciation	Quantity change	Value change
1980–85	38.8	–13.6	–5.9
1996–98	21.3	8.0	10.3
2000–2001	14.5	–2.3	0.4
<i>Average</i>	24.9	–2.6	1.6

B. Identified by end-period exchange rates

Year	Depreciation	Quantity change	Value change
1976–78	–13.5	0.3	–6.2
1985–88	–33.8	7.3	–5.9
1990–91	–7.9	1.9	–0.2
1994–95	–4.7	4.4	0.1
2002–2004	–25.2	2.0	–5.6
<i>Average</i>	–17.0	3.2	–3.6

Year	Appreciation	Quantity change	Value change
1980–84	39.0	–13.9	–0.5
1992–93	8.5	3.4	5.8
1996–97	16.4	2.3	6.1
2000–2001 ^c	16.3	–2.4	0.4
<i>Average</i>	20.0	–2.6	3.0

Table 3 23 reserve composition disclosing countries, published value data, 2000–2005
(percent, ranked by total reserve size)

Country	Foreign exchange reserves, 2005 (billions of US dollars)	US dollar		Euro		Yen		Other currencies	
		Share, 2005	Change, 2000–2005	Share, 2005	Change, 2000–2005	Share, 2005	Change, 2000–2005	Share, 2005	Change, 2000–2005
Hong Kong ^a	124.2	79.0	11.5	10.4	–1.4	1.6	–2.5	9.0	–7.6
Norway	46.4	36.6	14.7	39.8	–5.7	6.6	–6.0	17.0	–3.0
Australia	41.0	45.0	5.0	45.0	15.0	10.0	–20.0	0.1	0.0
United Kingdom	40.9	30.6	–5.2	59.1	21.0	10.3	–15.9	0.0	0.0
Germany	39.8	98.2	–1.0	0.0	0.0	1.7	1.0	0.0	0.0
United States	37.8	0.0	0.0	57.4	10.1	42.6	–10.1	0.0	0.0
Switzerland	35.4	34.9	–5.8	47.1	3.0	3.1	–0.3	14.9	3.1
Canada	30.7	53.3	–21.4	43.7	21.8	3.0	–0.4	0.0	0.0
Romania ^b	19.9	35.9	–37.1	59.3	35.0	0.0	0.0	4.8	2.1
Philippines	15.8	82.0	–9.7	8.8	7.6	4.3	–1.1	4.9	3.2
Slovak Republic	14.9	22.2	–0.2	77.8	3.1	0.0	–2.9	0.0	0.0
Colombia	14.2	85.0	4.6	12.0	–3.3	3.0	–1.2	0.0	–0.1
Finland	10.1	30.0	0.0	0.0	0.0	5.0	–10.0	65.0	10.0
Croatia	8.8	15.1	–11.1	84.9	15.3	0.0	0.0	0.0	–4.2
New Zealand	8.7	52.1	–0.6	42.8	26.2	0.0	–30.6	5.1	5.0
Slovenia	8.0	14.6	–6.5	75.9	3.7	0.0	0.0	9.5	2.8
Bulgaria	8.0	4.5	–5.5	93.7	4.8	0.0	0.0	1.8	0.7
Lithuania	3.7	1.7	–80.9	88.5	72.8	9.8	8.8	0.0	–0.7
Latvia	2.2	39.9	–13.9	56.7	24.2	2.2	–2.6	1.1	–7.8
<i>Subtotal</i>	<i>510.6</i>	<i>51.1</i>	<i>–4.4</i>	<i>35.6</i>	<i>11.2</i>	<i>6.7</i>	<i>–5.2</i>	<i>6.7</i>	<i>–1.6</i>
Sweden ^c	21.4	20.0	–17.0	50.0	13.0	0.0	–8.0	30.0	12.0
Peru ^d	13.6	80.8	–16.0	n.a.	n.a.	n.a.	n.a.	19.2	16.0
Uruguay ^e	3.1	80.7	–11.5	14.5	7.0	2.5	2.3	2.3	2.2
Iceland ^f	1.0	40.0	0.0	40.0	0.0	5.0	0.0	15.0	0.0
<i>Grand total</i>	<i>549.6</i>	<i>50.7</i>	<i>–5.1</i>	<i>35.1</i>	<i>10.9</i>	<i>6.2</i>	<i>–5.2</i>	<i>7.9</i>	<i>–0.6</i>

n.a. = not available

a. Since 2003, the Hong Kong Monetary Authority has grouped yen, euro, and other European currencies into one category a “Non US dollar bloc.” The 2003–04 yen and euro shares in this table are derived by assuming that they remain the same as in 2002 in the “Non-US dollar bloc,” which has decreased as a share of the total since that time. (Source: Annual Report).

b. Romania 2005 data not available

c. Sweden 2000–2003 data assumed to be the same as 2004.

d. Peru 2000–2001 data assumed to be the same as 2002.

e. Uruguay’s earliest data are for 2003. It is assumed that 2000–2002 data are the same as in 2003.

f. Iceland 2000–2002 data assumed to be same as 2003.

Table 4 US dollar share in 11 industrial countries
(ranked in ascending order by quantity share changes)

Country	Foreign exchange reserves, 2005 (billions of US dollar)	Value		Quantity	
		Share, 2005	Change, 2000– 2005	Share, 2005	Change, 2000– 2005
Canada	30.7	53.3	–21.4	59.8	–14.9
United Kingdom	40.9	30.6	–5.2	33.1	–2.6
Switzerland	35.4	34.9	–5.8	38.3	–2.4
Germany	39.8	98.2	–1.0	98.3	–0.9
New Zealand	8.7	52.1	–0.6	52.6	–0.1
United States	37.8	0.0	0.0	0.0	0.0
Finland	10.1	30.0	0.0	31.0	1.0
Australia	41.0	45.0	5.0	46.0	6.0
Norway	46.4	36.6	14.7	39.3	17.4
<i>Subtotal</i>	<i>290.8</i>	<i>42.4</i>	<i>–6.3</i>	<i>45.2</i>	<i>–3.5</i>
Sweden ^a	21.4	20.0	–17.0	21.0	–16.0
Iceland ^b	1.0	40.0	0.0	41.1	1.1
<i>Total</i>	<i>313.2</i>	<i>40.9</i>	<i>–7.2</i>	<i>43.5</i>	<i>–4.6</i>

a. The earliest data point for Sweden is 2004. The missing data in 2000–2003 are imputed as the 2004 numbers.

b. The earliest data point for Iceland is 2003. The missing data in 2000–2002 are imputed as the 2003 numbers.

Table 5 US dollar share in 12 nonindustrial countries (ranked in ascending order by quantity share changes)

Country	Foreign exchange reserves, 2005 (billions of US dollars)	Value		Quantity	
		Share, 2005	Change, 2000– 2005	Share, 2005	Change, 2000– 2005
Lithuania	3.7	1.7	–80.9	1.9	–80.7
Romania	19.9	35.9	–37.1	35.9	–37.1
Peru	13.6	80.8	–16.0	80.8	–16.0
Latvia	2.2	39.9	–13.9	41.4	–12.4
Uruguay	3.1	80.7	–11.5	80.4	–11.8
Croatia	8.8	15.1	–11.1	16.7	–9.5
Philippines	15.8	82.0	–9.7	82.2	–9.4
Bulgaria	8.0	4.5.0	–5.5	5.0	–5.1
Slovenia	8.0	14.6	–6.5	17.7	–3.4
Slovak Republic	14.9	22.2	–0.2	23.8	1.3
Colombia	14.2	85.0	4.6	86.2	5.8
Hong Kong	124.2	79.0	11.5	82.3	14.8
<i>Total</i>	236.4	63.8	–4.4	66.5	–1.7

Figure 1 Quantity shares calculated from US dollar, euro and yen as numeraire

Figure 2 Value and quantity of reserve currencies and their real effective exchange rate, 1999-2005

Figure 2 (continued)

Figure 2 (continued)

Figure 3 Measure of exchange value sensitivity: Correlations of value vs. quantity share changes (all countries)

		Quantity shares				
		US dollar	Euro	Yen	Pound	Swiss franc
Value shares	US dollar	0.19				
	Euro		0.14			
	Yen			0.66**		
	Pound				0.88**	
	Swiss franc					0.96**

Figure 4 Measure of exchange value sensitivity: Correlations of real effective exchange rate vs. quantity share changes (all countries)

		Real effective exchange rate				
		US dollar	Euro	Yen	Pound	Swiss franc
Quantity shares	US dollar	-0.18				
	Euro		-0.13			
	Yen			0.20		
	Pound				0.04	
	Swiss franc					-0.24

Figure 5 Measure of substitutability: Correlations of quantity share changes (all countries)

		Quantity shares				
		US dollar	Euro	Yen	Pound	Swiss franc
Quantity shares	US dollar	1.00				
	Euro	-0.87**	1.00			
	Yen	-0.34*	-0.06	1.00		
	Pound	-0.39**	0.09	0.18	1.00	
	Swiss franc	-0.30	0.15	0.31	0.14	1.00

** denotes significance at less than 10 percent

* denotes significance at less than 5 percent

Figure 6 Industrial-country value and quantity shares, 1999Q1–2005

Figure 6 (continued)

Figure 6 (continued)

Figure 7 Developing-country value and quantity shares, 1999Q1–2005

Figure 7 (continued)

Figure 7 (continued)

Figure 8 Measure of exchange value sensitivity: Correlations of value vs. quantity share changes (industrial countries)

Value shares		Quantity shares				
		US dollar	Euro	Yen	Pound	Swiss franc
US dollar		0.61**				
Euro			0.61**			
Yen				0.74**		
Pound					0.94**	
Swiss franc						0.99**

Figure 9 Measure of exchange value sensitivity: Correlations of real effective exchange rate vs. quantity share changes (industrial countries)

Quantity shares		Real effective exchange rate				
		US dollar	Euro	Yen	Pound	Swiss franc
US dollar		-0.40**				
Euro			-0.20			
Yen				0.01		
Pound					-0.01	
Swiss franc						-0.29

Figure 10 Measure of substitutability: Correlations of quantity share changes (industrial countries)

Quantity shares		Quantity shares				
		US dollar	Euro	Yen	Pound	Swiss franc
US dollar		1.00				
Euro		-0.90**	1.00			
Yen		-0.36*	0.00	1.00		
Pound		-0.51*	0.39**	0.07	1.00	
Swiss franc		-0.20	0.10	0.02	0.17	1.00

** denotes significance at less than 10 percent

* denotes significance at less than 5 percent

Figure 11 Measure of exchange value sensitivity: Correlations of value vs. quantity share changes (developing countries)

		Quantity shares				
		US dollar	Euro	Yen	Pound	Swiss franc
Value shares	US dollar	0.41**				
	Euro		0.36*			
	Yen			0.80**		
	Pound				0.90**	
	Swiss franc					0.97**

Figure 12 Measure of exchange value sensitivity: Correlations of real effective exchange rate vs. quantity shares changes (developing countries)

		Real effective exchange rate				
		US dollar	Euro	Yen	Pound	Swiss franc
Quantity shares	US dollar	0.17				
	Euro		0.03			
	Yen			0.30		
	Pound				0.18	
	Swiss franc					0.08

Figure 13 Measure of substitutability: Correlations of quantity share changes (developing countries)

		Quantity shares				
		US dollar	Euro	Yen	Pound	Swiss franc
Quantity shares	US dollar	1.00				
	Euro	-0.89**	1.00			
	Yen	-0.32*	-0.05	1.00		
	Pound	-0.14	-0.22	0.39**	1.00	
	Swiss franc	-0.09	0.03	-0.02	0.10	1.00

** denotes significance at less than 10 percent

* denotes significance at less than 5 percent

Figure 14 23-country aggregate versus 115-country IMF COFER aggregate

Figure 14 (continued)

Figure 15 Comparison between 11 industrial countries plus Japan and IMF COFER industrial countries

Figure 15 (continued)

Figure 16 US dollar value and quantity shares of 11 disclosing industrial countries minus Japan

Figure 17 US dollar share in the world, IMF COFER countries minus 23 disclosers and Japan (115 minus 24 known countries = 92 countries)

Figure 18 Comparison between 12 nonindustrial countries and 90 IMF COFER nonindustrial countries

Figure 18 (continued)

Figure 19 Reserve share for 90 nonindustrial countries minus 12 known nonindustrial countries (= 78 countries)

a. US dollar share

b. Euro share

APPENDIX A

DIFFERENCES IN QUANTITY SHARES CALCULATED FROM BASE YEAR AND MOVING AVERAGE METHODS

The complete IMF COFER data series is divided into three subperiods, where each new base year reflects a break in the series (table A.1). The length of the time series in each subperiod varies, with panel A containing 13 years, panel B 3 years, and panel C 6 years. The differences in the quantity share changes calculated using base year exchange rates and moving average rates (all using end-period exchange rates) for each of these three periods are shown in table A.1.

As mentioned in the text, the difference between the constant exchange rate and the moving average exchange rate methods becomes larger the more the current nominal exchange rate persistently deviates from the base year exchange rate. Usually, this happens when the time-series comparison is longer, as shown in the results from the three estimation periods in table A.1. As the comparison is made for a shorter period, the difference between the two methods diminishes. The difference is smallest for panel B where the length of the estimation period is 3 years; as the length of the estimation period increases to 6 years in panel C and then to 13 years in panel A, the methodological difference amplifies.

Both methods in general yield the same direction of change in each currency's share of global reserves.¹ The more interesting question is, What drives the magnitude in the difference between the two methods?

To understand how and why differences in the share changes obtained from the two methods arise, it is instructive to examine the construction of their calculation. Recall two aspects of the quantity share calculation: (1) the quantity share of currency k at time t depends on its numerator Q_t^k (its own quantity level) as well as denominator $\sum_{k=1}^i Q_t^k$ (the sum of the quantity levels of all 1 to n reserve currencies), and (2) the quantity level of a currency at time $t=T$ is the sum of all the quantity changes in each of the estimation intervals up to time T .

How the Choice of the Exchange Rate Affects Quantity Levels

Let's begin by decomposing the methodological difference of Q_t^k for one currency. For any given currency k at time $t=T$, the methodological difference measured as the quantity level estimated at the base year exchange rate minus the quantity level estimated by the moving average exchange rate is:

$$Q_T^k(e^k) - Q_T^k(ae_1^k) = (e^k - ae_1^k) \cdot (R_1^k - R_0^k) + (e^k - ae_2^k) \cdot (R_2^k - R_1^k) \cdots + (e^k - ae_T^k) \cdot (R_T^k - R_{T-1}^k) \quad (\text{A.1})$$

1. Except one instance in panel A, where the deutsche mark indicates a positive change for 1981–95 calculated by the moving average method but a negative change by the constant exchange rate method.

And the net methodological difference in the global quantity levels is the sum of equation (A.1):

$$\sum_{j=1}^n [Q_T^j(e^j) - Q_T^j(ae_t^j)] \quad (\text{A.2})$$

where $Q_T^k(e^k)$ is the quantity level calculated by the base year method for currency k , and

$Q_T^k(ae_t^k)$ is the quantity level calculated by the moving average method for currency k .

$$ae_t^k = \frac{e_t^k + e_{t-1}^k}{2}$$

e^k is the exchange rate fixed at the base year for currency k

R_t^k is the reserve level in value terms at time t for currency k

Equation (A.1) reveals two explanations that could drive the direction of the methodological difference in each currency: (1) the sign on the methodological difference in equation (A.1) would be positive (negative) if reserve level changes in each period are typically positively (negatively) associated with the difference between the base year exchange rate and the moving average exchange rate, or (2) the magnitude of the changes in either the reserve levels or the exchange rate in a certain episode is large.

It is commonplace for exchange rates to deviate from an indexed exchange rate on a sustained basis. The trends in each currency's exchange rate will drive the direction of the methodological difference.

Table A.2 shows the percentage deviations of each major reserve currency ae_t^k from its constant exchange rate fixed to the base year of its set. The table illustrates three types of currency movements over the estimation period. Case 1: currencies that remained significantly below the base year exchange rate during most of the period, as exemplified by the pound sterling and French franc in panel A and the yen and Swiss franc in panel B. Case 2: currencies that continuously stayed above the base year exchange rate, such as the yen in panel A and the US dollar and the pound in panel B. Case 3: rest of the currencies that had departed from the base rate in both directions for a while at some point during the estimation period.

While the mixed exchange rate movements of the third case make it difficult to generalize about the sign of equation (A.1), it is possible to reasonably predict the signs for currencies that fell under the first and second cases. For example, it is likely that $Q_T^k(e^k) - Q_T^k(ae_t^k) > 0$ for the pound sterling and the French franc in panel A, since $e^k - ae_t^k > 0$ for each of these currencies throughout that estimation period. As long as the quantity level reserves held in each of these currencies did not drop precipitously in any one or more of its estimation intervals, the methodological difference should be positive.

Table A.3 displays the quantity levels of each method and their differences. The data is for the last year of the three sets: 1994, 1998, and 2005.

Indeed, the methodological difference for the pound and the French franc is respectively positive. All the other currencies that fell under case 1 also indicate a positive sign. Those currencies in case 2 predictably indicate a negative sign. The conclusion from this exercise is that deviations from the base year exchange rate do apparently drive the methodological differences.

The last line in each of the tables presents the data for equation (A.2), which is the sum of the methodological differences across currencies. Overall, the global quantity level estimated by the constant exchange rate method is higher than that estimated by the moving average method for panels A and C but lower for panel B.

How the Choice of Base Year versus Moving Average Affects Quantity Shares

Once we know how the methodological difference comes about, we can explain the difference in the sign and magnitude of the quantity shares. The calculation of shares scales the level of an individual currency by the total level, thus the methodological difference for one currency now depends not only on its own size but also the sign and magnitude of it relative to that of other currencies. There are few ways how one currency could tip the balance. For example, if a currency experienced a much larger swing compared with other currencies during the estimation period, creating a larger methodological difference for that currency than the other currencies, then this would drive the direction of the methodological difference in other currencies.

Table A.1 Change in quantity share

A. 1981–94			
Currency	Base year 1981 (A)	Moving average (B)	(A) – (B)
US dollar	–2.4	–4.9	2.5
Japanese yen	0.0	1.0	–0.9
Pound sterling	1.7	1.2	0.5
Swiss franc	–1.9	–1.9	0.0
Deutsche mark	–0.5	0.7	–1.2
French franc	1.2	1.1	0.1
Netherlands guilder	–0.5	–0.5	0.0
European currency unit (ecu)	–7.5	–7.2	–0.3
Other	9.9	10.6	–0.7
B. 1995–98			
Currency	Base year 1995 (A)	Moving average (B)	(A) – (B)
US dollar	7.8	7.9	–0.1
Japanese yen	0.0	–0.1	0.1
Pound sterling	0.3	0.3	0.0
Swiss franc	0.0	0.0	0.0
Deutsche mark	–0.2	–0.5	0.3
French franc	–0.6	–0.6	0.0
Netherlands guilder	0.0	0.0	0.0
European currency unit (ecu)	–7.1	–6.8	–0.4
Other	–0.2	–0.3	0.1
C. 1999–2005			
Currency	Base year 1999 (A)	Moving average (B)	(B) – (A)
US dollar	–2.1	–3.3	1.2
Euro	3.5	4.7	–1.2
Japanese yen	–2.1	–2.2	0.1
Pound sterling	0.7	0.8	–0.1
Swiss franc	–0.1	–0.1	0.0
Other	0.0	0.0	0.0

Table A.2 Percentage deviations of moving average exchange rates from base year^a

	US dollar	Euro	Yen	Pound	Swiss franc	Deutsche mark	French franc	Netherlands guilder
A. Deviations from 1981								
1982	2.8		-0.6	-5.4	-2.4	0.1	-4.9	-0.4
1983	8.3		2.0	-13.1	-6.6	-3.9	-16.6	-5.6
1984	15.0		4.6	-21.7	-12.8	-11.5	-26.1	-13.9
1985	12.4		10.1	-23.9	-12.8	-8.9	-24.1	-11.5
1986	0.6		23.9	-23.1	-1.4	3.8	-17.4	0.8
1987	-11.4		38.8	-23.0	10.4	13.8	-13.5	10.6
1988	-15.7		48.6	-18.7	9.4	13.3	-14.8	10.4
1989	-12.5		43.5	-21.7	3.2	13.6	-15.0	10.5
1990	-14.8		34.8	-21.4	8.3	20.6	-10.2	16.8
1991	-18.4		38.4	-18.8	10.8	22.3	-9.0	18.5
1992	-17.0		46.1	-26.6	6.3	19.6	-10.7	16.3
1993	-15.3		57.9	-33.6	3.8	14.5	-14.5	11.5
1994	-17.8		71.2	-34.5	6.2	13.4	-15.8	10.6
B. Deviations from 1995								
1996	0.8		-6.5	5.2	-0.5	0.5	1.8	0.5
1997	5.8		-12.8	13.9	-7.3	-5.6	-3.3	-5.9
1998	6.9		-11.7	13.9	-7.4	-8.1	-5.8	-8.7
C. Deviations from 1999								
2000	4.0	-1.2	4.0	-1.5	-4.8			
2001	8.6	-3.3	-4.2	-2.5	-2.9			
2002	6.4	0.6	-8.3	-0.8	3.4			
2003	-2.1	10.8	-6.4	1.2	10.6			
2004	-8.5	18.0	-6.1	3.6	14.6			
2005	-6.6	16.3	-8.7	3.8	13.4			

a. Expressed as the percentage change of the current year from the base-year special drawing rights (SDR) price of the reserve currency. A rise in the exchange rate represents an appreciation of the reserve currency.

Table A.3 Quantity levels (in millions of special drawing rights)

Currency	Base year 1981 (A)	Moving average (B)	$Q_n^k(e^k) - Q_n^k(ae_t^k)$ (A) – (B)
A. 1994			
US dollar	498,427	454,763	43,664
Japanese yen	33,427	39,877	-6,450
Pound sterling	32,642	26,605	6,037
Swiss franc	4,374	4,290	84
Deutsche mark	98,410	104,402	-5,992
French franc	21,787	19,667	2,120
Netherlands guilder	4,306	4,352	-46
European currency unit (ecu)	63,750	63,505	245
<i>Sum</i>	757,122	717,461	39,661
B. 1998^a			
US dollar	597,867	605,872	-8,005
Japanese yen	60,523	60,066	457
Pound sterling	21,401	21,950	-549
Swiss franc	3,410	3,316	94
Deutsche mark	138,928	138,179	749
French franc	16,066	16,057	9
Netherlands guilder	2,763	2,739	24
European currency unit (ecu)	12,607	15,945	-3,338
<i>Sum</i>	853,566	864,124	-10,558
C. 2005^b			
US dollar	1,362,327	1,328,059	34,268
Euro	425,219	444,619	-19,400
Japanese yen	84,713	82,588	2,125
Pound sterling	72,024	73,153	-1,129
Swiss franc	2,400	2,178	222
<i>Sum</i>	1,946,683	1,930,596	16,087

a. The base-year exchange rate is 1995 due to a change in IMF data estimation procedure in that year.

b. The base-year exchange rate is 1999 due to the introduction of euro.

APPENDIX B

EFFECT OF DIFFERENT NUMERAIRES ON QUANTITY SHARES

The calculations of quantity levels in the text employ the moving average method, which leads to slightly different quantity shares for different numeraires, as shown in figure 1. The short explanation for this is that the conversion factor does not cancel out under this method, as it would under the base year conversion method. The following explains the reason and implications of the numeraire change for the moving average method.

Consider the effect of converting the current numeraire currency $N1$ to $N2$ on the quantity levels of currency k . All variables denominated in $N1$ will be multiplied by a factor of $N1/N2$, the numeraire price of the old numeraire for the equivalent period.

Let's first take as an example the quantity levels of currency k at $t=0$ and 1 , using $N1$ as the original numeraire. The first subscript is indexed by time. The superscript denotes the currency in which the reserves are held.

Quantity level at the base (or indexed) period: $Q_{0,N1}^k = V_{0,N1}^k$

Quantity level one period ahead¹: $Q_{1,N1}^k = Q_{0,N1}^k + \frac{e_1^k + e_0^k}{2} \cdot (R_1^k - R_0^k)$

Switching to numeraire $N2$:

Quantity level at the base (or indexed) period: $Q_{0,N2}^k = V_{0,N1}^k \cdot \frac{N2_0}{N1_0}$

Quantity level one period ahead: $Q_{1,N2}^k = Q_{0,N2}^k + \frac{e_1^k \cdot \frac{N2_1}{N1_1} + e_0^k \cdot \frac{N2_0}{N1_0}}{2} \cdot (R_1^k - R_0^k)$

At $t=0$, the quantity share measured by both numeraires $N1$ and $N2$ are the same because the conversion factor cancelled out in the numerator and denominator. At $t=1$, the quantity share is calculated by equation (5) in the text. The equation is a recursive formula for the quantity shares, expressing the next-period quantity share of a currency at $t>0$ as its previous quantity share multiplied by the ratio of percentage changes:

1. Recall that R is based in currency k , and e is the exchange rate converting the currency k value of the reserves R to the numeraire $N1$; in other words, e is $N1/k$.

$$QS_1^k = QS_0^k \cdot \frac{1 + \Delta Q_1^k}{1 + \sum_{j=1}^n (QS_0^j \cdot \Delta Q_1^j)} = \frac{Q_0^k}{\sum_{j=1}^n Q_0^j} \cdot \frac{1 + \Delta Q_1^k}{1 + \sum_{j=1}^n \left(\frac{Q_0^j}{\sum_{j=1}^n Q_0^j} \cdot \Delta Q_1^j \right)}$$

The first component is the quantity share at $t=0$, so the quantity share does not change with the choice of numeraire (since we already know that quantity shares at $t=0$ are the same for both numeraires). But the second component of the equation depends on ΔQ_1^k , the percentage changes of the quantity levels at the new period, which in turn is dependent on the choice of numeraire. We shall explore how this term changes with an alternative numeraire.

Percentage Change in Quantity Levels Measured by $N1$ and $N2$

The percentage change in quantity levels ΔQ_1^k , measured by $N1$, from $t=0$ to $t=1$ can be expressed as:

$$\Delta Q_{1,N1}^k = \frac{\frac{e_1^k + e_0^k}{2} \cdot (R_1^k - R_0^k)}{Q_{0,N1}^k}$$

Switching to the new numeraire $N2$, the expression becomes:

$$\Delta Q_{1,N2}^k = \frac{\frac{e_1^k \cdot \frac{N2_1}{N1_1} + e_0^k \cdot \frac{N2_0}{N1_0}}{2} \cdot (R_1^k - R_0^k)}{Q_{0,N1}^k \cdot \frac{N2_0}{N1_0}}$$

A measure that gives a comparison of the quantity level percentage changes is the ratio between the two:

$$\frac{\Delta Q_{1,N2}^k}{\Delta Q_{1,N1}^k} = \frac{e_1^k \cdot \frac{N2_1}{N1_1} + e_0^k \cdot \frac{N2_0}{N1_0}}{e_1^k + e_0^k} \cdot \frac{1}{\frac{N2_0}{N1_0}} \quad (B.1)$$

This ratio measures the discrepancy in the quantity changes due to different numeraires.

When $\frac{\Delta Q_{1,N2}^k}{\Delta Q_{1,N1}^k} = 1$, implying that $\frac{N2_1}{N1_1}$ and $\frac{N2_0}{N1_0}$ are the same, there are no numeraire effects

on quantity shares. When $\frac{\Delta Q_{1,N2}^k}{\Delta Q_{1,N1}^k} > 1$, the quantity shares measured by $N2$ will be higher.

Let's call this ratio the numeraire discrepancy factor.

Quantity Shares Measured by $N1$ and $N2$

Now we can express the quantity share in terms of the numeraire discrepancy factor for quantity reserves measured by $N2$:

$$QS_{1,N2}^k = QS_0^k \cdot \frac{1 + \Delta Q_{1,N1}^k \cdot \frac{\Delta Q_{1,N2}^k}{\Delta Q_{1,N1}^k}}{1 + \sum_{j=1}^n \left(QS_0^j \cdot \Delta Q_{1,N1}^j \cdot \frac{\Delta Q_{1,N2}^j}{\Delta Q_{1,N1}^j} \right)} \quad (B.2)$$

The formula for the quantity share under $N1$ is the same except without the numeraire discrepancy factor in the numerator and denominator. The ratio between the quantity shares measured by $N2$ and $N1$ gives a measure of the discrepancy in the quantity share due to choice of numeraires:

$$\frac{QS_{1,N2}^k}{QS_{1,N1}^k} = \frac{1 + \Delta Q_{1,N1}^k \cdot \frac{\Delta Q_{1,N2}^k}{\Delta Q_{1,N1}^k}}{1 + \Delta Q_{1,N1}^k} \cdot \frac{1 + \sum_{j=1}^n \left(\frac{Q_0^j}{\sum_{j=1}^n Q_0^j} \cdot \Delta Q_{1,N1}^j \right)}{1 + \sum_{j=1}^n \left(\frac{Q_0^j}{\sum_{j=1}^n Q_0^j} \cdot \Delta Q_{1,N1}^j \cdot \frac{\Delta Q_{1,N2}^j}{\Delta Q_{1,N1}^j} \right)} \quad (B.3)$$

Expanding the above equation,

$$\frac{QS_{1,N2}^k}{QS_{1,N1}^k} = \frac{1 + \Delta Q_{1,N1}^k \cdot \left(\frac{e_1^k \cdot \frac{N2_1}{N1_1} + e_0^k \cdot \frac{N2_0}{N1_0}}{e_1^k + e_0^k} \cdot \frac{1}{\frac{N2_0}{N1_0}} \right)}{1 + \Delta Q_{1,N1}^k} \cdot \frac{1 + \sum_{j=1}^n \left(\frac{Q_0^j}{\sum_{j=1}^n Q_0^j} \cdot \Delta Q_{N1,1}^j \right)}{1 + \sum_{j=1}^n \left(\frac{Q_0^j}{\sum_{j=1}^n Q_0^j} \cdot \Delta Q_{1,N1}^j \cdot \left(\frac{e_1^j \cdot \frac{N2_1}{N1_1} + e_0^j \cdot \frac{N2_0}{N1_0}}{e_1^j + e_0^j} \cdot \frac{1}{\frac{N2_0}{N1_0}} \right) \right)}$$

This expanded version of equation (B.3) displays clearly the relevant factors that contribute to the differences in quantity shares. We can see that as currency k receives higher valuation under $N2$ (the first term in the numerator) relative to the other currencies (the double bracketed term in the denominator), the quantity share measured by $N2$ would tend to be bigger.

Implications

Quantity Shares

The discrepancy in the quantity shares measured at $t=I$ by any two numeraire is the ratio expressed in equation (B.3). Recall that for periods $t > I$, quantity levels are estimated by adding the quantity changes between the two endpoints in the estimation increments across time. To get a generalized equation for the discrepancy factor ratio for $t > I$, we will need to take into account the multiple estimation periods:

$$\frac{QS_{t,N2}^k}{QS_{t,N1}^k} = \frac{\prod_{l=1}^t 1 + \Delta Q_{l,N1}^k \cdot \frac{\Delta Q_{l,N2}^k}{\Delta Q_{l,N1}^k}}{\prod_{l=1}^t 1 + \Delta Q_{l,N1}^k} \cdot \frac{\prod_{l=1}^t 1 + \sum_{j=1}^n (QS_{l-1,N1}^j \cdot \Delta Q_{l,N1}^j)}{\prod_{l=1}^t 1 + \sum_{j=1}^n \left(QS_{l-1,N1}^j \cdot \Delta Q_{l,N1}^j \cdot \frac{\Delta Q_{l,N2}^j}{\Delta Q_{l,N1}^j} \right)} \quad (B.4)$$

The interpretation, slightly different from equation (B.3), is that the quantity share measured by $N2$ would be higher than $N1$ only if the discrepancy factor weighted by percentage changes in quantity levels over time is higher. This means that even if the discrepancy factor may be lower for one period, as long as

it is higher over time, or the percentage changes in the quantity level were big for some periods relative to the other currencies, the quantity shares measured by $N2$ would be higher than those measured by $N1$.

Quantity Share Changes

We want to compare the quantity share changes measured by each numeraire over m periods. The percentage changes of the quantity shares over m periods measured by $N2$ and $N1$, respectively, are given by:

$$\frac{QS_{t+m,N2}^k}{QS_{t,N2}^k} = \prod_{l=1}^m \frac{1 + \Delta Q_{t+l,N1}^k \cdot \frac{\Delta Q_{t+l,N2}^k}{\Delta Q_{t+l,N1}^k}}{1 + \sum_{j=1}^n \left(QS_{t+l-1}^j \cdot \Delta Q_{t+l,N1}^j \cdot \frac{\Delta Q_{t+l,N2}^j}{\Delta Q_{t+l,N1}^j} \right)} \quad (B.5)$$

$$\frac{QS_{t+m,N1}^k}{QS_{t,N1}^k} = \prod_{l=1}^m \frac{1 + \Delta Q_{t+l,N1}^k}{1 + \sum_{j=1}^n (QS_{t+l-1}^j \cdot \Delta Q_{t+l,N1}^j)} \quad (B.6)$$

The ratio of (B.5) and (B.6) gives the discrepancy between the percentage changes in the quantity shares:

$$\frac{\frac{QS_{t+m,N2}^k}{QS_{t,N2}^k}}{\frac{QS_{t+m,N1}^k}{QS_{t,N1}^k}} = \frac{\prod_{l=1}^m 1 + \Delta Q_{t+l,N1}^k \cdot \frac{\Delta Q_{t+l,N2}^k}{\Delta Q_{t+l,N1}^k}}{\prod_{l=1}^m 1 + \Delta Q_{t+l,N1}^k} \cdot \frac{\prod_{l=1}^m 1 + \sum_{j=1}^n (QS_{t+l-1}^j \cdot \Delta Q_{t+l,N1}^j)}{\prod_{l=1}^m 1 + \sum_{j=1}^n \left(QS_{t+l-1}^j \cdot \Delta Q_{t+l,N1}^j \cdot \frac{\Delta Q_{t+l,N2}^j}{\Delta Q_{t+l,N1}^j} \right)} \quad (B.7)$$

The quantity share changes measured by the numeraire $N2$ for currency k would be higher over time if the numeraire discrepancy factor for currency k weighted by the percentage changes in quantity reserves held in currency k is over time higher than for the weighted sum of all other currencies.

The interpretation of the contributing factors to the numeraire discrepancy presented in equation (B.7) is the same as equation (B.4). The only difference is that the discrepancy factor ratio is now considered from period $t+1$ to $t+m$, rather than from 1 to t .

Relevance of the Base/Indexed Year

Throughout this paper, the quantity level in the indexed year takes the same value as its value level. It is asserted in the text that quantity shares vary with the indexed year but share changes do not. Equations (B.2), (B.5), and (B.6) support this assertion. One can see from the recursive formula (B.2) that the quantity share at any time depends on the base year quantity level, QS_0 . Since the value of QS_0 changes according to the choice of the index year, the quantity share at any time, QS_t , also changes according to the choice of indexed year. On the other hand, the quantity share changes do not. Equations (B.5) and (B.6) show that the quantity share changes depend only on m , the number of periods over which one computes the quantity share changes, and does not depend on the quantity share of the indexed year.

What Does This Mean Intuitively?

Equations (B.1) to (B.7) present the common idea that the discrepancy in the quantity shares and quantity share changes for currency k introduced by switching the numeraire depends on the over time valuation given to k relative to the other currencies as well as on the weight—percentage changes in the quantity levels—given to the numeraire discrepancy factor.

Because the moving average method retains some characteristics of the value shares, it is not surprising that a numeraire that gives higher valuation to a currency relative to other currencies will tend to boost the quantity share of that currency.

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