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THE MANAGEMENT OF FOREIGN EXCHANGE RESERVES

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List of abbreviations

Sch.	Austrian schilling
A$	Australian dollar
B.fr.	Belgian franc
C$	Canadian dollar
D.kr.	Danish krone
F.mk	Finnish markka
Fr.fr.	French franc
DM	Deutsche Mark
HK$	Hong Kong dollar
IR£	Irish punt
Lit.	Italian lira
¥	Japanese yen
Won	Korean won
Fl.	Dutch guilder
NZ$	New Zealand dollar
N.kr.	Norwegian krone
Esc.	Portuguese escudo
S$	Singapore dollar
Pts.	Spanish peseta
S.kr.	Swedish krone
Sw.fr.	Swiss franc
NT$	New Taiwan dollar
Baht	Thai baht
£	Pound sterling
US$	United States dollar
bn	billions

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I. Introduction[1]

Questions about the management of foreign exchange reserves are likely to acquire increased prominence among the range of issues facing many central banks. Basic questions concerning the amount and form of reserves are particularly pressing for newly-established central banks, notably in the states of the former USSR. In most other formerly centrally-planned economies as well as many developing countries, central banks will need to consider the reserve implications of moving towards increasing currency convertibility and changes in exchange rate arrangements.[2] More generally still, the marked increase in the scale of private international capital flows and the large amplitude of recent swings in the exchange rates of the three major international reserve currencies – the US dollar, the Deutsche Mark and the yen – underline the importance of careful assessment of reserve needs and composition.

The purpose of this paper is to examine the main factors that should be taken into account in two basic aspects of foreign exchange reserves management: *what amount* and *what form* of reserves should be held. For the most part, the paper consists of a distillation of academic work – theoretical and empirical – on the demand for and currency composition of reserves. An important limitation of such analyses, as well as of this paper, is that the focus of attention is mainly on small economies, rather than on countries large enough to significantly influence foreign variables or whose own currencies serve as important international reserve assets or as a medium of exchange in international transactions.

Nor does the paper address the special questions raised by particular exchange rate arrangements such as the European Exchange Rate Mechanism. The specific institutional arrangements that underpin this mechanism – notably the provisions for joint intervention and extensive mutual credit facilities – raise issues that are well beyond the scope of this paper.

[1] I should like to thank Philip Turner for many helpful comments and suggestions, Julie Milne for typing, Nigel Hulbert for editorial suggestions, and Stephan Arthur for assistance with the graphics. Any remaining errors are my responsibility.

[2] In early 1993, the number of countries with flexible exchange rates (according to IMF definitions) was approximately equal to the number with pegged exchange rates; five years earlier more than twice as many countries had pegged exchange rates as had flexible rates.

The next section of this paper identifies three principal motives for holding reserves: a *transactions* demand, an *intervention-related* or *precautionary* demand and, third, a *wealth-related* or *portfolio* demand. Of these, the precautionary demand for reserves is generally regarded as by far the most important for most countries.

In Section III, the main factors influencing the desired or appropriate *level* of reserves are examined. These include the nature of the *exchange rate regime*, the external exposure of the economy, the *flexibility of the economy* in adjusting to or privately financing external payments imbalances, the extent of *constraints on international trade and capital flows* and, lastly, the *opportunity cost of holding reserves*.

With respect to the relationship between reserve levels and the magnitude of balance-of-payments disturbances this paper argues that, logically, it is more appropriate to assess reserve needs or reserve adequacy on the basis of the ratio of reserves to current account variability than on the basis of the more commonly used ratio of reserves to imports. Evidence on this issue, together with the implications of following alternative "rules of thumb" in setting reserve levels, is examined for a group of sixty countries over the period 1979–91.

Section IV turns to the issue of the *currency composition* of reserves. Two traditional approaches are discussed: the *mean-variance portfolio* approach and the *transactions-based* approach. A simple empirical test does not support the proposition that either of these approaches dominated in practice, in either industrial or developing countries, over the period 1975–92.

Also outlined is an alternative *intervention-oriented* approach to reserve currency composition, which takes the timing of reserve use into account in choosing the optimal reserve portfolio. Data covering the period 1988–92 are used to illustrate the potential implications of this approach for a variety of industrial countries.

II. Motives for holding reserves

The conventional identification of three fairly distinct motives behind individuals' holding of money balances – the transactions, precautionary and portfolio motives – can be applied, albeit with some caution, to central bank holdings of reserves.

Transactions needs

Reserves may be held for the purpose of financing readily foreseeable foreign exchange demands of either the public or private sector. This use of reserves is generally considered to be of fairly minor importance for developed economies with good access to international capital markets, but may be significant for developing countries. Many of these have limited access to external borrowing and experience marked seasonality in their foreign exchange earnings or outlays. In such cases, borrowing to finance current account deficits may be more costly than drawing on reserves. The transactions motive may be particularly important where extensive exchange controls lead a high proportion of a country's foreign currency transactions to be channelled through the central bank.

Intervention needs

Reserves are also held for the purpose of foreign exchange market intervention. Insofar as the timing and magnitude of such intervention is essentially uncertain, this source of demand corresponds to the precautionary demand for money. For most countries, the intervention motive is considered to be the most important source of demand for reserves, especially for those countries with very open goods and capital markets and/or a fixed exchange rate as the cornerstone of monetary policy.

Within the intervention motive, it is often useful to distinguish between two somewhat different sub-motives:

(i) *Very short-term exchange rate management.* Central banks in most developed countries (which tend to have very open capital markets) would probably identify this as the most important reason for holding and using reserves. Such intervention is typically *sterilised* (in order to prevent exchange market disturbances from spilling over into domestic financial markets) and geared towards offsetting the effects of short-term speculative capital movements which appear to be unrelated to fundamental economic developments, so as to prevent or correct speculative "bubbles" and reduce undesirable exchange rate volatility over the short term. Alternatively, and perhaps of particular importance for countries with exchange rate commitments (such as ERM participants), intervention may be undertaken simply in order to "buy time" while the authorities consider or imple-

ment other policy responses, such as adjusting domestic interest rates.

(ii) *Medium-term exchange rate management.* In addition to very short-term exchange rate management, *unsterilised* exchange market intervention can also be employed in the pursuit of medium-term macroeconomic stabilisation policy objectives with regard to output and prices. There is now an extensive literature[3] suggesting that, from a stabilisation policy perspective, it will usually be appropriate for monetary authorities to allow domestic interest rates and the money supply to react to exchange rate movements or pressures. In some cases, the optimal policy response will be to adjust domestic interest rates so as to strongly counter exchange rate movements.[4] In some other cases, the optimal policy may be to reinforce exchange rate movements.[5] A free-floating exchange rate policy, involving no monetary policy response to exchange rate movements, lies somewhere in between.

Essentially, there are two alternative means of implementing a monetary policy response to exchange market pressures. The most common is for the authorities to act directly in domestic financial markets, adjusting interest rates so as to dampen or accentuate exchange rate movements. In this case reserves will not be used.

Alternatively, however, the authorities can achieve the same outcome in terms of interest rates and the exchange rate by intervening in an unsterilised fashion in the foreign exchange market. Because such operations will alter the money supply, domestic interest rates will be affected, albeit *indirectly.* The main difference between these two approaches, at least for the purposes of this paper, is that in the latter case, official foreign exchange reserves will need to be held as an instrument of broadly defined monetary policy.

In most industrial countries, characterised by deep, well-developed domestic financial markets that are quite strongly integrated with international financial markets, operations to influence domestic financial market conditions are rarely implemented through

[3] See e.g. surveys by Genberg (1989) and Argy (1990).

[4] As, for example, if exchange rate movements are believed to be primarily attributable to instability in domestic money demand.

[5] As, for example, if exchange rate movements are believed to be primarily attributable to real disturbances to domestic aggregate demand.

unsterilised exchange market intervention.[6] As a result, such countries would not cite medium-term monetary or exchange rate policy implementation as a reason for holding reserves. In countries with much less well-developed domestic financial markets, however, reserves may be held and used for such purposes. The most extreme example occurs in countries where the monetary authority is in fact a currency board.[7]

Wealth diversification

Although wealth or portfolio considerations – the risk/return characteristics of different financial and non-financial assets – may be important in motivating individuals' holdings of foreign currency assets, wealth considerations are not generally thought of as greatly influencing the *level* of foreign exchange reserves held by the central bank. Rather, they are thought to be relevant mainly for decisions regarding the composition of reserves.

Wealth considerations may, however, have significance for reserve levels in certain circumstances. The most notable example is where the central bank has some responsibility for managing the *net* foreign currency exposure of the public sector or, perhaps, of the country as a whole. Thus, in response to an increase in government or government-backed foreign currency debt, the central bank may increase gross foreign exchange reserves, particularly if the central bank is concerned to maintain or enhance the country's international creditworthiness.

An alternative source of wealth or portfolio effects on reserve levels can arise from exchange controls or other measures which effectively substitute public for private sector acquisition of foreign exchange assets. However, such wealth effects are less an explicit motive for holding reserves than a consequence of measures aimed at preventing an export boom or capital inflow from boosting consumption, inflation and imports. Examples in this category include Taipei China and the "low absorber" oil exporters, although several of the oil exporters exclude much of the "wealth" portion of foreign assets from official reserve figures.

[6] Although intentions and actions may differ somewhat.
[7] See Osband and Villanueva (1993) for a discussion of currency boards.

III. The desired level of reserves

The range of motives for holding reserves, as well as the variety of factors likely to influence the relative importance of each motive, discussed in Section II, suggests that determining a "desired" or "optimal" level of reserves for any given country is likely to be a complex calculation. It also suggests that appropriate reserve levels will vary widely across countries, undermining the usefulness of very simple yardsticks for assessing reserve adequacy, such as the reserves-to-imports ratio.

Unfortunately, however, both analytical and empirical investigations of the demand for reserves[8] offer only limited practical improvement on simple, but experience-based "rules of thumb". The principal limitations of the literature are worth noting at the outset: first, almost all theoretical studies, and the empirical work based on them, focus fairly narrowly on the precautionary demand for reserves, ignoring demand related to the transactions and wealth motives. Moreover, even within the precautionary motive, the emphasis tends to be on the financing of trade imbalances rather than on very short-term capital flows. Second, most analyses adopt highly restrictive assumptions that further limit the number and "type" of countries to which such analyses are likely to be reasonably applicable. Given these limitations, it is fair to say that the countries to which the theoretical analyses apply best are those which (i) are price takers in world markets, (ii) have fairly unrestricted current account flows, but relatively limited private capital mobility, and (iii) maintain a fairly fixed exchange rate regime. In practice, this may describe many developing countries as well as some formerly centrally-planned economies "in transition", but it is clearly a less accurate description of the typical industrial country.

Bearing these limitations in mind, the principal factors likely to affect the assessment of reserve needs are discussed below. It should also be borne in mind, of course, that a country's actual reserves at any given point in time are quite likely to differ from the "desired" level. The latter should be regarded as a medium to long-term target level about which actual reserve levels may vary considerably.

[8] Black (1985) gives a good overview of the main theoretical models, while Lizondo and Mathieson (1987) and Bahmani-Oskooee (1985) provide fairly comprehensive examinations of the main empirical work on reserve demand.

The nature of the exchange rate regime

With the breakdown of the Bretton Woods system in the early 1970s, it was anticipated that the reserve needs of countries moving to a floating rate regime would be reduced. The basic reasoning for this expectation was that a floating exchange rate would tend to insulate the economy from external disturbances, serve to correct payments imbalances automatically, and largely eliminate speculative capital flows associated with fixed rates, all of which would undercut the rationale for intervention and the holding of reserves.

Some evidence to support this conclusion is provided by Lizondo and Mathieson (1987), who estimate that the shift to generalised floating after 1972 may have reduced industrial countries' demand for reserves by about 30%.[9] In contrast, developing countries, who by and large continued to peg their exchange rates even after 1972, are estimated to have experienced a decline in reserve demand of only 7%.

What is surprising, however, is not that the demand for reserves may have declined, but that it did not decline by more. A number of reasons may be suggested for this. First, a shift of exchange rate regimes, such as occurred in the early 1970s, may be more apparent than real. For example, a switch from a formally pegged, but frequently realigned, exchange rate to a formally floating, but heavily managed, exchange rate may not involve much greater exchange rate flexibility in practice.

Second, even though most industrial countries, at least, may have become more tolerant of exchange rate movements after the demise of the Bretton Woods system, reserve demand for the purpose of very short-term exchange rate management was likely to have been boosted by the marked increase in the short-term volatility of nominal exchange rates in the post-1972 period,[10] as shown in Table 1.

An additional factor that may obscure any systematic relationship between the choice of exchange rate regime and reserve needs is the effect on single currency peggers of exchange rate movements between the major currencies. After 1972, for example, many developing countries continued to peg their currencies against the US dollar or the

[9] The authors note, however, that for some specifications of the demand for reserves no statistically significant evidence of a shift in demand can be found after 1972.

[10] See Mussa (1986) for an analysis of the volatility of real exchange rates before and after the breakdown of the Bretton-Woods system.

Table 1

Nominal effective exchange rate volatility, 1963–1992

	Exchange rate volatility*			Percentage changes	
	1963–72	1973–82	1983–92	1963–72 to 1973–82	1973–82 to 1983–92
Italy	0.27	1.57	1.12	487.6	–28.5
Australia	0.34	1.96	2.72	469.5	38.8
Sweden	0.32	1.56	1.08	383.7	–30.8
Portugal	0.40	1.91	1.20	379.1	–37.2
Greece	0.38	1.79	1.80	370.0	0.6
United States	0.36	1.65	1.88	352.1	14.3
Japan	0.59	2.44	2.26	311.0	– 7.5
Switzerland	0.51	1.82	1.26	255.4	–31.0
Norway	0.34	1.05	0.79	210.2	–25.0
Belgium	0.33	1.01	0.56	207.5	–44.9
Netherlands	0.36	0.94	0.66	157.3	–30.0
Canada	0.44	1.10	1.02	150.1	– 7.3
Denmark	0.43	1.05	0.76	142.9	–27.4
Austria	0.33	0.79	0.53	139.7	–33.7
Spain	0.90	2.15	1.05	138.9	–51.1
Germany	0.69	1.44	0.93	107.9	–35.3
United Kingdom	1.02	1.78	1.91	74.4	7.2
Ireland	0.70	1.12	1.06	58.9	– 5.3
France	0.89	1.35	0.80	52.2	–40.8
New Zealand	1.72	1.63	2.62	– 5.3	61.3
Finland	2.19	1.11	1.12	–49.3	1.0
Geometric average	0.53	1.42	1.15	166.4	–18.8
Median	0.43	1.56	1.08	157.3	–27.4

* Standard deviation of percentage changes in monthly average nominal effective exchange rate (BIS 21-country index).

Source: BIS.

French franc. Given the large subsequent movements between the dollar and the other major currencies, the single currency peggers experienced substantially greater volatility in their effective exchange rates than previously.[11] As a result, their reserve needs may have increased even without any formal change in their exchange rate regimes.

[11] See Edwards (1989, Chapter 4).

The external exposure of the economy

There is a fairly broad consensus on the proposition that the greater the exposure of an economy to balance-of-payments disturbances, whether of domestic or foreign origin, the higher reserves will need to be. Perhaps the most important caveat to this is that exchange rate arrangements may vary systematically with the degree of exposure[12] in such a way as to undermine the linkage between external exposure and reserve needs. For example, if more exposed economies tend to have more flexible exchange rate regimes, it would be quite possible to find an inverse relationship between reserve holdings and balance-of-payments exposure. In practice, however, this does not appear to be the general rule. Where there is somewhat less consensus is on the issue of what is the most meaningful or useful measure of exposure. The scale of a country's trade is commonly used, though the variability of its current account or short-term capital account is argued to be a better measure (though also probably more difficult to project into the future).

A simple and traditional measure of the openness of an economy and, by implication its exposure to external disturbances, is given by the *average propensity to trade*, defined as the ratio of external trade (imports, exports or an average of the two) to GDP. This ratio, averaged over the period 1979–91, is shown in Table 2 (data for individual countries are shown in Table A1 in Appendix A) for a group of sixty countries.[13] In principle, a high degree of trade openness might be expected to be associated with higher reserve holdings, at least in relation to GDP. Although a positive relationship is evident in Figure 1, the relationship is not particularly close.[14]

A much stronger relationship appears to exist between the scale of reserves and the *scale of trade*,[15] regardless of the degree of openness

[12] It can be noted, however, that the optimum currency area literature (see Masson and Taylor (1992) for a recent review) is rather divided on this question, while the optimal intervention literature cited earlier emphasises that the optimal degree of exchange rate flexibility should depend not just on the magnitude of balance-of-payments disturbances, but also on the source, type and permanence of the underlying shock.

[13] The selection of countries partly reflects a desire to exclude the largest industrial countries (for which the small country assumptions underlying most models of reserve demand are least valid), and partly reflects data limitations. The sample period was also selected on the basis of data availability.

[14] As reported in Appendix A, a cross-sectional regression of reserves/GDP on trade/GDP yields a positive and significant coefficient, but a corrected R-squared of only 0.42.

[15] A regression of the level of reserves on the level of trade, reported in Appendix A, yields a corrected R-squared of 0.79 and an elasticity of 0.92.

Table 2

Foreign exchange reserves, trade and GDP, 1979–91

	Average annual GDP		Average annual trade		Foreign exchange reserves			
	Level (in US$ bn)	Per capita (in US$)	Level (in US$ bn)	As a % of GDP	Average year-end level (in US$ bn)	As a % of GDP	As a % of annual trade	In months of trade cover
Geometric average for:								
High-income countries[1]	66.8	12,970	29.7	44.2	4.2	6.3	14.2	1.7
Middle-income countries[2]	19.0	3,890	8.4	43.6	1.5	7.7	18.0	2.2
Low-income countries[3]	13.8	770	3.9	27.9	0.7	5.1	18.8	2.3
All countries	22.0	2,410	7.9	35.5	1.4	6.0	17.4	2.1
Median	29.3	2,270	9.8	33.6	1.5	5.6	16.8	2.0

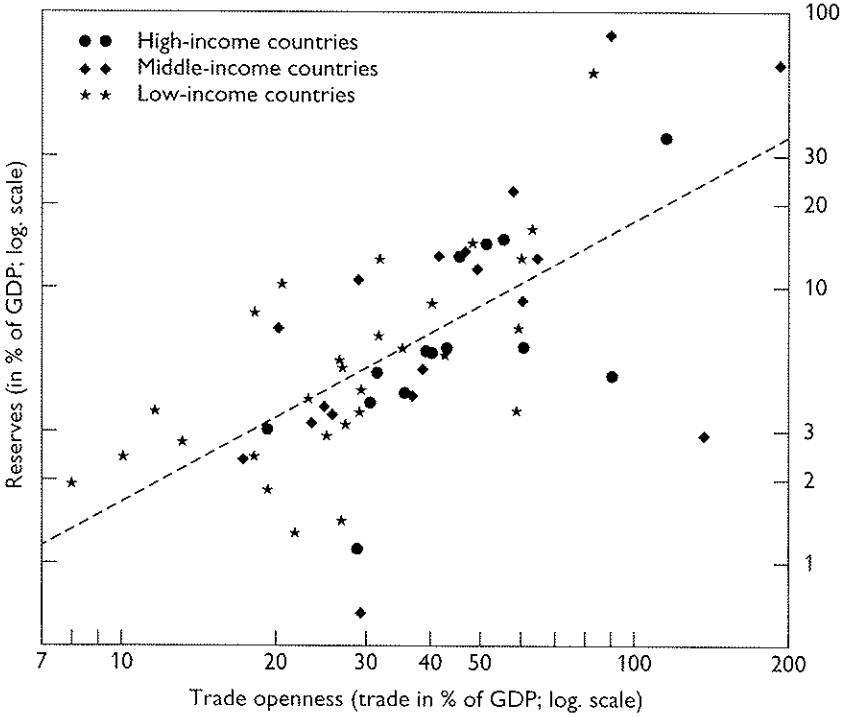
Note: See Appendix A for data definitions and calculations.

[1] 14 countries with GDP per capita above US$8,000. [2] 18 countries with GDP per capita between US$2,000 and 8,000. [3] 28 countries with GDP per capita below US$2,000.

Source: IMF International Financial Statistics.

Figure 1

Foreign exchange reserves/GDP versus trade openness, 1979–91



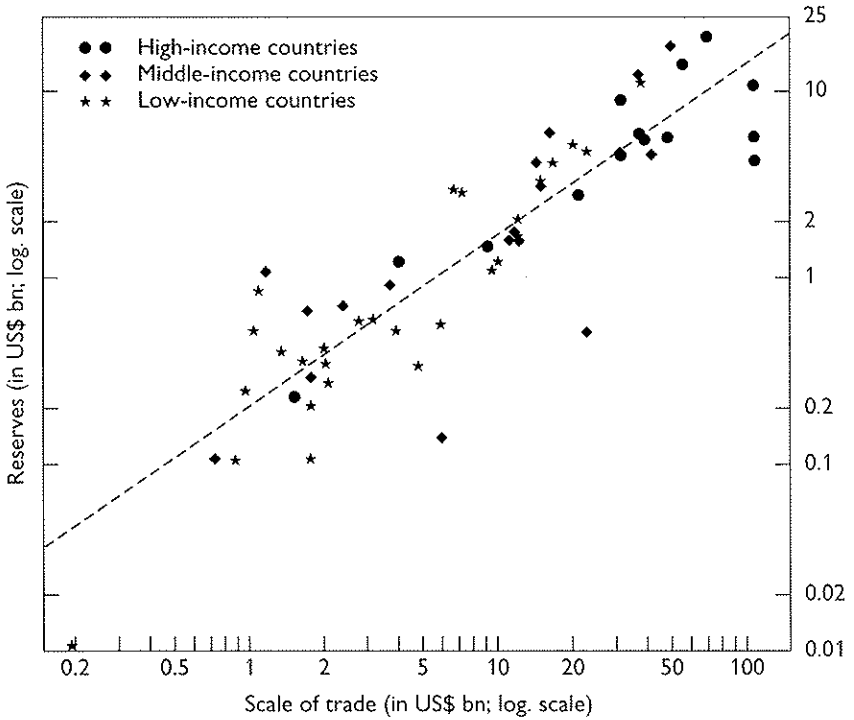
Note: See Appendix A for definitions of variables.

of the economy, as shown in Table 2 and Figure 2. In other words, whether a country is large or small, if its trade is large its reserves will also tend to be large. The logic behind such a relationship is as follows: the larger the scale of a country's trade flows, the larger will tend to be the absolute magnitude of potential current account imbalances to be financed. To the extent that such imbalances are financed through official rather than private capital flows, reserve needs will be increased.

In this context, it may be noted that the average reserves for the sixty countries were equivalent to around two months of average trade over the period 1979–91, somewhat below the three months' import cover that has often been advanced as a "rule of thumb" for assessing

Figure 2

Foreign exchange reserves versus scale of trade, 1979–91



Note: See Appendix A for definitions of variables.

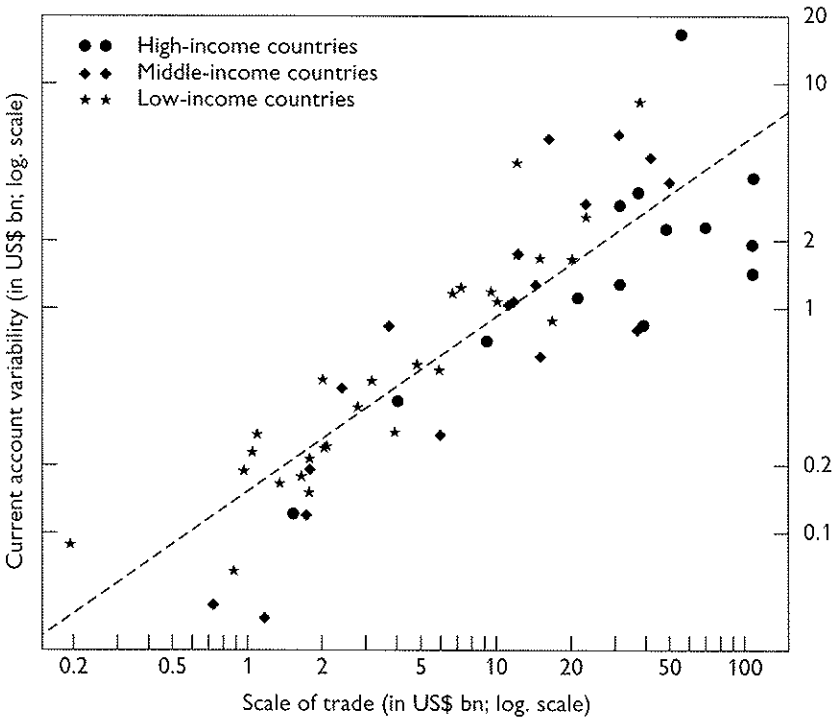
reserve adequacy.[16] Nonetheless, Table 2 also shows that the average trade coverage of reserves for low-income developing countries is substantially higher than for high-income countries, suggesting that low-income countries may have been more prone to follow the traditional rule of thumb.

There are, however, two potentially important weak links in the logic relating a country's reserve needs to the scale of its external trade. The first is that the magnitude of external payments imbalances is not a simple function of the scale of trade. The second is that the scale of

[16] To some extent the lower average figure in this paper may reflect the method of calculation; for example, the geometric average of the reserve/trade ratio for each country is generally lower than the arithmetic average commonly used in such calculations and the "three-month rule" is often expressed in terms of merchandise trade alone, rather than including trade in services as is the case in this paper.

Figure 3

Current account variability versus scale of trade, 1979–91



Note: See Appendix A for definitions of variables.

official reserve use need not be systematically related to the magnitude of external payments imbalances. Each of these aspects is discussed below.

As regards the linkage between the scale of trade and the magnitude of external imbalances, it is true that, all other things being equal, a larger scale of trade would lead to larger imbalances. But, as can be seen in Figure 3, although there is a positive relationship between trade levels and current account variability, it is by no means one-to-one,[17] indicating that other things are not equal.

[17] As reported in Appendix A, a cross-sectional regression of the standard deviation of current account changes on the scale of trade yields a corrected R-squared of 0.74. The regression also shows the elasticity of current account variability to the scale of trade to be well below unity.

Two factors tend to loosen the relationship between the scale of trade flows and the magnitude of imbalances, particularly in cross-sectional analyses. The first is that the *correlation* between changes in export receipts and import expenditures varies greatly between countries (see Appendix A, Table A2 for individual country figures). As discussed in greater detail in Appendix A, this variation appears mainly to reflect country-to-country differences in the degree of similarity between the composition of imports and exports. As is evident in Table 3, changes in imports and exports of high-income industrial countries tend to be much more highly correlated than is generally the case for low-income developing countries[18] and fuel exporters in particular. As a consequence, industrial countries will tend to experience smaller imbalances than the scale of their trade flows might suggest, while fuel exporters will have imbalances that are large in relation to their trade flows.

The second factor is that the *variability of exports and imports,* relative to the scale of trade, also differs considerably between countries. As discussed in Appendix A, this may largely reflect country-to-country differences in the degree of commodity concentration in imports, exports and domestic production. Table 3 shows that fuel exporters in particular tend to have considerably more variable exports and imports, relative to the scale of trade, than high-income industrial countries.

These considerations suggest that, in assessing reserve adequacy, it may be better for countries to focus directly on the *variability* of their external imbalances rather than on the scale of trade as a measure of potential balance-of-payments financing needs. As can be seen from Figure 4, reserve levels do indeed tend to increase with the variability of current accounts. A comparison of Figures 4 and 2 shows some notable differences. In Figure 2, nine of the fourteen high-income countries have reserves below the levels expected from the regression of reserves on the scale of trade, whereas in Figure 4 only three of these countries have lower than expected reserves. By contrast, sixteen of the twenty-eight low-income countries have higher than expected reserves in Figure 2, compared with only ten in Figure 4.

[18] Roger (1991) argues that Japan and Australia are notable exceptions to this generalisation; Australia's trade composition is similar to that of a stereotype developing country, while Japan's is almost a mirror image. As a result, it is not surprising to observe, in Appendix A, Table A2, a much lower correlation between Australia's imports and exports than is typical of industrial countries.

Table 3

Foreign exchange reserves and current account variability, 1979–91

	Current account variability		Exports variability	Imports variability	Correlation between changes in imports and exports	Ratio of foreign exchange reserves to current account variability
	In US$ bn	As a % of trade	As a % of trade			
Geometric average for:						
High-income countries[1] . . .	1.5	5.0	10.4	11.2	0.84	2.81
Middle-income countries[1] . .	0.8	9.2	12.9	14.2	0.63	1.96
Low-income countries[1] . . .	0.5	13.6	11.0	16.4	0.52	1.38
Fuel-exporting countries[2] . .	*2.3*	*20.3*	*21.9*	*18.3*	*0.40*	*1.05*
Others	*0.6*	*8.4*	*10.2*	*13.8*	*0.67*	*1.99*
All countries	0.8	9.6	11.4	14.4	0.62	1.81
Median	0.9	10.2	10.3	13.6	0.68	1.82

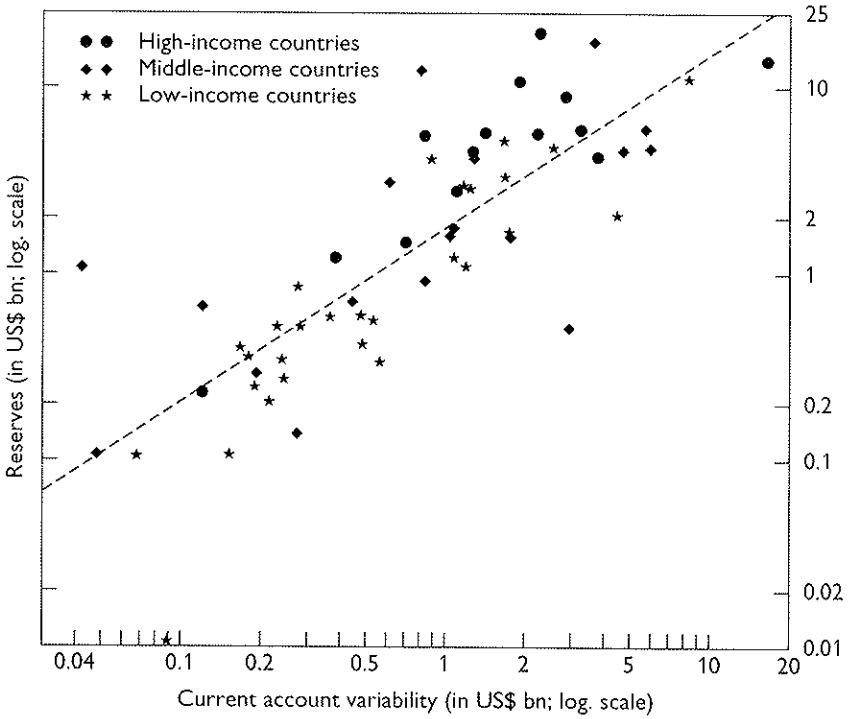
Note: See Appendix A for data definitions and calculations.

[1] See Table 2, footnotes 1–3. [2] Comprising Algeria, Ecuador, Indonesia, Mexico, Nigeria, Oman, Saudi Arabia, Trinidad & Tobago and Venezuela.

Source: IMF International Financial Statistics.

Figure 4

Foreign exchange reserves versus current account variability, 1979–91



Note: See Appendix A for definitions of variables.

To illustrate more clearly the difference between assessing reserve adequacy on the basis of the scale of trade and on the basis of current account variability, Table 4 (and Table A3 in Appendix A) and Figure 5 compare countries' actual reserves with those that would be implied by following two alternative "rules of thumb" in setting reserves.[19] The first is the traditional type of rule whereby reserves are set in proportion to the scale of a country's trade – in this case, at the equivalent of about two months imports or exports – while the second rule sets reserves in proportion to the variability of a country's current account.

[19] The "rules of thumb" were designed so that under both rules, half of the countries would have actual reserves above the figure suggested by the rule. The rules therefore reflect *median* rather than *average* practice.

Table 4

Foreign exchange reserves under alternative simple rules, 1979–91

	Average reserve levels (in US$ bn)			Actual reserves as a % of reserves		Reserves as a % of trade		Ratio of reserves/trade to current account variability	
	Actual	Under a trade rule*	Under a variability rule*	Under a trade rule	Under a variability rule	Actual	Under a variability rule	Actual	Under a trade rule
Geometric average for:									
High-income countries[1] . . .	4.20	5.05	2.72	83.3	154.5	14.2	9.2	2.81	3.38
Middle-income countries[1] . .	1.52	1.43	1.41	106.5	108.0	18.0	16.8	1.96	1.85
Low-income countries[1] . . .	0.72	0.66	0.96	108.6	74.8	18.8	24.7	1.38	1.25
All countries	1.36	1.34	1.37	101.5	98.9	17.4	17.4	1.81	1.78
Median	1.53	1.67	1.70	99.0	99.2	16.8	18.6	1.82	1.66

Note: See Appendix A for data definitions and calculations.

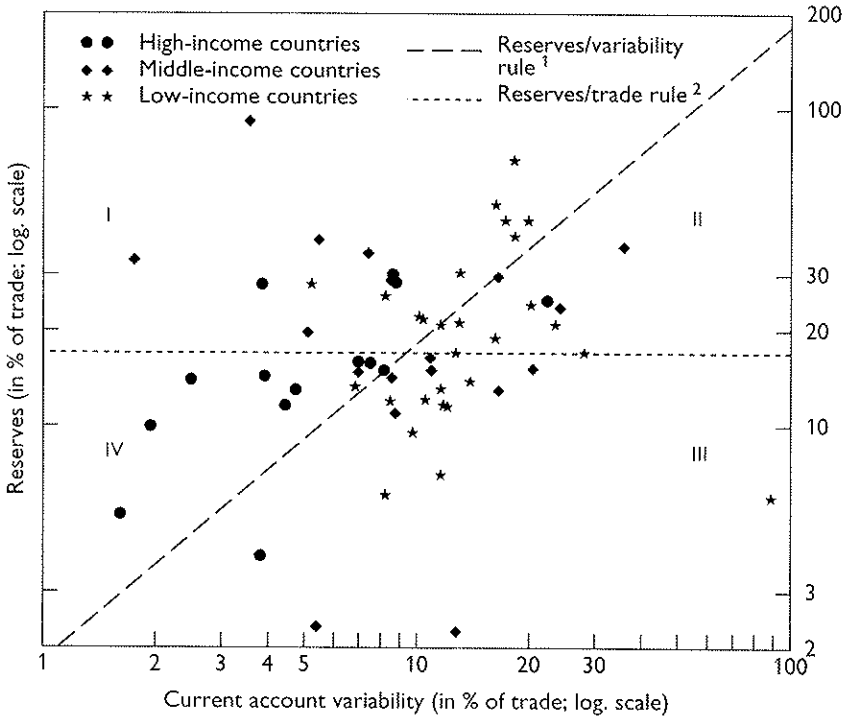
* The *trade rule* sets reserves equal to 17% of the average of imports and exports (i.e. just over two months of trade cover), and is based on the median value of the reserves/trade ratio of 16.8%, as shown in Table 2. The *variability rule* sets the reserves/trade ratio at 1.82 times the current account variability/trade ratio, and is based on the median value of the reserves/current account variability ratio as shown in Table 3.

[1] See Table 2, footnotes 1–3.

Sources: IMF International Financial Statistics and author's calculations.

Figure 5

Foreign exchange reserves/trade versus current account variability/trade, 1979–91



Note: See Appendix A for definitions of variables.

[1] The ratio of reserves/trade set equal to 1.82 times the ratio of current account variability/trade.
[2] Reserves set equal to 17% of the scale of trade.

In quadrants I and III of Figure 5 are countries whose reserves appear unusually high and low, respectively, whether judged in relation to the scale of their trade or to the variability of their current account. More interesting are the countries in quadrants II and IV. These countries have reserves that appear to be unusually low when judged according to one rule, but unusually high according to the other rule. What is particularly striking is that more than half of the high-income countries lie in quadrant IV, with reserves that appear low in relation to their trade, but high in relation to their current account variability. By contrast, in quadrant II

are found almost exclusively low and middle-income countries, whose reserves appear fairly high in relation to their trade, but low in relation to their current account variability.[20] Finally, it is also apparent from Figure 5 that many countries are clustered fairly close to the centre of the figure, indicating that, for them, it would make relatively little difference whether they followed one rule or the other in setting reserves.

The flexibility of the economy

The term "flexibility" is used here, loosely, to describe the responsiveness of the economy and the balance of payments to exogenous developments and policy actions, including exchange market intervention. Although the optimal intervention literature suggests that virtually all the parameters describing the economy should influence the degree of intervention and therefore reserve needs (relative to GDP or, perhaps, money supply), a few may be particularly important.

Traditionally, the *marginal propensity to import* has been identified as a key parameter. The literature suggests that the higher this propensity, the lower the need to intervene or hold reserves (at least relative to trade or the variability of the current account). The underlying argument runs as follows: the alternatives to official reserve financing of a balance-of-payments shortfall are either to induce external financing through private capital flows, or to close the gap by reducing net import demand. The latter can be achieved by expenditure-switching, through exchange rate adjustment (depreciation in this case), or by expenditure-changing (reduction in this example), brought about by monetary and fiscal measures. If the marginal propensity to import is high, expenditure-changing measures will be quite effective because a small reduction in income and expenditure will generate a relatively large compression of imports. Eliminating a financing gap – and the need to finance it from reserves – consequently has much less impact on the stability of

[20] These fairly systematic differences point to the importance of other influences on reserve holdings, such as the nature of the exchange rate regime, discussed earlier, as well as those discussed in the remainder of Section III. In addition, however, there may be an important measurement issue. In many developing country cases, limited capital mobility may justify focusing on current account variability as a yardstick for assessing reserve needs. For industrial countries, however, it may be more appropriate to focus on the variability of the short-term capital account.

domestic output and spending than when the marginal propensity to import is low.[21]

These means of filling or eliminating a financing gap point to other key variables. Expenditure-switching, for example, is most efficient when the *exchange rate elasticity of net exports* is high. In this case, even limited exchange rate flexibility will be quite effective in eliminating external payments imbalances and therefore reduce the incentive to hold and use reserves.[22]

The expenditure-switching and expenditure-changing options and the parameters on which they depend are likely to be more important for developing countries and the economies in transition than for more developed economies, since these countries generally tend to have much more limited access to international financial markets than do the industrial economies.

For most industrial countries the option of inducing private sector financing of temporary current account imbalances will tend to be more attractive than the alternative of reducing current account gaps via expenditure-switching or changing measures. Clearly, the relative attractiveness of financing as opposed to eliminating a current account imbalance depends heavily on the willingness of domestic and foreign residents to trade financial claims (the degree of international asset substitutability), as well as the ease with which they can do so (the degree of capital mobility).

The implications for reserve needs of a high degree of private international capital mobility and asset substitutability, however, are not entirely clear-cut. On the one hand, ready private sector access to international

[21] Unfortunately, most empirical models of the demand for reserves have used the *average* propensity to import (APM) as a proxy for the *marginal* propensity to import (MPM). Whereas the APM is expected to be positively related to reserve demand (through trade scale effects, at least), the MPM is expected to be negatively related. In addition, using the APM as a proxy for the MPM implicitly assumes that the income elasticity of demand for imports is fairly constant across countries. Both of these points may help to explain the frequent finding that the APM proxy for the MPM is either insignificant or perversely signed.

[22] However, even if the relevant *medium-term* elasticities favour expenditure-changing or switching policies as a means of adjustment over reserve financing, the *short-run* elasticities may be quite low. A classic example of this is the "j-curve" effect of depreciation; although depreciation may ultimately work very well to improve the trade balance, over the short term the balance may worsen. In such circumstances, reserves may be used to support the balance of payments until other policy measures generate the desired effects, at which point reserves may be recouped. Consequently, econometric estimates of the key elasticities, based on quarterly or annual data, may give a somewhat misleading impression of the need for intervention and reserves.

capital markets will facilitate private sector financing of balance of payments gaps, reducing the need for reserves (particularly relative to the variability of the current account). On the other hand, very open capital markets increase the exposure of the economy to external financial disturbances and, in particular, to substantial short-term capital flows induced by shifts in asset holders' expectations or asset preferences. These will tend to increase the need for reserves, notably, for very short-term smoothing purposes. On balance, therefore, increased capital market openness, especially if combined with a fixed exchange rate regime, may well increase the need for reserves.

A final point worth noting is that, by design or by trial and error, countries may gravitate towards the use of policies and exchange rate regimes which most efficiently stabilise domestic expenditure and correct external imbalances.[23] For example, countries for which expenditure-switching tends to be most effective (e.g. those with relatively sticky nominal wages and prices) may gravitate towards flexible exchange rates, while those for which expenditure-changing tends to be most effective may gravitate towards fixed exchange rates. In doing so, they will also tend to minimise their reserve needs.

Constraints on trade and capital flows

(i) *Trade restrictions.* Countries with fairly liberal trade regimes are likely to require higher levels of precautionary reserves than those with extensive controls over imports and exports, for two reasons. The first is that trade liberalisation, especially when involving reduced tariff and quota restrictions, is almost invariably associated with an expansion of the levels of imports and exports relative to national income and, consequently, an increase in the scale of potential trade imbalances to finance.[24] The second is that trade liberalisation eliminates the possibility of directly tailoring import spending to export receipts, so that larger external trade imbalances may emerge.[25]

[23] To the extent that this is the case, the nature of the exchange rate regime will not be a distinct analytical issue. For a survey of the relationship between exchange rate regimes and country characteristics, see Edison and Melvin (1990).

[24] In principle, however, trade liberalisation could reduce current account variability if liberalisation also led to increased intra-industry trade and, consequently, a higher correlation between import and export changes.

[25] It may be noted, however, that the negative correlation between import and export changes observed for China in Appendix A, Table A2, runs against the grain of this argument.

(ii) *Capital flow restrictions.* As noted earlier, an alternative to official financing of external payments imbalances is private financing. Capital account liberalisation and a high degree of international capital mobility therefore offer scope for substantial reductions in reserves held mainly for financing of current account imbalances. Capital account liberalisation can, in effect, lead to a shifting of precautionary holdings of foreign exchange off the books of the central bank.

At the same time, however, liberalised capital flows may expose the economy to destabilising speculative flows, increasing the need for reserves for very short-term exchange rate management purposes. Such needs will increase the greater the central bank's aversion to exchange rate movements (whether or not there is a formal commitment to a stable exchange rate). In this regard, it is important to take into account the fact (usually neglected in theoretical models) that capital mobility or, more precisely, asset substitutability can vary significantly between different currency areas. This can lead to large reserve needs for countries attempting to stabilise their exchange rates against currencies for which their own is not regarded as a close substitute by the private sector. For example, imperfect asset substitutability between different European currencies may contribute to the tendency for substantial movement in the US dollar-Deutsche Mark exchange rate to be accompanied by exchange market pressures *within* the ERM.

Constraints on capital flows may also be of external origin. The most important example is that of market-imposed creditworthiness constraints on sovereign borrowers. Although, in principle, virtually any borrower will potentially face such a constraint,[26] developing economies may be inherently more vulnerable to external borrowing limitations than more developed economies for a number of reasons. One concerns the nature of their borrowing needs. Almost by definition, most developing countries have large-scale investment needs relating to basic infrastructure (roads, water management, schools, etc). Such investments have long lead times and may not generate large earnings of foreign exchange; both features raise the chances

[26] See e.g. Eaton and Gersovitz (1981). Good surveys of most of the major issues in international debt are offered in Glick (1986) and Eaton (1993).

of debt-servicing problems. In addition, the social returns to such investments usually far exceed private returns, with the result that they are more likely to be undertaken by the public sector. This tends to amplify the sovereign debt component of external borrowing and thus raises the question of the government's ability to service such debt. In most developing countries, governments have much more limited capacity to appropriate domestic resources through taxation than is the case in developed economies, which constrains their external creditworthiness.

A second source of vulnerability arises from institutional arrangements. Many developing countries have non-convertible currencies and highly distorted domestic price structures. The former feature leads external creditors to focus more closely on developing countries' hard-currency earnings potential than is typically the case for lending to countries with convertible currencies. The latter feature – price distortions – makes the real worth of investments difficult to assess for borrowers and lenders alike. As a result, lenders may shy away from sound projects while borrowers may invest in projects with low real returns; both aspects will impair creditworthiness.

Common sense suggests that additional foreign exchange reserves will reduce the potential for liquidity difficulties and thereby enhance a country's creditworthiness, both by lowering risk premia and by raising its borrowing limit. This may imply a *positive* relationship between the risk premium and reserve holdings: as the risk premium, reflected in the spread between a country's borrowing costs and, say, LIBOR widens, the country should raise its reserves. But an *inverse* relationship is also plausible: as a country raises its reserves, the risk premium should decline. The two are not really inconsistent, but essentially simultaneous, so that high-frequency data might be needed to establish the correct sequence of cause and effect. This may explain why, in practice, it has been difficult to find any significant statistical relationship between reserve holdings and risk premia in bond markets.[27]

[27] See e.g. Edwards (1986). Ben-Bassat and Gottlieb (1992a), however, claim some success in overcoming the simultaneity problem by using a 2SLS technique applied to Israeli data. They then construct an "optimal" reserves series incorporating information on the risk premium and find that actual Israeli reserves correspond more closely to this measure of optimal reserves than to a measure that does not reflect creditworthiness considerations.

The cost of holding reserves

A general presumption in the demand for reserves literature is that, other things being equal, desired reserves decline as the cost of holding reserves rises although, as discussed in the previous section, creditworthiness considerations may in particular instances overturn the normally inverse relationship.

There is also a general consensus that the most appropriate definition of the cost of holding reserves is the net social opportunity cost – that is, the best alternative social yield on the resources tied up in reserves minus the actual yield on reserves. The difficulties arise in measuring either of these rates of return. Indeed, measurement problems have been blamed for the failure of many studies to find a significant, "correctly" signed relationship between reserve holdings and their estimated net opportunity cost.[28] Three relatively recent studies[29] have attempted to measure opportunity costs more accurately than earlier studies and have found a significant negative relationship between reserve holdings and their opportunity cost.

With respect to the *return* on reserve assets, a standard assumption maintained in these studies is that the vast majority of reserves are held in low-risk, highly liquid form and, therefore, will earn a yield close to LIBID or a short-term Euro-dollar deposit rate.[30]

Much more difficult to assess is the return on alternative uses of the resources held as reserves. Perhaps the most traditional approach considers the gross real cost of holding reserves as equal to the social *marginal product of capital* in the country concerned. Ben-Bassat and Gottlieb (1992b) follow this approach for Israel, using rates of profit in the business sector, as well as minimum rate of return thresholds applied to public sector investment projects.

Unfortunately, this kind of approach cannot be readily applied elsewhere. Quite apart from difficulties in obtaining the necessary data, there is often likely to be a large gap between the true social rate of

[28] See e.g. Edwards (1985).

[29] Edwards (1985), Landell-Mills (1989) and Ben-Bassat and Gottlieb (1992b).

[30] Ben-Bassat and Gottlieb (1992b) use a weighted average (based on currency shares in reserves) of US dollar and Deutsche Mark deposit rates. It is not obvious that this is an improvement on using the US dollar rate alone, since expected yields in a common currency may be more similar than the deposit rates themselves, if uncovered interest parity holds even approximately.

return on capital and the return actually observed. Moreover, any such comparison of rates of return, particularly in cross-sectional analyses, should take into account the substantial differences in risk associated with the alternative uses of the resources.

There is also a macroeconomic argument against using returns on domestic investment as a measure of opportunity cost, except over the long term. Suppose, for example, that short-term interest rates declined in the major industrial countries. Unless long-term borrowing rates fell equally, the measured difference between investment returns and the yield on reserves would rise and lead to some decline in desired reserves. The channelling of "excess" reserves into domestic investment and demand, however, might be entirely undesirable from a stabilisation policy perspective. The basic point to be made is that when macroeconomic stabilisation policy is taken into account, domestic real investment may not represent the "best" alternative use of foreign exchange reserves.[31]

The main alternative measure of a country's gross cost of holding reserves is its *marginal cost of borrowing in international capital markets*[32] and is the measure used in the Edwards (1985) and Landell-Mills (1989) studies. This measure has two notable advantages over the marginal product of capital measure. The first is simply that it is much more readily observed or calculated. The second is that while from a national planner's perspective it may be more appropriate to focus on the opportunity cost in terms of domestic real investment opportunities, decisions regarding reserve management are much more likely to focus on the cost of funding reserves, or alternatively, the gain from using reserves to repay external debts.

Whichever of the two basic alternative measures of opportunity cost is used, the empirical tests suggest that the net cost of holding reserves

[31] This is likely to be especially the case for economies where reserves are relatively large compared with the size of the domestic economy and relative to investment opportunities in particular. In these cases, reallocation of resources from reserves to domestic investment will tend to result in a relatively larger stimulus than in larger economies with greater investment opportunities at any given rate of return.

[32] Edwards (1985) observes that in the absence of capital market inefficiencies and other distortions affecting real returns on domestic investment, the two alternative measures would be equivalent, at least when adjusted for risk differences, since domestic investment would proceed to the point where the marginal product of capital was equal to the marginal cost of borrowing abroad.

is an important influence on reserve demand, at least for developing countries. The Ben-Bassat and Gottlieb analysis, being restricted to the case of Israel, makes it impossible to draw very general, cross-country conclusions but it can be noted that they find that changes in the measured opportunity cost of holding reserves do exert a substantial influence on reserve holdings *over time*, while Edwards finds inter-country differences in opportunity costs to be an important influence on differences in reserve holdings *across countries*.[33]

The Landell-Mills study, however, suggests some need for caution in interpreting econometric results and generalising across countries. A curious result in her analysis is that the demand for reserves appears to be much more sensitive to opportunity costs in the case of developing countries which ran into debt difficulties in the 1980s than for other countries. This seems counter-intuitive insofar as it might be expected that countries facing debt difficulties and high borrowing costs might hold higher, not lower, reserves in order to improve their creditworthiness, which would tend to dampen the normally negative relationship between cost and demand. Landell-Mills suggests that the high sensitivity observed for countries with debt problems may result from a systematic tendency for such countries to be more reliant on borrowed rather than owned reserves. Although illogical from an economic point of view, countries relying on borrowed reserves might be more sensitive to the opportunity cost of holding reserves than countries with mainly owned reserves for the simple reason that for borrowers the opportunity cost will be much more visibly reflected in the accounting cost of holding reserves.

An alternative story may be more plausible. This is that after 1982, when lenders became much more sensitive to measures of developing country creditworthiness – such as reserves/import ratios – declines in developing countries' actual reserves (as opposed to desired reserves) could have led to increases in lending rates to such borrowers. This would generate the observed inverse relationship between changes in reserves and measured opportunity cost, but with a reversal of causality.

[33] Indeed, differences in borrowing costs facing developed and developing countries may partly account for the tendency, seen in Figure 5, for industrial countries to hold higher reserves and for developing countries to hold lower reserves than would be expected on the basis of current account variability.

Most importantly, it would give a false indication of the relationship between *desired* reserves and opportunity costs. From this perspective, Landell-Mills' finding that, for countries which did *not* run into debt difficulties, reserves were fairly insensitive to the net holding cost may be the most important result.

IV. The desired composition of reserves

Just as there is no "general" theory of the demand for reserves, integrating the full range of considerations that can be expected to influence a country's desired level of reserves, so too there is no comprehensive theory of optimal reserve composition.

Curiously, a very basic consideration in reserve portfolio management – the degree of liquidity characterising or required of the portfolio – is not very well integrated into existing models.[34] How important liquidity considerations are depends crucially on the motive for holding reserves. If reserves are held primarily for the purposes of exchange market intervention, an extremely high degree of liquidity will be required of reserve assets, while other reserve asset properties, such as their risk/return characteristics, will be much less important. By contrast, for reserves held primarily as medium to long-term investments, risk/return characteristics will be relatively important.

The models outlined below tend to suit one or other of these portfolio criteria, but do not readily accommodate the fact that central banks take liquidity *and* risk/return (as well as other) characteristics into account in their portfolio choices. One way of dealing with this problem may be to manage different "tranches" of the overall reserve portfolio according to different liquidity requirements.[35] The most liquid "tranche" would reflect transactions needs, while a less liquid "tranche" would reflect risk/return considerations, so that the overall portfolio

[34] One reason why it is inherently difficult to integrate liquidity considerations into the models is that the effective liquidity of different reserve assets depends partly on the size of holdings relative to the size of the market. For example, even if, say, Barbados held a high proportion of its reserves in Dutch guilders, these would be highly liquid given the size of its holdings relative to the size of the market. However, if the United States held a high proportion of its reserves in guilder instruments identical to those of Barbados, they would be much less liquid.

[35] See e.g. Blackman (1981).

would be a mixture of the two. Alternatively, an optimal risk/return portfolio might be modified on a judgemental basis to take account of liquidity requirements.

The next section reviews the evolution of the currency composition of global reserves over the period 1975–92. The following three sections examine alternative but, as discussed above, not necessarily incompatible, approaches to the determination of the desired currency composition of reserves. A final section examines other considerations that may constrain the currency composition of reserves of both large and small reserve holders.

The currency composition of reserves, 1975–92

Tables 5–7, together with Figures 6–8, show the evolution of the currency composition of global, industrial country and developing country reserves over the period 1975–92, both at current and at end-1992 exchange rates. These show a number of noteworthy features:

(i) The share of the US dollar in global, industrial country and developing country reserves declined substantially over the period 1975–92, but the fall is much more pronounced at current exchange rates than at constant exchange rates. Indeed, since about 1984 the share of the dollar, which has continued to shrink at current exchange rates, shows no clear trend in constant exchange rate terms in industrial countries and has tended to drift upwards in developing countries.

(ii) The currency composition of reserves has been noticeably more stable, whether in current or constant exchange rate terms, for developing countries than for industrial countries.

(iii) Throughout the period, and in both current and constant exchange rate terms, changes in the share of the US dollar in global and industrial country reserves have mostly found their counterpart in changes in the share of the Deutsche Mark and, to a much lesser extent, the yen. The data in Table 7 largely support this observation, but also reveal differences between the industrial and developing countries.

Among the industrial countries, the shares of the yen and Deutsche Mark have tended to rise and fall together as the share of the dollar

Table 5

Currency composition of foreign exchange reserves at current exchange rates, 1975–92

	Currency composition in selected years* (in % of total)					Average share (%) (A)	Standard deviation (B)	B as a % of A
	1976	1980	1984	1988	1992	1975–1992		
All countries								
US$	77.3	69.7	70.2	64.1	64.6	69.1	6.9	10.0
¥	2.0	4.2	5.8	7.8	8.3	5.6	2.7	47.5
DM	9.0	14.8	12.7	15.3	13.2	13.2	3.1	23.7
£, Fr.fr., Fl., Sw.fr.	6.6	8.5	6.3	7.1	8.4	7.2	1.1	15.0
Unspecified/other	5.1	2.8	5.1	5.7	5.5	4.9	1.4	28.3
Industrial countries								
US$	87.1	77.2	73.6	67.7	63.6	73.4	11.3	15.3
¥	1.8	3.3	6.3	7.0	7.7	5.5	3.2	57.3
DM	6.2	14.3	15.1	17.3	14.9	13.9	5.6	40.3
£, Fr.fr., Fl., Sw.fr.	3.0	3.9	3.6	5.0	6.6	4.3	1.7	40.6
Unspecified/other	1.9	1.3	1.4	3.0	7.2	2.9	2.3	78.6
Memo item: Share of global reserves	*46.5*	*56.8*	*53.0*	*63.9*	*54.2*			
Developing countries								
US$	68.9	59.9	66.3	57.6	65.9	64.1	3.6	5.6
¥	2.2	5.4	5.2	9.3	8.9	5.7	2.3	39.9
DM	11.4	15.4	10.0	11.7	11.2	11.8	1.8	15.0
£, Fr.fr., Fl., Sw.fr.	9.7	14.5	9.3	10.8	10.5	10.8	1.2	11.2
Unspecified/other	7.8	4.8	9.2	10.6	3.5	7.6	2.1	27.8
Memo item: Share of global reserves	*53.5*	*43.2*	*47.0*	*36.1*	*45.8*			

* Global currency shares were calculated using aggregated data for industrial and developing countries.

Source: IMF *Annual Reports;* data for 1992 are partly estimated.

Table 6

Currency composition of foreign exchange reserves at end-1992 exchange rates, 1975–92

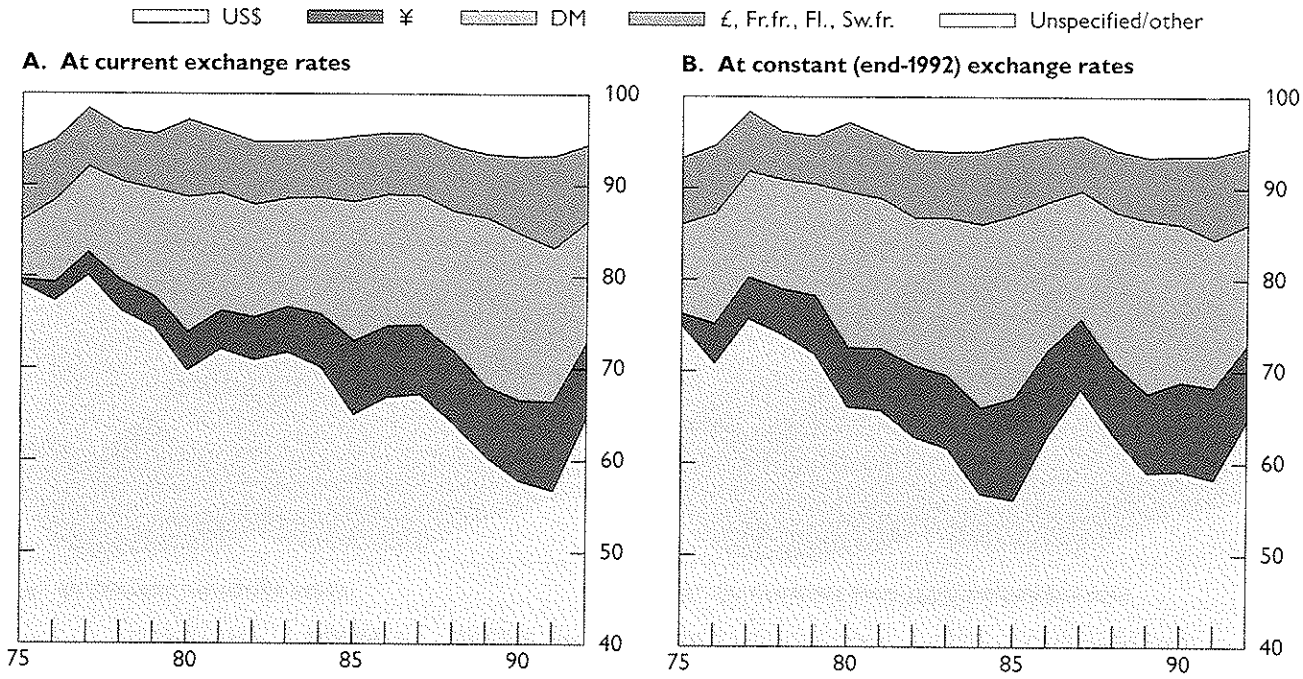
	Currency composition in selected years (in % of total)					Average share (%) (A)	Standard deviation (B)	B as a % of A
	1976	1980	1984	1988	1992	1975–1992		
All countries								
US$	70.8	66.1	56.6	63.1	64.6	65.1	6.3	9.7
¥	4.3	6.5	9.4	7.8	8.3	7.4	2.4	33.0
DM	12.1	17.0	20.0	16.6	13.2	15.4	3.0	19.6
£, Fr.fr., Fl., Sw.fr.	7.5	7.7	8.0	6.8	8.4	7.2	1.0	13.8
Unspecified/other	5.3	2.8	5.9	5.8	5.5	5.1	1.4	27.5
Industrial countries								
US$	82.1	73.5	59.3	66.4	63.6	69.5	10.8	15.6
¥	4.0	5.1	10.2	6.9	7.7	7.1	3.2	44.8
DM	8.6	16.5	23.8	18.7	14.9	16.2	5.9	36.4
£, Fr.fr., Fl., Sw.fr.	3.6	3.8	4.7	4.9	6.6	4.4	1.5	34.6
Unspecified/other[1]	1.7	1.1	1.9	3.0	7.2	2.8	2.1	75.0
Memo item: Share of global reserves at 1992 exchange rates	*45.2*	*56.6*	*53.1*	*64.1*	*54.2*			
Developing countries								
US$	61.5	56.5	53.6	57.1	65.9	60.1	3.8	6.3
¥	4.6	8.3	8.5	9.3	8.9	7.6	1.8	24.3
DM	14.9	17.6	15.8	12.8	11.2	13.9	2.2	15.9
£, Fr.fr., Fl., Sw.fr.	10.7	12.7	11.8	10.1	10.5	10.6	1.1	10.7
Unspecified/other[2]	8.3	4.9	10.4	10.7	3.5	7.9	2.3	28.5
Memo item: Share of global reserves at 1992 exchange rates	*54.9*	*43.4*	*46.9*	*35.9*	*45.8*			

[1] Estimated using SDR/$ exchange rate from 1975 to 1978, and ECU/$ rate subsequently. [2] Estimated using SDR/$ exchange rate.

Source: IMF *Annual Reports;* data for 1992 are partly estimated.

Figure 6

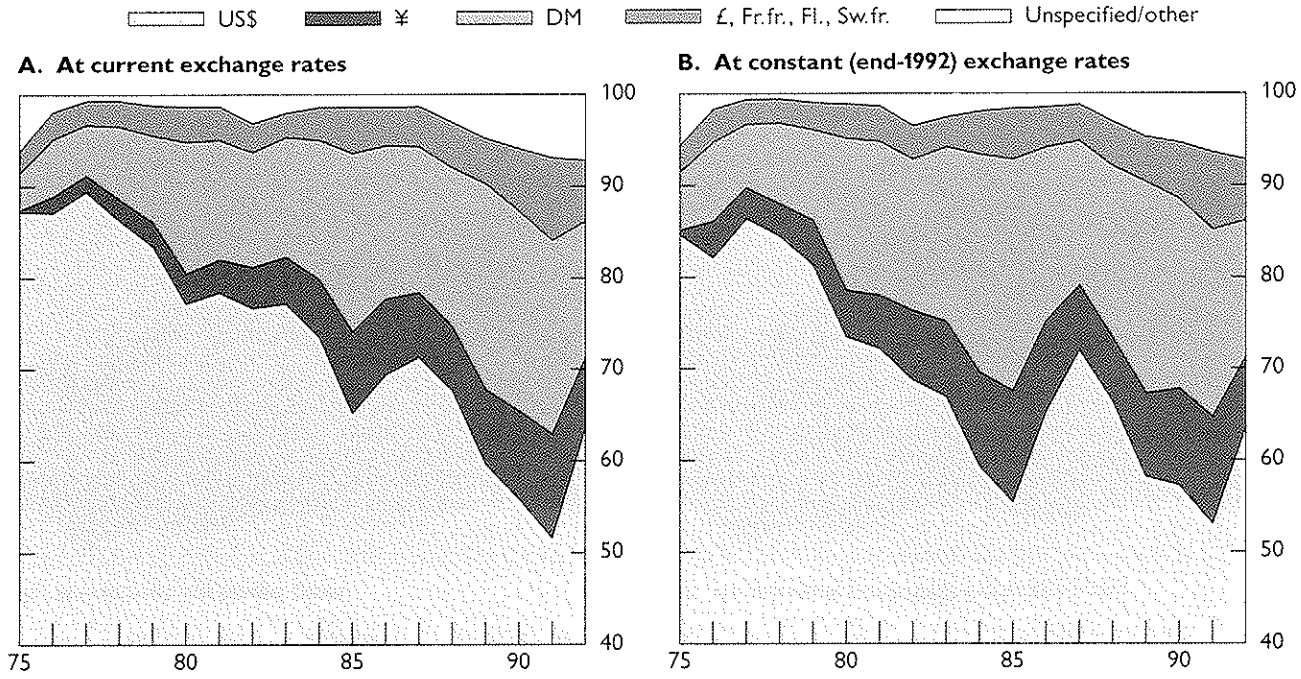
Currency shares in global foreign exchange reserves, 1975–92



Note: Global reserves are calculated as the sum of industrial and developing countres' reserves.
Source: IMF Annual Reports; figures for 1992 are partly estimated.

Figure 7

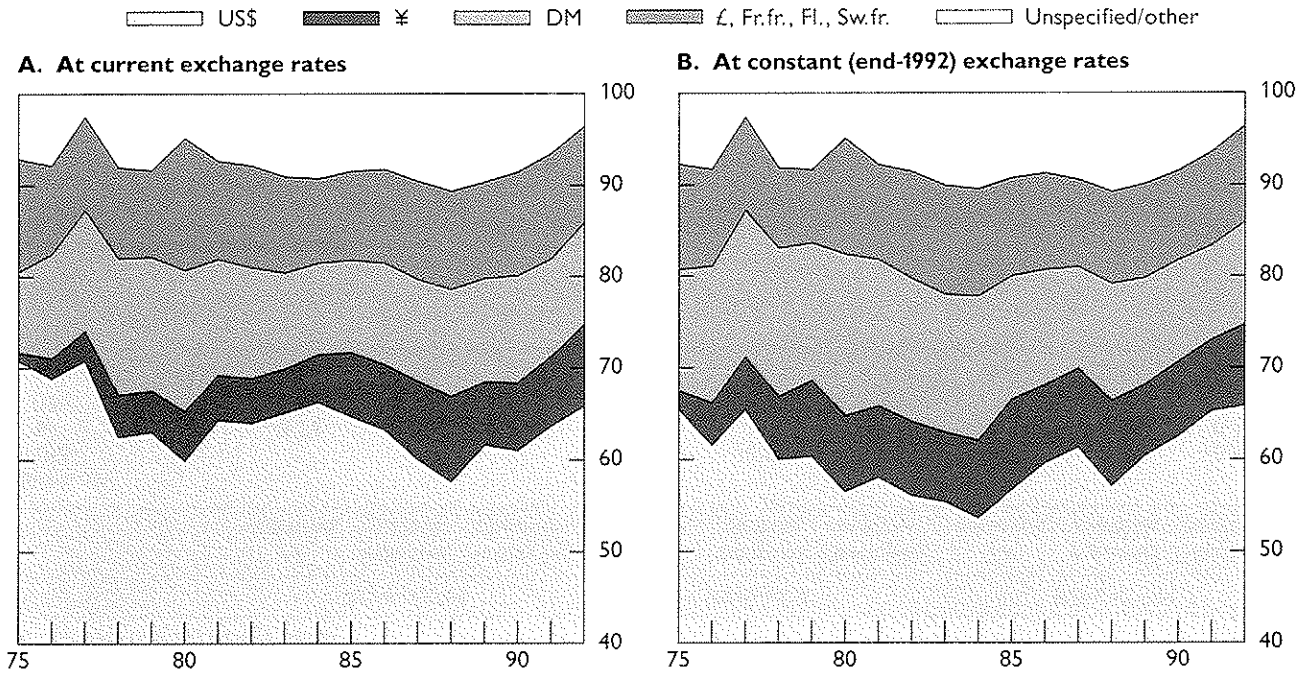
Currency shares in industrial countries' foreign exchange reserves, 1975–92



Source: IMF Annual Reports; figures for 1992 are partly estimated.

Figure 8

Currency shares in developing countries' foreign exchange reserves, 1975–92



Source: IMF Annual Reports; figures for 1992 are partly estimated.

Table 7

Correlations between changes in currency shares in reserves, 1976–92

A. At current exchange rates

	Share of US$			Share of ¥			Share of DM		
	All countries	Industrial countries	Developing countries	All countries	Industrial countries	Developing countries	All countries	Industrial countries	Developing countries
Share of:									
US$				−0.72	−0.85	−0.62	−0.83	−0.89	−0.58
¥	−0.72	−0.85	−0.62				0.59	0.72	0.53
DM	−0.83	−0.89	−0.58	0.59	0.72	0.53			
£, Fr.fr., Fl., Sw.fr. .	−0.66	−0.76	−0.38	0.54	0.79	0.17	0.43	0.52	0.26

B. At end-1992 exchange rates

	Share of US$			Share of ¥			Share of DM		
	All countries	Industrial countries	Developing countries	All countries	Industrial countries	Developing countries	All countries	Industrial countries	Developing countries
Share of:									
US$				−0.71	−0.81	−0.42	−0.88	−0.92	−0.64
¥	−0.71	−0.81	−0.42				0.55	0.67	0.37
DM	−0.88	−0.92	−0.64	0.55	0.67	0.37			
£, Fr.fr., Fl., Sw.fr. .	−0.66	−0.74	−0.29	0.34	0.67	−0.21	0.59	0.55	0.57

Source: IMF *Annual Reports;* data for 1992 are partly estimated.

has fallen and risen, respectively (as is reflected in the positive correlation between changes in the shares of the yen and Deutsche Mark in reserves and the highly negative correlations between changes in the shares of these currencies and the dollar). Among developing countries, however, changes in the shares of Deutsche Mark and yen have not been as closely correlated, particularly at constant exchange rates.

(iv) Much of the movement in the currency composition of industrial countries' reserves appears to reflect the effects of intervention related to exchange rate movements rather than more fundamental shifts in portfolio preferences.

The mean-variance approach

The mean-variance approach to analysing the composition of reserves is an adaptation of the traditional Markowitz portfolio model, widely used in the theory of finance. Essentially, the model treats reserves as a store of wealth and the central bank as an investor wishing to maximise the value of the portfolio while minimising its riskiness. Within this framework, the basic analytical task is to find the set of investment portfolios (i.e. the different combinations of currencies in reserves) which offer the greatest return for any given degree of risk. This set is known as the *efficient frontier*, since any other portfolio (currency mix) will yield a lower return for the risk involved. In principle, optimising central banks should always pick a currency portfolio somewhere along the efficient frontier, so long as the risk and return on the portfolio are their sole concern.

An important difference between the traditional portfolio analysis and that for a central bank is that, in the traditional analysis, the investor is assumed to focus on the mean and variance of the portfolio returns in domestic currency terms. In contrast, the central bank is usually regarded as focusing on the mean and variance of returns on its reserves in terms of a "basket" of either foreign currencies or imported goods and services. Since this basket will differ from one country to the next, the efficient frontier will also vary from one country to the next. Consequently, even if two central banks have identical preferences in terms of the trade-off that they are willing to make between risk and

return on their reserves, they will still select different currency mixes for their reserves.[36]

The application of the mean-variance approach to the currency composition of reserves runs into three sorts of practical difficulties discussed below: the first two concern the identification of the efficient portfolio frontier, while the third relates to the choice among efficient portfolios.

(i) *Defining the appropriate reference basket.* Two basic alternatives have been employed in the literature. The first emphasises the role of reserves as a means of financing *current account deficits,* by evaluating portfolios in terms of their real purchasing power over imports. In this case, the means and variances of alternative portfolio yields would be evaluated with reference to an index of foreign prices, usually weighted according to import shares from various countries or according to currency shares in the denomination of imports.[37]

The second alternative emphasises the role of reserves in intervention or capital account financing. In this case, the central bank is regarded as aiming to maximise the value of reserves, and minimise their variance, in terms of the *currency of intervention* (e.g. the US dollar)[38] or in terms of a currency basket against which it may have an exchange rate target, or at least an intervention reaction function.[39]

It should be noted that the choice of reference basket also affects the relevant types of instrument in each currency. In the first case, for example, with reserves held for current account financing, the degree of liquidity required of reserve assets will tend to be lower than in the second case, where reserves are held mainly for coping

[36] To illustrate this point, consider the following simple example: suppose that the Austrian and Mexican central banks have identical risk/return preferences and that expected returns on US dollar and Deutsche Mark assets are also identical. Suppose also that Austria's trade is primarily with Germany while Mexico's is with the United States. In these circumstances, Mexico will regard the US dollar as a less risky currency than the Deutsche Mark in terms of its import basket, while the reverse will be the case for Austria. Other things being equal, Mexico would hold a high proportion of dollars in reserves, while Austria would hold Deutsche Marks.

[37] See e.g. studies by Kouri and de Macedo (1978), Ben-Bassat (1980), Healy (1981), Ben-Bassat (1984), Horii (1986), Dellas (1989).

[38] See e.g. Ben-Bassat (1980).

[39] See e.g. Rikkonen (1989). It is, of course, possible that the "target" basket may use trade weights, but not necessarily.

with short-term capital flows. These differences in liquidity requirements imply that the alternative reference baskets will differ not only in the weights of various currencies but also in the types of currency instrument and their associated risk/return characteristics.

(ii) *Instability of risk/return relationships.* The second source of difficulty in any portfolio management problem is that the statistical characteristics of the alternative investments – in this case the expected returns, variances and covariances of returns on different currencies – may be unstable over time. Changes in the key statistical parameters of the currencies involved will, of course, alter the currency composition of portfolios along the efficient frontier, as well as the shape and position of the frontier itself. As a result, portfolios which appear efficient *ex ante,* based on earlier data, are quite likely to turn out to be less efficient *ex post.*[40]

While there is no complete solution to this problem, there may be some ways of reducing its importance. Rikkonen (1989), for example, employs alternative exchange rate forecasting techniques to improve estimates of expected returns on different currencies and select variances and covariances of returns that minimise forecast errors. An alternative approach, taken by Jorion (1985) and Dumas and Jacquillat (1990), employs Bayesian forecasting techniques. For example, expectations regarding returns on different currencies may be based partly on historical data and partly on the "prior" that uncovered interest parity will hold. In practice, this approach tends to favour fairly conservative portfolio management, partly because it suggests that there is less scope for trading off risk against return than a backward-looking analysis might suggest, (inducing a bias in favour of the minimum variance portfolio) and partly because expectations shift more gradually in response to new data.

The instability of key parameters also raises practical questions of *how frequently* to update the estimates and *how quickly* to adjust the currency composition of the portfolio. For example, it can be argued that a very "conservative" central bank should lean towards fairly frequent portfolio re-estimation and adjustment, since this

[40] See e.g. Papaioannou and Temel (1993).

could help reduce the riskiness of the portfolio. Doing so, however, runs the risk of destabilising exchange markets,[41] which may conflict with the central bank's broader responsibilities or concerns.

(iii) *Choosing among efficient portfolios.* The third source of difficulty in applying the mean-variance framework to reserve management is that it can be used only to identify the set of efficient portfolios. Which of these represents the best or "optimal" portfolio for a country remains a subjective choice, dependent on the balancing of risk and return. This ultimately subjective element in the mean-variance approach also makes it virtually impossible to determine whether, and to what extent, the currency composition of central banks' reserves reflects optimising behaviour. The basic difficulty is in selecting a "benchmark" portfolio against which to compare the actual portfolio held by the central bank. Various alternatives have been used in the empirical literature, but none is fully satisfactory. A diagram is probably helpful in understanding the problem.

In Figure 9, the curve *EF1* traces the efficient portfolio frontier, as calculated at time *t*. Point *A* represents the portfolio actually held by the central bank, with a mean return of *Ra* and a variance of *Va*. Since *A* lies within the frontier, rather than on it, it appears to be inefficient. The question is how to measure the degree of inefficiency. The most commonly used reference point, or "benchmark", is the minimum variance portfolio, represented by point *B* (with a mean return of *Rb* and a variance of *Vb*).[42] Unfortunately, there is no simple way of measuring by how much portfolio *A* differs from portfolio *B:* differences in currency composition may be compared, but no overall measure of disparity is available.

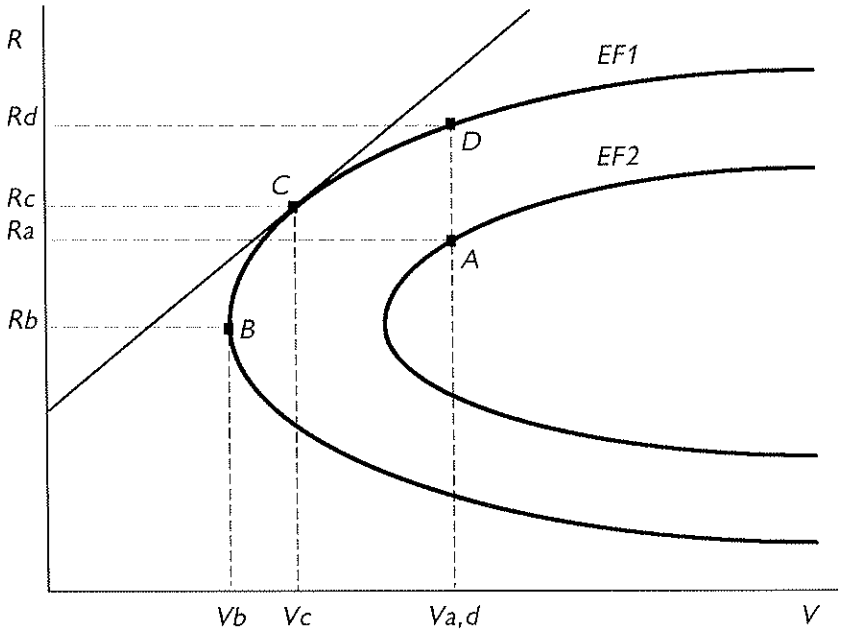
An alternative benchmark is portfolio *C*. This portfolio occurs at the point of tangency between the efficiency frontier and a line intersecting the vertical axis at the rate of return on a hypothetical "risk-free" asset. If a risk-free asset does not exist, its closest equiv-

[41] On this point, Brady (1992) discusses how the extremely active portfolio management of a central bank can affect exchange rates.

[42] See e.g. Kouri and de Macedo (1978), Healy (1981) and Horii (1986). One argument in favour of using the minimum-variance portfolio as a benchmark is that, analytically, any given portfolio can be decomposed into two sub-portfolios: a minimum-variance portfolio plus a "speculative" portfolio.

Figure 9

Actual versus "benchmark" portfolios



alent may be the numeraire basket itself.[43] Again, it is difficult to compare the actual and benchmark portfolios.

Perhaps the best benchmark, used by Dellas,[44] is portfolio *D* (having the same variance as portfolio *A* but on the efficiency frontier), for two reasons. The first is that the difference between *A* and *D* can be measured simply by the difference in the overall rates of return *(Rd* minus *Ra)* on the two portfolios. The second reason is that the difference in returns on portfolios *A* and *D* involves no judgement as to the optimality of the portfolio, in contrast with

[43] See e.g. Ben-Bassat (1980, 1984). Ben-Bassat notes that if the objective of the central bank is, say, to optimise with respect to the dollar value of reserves (i.e. a US dollar numeraire) then the "risk-free" return would be the yield on US Treasury bills. When the objective is cast in terms of a basket of currencies or imports, there is no truly risk-free asset available. Ben-Bassat uses a numeraire-weighted average of interest rates on the numeraire currencies.

[44] Dellas (1989) and Dellas and Yoo (1991).

portfolios *B* and *C*. To see this, suppose that the actual portfolio had been at point *D*. In this case the portfolio would rightly be measured as an efficient portfolio. But if portfolio *D* were measured against either portfolio *B* or *C*, it might be regarded as inefficient, which it is not.

Unfortunately, even Dellas' inefficiency measure may be misleading. As was discussed earlier, calculation of the efficient frontier is sensitive to differences in the definition of the reference basket and the way in which expectations are formed.[45] As a result, there is no guarantee that the relevant frontier is *EF1*. It would be quite possible, for example, that the central bank's calculation of the efficient frontier was actually *EF2*. In this case, portfolio *A* should be seen as efficient and the difference between *D* and *A* would be a measure of the error in the researcher's judgement regarding the central bank's objective or its forecasting methodology.

The kinds of "technical" problems discussed above are not only a source of frustration for academic researchers, but also for central banks attempting to apply the mean-variance approach to their reserve portfolio decisions. Nonetheless, the mean-variance approach may at least have a useful role to play as a complement to judgemental decisions on portfolio composition.[46] In particular, the approach can offer a starting-point for forward-looking portfolio choices as well as provide benchmarks against which past portfolio choices can be assessed.

The transactions approach

In an important contribution to the reserve management literature, Dooley (1987)[47] suggests that the composition of foreign exchange reserves may depart from efficient portfolio mixes for sound reasons unrelated to the practical problems associated with applying the mean-variance framework.

[45] Ben-Bassat (1980) and Horii (1986), for example, used lagged values of the actual frontier as a proxy for the "expected" frontier against which actual portfolios are compared. There is no guarantee that even optimising central banks forecast efficiency frontiers in the same way.

[46] To the extent that factors other than the mean and variance of the portfolio influence the desired composition of reserves, some judgmental adjustment input to portfolio decisions will be essential. Even so, the approach can be helpful in clarifying the "cost" (in terms of departure from the efficient frontier) of these additional considerations or constraints.

[47] Building on earlier work by Heller and Knight (1978).

The basic thrust of Dooley's argument is that the mean-variance framework is most logically applied to the *net* foreign assets of the authorities rather than to *gross* reserves alone. From this perspective, an efficient portfolio of net assets can be obtained by manipulating the composition of gross assets, gross liabilities or both. An implication which follows is that even if the currency composition of the net asset portfolio is efficient (in a mean-variance sense) there is no reason to expect that the currency composition of either gross assets or gross liabilities, examined in isolation, will represent efficient portfolios.

The fact that the currency composition of net reserves can be optimised on either the assets or the liabilities side may give the authorities an extra degree of freedom to pursue other objectives. Dooley suggests that a logical way in which to use this freedom is for the central bank to place a relatively high weight on transactions cost or liquidity considerations in setting the composition of reserve assets, while mean-variance considerations (with respect to the net asset portfolio) are given a fairly heavy weight in the make-up of liabilities.

Nonetheless, Dooley readily acknowledges that institutional arrangements may well preclude portfolio optimisation with respect to the currency composition of net foreign exchange assets. This is particularly likely if reserve assets are managed quite separately from liabilities. In addition, the ability to manage foreign currency positions may be much more constrained on the liabilities side than on the assets side if foreign currency borrowing decisions are highly decentralised, if liabilities are typically in instruments with longer maturity than assets, or if foreign lenders constrain the currency denomination of liabilities.[48] Finally, foreign exchange transactions costs, at least among the major currencies, may be fairly low anyway.

In such circumstances, it may be more feasible and, possibly, less costly to optimise reserves on the assets side than on the liabilities side. Even in this case, however, the central bank may well take known foreign exchange liabilities into account in determining the optimal composition of reserves – an aspect that has hitherto been neglected in the mean-variance literature.

Whether the currency composition of foreign exchange reserves is

[48] Dooley (1987) notes, for example, that the IMF, the World Bank and national entities usually do not give borrowers any choice in the currency denomination of loans.

more readily explained by transactions considerations than by mean-variance optimisation is essentially an empirical issue. In order to shed some light on the question, Dooley (1987) examined data on the currency composition of foreign exchange reserves and foreign currency debt of ninety-three developing countries, as well as various sub-groups.[49]

Dooley drew two "tentative" conclusions from his examination. One was that changes in the currency composition of net assets at an aggregated level gave a misleading impression of shifting portfolio preferences. At a disaggregated level, the composition of net assets was much more stable, but varied considerably from one group to the next. Changes in composition at the aggregated level, therefore, mainly reflected weight shifts between groups of countries with quite different, but relatively stable, net liability positions in different currencies. This observation underscores the argument that the mean-variance approach is most validly applied at the individual country level; applied to groups of countries[50] it may produce entirely spurious results.

A second conclusion was that the currency composition of gross reserve assets did not appear to be consistent with mean-variance portfolio optimisation. The first point in this respect is that, at both aggregated and disaggregated levels, there was a very limited correspondence between the currency compositions of gross and net asset positions. This implies that if the composition of either gross or net assets was roughly optimal, the composition of the other was far from optimal. On balance, Dooley seems to suggest that the global diversification of assets away from the US dollar, particularly towards the Deutsche Mark and yen, after the collapse of the Bretton Woods system is more consistent with the evolution of net asset positions than of gross reserve positions. In other words, to the extent that portfolio optimisation occurred at all, it may have been as much on the liabilities side as on the assets side.

Dooley's second piece of evidence to suggest that the composition of reserves was significantly influenced by transactions considerations is that the share of the dollar in gross reserves, at aggregated and disaggregated levels, appears largely to reflect exchange rate movements. To suppose that portfolio preferences moved so closely in line with

[49] Comprising major oil exporters, middle-income oil importers, low-income countries, manufacturing exporters and net oil exporters.

[50] See e.g. Horii (1986) and Dellas (1989).

exchange rate movements seems implausible.[51] A more plausible explanation is that revaluation effects on reserve composition were accepted "passively" simply because they would be quite consistent with the effects of exchange rate movements on transactions needs.

Dooley's reasoning suggests a relatively straightforward means of gauging, at least roughly, the relative weight central banks place on transactions considerations as against portfolio optimisation in determining the currency composition of reserves. On the one hand, if currency shares in reserves are much more stable at prevailing exchange rates than at constant exchange rates, this suggests that the central bank focuses mainly on portfolio considerations. On the other hand, if currency shares are much more stable at constant exchange rates, this suggests that the main focus is on transactions considerations. Of course, whether shares are calculated at current or at constant exchange rates, there is bound to be some instability, partly due to actual use of reserves (for transactions or intervention purposes) and partly due to shifts in portfolio preferences or transactions needs. Nonetheless, a ratio of the variability of reserves at constant and at current exchange rates should still give a broad indication of reserve management priorities.

Table 8 shows calculations of the variability of the currency composition of reserves, at current and at constant exchange rates over the period 1975–92. As discussed earlier, these calculations are intended to give a rough indication of the relative weight attached to transactions considerations and portfolio optimisation considerations in the determination of the currency composition of reserves.

Two alternative measures of the variability and relative variability of currency shares are used: the standard deviations of currency shares and the coefficients of deviation (i.e. the standard deviation as a percentage of the average share). Both alternatives give fairly similar results, but it may be more helpful to focus on the coefficient of deviation figures, since these facilitate comparisons across currencies and also adjust for the fact that average currency shares differ according to whether they are calculated at current or at constant exchange rates.

[51] Dooley allows that reversed causality could be consistent with this pattern. That is, a portfolio shift towards the US dollar would raise its exchange rate. However, although this would be a reasonable view at the global level (including private investors), it seems improbable that each developing country sub-group would have a shift in portfolio preferences that so closely coincided with the global shift.

Table 8

Variability of reserve composition at current and constant exchange rates, 1975–92

	Standard deviation of currency shares			Coefficients of deviation[1] of currency shares			Average 1975–1992 currency shares (in %)	
	At current exchange rates (A)	At end-1992 exchange rates (B)	B as a % of A	At current exchange rates (C)	At end-1992 exchange rates (D)	D as a % of C	At current exchange rates	At end-1992 exchange rates
All countries								
US$	6.9	6.3	91.1	10.0	9.7	96.8	69.1	65.1
¥	2.7	2.4	90.8	47.5	33.0	69.5	5.6	7.4
DM	3.1	3.0	96.2	23.7	19.6	82.6	13.2	15.4
£	0.8	0.8	102.3	28.3	34.8	122.7	2.7	2.2
Fr.fr.	0.7	0.7	95.4	50.2	50.1	99.8	1.4	1.3
Fl.	0.2	0.2	98.7	18.9	16.2	85.7	1.0	1.1
Sw.fr.	0.5	0.7	160.2	21.8	29.7	136.5	2.1	2.5
Unspecified/other	1.4	1.4	100.0	28.3	27.5	97.1	4.9	5.1
Average[2]	4.4	4.1	93.9	14.5	13.6	93.4		
Industrial countries								
US$	11.3	10.8	96.1	15.3	15.6	101.5	73.4	69.5
¥	3.2	3.2	100.8	57.3	44.8	78.1	5.5	7.1
DM	5.6	5.9	104.7	40.3	36.4	90.4	13.9	16.2
£	0.5	0.6	102.0	44.3	53.0	119.6	1.2	1.0
Fr.fr.	1.3	1.2	97.9	140.5	144.0	102.5	0.9	0.9
Fl.	0.3	0.3	91.3	40.4	32.5	80.5	0.8	0.9
Sw.fr.	0.4	0.5	125.8	30.1	32.5	108.0	1.4	1.6
Unspecified/other	2.3	2.1	94.2	78.6	75.0	95.3	2.9	2.8
Average[2]	7.7	7.5	98.1	21.7	21.2	97.7		

Table 8 (continued)

Variability of reserve composition at current and constant exchange rates, 1975–92

	Standard deviation of currency shares			Coefficients of deviation[1] of currency shares			Average 1975–1992 currency shares (in %)	
	At current exchange rates (A)	At end-1992 exchange rates (B)	B as a % of A	At current exchange rates (C)	At end-1992 exchange rates (D)	D as a % of C	At current exchange rates	At end-1992 exchange rates
Developing countries								
US$	3.6	3.8	106.3	5.6	6.3	113.4	64.1	60.1
¥	2.3	1.8	80.5	39.9	24.3	60.9	5.7	7.6
DM	1.8	2.2	124.3	15.0	15.9	105.9	11.8	13.9
£	1.3	1.3	95.2	28.6	33.0	115.3	4.6	3.8
Fr.fr.	0.3	0.2	76.7	15.0	12.0	80.2	2.0	1.9
Fl.	0.3	0.4	124.6	28.3	30.4	107.2	1.1	1.3
Sw.fr.	0.7	1.1	148.7	24.0	30.6	127.7	3.0	3.5
Unspecified/other	2.1	2.3	107.1	27.8	28.5	102.4	7.6	7.9
Average[2]	2.5	2.7	106.8	9.9	10.5	106.0		

[1] Standard deviation of currency shares as a percentage of average share. [2] Geometric average using shares in the last column as weights.

Source: IMF *Annual Reports;* data for 1992 are partly estimated.

Two features of Table 8 may be highlighted:

(i) As suggested by Figures 6–8, the variability of currency shares was, on average, more than twice as great in industrial country reserves than in developing country reserves. Moreover, despite considerable differences in the relative variability of currency shares within each group of countries, the shares of every currency except the Swiss franc were more variable (relative to average shares) in the industrial country group than in the developing country group.

(ii) On average, however, the variability of currency shares at current exchange rates was about the same as at constant exchange rates for both groups of countries, as indicated by the ratio of variability in column 6. These results suggest two tentative conclusions: the first is that both transactions considerations and portfolio optimisation considerations received fairly similar weight in decisions regarding the composition of reserves. As is illustrated with an example in Table B1 in Appendix B, had transactions considerations dominated reserve management, the variability of reserves at constant exchange rates would have been much lower than at current exchange rates, resulting in ratios of well below 100 in column 6 of Table 8. Had portfolio optimising considerations dominated, the ratios in column 6 would tend to have been well above 100.

The second conclusion is that neither group of countries tended, on average, to be clearly more transactions or portfolio-oriented in reserve management than the other. This contrasts with the conclusion of Ben-Bassat (1980) that, at least around the middle of the 1970s, developing countries appeared to place greater emphasis on portfolio considerations than industrial countries. It also contrasts with the opposite assessment of Dellas (1989) for the period 1977–84.

While the above analysis suggests that transactions considerations do not necessarily dominate decisions regarding the currency composition of reserves, they may nonetheless explain the composition of reserves at least as well as the portfolio models examined earlier.

Dooley, Lizondo and Mathieson (1989), hereafter referred to as DLM, estimate a transactions-based model of the currency composition of reserves for a group of 58 countries over the period 1976–85. In essence, the analysis is an updating and refinement of the study by Heller

and Knight (1978). To the extent that transactions considerations are important, DLM argue that the proportion of reserves held in a particular currency should tend to increase with the proportion of the country's external transactions in that currency. In the absence of good data on the currency composition of current account transactions of most countries, DLM use bilateral trade shares as a proxy for the currency composition of trade, while using the currency denomination of external debt (available only for the developing countries in the study) as a proxy for the currency composition of services transactions. In addition, and like Heller and Knight (1978), DLM presume that the choice of exchange rate regime will influence the composition of reserves. For example, a country pegging its currency to, say, the French franc may be expected to have a larger share of francs in its reserves than would be indicated by its trade with France, simply because its exchange market intervention may take place mainly in francs.

Apart from including information on the currency composition of debt service payments as an additional variable, the most important improvement in the DLM analysis over the Heller and Knight study is in the estimation technique. DLM note that currency shares in gross reserves are bounded; that is, they cannot be less than zero or greater than 100 per cent. Econometrically, this is recognised by using a symmetrically-censored least squares (SCLS) technique as an alternative to the traditional ordinary least squares (OLS) technique.

The principal results of DLM's analysis may be summarised as follows:

(i) For both industrial and developing countries, the nature of exchange rate arrangements, as well as the relative importance of transactions (including debt service payments in the case of developing countries) with the various major reserve currency issuers, exert a significant influence on the currency composition of reserves.

(ii) Transactions considerations appear to vary in importance from one currency to the next. The share of reserves in French francs, for example, is well explained by trade patterns and exchange rate arrangements, but shares of other currencies, such as the Deutsche Mark and pound sterling, are much less well-explained, especially in the case of industrial countries.

(iii) Among industrial countries, flexible exchange rate arrangements or

membership in the ERM or the "snake" tended to boost the US dollar share of reserves.

(iv) The results using the SCLS technique suggest that the composition of trade and debt service flows are more important for the composition of reserves than is implied by OLS estimates.

An intervention-oriented approach

In contrast with the mean-variance optimisation and transactions approaches, the approach discussed below focuses on the implications for reserve composition of the *timing* of reserve use, whether in pursuit of balance-of-payments or exchange rate objectives.

The basic idea is essentially similar to that underlying the consumption-based capital asset pricing model (CCAPM).[52] In that model it is posited that investors will tend to draw on their portfolios at times when their income is low in order to smooth their consumption path. It follows that a portfolio which has a fairly high variance, but that is high in value when income is low and low in value when income is high (i.e. negatively correlated with income), may be preferable to the ideal mean-variance portfolio, which is fairly stable in value at all times.

Adapting this approach to reserve management would lead a country holding reserves for the purpose of current account financing to favour reserve assets which tend to be high in value vis-à-vis a basket of imports when its current account position is weakest and lowest in value when its current account position is strongest.

Alternatively, if reserves are mainly used to dampen movements of the exchange rate against some reference currency[53] or currency basket, reserves would be held in currencies that tend to be strongest vis-à-vis the reference currency (or currency basket) when the home currency depreciates and vice versa. In other words, reserves would be held in such a way that positive revaluation effects in terms of the reference currency would be maximised precisely when reserves are most likely to be used, and reserves would be acquired when they were relatively cheap in terms of the reference currency. As shown in Appendix

[52] See e.g. Breeden (1979) or Stulz (1985). I am grateful to John Murray for pointing out this similarity.

[53] The reference currency may or may not serve as a "target": even countries with floating exchange rates may intervene to smooth a particular exchange rate without having any target level in mind.

B, however, the potential gains from this approach depend importantly on temporary violations of the uncovered interest parity condition.

An implication of this "intervention"[54] approach is that the set of efficient portfolios is not comprised of those which have the lowest variance for any given mean return, but instead comprised of those which have strongly negative correlations and covariances with the use of reserves, whether in defence of the exchange rate or in financing of the current account.[55]

The "intervention" approach, of course, suffers from many of the same problems as the mean-variance approach, since its potential usefulness also depends on the ability of the authorities to forecast the means, variances and covariances of returns in different currencies. It also requires a clear idea of the circumstances in which reserves are likely to be used.

An important issue in this context concerns the appropriate reference currency (or currency basket). For a number of countries this may not be entirely straightforward. For example, although Belgium may formally target its bilateral exchange rate vis-à-vis the Deutsche Mark, much of its intervention in practice may be triggered by movements of the Belgian franc vis-à-vis the ECU currency basket, reflecting Belgium's ERM obligations. Alternatively, even if a country seeks, in general, to smooth movements in its effective exchange rate, it may nonetheless intervene mainly with respect to movements in a particular bilateral rate.[56]

A second issue concerns the character of the intervention response to exchange rate movements. Some countries, for example, may intervene in proportion, say, to the deviation of their exchange rate from some target level, while others may intervene only with respect to rapid or "disorderly" rates of change in the exchange rate. The point here is that the pattern of correlations and covariances will vary somewhat according to the particular form of a country's intervention "rules".

[54] The term "intervention" is used partly for convenience, but also because the approach focuses squarely on the issue of *when* reserves are actually used or acquired.

[55] If optimisation were on the liabilities rather than on the assets side, high *positive* correlations and covariances would be sought. Unless liabilities have extremely short maturities, however, the gains from the "intervention" approach will be much greater when applied to the assets side.

[56] Following the optimal intervention literature, this might be appropriate if the typical type of disturbance underlying bilateral exchange rate movements varied from one country to another, calling for different intervention responses to different sources of movement in the effective exchange rate.

Table 9

Correlations and covariances between monthly average exchange rate movements and levels in relation to the US dollar, 1988–92

Squared % *change* in exchange rate versus US$[1]	Correlation with *level* of exchange rate in relation to US$ (non-negative values omitted)						Covariance (× 100) with *level* of exchange rate in relation to US$				Standard deviation of % changes versus US$	Stability against DM relative to US$[2]
	DM	Fl.	Fr.fr.	Sw.fr.	£	¥	DM	¥	Other			
DM						–0.07	10.9	– 6.4			2.97	100.0
Fl.						–0.07	11.3	– 6.4			2.97	97.6
Fr.fr.						–0.07	10.6	– 6.2			2.88	92.1
Sw.fr.						–0.13	19.5	–14.3			3.29	79.1
£	–0.09	–0.09	–0.08	–0.03		–0.22	–15.3	–28.9			3.37	66.8
¥							25.2	14.6			2.61	51.1
NZ$							13.5	1.9			1.92	36.2
A$	–0.05	–0.05	–0.05				– 2.8	1.8	Fr.fr.	–2.9	1.99	33.9
S$						–0.001	1.0	– 0.01			1.03	26.5
NT$	–0.20	–0.20	–0.21	–0.23	–0.03		– 4.9	2.8	Sw.fr.	–5.4	1.10	21.2
C$	–0.31	–0.31	–0.30	–0.14		–0.17	– 4.4	– 1.9			1.04	20.8
Won	–0.12	–0.11	–0.12				– 1.3	3.4	Fr.fr.	–1.4	0.84	16.3
Baht							0.6	0.2			0.50	12.0
HK$	–0.10	–0.10	–0.10	–0.13	–0.14	–0.14	– 0.04	– 0.04	Sw.fr.	–0.05	0.13	2.8

[1] Preserving the sign of changes. [2] Values range from 100 for the DM to 0 for the US$ and are calculated as θ/0.9 where *tan* θ is the ratio of standard deviations of percentage changes in the exchange rate against the US$ and DM, respectively.

Sources: BIS and author's calculations.

Bearing such qualifications in mind, it is nonetheless interesting to consider how the composition of various countries' reserves might look if they followed an "intervention" approach.[57] Table 9 shows correlations and covariances between monthly movements[58] and levels of various exchange rates in relation to the US dollar over the period 1988–92. Included in the table are a number of non-European currencies for which the US dollar exchange rate may, in practice, serve as the principal reference currency for intervention purposes, as well as the major non-dollar reserve currencies.

A few features of Table 9 may be noted. The first is that for Japan, in particular, there appears to be no attractive alternative (in terms of correlations, if not in mean yield terms) to holding US dollar reserves: when the yen is depreciating (appreciating) against the dollar, the other major reserve currencies tend to be weak (strong) against the dollar. By holding US dollar reserves, therefore, Japan would minimise adverse reserve revaluation effects in terms of the US dollar. Second, and in contrast, there could be a potential gain[59] to Germany (as well as to the other major European countries) from holding Japanese yen for intervention purposes vis-à-vis its own exchange rate versus the dollar.[60]

Third, among the non-European countries the general pattern of correlations suggests that the gains, if any, of diversification away from US dollar reserves tend to favour the holding of ERM "core" currencies, rather than sterling or yen.

Table 10, showing correlations and covariances of exchange rate movements vis-à-vis the Deutsche Mark over the period 1988–92 shows a broadly similar, dichotomous pattern to that of Table 9. That is, those currencies which are most stable against the Deutsche Mark (rela-

[57] Since this is an illustrative exercise, interest rate differentials between currencies are ignored. In a fuller elaboration of the approach, of course, it would be necessary to take these into account.

[58] Correlations and covariances are shown for the squares of percentage movements in US dollar exchange rates. Implicitly, this assumes that countries intervene mainly to dampen exceptionally rapid or pronounced movements in their exchange rates. It may be noted, however, that the general pattern of correlations is very much the same using the simple percentage changes in exchange rates.

[59] The magnitude of expected gains, measured by the covariance, would be relatively large, reflecting the relatively high variances of both the Deutsche Mark and the yen against the dollar. However, the small size of the correlation coefficient suggests that the sign of coefficient could easily be positive – and gains turned to losses – for a slightly different sample period.

[60] i.e. if the Deutsche Mark were strengthening sharply against the dollar, Germany would purchase yen which, more often than not, would be relatively weak against the dollar.

Table 10

Correlations and covariances between monthly average exchange rate movements and levels in relation to the Deutsche Mark, 1988–92

Squared % *change* in exchange rate versus DM[1]	Correlation with *level* of exchange rate in relation to DM (non-negative values omitted)						Covariance (×100) with *level* of exchange rate in relation to DM			Standard deviation of % changes versus DM	Stability against DM relative to US$[2]
	Fl.	Fr.fr.	Sw.fr.	£	¥	US$	US$	¥	Other		
Sch.						–0.03	–0.006	–0.0002		0.11	97.7
Fl.		–0.16	–0.12	–0.19	–0.15	–0.15	–0.03	–0.03	£ –0.03	0.11	97.6
B.fr.			–0.003	–0.12	–0.23	–0.002	–0.002	–0.2	£ –0.1	0.22	95.4
IR£					–0.01		0.1	–0.01		0.25	94.4
D.kr.			–0.03	–0.06	–0.10	–0.03	–0.1	–0.2	£ –0.1	0.35	92.4
Fr.fr.							0.3	0.1		0.36	92.1
Sw.fr.				–0.07	–0.25	–0.06	–1.1	–5.0		1.12	79.1
Esc.							1.2	1.1		0.95	79.0
N.kr.							2.0	1.8		0.97	78.2
Pts.	–0.04						13.0	6.1	Fl. –0.04	1.33	74.4
Lit.	–0.02						26.0	8.1	Fl. –0.04	1.54	70.7
S.kr.	–0.08				–0.002		13.7	–0.2	Fl. –0.16	1.64	67.4
£							15.6	3.6		1.93	66.8
F.mk.	–0.07						36.9	16.8	Fl. –0.2	1.86	64.5
¥				–0.02		–0.11	–9.6	7.7	£ –1.2	2.52	51.1
US$		–0.01		–0.04			9.7	16.6	£ –3.8	3.01	0

[1] Preserving the sign of changes. [2] See Table 9, footnote 2.

Sources: BIS and author's calculations.

tive to the dollar) would tend to benefit most from reserve revaluation effects vis-à-vis the Deutsche Mark by holding yen, US dollars and, in some cases, pounds sterling. In contrast, the countries with currencies showing less stability against the Deutsche Mark would, generally, benefit most by holding currencies most like the Deutsche Mark including, of course, the Deutsche Mark itself.

It can also be noted that the pound sterling is somewhat unusual insofar as it would appear to be an attractive reserve currency (for intervention vis-à-vis the Deutsche Mark exchange rate) both for some of the countries with the most "Deutsche Mark-like" currencies and for those with the least "Deutsche Mark-like" currencies – the United States and Japan. In the Japanese case, however, the US dollar would offer the greater gains, whether intervening with respect to the yen's exchange rate against the Deutsche Mark or, as seen in Table 9, against the dollar.

For several of the countries represented in Table 10, although their bilateral exchange rates versus the Deutsche Mark may be the formal or informal target of exchange rate policy, a considerable proportion of their exchange market intervention in practice may be triggered by movements of their currencies vis-à-vis the ECU basket of currencies. For this reason, Table 11 shows correlations and covariances of European currency movements with respect to the ECU.

Some differences between Tables 10 and 11 may be highlighted. First, against the ECU reference basket, the distinction between the more "Deutsche Mark-like" and less "Deutsche Mark-like" currencies is brought into sharper focus. Second, negative correlations between currency movements and levels are generally much stronger vis-à-vis the ECU reference basket than vis-à-vis the Deutsche Mark. Third, for the countries with more "Deutsche Mark-like" currencies, the Japanese yen is much less attractive, while sterling and the dollar are much more attractive as reserve assets for intervention within the ERM than for intervention vis-à-vis bilateral exchange rates against the Deutsche Mark. Fourth, for the less "Deutsche Mark-like" currencies, the French franc and Dutch guilder are relatively more attractive as reserve assets for intervention within the ERM than vis-à-vis the Deutsche Mark.

In addition, Table 11 also draws attention to an issue of potential importance in the "intervention" approach. In contrast with the mean-variance approach, where the basic trade-off to be made is between the

Table 11

Correlations and covariances between monthly average exchange rate movements and levels in relation to the ECU, 1988–92

Squared % *change* in exchange rate versus ECU*	Correlation with *level* of exchange rate in relation to ECU (non-negative values omitted)							Covariance (×100) with *level* of exchange rate in relation to ECU				Standard deviation of % changes versus ECU
	DM	Fl.	Fr.fr.	Sw.fr.	£	¥	US$	US$	DM	Other		
DM					–0.41		–0.19	–1.0	0.5	£	–1.4	0.44
Sch.					–0.39		–0.18	–1.3	0.6	£	–1.7	0.48
Fl.					–0.41		–0.20	–1.1	0.5	£	–1.4	0.44
B.fr.					–0.43	–0.01	–0.18	–0.9	0.5	£	–1.4	0.42
IR£					–0.42		–0.17	–0.6	0.3	£	–1.0	0.36
D.kr.					–0.43	–0.03	–0.19	–1.2	0.5	£	–1.7	0.51
Fr.fr.					–0.38		–0.17	–1.1	0.5	£	–1.5	0.45
Sw.fr.					–0.19	–0.24	–0.11	–2.3	0.4	¥	–5.0	1.16
Esc.	–0.01	–0.003		–0.12			–0.02	–0.2	–0.03	Sw.fr.	–0.4	0.78
N.kr.	–0.50	–0.43	–0.47				–0.02	–0.3	–1.1			0.77
Pts.	–0.47	–0.47	–0.47	–0.03				5.0	–1.6	Fr.fr.	–1.7	1.01
Lit.	–0.56	–0.56	–0.50	–0.11				11.7	–4.8	Fl.	–4.8	1.22
S.kr.	–0.56	–0.56	–0.48	–0.03		–0.10		3.4	–8.9	¥	–9.6	1.50
£	–0.48	–0.46	–0.43			–0.04		3.7	–4.2			1.56
F.mk.	–0.28	–0.28	–0.20					24.6	–4.4	Fl.	–4.6	1.64

* Preserving the sign of changes.

Source: BIS.

stability and the expected returns on the reserve portfolio, under the "intervention" approach there may be two dimensions in which to make a trade-off. The first is the trade-off between the (expected) average return and the timing of those returns. The second may be between the *magnitude* and *precision* of portfolio revaluation effects.

To illustrate this latter trade-off, consider the correlations and covariances of movements in the Swedish krona with the Deutsche Mark and yen vis-à-vis the ECU, shown in Table 11. In this case, the correlations indicate that the Deutsche Mark tends much more reliably than the yen to be strong against the ECU when the Swedish krona is depreciating sharply against the ECU. However, because the Deutsche Mark is much more stable against the ECU than is the yen, the covariance of the krona's movements with the level of the yen in relation to the ECU is larger than the covariance with the Deutsche Mark against the ECU. As a result, reserves held in yen would, on average, experience larger revaluation gains in terms of the ECU than reserves held in Deutsche Mark, but the timing of those gains would be much less closely synchronised with the krona's movements against the ECU. From this perspective it might be anticipated that relatively risk-averse central banks following the "intervention" approach would focus primarily on the strength of correlations while more risk-tolerant, profit-maximising central banks would place more emphasis on the magnitudes of covariances.

Finally, Table 12 displays correlations and covariances of currency movements and levels with respect to the trade-weighted exchange rates of several countries currently maintaining floating exchange rate regimes. For the European currencies, it can be noted that the pattern of correlations is essentially similar to that found in Table 11, with the Deutsche Mark and Dutch guilder remaining the most attractive reserve currencies from an intervention perspective. Nonetheless, it may also be noted that in most cases, whereas correlations with the more "Deutsche Mark-like" currencies are weaker vis-à-vis effective exchange rates than vis-à-vis the ECU basket, correlations with the yen are stronger.[61]

[61] In the cases of Sweden and Britain, this results in covariances with the yen at least as great as with the Deutsche Mark vis-à-vis their respective trade-weighted exchange rates, despite much higher correlations with the Deutsche Mark. As discussed earlier, there would still be a presumption in favour of holding Deutsche Mark reserves in these cases.

Table 12

Correlations and covariances between monthly average exchange rate movements and levels in relation to trade-weighted exchange rate indexes (TWIs), 1988–92

Squared % *change* in exchange rate versus TWIs[1,2]	Correlation with *level* of exchange rate in relation to TWIs (non-negative correlations omitted)							Covariance (×100) with *level* of exchange rate in relation to TWIs			Stability against DM relative to US$[3]
	DM	Fl.	Fr.fr.	Sw.fr.	£	¥	US$	US$	DM	Other	
Sw.fr.					–0.08	–0.31	–0.10	–2.1	1.1	¥ – 6.6	79.1
N.kr.	–0.22	–0.20	–0.20	–0.08		–0.08	–0.17	–0.8	– 0.5		78.2
Lit.	–0.39	–0.39	–0.34	–0.07				17.2	– 6.2	Fl. – 6.3	70.7
S.kr.	–0.36	–0.36	–0.32	–0.15		–0.20	–0.02	–1.2	–14.4	¥ –16.9	67.4
£	–0.23	–0.22	–0.20	–0.02		–0.10		7.6	– 6.4	¥ – 6.4	66.8
F.mk.	–0.29	–0.29	–0.25	–0.15				17.6	– 9.6	Fl. – 9.7	64.5
¥							–0.38	–8.1	15.3		51.1
NZ$						–0.0004		0.3	1.1	A$ – 0.6	36.2
A$	–0.25	–0.24	–0.25	–0.12	–0.13	–0.11		0.5	– 3.6	Fr.fr. – 3.6	33.9
C$	–0.35	–0.35	–0.34	–0.18	–0.04	–0.14		0.3	– 2.7		20.8
US$					–0.16			6.1	1.8	£ – 6.7	0

[1] Preserving the sign of changes. [2] Switzerland: Swiss National Bank 15-country index; Norway: BIS 21-country index; Italy: Bank of Italy 15-country index; Sweden: BIS 21-country index; United Kingdom: Bank of England 17-country index; Finland: BIS 21-country index; Japan: BIS 21-country index; New Zealand: 5-country index using weights from *Reserve Bank of New Zealand* (1992); Australia: 23-country index using weights from *Reserve Bank of Australia* (1992); Canada: 10-country index using weights from *Bank of Canada* (1988); United States: Federal Reserve Board 10-country index. [3] See Table 9, footnote 2.

Sources: National authorities, BIS and author's calculations.

Among the non-European countries, the pattern of correlations tends to be stronger, but qualitatively similar to the pattern of correlations in Table 9. In the cases of Japan, Australia and Canada, the central banks would appear to gain the largest benefits in terms of revaluation effects by continuing to hold US dollars, French francs and Deutsche Marks, respectively, while New Zealand would have little, if anything, to gain by diversifying away from US dollars (except, perhaps, into Australian dollars).

Before moving on to consider various constraints on reserve portfolio choices, three final points should be made regarding potential implications of the "intervention" approach outlined above.

The first is that the scope for exploiting the potential benefits of the "intervention" approach are limited in the same way as the mean-variance approach, by liquidity considerations and transactions costs. For example, in several cases in the tables, it appears that the French franc or Dutch guilder would be more attractive reserve assets than the Deutsche Mark in terms of their potential for generating beneficial revaluation effects. The higher transactions costs and more limited liquidity in markets for these currencies, however, might well outweigh the fairly marginal potential benefit of holding reserves in these currencies rather than in Deutsche Mark.[62]

Second, the "intervention" approach, in particular, indicates that the issues of reserve composition and reserve levels are not completely separable. Compared with following a mean-variance or transactions approach, following an "intervention" approach would tend to allow for some reduction in a country's *average* level of reserves, precisely because their value would tend to be higher than under the alternative approaches when reserves are most needed.

Third, the "intervention" approach would have different, possibly more desirable, implications for the international monetary system generally than would the transactions or mean-variance approaches. Broadly speaking, the transactions and mean-variance approaches would tend to lead countries to hold reserves in the currencies of countries with which they trade a great deal or against which their own currencies

[62] Nonetheless, the existence of such potential benefits would provide an incentive for the development of markets for liquid instruments in these currencies and increased diversification of reserve assets towards such currencies.

Table 13

Correlations between average monthly movements in selected exchange rates, 1988–92

Correlations between % changes		Correlations between squared % changes[1]												
		US$/ DM	US$/ ¥	Can. TWI[2]	Aus. TWI[2]	ECU/ DM	ECU/ Fl.	ECU/ B.fr.	ECU/ Fr.fr.	ECU/ Pts.	ECU/ Lit.	ECU/ S.kr.	ECU/ $	DM/ Sw.fr.
	US$/DM		0.42	–0.17	–0.25	0.05	0.03	0.01	–0.04	–0.04	–0.03	0.002	–0.03	0.03
	US$/¥	0.60		–0.33	–0.31	0.03	0.05	0.01	0.02	–0.09	–0.07	–0.01	0.05	0.05
	Can. TWI[2]	–0.26	–0.30		0.34	–0.28	–0.33	–0.27	–0.22	0.40	0.33	0.04	0.20	–0.14
	Aus. TWI[2]	–0.38	–0.39	0.42		–0.03	–0.03	–0.01	0.001	0.10	–0.01	0.01	0.04	0.04
	ECU/DM	0.21	0.10	–0.29	–0.21		0.99	0.98	0.96	–0.73	–0.93	–0.02	–0.94	–0.05
	ECU/Fl.	0.19	0.12	–0.33	–0.24	0.97		0.98	0.94	–0.77	–0.94	–0.01	–0.93	–0.002
	ECU/B.fr.	0.17	0.06	–0.28	–0.14	0.88	0.92		0.97	–0.73	–0.93	–0.01	–0.95	0.02
	ECU/Fr.fr.	–0.06	0.02	–0.22	–0.07	0.68	0.69	0.75		–0.69	–0.90	0.06	–0.93	–0.03
	ECU/Pts.	–0.05	–0.09	0.36	0.23	–0.66	–0.69	–0.60	–0.59		0.72	–0.02	0.69	–0.13
	ECU/Lit.	–0.14	–0.28	0.34	0.01	–0.70	–0.69	–0.66	–0.51	0.49		0.22	0.81	–0.03
	ECU/S.kr.	–0.27	–0.14	0.24	0.16	–0.20	–0.18	–0.16	0.11	0.03	0.25		–0.07	0.03
	ECU/£	–0.07	0.11	0.18	0.22	–0.84	–0.85	–0.84	–0.78	0.63	0.35	–0.03		0.0004
	DM/Sw.fr.	0.11	0.16	–0.12	0.02	–0.11	–0.06	0.10	–0.03	–0.13	–0.06	0.03	0.09	

[1] Preserving the sign of percentage change. [2] Canadian and Australian trade-weighted exchange rates as defined in Table 12, footnote 2.

Source: BIS.

are relatively stable. Canada, Australia and New Zealand, for example, would hold a high proportion of reserves in US dollars while most European countries would tend to hold Deutsche Mark and dollars. Unfortunately, this can give rise to counter-productive or destabilising intervention.

As an illustration, consider the intervention responses to a weakening of the US dollar against the Deutsche Mark. As can be seen in Table 13, this movement would typically be accompanied by a strengthening of the yen against the dollar, and a weakening of the Australian and Canadian dollars in effective terms. Within Europe the more "Deutsche Mark-like" currencies would tend to strengthen against the ECU (and the Swiss franc rise against the Deutsche Mark), while less "Deutsche Mark-like" currencies would typically weaken against the ECU.

In such circumstances, uncoordinated intervention responses could quite conceivably involve net sales of US dollars by Australia and Canada (in defence of their effective exchange rates) as well as by some European countries with currencies weakening against the Deutsche Mark or ECU, thereby accentuating the initial pressure on the US dollar or, at least, offsetting some of the effects of G-3 intervention to support the dollar. Concerted or coordinated intervention among central banks offers one means of avoiding or, at least, minimising the potential for this sort of problem, but coordination may be insufficiently comprehensive or consistent to succeed at all times.

In contrast, reserve holdings following the patterns suggested by the "intervention" approach would lead, in this example, to sales of the more "Deutsche Mark-like" currencies by Canada, Australia and most European countries with weakening currencies, while the countries with strengthening, more "Deutsche Mark-like" currencies would tend to be selling their own currencies against US dollars and sterling. Such intervention would thus tend to reinforce G-3 action to support the US dollar, as well as ease associated ERM tensions, thereby reducing the need for coordination of intervention by central banks.

Constraints on the composition of reserves

The discussion of the appropriate currency composition of reserves noted the existence of a number of factors which in practice constrain the portfolio management options available to central banks. The most important factors appear to be: (i) non-negligible foreign exchange

transactions costs; (ii) liquidity and credit risk constraints; (iii) constraints on the speed of portfolio adjustment; and (iv) decentralised decision-making. These are discussed in somewhat greater detail below:

(i) *Non-negligible foreign exchange transactions costs.* The theoretical models of optimal portfolio analysis largely abstract from the existence of foreign exchange transactions costs. If transactions costs are very high, however, the range of currencies over which diversification is worthwhile will be greatly reduced. In general, the currencies most likely to be eliminated from portfolios are those for which markets are fairly small, resulting in fairly large bid-ask spreads, especially if they are close substitutes (in terms of their statistical properties) for one of the major international currencies.[63] In practice, most empirical models of portfolio selection do implicitly, if somewhat crudely, recognise this sort of constraint by including only a half dozen or so major currencies in the potential portfolio.

(ii) *Liquidity and credit risk constraints.* Even a portfolio composed of only a handful of major currencies may be significantly constrained by the lack of availability of the appropriate kinds of financial instrument in some of the currencies. Indeed, this may be the main reason why virtually all mean-variance analyses of optimal reserve portfolios find the actual proportion of US dollar holdings to be well above that suggested by efficiency considerations alone.

As noted as the outset, central banks generally require a very high degree of liquidity in reserves held for the purposes of exchange market intervention.[64] In practice, such requirements may be readily accommodated only in a very few currencies, most notably the US dollar. In an unusually candid discussion of reserve management, Nicholl and Brady (1992) indicate that liquidity and credit risk constraints are important even for central banks managing quite small portfolios. For central banks managing large portfolios, and especially for the central banks of major reserve currency issuers –

[63] Murray and DeSerres (1991) note, for example, that the close degree of substitutability between the Swiss franc and Deutsche Mark reduces the attractiveness of the Swiss franc for a Canadian reserve portfolio.

[64] For countries holding a portion of reserves as a long-term investment, the liquidity of such investments may not be of paramount importance but, by the same token, the long-term creditworthiness of the entities to which funds are lent (or in which direct investments are placed) may become quite important.

which cannot hold their own currency as foreign exchange reserves – the constraints will tend to be even more binding.[65] In New Zealand's case, Nicholl and Brady indicate that the diversification of reserves from US dollars into yen, which has taken place since about 1985, has tended to be constrained by a shortage of very short-term, highly secure (preferably sovereign) yen-denominated instruments. A similar sentiment is expressed by Nordman (1991) regarding Finland's reserve management. Nordman notes that the share of US dollars in the Bank of Finland's reserve portfolio has been above that indicated by the minimum variance portfolio, again because of a shortage of highly secure, liquid instruments, but in this case denominated in suitable European currencies.[66]

(iii) *Constraints on the speed of portfolio adjustment.* The actual composition of reserve portfolios may diverge from that of desired portfolios for fairly lengthy periods of time. The most common reason for such divergence is that for most countries the currency composition of intervention (usually just one or two currencies) is quite different from that of reserves, altering the composition of remaining reserves. Restoring the original composition may be spread out over an extended period of time so as to avoid reversing the effects of earlier intervention.

(iv) *Decentralised decision-making.* As discussed earlier, in the context of Dooley's critique of the mean-variance approach to reserve composition, decisions regarding the composition of reserves, particularly net reserves, may not be centralised. Dooley emphasises the separation between decisions on reserve management from those on external borrowing, but decisions may not be centralised even within these two areas. On the liabilities side, the currency

[65] It should be noted, however, that the "intervention" approach suggests that it would be sensible for the Bank of Japan and the Bundesbank to hold a high proportion of dollars in their portfolios, even if they were not constrained to do so for reasons of liquidity or credit risk.

[66] An additional problem, noted by Nicholl and Brady, is that virtually all trading of the New Zealand dollar is against the US dollar. Holding reserves in yen would not necessarily pose a major problem if yen holdings or yen available through lines of credit could be converted quickly into dollars at low cost. Doing so may be constrained, however, for at least a part of each trading day by gaps in the overlap of the New York and Tokyo financial market days with that of New Zealand. Although the New Zealand case may be somewhat exceptional, both in terms of time zone and in terms of the desired diversification into yen instruments, most other reserve holders would be likely to run into analogous problems or constraints in portfolio diversification.

composition of foreign currency borrowing may be widely dispersed among state enterprises and agencies. Even on the assets side, not all foreign exchange assets may be reflected in official reserves. Moreover, even official reserves may be managed in different "tranches", according to liquidity or ostensible purpose (e.g. a short-term asset portfolio, used for intervention, and a long-term investment portfolio).

Decentralised management of foreign currency assets and liabilities seems likely to make it very difficult, as Dooley suggests, to achieve an optimal foreign exchange portfolio except by chance. Even if there is some effort to coordinate decentralised portfolios, or if the central bank at least tries to take the composition of other portfolios into account in managing its own reserve portfolio, time lags in adjustments between different parts of the overall portfolio would interfere with achieving or maintaining a desired or optimal portfolio composition.

V. Concluding comments

This paper has focused on two basic issues in the management of foreign exchange reserves: the appropriate *quantity* and the optimal *currency composition* of reserves. It is evident that a wide range of considerations ought to be taken into account in decision-making in both areas. From a practical perspective, this inevitably makes it difficult to formulate very simple, widely applicable *quantitative* guidelines or "rules of thumb" for reserve management. Nonetheless, some more *qualitative* conclusions can be offered.

With regard to the appropriate *level* of foreign exchange reserves, a commonly used benchmark is the ratio of reserves/imports (reserves equal to three months' coverage of imports is often suggested as a reasonable target). In this paper it is suggested that a more reasonable approach may be to set a benchmark for the level of reserves in terms of some measure of the *variability* of the balance of payments. The most appropriate measure may vary from country to country. For many developing countries, the variability of the current account may be a good indicator of potential reserve needs, while for many industrial

countries the variability of short-term capital flows may be a more relevant indicator.

Important elements of judgement would still be necessary in deciding how far the medium-term "target" level of reserves should lie above or below such a benchmark. A key consideration in this respect would be the feasibility as well as the desirability of employing alternative means of closing or financing balance-of-payments gaps. In this context, developing countries and economies in transition, with limited private sector access to international capital markets and, often, fixed exchange rate regimes, would typically face a much narrower range of options than most industrial countries.

Where many developing countries might need to consider their options more carefully than most industrial countries is with respect to the true *cost of holding reserves*. On the one hand, the comparatively wide spreads between the costs of borrowing abroad and the return on reserve assets faced by most developing countries give them an incentive to cut external debts rather than build up reserves. On the other hand, by reassuring foreign creditors, higher reserve levels may facilitate and lower the cost of external borrowing.

With regard to the *currency composition* of foreign exchange reserves, this paper outlines three alternative approaches. All three may be useful in reaching and evaluating decisions on the composition of reserve assets as well as foreign currency liabilities. Indeed, the empirical evidence suggests that no single approach has been widely predominant at least since the mid-1970s. In part this may reflect the fact that reserves are generally held for a variety of motives – as a store of wealth, as a means of financing current account transactions, and for the purposes of exchange market intervention – and that each motive calls for a somewhat different approach.

From this perspective, an important conclusion which may be drawn from this paper is that a pre-condition for usefully applying these approaches to reserve management decisions is to be able to set out, in a fairly precise way, the amounts of reserves desired according to the different motives, and under the intervention motive in particular. In addition, it may be important to identify the possible thresholds that might trigger intervention (e.g. sudden flow of private capital, breach of exchange rate targets and so on) and the associated discontinuities in the rate at which reserves are likely to be used.

Although the various approaches discussed can play a useful role in narrowing the range of reserve portfolios which ought to be considered, as well as provide fairly objective performance criteria for reserve portfolios, they nonetheless have important limitations. In particular, reserve managers would still be required to make a trade-off between the riskiness and the return associated with different portfolios. They would also have to decide how liquid the portfolio should be. Judgement would thus remain an essential element in choosing actual portfolios.

Appendix A

1. *Data sources and methods for Tables 2–4 and A1–A3*

(i) Original data from IMF, International Financial Statistics:
GDP = annual nominal GDP in home currency = line *99b*
POP = mid-year population = line *99z*
PFX = annual average exchange rate versus US dollar = line *rf*, *rh*, *wf*, *wh*, or in a few cases, line *ae*
CA = current account balance = line *77 ad*
EX = exports of goods and non-factor services = (line *77aad* + line *77 add)*
IM = imports of goods and non-factor services = – (line *77abd* + line *77 aed)*
RES = end-year foreign exchange reserves = line *1dd*

(ii) Annual calculations for year t = 1979 to 1991 or most recent, for each country c = 1 to 60:
Y_{ct} = nominal GDP in US dollars = GDP_{ct}/PFX_{ct}
$YPCAP_{ct}$ = GDP/capita = Y_{ct}/POP_{ct}
$RESY_{ct}$ = foreign exchange reserves/GDP ratio = $100x[RES_{ct}/Y_{ct}]$
XM_{ct} = geometric average of exports and imports = $\sqrt{[EX_{ct} \times IM_{ct}]}$
XMY_{ct} = trade/GDP ratio = $100 x[XM_{ct}/Y_{ct}]$
$RESXM_{ct}$ = reserves/trade ratio = $100 \times [RES_{ct}/XM_{ct}]$
$COVER_{ct}$ = reserves/trade cover ratio = $RESXM_{ct} \times 12/100$
DCA_{ct} = change in current account balance = $CA_{ct} - CA_{ct-1}$
DEX_{ct} = change in exports = $EX_{ct} - EX_{ct-1}$
DIM_{ct} = change in imports = $IM_{ct} - IM_{ct-1}$
$DCAXM_{ct}$ = ratio of current account changes/trade = $100 \times [DCA_{ct}/XM_{ct}]$
$DEXXM_{ct}$ = ratio of export changes/trade = $100 \times [DEX_{ct}/XM_{ct}]$
$DIMXM_{ct}$ = ratio of import changes/trade = $100 \times [DIM_{ct}/XM_{ct}]$

(iii) Country calculations shown in Tables A1–A3, for each country c = 1 to 60:

Table A1

col. 1 = Y_c = geometric average of Y_{ct} over 1979–91 period
col. 2 = $YPCAP_c$ = geometric average of $YPCAP_{ct}$ over 1979–91 period
col. 3 = XM_c = geometric average of XM_{ct} over 1979–91 period
col. 4 = XMY_c = geometric average of XMY_{ct} over 1979–91 period
col. 5 = RES_c = geometric average of RES_{ct} over 1979–91 period
col. 6 = $RESY_c$ = geometric average of $RESY_{ct}$ over 1979–91 period
col. 7 = $RESXM_c$ = geometric average of $RESXM_{ct}$ over 1979–91 period
col. 8 = $COVER_c$ = geometric average of $COVER_{ct}$ over 1979–91 period

Table A2

col. 1 = $SDCA_c$ = standard deviation of DCA_{ct} over 1979–91 period
col. 2 = $SDCAXM_c$ = standard deviation of $DCAXM_{ct}$ over 1979–91 period
col. 3 = $SDEXXM_c$ = standard deviation of $DEXXM_{ct}$ over 1979–91 period
col. 4 = $SDIMXM_c$ = standard deviation of $DIMXM_{ct}$ over 1979–91 period
col. 5 = $CORXM_c$ = correlation coefficient between $DEXXM_{ct}$ and $DIMXM_{ct}$ over 1979–91 period
col. 6 = $RESSDCAXM_c$ = Table A1 col. 7 ($RESXM_c$) divided by col. 2 ($SDCAXM_c$)

Table A3

col. 1 = Table A1 col. 5 (RES_c)

col. 2 = 0.17 times Table A1 col. 3 (XM_c)

col. 3 = Table A1 col. 3 (XM_c) times .0182 times Table A2 col.2 ($SDCAXM_c$)

col. 4 = 100 times col. 1 divided by col. 2

col. 5 = 100 times col. 1 divided by col. 3

col. 6 = Table A1 col. 7 ($RESXM_c$)

col. 7 = 100 times col. 3 divided by Table A1 col. 3 (XM_c)

col. 8 = Table A2 col. 6 ($RESSDCAXM_c$)

col. 9 = 100 times col. 2 divided by Table A1 col. 3 (XM_c) divided by Table A2 col. 2 ($SDCAXM_c$)

(iv) Group calculations shown in Tables 2–4:

High, middle and low-income countries are defined as those with average annual GDP/capita above US$ 8,000, between US$ 8,000 and 2,000 and below US$ 2,000, respectively.

Averages for the high, middle and low-income country groups are calculated as the geometric averages of the figures in Tables A1 to A3, with the exception of Table 4 col. 5.

For Table 4 col. 5, the negative correlation coefficient for China prevents calculation of geometric averages for the low-income and all-country averages. The average figures were thus calculated as the weighted, arithmetic average of the figure for China and the value of the geometric average for all other countries.

Table A1

Foreign exchange reserves, trade and GDP, 1979–91

A. High-income countries*

	Average annual GDP		Average annual trade		Foreign exchange reserves			
	Level (in US$ bn)	Per capita (in US$)	Level (in US$ bn)	As a % of GDP	Average year-end level (in US$ bn)	As a % of GDP	As a % of annual trade	In months of trade cover
Switzerland	135.6	20,860	69.7	51.4	19.4	14.3	27.8	3.3
Norway	69.0	16,590	31.4	45.5	8.9	12.9	28.2	3.4
Sweden	136.1	16,210	48.5	35.6	5.6	4.1	11.6	1.4
Iceland	3.9	16,170	1.5	39.2	0.2	5.8	14.9	1.8
Denmark	78.1	15,240	31.5	40.3	4.5	5.8	14.3	1.7
Canada	376.9	14,940	108.6	28.8	4.2	1.1	3.9	0.5
Finland	67.0	13,740	21.2	30.5	2.8	3.8	13.0	1.6
Australia	193.8	12,240	37.3	19.3	5.9	3.0	15.7	1.9
Netherlands	176.7	12,170	107.4	60.8	10.7	6.0	9.9	1.9
Austria	91.0	11,970	39.2	43.0	5.5	6.0	13.9	1.7
Belgium	119.1	11,570	107.9	90.6	5.7	4.7	5.2	0.6
Saudi Arabia	100.1	8,850	55.7	55.5	13.8	14.9	24.8	3.0
New Zealand	28.4	8,820	9.2	31.5	1.5	4.9	15.9	1.9
Bahrain	3.4	8,360	4.0	115.5	1.2	34.7	30.0	3.6

* Countries with GDP per capita above US$ 8,000.

B. Middle-income countries*

	Average annual GDP		Average annual trade		Foreign exchange reserves			
	Level (in US$ bn)	Per capita (in US$)	Level (in US$ bn)	As a % of GDP	Average year-end level (in US$ bn)	As a % of GDP	As a % of annual trade	In months of trade cover
Singapore	19.2	7,460	37.0	192.5	12.4	64.6	33.6	4.0
Israel	30.9	7,260	14,4	46.8	4.2	13.6	29.1	3.5
Ireland	23.3	6,670	15.1	64.7	3.1	12.8	19.9	2.4
Spain	246.7	6,440	49.9	20.2	17.7	7.2	35.3	4.2
Oman	7.5	6,020	3.7	49.4	0.9	11.7	23.8	2.9
Trinidad & Tobago	5.8	5,030	2.7	41.5	0.7	13.1	29.8	3.6
Barbados	1.2	4,890	0.7	60.5	0.1	9.0	14.9	1.8
Cyprus	3.0	4,490	1.7	58.0	0.7	22.5	38.9	4.7
Greece	42.0	4,260	11.3	25.8	1.6	3.5	14.3	1.7
Malta	1.3	3,900	1.2	90.1	1.1	82.9	92.0	11.0
Venezuela	56.4	3,290	16.3	29.0	6.1	10.7	37.0	4.4
Portugal	28.6	2,900	11.8	38.6	1.8	5.1	15.1	1.8
South Korea	113.5	2,800	41.8	36.9	4.6	4.1	11.0	1.3
South Africa	78.2	2,480	22.9	29.3	0.5	0.7	2.3	0.3
Algeria	49.8	2,390	12.3	24.9	1.6	3.7	13.0	1.6
Uruguay	6.9	2,340	1.8	23.5	0.3	3.2	16.5	2.0
Mexico	166.7	2,190	31.2	17.3	4.8	2.4	15.3	1.8
Panama	4.3	2,020	6.0	136.9	0.1	2.9	2.4	0.3

* Countries with GDP per capita between US$2,000 and 8,000.

Source: IMF International Financial Statistics.

Table A1 (continued)

Foreign exchange reserves, trade and GDP, 1979–91

C. Low-income countries*

	Average annual GDP		Average annual trade		Foreign exchange reserves			
	Level (in US$ bn)	Per capita (in US$)	Level (in US$ bn)	As a % of GDP	Average year-end level (in US$ bn)	As a % of GDP	As a % of annual trade	In months of trade cover
Malaysia	30.0	1,940	20.1	63.2	5.2	16.3	25.8	3.1
Chile	22.7	1,870	7.2	31.9	2.9	12.7	39.9	4.8
Costa Rica	4.1	1,570	1.6	40.2	0.4	8.8	21.9	2.6
Mauritius	1.5	1,500	0.9	59.3	0.1	7.1	12.0	1.4
Paraguay	5.1	1,380	1.0	20.5	0.5	10.3	50.2	6.0
Jordan	4.6	1,350	2.8	60.2	0.6	12.8	21.3	2.6
Jamaica	3.0	1,320	1.8	58.8	0.1	3.6	6.1	0.7
Botswana	1.4	1,320	1.1	83.0	0.9	60.3	69.2	8.3
Colombia	36.8	1,270	6.7	18.2	3.0	8.1	44.7	5.4
Tunisia	9.2	1,270	3.9	42.6	0.5	5.7	13.4	1.6
Turkey	63.0	1,270	12.1	18.1	1.7	2.4	13.9	1.7
Ecuador	11.7	1,270	3.2	27.0	0.6	5.1	19.0	2.3
Dominican Republic	6.5	1,030	1.8	27.3	0.2	3.2	11.7	1.4
Papua New Guinea	2.8	860	1.4	48.3	0.4	14.6	30.6	3.7
Thailand	43.4	850	15.0	31.7	3.3	6.7	22.3	2.7

C. Low-income countries* (continued)

	Average annual GDP		Average annual trade		Foreign exchange reserves			
	Level (in US$ bn)	Per capita (in US$)	Level (in US$ bn)	As a % of GDP	Average year-end level (in US$ bn)	As a % of GDP	As a % of annual trade	In months of trade cover
Egypt	38.0	810	9.5	25.1	1.1	2.9	11.6	1.4
Ghana	9.6	770	1.0	10.1	0.3	2.4	24.2	2.9
Morocco	16.6	760	4.8	26.8	0.3	1.4	7.1	0.8
Philippines	34.8	640	10.1	29.1	1.2	3.5	12.2	1.5
Nigeria	52.5	550	12.1	23.1	2.1	4.0	17.1	2.1
Indonesia	83.2	510	22.9	26.6	4.8	5.5	20.9	2.5
Sri Lanka	5.8	360	2.0	35.3	0.4	6.0	17.1	2.1
Kenya	7.0	350	2.1	29.3	0.3	4.3	13.2	1.6
Pakistan	30.7	320	5.9	19.3	0.6	1.8	9.6	1.1
India	216.6	290	16.8	8.0	4.2	1.9	28.1	3.4
China	313.4	290	37.8	11.6	11.2	3.6	44.7	5.4
Sierra Leone	0.8	230	0.2	21.8	0.01	1.3	6.0	0.7
Bangladesh	15.3	150	2.0	13.1	0.4	2.8	21.0	2.5

* Countries with GDP per capita below US$2,000.

Source: IMF International Financial Statistics.

Table A2

Foreign exchange reserves and current account variability, 1979–91

A. High-income countries*

	Current account variability		Exports variability	Imports variability	Correlation between changes in imports and exports	Ratio of foreign exchange reserves to current account variability
	In US$ bn	As a % of trade	As a % of trade			
Switzerland	2.3	3.9	10.4	11.5	0.97	7.2
Norway	2.9	8.8	9.6	8.6	0.57	3.2
Sweden	2.2	4.4	8.9	11.4	0.95	2.6
Iceland	0.1	8.2	9.8	11.6	0.81	1.8
Denmark	1.3	3.9	8.8	9.6	0.94	3.7
Canada	3.8	3.8	6.3	7.4	0.88	1.0
Finland	1.1	4.7	11.4	13.7	0.96	2.7
Australia	3.3	7.5	8.6	11.6	0.75	2.1
Netherlands	1.9	1.9	9.9	10.4	0.99	5.1
Austria	0.8	2.5	10.2	11.0	0.99	5.6
Belgium	1.4	1.6	10.8	11.5	0.995	3.3
Saudi Arabia	16.5	22.4	30.6	19.5	0.64	1.1
New Zealand	0.7	7.0	6.9	9.1	0.58	2.3
Bahrain	0.4	8.6	16.8	14.0	0.94	3.5

* Countries with GDP per capita above US$8,000.

B. Middle-income countries*

	Current account variability		Exports variability	Imports variability	Correlation between changes in imports and exports	Ratio of foreign exchange reserves to current account variability
	In US$ bn	As a % of trade	As a % of trade			
Singapore	0.8	1.8	11.1	12.0	0.99	19.2
Israel	1.3	8.5	5.7	8.5	0.65	3.4
Ireland	0.6	5.1	7.8	11.0	0.93	3.9
Spain	3.7	7.4	8.5	13.3	0.91	4.8
Oman	0.8	24.2	27.7	15.3	0.56	1.0
Trinidad & Tobago	0.4	16.5	20.3	16.8	0.56	1.8
Barbados	0.1	7.0	11.8	10.1	0.80	2.1
Cyprus	0.1	5.5	9.3	9.9	0.81	7.1
Greece	1.0	8.6	9.7	12.5	0.82	1.7
Malta	0.04	3.6	14.5	14.3	0.99	25.8
Venezuela	5.7	35.9	25.1	26.7	0.02	1.0
Portugal	1.1	10.9	9.5	16.5	0.84	1.4
South Korea	4.7	8.8	8.6	8.2	0.58	1.3
South Africa	2.9	12.8	15.0	16.9	0.68	0.2
Algeria	1.8	16.6	22.4	10.5	0.72	0.8
Uruguay	0.2	10.9	11.4	18.3	0.79	1.5
Mexico	6.0	20.5	13.6	25.5	0.61	0.8
Panama	0.3	5.4	25.9	28.9	0.99	0.4

* Countries with GDP per capita between US$2,000 and 8,000.

Source: IMF International Financial Statistics.

Table A2 (continued)

Foreign exchange reserves and current account variability, 1979–91

C. Low-income countries*

	Current account variability		Exports variability	Imports variability	Correlation between changes in imports and exports	Ratio of foreign exchange reserves to current account variability
	In US$ bn	As a % of trade	As a % of trade			
Malaysia	1.7	8.2	12.7	12.6	0.85	3.1
Chile	1.2	18.3	12.9	23.3	0.58	2.2
Costa Rica	0.2	10.4	5.5	12.6	0.52	2.1
Mauritius	0.1	8.5	12.6	13.8	0.90	1.4
Paraguay	0.2	16.3	13.8	18.3	0.25	3.1
Jordan	0.4	13.0	8.6	20.8	0.83	1.6
Jamaica	0.2	8.2	7.2	12.1	0.64	0.7
Botswana	0.3	18.2	18.9	17.2	0.37	3.8
Colombia	1.2	17.3	14.1	11.8	0.20	2.6
Tunisia	0.3	6.8	12.9	12.9	0.83	2.0
Turkey	1.7	13.9	9.7	15.0	0.47	1.0
Ecuador	0.5	16.2	12.2	16.4	0.37	1.2
Dominican Republic	0.2	11.8	11.7	15.5	0.59	1.0
Papua New Guinea	0.2	13.0	11.2	14.4	0.60	2.3
Thailand	1.7	10.1	9.2	14.7	0.89	2.2

C. Low-income countries (continued)

	Current account variability		Exports variability	Imports variability	Correlation between changes in imports and exports	Ratio of foreign exchange reserves to current account variability
	In US$ bn	As a % of trade	As a % of trade			
Egypt	1.2	12.1	9.5	14.2	0.63	1.0
Ghana	0.2	20.2	19.5	22.3	0.46	1.2
Morocco	0.6	11.6	9.0	12.8	0.59	0.6
Philippines	1.1	10.5	7.7	14.8	0.66	1.2
Nigeria	4.5	28.1	44.7	31.3	0.55	0.6
Indonesia	2.6	11.6	16.2	12.3	0.69	1.8
Sri Lanka	0.2	12.7	8.1	13.5	0.32	1.4
Kenya	0.2	11.6	9.4	17.9	0.80	1.1
Pakistan	0.5	9.7	7.4	11.0	0.36	1.0
India	0.9	5.2	6.1	10.7	0.76	5.4
China	8.3	19.9	8.4	16.5	−0.12	2.3
Sierre Leone	0.1	88.6	15.7	102.9	0.61	0.1
Bangladesh	0.5	23.5	7.4	19.4	0.41	0.9

* Countries with GDP per capita below US$2,000.

Source: IMF International Financial Statistics.

Table A3

Foreign exchange reserves under alternative simple rules, 1979–91[1]

A. High-income countries[2]

	Average reserve levels (in US$ bn)			Actual reserves as a % of reserves		Reserves as a % of trade		Ratio of reserves to current account variability	
	Actual	Under a trade rule[1]	Under a variability rule[1]	Under a trade rule	Under a variability rule	Actual	Under a variability rule	Actual	Under a trade rule
Switzerland	19.4	11.9	4.9	164	397	27.8	7.0	7.2	4.4
Norway	8.9	5.4	5.0	166	177	28.2	16.0	3.2	1.9
Sweden	5.6	8.2	3.9	68	143	11.6	8.1	2.6	3.8
Iceland	0.2	0.3	0.2	88	100	14.9	14.9	1.8	2.1
Denmark	4.5	5.4	2.2	84	201	14.3	7.1	3.7	4.3
Canada	4.2	18.5	7.5	23	56	3.9	6.9	1.0	4.5
Finland	2.8	3.6	1.8	76	151	13.0	8.6	2.7	3.6
Australia	5.9	6.4	5.1	93	115	15.7	13.6	2.1	2.3
Netherlands	10.7	18.3	3.8	58	281	9.9	3.5	5.1	8.8
Austria	5.5	6.7	1.8	82	308	13.9	4.5	5.6	6.8
Belgium	5.7	18.3	3.2	31	179	5.2	2.9	3.3	10.6
Saudi Arabia	13.8	9.5	22.7	146	61	24.8	40.7	1.1	0.8
New Zealand	1.5	1.6	1.2	93	125	15.9	12.7	2.3	2.4
Bahrain	1.2	0.7	0.6	176	191	30.0	15.7	3.5	2.0

[1] See footnotes to Table 4 for definitions of rules.

[2] Countries with GDP per capita above US$8,000.

B. Middle-income countries[2]

	Average reserve levels (in US$ bn)			Actual reserves as % of reserves		Reserves as a % of trade		Ratio of reserves to current account variability	
	Actual	Under a trade rule[1]	Under a variability rule[1]	Under a trade rule	Under a variability rule	Actual	Under a variability rule	Actual	Under a trade rule
Singapore	12.4	6.3	1.2	197	1,053	33.6	3.2	19.2	9.7
Israel	4.2	2.5	2.2	171	188	29.1	15.5	3.4	2.0
Ireland	3.1	2.6	1.4	122	224	19.9	9.3	3.9	3.3
Spain	17.7	8.5	6.7	208	263	35.3	13.5	4.8	2.3
Oman	0.9	0.6	1.6	146	57	23.8	44.0	1.0	0.7
Trinidad & Tobago	0.7	0.4	0.7	175	99	29.8	30.1	1.8	1.0
Barbados	0.1	0.1	0.1	88	117	14.9	12.7	2.1	2.4
Cyprus	0.7	0.3	0.2	229	392	38.9	9.9	7.1	3.1
Greece	1.6	1.9	1.8	84	92	14.3	15.6	1.7	2.0
Malta	1.1	0.2	0.1	546	1,431	92.0	6.5	25.8	4.5
Venezuela	6.1	2.8	10.7	218	57	37.0	65.3	1.0	0.5
Portugal	1.8	2.0	2.4	89	76	15.1	19.9	1.4	1.6
South Korea	4.6	7.1	6.7	65	69	11.0	15.9	1.3	1.9
South Africa	0.5	3.9	5.3	13	10	2.3	23.2	0.2	1.3
Algeria	1.6	2.1	3.7	76	43	13.0	30.2	0.8	1.0
Uruguay	0.3	0.3	0.4	97	84	16.5	19.8	1.5	1.6
Mexico	4.8	5.3	11.6	80	41	15.3	37.3	0.8	0.8
Panama	0.1	1.0	0.6	14	24	2.4	9.8	0.4	3.2

[1] See footnotes to Table 4 for definitions of rules.

[2] Countries with GDP per capita between US$2,000 and 8,000.

Source: IMF International Financial Statistics.

Table A3 (continued)

Foreign exchange reserves under alternative simple rules, 1979–91[1]

C. Low-income countries[2]

	Average reserve levels (in US$ bn)			Actual reserves as a % of reserves		Reserves as a % of trade		Ratio of reserves to current account variability	
	Actual	Under a trade rule[1]	Under a variability rule[1]	Under a trade rule	Variability rule	Actual	Under a variability rule	Actual	Under a trade rule
Malaysia	5.2	3.4	3.0	152	173	25.8	15.0	3.1	2.1
Chile	2.9	1.2	2.4	235	120	39.9	33.3	2.2	0.9
Costa Rica	0.4	0.3	0.3	129	116	21.9	18.9	2.1	1.6
Mauritius	0.1	0.2	0.1	71	78	12.0	15.4	1.4	2.0
Paraguay	0.5	0.2	0.3	295	170	50.2	29.6	3.1	1.1
Jordan	0.6	0.5	0.7	125	90	21.3	23.6	1.6	1.3
Jamaica	0.1	0.3	0.3	36	41	6.1	15.0	0.7	2.1
Botswana	0.9	0.2	0.4	460	236	69.2	33.1	3.8	0.9
Colombia	3.0	1.1	2.1	263	142	44.7	31.4	2.6	1.0
Tunisia	0.5	0.7	0.5	79	108	13.4	12.4	2.0	2.5
Turkey	1.7	2.1	3.1	82	55	13.9	25.3	1.0	1.2
Ecuador	0.6	0.5	0.9	112	65	19.0	29.5	1.2	1.1
Dominican Republic	0.2	0.3	0.4	69	55	11.7	21.4	1.0	1.5
Papua New Guinea	0.4	0.2	0.3	176	126	30.6	23.7	2.3	1.3
Thailand	3.3	2.6	2.8	131	121	22.3	18.4	2.2	1.7

C. Low-income countries* (continued)

	Average reserve levels (in US$ bn)			Actual reserves as a % of reserves		Reserves as a % of trade		Ratio of reserves to current account variability	
	Actual	Under a trade rule[1]	Under a variability rule[1]	Under a trade rule	Variability rule	Actual	Under a variability rule	Actual	Under a trade rule
Egypt	1.1	1.6	2.1	68	53	11.6	21.9	1.0	1.4
Ghana	0.3	0.2	0.4	152	70	24.2	36.7	1.2	0.8
Morocco	0.3	0.8	1.0	42	34	7.1	21.0	0.6	1.5
Philippines	1.2	1.7	1.9	72	64	12.2	19.2	1.2	1.6
Nigeria	2.1	2.1	6.2	101	34	17.1	51.1	0.6	0.6
Indonesia	4.8	3.9	4.8	123	100	20.9	21.0	1.8	1.5
Sri Lanka	0.4	0.4	0.5	101	74	17.1	23.1	1.4	1.3
Kenya	0.3	0.4	0.4	77	63	13.2	21.1	1.1	1.5
Pakistan	0.6	1.0	1.1	56	54	9.6	17.7	1.0	1.8
India	4.2	2.9	1.6	146	261	28.1	9.5	5.4	3.3
China	11.2	6.4	13.6	174	82	44.7	36.1	2.3	0.9
Sierre Leone	0.01	0.03	0.3	33	4	6.0	161.2	0.1	0.2
Bangladesh	0.4	0.3	0.9	124	49	21.0	42.7	0.9	0.7

[1] See footnotes to Table 4 for definitions of rules.
[2] Countries with GDP per capita below US$2,000.

Source: IMF International Financial Statistics.

2. *"Fitted" regression lines shown in Figures 1–4 and A1–A3*

Figures 1–4 and A1–A3 show the "fitted" values of the equations reported below. In all cases, parameter values were derived by the ordinary least squares method. In cases where a constant term was not significant at the 5% level, the reported and plotted regression results are shown without a constant term. In all cases, the number of observations is 60 and t-statistics are significant at the 5% level. Variables are as defined in Appendix A, part 1, and observation values are those shown in Tables A1 and A2.

Equation 1 (Figure 1)

ln (RESY) = a + b. ln (XMY)

	point estimate	standard error	t – ratio
a	−1.837	0.562	−3.27
b	1.019	0.155	6.56
	F: 43.02	SE: 0.73	corrected R^2: 0.416

Equation 2 (Figure 2)

ln (RES) = a + b. ln (XM)

	point estimate	standard error	t – ratio
a	−1.589	0.158	−10.064
b	0.919	0.062	14.746
	F: 217.43	SE: 0.71	corrected R^2: 0.786

Equation 3 (Figure 3)

ln (SDCA) = a + b. ln (XM)

	point estimate	standard error	t – ratio
a	−1.879	0.150–	12.553
b	0.777	0.059	13.165
	F: 173.33	SE: 0.67	corrected R^2: 0.745

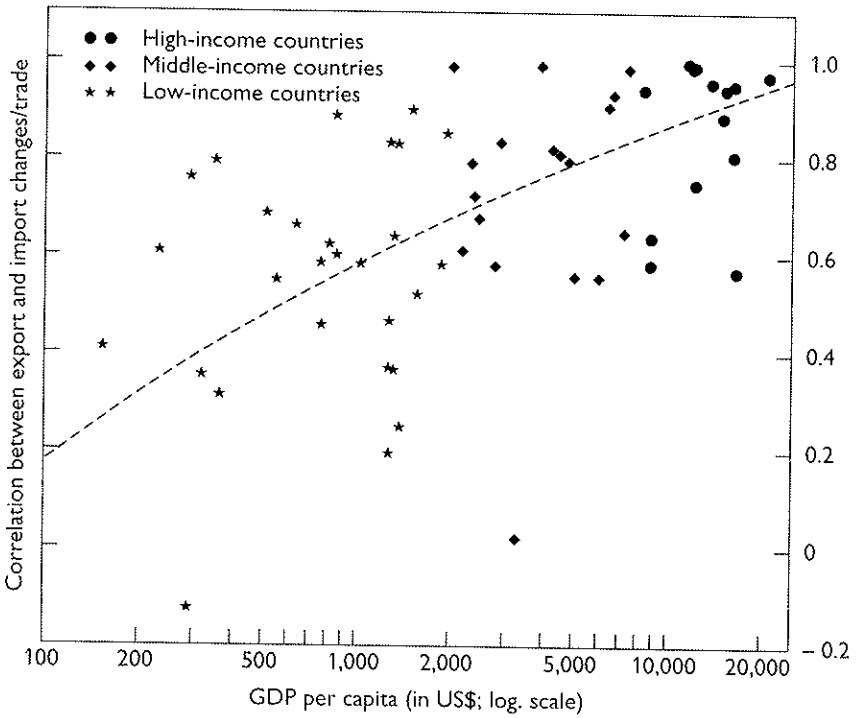
Equation 4 (Figure 4)

ln (RES) = a + b. ln (SDCA)

	point estimate	standard error	t-ratio
a	0.562	0.120	4.683
b	0.930	0.089	10.459
	F: 109.399	SE: 0.91	corrected R^2: 0.648

Figure A1

Correlation between export and import changes/trade versus GDP per capita, 1979–91



Note: See Appendix A for definitions of variables.

Equation A1 (Figure A1)

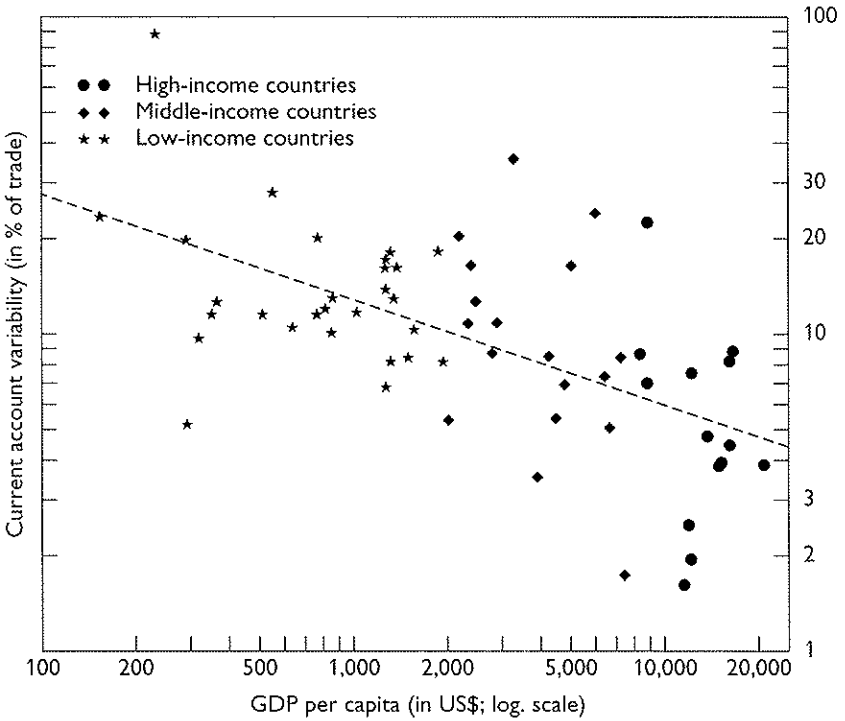
exp (CORXM) = *b*. ln (YPCAP)

	point estimate	standard error	t-ratio
b	0.259	0.006	40.595
	F: 1648.0	SE: 0.39	corrected R^2: 0.965
			corrected R^2 (Theil): 0.260

Note: the exponent of CORXM was used as the dependent variable in order to better (but still imperfectly) reflect the fact that in several cases the observed values of CORXM were very close to the upper limit of possible values. Strictly speaking, a censored-variable estimation method should be used.

Figure A2

Current account variability/trade versus GDP per capita, 1979–91



Note: See Appendix A for definitions of variables.

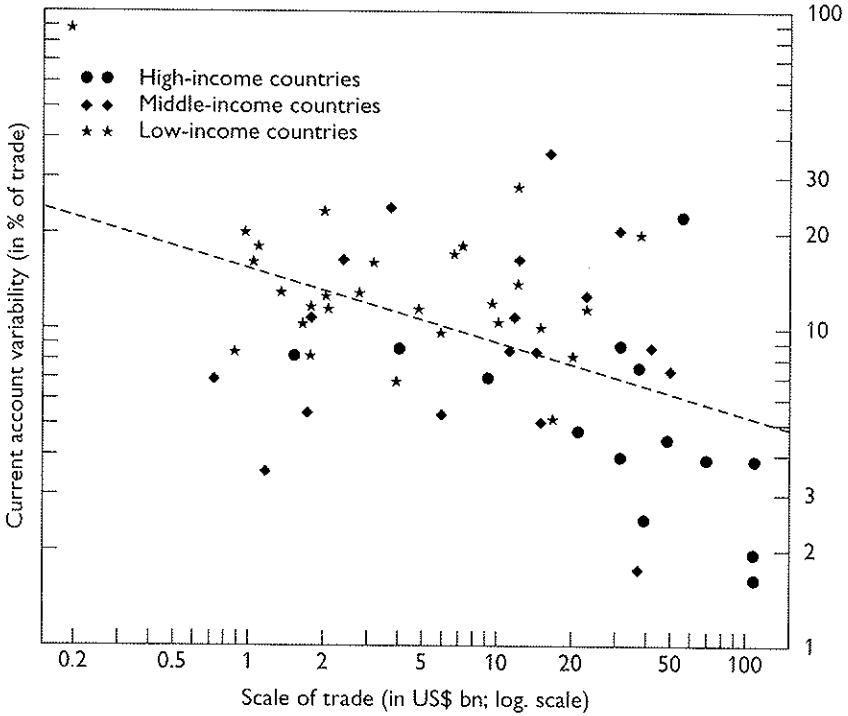
Equation A2 (Figure A2)

ln (SDCAXM) = a + b. ln (YPCAP)

	point estimate	standard error	t-ratio
a	4.846	0.481	10.065
b	−0.332	0.061	−5.443
	F: 29.625	SE: 0.60	corrected R^2: 0.327

Figure A3

Current account variability/trade versus scale of trade, 1979–91



Note: See Appendix A for definitions of variables.

Equation A3 (Figure A3)

ln (SDCAXM) = *a* + *b*. ln (XM)

	point estimate	standard error	t-ratio
a	2.739	0.146	18.777
b	−0.232	0.058	−4.037
	F: 16.299	SE: 0.66	corrected R^2: 0.206

3. *Trade and current account variability*

(i) *Import-export correlations*

As discussed in Section III, the correlation between changes in imports and exports vary greatly between countries; as can be seen in Table A2 and Figure A1, correlations among the sixty countries examined range from nearly unity to slightly below zero. Although there is considerable dispersion about the regression curve (see also Equation A1), the correlation between changes in imports and exports does tend to increase with GDP per capita. This may well reflect the tendency for high-income industrial countries to engage in intra-industry trade to a much greater degree than most developing countries, with the result that the former current account balances of high-income countries are less affected by terms-of-trade disturbances. Major exceptions are the fuel exporters, with relatively high incomes but exceptionally dissimilar imports and exports.

(ii) *Variability of imports and exports*

As can be seen from Table A2, there are also significant differences between countries in the degree of variability of their imports and exports. The less diversified the production base of an economy, the more concentrated will tend to be the composition of its exports. This in turn will tend to reduce the likelihood that a shock (such as a decline in domestic output or lower foreign demand) to one type of export will be offset by shocks to other exports. On the import side, a narrow range of domestic production may imply fairly diversified imports, but demand may also be fairly inelastic owing to the lack of domestically available substitutes. As a result of both of these factors, such countries might be expected to experience greater volatility in both their imports and exports (relative to the scale of trade) than larger, more diversified economies. Curiously, Table 3 shows no substantial differences in export variability (relative to trade) between high and low-income countries. Greater differences in variability are evident on the imports side. Very pronounced differences, however, are found between fuel-exporting countries and others.

The above considerations suggest that relatively undiversified economies will tend to have a high degree of current account variability relative to their total trade, and require relatively higher reserves/trade

ratios than more diversified economies. In this context it may be noted that although, as can be seen from Table 3 and Figure A2, low-income countries tend to have greater current account variability, relative to the scale of trade, than do high-income countries, the relationship between current account variability (relative to trade) and the level of GDP/capita is not very close (see Equation A2). Nor is there an especially close relationship between current account variability (relative to trade) and the magnitude of a country's trade, as can be seen from Figure A3 and Equation A3. Once again, the oil-exporting countries stand out as notable exceptions to the broad pattern, essentially as a consequence of having exports that are far less diversified than might be expected from the scale of their trade and the size of their GDP per capita.

Appendix B

1. *Illustrative calculations of currency share variability under alternative reserve management rules*

In order to illustrate the effects of different portfolio management rules on the variability of currency shares in reserves, Table B1 shows calculations (corresponding to those in Table 8) for three hypothetical countries. *Country 1* follows an extreme version of the *transactions approach*, placing a 90 percent weight on preserving currency shares at the initial exchange rates and a 10 percent weight on preserving currency shares at current exchange rates. In contrast, *country 2* places equal weights on preserving currency shares at the initial and current exchange rates. Finally, *country 3* takes an extreme *mean-variance approach*, placing a 90 percent weight on preserving currency shares at current exchange rates and only a 10 percent weight on preserving shares at the initial exchange rates. For comparative purposes, it is assumed that the three countries start with identical currency shares: 70 percent in US dollars, 10 percent in yen and 20 percent in Deutsche Mark. The exchange rates used correspond roughly to actual year-end rates in 1980, 1984 and 1988: in period 1, US$1 = ¥200 = DM2.00; in period 2, US$1 = ¥250 = DM3.10 and in the final period, US$1 = ¥125 = DM1.80.

Table B1

Illustrative calculations of currency share variability under alternative reserve management rules

	Standard deviation of currency shares			Coefficients of deviation[1] of currency shares (in %)			Average currency shares (in %)	
	At current exchange rates (A)	At final exchange rates (B)	B as a % of A	At current exchange rates (C)	At final exchange rates (D)	D as a % of C	At current exchange rates	At final exchange rates
Country 1								
US$	4.5	0.6	13.0	6.4	0.9	14.2	70.5	64.6
¥	2.3	0.3	11.7	20.9	1.9	8.9	11.1	14.7
DM	2.6	0.4	14.1	14.0	1.8	12.5	18.4	20.8
Average[2]	3.7	0.5	13.0	9.0	1.2	12.9		
Country 2								
US$	2.5	2.9	115.7	3.6	4.5	126.8	70.3	64.2
¥	1.3	1.3	105.3	12.0	9.4	78.5	10.6	14.2
DM	1.4	1.8	124.9	7.5	8.3	110.3	19.1	21.7
Average[2]	2.0	2.3	116.1	5.0	5.7	115.0		
Country 3								
US$	0.5	5.1	1,029.6	0.7	8.0	1,131.7	70.1	63.7
¥	0.3	2.4	940.5	2.5	17.2	692.8	10.1	13.7
DM	0.3	3.2	1,105.0	1.4	14.0	972.3	19.8	22.5
Average[2]	0.4	4.1	1,033.2	1.0	10.1	1,022.4		

[1] Standard deviation of currency shares as a percentage of average share. [2] Geometric average using shares in the last column as weights.

Source: Author's calculations.

2. *Reserve effects of holding alternative currencies*

In order to illustrate the impact on the value of a country's reserves of holding reserves in alternative currencies and the importance of violations of the uncovered interest parity condition, consider the example of Australia holding reserves in either US dollars (US$) or Deutsche Marks (DM):

(i) If reserves are held entirely in US dollars, then in each period:

$$R_{ut} = R_{ut-1}(1 + i_{ut}) + V_{ut} \quad (1)$$

where: R_{ut} is the US$ value of gross reserves at the end of period t
i_{ut} is the US$ interest rate applicable in period t to reserve holdings from the previous period
V_{ut} is the US$ value of net purchases of US dollars (intervention) in period t.

(ii) Now suppose that intervention is proportional to the percentage change in the Australian trade-weighted exchange rate (TWI):

$$V_{ut} = X_{ut} \cdot M_t \quad (2)$$

where: M_t is a measure of the appreciation of the Australian dollar (A$), in terms of the TWI, in period t
X_{ut} is the quantity of US dollars purchased in period t per percentage point rise in the Australian TWI

and

$$X_{ut} = Z_u/U_t \quad (3)$$

where: Z_u is a constant number of US dollars
U_t is the value of the US$ in terms of the Australian TWI in period t

and

$$U_t = A_t \cdot E_{aut} \quad (4)$$

where: A_t is the TWI value of the A$ in period t
E_{aut} is the A$/US$ exchange rate in period t.

Note that the definition of the unit of intervention, X_{ut} in Equation (3), means that the rate of intervention in TWI terms will not vary according to the value of the US$ against the TWI.

Substituting (3) and (2) into (1) and rearranging:

$$\frac{R_{ut}}{R_{ut-1}} = (1 + i_{ut})\left[1 + \frac{Z_u M_t}{R_{ut-1} U_t (1 + i_{ut})}\right] \quad (5)$$

Now starting from an arbitrary period 0 and solving forward, it is straight-forward to show that:

$$\frac{R_{ut}}{R_{uo}} = C_{ut}\left[1+\frac{Z_{ut}}{R_{ut}}\left(\sum_{n=1}^{t}\frac{M_n}{U_n C_{un}}\right)\right] \tag{6}$$

where: $C_{ut} = \prod_{n=1}^{t}(1+i_{un})$ (7)

(iii) Alternatively, suppose that reserves are held in Deutsche Mark. Corresponding to equations (1) to (4), we have:

$$R_{dt} = R_{dt-1}(1 + i_{dt}) + V_{dt} \tag{1d}$$

$$V_{dt} = X_{dt} \cdot M_t \tag{2d}$$

$$X_{dt} = Z_u / D_t \tag{3d}$$

$$D_t = A_t \cdot E_{adt} = A_t \cdot E_{aut} \cdot \left(\frac{US\$}{DM}\right) \tag{4d}$$

where the subscript *"d"* refers to Deutsche Marks in place of the *"u"* for US dollars in the definitions of variables.

Note that X_{dt}, converted into US$ terms, is exactly equal to X_{ut}, so that whichever currency is held as reserves, the amount of intervention is equivalent in terms of the TWI.
Similarly, corresponding to equations (5) and (6) we have:

$$\frac{R_{dt}}{R_{dt-1}} = (1+i_{dt})\left(1+\frac{Z_u M_t}{R_{dt-1} D_t (1+i_{ut})}\right) \tag{5d}$$

and

$$\frac{R_{dt}}{R_{do}} = C_{dt}\left[1+\frac{Z_u}{R_{do}}\left(\sum_{n=1}^{t}\frac{M_n}{D_n C_{dn}}\right)\right] \tag{6d}$$

where: $C_{dt} = \prod_{n=1}^{t}(1+i_{dn})$ (7d)

(iv) Next, consider the value of reserve holdings expressed in terms of the reference currency basket: the Australian TWI:

$$R_{aut} = R_{ut} \cdot U_t \tag{8}$$

where: R_{aut} is the TWI value of US dollar reserves in period *t*.

and

$$R_{adt} = R_{dt} \cdot D_t \qquad (8d)$$

where: R_{adt} is the TWI value of Deutsche Marks reserves in period t.

Substituting (8) and (8d) into (6) and (6d), respectively, and rearranging slightly:

$$\frac{R_{aut}}{R_{auo}} = K_{ut} C_{ut} [1 + J_{ut}] \qquad (9)$$

where: $K_{ut} = U_t / U_o$ (10)

and

$$J_{ut} = \frac{Z_u}{R_{auo}} \left[\sum_{n=1}^{t} \frac{M_n}{K_{un} C_{un}} \right] \qquad (11)$$

$$\frac{R_{adt}}{R_{ado}} = K_{dt} C_{dt} [1 + J_{dt}] \qquad (9d)$$

where: $K_{dt} = D_t / D_o$ (10d)

and

$$J_{dt} = \frac{Z_u}{R_{ado}} \left[\sum_{n=1}^{t} \frac{M_n}{K_{dn} C_{dn}} \right] \qquad (11d)$$

(v) Now the TWI value of reserves held in Deutsche Marks can be compared with the alternative of US dollar reserves by normalising $R_{ado} = R_{auo} = 1$ and taking the ratio of (9) and (9d):

$$G_{dut} = \frac{R_{adt}}{R_{aut}} = \frac{K_{dt} C_{dt}}{K_{ut} C_{ut}} \cdot \frac{[1 + J_{dt}]}{[1 + J_{ut}]} \qquad (12)$$

Equation (12) shows that the relative gain from holding reserves in one currency as opposed to another depends fundamentally on violations of the uncovered interest parity (UIP) condition:

(a) If UIP holds *continuously*, then:

$K_{dt} C_{dt} = K_{ut} C_{ut}$ for all t, which also implies that $J_{dt} = J_{ut}$, meaning that neither currency yields a gain relative to the other.

(b) If there is *no intervention*, then:

$$J_{dt} = J_{ut} = 0$$

with the result that:

$$G_{dut} = \frac{K_{dt} C_{dt}}{K_{ut} C_{ut}}$$

In this case, the relative gain from holding one currency will depend only on cumulative violation of UIP in favour of that currency over the measurement period.

(c) If intervention does occur, then even if the UIP condition is satisfied, *cumulatively, but not continuously*, then:

$$K_{dt} C_{dt} = K_{ut} C_{ut}$$

with the result that:

$$G_{dut} = \frac{[1 + J_{dt}]}{[1 + J_{ut}]}$$

which need not equal unity. In effect, intervention serves to "capture" short-term deviations from UIP. The relative gains from holding one currency as opposed to another thus depend not only on cumulative or sustained departures from UIP but also on the relative degree of synchronisation between intervention and UIP violations.

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