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The Level of a Central Bank's International Reserves: Theory and Cross-Country Analysis

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The Level of a Central Bank's International Reserves: Theory and Cross-Country Analysis

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Abstract

The study introduces the theory of the level of foreign exchange reserves and examines, in light of prior research, the different factors that affect the demand for reserves. The empirical part of the study uses results based on new and more extensive data to discuss the validity of the dependency relationships that have been found in previous studies and compares developments in Finland's foreign exchange reserves with those of other countries.

The data used in the empirical analysis covers the period 1974–1991 for 56 different countries, of which 22 are industrialized countries and 34 are less-developed countries. The basic analysis uses unweighted least squares regressions on cross-section data. Also, results from two weighted regressions are examined. The time series and cross-section data for industrialized countries are also pooled for testing purposes and the results are compared with those from the normal least squares regressions.

The degree of openness is an important determinant of the level of foreign exchange reserves for both industrialized and less-developed countries: the larger a country's foreign trade relative to total output the more reserves it demands. The results of the study also indicate that money growth increases the need for reserves and that the interest rate level is negatively correlated with the relative reserve level, at least in the less-developed countries. In the industrialized countries, the demand for reserves increases as yearly balance of payments' fluctuations increase. Moreover, the amount of reserves adjusts slowly to its long-run target level.

Tiivistelmä

Tutkimuksessa esitellään valuuttavarannon koon teoriaa ja käydään läpi varannon kysyntään vaikuttavia tekijöitä aikaisempien tutkimusten valossa. Empiirisessä osassa selvitetään aiemmissa tutkimuksissa saatujen riippuvuussuhteiden paikkansapitävyyttä uuden ja laajemman aineiston pohjalta sekä verrataan Suomen valuuttavarannon kehitystä muihin maihin.

Empiirisen tutkimuksen aineisto on koottu vuosilta 1974–1991 kaikkiaan 56 eri maasta, joista 22 on teollisuusmaita ja 34 vähemmän kehittyneitä maita. Tutkimuksen perustana ovat pienemmän neliösumman (PNS) painottamattomat regressiot poikkileikkausaineistosta. Lisäksi tarkastellaan kahden painotetun regression tuloksia. Teollisuusmaita koskeva aikasarja- ja poikkileikkausaineisto myös yhdistettiin ja saatuja tuloksia verrattiin normaalin PNS-regression tuloksiin.

Sekä teollisuusmaille että vähemmän kehittyneille maille maan kaupan avoimuus on tärkeä tekijä valuuttavarannon kokoa määriteltäessä: mitä suurempi osuus ulkomaankaupalla on maan tuotannosta sitä enemmän pyritään pitämään valuuttavarantoa. Tulosten mukaan rahan kasvu lisää myös valuuttavarannon tarvetta, kun korkotaso vastaavasti korreloi negatiivisesti suhteelliseen varannon tasoon, ainakin vähemmän kehittyneissä maissa. Teollisuusmaissa varannon kysyntä kasvaa, kun maksutaseen vuosittaiset vaihtelut nousevat. Lisäksi valuuttavarannon koko sopeutuu hitaasti pitkän aikavälin tavoitetasoonsa.

Contents

1 Introduction

The first aim of this study is to review the theoretical literature on the international reserves of a central bank and to present some empirical findings on the desired level of reserves. Reserves are the foreign component of the money supply, which serve as a buffer for imbalances between the demand for and supply of foreign exchange. In a fixed exchange rate regime with free capital movements, the level of reserves is determined by the necessity of equilibrium in the domestic money market. However, if there are changes in policy instruments and/or objectives, for example, a change from fixed to floating exchange rates, or if the central bank begins to loose its credibility, the level of reserves becomes 'targetable' for the central bank. A country is able to finance an external imbalance with reserves instead of real adjustments only if it has a sufficient amount of reserves, but on the other hand holding an excessive amount of reserves can be costly. The different aspects of benefits and costs of holding reserves are discussed in order to define those factors that determine the appropriate level of reserves for a country; i.e. the level which equalizes the marginal benefit and the possible marginal costs of holding reserves.

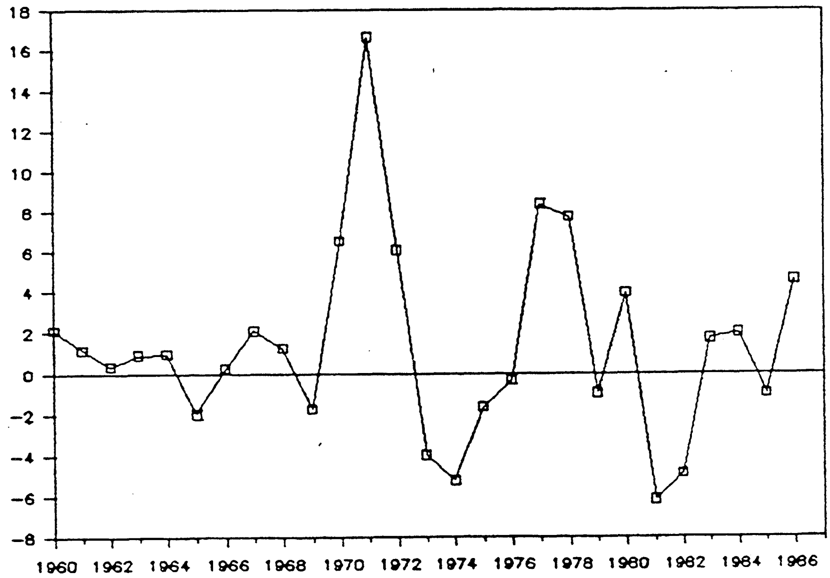
The second aim of the study is to formulate an empirical model based on the previous studies, and estimate it with as large a sample as possible and with new data from the period 1974–1991 (56 countries, 903 observations). The beginning of the sample period was chosen because of the structural change in the foreign exchange system in 1972–1973 with the breakdown of the Bretton Woods system.[1] After the collapse there was a movement towards managed floating and away from the fixed exchange rates, which had required frequent interventions. Later, currency unions like the European Monetary System have actually returned to fairly rigid 'bands', which require as much interventions as fixed exchange rate regimes. However, the shift to a managed float after Bretton Woods was expected to decrease the volume of interventions as well as the demand for reserves. However, during the late 1970s and early 1980s the volume of changes in foreign exchange reserves has actually increased in the industrialized countries (De Grauwe (1989), p. 183), see Figure 1. According to the graph, central banks have intervened in the exchange market to a greater extent during the period of floating exchange rates than they did before.[2] The economic growth and increased volume of international trade, which increase the absolute amount de facto, and capital market liberation, which increases the variability of the capital account balance, are possible reasons for this development, in addition to more active intervention policy.

[1] For an analysis of the link between the demand for reserves and the structural change, see Frenkel (1978).

[2] Bearing in mind the discrepancy between the reported reserve changes and the actual volume of interventions due to forward positions of the central banks and the possible statistical errors of the data, especially for the early years.

Figure 1. **Real changes in the foreign exchange reserves of the major industrialized countries, 1960–1986**

Billion SDRs, 1960 prices



Source: De Grauwe (1989), p. 183.[3]

The purpose of the empirical model is to try to answer questions such as what are the important factors affecting central banks' demand for reserves? Does the floating of a currency really decrease the demand? Can the previous theories be applied in the current environment?

The third, and final, aim of the study is to estimate the model for Finland, and compare the historical levels of Finnish reserves to the levels predicted by the model. The interesting question is whether the old model applies for the whole period, and whether the actual real level of reserves differs significantly from the level predicted by the model. As background, the Finnish markka has been floating since September 8, 1992, after the central bank had sold massive amounts of reserve currencies in a futile attempt to strengthen the markka. If the markka is to be linked to a basket or another currency in the future, the reserves must be large enough to re-establish confidence in a stable exchange rate policy. By observing and evaluating Finland's reserve levels over time and comparing them to those of other countries, some interesting relationships can be found.

The approach of the study is based on the positive theory of international reserves, which focuses on issues faced by a single country trying to optimize its level of reserves and its policy actions. The study assumes that currency fluctuations reduce social welfare, implying the aim of fixed, or at least stable, exchange rates, and that a central bank has power over the markets and is able to equilibrate the foreign exchange markets, at least in the short run.

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[3] The graph figures have been obtained by counting the annual changes in the official foreign exchange reserves of the major industrialized countries and dividing these changes by an average price index to get changes based on the 1960 price level. Primary source: International Financial Statistics, IMF.

The empirical results of this study support the theoretical notion that a higher level of openness of the economy, greater money growth, lower interest rates and greater variability of the balance of payments[4] increase the demand for international reserves. Further, the estimated model has a fairly good fit, although the fit for Finland worsens after the mid-1980s.

Chapter 2 illustrates the link between the reserve holdings of a central bank and the rest of the economy. It explains the functions of reserves and the forces driving changes in reserve levels. The theoretical background and previous findings are presented in Chapter 3. The model employed in the study is introduced in Chapter 4, leading to the estimation results and conclusions in Chapters 5 and 6.

2 The role of international reserves in an economy

2.1 Definition of reserves and foreign exchange intervention

By definition, international reserves are assets which national governments are willing to accept from other national governments to settle debts (Grubel (1984), p. 44). Most commonly, they include officially held gold,[5] convertible currencies, Special Drawing Rights (SDRs)[6] and reserve positions at the International Monetary Fund (IMF) (Winters (1991), p. 398). Convertible currencies are the only reserve item owned by both the official and private sectors of the economy. This paper focuses on international reserves held by the monetary authority of a country, the central bank.[7]

The reserve assets of a central bank can be divided into owned and non-owned reserves. Gold, SDRs and foreign convertible currencies are owned reserves, also called unconditional reserves (Winters (1991), p. 403), which are actually held by the central bank. Non-owned (conditional) reserves are nations' pre-negotiated credit arrangements with the International Monetary Fund, regional credit organizations, Euro-currency markets, or other central banks (Grubel (1984), p. 46–47). Borrowing directly from private markets may be unconditional in some extent, but this is for the most part a conditional source of money (Winters (1991), p. 403). The balance sheet of the Bank of Finland, specifies gold, SDRs, IMF

[4] Only for developed countries.

[5] Private holdings of gold are considered to be commodities, not means of payments.

[6] The Special Drawing Right is an artificial asset unit created by the International Monetary Fund in 1970 to substitute for gold as a main reserve asset and to improve international liquidity, which was becoming tighter (Tew (1988), p. 136).

[7] In this study a central bank is considered to be an institution responsible for implementing the market operations for both the monetary and foreign exchange policies of an open economy.

reserve tranche and convertible currencies as international reserves.[8] Its reserves also include swap agreements with several European countries, which, however, are not included in the balance sheet. The latest non-owned reserves of the Bank of Finland were acquired by revising the swap arrangement between the Nordic central banks. The new agreement came into force at the beginning of 1993 (Bank of Finland Bulletin, January 1993, p. 15). From here on, this study will discuss official reserves in general, without specifying the composition in detail. For empirical purposes in this study, reserves are considered to be total reserves, including gold, as obtained from the data base.[9]

Intervention in the foreign exchange market is the central bank policy instrument which de facto always changes the level of reserves. Traditionally, it is defined as a central bank's purchase or sale of foreign currency for domestic currency in the interbank market. A slightly broader definition would include foreign currency transactions carried out directly with entities like other central banks. The broadest definition would also include foreign currency-denominated public sector borrowing in those countries where it is controlled by the monetary authority. (Federal Reserve Bulletin, Nov 1983, pp. 880–883).

Interventions can be classified into two categories: non-sterilized and sterilized. A non-sterilized intervention affects the domestic monetary base: as foreign currency is sold (bought), the stock of domestic currency decreases (increases). In contrast, a sterilized intervention does not affect the domestic money supply because of an offsetting open market operation: as foreign currency is sold (bought), domestic currency is pumped into (drained from) the economy through central bank purchases (sales) of open market instruments.

2.2 Motives for holding reserves

Heller (1966) and Tobin (1973) discuss the basic motives for holding means of payment in connection with international reserves. They distinguish between transaction, speculative and precautionary motives. International trade gives rise to currency flows, which are assumed to be handled by private banks driven by the transaction motive, which does not affect central banks, as they are not directly involved in international trade. Similarly, the speculative motive is left to

[8] See Appendix 1 for the detailed balance sheet of the Central Bank of Finland. The term "convertible" is used, because the Bank of Finland also held a small amount of tied currencies as reserves until autumn 1992 (Bank of Finland Bulletin, January 1993, S3).

[9] There are arguments for and against including gold. The advantage is to get a more reliable level of total reserves for countries having a large amount of their reserves in gold, like the LDCs. The counter argument is the difficulty of measuring the value of gold reserves. The valuation differs from one country to another, and, for example, in Finland the undervaluation during the early 1900s was to the advantage of the central bank as it had to pay proceeds to the Ministry of Finance accordingly. In 1974 Finland started a new accounting method, which reduced the valuation error almost to zero, but several LDCs most likely still have the problem. In this study, the data includes gold at a fixed value of 35 SDRs per ounce, the amounts being reported by the countries themselves.

individual speculators.[10] Central bank reserves are characterized primarily as a last resort stock of foreign currency for unpredictable flows, which is consistent with the precautionary motive for holding assets. The precautionary money demand is positively related to wealth and the cost of covering an unplanned deficit and negatively related to the return from alternative assets (Landell–Mills (1989), p. 709). Courchene and Youssef ((1967), p. 405) explain the connection between the different motives in the following way: the transaction and speculation motives drive the actions of individuals, and the aggregate sum of these motives accumulates to the demand for reserves of the central bank. However, the authority cannot know the motives of the individuals beforehand and therefore has to act on a precautionary basis.

Winters (1991) views the subject more broadly and specifies four explanations for officially held reserves. First, the economy is assumed to benefit from pooling the transaction reserves because of economies of scale. Therefore, the central bank acts as a collector of the balances and is motivated by the transaction motive as well as the social benefit. Second, the official reserves are seen as a 'war chest' held because of the precautionary motive of the government. Third, reserves are an instrument to intervene either to maintain a certain fixed rate or to manage the exchange rate. Last, under capital control the reserves absorb the international money not allowed to be held by individuals.

To sum up, official reserves are held to enable intervention on a precautionary basis to balance demand for and supply of foreign currencies, and to preserve confidence in the country's ability to carry out transactions.[11]

2.3 External and monetary balances in an open economy

Policy measures aim for stability, both internal and external. The internal equilibrium is often defined as a combination of full employment and stable prices. External equilibrium can be considered as a state of long-run optimality in the current account, which in the case of a deficit means stabilizing the current account before the country's credit status begins to deteriorate due to excess foreign debt, or as a state of equilibrium in the balance of payments. (Krugman and Obstfeld (1988), Chapter 18)

All currency flows into and out of a country are reflected in its balance of payments. A balance of payments equilibrium is a state where the current account deficit (surplus) equals the surplus (deficit) on the capital account excluding foreign reserves (Krugman and Obstfeld (1988), p. 506). In other words, in an equilibrium the demand for international reserves equals the supply, without intervention by the central bank.

[10] However, Tobin ((1973), p. 529–530) views the speculative flows of individuals as a reason for the central bank to hold speculative balances, too. He also mentions that before August 1971 the monetary authorities of developed countries were obligated to meet the transaction flows, and hence the need for official reserves was also driven by the transaction motive.

[11] Heller (1966) pointed out the problem in the case of a global banker country, the currency of which is used as a reserve currency, as it might need additional reserves to back up its liabilities. So, the previous analysis as such holds only for a non-reserve currency country.

The following table summarizes the balance of payments accounts, which reflect a country's demand for and supply of foreign exchange.

Table 1. **Balance of payments**

CREDIT(+) = $S^{For.Exchange}$ / DEBIT(−) = $D^{For.Exchange}$
TRADE BALANCE (Export/Import of Goods) + Services Balance
= Goods & Services Balance + Current Account Receipts and Expenditure
= CURRENT ACCOUNT BALANCE + CAPITAL ACCOUNT BALANCE (Import/Export of capital)
= OVERALL BALANCE = Change in Foreign Exchange Reserves

Adapted from a Notification of Bank of Finland, 28 January 1993.[12]

Foreign exchange demand is reflected in debit entries in the balance of payments, supply in credit entries. The foreign exchange market is in equilibrium at a certain exchange rate when the demand equals the supply. However, foreign exchange transactions and different types of monetary and real shocks shift the demand and supply, causing disequilibriums, which lead to fluctuations in the price of the currency if they are not otherwise corrected. A country maintaining a fixed exchange rate has to implement real adjustment policies to shift the demand and supply curves or, alternatively, the central bank has to act as a residual supplier of currencies and increase or decrease the level of foreign reserves with the amount of the overall surplus or deficit in order to keep the exchange rate stable. The latter alternative is also a method of financing a deficit and is further discussed in the following section.

2.4 External disequilibrium and its correction

As stated above, an external equilibrium can be restored by either financing it through foreign exchange interventions, thus depleting or replenishing the reserves, or by macroeconomic adjustment.[13]

[12] Detailed Balance of Payments data for Finland (1992) is presented in Appendix 2.

[13] A disequilibrium can also be partially financed by external borrowing, but as the budget constraint makes the borrowing conditional (Kim (1989), p. 5) and as most of the early studies focused on the current account side, this is ignored for now. The issue will be touched upon in the section analyzing previous studies. See, for example, Edwards (1984b) for a discussion.

2.4.1 Financing of the external disequilibrium and central bank credibility

Reserve changes are the link between a country's balance of payments and its monetary balance. Following Tarkka ((1993), chapters 5–9) I describe the relationship between domestic money balances and foreign exchange policy.

In monetary equilibrium money demand equals money supply in a country. The Keynesian demand for money, assuming constant short-term prices, is stated as a function of income and the interest rate level:

$$M^d = P(\alpha \cdot Y - \beta \cdot i) \qquad (1)$$

M^d = demand for money
P = domestic price level
Y = total level of production (in real terms)
i = domestic interest rate level

The money supply is the sum of the foreign and domestic money supplies, which are tightly linked to the central bank balance sheet, and the level of foreign exchange reserves. Table 2 gives a simplified balance sheet; a detailed specimen (Bank of Finland) is given in Appendix 1.

Table 2. **Central bank balance sheet**

Assets	**Liabilities**
International Reserves (R)	Notes and coins in circulation (MC)
Domestic Credit (DC) and other items	Banks' free deposits (BFD) Banks' required deposits (BRD)
	Own capital (OC) and other items

Using the central bank balance sheet items the monetary base (B) can be specified in two different ways. First, according to the origin of the central bank assets that back the country's money supply: the sum of net international reserves and domestic credit, minus the value of own capital, which is further divided into profit minus transfers to the state. Second, on the basis of liabilities, which indicate the different forms in which the banking system holds reserves. Thus:

$$\begin{aligned} B &= R + DC - OC \\ B &= MC + BFD + BRD \end{aligned} \qquad (2)$$

Further, the financial institutions create money on the basis of the amount of monetary base they obtain from the central bank according to the following formula:

$$M^s = m \cdot B \quad (3)$$

m = money multiplier[14]

In monetary equilibrium money supply equals money demand. In a fixed exchange rate regime, the adjustment occurs through changes in foreign exchange reserves. Equations (1)–(3) imply the following expression for the level of reserves:

$$R = (P/m) \cdot (\alpha \cdot Y - \beta \cdot i) - DC + OC \quad (4)$$

Equation (4) provides a clear link between domestic credit creation and the foreign money supply effect of reserves: with a constant demand for money, domestic credit has to be decreased if the level of reserves increases through a balance of payments surplus and monetary equilibrium is to be maintained. This operation is called sterilization, as the central bank does not allow the balance of payments' surplus (or deficit) to be carried over to the money supply. As the operation changes only the balance between the domestic credit component and the foreign component of the money supply, but not the actual amount of supply or demand, it is also referred to as financing with reserves.

Financing the imbalance by foreign exchange interventions is a feasible course in the event of a temporary disturbance in the foreign exchange markets. With a fixed exchange rate target, a country can restore equilibrium with sterilized interventions, leaving the domestic money supply constant, but only so long as the central bank's policy is credible, i.e. there is widespread confidence in its ability and willingness to maintain the chosen exchange rate. For example, a balance of payments deficit would be financed by selling international reserves, which would in itself decrease the money supply, but domestic credit would be simultaneously increased to offset the effect. Monetary equilibrium can be maintained if the disturbance is only temporary. However, if credibility weakens, expectations will grow that the currency will be devalued in the future, and the disequilibrium will become permanent, due to capital outflows. Even if the interventions were not sterilized, the interest rate increase might not be sufficient to reverse the outflow of capital.

The effects of loosing credibility can be illustrated with equation (4). As credibility weakens, with the exchange rate fixed, the real domestic interest rate goes too high because the expected devaluation and thus expected inflation are incorporated into the investors' required rate of return in the country. Further, the country's international price competitiveness weakens, and the economy goes into a recession. These factors, excluding the price level effect, decrease the central bank's international reserves. The lower production (Y) and higher interest rate (i) decrease the demand for money, but as the central bank increases domestic credit (DC) to stabilize domestic liquidity (as is likely), the supply actually increases. The price level (P) will then increase, which increases the demand for money, although the impact is less powerful than the countereffects. The own capital component

[14] In the simple money multiplier model: $m = 1/[k+v(1-k)]$, where k measures the willingness of people to hold cash money and v is the banks' reserve ratio, including free and required reserves.

will actually increase as central bank profits rise, because the liquidity granted to banks bears higher interest than the central bank has to pay for its liabilities and this improves the central bank's ability to hold reserves. In the end, the amount of reserves will decrease due to the loss of credibility, which implies a greater need for reserves in this type of speculative environment.

2.4.2 Adjustment policies

As an alternative to financing, the money supply and demand levels can be altered through various adjustment policies. The literature[15] gives two different real adjustment policies to restore equilibrium in the foreign exchange market.

The classical approach is based on the flexible prices. An **expenditure-switching** policy achieves balance through a shift of demand between domestic and foreign products through price level changes at home. A deficit can be eliminated through a reduction in domestic prices, which boosts exports. If commodity prices and wages are sticky, a devaluation or revaluation of the currency is probably the easiest way to switch expenditure between domestic and foreign products, as it affects the country's competitiveness. As an example, a deficit country might be tempted to devalue even though it is "committed" to a fixed exchange rate because a devaluation would boost exports, make domestic products more price competitive and increase the central bank's profits through seigniorage, i.e. through a favourable re-evaluation of domestic currency liabilities and foreign currency assets. Further, if a country is forced to use devaluations over and over again to boost its economy, the central bank looses its credibility, and encounters the problems discussed in the previous section.

In addition to the devaluation/revaluation alternatives to balance the discrepancy, Clark ((1970a), p. 359) notes the following instruments for expenditure-switching policy: tariffs, import/export quotas and exchange controls. Adjustment methods like tariffs and direct import controls distribute the welfare loss widely in the society and favour tightly organized economic groups (Grubel (1984), p. 51). However, international agreements like the General Agreement on Tariffs and Trade (GATT) have limited the scope for tariffs and trade controls as a domestic policy tool. Similarly, capital controls have diminished in importance as the international capital markets have developed and the industrialized countries have opened their capital markets, although several developing countries still have capital controls in effect.

To illustrate the ability of capital controls to increase the independence of a country's monetary policy vis-à-vis other countries through an interest rate differential and better control over domestic interest rates, let us look at the Mundell–Fleming model for a small open economy with imperfect capital movements. In the short run with stable exchange rate expectations, the limited capital flows (and the level of reserves) are dependent on the level of domestic interest rates. Due to the imperfect capital movements, the country can determine the domestic interest rate level somewhat independently from the international

[15] The following categories are introduced by several authors: Heller (1966), Clark ((1970a), p. 359), Grubel (1984) and Krugman and Obstfeld ((1991), p. 533) among others. Originally they were introduced by H.Johnson in 1958 (Clark (1970b), p. 580).

level, and a differential arises between the two. The foreign component of the money supply, i.e. the level of net reserves, becomes a function of a coefficient for the level of capital movements (ω), the price level (P) and the interest rate differential between domestic and foreign rates ($i-i^*$):

$$R = \omega \cdot P \cdot (i - i^*) + R_0 \tag{5}$$

R_0 = the hypothetical level of reserves with interest rate parity, i.e. if capital movements equalize interest rates across countries.

The level of reserves increases in the short run as the domestic interest rate increases, assuming stable exchange rate expectations. By inserting the reserve function from the above to the earlier presented model of money supply, solving for the equilibrium domestic interest rate and inserting the rate in the reserve function, a relation between reserve level, credit creation and capital movements is obtained:

$$R = -w_1 \cdot DC + (w_1/m) \cdot (\alpha \cdot Y - \beta \cdot i^*) + w_2 \cdot R_0 \tag{6}$$

$$w_1 = \omega/(\omega + \beta/m)$$

$$w_2 = (\beta/m)/(\omega + \beta/m)$$

$$w_1 + w_2 = 1$$

If there are no capital controls, w_1 equals one and the increase of domestic credit spills over to the balance of payments as such, decreasing the level of reserves. However, the lower the coefficient, i.e. the more effective the capital controls, the more the country has independence in its monetary policy without implications for the external balance. (Tarkka (1993), pp. 310–317)

The second real adjustment policy for restoring equilibrium is the Keynesian type of **expenditure-changing** (or reducing) policy, which requires the economy to change its total demand for goods and services in order to achieve an external balance. As an example, a country facing a current account deficit would regain its balance through a dampening of the economy as the level of imports declines according to the marginal propensity to import. The instruments available include fiscal policy and interest rate policy. With a fixed exchange rate system, expenditure-changing policy tends to be favoured over expenditure-switching policy because, with the former, the exchange rate parity can be maintained. Nevertheless, with weak credibility, the interest rate instrument has much less power than under normal conditions due to devaluation expectations, which lower the anticipated real interest rate.

All the above stabilization methods entail costs. Financing requires reserve holdings, which means that reserves cannot be put to productive use elsewhere in the economy and that they have to be maintained, which involves time and effort. Expenditure-changing policy requires dampening of the economy; expenditure-switching policy produces instability in prices and exchange rates (as does a change in the terms of trade or capital allocation), which diminishes social welfare. Fluctuations in foreign exchange rates could diminish the volume of world trade and allocate excessive resources into risk-reducing techniques. So, an efficient policy mix should include the use of both international reserves and adjustment policies.

2.5 Temporary versus fundamental disequilibrium

A balance of payments disequilibrium is considered temporary if the fluctuations in foreign exchange reserves (and fundamentally in the foreign exchange market) are random with a mean of zero. As long as the reserves are large enough, this type of a disequilibrium (deficit) can be financed by running down the reserves. The fundamental issue regarding the demand for reserves is the trade-off between the probability of an imbalance occurring and the cost of holding reserves. The speed of correction is assumed to be relatively short, whether it occurs through financing or adjustment, i.e. quick restoration of reserves to the 'optimal' level, say during the first year following a shock.

If a country faces a fundamental disequilibrium, it is able to restore equilibrium only by means of adjustment measures, like expenditure reduction, usually over a relatively long period of time. The economy cannot rely on the randomness of the imbalances to offset each other over time, as in a temporary disequilibrium, but is rather forced to change key macroeconomic variables in order to restore balance. Statistically speaking, the mean of the distribution of changes in foreign exchange reserves differs from zero. Reserves can be used to finance this type of a disequilibrium only partially, acting as a buffer, before the macroeconomic adjustment measures become effective. The speed of adjustment becomes an important issue in determining the appropriate level of reserves. During the period of a fundamental disequilibrium the country might face additional temporary disturbances, which can be financed with reserves to the extent feasible.

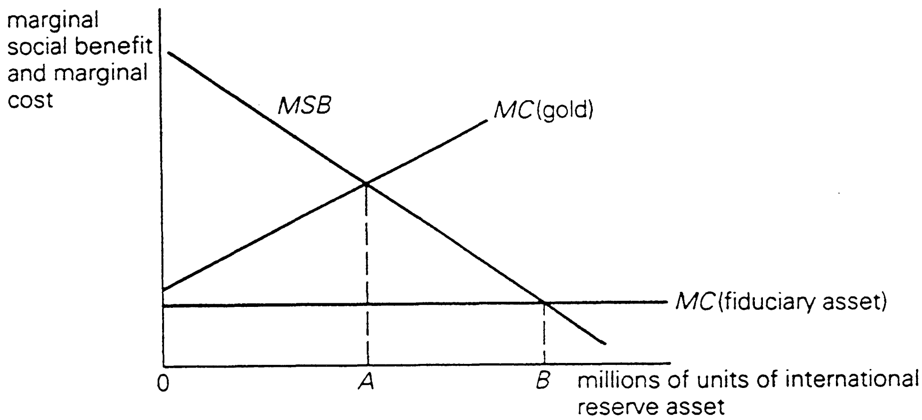
To sum up this section, the foreign exchange market is affected by several fundamental issues which drive the demand for international reserves. The private sector impacts the markets through credit demand, savings and capital movements, whereas the public sector effect stems from the targets for finance, monetary and exchange policies as well as the policy instruments employed. Having presented one viewpoint on reserves as a policy instrument, it is time to look at the more functional variables used to model the demand for reserves.

3 The demand for reserves

3.1 Optimal level of reserves

The following figure introduces the concept of the optimal level of international reserves worldwide.

Figure 2. **Optimal international liquidity**



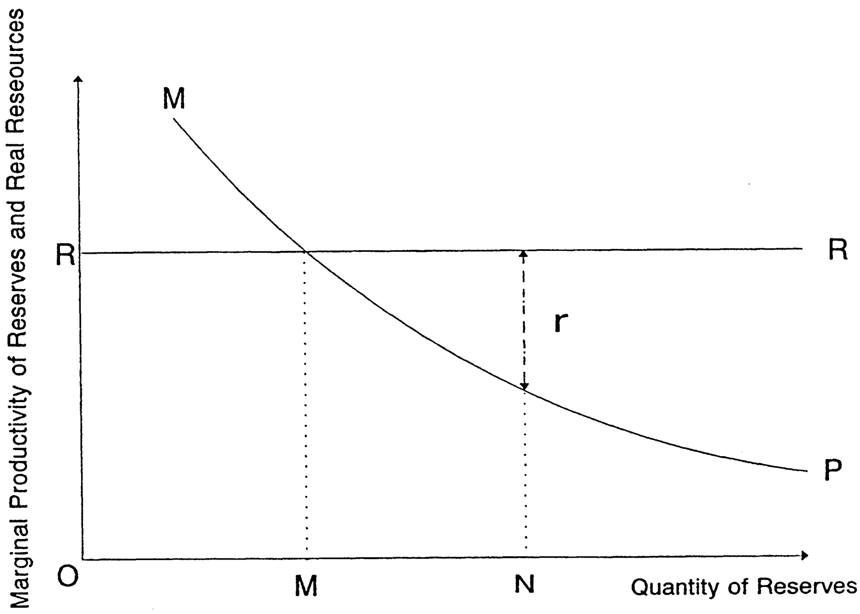
Source Hallwood and McDonald (1986), p. 173

The optimal level of reserves can be found from the horizontal axis at the intersection of the marginal cost and marginal benefit functions. When a commodity like gold is used as a main reserve asset, the optimal size (A) is lower than when a fiduciary asset (B), like SDRs or dollars, is used because a commodity requires more production resources, and is therefore more scarce (Hallwood and MacDonald (1986), p. 173), and is assumed here not to earn interest, in contrast to fiduciary assets. Therefore, the switch from a commodity based monetary system to extensive use of fiduciary assets might have increased the optimal level of international reserves in the world as well as the demand for reserves, even though the movement away from fixed exchange rates at the same time was expected to dampen demand (see also Figure 1).

If world reserves were less than the optimum amount, the world economy would suffer from excess fluctuation in exchange rates. Accordingly, if reserves were to exceed the optimum, countries would attempt to run balance of payments deficits in order to dispose of excess reserves. Increased imports would stimulate excess demand for goods and assets and lead eventually to inflation, which would reduce the real value of the reserves, and equalize the demand for and the supply of international reserves. (Grubel (1984), p. 34–35)

Let us focus on an individual country attempting to hold an adequate amount of reserves without sacrificing too much resources.

Figure 3. **Optimal level of reserves in a country**



Source: Grubel (1984), p. 33

In the figure above the RR function represents the return on real resources in the economy, the MP function gives the marginal social productivity as well as the demand for reserves, and r represents the yield on reserve assets.[16] If gold is the only reserve asset, the long-run equilibrium and the optimal level of reserves is OM,[17] whereas if some fiduciary assets are used the equilibrium level is ON, which is greater than OM (Grubel (1984), p. 31). The equilibrium is based on the efficiency condition: the marginal productivity of reserves plus the interest rate earned on reserve assets equals the marginal productivity of real resources (Grubel (1981), p. 518). The optimal level of reserves, and the optimal exchange rate stability for a single country follow from the above analysis, and the sum of the MP curves for each country equals the MSB function in Figure 2.

The above analysis is logical and simple but a number of problems occur on a practical level, as the productivities of reserves and real resources are difficult to specify. The social benefit stemming from reserves can be identified as a decrease in exchange rate fluctuations. The costs involved are more difficult to identify, as the above approach focuses on the current account only and assumes real productive investment to be the alternative use of the reserves. Yet, with relatively free capital flows between countries, the opportunity cost for holding reserves should also include the effect of destabilizing capital flows.

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[16] The assets are assumed to be at least partly fiduciary and invested to earn an average return of r.

[17] Assuming gold is not invested to earn a return.

3.1.1 The early theoretical models

Heller (1966) was the first to model the optimal level of reserves for a country considering the benefits and costs in a random walk framework. The benefit of holding reserves can be stated as a cost of the alternative policy, i.e. adjustment, which Heller assumed to be expenditure-changing policy, finding it easier to model than expenditure-switching policy.

Figure 4a illustrates his basic idea of a country adjusting through a dampening of the economy. The assumed shock is a drop in exports, creating a balance of payments deficit, which can be corrected by dampening the economy by the amount TC_a in the figure. These events move the country to a lower level of total wealth: from point A to point B.

Figure 4a. **Heller's optimality model**

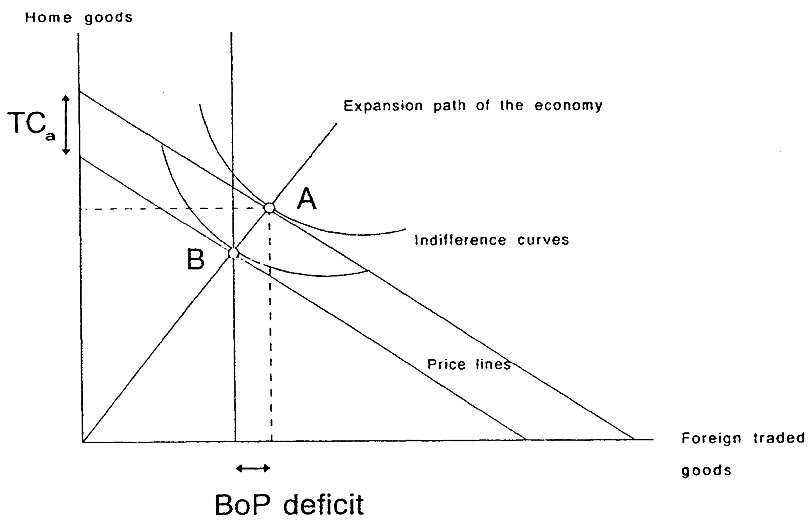
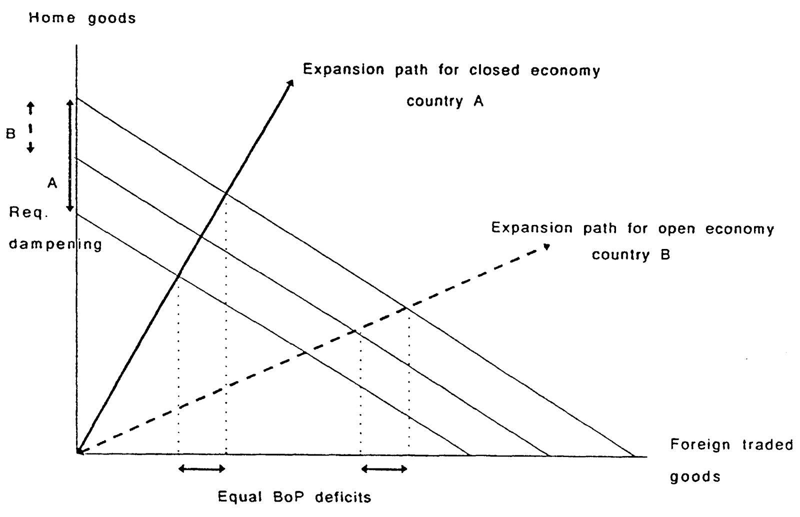


Figure 4b. **Heller's optimality model**



Source: Heller (1966), p. 298

The expansion paths in Figure 4b illustrate different types of countries; the lower the slope, the more open the economy. So, the dampening needed for a given amount of balance of payments correction is higher for a economy trading less with foreign countries. The cost of adjustment is therefore inversely related to the propensity to import:

$$TC_a = \frac{\Delta B}{m} \tag{7}$$

TC_a = total cost of adjustment, i.e. benefit of holding reserves
ΔB = external imbalance
m = propensity to import

As to the costs of holding reserves, Heller looked at the social rate of return on capital, although it is not empirically quantifiable, and the average yield on liquid reserves; the difference between these two is the lost return due to holding reserves. The formula for the opportunity cost of holding reserves does not include uncertainty:

$$TC_f = r \cdot R \tag{8}$$

TC_f = total cost of holding reserves
r = social rate of return – return on reserve assets
R = level of reserves

In addition to the adjustment cost and the cost of holding reserves the model has to include the probability of using precautionary reserves. Heller (1966) utilized a random walk process with equal probabilities[18] for an increase or decrease in reserves of size h. He also assumed that the country involved was small enough to have no significant effect on the level of world trade. With these assumptions and models he obtained the following formula for the optimal level of reserves:

$$R_{Opt} = h\frac{\log(rm)}{\log(0.5)} \tag{9}$$

h = average absolute change in international reserves
r = opportunity cost of reserves
m = propensity to import

Heller ran the model with data from some 60 countries for 1949–1963; the results showed that the aggregate level of reserves was adequate but that the distribution was faulty. In comparison to the reserves-import ratio as a tool to approximate the

[18] In other words, the country was in a fundamental equilibrium.

adequate level of reserves, Heller's optimality formula gave more reliable results in his test.[19]

The optimization approach pioneered by Heller was further developed by Clark (1970a), who assumed that the country involved was small with a fixed exchange rate and constant export prices and that it faced random disturbances with a zero mean, i.e. the model is applicable only to countries in fundamental equilibrium. Like Heller (1966), he also excluded expenditure-switching policies;[20] but he introduced the speed of adjustment concept. His central idea was that the greater the level of reserves and reliance on financing the imbalances, the lower the national income, whereas a quicker real adjustment to imbalances increases the variance of income, (Clark (1970a), p. 357). Both of the above ways represent costs to the country. By minimizing these costs, he derived the optimal speed of adjustment and the optimal level of reserves. The optimal reserve level was found to be positively related to changes in balance of payments volatility and the full-employment output level and negatively related to the marginal propensity to import and the interest rate level. Quite to the contrary, the optimal speed of adjustment was found to have exactly the opposite signs for the same variables. The empirical part of the study (Clark (1970b)) obtained only one significant factor for the level of reserves: the variance of the error term measuring the balance of payments volatility, with the expected (positive) sign. In the speed of adjustment regression he found statistical significance for all three variables, although the volatility obtained a positive sign, contrary to expectations.[21]

Kelly (1970) also modelled a country in fundamental equilibrium using expenditure-changing policy as an alternative to the use of reserves. His theory found that the optimal reserve level varied directly with the standard deviation of exogenous reserves and the marginal decrease of utility due to the income variance. But the marginal disutility of a diminished income, the opportunity cost of reserves and the marginal propensity to import were found to be inversely related to the optimum reserve level. His empirical results found the variables significant, although the signs of the average propensity to import and foreign liabilities[22] were, against his theory, positive for all countries together, and negative only for separate country groupings.[23]

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[19] He tested both measures against country studys made by a research institution.

[20] This excludes the use of interest rates to direct short-term capital flows, which is, of course, unrealistic in the present world.

[21] The model assumed an adjustment through income changes, but in reality the countries also adjust by import quotas, tariffs and exchange controls, which might cause countries to adjust quicker in the case of higher volatility than predicted by the theory and the data to give a "wrong" sign for the variable (Clark (1970b), p. 591).

[22] Foreign assets and liabilities were used as a proxy for opportunity cost in his second equation, based on the following logic: a country having a high level of foreign assets (low level of foreign liabilities) is relatively better of, and does not have a great need for capital, so its opportunity cost for reserves is lower.

[23] He divided the countries both according to per capita income and import/income ratio.

3.1.2 Models incorporating fundamental equilibrium

Frenkel and Jovanovic (1980 and 1981) based their theory on the possibility of a fundamental disequilibrium, but for the empirical analysis they assumed an equilibrium. First, they supposed that changes in reserve holdings behave according to the following model:

$$dR(t) = -\mu dt + \sigma dW(t);\ R(0) = R_0,\ \mu \geq 0 \tag{10}$$

W(t) = standard Wiener process with mean zero and variance t

In the case of a fundamental equilibrium, the character μ would be zero, meaning that the stochastic process is without drift. They minimized the expected sum of the cost of adjustment (using expenditure-changing policy) and the foregone earnings, and obtained the following formula for the optimal level of reserves:

$$R_0 = \sqrt{\frac{2C\sigma^2}{(\mu^2 + 2r\sigma^2)^{\frac{1}{2}} - \mu}} \tag{11}$$

C = fixed cost of adjustment
σ = multiplier of the variance of reserve holdings ($\sigma^2 t$)
μ = drift factor (zero if fundamental equilibrium)
r = %-cost of holding reserves per time unit

Kim (1989) studied the optimal demand for reserves, emphasizing in particular the fundamental disequilibrium faced by several countries, at least certain LDCs. Due to the fundamental disequilibrium he also measured the cost of adjustment by the cumulative decline of economic welfare over the adjustment period, rather than using the static marginal propensity to import. He assumed that the country is a small open economy with a fixed exchange rate regime, producing traded goods which are not perfectly substitutable for foreign goods. Further, prices are exogenous, output is constant and no speculation occurs. The monetary authority is assumed to be aware of the probability distribution of the excess demand for foreign exchange but unaware of its magnitude. The size can be characterized by the following equation for a given time period:

$$\mu = A - Y \tag{12}$$

μ = excess demand for foreign exchange without adjustment
A = expected value of domestic absorption without adjustment
Y = expected value of domestic income without adjustment

The time of adjustment and the level of reserves needed to accomplish adjustment are decided by the monetary authority, focusing on the following two issues in particular: the extent of dampening of domestic expenditure needed for the adjustment and the variability of the excess demand for foreign exchange. The adjustment itself can be expressed using expected domestic absorption relative to income during a period t in the following way:

$$A_t = Y_t + (1 - \gamma t)\mu \tag{13}$$

γ = average speed of the external adjustment

The adjustment is assumed to effect the supply side through increased productivity and efficiency, which can be incorporated in the model. The expected output during the adjustment period is:

$$\begin{aligned} Y_t &= Y + \theta\gamma\mu t, \quad \text{for } t = 0, 1, ..., T-1 \\ &= Y + \theta\mu, \quad \text{for } t = T, T+1, ... \end{aligned} \tag{14}$$

Y = expected value of output without adjustment, i.e. $A-\mu$
θ = constant coefficient between 0 and 1 representing the output effect of external adjustment

In Kim's model the reserve demand function is derived by minimizing the sum of opportunity cost and the potential cost of reserves depletion.[24] A fundamental disequilibrium is found to increase the demand for reserves ceteris paribus. To obtain an optimal level of adjustment and reserves, the monetary authority seeks a speed of adjustment which will minimize the present value of the intertemporal decline in domestic expenditure, trying to keep the balance of payments volatility due to the adjustment as low as possible. Kim (1989) finds the optimal speed of adjustment positively related to the variability of foreign exchange demand, the output effect of adjustment and the social discount rate, and negatively related to the expected level of the fundamental disequilibrium. Similarly, the optimal level of reserves is positively related to the expected level of the fundamental disequilibrium, the variability of the foreign exchange demand and the marginal cost of external borrowing, and negatively related to the output effect of the adjustment, the marginal opportunity cost of reserve holdings and the social discount rate. Finally, Kim (1989) cites the disregard of flexible exchange rates, the budget constraint on external borrowing and the possible serial correlation in the excess demand for foreign exchange as weaknesses of his model.

Ben-Bassat and Gottlieb (1992a) is the most recently published study in this field. They derive a precautionary reserve demand model for a borrowing country, which suffers a fundamental deficit. They introduce sovereign risk into the model and consider the cost of running out of reserves as a cost of possible default on foreign debt payments and, accordingly, they equate the probability of reserve depletion with the probability of the country defaulting on its foreign debt. The

[24] The potential cost of reserve depletion is specified as i(x−R), where i is the marginal cost of external borrowing and x−R is the amount of external borrowing. The external borrowing specified here does not affect the capital account.

objective function of the model minimizes the sum of the cost of foregone earnings and the social cost of reserve depletion. Thus their model becomes

$$\min EC = \pi C_0(m,Y) + (1-\pi)rR \tag{15}$$

π = the probability of reserve depletion (sovereign risk), which is a function of the reserve to import ratio (negative relation), debt to exports ratio (positive relation) and other economic variables
C_0 = the cost of foregone earnings
m = openness of the country
Y = GNP
r = $\rho - i$, i.e foregone earnings – yield on reserves
R = level of reserves

The wealth constraint for the function is

$$D = K + A - W + R = D_n + R \tag{16}$$

D = external debt
K = capital stock
A = other assets
W = net wealth
D_n = debt net to official reserves (exogenous)

The probability of reserve depletion is estimated by a logistic probability function, where a growing reserve ratio (R/M) and a decreasing debt ratio (D/X) increase the country's creditworthiness at a diminishing rate. Ben–Bassat and Gottlieb (1992a) conclude their theoretical section by suggesting that the level of optimal reserves is positively related to the cost of default, the yield on reserves and, (mostly likely) the net debt level,[25] and negatively related to capital productivity. Their empirical results support the theoretical analysis and find significant coefficients with the expected signs, and the model is found to have more explanatory power than the models of Heller (1966), Hamada and Ueda (1977) and Frenkel and Jovanovic (1981).[26]

The basic idea in all models trying to specify a formula for the optimal level of reserves is to maximize the benefits of holding reserves, in other words, to minimize the probability of running out of reserves when financing is preferred to real adjustment. The constraint is the aim of minimizing costs in the form of lost

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[25] The relationship between net debt (external debt minus reserves) and the level of reserves could be negative if the probability of depletion is dominated by the positive effect of the increased liquidity over the decreased creditworthiness through higher debt to export ratio. However, the results of Edwards (1985) and Landell–Mills (1989) support the positive relationship between the optimal reserves and net debt, as they found a negative relationship between the demand for reserves and the interest rate on the external debt, i.e. the higher the interest rate and the lower the demand for external debt, the lower the demand for reserves.

[26] Comparison made with single country data (Israeli). This could give country-specific results.

earnings. The demand for reserves is expected to be positively related to the probability of running out of reserves and the cost of adjusting if financing is preferred but not possible because reserves are not adequate. Similarly, the required level of reserves is assumed to decrease as the cost of holding reserves rises.

3.2 Previous empirical results and specification of the factors affecting the demand for reserves

The earlier empirical studies have generally explained the level of reserves by the following variables: the variance of disturbances to reserves, the scale of the country, the openness of the economy and the opportunity cost of holding reserves. The variability factor clearly indicates the probability of running out of reserves, as a country with more overall variability in its balance of payments has to hold more financing capability. The scale of the country is most often measured by gross domestic product or income per capita. One would expect that the larger the economy, the greater the absolute level of reserves needed to provide a sufficient buffer stock.

There are two opposing views regarding the openness of an economy. Heller (1966) cited the Keynesian inverse relation between reserves and openness (measured by the marginal propensity to import) based on the idea that a high level of foreign trade is expected to help the adjustment process. However, a second school of thought, led by Frenkel, considers an open economy more vulnerable and expects openness to be positively related to the demand for reserves. Theoretical justification for including the opportunity cost in the model is clear, but as it is very hard to specify, it is rarely seen in estimation models.

In addition to these basic variables, other studies have sometimes added an additional variable to the model in order to test for possible effects on the demand for reserves. The changes in the model have, for example, involved the foreign exchange markets, the money supply and the price of gold.

The previous empirical studies on the reserve level are presented here in a summary table, and the results are analyzed in detail in a discussion of specific variables.

Table 3. **Summary of previous studies**

Author (year)	Dependent Variable – Reserves (R)	Explanatory Variables	Sign if significant (weak or group-related)	Regression Type (estimation method)	Countries	Years	Frequency
Kenen and Yudin (1965)	ΔR	1. reserve change at t-1	+	time-series (AR) cross-section (OLS)	14 Dcs	1958–1962	monthly
	R	1. variance of disturbances 2. per capita income 3. liquid liabilities of a country or money supply	+		- " -	12/1957 and 12/1962	- " -
Courchene and Youssef (1967)	R and R(log)	1. imports or money supply 2. long-term interest rate	+ (+) (–)	time-series (OLS)	9 DCs	1958–1964	quarterly
Clark (1970b)	R	1. time 2. reserves at t-1	na +	time-series	38 LDCs and DCs all together and sub-groups of 17 DCs and 21 LDCs	2/1958–9/1967 in all	monthly in all
	R and R/EX+IM	1. MPI 2. PCI 3. st.dev. of the payments disturbances (per se or scaled like R)	 +	cross-section time-series for the rest			
	Speed of adj.	1. MPI 2. PCI 3. st.dev. of the payments disturbances (per se or scaled w/ population)	(+) (–) +				
	R(log)	1. st.dev. (3. above in log-form) 2. speed of adjustment (log)	+ –		38 DCs and LDCs		

Table 3 continued

Kelly (1970)	R (log)	1. standard deviation of export 2. API 3. opportunity cost all in log-form 4. policy dummies – pegged exchange rate – convertibility of the currency – independent monetary policy	+ (+/–) (+/–) + +	time-series, cross-section, and pooled (w/ year dummies); all together and some groupings (OLS)	46 LDCs and DCs	1953–1965	annual
Archibald and Richmond (1971)	R	1. time 2. reserves at t–1	+/– +	time-series (OLS)	14 DCs	11/1961–5/1967	monthly
Frenkel (1974a)	R (log)	1. API 2. variability measure – variance of the reserve changes 3. imports all in log-forms	+ + +	cross-section and pooled time-series (OLS)	55 LDCs and DCs	1963–1967	annual
Frenkel (1974b)	R (log)	1. API 2. variability measure – variance of the reserve changes 3. imports all in log-forms	+ + +	cross-section and pooled (OLS)	22 DCs and 32 LDCs	1963–1967	annual
Frenkel (1978)	R (ln)	1. variability measure – variance of the reserve changes 2. imports 3. API all in ln-forms	 + + (+)	cross-section and pooled (OLS, SURE and RSURE)	22 DCs and 32 LDCs	1963–1975	annual

Table 3 continued

Bilson and Frenkel (1979)	R (ln) (Δ lnR)	1. variability measure – ratio of the st.error of the reserve changes to imports 2. API 3. GNP all in ln-forms (adjustment significant w/ country-specific factors)	 + + +	pooled cross-section time-series in two groups	22 DCs and 32 LDCs	1964–1972	annual
Frenkel and Jovanovic (1981)	R (ln) R (ln)	1. st.error of the reserve changes 2. opportunity cost (discount or bond yield) 1. and 2. like above 3. level of imports all in ln-forms	+ – +	pooled cross-section time-series (w/ country-specific constants)	22 DCs	1971–1975 1963–1972	annual
Edwards (1983)	R (log) Long-run demand R (log) Short-run desired level	1. GNP 2. API 3. variability measure – ratio of the st.error of the reserve changes to imports. The above model + 4. reserves at t–1 all in log-forms also seperately w/ 5. devaluation dummy (1, the year before)	+ (+) (+) + –	cross-section (OLS) pooled cross-section time-series (Nerlove's 2GLS)	23 LDCs with fixed exchange rate and 18 with devalu-ations	1964–1972	annual
Edwards (1984a)	R (log)	1. GNP 2. API 3. variability measure – ratio of the st.error of the reserve changes to imports 4. reserves at t–1 5. excess money demand all in log-forms	+ + +	pooled cross-section time-series (w/ country-specific dummies; LSDV)	23 LDCs (w/ fixed exchange rates)	1965–1972	annual

Table 3 continued

Edwards (1984b)	R (log) R (log)	1. GNP 2. API 3. st.deviation of exports 1–3 like above + 4. level of debt all in log-forms	+ + (+) (–)	cross-section (OLS) (Fuller–Batesse method)	19 LDCs	1975–1980	annual
Edwards (1985)	R (log)	1. GNP 2. API 3. st.deviation of exports 4. net opportunity cost all in log-forms	+ –	cross-section (2SLS and JGLS)	17 LDCs	1976–1980	annual
Bahmani-Oskooee (1985b)	R (log) R (log)	1. imports (log) 2. API 3. price of gold (log) + supply side included in the 2SLS-version, which gave weaker significances 1–3 like above + 4. reserves at t–1 (log) –> disequilibrium model	+ – – +	pooled cross-section time-series (2SLS and OLS) (OLS)	19 DCs	1972–1977	quarterly
Bahmani-Oskooee (1987)	R (log) R (log)	1. GNP 2. st.deviation of exports 1–2 like above + 3. reserves at t–1 –> diequil.model all in log-forms	+ + +	pooled cross-section time-series (Kmenta's transfor-mation & OLS)	17 DCs and 15 LDCs	1973–1980	quarterly
Bahmani-Oskooee and Malixi (1987)	R (log)	1. GNP 2. BoP variability – st.deviation of exports 3. exchange rate variability – st.deviation of the %-change in the real eff.exchange rate all in log-forms	+ + –	pooled cross-section time-series (GLS ac-cording to Kmenta)	13 DCs	1976–1985	quarterly

Table 3 continued

Bahmani-Oskooee and Niroomand (1988)	R (log)	1. GNP 2. BoP variability – st.deviation of exports 3. real effective exchange rate all in log-forms	+ –	pooled cross-section time-series (Kmenta's transformation & LSDV)	13 DCs	1973–1985	quarterly
Landell-Mills (1989)	R	1. variability of reserves 2. API 3. import 4. net opportunity cost	(+) – + (–)	pooled cross-section time-series (GLS, OLS, OLS w/ country-dummies)	6 DCs, 7 nondebt LDCs and 11 LDCs w/ debt problems after 1982	1978–1986	quarterly
Malixi (1990)	R (log)	1. GNP 2. BoP variability – st.deviation of exports 3. exchange rate variability – st.deviation of the %-change in the real eff.exchange rate 4. reserves at t–1 all in log-forms (w/ country-specific dummies weaker significances)	+ + – +	pooled cross-section time-series (Kmenta's 2GLS w/Instrumental variable estimation, LSDV)	13 DCs and 22 LDCs	1973–1986	quarterly
Ben-Bassat and Gottlieb (1992b)	R (log) R (log)	1. st.error of the reserve changes (log) 2. net opportunity cost (log) 1. st.error of the reserve changes (log) 2. return to alternative investment 3. return on reserves	+ – + – +	time-series (OLS and MA)	Israel	1968–1988	annual

3.2.1 Fluctuations in the level of reserves

The variability of the balance of payments, including capital movements, and weak credibility of a central bank are examples of factors that increase the probability of running out of reserves.

The variability of the balance of payments was incorporated in the models to capture the precautionary motive for holding reserves. Cyclical or random fluctuations in the demand for or supply of traded commodities cause fluctuations in the current account of a country's balance of payments. Similarly, fluctuations in the capital account (examined later) affect the overall balance. The need for reserves increases as the probability of these fluctuations increases, because the probability of financing then increases. A study by Kenen and Yudin (1965) focused on payments instabilities and found the variance of the error term in an estimated first-order autoregressive scheme for the change of reserves to be a significant explanatory variable with a positive sign. The study of Kenen and Yudin met criticism, but the idea of including payments variability as a variable in the function has taken root.

Heller (1966) included the observed imbalance of reserves in his optimality model as a positively-related variable. Clark (1970a) stated that optimal reserves are positively related to payments variability, and Clark (1970b) found strong supportive empirical evidence, as the balance of payments variability was the only significant variable in his demand regression. Kelly (1970) found also support for these results in his empirical study, which obtained a positive relation between the level of reserves and the standard deviation of exports. Archibald and Richmond (1971) estimated the monthly level of reserves, instead of the change as in Kenen and Yudin (1965), and their autoregressive equation obtained satisfactory fits for most of the countries included.

Although the empirical results supported reserve fluctuations as a variable, Niehans (1970) mentioned a number of complicating factors. First, actual changes in reserves reflect measures taken by the authorities as well as the original imbalance. Second, seasonal or technical flows, for example, due to international government borrowing or tax payments, could disturb the data. Third, the sample period should be carefully chosen so as to include the observed underlying shocks, like speculative attacks or devaluation.

Frenkel (1974a) followed Heller's (1966) approach and included the trend-adjusted yearly imbalance of reserves in his regression, finding it significant and positively related to the level of reserves. Frenkel (1974b, 1978 and 1980) found the coefficient for the variability measure significantly higher for developed countries than for LDCs during the era of pegged exchange rates, although it was positive and significant for both country groups over time. Frenkel and Jovanovic (1981) also estimated the variability by a trend-adjusted annual change in the stock of reserves for their optimality model, and the results were again significant, the variability elasticity of reserves being 0.5 on average.[27]

Edwards (1984a and 1985) were among the few studies to find the variability coefficient insignificant, although his studies included only developing countries. However, Bahmani–Oskooee and Niroomand (1988) also obtained an insignificant variability factor for developed countries, although Bahmani–Oskooee and Malixi

[27] Further support for the significance of the variability measure is given by Edwards (1984b).

(1987) had found a variability elasticity of about 0.4 for the developed countries, supporting the results of Frenkel and Jovanovic (1981). The only significant difference between the studies was the evaluation period; Bahmani–Oskooee and Niroomand (1988) used the years 1973–1985, compared to the slightly shorter period of 1976–1985 in Bahmani–Oskooee and Malixi (1987).

Landell–Mills (1989) obtained somewhat surprising results concerning the variability of past reserves in her reserve demand estimations; the relation turned out to be negative in the OLS regression for all countries together. But it became positive after she added country-specific dummies to the model and obtained a better overall fit. More detailed regression analysis showed that the negative sign came from the behaviour of developing countries that did not have debt problems. However, for the debt-problem countries, the variability measure lost its significance.

3.2.2 Adjustment costs

The relative importance of foreign trade and foreign exchange and monetary policies determine the extent of damage the economy incurs if a country utilizes adjustment instead of financing to equilibrate its external balance, even in a situation where financing would be preferred.

The marginal (or average) propensity to import has gained more support in studies of the demand for reserves than has the absolute level of imports. Yet, there is clearly a difference of opinion regarding the direction of the relation. The marginal propensity to import (MPI) gives the portion of income that is spent on imported items; it is a frequently used measure of the openness of a country. According to the Keynesian model it is more troublesome to a country with a very low MPI to run out of reserves and be forced to use aggressive income changes to restore equilibrium to its foreign exchange market (Frenkel (1974a), p. 289).[28] The logic assumes that expenditure switching policy is the utilized means of adjustment, the alternative to the use of reserves.

Clark's (1970a) theoretical optimality formula found the optimal reserve level negatively correlated to the MPI, but his regression analysis of the demand for reserves (Clark (1970b)) found its impact to be insignificant. Kelly's (1970) regression also found the average propensity to import (API, imports to income ratio) positively related to the level of reserves, although his model for the optimal level had indicated a reverse relation. However, separating the different country groups, Kelly (1970) obtained negative signs for the variable.[29]

The price adjustment model introduced in Frenkel (1974a) studies the relation between the average propensity to import, which was often used as a proxy for openness in the empirical studies, and the level of reserves. The analysis relies on

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[28] The goods market is in an equilibrium when output equals the sum of consumption and net foreign trade (exports–imports) and the trade balance is in balance when exports equal imports. The export elasticity of income becomes 1/s+m and of the trade balance s/s+m, which means that the trade deficit induced by the export decline shock, and the need to run down reserves as well, is in an inverse relation to m. Note: the marginal propensity to save is denoted s and to import m. (Frenkel (1974a), p. 290)

[29] He divided the countries according to both per capita income and import/income ratio.

the positive relation between money supply and reserves in a country with a pegged exchange rate and only tradable goods. A shock that reduces foreign demand for domestic products causes the terms of trade to deteriorate, which then dampens real domestic income and the demand for money. Imports become relatively more expensive and the excess demand for foreign exchange (the deficit) is likely to be greater the higher the average propensity to import. He concludes that the positive relation between API and the level of reserve holdings remains plausible as long as the income elasticity of the demand for money does not deviate substantially from unity. Frenkel (1974a, 1974b, 1978 and 1980) also presents empirical results supporting his theory.[30] Accordingly, Hipple (1974) and Iyoha (1976) also agree with Frenkel and interpret the average propensity to import as an estimate of the external vulnerability of a country (Frenkel (1978), p. 113).

Edwards' (1984b) empirical results support a positive relation between the demand for reserves and the openness of a country, which he measured by the average propensity to import. However, both Edwards (1984a) and Edwards (1985) find insignificant openness coefficients, and both Bahmani–Oskooee (1985b) and Landell–Mills (1989) find strong evidence for a negative relation between the demand for reserves and the import to income ratio. Their results concerning the level of imports were traditional: a highly positive relation. Landell–Mills (1989) ran regressions also for country groups[31] and still obtained a highly significant scale factor, but the average propensity to import lost its significance for the debt-problem countries.

The more committed a country is to a fixed exchange rate, the more it needs reserves to maintain equilibrium and prevent market forces from setting a new exchange rate. Theoretically, a clean freely floating exchange rate system would be the other extreme, requiring little or no reserves and no central bank intervention. However, as was discussed in the introduction, the shift to freer floating exchange rates after the collapse of the Bretton Woods system did not dramatically diminish the incentive to hold international reserves.

Kelly (1970) presented a concept of policy dummies, and used a dummy for the commitment of a country to its exchange rate regime. He found it to be significant and positive, supporting the theoretical relation between the exchange rate regime and the level of reserves. Frenkel (1978) analyzed changes in the world monetary system in detail and concluded that the demand for reserves function underwent a structural change by the end of 1972, as pegged exchange rates were abandoned on the way to managed floating. However, the change was found to be insufficient to render estimations made during the pegged exchange rate era irrelevant for the future (Frenkel (1978), p. 127).

Although many studies have divided countries into developed and less-developed countries, Edwards (1983), with good reason, suggests that this type of division might not be sufficient, as it does not include the willingness of countries to use currency devaluation or revaluation as a tool. He uses LDCs in his empirical study, but further divides them according to their foreign exchange policy. His

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[30] Frenkel (1978) obtained a significant positive coefficient for the average propensity to import only for the pegged exchange rate period, up to 1972. Frenkel (1980) got like results using fresh data.

[31] Country groups: industrial countries, developing countries without debt problems and developing countries with debt problems after 1982.

results imply that there is a difference in the demand functions of the two country groups, and that the average reserve levels of the devaluation countries are less. This could be due to a tendency for countries that resort to devaluation to hold reserves only for transaction purposes (not precautionary) or, alternatively, because countries with lower reserves are driven to devalue against their will (Edwards (1983), p. 272–264).

Bahmani–Oskooee and Malixi (1987) included an exchange flexibility variable in the reserves demand equation giving the real level of reserves as a function of real GNP (expected sign +), variability of the balance of payments (+) and exchange rates (–). The variability of exchange rates was measured by the standard deviation of changes (in percentages) in the real effective exchange rate over the preceding eleven quarters and the current quarter. The foreign exchange rate variability elasticity of the demand for reserves was found to be highly significant and negative (around –0.4) using data for 13 developed countries over 1976–1985, which supports the logic that a managed float should lower the demand for reserves as compared to a fixed exchange rate regime.[32]

Bahmani–Oskooee and Niroomand (1988) included the real effective exchange rate in a standard reserves demand equation[33] in order to examine the effects of an exchange rate adjustment on the desired level of reserves. Their results using data from industrial countries supports their analysis; the demand for reserves was found to decrease by approximately a quarter of a per cent as the real exchange rate depreciated by one per cent.

Capital controls were introduced as an adjustment method, as they diminish the variance of the capital account and therefore the probability that a country will run out of reserves. Accordingly, the relation between the need for reserves and the level of capital controls should be negative. In practice, the capital account issue has not been the focus of the empirical studies, except for Kelly's (1970) use of a dummy for the use of commercial policy in a country, i.e. to indicate whether the country has declared its currency "convertible" in the sense that it is unable to restrict trade-oriented currency flows. He found the dummy significant with the expected positive sign. Nowadays, developed countries in particular face increasing degrees of instability due to capital flows rather than the trade flows. Hopefully, future research will pay more attention to this issue.

3.2.3 Opportunity cost of holding reserves

The difference between the interest rate on a domestic investment and the return obtained on reserves is a fairly commonly cited definition of the opportunity cost of reserves, although the empirical constructs are numerous.

Heller (1966) set the opportunity cost of holding reserves arbitrarily at 5 % in his optimality formula, but admitted that it should be measured with more precision. A year later Courchene and Youssef (1967) included the a long-term

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[32] Malixi (1990) used the same basic model, and found significance for the foreign exchange variability for the developed countries.

[33] Other variables were the level of real GNP as an income scale factor and balance of payments variability.

interest rate in their regressions and found its coefficient to be negative in most cases, but significant in only four cases out of nine. Kelly (1970) mentioned the possible use of long bond yields as a proxy for the opportunity cost, but used either per capita income (significant and positive) or the amounts of both foreign assets (significant and positive) and liabilities (insignificant and 'wrong signed' positive) together (to measure indebtedness) as variables in his overall regressions. Several other studies, like Clark (1970a, 1970b) and Frenkel (1978), mentioned the importance of the opportunity cost and its expected negative sign, but did not include it in their analyses because of estimation problems.

Frenkel and Jovanovic (1980) obtained the first significant evidence that the interest rate elasticity of reserves is negative, about –0.25. They used the government bond yield or discount rate as a proxy for foregone earnings, although the method is flawed in that it does not take into account a possible yield on reserve assets. Further, they pointed out the sensitivity of the variable to model specification, which makes their results even more tentative than is generally the case in empirical research.

Edwards (1985) emphasized the fact that reserves are invested to earn interest in the short term, whether in deposits or fixed income instruments, and therefore the real variable for the demand function should adjust for obtained return the marginal social productivity forgone by holding reserves. However, he also pointed out the difficulty in estimating these variables, as there is no reliable data available. Edwards (1985) assumed that the gross forgone income at the equilibrium equals the cost of foreign debt,[34] and so he estimated the spread between a country's borrowing cost and LIBOR[35] as a variable in the reserve demand function. His empirical estimation included 17 developing countries over 1976–1980, and the logarithm of the reserves level was stated as a function of the logarithms of the following variables: GNP (expected sign +), average propensity to import (+), standard error of log detrended export earnings (+) and net opportunity cost (–). Two-stage least squares estimation gave significantly negative coefficients for the net opportunity cost with relatively high elasticities (–2.5 on average), implying significant reserve adjustments as the net cost changes.

Landell–Mills (1989) extended the work of Edwards (1985) and minimized the total cost of reserves, which was defined as the sum of the net opportunity cost of forgone debt repayment (borrowing cost minus the return on reserves)[36] and the cost of forgone reflation of the economy (net deficit divided by the marginal propensity to import, MPI). The modelled country is assumed to be in equilibrium and facing a random deficit varying between zero and infinity. She followed Heller (1966) and obtained a negative relation between the reserves demand and the MPI, as well as the borrowing cost, and an expected positive relation between demand and risk. Her empirical findings also supported the theory and the negative relation

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[34] The underlying principle states that a country will borrow from abroad until the cost of borrowing equals or exceeds the social marginal productivity of the obtained funds (Edwards (1985), p. 289).

[35] London Interbank Offered Rate; the interest London banks charge each other for short-term money. The central banks are assumed to earn the LIBOR on average on their reserves.

[36] The return on reserves was approximated by the U.S. dollar denominated borrowing cost because a large amount of the officially held reserves are invested in U.S. dollars (Landell–Mills (1989), p. 712).

between reserves and the net opportunity cost (opportunity cost of holding reserves), although she found it to be highly significant (elasticity of –0.46) only for those developing countries which suffered from debt problems. In other words, debt problem economies tend to lower their reserves more during tight financial markets than do countries without debt problems.

Ben–Bassat and Gottlieb (1992b) point out the failure of previous studies to measure opportunity cost according to its theoretical definition: the highest possible foregone marginal productivity minus the yield on reserves. They also criticize the use of the interest rate on external debt as a proxy for foregone productivity, as in Edwards (1985), as the actual return on capital is usually higher. This causes a downward bias in the opportunity cost in Edwards (1985) and Landell–Mills (1989). Ben–Bassat and Gottlieb (1992b) estimate the opportunity cost for Israel by a rather complex method. The real rate of return is defined as the ratio of profits to gross capital stock of the business sector, or the rate of return used as a criterian for government infrastructure projects, whichever is higher at any point in time. The real return on reserves was based on the asset composition of the reserves, which was obtained by risk minimization using the import currency mix as a numeraire. For Israel the returns consisted of a weighted average of U.S. dollar and German mark short-term deposit yields. They obtain a significant opportunity-cost elasticity for the demand for reserves (–0.42), which is lower than the results of Edwards (1985) and Landell–Mills (1989), as they anticipated. The significance remained when they further analyzed the opportunity cost in two components: foregone return and yield on reserves.

3.2.4 Scale factors – income and imports

Income level, usually measured by the gross national product, is a scale factor often incorporated into demand models instead of, or in addition to, the level of imports. An increase in the level of real income in the world, ceteris paribus, increases both the demand for and supply of foreign exchange due to increased foreign trade and cooperation among countries. The demand for reserves is also affected for three reasons. First, disturbances often affect the society in proportion to its income level; the higher the income the higher the magnitude of correcting methods needed. Second, through the Phillips curve effect on inflation versus unemployment, the welfare cost of using stabilizing tools other than intervention increases as the income level rises.[37] Third, a higher income also reduces the demand for reserves, due to the lower marginal utility of income. A loss of income does not affect total welfare as much at a higher income level as it does at a lower level. (Grubel (1984), p. 61)

Further, the wealthier the nation the less the social costs for maintaining reserves balance and the greater the speculative investments, which are easy to transfer to other countries when a shock hits the exchange market. For both of these reasons, the demand for reserves and the wealth of a nation, which can be

[37] The Phillips curve states that a lower level of inflation is accompanied by a higher level of unemployment (Barro (1987), p. 455). The higher the real income level (and production capacity) the higher the real loss of output (and employment) in the case of inflationary development, because the price changes affect unemployment proportionately (Grubel (1984), p. 61).

measured by per capita income (PCI), are expected to be positively correlated. (Grubel (1984), p. 62)

Clark (1970a) found the optimal level of reserves to be positively related to the full-employment level of output in his theoretical optimality model. However, in his empirical study (Clark (1970b)) per capita income did not explain significantly the demand for reserves.[38] Kelly (1970) obtained a significant and positive relation between reserve level and per capita income, which, however, disappeared when he split the sample into country groups.

Edwards (1984a) found a coefficient larger than unity for the production scale factor, indicating diseconomies of scale. However, Edwards (1985) presents contradicting results by obtaining scale factor coefficients not significantly different from zero, which points to the importance of the selected time period, as it differs in these two studies. For comparison, Bahmani–Oskooee and Malixi (1987) and Bahmani–Oskooee and Niroomand (1988) again found clear indication of economies of scale, with income elasticity of 0.4 in 1976–1985 and 0.3 in 1973–1985 for developed countries. To sum up, the empirical results for the income variable seem to be quite mixed and affected by methodology and the chosen time period.

The level of imports has been frequently used in models to capture the essence of reserves as a means of financing international transactions, although the reserves are not utilized for financing the trade itself but rather the imbalances, which might also occur solely from the capital account side of the balance of payments.

In Courchene and Youssef (1967) the level of imports was found to be a positive and significant factor with a coefficient less than unity.[39] Also Frenkel (1974a) found evidence of a positive relation between reserves level and imports; he obtained an average import elasticity of 0.6. However, in Frenkel (1974b), where the analysis was done for developed countries and LDCs separately, the level of imports was found significant only for LDCs. Later on, Frenkel (1978) obtained a positive and significant imports coefficient also for developed countries separately, although the magnitude was smaller than for LDCs.[40]

3.2.5 Additional factors affecting demand

Money supply, price level factors, the foreign debt issue and the role of invoicing currencies in foreign trade are discussed briefly in this section, as they do not fit readily into the above variable categories but are nonetheless closely related to the demand for reserves.

Although in the early Keynesian period more attention was paid to the actual volumes of trade, some authors like Scitovsky and Johnson developed the relation

[38] Kenen and Yudin (1965) had not found PCI to be significant either.

[39] Niehans ((1970), p. 77) pointed out that the results of Courchene and Youssef might be biased, as reserves as well as the imports grew steadily during the estimated period, most likely due to factors external to the model.

[40] Frenkel's study with fresh data in 1980 found the scale factor positive and significant, but not different for the two country groups during the managed float.

between money supply and reserves further in the late 1950s (Niehans (1970), p. 60–62). Scitovsky developed a formula for the minimum ratio of reserves to money supply from the Keynesian foreign trade model.[41] The greater the share of expenditure allocated to imports, compared to domestic goods, the higher the required ratio of reserves to money supply, because a greater share of money demand is foreign originated and requires reserves. On the empirical side, Courchene and Youssef (1967) found the money supply variable to be more significant (with the expected positive sign) than the level of imports, which at that time was a major focus of attention in studies.[42]

Almost two decades later Edwards (1984a) developed the issue slightly further and included in his model a variable describing the degree of monetary equilibrium (the difference between the long-run demand for money and the actual stock), which turned out to be significant. He integrated the idea of early studies on the demand for reserves as a function of the difference between actual and desired reserves and the monetary approach to the balance of payments, which treats the level of reserves as a residual. The reserve changes were seen to be a joint function of the monetary authority's excess demand for international reserves and the public's excess demand for money. The empirical results using data from developing countries with fixed exchange rates (1965–1972) show monetary disequilibrium to be a significant predictor of movements in reserves, with a positive coefficient, along with real income and the actual starting level of reserves. The outcome shows that if there is excess demand for money in the economy, the level of reserves tends to increase, and vice versa. A one per cent excess supply of money is estimated to reduce the level of reserves by 0.3 per cent.

During the 1960s and 1970s the concept of inflation was introduced as a factor affecting (decreasing) the demand for money. An expectation of high inflation would seem to decrease the willingness to hold money as well as reserves (Grubel (1984), chapter 8). On the other hand, domestic inflation reduces the demand for domestic money and thus could increase the need for foreign reserves, which hold their value better.

Edwards (1984a) pointed out the problem of choosing between nominal and real variables in the equation. He used real variables in his studies, basing his choice on the demand for reserves stemming from real needs. Bahmani–Oskooee and Malixi (1987) also argue in favour of real reserves, based on the Saidi's (1981) proposition that price level movements imply a one-to-one proportionate change in nominal reserves. Briefly, most of the authors (Edwards, Bahmani–Oskooee, Malixi, Ben–Bassat and Gottlieb) who have studied this subject recently tend to favour real variables.

Terms of Trade is the relationship between the prices of exports and the prices of imports; it changes in line with the relative price of exports. The lower the terms of trade the less the country can import, in volume terms, against a given volume of exports. The absolute value of the terms of trade reflects the reserves

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[41] Scitovsky (1958) formulated the optimal level of reserves under certain assumptions: $R = M^s m/(s+m)$, where M^s is the money supply, m marginal propensity to import and s marginal propensity to spend domestically. The level of reserves is positively related to both money supply and the propensity to import. (Frenkel (1974b), p. 22)

[42] Kenen and Yudin (1965), however, had not found any relevancy for the money supply variable.

demand functions through the price and foreign trade levels, if these are taken into account. However, the variance of the terms of trade might be treated as a separate variable, as it implies variability in foreign trade income; the higher the variance the more reserves are needed. In the empirical applications, it is not used as a variable in traditional demand functions.

Foreign debt as an adjustment method to a balance of payments imbalance has thus far been more or less disregarded in theoretical analysis as well as in previous empirical studies (except in optimality models). However, I would like to note briefly the study of Edwards (1984b), which considered side-by-side the use of reserves, debt and devaluation or revaluation as adjustment methods. He ran a regression for the demand for reserves taking into account the external debt demand function at the same time. He got support for the substitutability of reserves and debt, although the significance was not very high. His later study, Edwards (1985), focused on the net opportunity cost issue, but spread the implications to the debt level by launching the idea of reserves and debt as "complements", as the relation between the reserves and the cost of foreign debt was negative.

Finally, I say a few words about vehicle currencies in international trade and their effect on the demand for reserves in different countries. Grilli and Roubini (1990) discusse the issue based on invoicing data for exports and imports, mainly for the late 1970s, and cite the US dollar, the German mark, the Swiss franc and the British pound as significant vehicle currencies. The US dollar is used in 55 per cent of exports and 54 per cent of imports and the German currency ranks second with 14 per cent of exports and imports. Further, Germany utilizes its own currency for 82 per cent of its exports and 43 per cent of its imports, whereas Finland's shares are the lowest, only 2 per cent and 3 per cent respectively. For comparison, Italy has the second lowest figures, 31 per cent and 9 per cent.

Grilli and Roubini ((1990), p. 40) also mention that clear evidence has been found for high correlation between reserve currencies and invoicing currencies. So, although it was previously argued that countries acting as suppliers of reserves might have greater demand for reserves (see Footnote 11), the above analysis implies that a supplier country could actually hold less reserves than countries doing small amounts of trade in their own currency because the former does not need reserves for the foreign trade. This line of reasoning would also indicate that Finland would demand relatively more reserves than other countries on average.

4 Empirical application of the reserves model

4.1 Empirical problems concerning the reserves demand equation

Using empirical data to donstruct a function for the demand for international reserves involves a number of problems. First, "ex post" data cannot reflect the actual behavioural pattern behind the figures.[43] Already Kenen and Yudin

[43] Grubel ((1984), p. 65), Heller ((1966), p. 310) and Frenkel ((1974b), p. 15).

((1965), p. 243) noted that changes in real reserves, used as a proxy for imbalances, include the possible effects of adjustment measures and interventions. Archibald and Richmond ((1971), p. 257) were among the first to note the difficulty of including the value of swap agreements in the analysis, which further widens the discrepancy between the actual data used and the original disturbance in the level of reserves.

Second, the variables tend to have high multicollinearity[44] (Grubel (1984), p. 65), and the statistical properties of the error terms violate the basic assumptions of the Ordinary Least Squares method,[45] which makes the statistical analysis difficult, and the conclusions less reliable. The presence of multicollinearity would jeopardize the consistency of the OLS method and is therefore more serious than autocorrelation or heteroskedasticity, which only reduce the efficiency of the model. Bahmani–Oskooee (1987) investigated the possibility of taking into account possible serial correlation and heteroskedasticity when using pooled cross-section and time-series data. Most of the prior studies had simply assumed that the error terms were homoskedastic across countries and serially uncorrelated within a country so as to be able to use OLS. He found both serial correlation (Durbin–Watson test for each section) and heteroskedasticity (Bartlett's test) in his demand function, which used real income and variability of the balance of payments as regressors. He adjusted the model using Kmenta's method,[46] which changed the coefficient for income quite significantly: income elasticity for LDCs dropped by 0.1 to 0.4 and for DCs it increased by 0.3 to 0.8.

Courchene and Youssef (1967) mentioned the third problem: modelling the demand side apart from the supply of reserves. The identification of the demand function becomes difficult, as some of the relevant variables would also affect the supply side but with an opposite sign. However, by assuming that countries are always on their demand curves and that the need for reserves is stable, they felt comfortable in analyzing the demand side only. Bahmani–Oskooee (1985b) included the supply side in his model to avoid the usual assumption of elastic supply. In his model the supply of international reserves was dependent on the price of gold, as well as the return on investments, the price level and real income in the United States relative to the rest of the world. Further, the demand for international non-gold reserves was a function of imports, average propensity to import and the market price for gold. He made a comparison of results using two-stage least squares and ordinary least squares with pooled data from 19 developed countries (1972–1977) focusing on the gold price elasticity. He found the elastic supply assumption justifiable but preferred 2SLS to OLS because of the unbiasedness and a better fit obtained (Bahmani–Oskooee (1985b), p. 502).

The approach to these problems is very conservative in this study; the data have been used in raw form, and no attempt has been made to include the effects of swaps or similar "distractions" in the "ex post" figures; similarly, the supply has

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44 Multicollinearity means that there is high correlation among the dependent variables or linear combinations thereof.

45 See for example Kim (1989), p. 6.

46 Method applied according to Kmenta, J. (1971) Elements of Econometrics, Macmillian, New York, p. 508. Later in this study the adjustments are based on the new edition of Kmenta's book.

been assumed elastic. The section on estimation will explain the efforts made here in connection with the statistical problems.

4.2 Focus and limitations of the empirical study

The model includes the probability of using reserves, the cost of running out of reserves when they are needed and the opportunity cost of holding them, as presented in the theoretical framework. Special attention has been devoted to the possible impact of the foreign exchange regime or convertibility of the domestic currency on the level of reserves as well as to a comparison of developed and less-developed countries. Further, the model is used to simulate reserve levels for Finland and, for the sake of comparison, Germany, which are compared with observed levels for the period 1975–1991.

As large a set of observations as possible from different countries was included to cover the world reserves, which on the other hand eliminated the use of some very interesting variables, such as the credibility of the chosen exchange rate system and the flexibility of domestic wage and price levels. The target zone credibility has been studied systematically for small homogenous country groups, but the methods are too complicated to be employed in a world-wide model as used here.[47] An increase in domestic wage and price flexibility or in the mobility of production resources, is expected to increase the ability of a country to survive external shocks and to decrease the demand for reserves (Grubel (1984), p. 62). However, the flexibility data could not be easily obtained for such a large data set and are therefore left out of this study, as is target zone credibility.

4.3 The basic model estimated in the study

Generally speaking, the previous literature has assumed the demand for international reserves to be dependent on a reserves variability factor, size of the country, degree of openness of the country and the cost of holding reserves. The basic model of this study has been built along these lines, though with slightly different formulations. The basic equation explains the level of international reserves relative to gross domestic product by the country's level of wealth, the openness of its economy, the variability of its balance of payments (probability of running out of reserves), the lagged dependent variable, the domestic level of interest rates (opportunity cost) and the growth rate of the domestic monetary base (ability of the domestic currency to maintain its value).[48] Simply, the demand for reserves takes the following form:

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[47] For details, see Svensson (1991), Bertola and Svensson (1991) and Geadah, Saavalainen and Svensson (1992).

[48] The money growth instead of the inflation rate was chosen for the basic model because it had more explanatory power than did inflation calculated from the GDP (or CPI) deflators. The inflation alternative will be presented in the alteration regressions.

$$\left(\frac{R}{GDP}\right)_{nt} = \beta_0 + \beta_1 INCOME_{nt} + \beta_2 TRADE_{nt} + \beta_3 VARIABILITY_{nt} + \beta_4 INTEREST_{nt} + \beta_5 MONEYG_{nt} + \beta_6 \left(\frac{R}{GDP}\right)_{nt-1} + u_{nt} \tag{17}$$

R/GDP = level of the nominal reserves including gold relative to the nominal gross domestic product
INCOME = GDP in US dollars divided by the population (level of wealth)
TRADE = the sum of nominal exports and imports in US dollars divided by GDP (openness of the economy)
VARIABILITY = balance of payments variability (probability of running out of reserves)
INTEREST = domestic short-term interest rate level (opportunity cost)
MONEYG = growth rate of narrow money (measured in domestic currency)
u = random error
t = time period, t = 1975, 1976, ..., 1991
n = country, n = 1, 2, ..., 56[49]

The level of reserves, trade and overall balance are scaled by GDP, income is scaled by population, and interest rate and money growth are percentage figures, which allows comparison across countries and over time. Several earlier studies did not use pooled data, but ran either cross-section or time-series regressions, which did not require comparability for all data. The earlier pooled regressions have often used country-dummies to capture the special features of a country and to make the data comparable across the whole set of observations. With an extensive number of observations and countries, as in this study, scaling of variables is preferred to country-dummies, which would complicate the data set calculations.

Two dummy variables were included in the model from the beginning in order to eliminate two types of exceptions in the data. The first dummy represents the Unites States (DUS), which acts as a major supplier of reserves and has a freely floating currency, and might therefore have slightly different variables in its demand function or at least a lower overall demand compared to other countries, as discussed earlier. The second dummy represents the two financial centers included in the data set, Switzerland and Singapore (DFinCenter).

The coefficient for the lagged dependent variables is, of course, expected to have a positive sign. The level of income, share of foreign trade and the variability variables are also expected to have positive coefficients, as is money growth because a larger money supply increases the probability of a balance of payments deficit, which further increases the demand for reserves. The interest rate variable is expected to have a negative coefficient.

[49] For exact construction of the data, data sources and country lists, see Appendix 3.

5 Estimation results

5.1 Methodology and regression result tables

The basic equations are estimated using annual cross-section and time-series data over the period 1975–1991 for 22 developed countries and 34 less developed countries, listed in Appendix 3. The total number of observations, after omitting some missing values from the time series, is 903.[50] However, for the country group equations the number of observations is 357 for the developed countries and 530 for the less developed countries. Appendix 5 (figures A–J) illustrates the data for each variable used, giving the mean over the estimation period for every country in the sample.

The econometric computer program SHAZAM, version 7.0 was used in all the estimations. The results are presented in three tables: Table 4 gives the results from the basic unweighted Ordinary Least Squares regressions as well as from the weighted regressions of the basic model (regressions 1–6), Table 5 gives the different variable experiments for the basic OLS regression (regressions 7–12) and, finally, Table 6 gives the equation results after dividing the data into developed and less developed countries (regressions 13–18).

In the Weighted Least Squares regressions in Table 4 every observation of the dependent and independent variables is multiplied by the square root of the weight variable, which is either GDP or the sum of imports and exports. Figures K, L and M in the Appendix 4 show the absolute levels of reserves, GDP and the sum of imports and exports for each country. The countries are ordered by decreasing level of reserves in all three figures. As can be seen, both the GDP level and the sum of imports and exports seem to correlate with the level of reserves, which makes them fairly natural weights for regression analysis aimed at dampening the impact of countries holding a very small fraction of world reserves, and strengthening the impact of countries that contribute more to the demand for reserves in the world.

[50] Detailed statistics about the data sets for each country, from where the incomplete series can be seen, are available upon request.

Table 4. **Basic model – Unweighted and Weighted Least Squares regressions for the level of reserves relative to GDP**

Regression	1.	2.	3.	4.	5.	6.
	Unweighted OLS		GDP-weighted		Trade-weighted	
Regressor						
Constant	-.521	-.521	-.181	-.180	-.356	-.357
	(-2.03)	(-2.03)	(-1.38)	(-1.37)	(-2.37)	(-2.37)
INCOME	-.018	-.018	-.005	-.006	-.010	-.011
	(-1.64)	(-1.67)	(-.98)	(-1.00)	(-1.41)	(-1.45)
TRADE	2.365	2.364	1.101	1.096	.865	.864
	(4.45)	(4.45)	(4.56)	(4.53)	(4.06)	(4.05)
VARIABI-	-.287	-.293	82.356	82.144	75.934	75.714
LITY	(-.01)	(-.01)	(2.70)	(2.69)	(2.51)	(2.50)
$(R/GDP)_{-1}$	.894	.894	.926	.926	.975	.975
	(36.32)	(36.28)	(64.40)	(64.36)	(76.46)	(76.44)
INTEREST	-.006	-.006	-.005	-.005	-.006	-.006
	(-2.69)	(-2.69)	(-2.27)	(-2.27)	(-2.00)	(-2.00)
MONEYG	.023	.023	.016	.016	.020	.020
	(2.44)	(2.44)	(4.46)	(4.46)	(4.23)	(4.22)
DUS	.436	.441	.132	.135	.363	.368
	(2.38)	(2.39)	(1.52)	(1.54)	(2.76)	(2.79)
DFinCenter	1.274	1.277	.800	.782	.494	.497
	(1.86)	(1.86)	(2.05)	(2.06)	(1.33)	(1.33)
DFinland		.088		.219		.327
		(.25)		(.50)		(.68)
R^2 adj.	.945	.945	.944	.944	.978	.978
SEE	2.446	2.448	1.032	1.032	1.358	1.358
DW	1.72	1.72	1.80	1.80	1.81	1.82
h-test	4.45	4.44	3.06	3.06	2.83	2.82
H1	63.42	63.42	72.36	72.38	57.01	57.02
H2	185.12	185.44	296.41	296.04	284.80	284.54

Number of oservations: 903.
Sample period: cross-section time series 1975–1991.
t-ratios of estimates are in parentheses.
Critical t-values: 1.645 (5 % level of significance) and 2.326 (1 % level of significance).
Variable descriptions: Appendix 3.
SEE = the standard error of the estimate
DW = Durbin Watson statistic for autocorrelation
h-test = Durbin's h statistic for autocorrelation when the regression includes the lagged dependent variable
H1 = χ^2 statistic for heteroskedasticity on $\hat{Y}^2$
H2 = χ^2 statistic for heteroskedasticity on X, according to Breusch–Pagan–Godfrey

Table 5. **Basic model with alterations – regressions for the level of reserves relative to GDP**

Regression	7.	8.	9.	10.	11.	12.
Alteration to regression 1.	INFLATION instead of DELTAM	IMPORT instead of TRADE	$DINV_{-1}$ added	$PFINV_{-1}$ added	D1 added	D2 added
Regressor						
Constant	-.349	-.377	-.511	-.473	-.544	-.560
	(-1.54)	(-1.47)	(-2.00)	(-1.83)	(-1.78)	(-2.07)
INCOME	-.021	-.011	-.002	-.021	-.017	-.019
	(-1.92)	(-1.00)	(-.13)	(-1.90)	(-1.35)	(-1.71)
TRADE	2.300		2.145	2.296	2.375	2.401
	(4.31)		(4.07)	(4.37)	(4.41)	(4.46)
VARIABI-LITY	-.847	-3.631	.792	1.149	-.356	-.386
	(-.04)	(-.18)	(.04)	(.06)	(-.02)	(-.02)
$(R/GDP)_{-1}$	.899	.908	.883	.890	.894	.895
	(36.17)	(34.43)	(34.09)	(35.64)	(36.69)	(36.12)
INTEREST	-.004	-.007	-.006	-.007	-.006	-.006
	(-2.32)	(-2.69)	(-2.67)	(-2.75)	(-2.69)	(-2.70)
MONEYG		.023	.023	.024	.023	.023
		(2.41)	(2.43)	(2.45)	(2.44)	(2.45)
DUS	.379	.248	.216	.420	.441	.351
	(2.12)	(1.52)	(1.05)	(2.27)	(2.32)	(1.71)
DFinCenter	1.156	1.510	1.291	1.873	1.277	1.162
	(1.66)	(2.13)	(1.87)	(2.31)	(1.88)	(1.58)
Variable in column heading	.013	3.295	18.151	12.063	.035	.134
	(2.35)	(3.40)	(1.88)	(2.66)	(.163)	(.66)
R^2 adj.	.944	.944	.946	.946	.945	.945
SEE	2.468	2.476	2.439	2.439	2.447	2.447
DW	1.71	1.72	1.73	1.72	1.72	1.72
h-test	4.53	4.42	4.36	4.42	4.54	4.43
H1	61.18	63.07	65.98	61.61	63.42	63.66
H2	178.07	187.00	194.85	185.70	189.35	186.66

Notes as in Table 4.

Table 6. **Regressions for industrialized countries – comparison of OLS and pooled cross-section time series regressions for the level of reserves relative to GDP**

Regression	13. OLS	14. OLS	15. OLS	16. POOL	17. POOL	18. OLS
Description	Basic model – DCs	DFinland added – DCs	D1 & D2 added – DCs	15. pooled – DCs	DFinland added – DCs	Regres-sion 15. – LDCs
Regressor						
Constant	−.001 (−.00)	−.005 (−.01)	.916 (2.33)	.534 (2.02)	.547 (2.05)	−1.229 (−2.33)
INCOME	−.008 (−.66)	−.008 (−.64)	−.035 (−2.48)	−.005 (−.56)	−.004 (−.51)	−.044 (−.43)
TRADE	1.173 (1.92)	1.180 (1.91)	.509 (.90)	.596 (1.68)	.597 (1.68)	3.787 (3.55)
VARIABI-LITY	665.34 (2.12)	667.26 (2.13)	717.41 (2.46)	863.81 (5.50)	870.19 (5.52)	−6.827 (−.34)
$(R/GDP)_{-1}$	.881 (17.47)	.880 (17.21)	.857 (16.99)	.841 (31.74)	.839 (31.35)	.876 (30.74)
INTEREST	−.006 (−.34)	−.007 (−.36)	.006 (.31)	−.008 (−.73)	−.008 (−.77)	−.006 (−2.37)
MONEYG	.017 (1.64)	.017 (1.64)	.022 (2.25)	.015 (2.26)	.015 (2.26)	.025 (2.24)
DUS	−.010 (−.05)	−.018 (−.09)	.232 (1.09)	−.011 (−.09)	−.015 (−.12)	
DFinCenter	1.024 (1.30)	1.026 (1.30)	2.127 (2.45)	1.870 (3.47)	1.890 (3.49)	−.995 (−.42)
DFinland		−.084 (−.25)			−.203 (−.47)	
D1			−1.025 (−3.21)	−.265 (−1.21)	−.260 (−1.18)	.233 (.896)
D2			−.776 (−3.08)	−.439 (−2.99)	−.450 (−3.03)	.530 (1.53)
R^2 adj.	.906	.906	.910	.975	.975	.949
SEE	1.545	1.547	1.511	.578	.528	2.887
DW h-test	2.04 -.38	2.03 -.36	2.05 -.49	1.82 .05	1.82 .06	1.66 n.a.
H1 H2	64.49 159.47	64.53 161.74	59.87 151.37	68.40 155.75	68.51 159.40	37.75 114.36

Number of observations: 357 for developed countries, 530 for LDCs.
In the R^2 adj. row, regresssion 16 and 17 have the Buse Raw-moment R^2. The Buse R^2 value is 0.538 for both regressions. For the formulas, see SHAZAM (7.0) – User's Reference Manual p. 243.
Other notes as in Table 4

As discussed earlier, the variables in the equations are scaled to make the observations comparable across countries and time series, because country-dummies are not used. In order to include cross-section-specific effects in the model by applying the pooling method in SHAZAM, the time series for each unit (country) have to be of equal length. Hence, the test has been applied only to the developed countries in the sample.[51] The method used by Kmenta is capable of handling a model that is both cross-sectionally heteroskedastic and timewise autoregressive,[52] although in this particular study the autoregression coefficient, rho, is set to zero because the sample does not suffer from excessive autocorrelation according to the analysis using the basic OLS estimation (regression 15 in Table 6). So, Kmenta's pooling method in regressions 16 and 17 in Table 6 allows cross-section heteroskedasticity but not timewise autocorrelation.

5.2 Statistical properties of the model

The presence of multicollinearity, autocorrelation and heteroskedasticity in the basic estimation (regression 1) is analyzed in detail, and, as all the subsequent regression results turn out to have similar statistical characteristics, separate analysis of them was not considered necessary.[53] First, the multicollinearity of the basic model is studied with the help of a table showing the coefficients of determination for each regressor against all other dependent variables.

Table 7. **Test of multicollinearity for the basic model**

Regressor tested on other independent variables	R^2-value
INCOME	0.7710
TRADE	0.9781
VARIABILITY	0.9086
$(R/GDP)_{-1}$	0.9828
INTEREST	0.9207
MONEYG	0.9777
DUS	–0.7918
DFinCenter	0.9350

Based on the output of the first regression in Table 4.

[51] Excluding Belgium, which did not have money data for the whole period.

[52] For a description of the method, see Kmenta ((1986), pp. 616–622).

[53] As an exception to this statement the regression results for the developed countries only (regressions 13–17 in Table 6) did not suffer from autocorrelation as did all the other estimation results.

The above table gives the R^2-values for regressions where each independent variable, one at a time, is explained by the other regressors. The explanatory power in each regression seems to be relatively high, indicating possible multicollinearity or spurious regressions problem, which simply means that two random walk variables can have a high correlation even if there is no real explanatory power in the relation.[54] However, the correlation matrices for both the basic regression 1 and regression 13 presented in Appendix 5 do not indicate systematically high correlations between the independent variables. The only relatively high correlations there (disregarding the lagged dependent variable) are between money growth and interest rate level (0.69 and 0.42). Although the results indicate some multicollinearity, the tests are not clear cut and, as the sample size is very large, the results can be analyzed bearing in mind the possible inconsistency.

The bottom part of the regression tables lists test statistics for the fit of the model, autocorrelation and heteroskedasticity. To start with, the presence of autocorrelation is usually tested using the Durbin-Watson statistic, as is done here also, but the Durbin's h-test is used as well, as it was developed especially for models where the lagged dependent variable is a regressor.[55] Indication of residual autocorrelation is provided by the value of the Durbin's h-test, 4.45, which is clearly significant at the conventional significance level. The Durbin-Watson d-test value, 1.72, falls in the inconclusive test region and is therefore an unreliable test for this model.[56]

The tables also present two heteroskedasticity tests for each regression, both of which indicate that there is also a need to correct the t-statistics for heteroskedasticity.[57] So, the autocorrelation and heteroskedasticity correction procedure developed by Newey and West (1987) and available in SHAZAM was implemented in all regression estimations in this study,[58] except for the weighted estimations (regressions 3–6) and Kmenta's pooling method (regressions 16–17), where the option was not available.

To analyze the fit of the model, the perspective has to be widened from the basic regression results to include the other estimations as well. Looking at the explanatory power (R^2) and the standard error of the estimate (SEE) in all three regression tables, the following features stand out. First of all, the overall R^2 for the basic OLS model (regressions 1–2 and 7–12) is very high, 94.5 per cent, considering the great variety of countries included in the sample. Similarly, the SEE for the above basic regressions is only 2.4 per cent on average, which indicates fairly narrow confidence intervals. The use of a weight and the pooling for a smaller group of countries both diminish the outlier effect and the effect of

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[54] Granger and Newbold (1977) discuss this on pages 202–214.

[55] For details, see Kmenta (1986), p. 333–334.

[56] DW-limits: $d_L = 1.686$ and $d_U = 1.852$ at 5 % significance, h-test: standard normal distribution limit 1.96 at 5 %. These numbers as well as all figures from statistical tables are from the Statistical Tables in Kmenta (1986), pp. 758–770.

[57] Critical values of chi-square for the basic estimation: H1 – one degree of freedom, 3.841 (5 % level of significance) and 6.635 (1 % level of significance); H2 – degrees of freedom is eight, critical values 15.507 (5 %) and 20.090 (1 %).

[58] The greatest required order of autocorrelation was set to one.

intra-country differences in the equations equally as much. Therefore, the SEEs for the weighted regressions (numbers 3–6) and the OLS regressions for the developed countries (13–15) are lower, ranging from 1.0 per cent to 1.5 per cent. Regressions 16 and 17 have extremely low SEEs, 0.6 per cent and 0.5 per cent, as they use the pooling method allowing for heteroskedasticity, which dampens the variance of the errors. As an exception to the above argument, the SEE for the less developed country regression (number 18 with SEE of 2.9 per cent) exceeds the SEEs for the basic model alterations with all observations, which might indicate that most of the data outliers are in the LDC data. This agrees with intuition in light of the more developed and accurate statistical methods used in the developed countries. To sum up, the model seems to fit the data very well, taking into account the wide range of countries included in the sample, and the confidence intervals for the dependent variable also become reasonably narrow, especially using Kmenta's pooling method for developed countries.

5.3 Analysis of coefficients in the basic model

The estimation results for the basic equation can be seen in the first column of Table 4. The openness of the economy, the money growth and the lagged dependent variable all had the expected positive sign and were highly significant. Also, the interest rate level was highly significant, with the expected negative sign. On the other hand, the coefficients of per capita income and the balance of payments variability were both insignificant and had a wrong (negative) sign. Of the two dummies included in the basic equation, only that for the United States was significant, with a positive sign; the dummy for the financial center was positive but insignificant. The positive sign for the Unites States dummy seems to indicate that the role of the U.S. as a major supplier-backer of dollars abroad would dominate the effect of foreign trade which is invoiced mostly in dollars, and therefore should decrease the U.S. demand for reserves.

The coefficient for the lagged dependent variable is 0.89 for the basic equation, which indicates fairly slow adjustment in the level of reserves whenever the country faces a discrepancy between its actual and optimal levels of reserves. Alternatively, the high coefficient could indicate that there are non-economic factors, such as political psychology, for example, affecting relative reserves, which could be incorporated in the model. Further, the high significance level and the fact that the coefficient approaches unity in some of the regressions might indicate unit root behaviour for relative reserves. However, as the coefficient is under one in all regressions, the stationarity of the dependent variable is assumed to be a fair starting assumption.

The coefficient for the trade share shows that, ceteris paribus, the reserves to GDP ratio increases by 0.024 percentage point when the share of foreign trade from the GDP increases by 1 percentage point in the short run. However, the long-run coefficient is 0.22.[59] The coefficient of the opportunity cost (interest rate level) is fairly low: an increase of 1 percentage point in the rate decreases the percentage point share of reserves in the short run only by 0.006. Even the long-

[59] The long-run solution is calculated by multiplying the coefficient of the variable by $1/(1-b_6)$, where b_6 = the coefficient for the lagged dependent variable, 0.894 in this case.

run interest rate coefficient of 0.06 seems to be low, but it should be compared with the sample average value of the level of reserves relative to GDP, which is 9 %. Moreover, the result is qualitatively similar to the result obtained in other studies. The money growth coefficient is 0.023 in the short-term and 0.22 in the long-term, indicating that in the long-run a 1 percentage point increase in the money growth rate would increase the reserve share need by 0.2 percentage point. The next section evaluates whether the extensions of the basic model change the results in any significant way.

5.4 Coefficients in the extensions of the basic model

The weighted models continue to have significant interest rate coefficients with a negative sign, and a positive sign for trade, lagged relative reserves and money growth, with even greater significance than in the basic model and, again, an insignificant and wrong (negative) sign for income. However, the variability of the balance of payments becomes highly significant and positive, which is consistent with the a priori theoretical sign. Another notable change is in the coefficient for the lagged dependent variable, which rises to 0.93 (GDP weighted) and 0.98 (trade weighted), indicating even slower adjustment to a new level of reserves than first seen in the basic regression.

Whereas the extensions to the basic model discussed above are simply methodological in nature, Table 5 lists some regressions with alternative or new variables in the basic model. Regression 7 has an inflation measure calculated from the deflators instead of the amount of money, which does not change the results significantly but has less explanatory power than the model including the money growth. Previous studies have used the average propensity to import as a variable for the openness of an economy. However, the country-specific regressions in this study indicate that the trade propensity has more explanatory power than the import propensity,[60] and therefore the trade-ratio has been chosen for the basic openness variable. For the sake of comparison, the trade propensity was replaced by the import propensity in regression 8, which did not change the results significantly.

As mentioned earlier, special attention should be paid to the foreign exchange regime and capital movements. In order to analyze the effect of capital flows, the volume of investments into and out of the country should, of course, be examined. The only available investment data for this study is in net form, which is unfortunate as it does not capture the actual effect of volumes but rather has an impact on reserves by definition. The net amount of direct investments (DINV) and portfolio investments (PFINV) as included in the regression have been lagged to correct for the bias. It should be noted, however, that, for example, in the case of Finland during the last few years, relatively large capital imports by the government increase the level of reserves directly, and this dominates the net portfolio investment figures. Regressions 9 and 10 show the effects of adding the two lagged investment variables to the model. The only (and minor) difference

[60] The regression run for each country was simplified to include only the lagged dependent variable, variability and openness as regressors. Openness was measured by both trade and import propensity: TRADE was significant and positive in 16 cases out of 56 countries, IMPORT in only 8 cases.

with respect to the core variables is the change of sign in the variability variable, although it still remains insignificant. Both investment variables appear to be significant (portfolio investments even at the one per cent level) and positive.

To incorporate a variable for restrictions on capital movements, a dummy for the inconvertibility of a country's currency has been formulated according to the status of a country at the International Monetary Fund. The dummy value D1 = 1 is assigned for all the years for which a particular country did not have a convertible currency and therefore could not have had well-functioning capital markets. The coefficient is expected to be negative, as a country with very restricted exchange markets does not need reserves to buffer nonexistent flows. Regression 11, however, shows that the coefficient for D1 is positive and insignificant for the sample including all countries.

Further, to capture some evidence of the impact of the country's exchange rate regime on its demand for reserves, a dummy was triggered for each period in which a country had an independently floating currency. The classification of exchange rate regimes was taken from the Exchange Arrangements and Exchange Restrictions – annual reports produced by the International Monetary Fund, based on yearly country analysis. However, the classification is not straightforward, or totally without subjective bias, which means that this dummy suffers from severe measurement error and might produce unreliable results. As has been argued in the theoretical section of this study, a country with freely floating currency should not need any reserves, which means that the coefficient for the dummy, D2, should be negative. Again, as for D1, the basic regression gives an insignificantly wrong sign, although both dummies are significant in the regression for the developed countries, to be reviewed next.[61]

As a final variation the model was applied only to the developed countries, and the results can be found in Table 6. The most striking differences are the significance of the volatility variable with the right (positive) sign, and the significance of the dummies describing the status of the present exchange rate regime. The inconvertibility dummy (D1) and the floating dummy (D2) both appear with the right (negative) sign and are both significant in OLS regression 15, although only the floating dummy remains significant in the regression pooled according to the Kmenta's method.

5.5 Results for Finland

The level of reserves in Finland during the estimation period is studied in two ways. First, most of the regressions are also run with a dummy for Finland (DFinland in the tables), the sign and value of which is observed, and, secondly, ex post simulation is employed to examine the statistical performance of the model and to compare the actual reserve levels with both static simulation and long-run

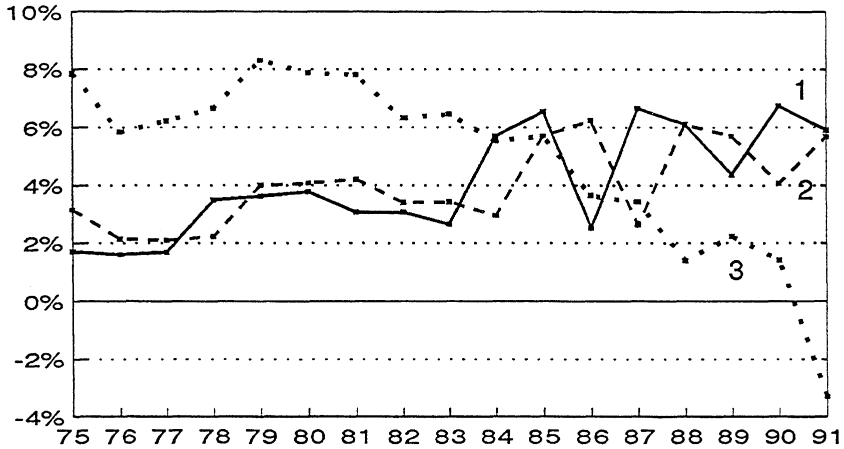
[61] In addition to the alterations analyzed here and presented in the tables, several others were also examined but not considered worth extensive evaluation, as they were insignificant and did not alter the results. Dummies for Newly Industrialized Economies, OECD countries as well as for countries with very low average income for the period (less than 1000 USD per capita) and with medium income (5000–1000 USD per capita) were added, but found insignificant for the model. As an additional variable the absolute GDP level was also found insignificant.

solution estimates. For comparison, the simulation experiments are also carried out for Germany.

The coefficient of the Finland dummy is not significantly different from zero in any of the regressions. Its sign is positive in 11 cases of 16, and it ranges from –.203 in regression 17 to +.327 in regression 6. The results imply that the Finnish reserves have more or less been on the average level compared to other countries in the sample. When only the developed countries are considered, they are perhaps slightly below the average.

A comparison between actual and the estimated relative reserves is used in two regressions: the basic model for all countries (regression 1 in Table 4) and for developed countries only (regression 13 in Table 6). This is done because the above-mentioned dummy results as compared to other developed countries are somewhat different than the ones compared to all of the sample countries. The following figure illustrates the actual reserve ratio compared to the static simulation and the long-run solution based on regression 1.[62] In static simulation the lagged dependent variable obtains its actual historical values for each period. The long-run solution sterilizes the effect of the lagged dependent variable by calculating the share of reserves using the long-run coefficients for the independent variables.[63]

Figure 5. **Reserve levels relative to GDP for Finland, 1975–1991, based on regression 1**



1 Actual share of reserves
2 Static ex post simulation path
3 Long-run solution

During the observation period, 1975–1991, the actual level of reserves relative to GDP in Finland reached its minimum in 1976 (1.6 per cent) and maximum in 1990 (6.8 per cent), and the trend has been upwards. The static simulation path follows

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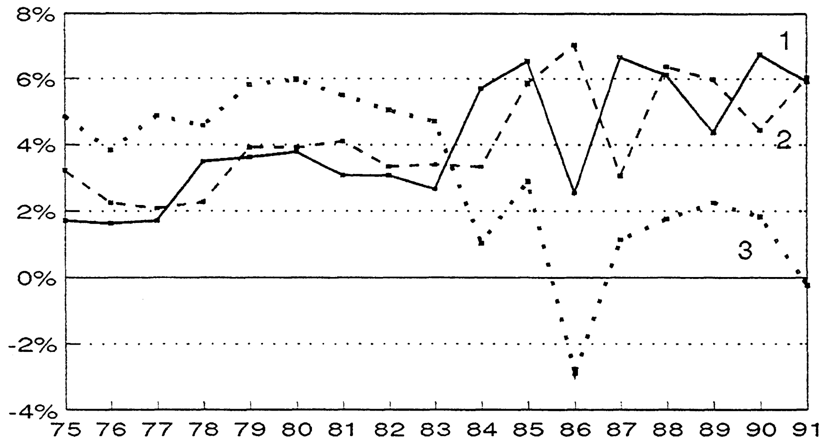
[62] The exact figures for the tables as well as the differences are presented in Appendix 6.

[63] As mentioned earlier the long-run coefficients are simply the short-run coefficients multiplied by the $1/(1-b_6)$, where b_6 is the short-run coefficient for the lagged dependent variable.

the actual path closely with one period lag, which illustrates the high coefficient of the lagged dependent variable, suggesting that the process of adjustment to the desired level of reserves is slow. Further, the long-run solution path lies clearly above the actual and static simulation lines for the late 1970s and early 1980s, which indicates that there was a need to drive the reserve share towards a higher level. In fact, during 1984–1985 the share seems to have been in balance, but it starts to move in the opposite direction subsequently, during the period of capital deregulation.

However, the trend after the mid-1980s also suggests that the dynamic fit of the model becomes worse, as the disequilibrium seems to widen with no apparent bounds. One reason for this could be the difficulty of properly accounting for the increased capital flows. Another fault of the model is the possibility of spurious negative reserves, as was the case in 1991 for the long-run solution of the model. The main reason for this is the exceptional negative money growth in Finland in 1991. Clearly, the model should be reformulated in accord with the current situation if it is to be used for forecasting. Next, the same kinds of curves are presented based on regression 13, which was run only for the developed countries.

Figure 6. **Reserve levels relative to GDP for Finland, 1975–1991, based on regression 13**



1 Actual share of reserves
2 Static ex post simulation path
3 Long-run solution

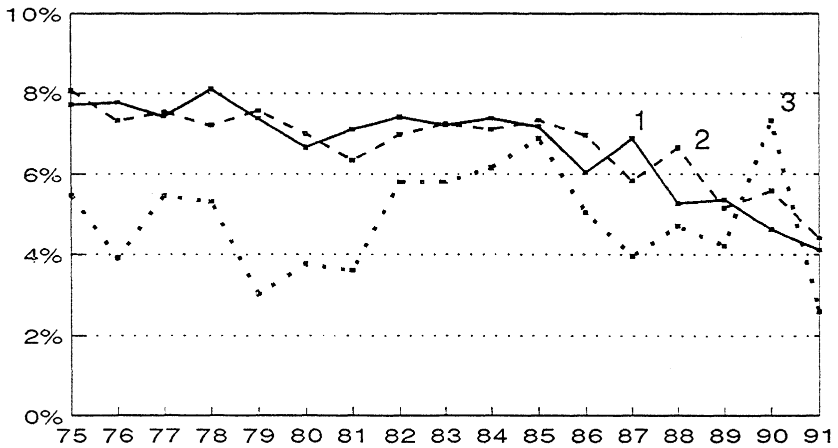
The figure looks very similar to the previous one, although some differences in the magnitudes can be observed. The long-run solution lies less above the actual and simulated levels during the early years than in the first figure and, correspondingly, more below the lines in the latter part of the period. So, the differences in this model seem to be more on the positive side, i.e. needing less upward adjustment and more downward adjustment, than in the first model for all countries in the sample.

For comparison, let us look at the same curves for Germany, which is definitely viewed as a country with good credibility, although its level of reserves might be distorted due to its supplier role, as the deutschmark is one of the reserve currencies for other countries, particularly in Europe.

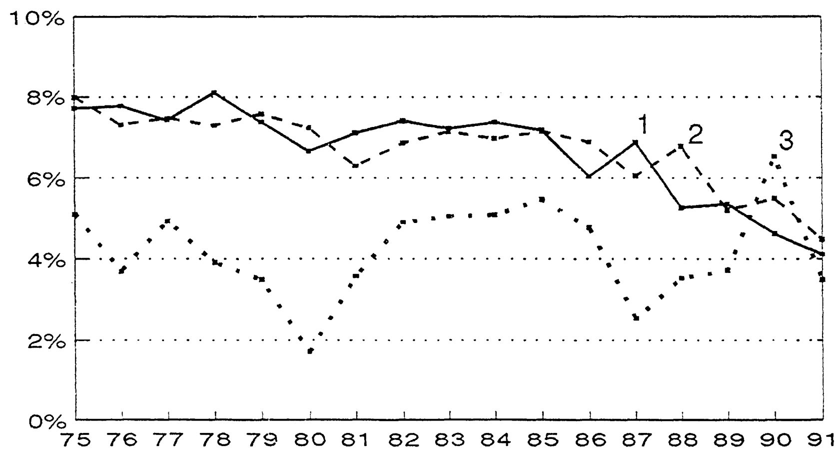
The actual level of reserves relative to GDP in Germany during 1975–1991 was at its lowest level in 1991 (4.1 per cent) and at its highest in 1978 (8.1 per cent), and the overall trend has been almost the opposite of the Finnish case, as the share in Germany has been decreasing over the years. So, it is not a surprise that Germany has maintained a reserve share which is clearly above the long-run levels, and has therefore been adjusting its reserves downwards during the observation period.

Figure 7. **Reserve levels relative to GDP for Germany, 1975–1991**

Based on regression 1



Based on regression 13



1 Actual share of reserves
2 Static ex post simulation path
3 Long-run solution

6 Conclusions

The theory behind the previous studies, which focused on the current account side of the balance of payments, and relied on dampening of the economy for adjustment purposes, when international reserves are not used to finance imbalances, tended to neglect capital flows between countries. As the central bank credibility aspect has become more important and as international capital markets have developed and opened after periods of deregulation in several developed countries, the capital flows should now be incorporated in the model, although it is not an easy task.

However, the familiar theoretical framework was used for the empirical part of this study, which examined reserves relative to GDP using new data from 1974 to 1991 in a sample of 56 countries. The results were promising even though the environment has changed from the early years of research on the demand for international reserves. The empirical results were corrected for autocorrelation and heteroskedasticity, but the possibility of multicollinearity could not be ruled out, which has to be kept in mind, although the sample size, 903, was clearly large enough to provide good informational content. The variables included the income level, openness of the country, variability of the balance of payments, interest rate level, money growth and lagged relative reserves.

The income level was insignificant and had a wrong (negative) sign, although previous studies had found some evidence for the hypothesis that the wealthier the nation the more reserves it demands. The openness of the country was a highly significant variable, with the expected positive sign. The volatility variable was expected to be significant with a positive sign, based on a review of previous studies, but I found similar evidence only for the developed countries, not for the whole sample. The interest rate level, as a measure of the opportunity cost of holding reserves, had a negative sign and was highly significant, though not for the developed countries separately. Further, money growth had a positive sign and was also highly significant in most of the cases. Last, the coefficient for the lagged dependent variable was higher than anticipated, implying slow adjustment from actual to desired reserves.

Special attention was paid to convertibility of the domestic currency as a proxy for the level of capital liberation and the status of the foreign exchange rate regime. According to the basic results, a dummy for inconvertibility of the currency and another for a freely floating exchange regime both had the expected negative sign for the sample of developed countries. The inconvertibility dummy was significant in most of the cases and the floating regime dummy in all cases. Hence, a free float of a currency seemed to decrease the demand for reserves significantly in the developed countries.

The results for Finnish data did not reveal any significant divergence from the average of the countries. Comparing the actual relative reserves, the static simulation path and the long-run solution obtained from the model, Finland seems to have been aiming for a higher ratio of reserves to GDP from 1975 to the mid-1980s, after which the relation has been the opposite; the model's long-run desired level is lower than the actual realized relative reserves, although the model seems to lose its stability in the case of Finland after the start of capital deregulation.

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Appendix 1

Balance sheet of Suomen Pankki

SUOMEN PANKKI – BANK OF FINLAND 23.09.1993 , FIM

ASSETS		
Gold and foreign currency claims		
Gold	2 180 085 713,82	
Special drawing rights	689 866 705,25	
IMF reserve tranche	1 910 902 282,32	
Convertible currencies	22 791 301 565,32	27 572 156 266,71
Other foreign claims		
Markka subscription to Finland's quota in the IMF	4 904 279 561,56	
Term credit	462 564 950,72	5 366 844 512,28
Claims on financial institutions		
Liquidity credits	200 000,00	
Certificates of deposit	1 667 608 651,80	
Securities with repurchase commitments	6 013 412 427,59	
Term credits	–	
Till – money credits	–	
Bonds	1 232 915 000,00	
Other claims on financial institutions	238 489 599,80	9 152 625 679,19
Claims on the public sector		
Treasury notes and bills	–	
Bonds	–	
Loans to the Government Guarantee Fund	–	
Total coinage	1 437 878 854,20	
Other claims on the public sector	–	1 437 878 854,20
Claims on corporations		
Financing of domestic deliveries (KTR)	563 423 568,50	
Other claims on corporations	2 807 239 707,71	3 370 663 276,21
Other assets		
Loans for stabilizing the money market	7 407 000 000,00	
Accrued items	–	
Other assets	164 472 817,68	7 571 472 817,68
Capitalized expenditures and losses due to safeguarding the stability of the money market		1 700 000 000,00
		56 171 641 406,27

Total foreign exchange reserves	27 355 362 487,52

Right of note issue	27 572 156 266,71
Utilized :	
Notes in circulation	– 12 016 481 448,00
Other commitments payable on demand	– 434 146 415,58
Unused right of note issue	15 121 528 403,13

LIABILITIES		
Foreign currency liabilities		
Convertible currencies	216 793 779,19	216 793 779,19
Other foreign liabilities		
IMF markka accounts	4 904 292 700,72	
Allocations of special drawing rights	1 189 883 348,60	
Other foreign liabilities	–	6 094 176 049,32
Notes and coin in circulation		
Notes	12 016 481 448,00	
Coin	1 282 495 908,50	13 298 977 356,50
Certificates of deposit		13 185 000 000,00
Liabilities to financial institutions		
Call money deposits	564 863 568,23	
Term deposits	–	
Minimum reserve deposits	6 303 763 631,00	
Other liabilities to financial institutions	131 918,40	6 868 759 117,63
Liabilities to the public sector		
Cheque accounts	1 884 320,49	
Deposits of the Government Guarantee Fund	147 478 325,92	
Other liabilities to the public sector	–	149 362 646,41
Liabilities to corporations		
Deposits for investment and ship purchase	2 214 037 051,82	
Other liabilities to corporations	–	2 214 037 051,82
Other liabilities		
Accrued items	–	
Other liabilities	202 632 694,14	202 632 694,14
Valuation account and reserves		8 177 785 671,70
Capital accounts		
Primary capital	5 000 000 000,00	
Reserve fund	764 117 039,56	
Net earnings	–	5 764 117 039,56
		56 171 641 406,27

Appendix 2

Finland's balance of payments

BALANCE OF PAYMENTS, FIM million

BANK OF FINLAND
Statistical Services Department
29.4.1993

	1991*		1992*		1992* I		II		III		IV		1993* I	
	CREDIT	DEBIT	CREDIT	DEBIT	CREDIT	DEBIT	CREDIT	DEBIT	CREDIT	DEBIT	CREDIT	DEBIT	CREDIT	DEBIT
Trade (exports f.o.b., imports c.i.f.)	92872	87720	107471	94988	25194	23142	26859	24623	25245	21114	30173	26109	31312	25962
Adjustment items	-1772	-1372	-1844	-1510	-458	-382	-455	-384	-471	-378	-460	-366	-468	-393
Trade account	**91100**	**86348**	**105627**	**93478**	**24736**	**22760**	**26404**	**24239**	**24774**	**20736**	**29713**	**25743**	**30844**	**25569**
Transport	7508	3974	8134	4173	1836	1000	2045	1033	2253	1069	2000	1071	2007	1018
Travel	5044	11089	6087	10962	1159	2725	1492	2813	1957	2853	1479	2571	1211	2198
Other services	5636	11011	7735	13325	1791	3427	1782	3027	1873	3223	2290	3648	2502	4195
Services account	**18189**	**26074**	**21956**	**28459**	**4786**	**7152**	**5319**	**6872**	**6083**	**7145**	**5769**	**7290**	**5720**	**7412**
Goods and services account	**109289**	**112421**	**127583**	**121938**	**29522**	**29912**	**31723**	**31111**	**30857**	**27881**	**35482**	**33034**	**36564**	**32981**
Investment income	10003	28674	6994	30763	2494	8357	1484	7661	1405	6914	1611	7831	2098	10326
- Reinvested earnings	-3855	-918	-4500	-900	-1125	-225	-1125	-225	-1125	-225	-1125	-225	-1125	-225
- Interest and dividends	13858	29592	11494	31663	3619	8582	2609	7886	2530	7139	2736	8056	3223	10551
Unrequited transfers	1178	5175	1666	5526	342	1970	346	1216	434	1248	544	1091	471	1761
Other	3942	4838	3973	4767	987	1196	985	1201	993	1173	1008	1197	1126	1406
Current account receipts and expenditure	**124412**	**151108**	**140217**	**162994**	**33345**	**41437**	**34539**	**41190**	**33689**	**37215**	**38645**	**43152**	**40259**	**46475**
A. CURRENT ACCOUNT		-26696		-22777		-8092		-6651		-3526		-4508		-6216
	CHANGE IN ASSETS	CHANGE IN LIABILITIES	CHANGE IN ASSETS	CHANGE IN LIABILITIES	CHANGE IN ASSETS	CHANGE IN LIABILITIES	CHANGE IN ASSETS	CHANGE IN LIABILITIES	CHANGE IN ASSETS	CHANGE IN LIABILITIES	CHANGE IN ASSETS	CHANGE IN LIABILITIES	CHANGE IN ASSETS	CHANGE IN LIABILITIES
Loans	-815	14883	-3472	5951	-615	-160	-123	428	-1121	726	-1612	4957	692	9232
Direct investment	-4303	-997	-4369	807	-1613	464	-156	35	-1018	-49	-1582	357	-1497	151
Portfolio investment	372	37285	-221	36618	-182	4023	-1142	12934	968	5306	134	14354	-2915	16270
Other long-term capital	-101	521	-304	-233	-273	263	-187	-321	-182	139	337	-314	106	-384
B. LONG-TERM CAPITAL ACCOUNT	-4847	51692	-8366	43143	-2683	4590	-1608	13076	-1353	6122	-2722	19354	-3614	25269
BASIC BALANCE (A+B)		20149		12000		-6185		4817		1243		12124		15439
Trade credits	-981	817	-4232	8198	-975	306	-1192	4056	-305	1537	-1761	2299	-1376	265
Short-term capital of banks	-6261	-13133	567	-28310	4134	-2010	1612	-9527	-6064	-11092	885	-5681	-18341	-3922
Other short-term capital	-3285	-1301	-6593	10454	-1723	3490	3403	416	-176	12295	-8096	-5747	1256	-5922
Errors and omissions		-2410		-1332		1323		-4634		-3603		5583		6907
C. SHORT-TERM CAPITAL ACCOUNT		-26553		-21249		4543		-5866		-7409		-12518		-21133
OVERALL BALANCE (A+B+C)		-6404		-9249		-1641		-1049		-6165		-394		-5694
Change in foreign exchange reserves		**6404**		**9249**		**1641**		**1049**		**6165**		**394**		**5694**

Assets: Increase -, decrease +
Liabilities: Increase +, decrease -

* preliminary data

Appendix 3

Data description

Countries included in the study

Developed countries	Less-Developed countries	
Australia	Bangladesh	Peru
Austria	Chile	Philippines
Belgium	Colombia	Rwanda
Canada	Costa Rica	Singapore
Denmark	Cyprus	South Africa
Finland	Ecuador	Sri Lanka
France	Egypt	Thailand
Germany	El Salvador	Trinidad and Tobago
Greece	Fiji	Tunisia
Iceland	Guatemala	Turkey
Ireland	Honduras	Uruguay
Italy	Indonesia	Venezuela
Japan	Israel	
Netherlands	Jamaica	
New Zealand	Jordan	
Norway	Korea	
Portugal	Malaysia	
Spain	Mauritius	
Sweden	Morocco	
Switzerland	Mexico	
United Kingdom	Nigeria	
United States	Pakistan	
22 countries	34 countries	

Classification based on the International Financial Statistics Yearbook 1992, International Monetary Fund

Data sources

Exchange Arrangements and Exchange Restrictions, Annual Report (1975–1993), International Monetary Fund (dummies D1 and D2).

International Financial Statistics (various issues), International Monetary Fund (primary data source).

SG Warburg Securities, London (base rate series for interest rate variable of United Kingdom).

Suomen Pankki, Central Bank of Finland (Mr. Antti Ripatti provided the money data for Finland; M1 series generated according to the new money aggregates, introduced in January 1991).

Sveriges Riksbank (Money data for Sweden).

World Economic Outlook (WEO, May 1993), International Monetary Fund (the 1991 GDP/GNP and deflator/CPI forecasts for Portugal, Turkey, Malaysia, Thailand and Fiji)

Definition of variables in Tables 4–6

<u>Dependent variable: R/GDP*100 (%)</u>

R = amount of reserves, including gold (line 1xxs in IFS)

GDP =gross domestic product in (line 99b in IFS)

<u>Independent variables (lines in IFS in parentheses):</u>

INCOME = per capita income, GDP/POPULAT (lines 99b/99z in IFS), scaled to thousands of US dollars for the regressions

TRADE = exports plus imports per GDP, EX+IM/GDP (70xxd+71xxd/99b)

IMPORT = imports per GDP (71xxd/99b)

VARIABILITY = u^2, squared error term from the first order autoregressive regression for the balance of payments-GDP ratio for each country separately, using the following regression:

$$BoP/GDP = \alpha_0 + \alpha_1 (BoP/GDP)_{-1} + u$$

BoP = the overall balance in millions of US dollars (line 78xxd in IFS)
u = error term

INTEREST (%) = interest rate level, end of period discount rate in most of the countries (line 60 in IFS), %

MONEYG (%) = money growth, [log(MDOM) – lagged log(MDOM)] * 100, MDOM is the M1 in billions of domestic currency (line 34 in IFS), %

INFLATION (%) = [log(DEFLATOR) – lagged log(DEFLATOR)] * 100,
DEFLATOR = GDPDOM/GDPFIX*100 or GNP/GDPFIX*100
GDPFIX = fixed price (base year 1985) GDP/GNP in billions of domestic currency (line 99bxp or 99bxr for GDP / 99axp or 99axr for GNP)
GDPDOM = GDP in billions of domestic currency (99b or 99bxc)
GNP = GNP in billions of domestic currency (99a or 99axc)

[Note: for Jamaica and Egypt CPI (line 64) was used instead of GNP/GDP deflators due to lack of data]

DINV = net direct investments in US dollars divided by the GDP (line for direct investments: 77bad)

PFINV = net portfolio investments in US dollars divided by the GDP (line for portfolio investments: 77bbd)

DUS = dummy for United States
DFinCenter = dummy for financial centers, Switzerland and Singapore
DFinland = dummy for Finland
D1 = dummy for an inconvertible currency, IMF Article XIV
D2 = dummy for an independent float of the currency

All data is annual.

The sub-notation $_{-1}$ stands for a lagged variable.

All variables which were not obtained directly in millions of US dollars from IFS were converted into those with the average foreign exchange rate for each year (line rf, rh, wf, we or ae in IFS, depending on the country).

Appendix 4

The figures are based on the means of annual figures for 1974–1991. The name of the variable formulated from each table is in the parentheses. The order of countries follows Figure A in Figures B–J, and Figure K in L–M.

Figure A. **Reserves to GDP in per cent (R/GDP)**

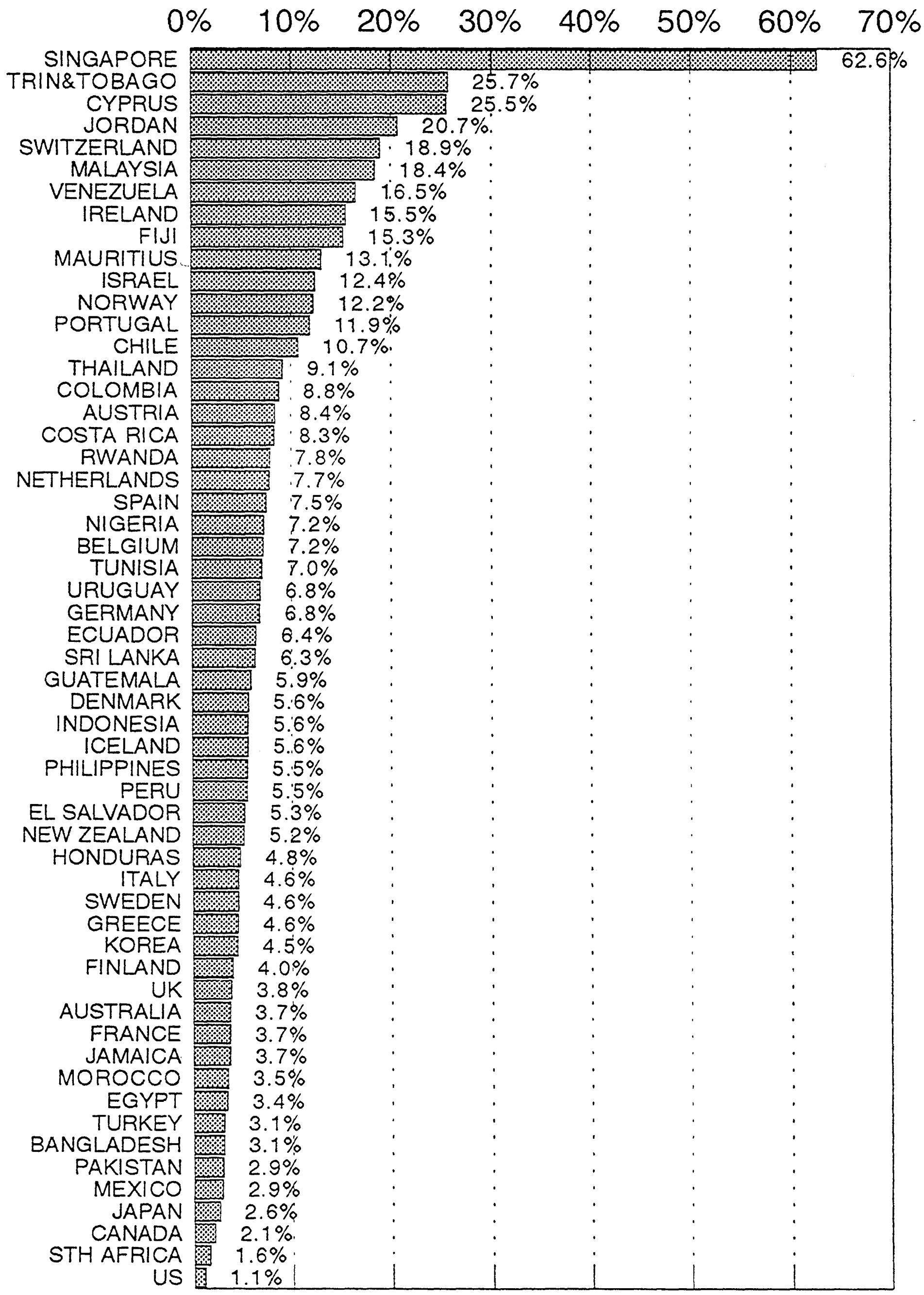


Figure B. **GDP per capita in US dollars (INCOME)**

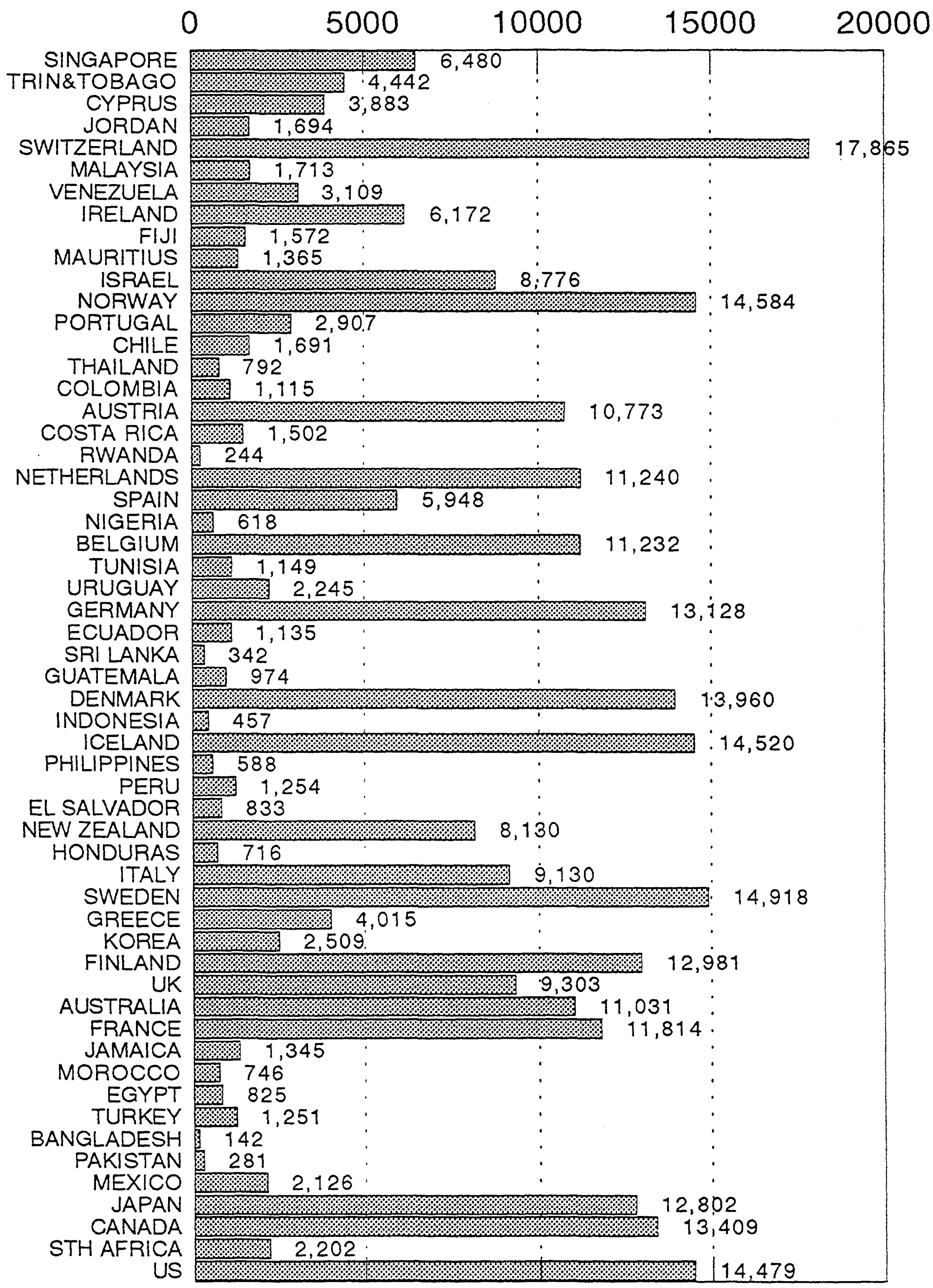


Figure C. **Sum of exports and imports to GDP ratio in per cent (TRADE)**

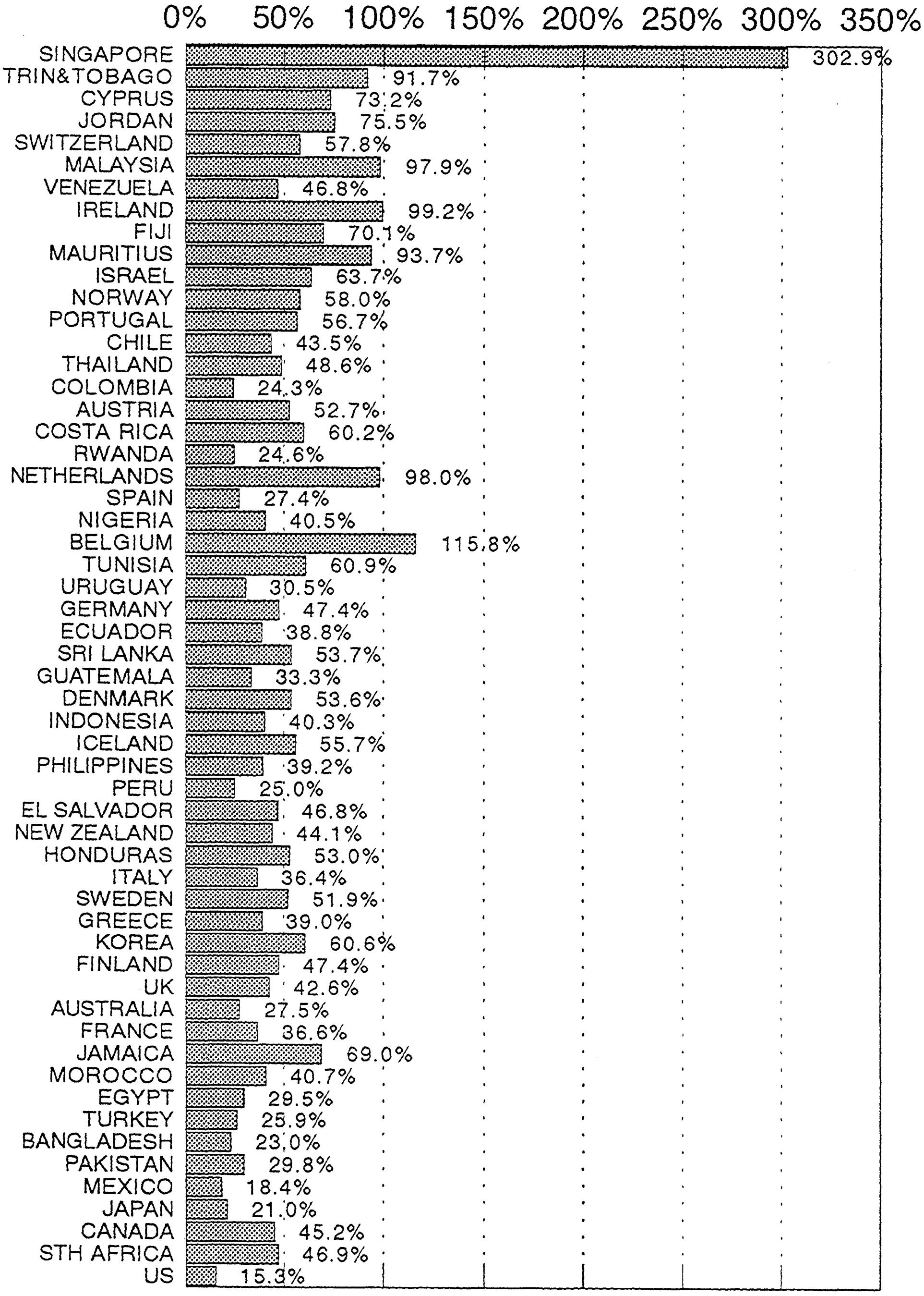


Figure D. **Balance of payments variability (VARIABILITY)**

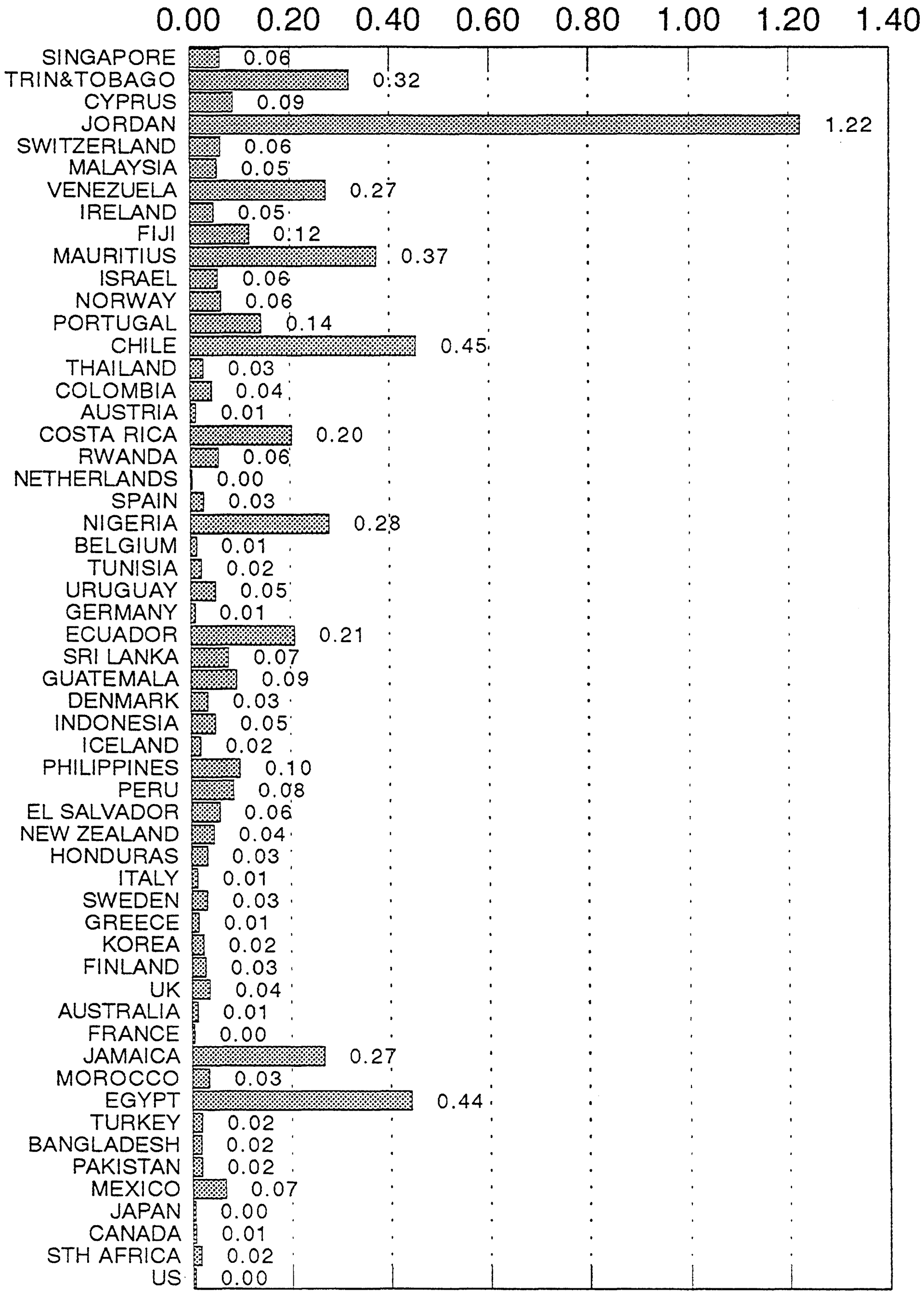


Figure E. **Interest rate in per cent (INTEREST)**

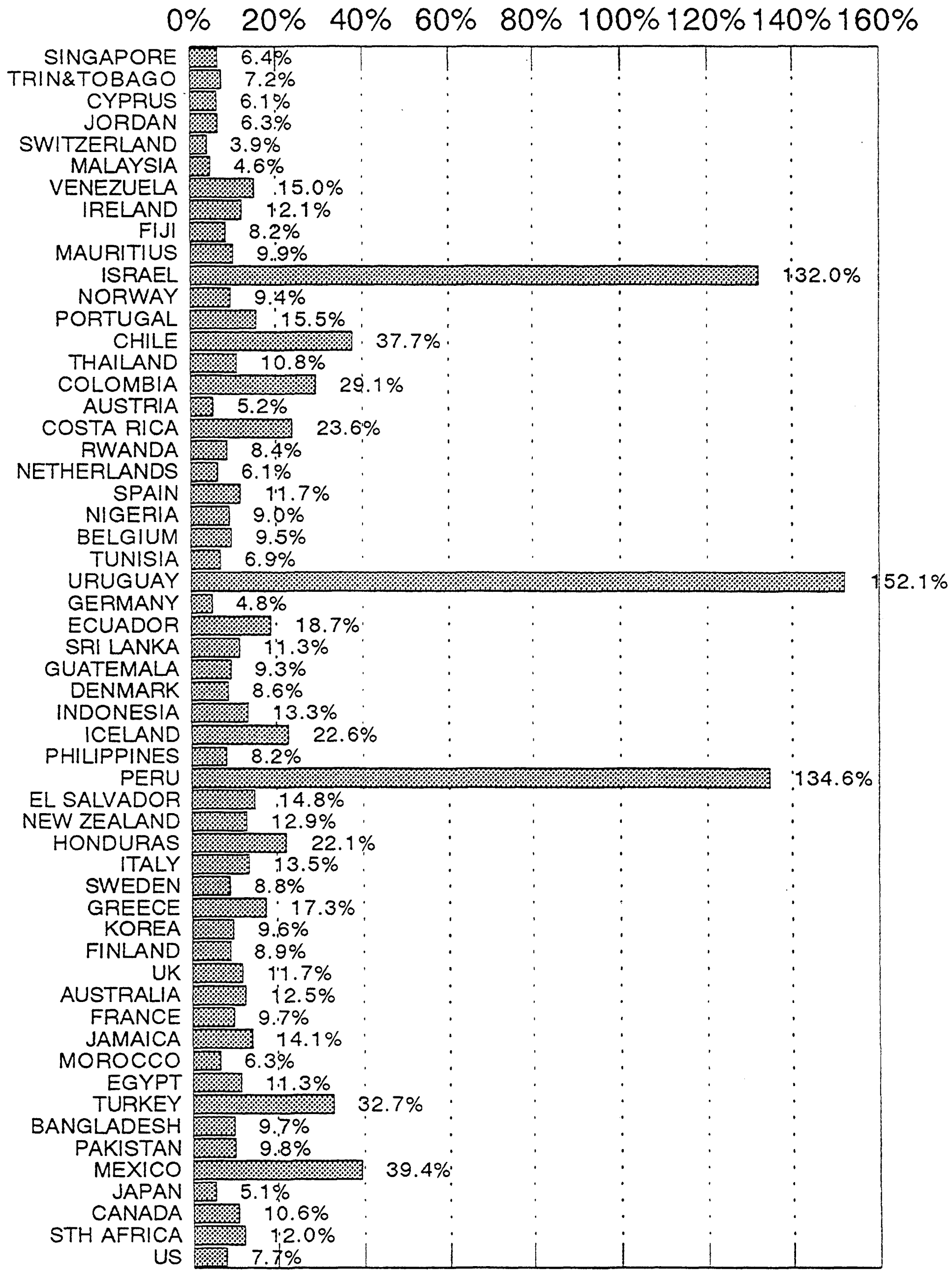


Figure F. **Money growth in per cent (MONEYG)**

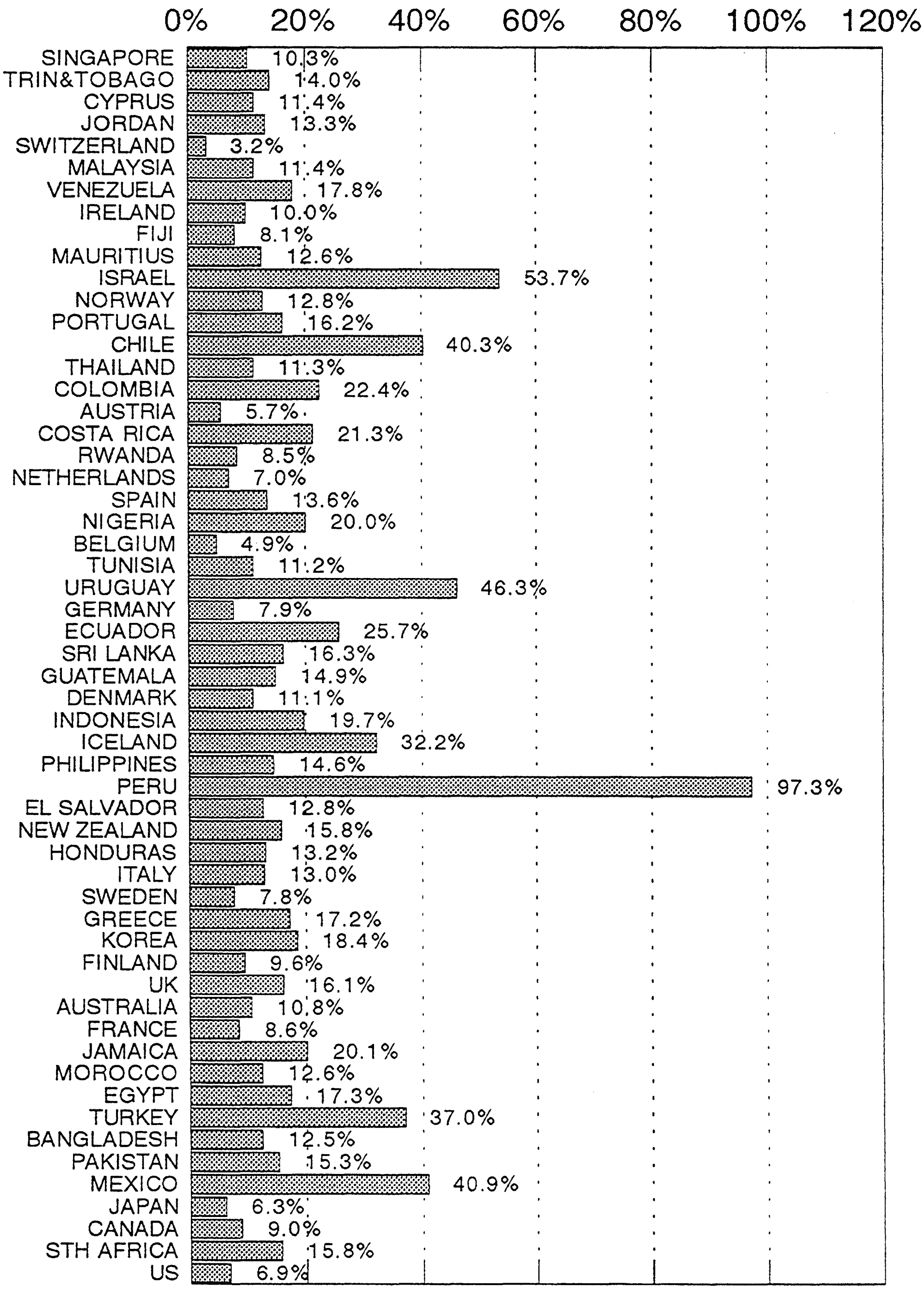


Figure G. **Inflation in per cent (INFLATION)**

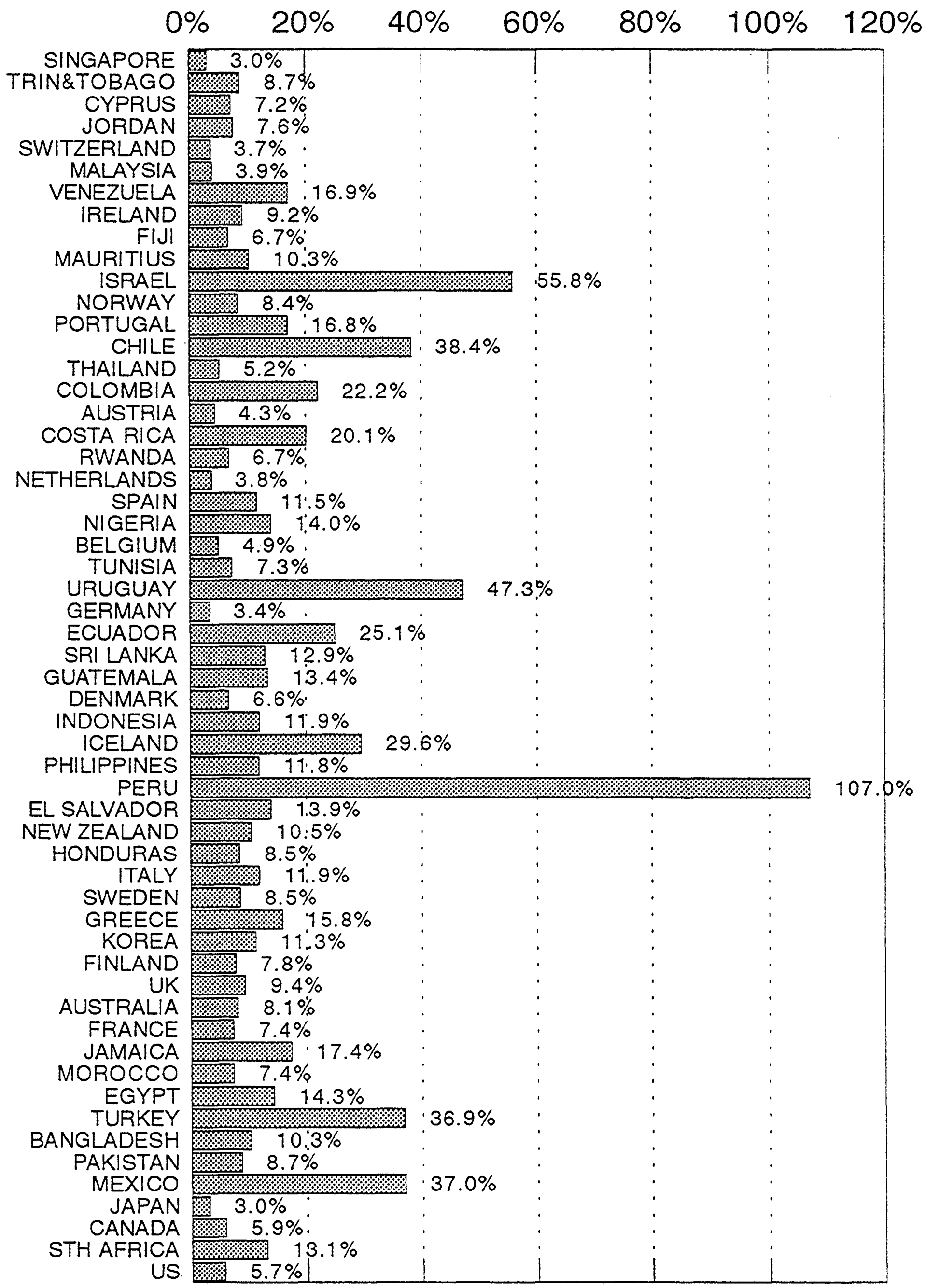


Figure H. **Imports to GDP ratio in per cent (IMPORT)**

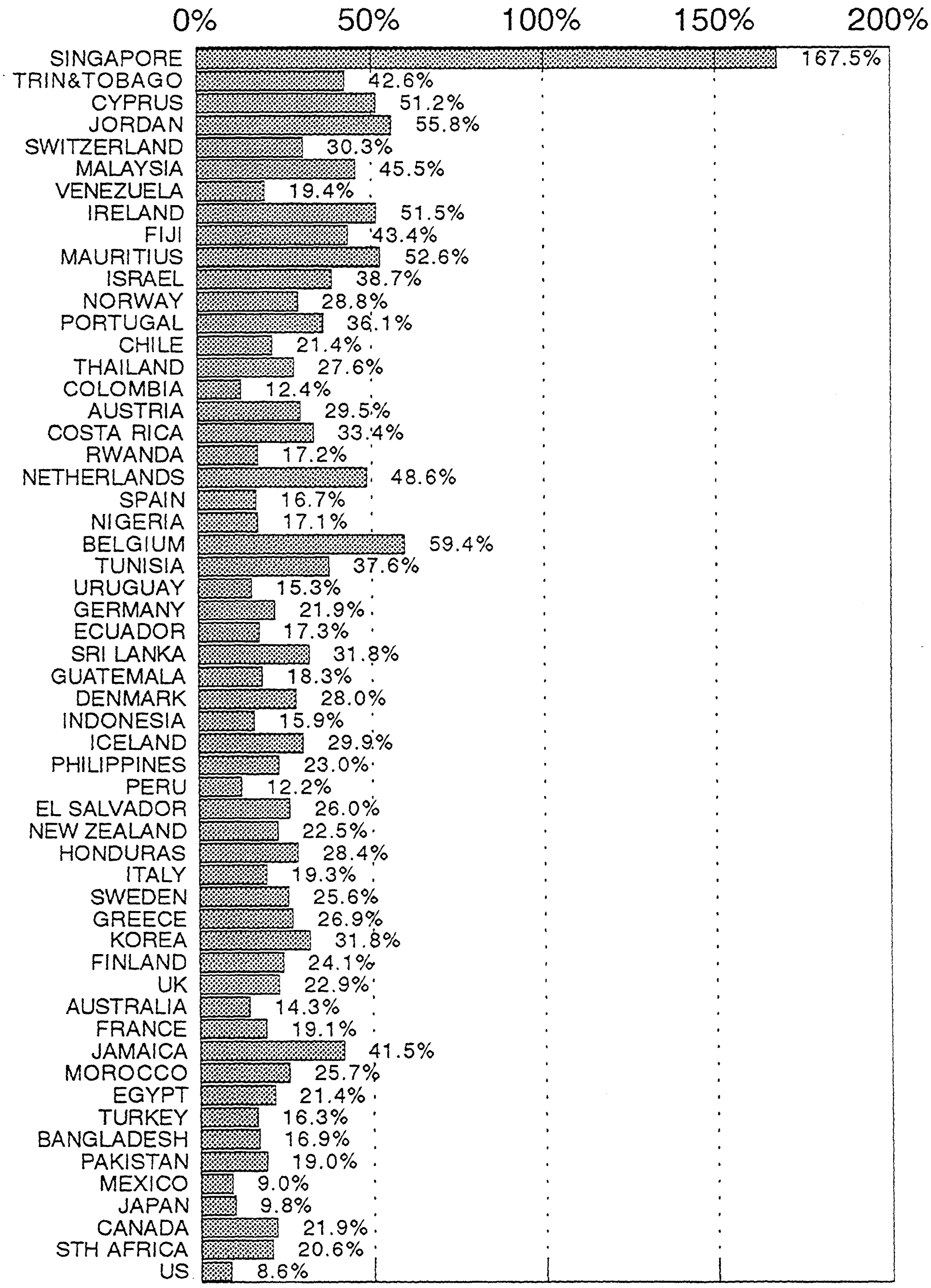


Figure I. **Net direct investments to GDP ratio in per cent (DINV)**

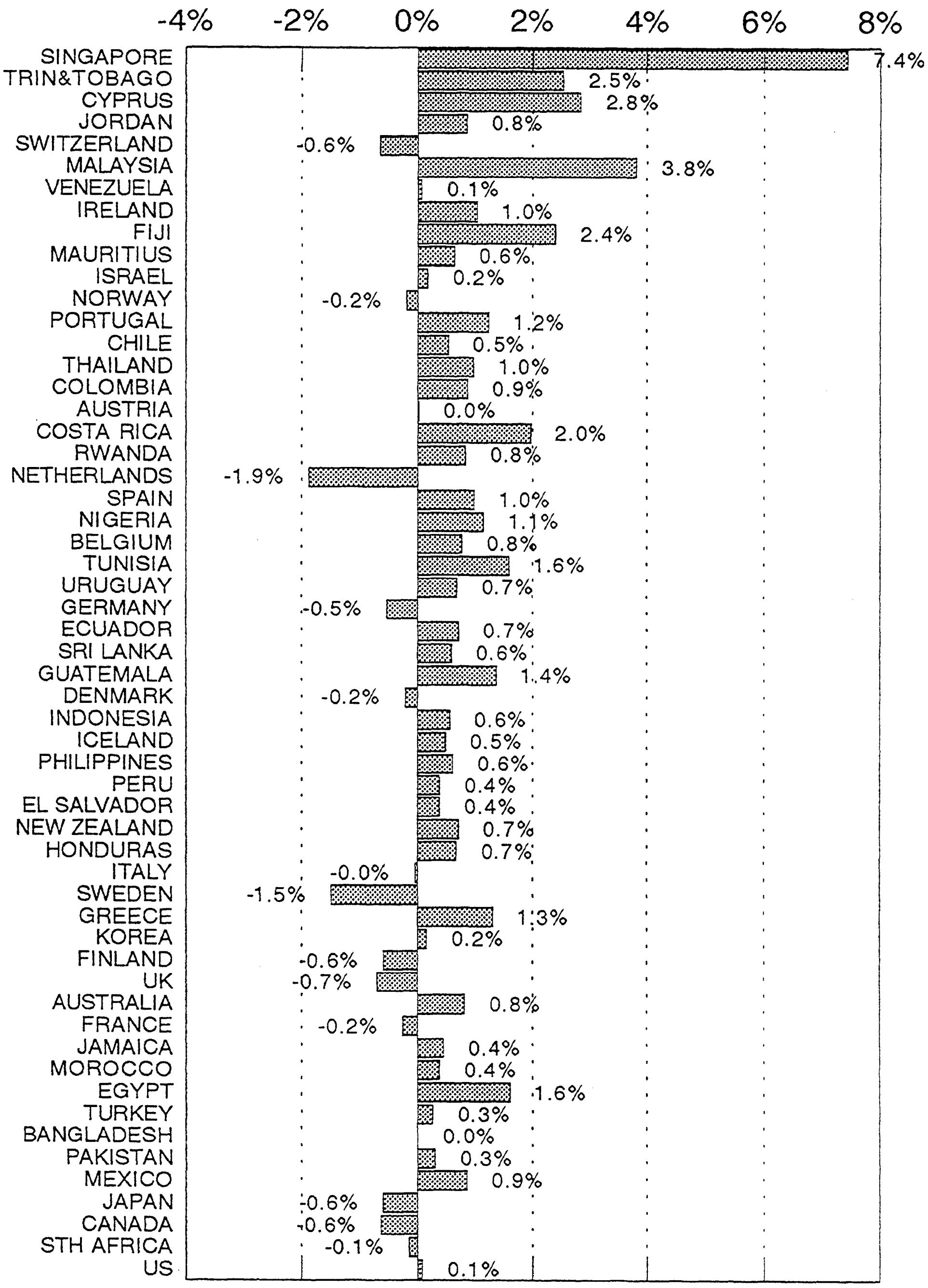


Figure J. **Net portfolio investments to GDP ratio in per cent (PFINV)**

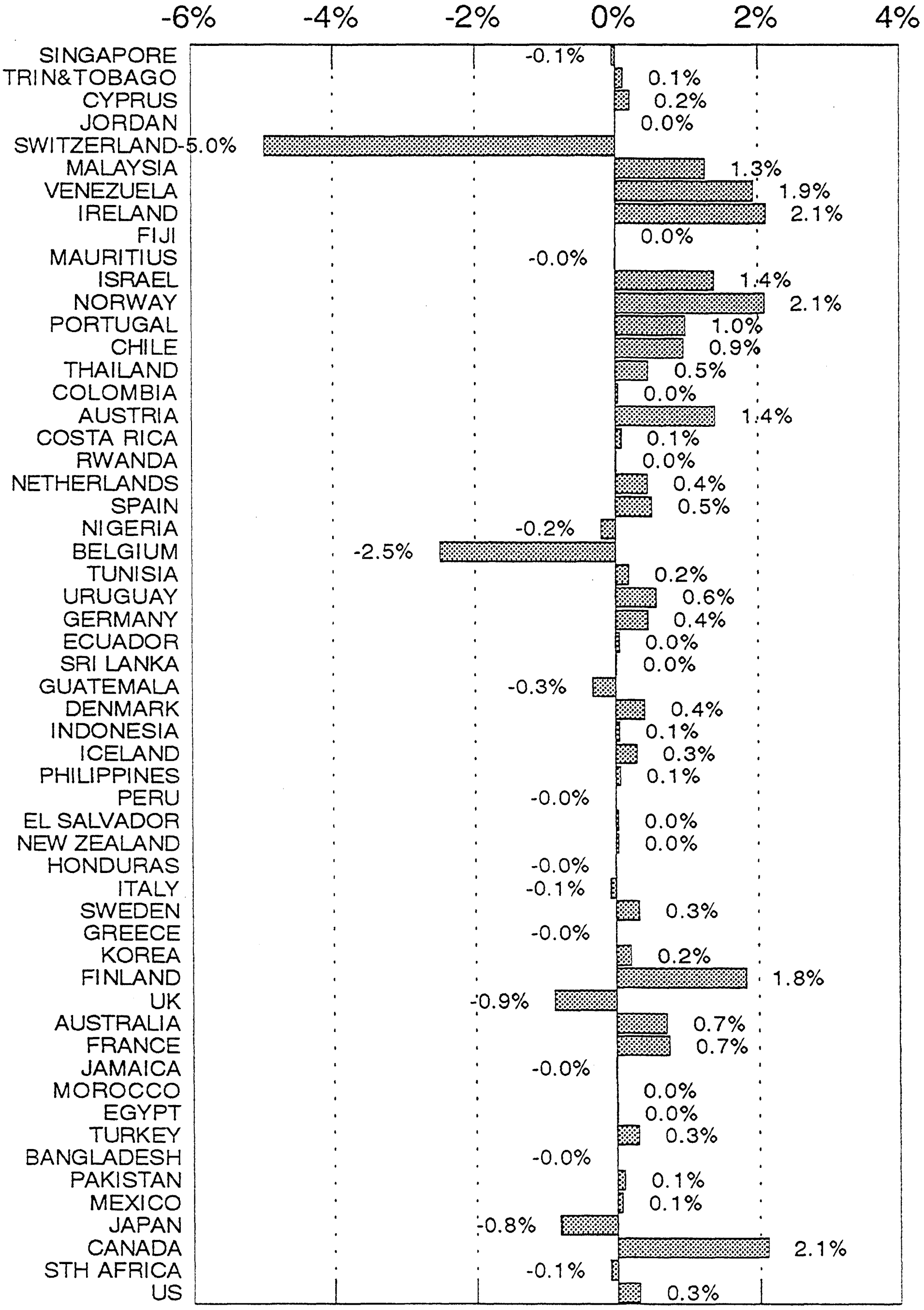


Figure K. **Level of reserves in millions of US dollars**

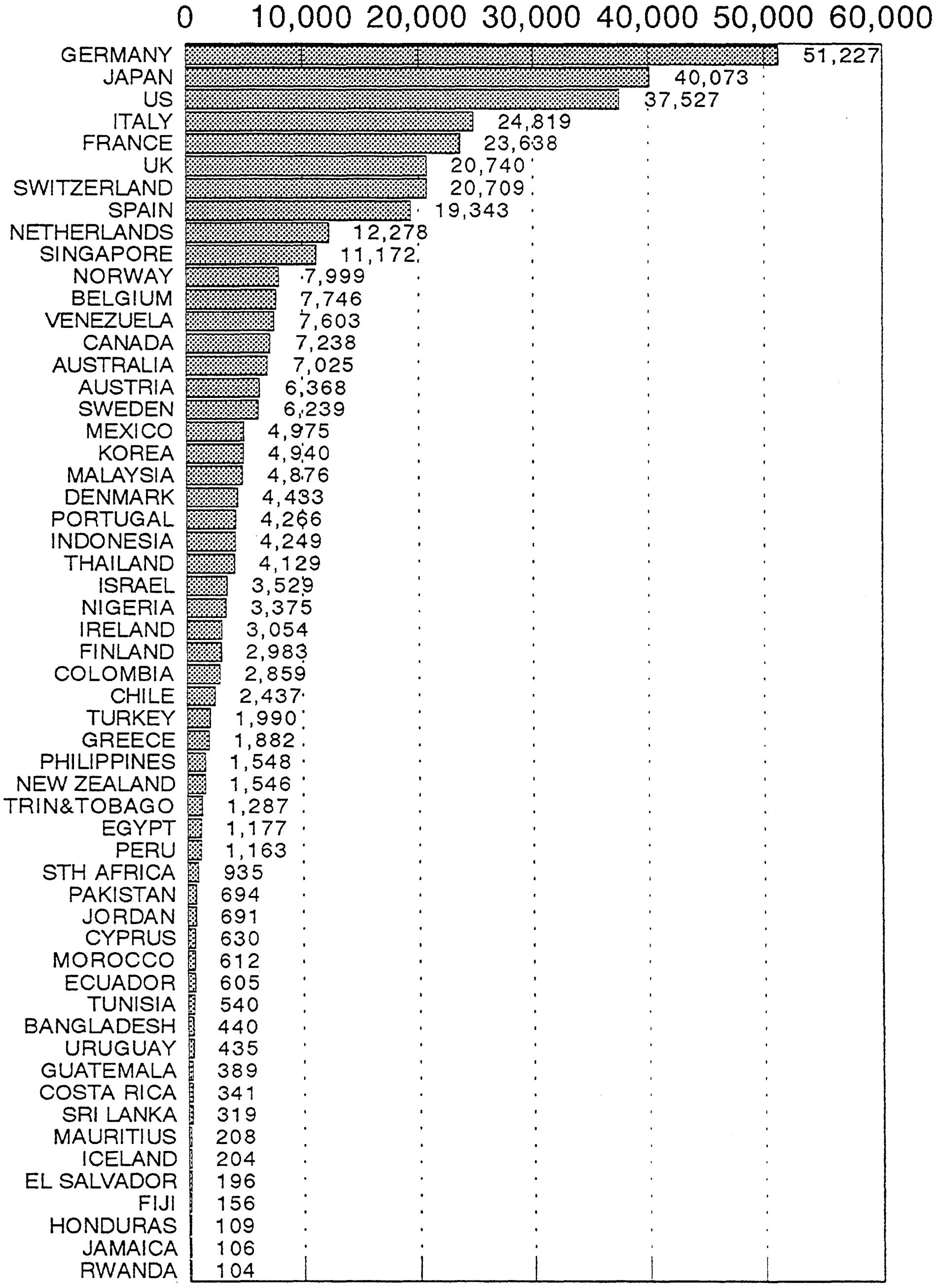


Figure L. **GDP in billions of US dollars**

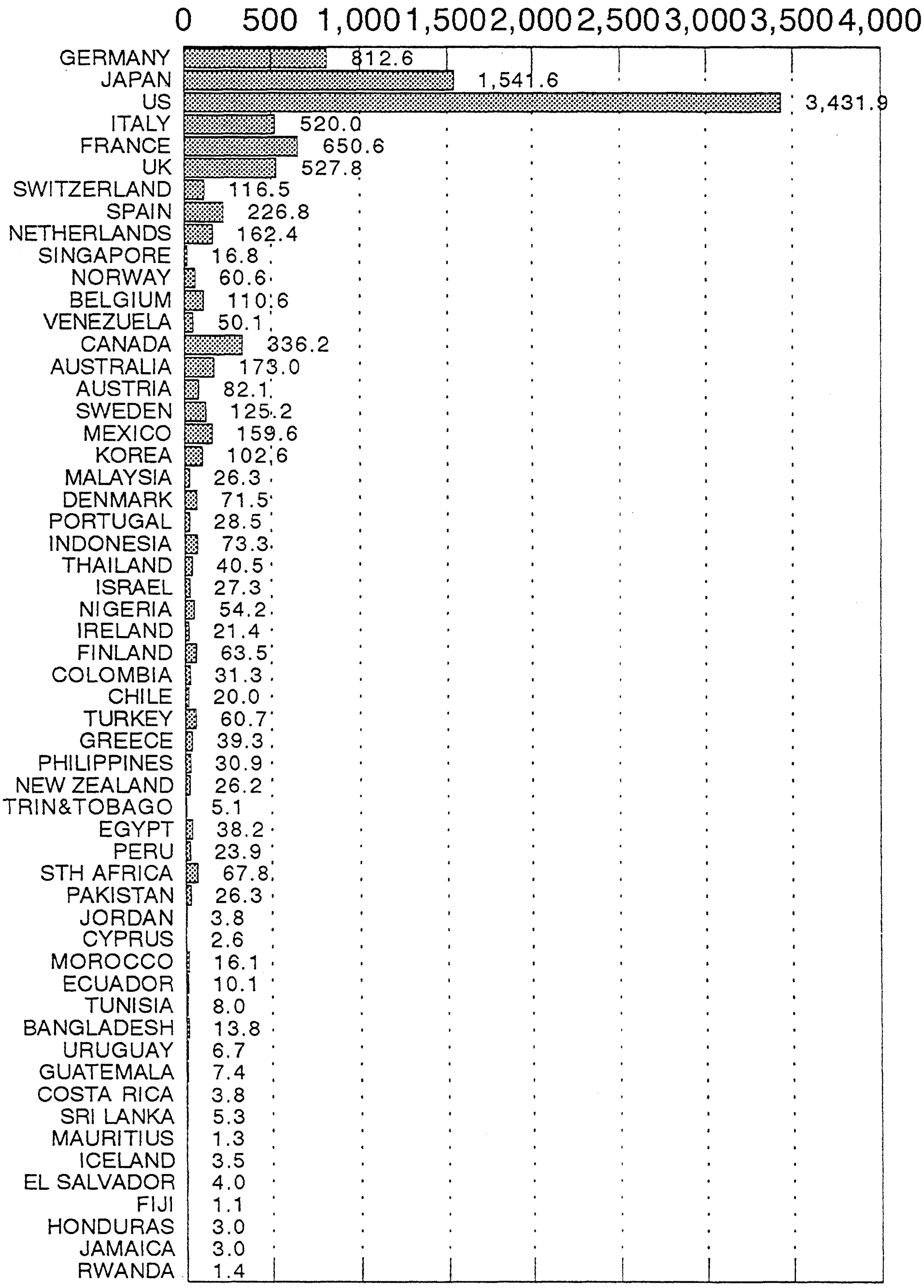
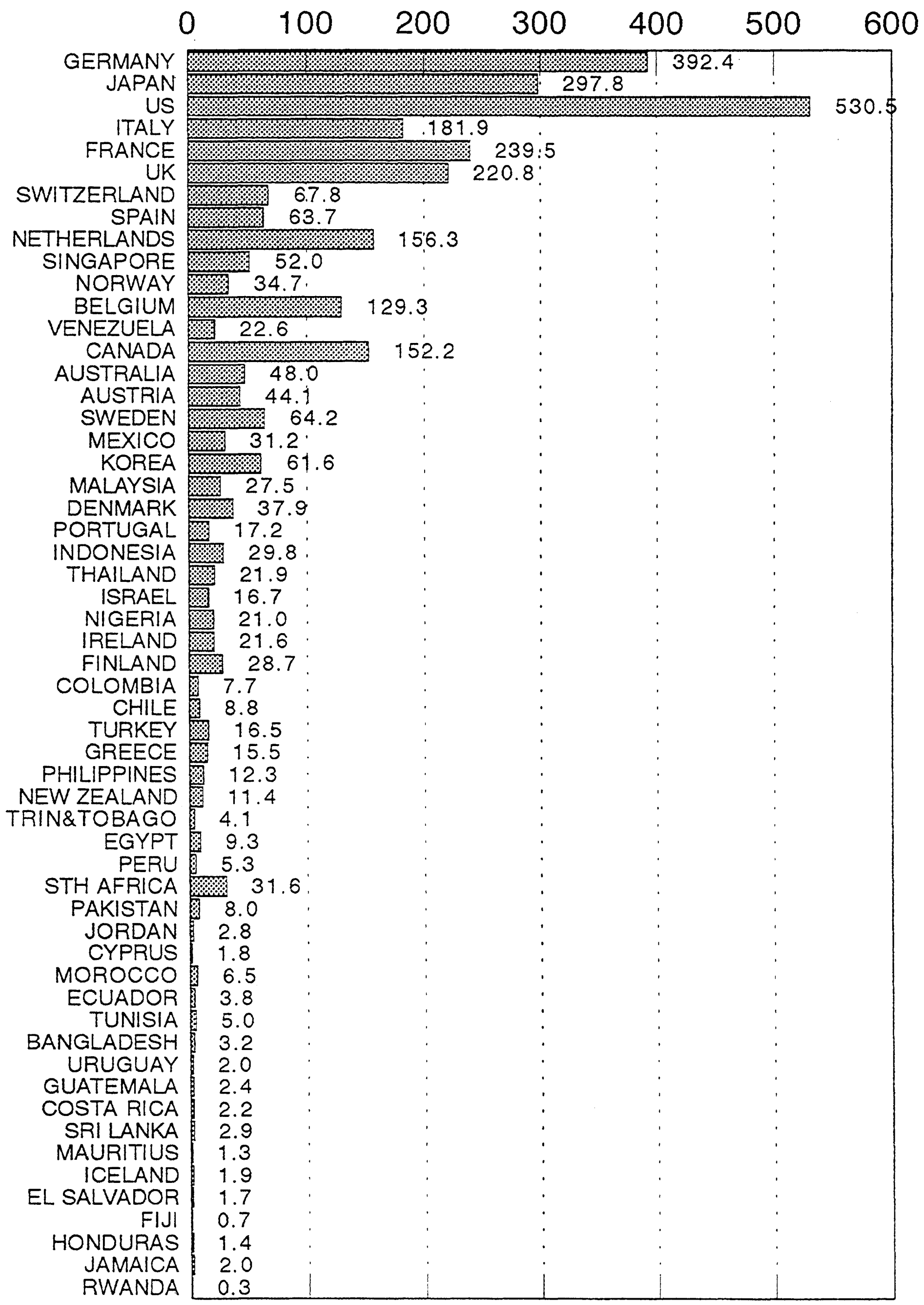


Figure M. **The sum of exports and imports in billions of US dollars**



Appendix 5

Correlation matrices for the independent variables

Correlation matrix for the independent variables – Regression 1
903 observations

	R/GDP	INCOME	TRADE	VARIA-BILITY	R/GDP_{-1}	INTEREST	MONEYG	DUS	DFin-Center
R/GDP	1								
INCOME	-0.013	1							
TRADE	0.803	0.046	1						
VARIABILITY	0.100	-0.097	0.046	1					
R/GDP_{-1}	0.970	-0.007	0.791	0.107	1				
INTEREST	-0.057	-0.081	-0.092	-0.007	-0.060	1			
MONEYG	-0.024	-0.175	-0.112	0.005	-0.049	0.685	1		
DUS	-0.105	0.199	-0.128	-0.026	-0.106	-0.028	-0.060	1	
DFinCenter	0.606	0.212	0.591	-0.016	0.604	-0.051	-0.087	-0.027	1

Correlation matrix for the independent variables – Regression 13
357 observations

	R/GDP	INCOME	TRADE	VARIA-BILITY	R/GDP_{-1}	INTEREST	MONEYG	DUS	DFin-Center
R/GDP	1								
INCOME	0.016	1							
TRADE	0.534	-0.071	1						
VARIABILITY	0.383	-0.122	0.144	1					
R/GDP_{-1}	0.948	0.039	0.538	0.325	1				
INTEREST	-0.087	-0.160	0.008	0.104	-0.108	1			
MONEYG	0.000	-0.180	-0.022	0.032	-0.030	0.420	1		
DUS	-0.249	0.123	-0.355	-0.086	-0.251	-0.108	-0.102	1	
DFinCenter	0.546	0.250	0.104	0.110	0.568	-0.261	-0.185	-0.050	1

Appendix 6

Simulation data for Finland and Germany

The level of reserves relative to GDP in per cent

FINLAND		Regression 1				Regression 13			
	Actual	**Static Simulation**		**Long-term Solution**		**Static Simulation**		**Long-term Solution**	
	R/GDP in %	Model level	Difference from actual	Model level	Difference from actual	Model level	Difference from actual	Model level	Difference from actual
1975	**1.71**	3.16	−1.45	7.85	−6.14	3.21	−1.50	4.85	−3.14
1976	**1.62**	2.15	−0.53	5.83	−4.21	2.25	−0.63	3.83	−2.21
1977	**1.70**	2.11	−0.41	6.23	−4.53	2.09	−0.39	4.88	−3.18
1978	**3.49**	2.23	1.26	6.67	−3.17	2.27	1.22	4.58	−1.08
1979	**3.63**	4.01	−0.38	8.31	−4.68	3.91	−0.29	5.81	−2.18
1980	**3.78**	4.08	−0.30	7.88	−4.10	3.91	−0.12	5.97	−2.19
1981	**3.07**	4.21	−1.14	7.81	−4.73	4.11	−1.03	5.50	−2.43
1982	**3.08**	3.42	−0.34	6.32	−3.25	3.35	−0.27	5.05	−1.98
1983	**2.66**	3.44	−0.78	6.46	−3.80	3.41	−0.75	4.71	−2.05
1984	**5.70**	2.96	2.74	5.54	0.16	3.33	2.37	1.03	4.67
1985	**6.54**	5.70	0.83	5.70	0.84	5.85	0.68	2.90	3.64
1986	**2.54**	6.23	−3.69	3.64	−1.10	7.05	−4.51	−2.87	5.42
1987	**6.67**	2.64	4.02	3.43	3.23	3.06	3.60	1.13	5.53
1988	**6.11**	6.11	0.00	1.41	4.70	6.38	−0.27	1.76	4.36
1989	**4.38**	5.71	−1.33	2.24	2.14	5.98	−1.59	2.26	2.12
1990	**6.76**	4.08	2.68	1.43	5.33	4.45	2.31	1.83	4.93
1991	**5.92**	5.69	0.23	−3.29	9.22	6.05	−0.13	−0.24	6.16

GERMANY		Regression 1				Regression 13			
	Actual	**Static Simulation**		**Long-term Solution**		**Static Simulation**		**Long-term Solution**	
	R/GDP in %	Model level	Difference from actual	Model level	Difference from actual	Model level	Difference from actual	Model level	Difference from actual
1975	**7.71**	8.07	−0.35	5.47	2.24	7.99	−0.28	5.12	2.60
1976	**7.77**	7.31	0.46	3.91	3.86	7.31	0.46	3.70	4.07
1977	**7.42**	7.53	−0.11	5.47	1.95	7.47	−0.05	4.94	2.48
1978	**8.10**	7.20	0.90	5.32	2.79	7.30	0.81	3.91	4.19
1979	**7.37**	7.57	−0.20	3.03	4.34	7.57	−0.20	3.49	3.88
1980	**6.66**	6.99	−0.33	3.76	2.90	7.22	−0.57	1.70	4.96
1981	**7.10**	6.34	0.76	3.62	3.48	6.29	0.81	3.58	3.52
1982	**7.41**	6.97	0.44	5.80	1.60	6.86	0.55	4.91	2.49
1983	**7.21**	7.24	−0.03	5.80	1.41	7.13	0.08	5.06	2.15
1984	**7.38**	7.10	0.27	6.16	1.22	6.97	0.41	5.09	2.29
1985	**7.17**	7.33	−0.16	6.87	0.30	7.15	0.02	5.48	1.69
1986	**6.04**	6.95	−0.91	5.05	0.99	6.89	−0.85	4.78	1.26
1987	**6.87**	5.82	1.05	3.97	2.91	6.05	0.82	2.53	4.34
1988	**5.27**	6.65	−1.38	4.70	0.57	6.78	−1.51	3.52	1.75
1989	**5.37**	5.17	0.20	4.23	1.14	5.22	0.15	3.73	1.64
1990	**4.63**	5.58	−0.96	7.32	−2.69	5.51	−0.88	6.53	−1.90
1991	**4.12**	4.42	−0.30	2.61	1.51	4.49	−0.37	3.49	0.62

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