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DYNAMIC ADJUSTMENT AND THE DEMAND FOR INTERNATIONAL RESERVES

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Dynamic Adjustment and the Demand for International Reserves

ABSTRACT

Although there have been a large number of empirical studies of the demand for international reserves, there have not been many successful demonstrations that deviations of the actual stock of reserves from the target level defined by the demand function trigger a process of adjustment. This paper presents new evidence which suggests that central banks do have a target level of international reserve holdings, and that the adjustment of actual reserves towards the target level is quite rapid. In addition, an economic theory of the speed of adjustment is presented and tested. The evidence suggests that central banks adjust more rapidly to reserve deficiencies than to surpluses, that the speed of adjustment is positively related to the divergence between the actual level of reserves and the target level, and that countries which hold abnormally large quantities of reserves do so, in part, in order to adjust more slowly. Finally, the paper examines the applicability of the model to the current regime of managed flexible exchange rates. The evidence suggests that the move towards greater exchange rate flexibility has not significantly altered the reserve holding behavior of the world's central banks.

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I. Introduction

Studies of the dynamics of international reserve behavior have typically assumed that countries have a desired stock of reserves and that deviations of the actual stock from the desired stock trigger a process of adjustment. In theoretical models in which the cost of holding reserves increases with the stock of reserves and in which the cost of adjustment increases with the speed of adjustment, an optimal tradeoff between the level of reserves and the speed of adjustment has been defined.[1/] In the empirical research on this topic, a number of studies have successfully identified a stable demand function for the stock of reserves held by central banks, but estimates of the speed of adjustment have been very low and often not significantly different from zero.[2/] These latter findings are disturbing since they cast serious doubt on the usefulness of the optimizing approach to the demand for international reserves: evidence on a stable long run demand function is of little value if it cannot be shown that discrepancies between actual and desired stocks are eliminated over time.

In this paper we present new evidence on this issue. After developing a method for estimating the desired stock of reserves, we show that deviations of the actual stock from the desired level do trigger a process of adjustment and, in contrast to previous studies, we find that the speed of adjustment is quite high. We also suggest some reasons why previous estimates of the speed of adjustment are likely to be subject to a downward bias. We then study the determinants of the speed of adjustment and examine the empirical content of

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[1/] See, for example, the important study by Peter B. Clark (1970a).

[2/] Clark (1970b) and Milton Iyoha (1976) have estimated the speed of adjustment from a partial adjustment model. Other studies, like those of Peter B. Kenen and Elinor B. Yudin (1965) and H. Robert Heller and Mohsin Khan (1978), have introduced dynamics through assumptions about the persistence of balance of payments shocks. The strong persistence found in the Heller-Kahn model is statistically related to the low speed of adjustment estimated in Iyoha's partial adjustment model.

of the hypotheses that (i) countries trade-off large equilibrium stocks of reserves for low speeds of adjustment; (ii) the speed of adjustment depends upon the (absolute) size of the discrepancy between desired and actual stocks; and (iii) the speed of adjustment depends upon whether the discrepancy between actual and desired stocks is positive or negative.

Although most of the theoretical and empirical research on the demand for international reserves has been undertaken within the context of the Bretton Woods system, it is clear that the use of reserves has been widespread during the post-1973 period of managed floating. In the penultimate section of the paper we explore the applicability of our model to the managed float period, and in the final section we provide some concluding remarks.

II. The Partial Adjustment Model and the Desired Stock of Reserves

II.1 A Brief Review of Previous Work

In the partial adjustment model, countries are assumed to adjust their current stock of reserves in proportion to the discrepancy between actual and desired reserves. Algebraically, the partial adjustment model can be written as

$$(1) \qquad R_t - R_{t-1} = \alpha + \gamma[R_t^* - R_{t-1}] + w_t$$

where R_t and R_t^* denote, respectively, the actual and desired stocks of reserves in period t, α and γ are parameters representing, respectively, the trend in reserves and the speed of adjustment, and w_t is an independently and identically distributed random variable.

Since the desired level of reserves is unobservable, the model must be supplemented by an additional hypothesis relating the desired stock of reserves to a set of observable variables. An early estimate of this type of model is presented by Clark (1970b) who assumed that the desired stock of reserves was a linear function of time. Since this relationship is unlikely to be exact, we supplement Clark's formulation with an error term, u_t, which is also assumed to be idependently and identically distributed.

$$R^*_t = \beta_o + \beta_1 t + u_t \tag{2}$$

Substituting equation (2) into equation (1) yields

$$R_t = \alpha + \gamma\beta_o + \gamma\beta_1 t + (1-\gamma) R_{t-1} + v_t \tag{3}$$

where $v_t = \gamma u_t + w_t$. Under the assumptions of the model, particularly that the error terms are serially independent, the ordinary least squares estimates of the parameters of this linear regression will be unbiased. However, if the errors are serially correlated, the estimated coefficient on the lagged dependent variable will be biased towards unity and the estimate of the speed of adjustment, γ, will be biased towards zero. It is reasonable to assume that the errors are serially correlated, particularly in the monthly data employed by Clark. In the first place, the deviations of the desired stock of reserves from the trend will tend to be positively correlated: this characteristic is evident in the behavior of economic variables, like aggregate income or imports, that have been shown to influence long run reserve holdings. Second, it is also likely that the balance of payments shocks will be positively correlated, thus inducing positive serial correlation in the w_t residuals.[3/] These sources of residual autocorrelation may account for Clark's extremely low estimates of the speed of adjustment.[4/]

3/ The serial correlation in balance of payments shocks is a characteristic of the model developed by Kenen and Yudin (1965). The Kenen-Yudin model, based upon the persistence of shocks, can be obtained by taking the first difference of equation (3) and assuming that the v_t residuals follow a random walk. For a more recent investigation of this model, see Heller and Khan (1978).

4/ Clark estimated equation (3) using monthly data over the period from February 1958 to September 1967 for thirty eight countries. In forty-five per cent of the cases studies, the estimated speed of adjustment was not significantly different from zero. Clark reports that correction for serial correlation resulted in higher estimates of the speed of adjustment in some cases.

After Clark's study, most of the empirical research on the demand for international reserves concentrated on the estimation of a desired reserves function. These studies avoided the need to specify or estimate the adjustment dynamics by concentrating on annual and/or cross-section data. Their contribution was to isolate the empirically important arguments in the desired reserve function. In general, these arguments included a measure of the openness of the economy, a measure of scale and a measure of the variability of international receipts and payments.[5/] Although these studies were successful in explaining the long run behavior of reserves, they contained little or no information about the length of time needed for the adjustment process.

Recently, Milton Iyoha (1976) has attempted to combine the advances in the form of the desired reserve function with a variant of the partial adjustment model. The important feature of Iyoha's model is the use of a pooled cross section-time series data base. The procedure is attractive because the cross-sectional variation in the data permits a precise estimate of the parameters of the desired reserve function while the time-series variation allows estimates of the dynamic adjustment parameters. Like Clark, Iyoha's estimates of the speed of adjustment are very low: three years are required before half of the discrepancy between actual and desired reserves is completed. We shall demonstrate, however, that the low estimates of the speed of adjustment may be due to an inappropriate characterization of the error structure. We find that an alternative statistical specification yields a much higher estimate of the speed of adjustment. Before presenting the alternative estimates, we start by pointing out the source of the downward bias in Iyoha's model.

5/ See, for example, Heller (1966), Michael Kelley (1970), Jacob A. Frenkel (1974a, 1974b, 1978) and Steb F. Hipple (1974). These and other studies are surveyed in Herbert G. Grubel (1971), John Williamson (1973) and Benjamin J. Cohen (1975).

II.2 Country-Specific Factors and the Bias in Estimates of the Speed of Adjustment

In order to simplify the expostion, we assume that the desired level of reserves in country 'n' at time 't' is a linear function of a single exogenous variable, x_{nt}, and a residual, u_{nt}.

(4) $$R^*_{nt} = \beta_o + \beta_1 x_{nt} + u_{nt}$$

This desired reserves function is coupled with the simple partial adjustment function

(5) $$R_{nt} - R_{nt-1} = \alpha + \gamma(R^*_{nt} - R_{nt-1}) + w_{nt}.$$

Clearly, the properties of the estimated parameters of this simple two equation system depend crucially upon the properties of the two error terms. In particular, in order for the ordinary least squares estimates to be unbiased, it is necessary that the error terms be serially independent. In what follows, we concentrate on the properties of the error term in the desired reserves function, u_{nt}, since we believe that the degree of serial correlation in the balance of payments shock, w_{nt}, is likely to be reasonably small in annual data.

Earlier studies of the demand for international reserves (e.g. Frenkel 1974b, 1978) have found that there are large errors in cross-sectional models which do not disappear when the data are aggregated over time. There are, for example, some countries with persistent positive residuals - Switzerland and Austria - and others with persistent negative residuals - the United Kingdom and New Zealand. These residuals suggest that in addition to the cross-sectional differences in the holdings of reserves which may be attributed to the arguments in the desired reserves function, there are also important differences among countries' holdings of international reserves which are not explained by the exogenous variables but which are stable through time. These country-specific factors may be the result of historical, political and social influences that are not captured by the conventional set of arguments in the desired reserves function. Although it may not be possible to explain the country-specific factors, it is important to take account of their influence on the error structure.

A useful approach to this problem is the error-components model that was pioneered by Paul Balestra and Marc Nerlove (1966). In the error-components framework, the error term in equation (4) is decomposed into two parts: (i) u_n, the 'country-specific' factor that is fixed through time, and (ii) e_{nt}, a serially uncorrelated identically distributed random variable. Formally, u_{nt} is defined by the following conditions:

$$(6) \qquad u_{nt} = u_n + e_{nt}$$

where

$$E(u_n, u_{n'}) = \begin{cases} \sigma_u^2 & \text{for } n = n' \\ 0 & \text{for } n \neq n' \end{cases}$$

$$E(e_{nt}, e_{n't'}) = \begin{cases} \sigma_e^2 & \text{for } n = n' \text{ and } t = t' \\ 0 & \text{for } n \neq n' \text{ and } t \neq t' \end{cases}$$

and $\quad E(u_n, e_{nt}) = E(u_n) = E(e_{nt}) = E(u_n, x_{nt}) = E(e_{nt}, x_{nt}) = 0.$

Basically, this error structure combines the error structures that are (implicitly) assumed by most models of international reserves behavior. The u_n residuals are found in models which are purely cross-sectional or in models where the unit of observation is an average over time. The e_{nt} residuals are found in models which allow for dummy variable for each country or in which the unit of observation is a deviation from the country sample mean. In a pooled cross section-time series data base, both types of errors will generally be present. If this is the case, then it is easy to see that the

u_{nt} residuals will be serially correlated since, in general,

(7) $$E(u_{nt}, u_{nt'}) = E(u_n^2) = \sigma_u^2.$$

The immediate implication of this error structure is that the lagged level of reserves will be correlated with the residual so that ordinary least squares estimation will lead to a positive bias in the estimated coefficient on the lagged dependent variable. In the extreme case in which all differences in the holdings of international reserves reflect time invariant country-specific preferences, the estimated coefficient on the lagged dependent variable would be unity and would be independent of the speed of adjustment.

II.3 New Estimates of the Speed of Adjustment

The preceding demonstrates the theoretical possibility that the neglect of country-specific factors in the error structure leads to downward biased estimates of the speed of adjustment. We now analyse the empirical content of this possibility by adopting a two-stage procedure. The basic idea is that the average value of each variable may be used to estimate the parameters of the desired reserves function as well as the country-specific factors and then, in a second stage, the deviations of the actual stock of reserves from the desired level may be used to estimate the parameters of the adjustment function.

Following previous work on the demand for international reserves, the desired level of reserves is assumed to be positively related to (i) the variability of international receipts and payments -- reflecting the role of reserves as a buffer stock accomodating fluctuations in external transactions; (ii) a measure of scale -- reflecting the value of international transactions or of wealth; and (iii) the average propensity to import -- reflecting the degree of openness of the economy.[6/] Under the assumption that the true

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6/ For a discussion of the rationale for the choice of these variables and of the difficulties of including a variable measuring the interest cost of holding reserves, see Frenkel (1978). For definitions of the variables, see the Appendix.

functional form is log-linear, the desired reserves function can be written as

$$(8) \qquad \ln R^*_{nt} = \beta_o + \beta_1 \ln \sigma_{nt} + \beta_2 \ln Y_{nt} + \beta_3 \ln m_{nt} + u_n + e_{nt},$$

where the error $u_n + e_{nt}$ has the properties assumed in equation (6). In equation (8), the variability measure σ is defined as the ratio of the standard error of the trend-adjusted change in the stock of reserves to the level of imports. We normalize this variable by the level of imports in order to obtain a measure of variability that is independent of scale. The average propensity to import, m, is defined as the ratio of imports to GNP. In the few cases where GNP figures were not available, the ratio of imports to GDP was employed. The scale variable, Y, is defined as the value of GNP.

In the log-linear form, the dynamic adjustment equation can be written as

$$(9) \qquad \ln R_{nt} - \ln R_{nt-1} = \alpha + \gamma(\ln R^*_{nt} - \ln R_{nt-1}) + w_{nt}.$$

Equation (9) can be rewritten as

$$(10) \qquad \ln R_{nt} = \ln R^*_{nt} + (1/\gamma)\,\alpha - \frac{1-\gamma}{\gamma}\,[\ln R_{nt} - \ln R_{nt-1}] + (1/\gamma)\,w_{nt}.$$

Equation (10) provides a desirable form of the adjustment equation for illustrating the role of the constant term. One reasonable feature of a partial adjustment model is that the actual level of reserves is, on average, equal to the desired level. In terms of equation (10), this feature requires that on average the second and third terms in the equation cancel. Algebraically, the requirement is that

$$(11) \qquad \alpha = (1 - \gamma)\,\Delta \ln R_{..}\,,$$

where '..' denotes the average across countries and time. If equation (11) is satisfied, and if the trend rate of growth in reserves is the same for all countries in the sample, then the parameters of the desired reserves function may be estimated from the sample averages of the dependent and independent variables independently of the parameters of the adjustment function. From (8), (10) and (11), we arrive at

(12) $\ln R_{n.} = \beta_0 + \beta_1 \ln \sigma_{n.} + \beta_2 \ln Y_{n.} + \beta_3 \ln m_{n.} + u_n + e_{n.} + (1/\gamma)w_{n.}$,

where the average over time for country n is denoted by 'n.' As the number of time periods becomes large, the variance of the error term will be increasingly dominated by the variance of the country specific error, u_n, since the sample average of the other errors ($e_{n.}$ and $(1/\gamma)w_{n.}$) will tend towards zero.

Equation (12) was estimated for a sample of 22 developed countries and 32 less-developed countries using annual averages from the period 1964 to 1972; a period during which the international monetary system was characterized as a pegged exchange rate regime. The exact definitions of the variables and a list of the country sample is given in the Appendix. The period was terminated in 1972 since there is evidence that, by the end of 1972, the demand for international reserves underwent a structural change associated with the move to a regime of managed floating (See Frenkel, 1978). The results are presented below with the standard errors shown in parentheses beneath the coefficients.

Developed Countries

(13) $$\ln R_{n.} = \underset{(.821)}{3.783} + \underset{(.262)}{.723} \ln \sigma_{n.} + \underset{(.090)}{1.077} \ln Y_{n.} + \underset{(.303)}{1.505} \ln m_{n.}$$

$R^2 = .89$; $F(3, 18) = 50.51$; s.e. = .453

Less-Developed Countries

(14) $$\ln R_{n.} = \underset{(.729)}{4.854} + \underset{(.193)}{.367} \ln \sigma_{n.} + \underset{(.116)}{1.237} \ln Y_{n.} + \underset{(.285)}{1.537} \ln m_{n.}$$

$R^2 = .83$; $F(3, 28) = 44.38$; s.e. = .536

These results offer further support to the standard specification of the desired reserves function. All of the coefficients are of the correct sign and all but the coefficient on ln σ in the less-developed countries sample are significantly different from zero at the 5 per cent level. In addition, the three variables account for over 8o per cent of the cross-countries variation in the average holdings of international reserves. There are two noteworthy features of the cross-sectional results. First, in both country samples, the estimated income elasticity does not differ significantly from unity at the 5 per cent significance level, a result that is in accord with the homogeneity postulate.[7/] Second, in accordance with previous findings (Frenkel, 1974b, 1978) the demand for reserves by less-developed countries appears to be less sensitive to the measure of variability than the demand by developed countries. The higher sensitivity of the developed countries might reflect a greater reluctance on the part of those countries to cope with balance of payments disturbances by the imposition of trade controls and other restrictions.

In the second stage of our estimation procedure, the estimated parameters from the cross-section analysis are used to construct estimates of the desired stock of reserves, R^*_{nt}, and of the country-specific factor, u_n. The two-stage procedure is motivated by a number of considerations. The most important of these is our desire to obtain estimates of the desired stock of reserves that are independent of the time-series variation in the data. This allows for a strong test of the partial adjustment model, since there is no purely statistical reason why the change in the actual stock of reserves should be related to

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7/ Earlier work using a similar data base reports income elasticities that are smaller than unity (Frenkel, 1978). The source of the difference is the different definition of the variability measure which, in the present study, is normalized by the value of imports and is hence independent of scale. None of the estimates of the adjustment function are influenced by this normalization.

the deviation of our estimate of R^*_{nt} from R_{nt-1}. In other words, the two-stage procedure enables us to test if cross-sectional estimates of the desired reserves function are useful for predicting time-series variation in the actual stock of reserves. Secondly, there is sufficient variation in the cross-sectional data to obtain precise estimates of the parameters of the desired reserves function, so that little precision is lost by ignoring the time-series variation in the data. Finally, in a later part of the paper, we introduce adjustment functions that are non-linear in the desired level of reserves. The two-stage procedure avoids the problems of non-linear estimation in these cases.

Using a circumflex (^) to denote an estimated value, we define the country-specific factor as[8/]

$$(17) \quad \hat{u}_n = R_{n.} - \hat{\beta}_o - \hat{\beta}_1 \ln \sigma_{n.} - \hat{\beta}_2 \ln Y_{n.} - \hat{\beta}_3 \ln m_{n.},$$

and the desired level of reserves as

$$(18) \quad R^*_{nt} = \hat{\beta}_o + \hat{\beta}_1 \ln \sigma_{nt} + \hat{\beta}_2 \ln Y_{nt} + \hat{\beta}_3 \ln m_{nt} + \hat{u}_n.$$

It is worthwhile to reiterate two of the features of this definition of the desired stock of reserves. First, the series has not been constructed to 'fit'

8/ This estimate also includes the sample average of the e_{nt} and w_{nt} residuals. When the number of time periods is large, the correlation between the country-specific factor and the time-series residual will be small. In a small sample, the covariance between $\hat{u}_n$ and v_{nt} $(=\gamma e_{nt}+w_{nt})$ is equal to $(1/\gamma T)\sigma_v^2$, where T is the number of years in the sample. In assessing the extent of the bias, it is important to note that the country-specific factor only enters through the term $R^*_{nt} - R_{nt-1}$. The sample variance of this term will be dominated by variation in the exogenous variables, since the variation in the country-specific factor will tend to cancel when R_{nt-1} is subtracted from R^*_{nt}.

the time-series variation in actual reserves, and it is quite possible that the two series could exhibit disparate trends. Second, because the definition includes the country-specific factor, it avoids the problem of downward bias in the estimate of the speed of adjustment.

With our estimates of the desired stock of reserves in hand, we now turn to the estimation of the adjustment function specified in equation (9). We estimate this equation for the groups of the developed and the less-developed countries over the period from 1964 to 1972. The ordinary least squares estimates are reported in equations (19) and (20); the standard errors are reported in parentheses below the coefficients.

Developed Countries

$$\Delta \ln R_{nt} = \underset{(.016)}{.053} + \underset{(.055)}{.540}[\ln R^*_{nt} - \ln R_{nt-1}] \tag{19}$$

$$R^2 = .32;\ F(1,\ 196) = 93.45;\ \text{s.e.} = .208$$

Less-Developed Countries

$$\Delta \ln R_{nt} = \underset{(.018)}{.049} + \underset{(.047)}{.415}[\ln R^*_{nt} - \ln R_{nt-1}] \tag{20}$$

$$R^2 = .21;\ F(1,\ 286) = 76.48;\ \text{s.e.} = .295$$

These results support the partial adjustment model. The estimates of the speed of adjustment are large and precise relative to previous estimates.

The results indicate that the developed countries have adjusted somewhat more rapidly than the less-developed countries: 54 per cent of the discrepancy between actual and desired reserves are made up within one year in the developed countries sample whereas approximately 42 percent of the discrepancy is made up within one year in the less-developed countries sample. In addition, we note that the estimated constant terms are also broadly consistent with the theoretical model which predicts that the constant term will be equal to $(1-\gamma)$ times the average rate of growth of reserves. The regression results yield estimated average growth rates of 11.5 percent per annum for the developed countries and 8.3 percent per annum for the less-developed countries. The actual rate of growth of international reserves for all of the member countries of the IMF during this period was 9.4 per cent per annum.

In order to appreciate the effect of the inclusion of country-specific factors in the desired reserves function, we have also estimated the standard form of the partial adjustment model under the assumption that the residuals are serially independent. The estimated equation was:

$$\text{(21)} \quad \ln R_{nt} = \gamma\beta_0 + \gamma\beta_1 \ln \sigma_{nt} + \gamma\beta_2 \ln Y_{nt} + \gamma\beta_3 \ln m_{nt} + (1-\gamma) \ln R_{nt-1} + v_{nt}.$$

According to our previous analysis, the ordinary least squares estimate of the coefficient on the lagged dependent variable is biased towards unity, so that the estimate of the speed of adjustment is biased towards zero. The estimates reported in equation (22) and (23) conform with this prediction.

<u>Developed Countries</u>

$$\text{(22)} \quad \ln R_{nt} = \underset{(.190)}{.221} + \underset{(.042)}{.201} \ln \sigma_{nt} + \underset{(.040)}{.157} \ln Y_{nt} + \underset{(.070)}{.223} \ln m_{nt} + \underset{(.035)}{.867} \ln R_{nt-1}$$

$$R^2 = .97;\ F(4,\ 193) = 1497;\ s.e. = .237$$

Less-Developed Countries

$$\ln R_{nt} = \underset{(.190)}{.743} + \underset{(.038)}{.011} \ln \sigma_{nt} + \underset{(.043)}{.157} \ln Y_{nt} + \underset{(.069)}{.168} \ln m_{nt} + \underset{(.032)}{.881} \ln R_{nt-1} \tag{23}$$

$$R^2 = .94; \quad F(4, 283) = 1035; \text{ s.e.} = .325$$

These equations yield very low estimates of the speed of adjustment. Relative to our earlier results, the partial adjustment coefficient falls from .54 to .13 in the developed countries sample and from .42 to .12 in the less developed countries sample. A more complete description of the difference in the implied pattern of dynamic adjustment is given in Table 1, where the response of actual reserves to a one unit change in desired reserves is described for the two models. After four years, the traditional formulation, as embodied in equations (22) and (23), suggests that approximately forty percent of the adjustment will be complete. In contrast, the alternative model embodied in equations (19)-(20) predicts that over 90 percent of the adjustment will be complete by this time.[9/]

We conclude that our two-stage procedure supports the notion that countries behave as if they have a desired stock of reserves and that divergences between actual and desired stocks trigger adjustments which tend to eliminate the discrepancy. Our estimates also suggest that the speed of adjustment to divergences between actual and desired reserves is quite high, particularly relative to previous estimates. In the prededing analysis the adjustment coefficient γ was assumed to be constant rather than an economic variable reflecting the outcome of optimal choice. In the next section, we treat the speed

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[9/] For the sake of comparison, the corresponding cumulative changes for the first six years in the Iyoha model are .31, .29, .53, .49, .68, and .63. Likewise the Heller-Khan results imply that the system reacts to a one unit shock according to the following dynamics: 0, -.16, .23, .49, .67, .79, and .86. Both of these adjustment paths - based upon less-developed country samples - suggest significantly more gradual adjustment than the model with country-specific factors.

Table 1

Cumulative Change in Reserves
Due to a Unit Rise in the Desired Stocks

Period (years)	Cumulative Change Derived from eq. (19)-(20)		Cumulative Change Derived from eq. (22)-(23)	
	Developed Countries	Less-Developed Countries	Developed Countries	Less-Developed Countries
1	.54	.42	.13	.12
2	.79	.66	.25	.22
3	.90	.80	.35	.32
4	.95	.88	.44	.40
5	.98	.93	.51	.47
6	.99	.96	.58	.53

of adjustment as a behavioral variable and present an analysis of its determinants.

III. The Determinants of the Speed of Adjustment

In this section we extend the analysis by allowing for a variable speed adjustment. We examine the empirical content of three hypotheses concerning the size of the adjustment coefficient. The first hypothesis is that countries hold a larger stock of reserves in order to be able to adjust to balance of payments disturbances more gradually than otherwise. This trade-off between financing and adjustment is the essential feature of the optimizing models of international reserves developed by Clark (1970a), Heller (1966) and Kelly (1970). Within the terms of our model, the hypothesis implies that excess holdings of reserves are associated with smaller adjustment coefficients. We measure excess holdings of reserves by the country-specific factor, i.e., by the country's residual from the aggregate desired reserves function, the trade-off hypothesis implies a negative relationship between the country-specific factor and the speed of adjustment.

The second hypothesis, which we refer to the "Mrs. Machlup" effect following the argument put forward by Fritz Machlup (1966), is that the adjustment to a situation of deficient reserves is more rapid than it is to a situation of excess reserves.[10/] In our analysis we examine this postulate by testing the hypothesis that the speed of adjustment is positively related to the excess demand for reserves.

10/ A variant of the "Mrs. Machlup" effect can be phrased in terms of the asymmetric response of economic policy to balance of payments disequilibria. In this approach, deficit countries tend to direct their economic policies towards external balance targets more than surplus countries. This version of the hypothesis is analysed by Michaely (1971), who reports some evidence in support of it.

Finally, the third hypothesis is that the speed of adjustment is larger when the excess supply (or demand) is large relative to when it is small. This hypothesis is founded upon the presumption that the marginal cost of divergences between actual and desired reserves is an increasing function of the absolute size of the divergence. We test the hypothesis by relating the speed of adjustment to the square of the excess demand for reserves.

These three hypotheses are incorporated into equation (24) which summarizes the (linear form) of the adjustment function:

$$(24) \qquad \gamma = \gamma_o + \gamma_1 \ln(R^*_{nt}/R_{nt-1}) + \gamma_2 \ln(R^*_{nt}/R_{nt-1})^2 + \gamma_3 u_n.$$

In this equation, γ_o denotes the average speed of adjustment for the cross-section of countries when there is no discrepancy between desired and actual stocks of reserves. γ_1 is the coefficient on the excess demand for reserves and, according to the "Mrs. Machlup" effect, is expected to be positive. γ_2 is also expected to be positive under the hypothesis that the marginal cost of a divergence between desired and actual stocks rises with the absolute size of the discrepancy. Finally, γ_3, the coefficient on the country-specific factor, is expected to be negative under the hypothesis that countries trade-off larger stocks of reserves for more gradual adjustment. In order to test the model, we substitute equation (24) together with our estimates of desired reserves into the partial adjustment equation (9), and obtain the estimating equation

$$(25) \qquad \ln(R_{nt}/R_{nt-1}) = \alpha + \gamma_o \ln(R^*_{nt}/R_{nt-1}) + \gamma_1 \ln(R^*_{nt}/R_{nt-1})^2 + \gamma_2 \ln(R^*_{nt}/R_{nt-1})^3$$
$$+ \gamma_3 \ln(R^*_{nt}/R_{nt-1})u_n + v_{nt}.$$

In estimating this equation, we found a strong correlation between the squared and cubed values of the escess demand for reserves in the developed countries sample. This correlation is also present, but to a lesser extent, in the less-developed countries sample. For these reasons, we present in Table 2 a number of variants of equation (25).

In the developed country sample, equation DC-1 shows a statistically significant relationship between the rate of growth of reserves and (i) the excess demand for reserves, (ii) the squared excess demand, and (iii) the product of the excess demand and the country-specific factor, u_n. The coefficient on the cubed excess demand term is of the correct sign, but the magnitude of the coefficient is small and not significantly different from zero. These results provide support for two of the three hypotheses about the adjustment coefficient: the "Mrs. Machlup" effect where the speed of adjustment is positively related to the excess demand for reserves, and the 'country-specific' effect which states that countries hold excess reserves in order to adjust to balance of payments disequilibria more slowly.

Equation DC-2 demonstrates that the statistical insignificance of the coefficient on the cubed excess demand term reflects the strong colinearity between this variable and the squared excess demand term. When the latter variable is dropped from the equation, the coefficient on the cubed term becomes large and statistically significant. In equation DC-3, the cubed term is dropped in order to obtain a more precise estimate of the coefficient on the squared deviation term. As one would expect, the exclusion of the insignificant colinear variable substantially reduces the standard error of the coefficient on the remaining variable. It is noteworthy, however, that the estimated coefficient on the country-specific term remains invariant across the various specifications. Since the data cannot discriminate between equation DC-2 and DC-3 with any great degree of confidence, we will consider both alternatives in the following analysis.

Table 2

International Reserves and the Determinants of the Speed of Adjustment

Developed and Less-Developed Countries, 1964 - 1972

(standard errors in parentheses)

The estimating equation:

$$\ln(R_{nt}/R_{nt-1}) = \alpha + \gamma_o \ln(R^*_{nt}/R_{nt-1}) + \gamma_1 \ln(R^*_{nt}/R_{nt-1})^2 + \gamma_2 \ln(R^*_{nt}/R_{nt-1})^3 + \gamma_3 \ln(R^*_{nt}/R_{nt-1})u_n + v_{nt}$$

Equation	Constant	γ_0	γ_1	γ_2	γ_3	R^2	F-Stat.	S.E.
DC-1	.037* (.018)	.308* (.077)	.521* (.225)	.009 (.242)	-.298* (.132)	.39	31.33	0.198
DC-2	.059* (.016)	.337* (.076)		.482* (.131)	-.289* (.134)	.37	39.11	0.200
DC-3	.037* (.016)	.309* (.074)	.529* (.121)		-.298* (.132)	.39	41.99	0.197
LDC-1	.055* (.020)	.283* (.076)	-.004 (.069)	.196* (.104)	.016 (.085)	.23	20.60	0.294
LDC-2	.054* (.018)	.281* (.075)		.206* (.089)		.23	41.46	0.293

Note: An asterisk denotes parameter estimates that are significantly different from zero at the 95 percent confidence level. The number of observations for the developed countries sample is 198 (22 countries over 9 years) and 288 for the less-developed countries (32 countries over 9 years).

The estimated adjustment function for the less-developed countries sample is somewhat different. Equations LDC-1 and LDC-2 in Table 2 show a statistically significant relationship between the rate of growth of reserves and (i) the excess demand for reserves and (ii) the cubed value of the excess demand. This second result supports the hypothesis that the speed of adjustment increases with the squared deviation between desired and actual reserves. However, the results for the less-developed countries do not support the existence of a "Mrs. Machlup" effect or a "country-specific" effect. Finally, it is interesting to notethat the less-developed countries adjust to divergences between actual and desired reserves more gradually than do the countries in the developed countries sample. A comparison of equations DC-2 and LDC-2 reveals that both γ_0, the 'base' speed of adjustment, and γ_2, the coefficient on the cubed deviation, are larger in the developed countries sample, If, for example, actual reserves where 30 percent below the desired level, the typical developed country would make up 38 percent of the divergence in one year, while the typical less developed country would only make up 29 percent.

In Figure 1 we illustrate the relationship between the excess demand for reserves and the speed of adjustment for the developed countries sample. The histogram describes the distribution of the excess demand: magnitudes along the horizontal axis measure the excess demand for reserves relative to the actual stock.[11/] The left hand vertical axis indicates the frequency with which this relative excess demand occured in the sample. Thus an excess demand for reserves equal to 20 percent of the actual stock occurred in about 12 percent

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11/ Since the excess demand term is written as $\ln(R^*_{nt}/R_{nt-1})$, a positive value implies that actual reserves are <u>less</u> than desirec reserves.

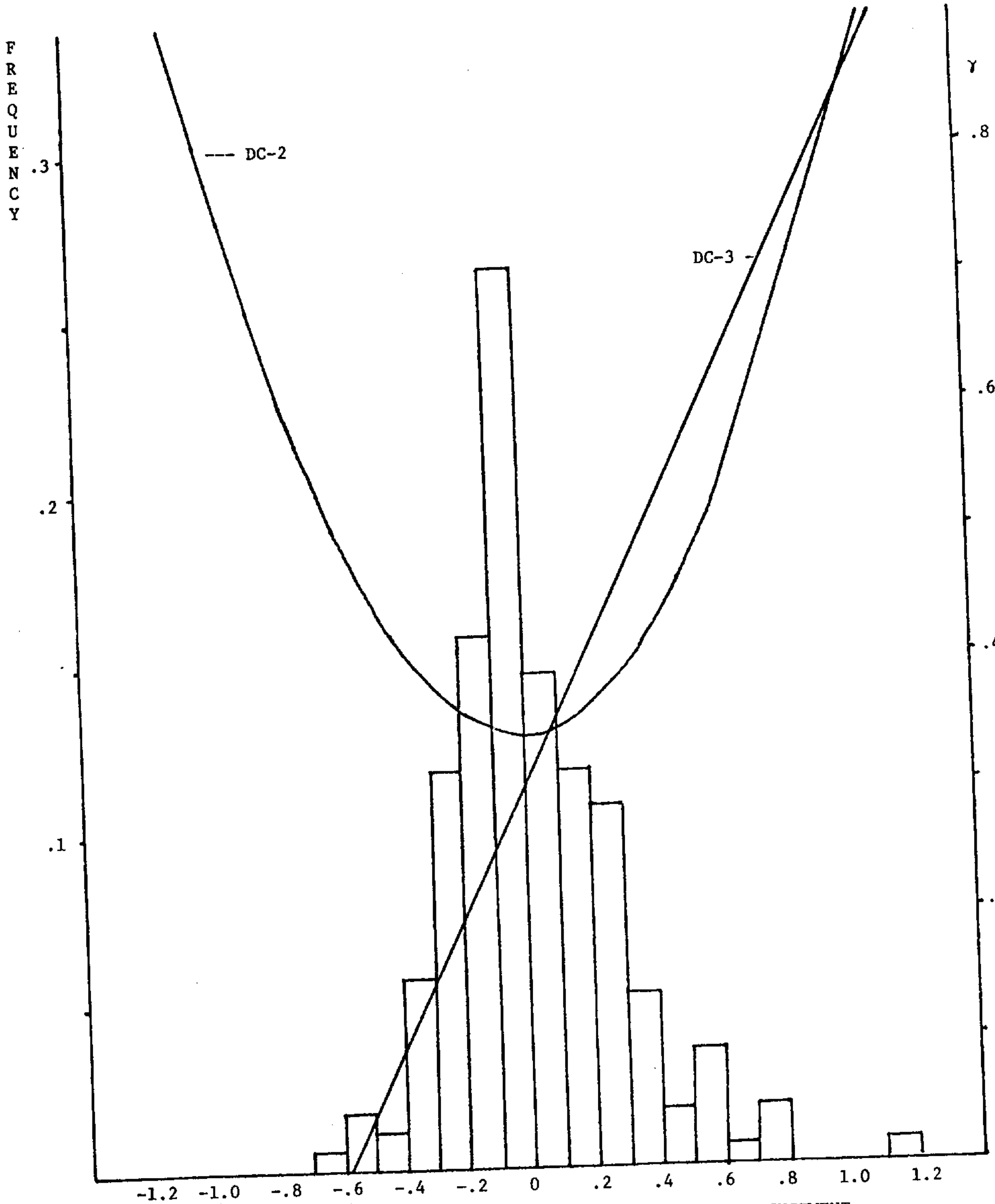

FIGURE 1: THE EXCESS DEMAND FOR RESERVES AND THE SPEED OF ADJUSTMENT
Developed Countries, 1964 - 1972.

of the observations. This histogram possesses a number of interesting characteristics. In the first place, the distribution is highly concentrated around zero: over sixty percent of the observations lie within the range from -20 per cent to + 20 per cent. This characteristic of the distribution is consistent with the large value of the speed of adjustment estimated from the developed countries sample. Secondly, the distribution is skewed to the right, which suggests that extreme values are more likely to be associated with an excess demand for reserves rather than an excess supply.

In order to illustrate the "Mrs. Machlup" effect, we examine the relationship between the size of the excess demand and the speed of adjustment. In Figure 1, this relationship is represented by the line DC-3 which gives the value of the adjustment coefficient (as measured on the right hand vertical axis) associated with the size of the excess demand. The relationship, based upon regression DC-3 in Table 2, illustrates the strong asymmetry in the association between the excess demand for reserves and the speed of adjustment For example, if a country has a relative excess supply of reserves equal to forty percent of the actual stock, only ten percent of the difference will be made up within one year. On the other hand, if the country has an excess demand for reserves equal to forty percent of the actual stock, over fifty percent of the difference will be made up within one year.

Although these results support the asymmetric adjustment hypothesis, they must be interpreted cautiously because of the small number of observations in the left hand tail of the distribution. This is clearly the reason why the quadratic and cubic terms in the adjustment function are highly colinear. In Figure 1, this colinearity is evident in the comparison between the line DC-3 and the curve DC-2 (which is based upon the regression DC-2 in Table 2): both models provide similar estimates of the adjustment coefficient over the range where the predominance of the values of the excess demand variable exist. It is consequently appropriate to conclude that the results indicate a strong positive relationship between the excess demand for reserves and the speed of adjustment when the excess demand is positive, but that the results are less informative when the excess demand term is negative.

In Figure 2, we present the histogram and the adjustment function for the less-developed countries sample. Relative to the developed countries sample, the histogram for the less-developed countries is both less highly concentrated and more symmetric. The greater variance in the excess demand for reserves is consistent with the lower estimate of the adjustment coefficient in this case. The results also illustrate the usefulness of describing the speed of adjustment as a variable rather than as a fixed parameter. For example, when the actual stock of reserves is within twenty percent of the desired stock, approximately thirty percent of the difference is made up within one year. Although this estimate is large relative to other studies, it seriously underestimates the speed of adjustment to more extreme divergences between actual and desired reserves. If, for example, the excess demand was 100 percent of the actual stock -- a result which occurs with a non-negligible probability in the less-developed countries sample -- the adjustment coefficient is closer to fifty percent per year.

The preceding discussion has established that there is a discernible relationship between the adjustment coefficient and the excess demand for reserves in both the developed and less-developed countries. In the developed countries sample, there is also a strong relationship between the adjustment coefficient and the country-specific factor. This relationship is described in Table 3, which presents the average value of the adjustment coefficient and the value of the country-specific factor. These results demonstrate the

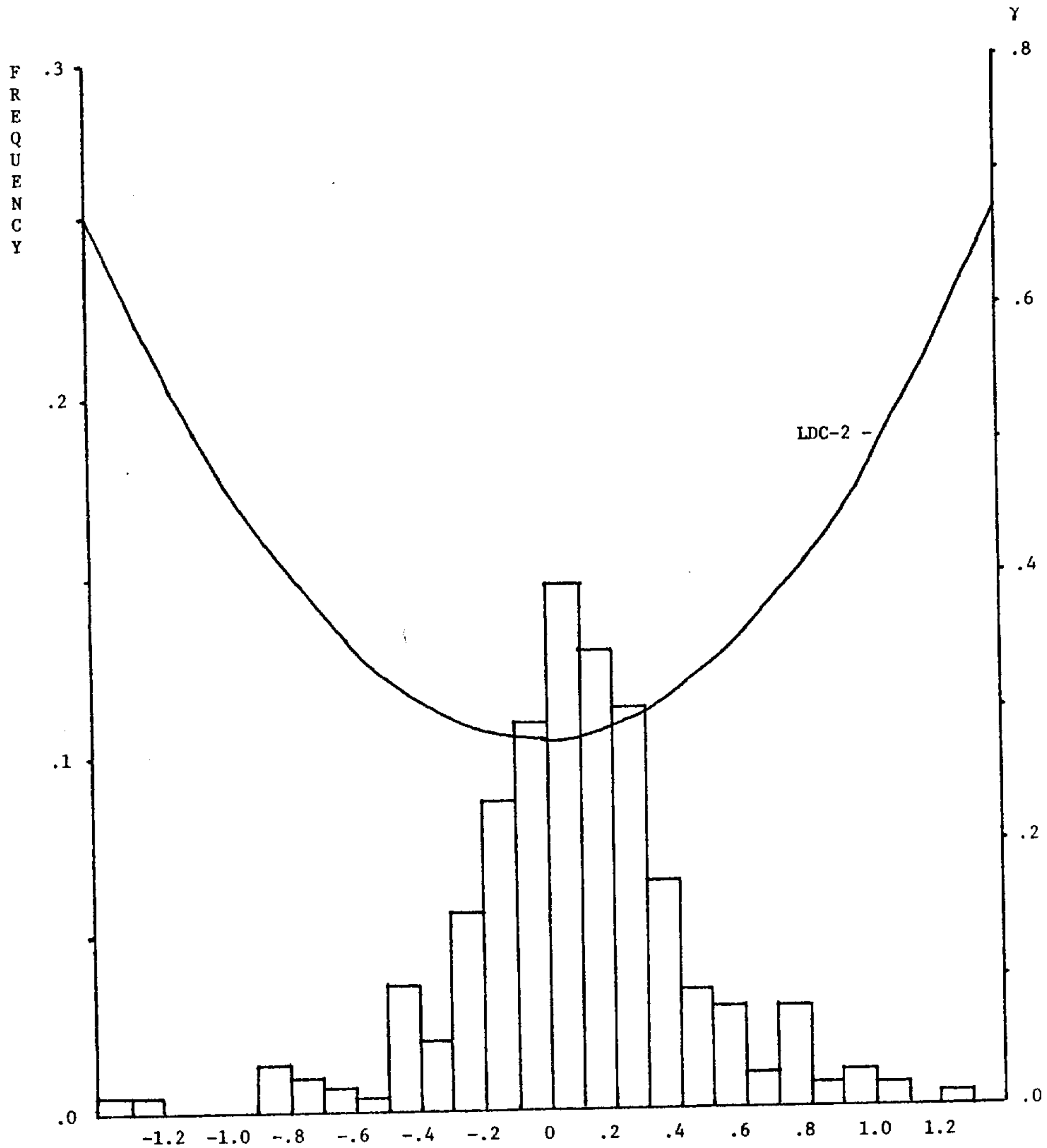

FIGURE 2: THE EXCESS DEMAND FOR RESERVES AND THE SPEED OF ADJUSTMENT
Less-Developed Countries, 1964 - 1972.

Table 3

AVERAGE SPEED OF ADJUSTMENT AND THE COUNTRY-SPECIFIC FACTOR

Developed Countries, 1964-1972

Country	Average Speed of Adjustment	Country-Specific Factor
Switzerland	.10	.86
Austria	.15	.66
Portugal	.17	.68
Italy	.21	.41
Ireland	.32	.16
Greece	.32	.18
Norway	.32	.20
France	.33	.07
Spain	.34	.16
Germany	.35	.08
Japan	.39	.14
Belgium	.39	-.15
Netherlands	.40	-.15
Iceland	.40	-.15
Sweden	.40	-.19
Turkey	.43	-.02
Australia	.44	-.19
South Africa	.47	-.45
Denmark	.50	-.52
Finland	.52	-.53
United Kingdom	.54	-.67
New Zealand	.56	-.58

Note: The average speed of adjustment is estimated from equation DC-3 reported in Table 2.

diversity in the adjustment coefficient in the developed countries sample: the estimates range from less than fifteen percent per annum - in the cases of Austria and Switzerland - to over fifty percent per annum in the United Kingdom, Denmark, Finland and New Zealand. There does appear to be some correspondence between our estimates of 'rapidly adjusting' countries (or, equivalently, countries with low country-specific factors) and casual empiricism concerning countries that have experienced persistent balance of payments difficulties during this period.

This discussion completes our analysis of the determinants of the adjustment coefficient during the pegged exchange rate period. In the next section, we extend the analysis to the managed float regime which began in 1973.

IV. Desired Reserves and the Speed of Adjustment During the Managed Float Regime.

It has often been argued that the evolution of the international monetary system from a regime of pegged exchange rates to the current regime of managed float should be associated with significant changes in the role of (and need for) international reserves. In this section, we examine whether the greater flexibility of exchange rates during the post-1973 period has been associated with either a change in the desired reserves function or a change in the adjustment function. As before, we estimate the parameters of the desired reserves function from the sample average of the data over the period from 1973 to 1977. The results for the two country samples are presented below.

Developed Countries

(26) $$\ln R_{n.} = \underset{(.760)}{3.139} + \underset{(.280)}{.828} \ln \sigma_{n.} + \underset{(.097)}{1.141} \ln Y_{n.} + \underset{(.449)}{1.795} \ln m_{n.}$$

$$R^2 = .90;\ F(3,\ 18) = 53.68;\ s.e. = .468$$

Less-Developed Countries

$$\ln R_{n.} = \underset{(.640)}{2.783} + \underset{(.194)}{.757} \ln \sigma_{n.} + \underset{(.096)}{1.140} \ln Y_{n.} + \underset{(.223)}{1.200} \ln m_{n.} \qquad (27)$$

$$R^2 = .85;\ F(3,\ 28) = 54.21;\ \text{s.e.} = .559.$$

A comparison of these estimates with the results from the earlier period reveals that the extent of the structural change in the desired reserves function has been extremely mild. Formally, the F-statistics corresponding to the hypothesis that the coefficients are the same in the two periods are 2.192 (with 4 and 36 degrees of freedom) in the developed countries sample and 1.298 (with 4 and 56 degrees of freedom) in the less-developed countries sample. In both cases the null hypothesis is not rejected since these values do not exceed the corresponding critical values at the 5 per cent significance level.[12/] It is also noticeable that the differences between the parameters of the desired reserves function for the developed and less-developed countries samples that were observed during the earlier period have diminished during the managed float regime. In the 1964-1972 period, the major difference between the results for the two countries samples was in the coefficient on the variability measure, where the less-developed countries were found to be less sensitive to this measure than the developed countries. In the subsequent period of the managed float, the variability coefficient in the less-developed countries sample increased to .757 (from the earlier estimate of .366), an estimate which is very similar to that estimated for the developed countries. The finding that the desired

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12/ The difference between these results and those in Frenkel (1978) stems from the differences in the empirical methodology. Frenkel (1978) uses a pooled cross section-time series data base and assumes that countries are always on their desired reserves function, whereas the present results refer to equations estimated on sample averages. Frenkel does find evidence of a structural change in the desired reserves function in 1972. Further evidence on structural change are provided by Heller and Khan (1978).

reserves function is more similar during the managed float period than it was during the fixed rate system is somewhat surprising, since differences in exchange rate arrangements are more pronounced during the managed float period.

As before, we use the estimated parameters from the cross-sectional regressions to construct estimates of the desired stock of reserves, R^*_{nt}, and the country-specific factor, u_n.[13/] These estimates are then used to estimate the adjustment functions presented in Table 4. For the developed countries sample, the results in equation DC-1 are very similar to those of the earlier period: the estimates of γ_0 and γ_1 are significantly positive, while the estimate of γ_2 is of the incorrect sign and not significantly different from zero. In addition, the estimate of γ_3, which relates the speed of adjustment to the country-specific factor, is approximately the same size as the earlier estimate, although the standard error is far larger. The increase in the standard error may reflect, to some extent, the smaller number of years used in the calculation of the variable and the greater uncertainty of the managed float period. The impression that the adjustment function for the developed countries is the same during the two periods is not rejected by the standard test: the F-statistic on the hypothesis that the true coefficients are the same in the two periods is 1.339 with 5 and 298 degrees of freedom. This value is well below the 5 per cent critical value for these degrees of freedom.

In equations DC-2 and DC-3, either the squared or the cubed excess demand term is omitted in order to examine if multicolinearity is again a problem. In this sample period, this does not appear to be the case, since

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13/ In the developed countries sample, the correlation coefficient between the country-specific factors estimates for the two periods is .80, thus supporting the idea that these errors are the result of temporally stable preferences. In the less-developed countries sample, the correlation coefficient is only .63, which suggests that a similar pattern of temporal stability is less evident in this case. The instability of the country-specific factor in the less-developed countries sample may also explain, in part, why this variable is not related to the adjustment coefficient.

Table 4

International Reserves and the Determinants of the Speed of Adjustment

Developed and Less-Developed Countries, 1973-197

(standard errors in parentheses)

The Estimating Equation:

$$\ln(R_{nt}/R_{nt-1}) = \alpha + \gamma_o \ln(R^*_{nt}/R_{nt-1}) + \gamma_1 \ln(R^*_{nt}/R_{nt-1})^2 + \gamma_2 \ln(R^*_{nt}/R_{nt-1})^3 + \gamma_3 \ln(R^*_{nt}/R_{nt-1})u_n + v_{nt}$$

Equation	Constant	γ_0	γ_1	γ_2	γ_3	R^2	F-Stat.	S.E.
DC-1	-.034 (.025)	.419* (.104)	.600* (.131)	-.139 (.202)	-.298 (.262)	.44	20.87	0.22
DC-2	-.031 (.023)	.272* (.108)		.004 (.218)	-.746* (.265)	.33	17.63	0.24
DC-3	-.032 (.025)	.371* (.077)	.585* (.130)		-.185 (.204)	.44	27.81	0.22
LDC-1	.002 (.033)	.776* (.120)	.265* (.125)	-.116 (.175)	.202 (.121)	.43	29.51	0.31
LDC-2	.009 (.031)	.723* (.089)	.224* (.108)		.229* (.113)	.43	39.34	0.31
LDC-3	.027 (.031)	.771* (.122)		.071 (.153)	.287* (.115)	.42	37.00	0.31
LDC-4	.026 (.030)	.637* (.080)	.267* (.106)			.42	55.89	0.31

Note: An asterisk denotes parameter estimates that are significantly different from zero at the 5 percent confidence level. The number of observations for the developed countries sample is 110 (22 countries over 5 years) and 160 for the less-developed countries sample (32 countries over 5 years).

the cubic term is still not significant when the squared term is dropped from the equation. These results therefore support the "Mrs. Machlup" effect of asymmetric adjustment dynamics.

In the less-developed countries sample, there are quite drastic differences between the estimated values of the parameters of the adjustment function over the two periods. The 'base' value of the adjustment coefficient, γ_o, (in eq. LDC-1) increases from .283 to .776, thus signifying a far more rapid response to divergences between actual and desired reserves. Secondly, the cubic term, which was significant in the early sample, is now of the wrong sign but not significantly different from zero. In conjunction with the upward revision in the estimate of γ_o, this result suggests that less-developed countries adjust rapidly to deviations of actual from desired reserves under all circumstances during the managed float period whereas, in the earlier period, rapid adjustment only occured when the divergence between actual and desired reserves was large. Thirdly, the quadratic term in the adjustment function now bears a significant coefficient, thus signifying the presence of a "Mrs. Machlup" effect. The estimated coefficient is only approximately half the size of the estimated coefficient in the developed countries sample. Finally, we note that in equations LDC-2 and LDC-3 the coefficient on the country-specific factor is statistically significant but of the incorrect sign. We take this result as further evidence that for the less-developed countries sample the variable u_n does not capture the trade-off between financing and adjustment.

The results in Table 4 also support the idea that reserves holding behavior of developed and less-developed countries have become more similar during

[14] We note however that in equation DC-2 the country-specific factor is significant.

the managed float period. The similarity is primarily evident in the fact that evidence of a "Mrs. Machlup" effect is not found for both country groups.[15]

V. Concluding Remarks

Although a number of studies have successfully identified a stable long run demand function for international reserves during the Bretton Woods system, attempts to estimate the process of dynamic adjustment have generally been less successful. In the first part of the paper, we demonstrated that a predictable pattern of adjustment dynamics can be identified in the behavior of developed and less-developed countries. Our results suggest that developed countries adjust to divergences between actual and desired reserves more rapidly than less-developed countries, but that the speed of adjustment is quite high in both cases. It appears that between 40 and 50 percent of the divergence between actual and desired reserves is made up within one year.

These results carry implications for the analysis of the 'adequacy' of international liquidity. In the first place, the desired reserves function which we use, with its emphasis upon country-specific preferences for reserves, may be used to assess if actual stocks of international reserve assets are greater than or less than the country's 'desired' level. Such an analysis would reduce the risk that a new allocation of SDR's or other reserve assets would contribute to world inflationary pressure. Secondly, the analysis of the adjustment function suggests that countries do adjust their monetary and fiscal policies in order to attain target levels of reserves. The time-series of the actual and desired stocks of reserves may consequently contribute to the positive analysis of macroeconomic policy.

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[15] In addition, for countries with an excess demand for reserves, the speed of adjustment may not be very different because the lower base speed of adjustment in the developed countries will be compensated for by the larger γ_1 coefficient in this region. The behavior of the two country groups will, however, be very different when there is an excess supply of reserves.

Writers on the international monetary system have often argued that the policy response to a situation of deficient international liquidity is quite different from the response to a situation of excess liquidity. The reason for the asymmetric response is that the cost of holding excess reserves, represented by difference between the rate of return on the reserve assets and their marginal opportunity cost, is expected to be small relative to the cost of deficient reserves, which may result in a risk premium on the country's borrowing and the possibility of external control over its policies through the International Monetary Fund. Although widely recognized in institutional writings on reserve use, this feature has received less attention in studies of the demand for international reserves. In this paper, we investigated the possibility of asymmetric adjustment by relating the speed of adjustment to the divergence between actual and desired reserves. In the developed countries samples, the statistical evidence supported the view that the speed of adjustment is more rapid when actual reserves are less than desired reserves. However, no significant support for the hypothesis was found in the less-developed countries sample.

A second hypothesis which we examined is that the speed of adjustment is related to the absolute size of the divergence between actual and desired reserves. Our statistical results for the Bretton Woods period demonstrate that this pattern of adjustment is more likely to characterize the behavior of less-developed countries.

The third, and final, hypothesis that we examined in this paper concerns the alleged trade-off between financing and adjustment. Many theoretical models of the demand for international reserves demonstrate that one of the benefits from holding a greater quantity of international reserves is that domestic monetary and fiscal policies do not have to be closely tuned to balance of payments developments. We extend this argument by assuming that countries have a well defined and stable preference in their choice between financing versus adjustment, so that countries that hold more reserves, relative to their conditional average, do so in order to adjust to divergences between actual and desired reserves more slowly. We find strong evidence in support of this hypothesis in the sample of developed countries, but no support for it in the less-developed countries. It may be that the constraints placed upon the economic policies of less-developed countries by their domestic needs leave less room for preferences between financing and adjustment.

All of the preceding conclusions apply to the Bretton Woods system and it is important to know the extent to which the results also apply to the current regime of managed exchange rate flexibility. In the sample of developed countries, the results do appear to be robust: we are unable to reject the hypothesis that the parameters of <u>both</u> the desired reserves function and the adjustment function are the same in the two periods. In the case of the less-developed countries, the parameters of the desired reserves function appear to be stable over the two periods, but there does appear to have been a significant change in the parameters of the adjustment function. In particular, the less-developed countries appear to be adjusting to divergences between actual and desired reserves more rapidly during the managed float period, and their pattern of response also appears to have become more asymmetric. Overall, the evidence certainly supports the view that a stable demand fraction for international reserves can be defined for the post-Bretton Woods period and that adjustment of the actual stock of reserves towards the desired stock is quite rapid.

APPENDIX

List of Countries and Definitions of Variables

1. List of Countries[a]

Developed Countries

United Kingdom
Austria
Belgium
Denmark
France
Germany
Italy
Netherlands
Norway
Sweden
Switzerland
Japan
Finland
Greece
Iceland
Ireland
Portugal
Spain
Turkey
Australia
New Zealand
South Africa

Less-Developed Countries

Argentina
Brazil
Chile
Columbia
Costa Rica
Dom. Republic
Ecuador
El Salvador
Guatemala
Honduras
Mexico
Nicaragua
Panama
Paraguay
Peru
Venezuala
Jamaica
Israel
Jordan
Egypt
Burma
Sri Lanka
China
India
Korea
Malaysia
Pakistan
Philippines
Thailand
Ghana
Sudan
Tunisia

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[a] Classification based on the International Monetary Fund.

2. Definitions and Variables

All data sources are from the IFS tape obtained from the International Monetary Fund. (May 1979 version)

R - International reserves are measured in end-of-period 10^6 U.S. dollars. Reserves are defined as the sum of gold, SDRs, foreign exchange and reserve position at the Fund. When reserves are reported in local currency, they were converted to U.S. dollars using the end-of-period exchange rate.

IM - Imports are reported as cif in local currency units. These figures were then converted to U.S. dollars using the period average exchange rate. The figures used are measured in 10^9 U.S. dollars.

GNP - GNP and GDP are reported in local currency units. These figures were converted to U.S. dollars using the period average exchange rate. The figures are measured in 10^9 U.S. dollars.

m - The average propensity to import was defined as the ratio of imports to GNP. When the latter was unavailable, GDP was used instead.

σ - The variability measure. To calculate the value of σ_T^2 for year T for a given country, the following regression was first run:

$R_t = \alpha + \beta_T t + u$ over $t = T - 14,\ldots,T$, and then using the estimated trend $\hat{\beta}_T$, $\tilde{\sigma}_T^2$ was defined

$$\tilde{\sigma}_T^2 = \sum_{t=T-14}^{T} (R_t - R_{t-1} - \hat{\beta}_T)^2/14$$

(except for 1963 for which, due to lack of data, $\tilde{\sigma}_T^2$ is based on the previous 14 observations). Thus $\tilde{\sigma}_T^2$ is defined as the variance of the trend-adjusted changes in the stock of international reserves. A plot of the time-series of reserves revealed that the assumption of a linear trend seems more appropriate than that of an exponential trend. In order to obtain a measure of variability that is free of scale, our variability measure for period T is the ratio of the standard error of the trend-adjusted changes in reserves to the value of imports. Thus $\sigma_T = \tilde{\sigma}_T/IM_T$.

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