IMF WORKING PAPER

WP/92/81

INTERNATIONAL MONETARY FUND

Research Department

Currency Substitution and Cross-Border Monetary Aggregation: Evidence from the G-7

Prepared by Timothy D. Lane and Stephen S. Poloz 1/

Authorized for distribution by David Folkerts-Landau

October 1992

Abstract

Is there a stable aggregate money demand relationship for Europe? If so, why, and if not, why not? These questions are important for the implementation of policy by a European central bank, as well as for the appropriate speed of transition to EMU. This paper addresses them in a multi-country empirical study of money demand for the G-7 countries during the period since 1973. It looks for evidence of currency substitution and tests the restrictions implied by cross-border aggregation within Europe.

JEL Classification Numbers:

E41, F31

1/ The first author is in the Fund's Research Department; the second author is with the Research Department of the Bank of Canada, and was a Consultant at the Fund at the time of writing. We have benefitted from discussions with Doug Hostland. The views expressed below are those of the authors, and do not necessarily represent those of the International Monetary Fund or the Bank of Canada.

Contents

Summary

Recent studies have suggested that one can specify a stable aggregate demand for money for the countries participating in the European Monetary System (EMS). This paper evaluates two alternative interpretations of this result: first, the relationship between money demand and its determinants may be similar enough in the different countries that not much is lost by aggregating across national borders. Second, there may be currency substitution: if residents of EMS countries hold their money in a variety of European currencies and shift among them in response to exchange rate expectations and other difficult-to-measure factors, the demand for money in the EMS as a whole may be more predictable than in any one country.

The paper presents estimates of demand for narrow money in the Group of Seven (G-7) industrial countries; the smaller EMS countries are omitted because of data limitations, and the three non-European G-7 countries are included to allow for possible currency substitution outside as well as inside the EMS. Within a two-stage error-correction framework, Seemingly Unrelated Regressions (SUR) estimation is used to capture possible interaction between demand for money in the different countries and to permit tests of aggregation restrictions, namely, that the coefficients on income and interest rate variables for the money demand equations are the same for the four European G-7 countries. A common specification for the money demand equation is used for all seven countries, with dummy variables added to account for breaks in the data series (and for episodes of financial innovation documented in the literature). Exchange rates and foreign incomes are used to capture currency substitution.

In the first set of results, a cointegrating equation is estimated for the levels of the variables. It is found that for most countries, the currency substitution variables are needed to obtain a cointegrating relationship, while the aggregation restrictions do not appear to be consistent with the data. These results are borne out when dynamic error-correction equations are estimated using SUR: tests reject the hypothesis that currency substitution does not affect money demand and also the imposition of the aggregation restrictions on the four EMS countries. Moreover, both the static and dynamic equations yield significant and often negative correlations among the errors in money demand in different countries, and this also suggests cross-border shifts in money holdings.

These results support the view that currency substitution, and not merely similarities in money demand relationships across countries, may be responsible for the success of cross-border aggregation in money demand estimation. If borne out in further research, they would imply that national moneys may become more difficult to predict and control, strengthening the case for implementing monetary control on a supra-national level, such as through a European central bank.

I. Introduction

Economic and monetary union (EMU) among the members of the European Community (EC) implies the creation of a single monetary authority and the use of a single currency throughout the area. For this reason, aggregate monetary relationships within the area as a whole have been attracting increasing attention. In particular, some recent studies (Bekx and Tullio, 1989; Kremers and Lane, 1990; Monticelli and Strauss-Kahn, 1991; Bomhoff, 1991; Artis, 1991) have presented evidence supporting the conjecture that a stable aggregate demand for money relationship could be specified for the group of countries participating in the European Monetary System (EMS). It has even been suggested that the demand for money may be better specified for the EMS aggregate than for the individual member countries, and currency substitution has been suggested as a possible explanation: if EC residents hold their money in a variety of currencies, and shift among these currencies in response to exchange-rate expectations and other difficult-to-measure factors, the demand for money in the EC as a whole might be more predictable than that in any single country. 1/

If they stood up to further scrutiny, these results would have several important implications. First, they would strengthen the case for EMU, suggesting that a European central bank (ECB) might even be able to implement monetary control more effectively than the individual national central banks (Russo and Tullio, 1988, Kremers and Lane, 1990). Second, they could, after further refinement, provide a basis on which an ECB could set EMU-wide money-supply targets, and use interest-rate control to pursue these targets. Such targets might also be useful as a guide to monetary policy coordination during the transition to EMU, under the auspices of the European Monetary Institute. Third, if the aggregate European demand for money reflected increasing currency substitution among the individual countries' moneys associated with the increasing financial market integration and exchange rate stability of the EMS period, this would have implications for the appropriate speed of transition to monetary union: it suggests the danger that currency substitutability might increase further during the approach to EMU, making it increasingly difficult to conduct monetary policy at the national level, making exchange rates increasingly sensitive to shocks and to changes in expectations, and making foreign-exchange-market intervention increasingly ineffective in stabilizing exchange rates (Girton and Roper, 1981, Boyer and Kingston, 1987). 2/ If this happened, it would dictate a rapid approach to EMU, to avoid a high

---

1/ The implications of cross-border monetary aggregation in money demand have been examined more formally at a theoretical level by Kremers and Lane, 1992(b).

2/ A similar argument was made at the level of the world economy by McKinnon (1982). See also, for instance, Boyer (1972).

degree of instability in exchange rates, national money stocks, or both, during the transition (Kremers and Lane, 1992(a)). 1/

These potential implications of high currency substitution make it particularly relevant to ask why area-wide monetary aggregates for Europe seem to be well behaved. As argued, if the aggregation is appropriate because of high currency substitution, it might indicate not only that an early move to monetary union is feasible, but also that it might prove necessary. If there is some other reason that cross-border monetary aggregation proves to be acceptable to the data, however, the implications for management of the transition to monetary union may be quite different.

Accordingly, this paper seeks to examine the foundations of cross-border monetary aggregation in Europe, by examining the demand for money in each country in a multi-country setting, using Seemingly Unrelated Regressions (SUR) estimation. 2/ We use data for the G-7 countries, for the flexible exchange rate period--more precisely, 1972-IV through 1990-IV. Focusing on the G-7 implies both a broadening and a narrowing of the frame of reference, in relation to the EC countries that are of greatest immediate interest to us. Including the non-European G-7 countries is intended to permit us to allow for the possibility of currency substitution with non-European countries, and if possible to distinguish between effects that are specific to Europe and those that may be more general; excluding the smaller European countries--which together account for some 20 percent of total GNP in the EMS--is a choice made for the sake of tractability, as well as due to the availability of comparable quarterly data. 3/

The approach we follow is to estimate a common specification of money demand for the G-7 countries, look for evidence of currency substitution, and test the restrictions implied by aggregation across the four G-7 countries belonging to the EMS. The key question to be addressed is whether cross-country aggregation of money demand is successful because of currency substitution, because some other unobserved variables affect money demand in several countries, or simply because the individual countries' money demand equations do not differ much.

Our empirical approach includes the following features:

1. We use a cointegration/error-correction framework, as developed by Engle and Granger (1987). This takes account of the nonstationarity of many of the variables and is consistent with the approach followed in

---

1/ The implications of currency substitution in the context of European monetary unification were earlier examined by Melvin (1985).

2/ One previous study that used a multi-country approach to look for evidence of currency substitution is Brillembourg and Schadler (1979).

3/ There are no quarterly GNP or GDP series for Belgium, Denmark, Ireland, or Spain.

previous aggregative studies of money demand in Europe, including Kremers and Lane (1990), Monticelli and Strauss-Kahn (1991), and Artis (1991).

2. We use a common specification of money demand for all seven countries. This constrains any search for an appropriate specification for a single country, and sharpens the focus on tests of hypotheses pertaining to all seven, or only the four EC countries in the group.

3. We look for evidence of currency substitution in several places. First, we include all exchange rates, as well as aggregate income in other EC countries, as explanatory variables in the cointegrating equations for money demand in each country; we test whether these variables can collectively be excluded. Second, reminiscent of Brittain (1981), we examine the correlations between the error terms in money demand in different countries. Third, in a stripped-down model excluding exchange rates and foreign income, we test for cross-border error-correction effects, examining the possible influence of the error terms in the cointegrating equation in one country on the demand for money in another. All three of these approaches yield results suggestive of currency substitution--contrary to much previous literature which has found little evidence of currency substitution for developed countries. These results suggest the usefulness of looking for currency substitution in a multi-country setting.

4. We include dummy variables (a) for institutional changes that some previous studies have suggested resulted in important shifts in money demand, and (b) for reported series breaks in the data. In the event, it is the series breaks that appear to be of greatest importance.

The rest of the paper is organized as follows. Section II lays out the framework within which the empirical investigation will be pursued. Section III reports the results of the empirical tests. Section IV offers some concluding remarks.

II. The Framework

The main aim of this paper is to discriminate empirically between alternative interpretations of cross-border monetary aggregation in Europe. We therefore begin by presenting a framework that encompasses these alternatives. The basic approach to be followed will be to develop cointegrating equations for money demand in each of the countries under study, estimate dynamic error-correction models based thereon, and then test jointly the validity of cross-equation aggregation restrictions and the importance of currency substitution.

1. The maintained hypothesis

Currency substitution implies that households in each country allocate their total holdings of money across several countries' currencies. This means that holdings of domestic-currency real balances in a world with n currencies will depend on the n scale variables, n opportunity cost variables, and n-1 expected rates of depreciation (Poloz, 1984, 1986). The basic framework within which we will be working may thus be represented as follows:

$$
\begin{aligned}
(m-p)_1 &= f_1(y_1 \ldots y_n,\ R_1 \ldots R_n,\ s^e{}_1 \ldots s^e{}_{n-1}) \\
&\ \ \vdots \\
(m-p)_n &= f_n(y_1 \ldots y_n,\ R_1 \ldots R_n,\ s^e{}_1 \ldots s^e{}_{n-1}),
\end{aligned}
\tag{1}
$$

where m, p and y denote the logarithms of nominal money balances, prices and real output, respectively; R denotes the nominal rate of interest, and s^e denotes the expected rate of depreciation. The relevant interest rate may be either a short- or a long-term rate, or both, depending on the role of expectations and adjustment in the monetary sector; as in many studies, we may leave this as an empirical question.

It will be convenient to partition the model further, distinguishing between the k member countries of the EMS, and the remaining n-k countries under consideration. System (1) then may be rewritten as follows:

$$
\begin{aligned}
(m-p)_1 &= f_1(y_1, \ldots y_k \ldots y_n,\ R_1 \ldots R_k \ldots R_n,\ s^e{}_1 \ldots s^e{}_{k-1} \ldots s^e{}_{n-1}) \\
&\ \ \vdots \\
(m-p)_k &= f_k(y_1, \ldots y_k \ldots y_n,\ R_1, \ldots R_k \ldots R_n,\ s^e{}_1 \ldots s^e{}_{k-1} \ldots s^e{}_{n-1}) \\
(m-p)_{k+1} &= f_{k+1}(y_1, \ldots y_k \ldots y_n,\ R_1, \ldots R_k, \ldots R_n,\ s^e{}_1 \ldots s^e{}_{k-1} \ldots s^e{}_{n-1}) \\
&\ \ \vdots \\
(m-p)_n &= f_n(y_1, \ldots y_k, \ldots y_n,\ R_1 \ldots R_k, \ldots R_n,\ s^e{}_1 \ldots s^e{}_{k-1} \ldots s^e{}_{n-1}
\end{aligned}
\tag{2}
$$

With n countries in the study, each of the equations of (1) will include 3n-1 variables. Since nine currencies are presently in the EMS--those of Germany, France, Italy, Netherlands, Denmark, Belgium, Ireland, United Kingdom and Spain--and we intend to include the United States, Canada and Japan to represent the extra-EMS margins, there are clearly too many variables for the analysis to be tractable. It would be desirable to make some compromises in order to reduce the field of study to manageable dimensions:

1. Under the assumption of covered interest parity, system (2)--which includes domestic interest rates, foreign interest rates, and domestic expected rates of depreciation--includes n redundant variables. Furthermore, this is likely to be true to a first approximation regardless of how one chooses to measure the expected rate of depreciation. Therefore, it seems sensible at the outset to exclude either (a) the n-1 foreign rates

of interest or (b) the n-1 expected changes in the exchange rate from each equation. In this study, the first of these expedients was adopted. 1/

2. Cross-border monetary aggregation is likely to be appropriate for the EMS as a whole if it is appropriate for the four largest countries--Germany, France, Italy and the United Kingdom. These account for some 80 percent of EC GDP, and probably an even larger share of financial market activity. The unavailability of quarterly national accounts data for several of the smaller countries also makes it difficult to treat them on a comparable basis. Another consideration is that some of the smaller countries--viz. the Benelux countries--have maintained very stable exchange rates against the DM and their economies have been relatively highly integrated with that of Germany; this suggests that including the smaller countries might lead to a highly collinear information matrix in estimating system (2). For these reasons, in this paper we will treat the EMS as if it consisted of only its four largest economies.

3. We further simplify the structure by aggregating the effects of foreign income into two variables for each country: (a) nondomestic EC income, and (b) non-EC foreign income. This, of course, entails an additional restriction on the cross-border effects of different countries' incomes.

These restrictions result in a system of the following form:

$$
\begin{aligned}
(m-p)_1 &= f_1(y_1, (y_E-y_1), y_{NE}, R_1, s^e_1, \ldots s^e_{n-1}) \\
&\cdots \\
(m-p)_k &= f_k(y_k, (y_E-y_k), y_{NE}, R_k, s^e_1, \ldots s^e_{n-1}) \\
(m-p)_{k+1} &= f_{k+1}(y_{k+1}, y_E), y_{NE}, R_{k+1}, s^e_1, \ldots s^e_{n-1}) \\
&\cdots \\
(m-p)_n &= f_n(y_n, y_E, y_{NE}, R_n, s^e_1, \ldots s^e_{n-1}),
\end{aligned}
\qquad (3)
$$

where y_E represents EMS-wide output, and y_{NE} represents non-EMS foreign output. With the EMS represented by four countries, system (3) would contain nine exogenous variables per equation, which should be a manageable number.

The possibility remains that the variables that have been incorporated to capture currency substitution will fail to do so. This would mean that

1/ Some exploratory work included foreign interest rates and excluded exchange rates in each equation, testing both against an encompassing model. Cointegration results were similar under the two approaches; tests of linear restrictions implied by the exclusion of each set of variables showed that one could reject the exclusion of the exchange rates when interest rates were included, but not vice versa.

any such effects present in the data would fall into the error terms. To meet this possibility, we also consider a system that is even more restrictive than (3). This system would have the following form:

$$(m-p)_1 = f_1(y_1,R_1)$$
$$\cdots\cdots\cdots$$
$$\cdots\cdots\cdots$$
$$(m-p)_n = f_n(y_n,R_n) \qquad (4)$$

Notice that the form of systems (3) and (4) make them obvious candidates for seemingly unrelated regressions (SUR) estimation. This will raise the power of hypothesis tests and facilitate the imposition of cross-equation restrictions.

2. Testing for aggregation

The SUR framework is also a natural one in which to test the restrictions implied by aggregation across the member countries (Zellner, 1962). This involves testing the condition of micro homogeneity--that is, the restriction that the estimated parameters are identical across component equations and equal, in turn, to the corresponding parameters of the aggregate equation (Pesaran, Pierse and Kumar, 1989). 1/

In the system represented by equations (3), aggregation over the EMS would require that the following conditions hold for the k EMS countries: (a) the coefficients on domestic income, on domestic interest rates, and on aggregate nondomestic EMS income are equal across countries; (b) the coefficients on intra-EMS expected rates of depreciation sum to zero across countries.

For the parsimonious system (4), the aggregation conditions are simply that the coefficients on domestic income and those on domestic interest rates be equal across countries.

In a two-stage error-correction framework, the aggregation properties pertain to the cointegrating relations as well as to the dynamic equations. However, the variables in a cointegrating equation are by assumption nonstationary, and this violates the assumptions of the usual tests of restrictions in a SUR framework. This implies that the results of these tests for the cointegrating equations are only suggestive, rather than having well-established statistical properties. Formal testing of the

---

1/ This is a sufficient, not a necessary condition for perfect aggregation. An alternative sufficient condition is compositional stability, under which the composition of the regressors across the micro units remains fixed over time. Perfect aggregation also holds when these conditions obtain in combination--e.g., when micro homogeneity holds for a subset of the variables and compositional stability for the others. See Pesaran, Pierse and Kumar, 1989.

aggregation restrictions will occur at the second stage: SUR estimation of a system of dynamic error correction equations for each country's demand for money, imposing the cross-equation restrictions required for aggregation, and using error correction variables based on restricted SUR estimates of the cointegrating vectors.

3. Structural shifts and data breaks

Many previous studies of money demand in several of the countries in our sample have found evidence of structural shifts, particularly associated with financial innovation. Moreover, the International Financial Statistics (IFS) data which were used, while having the advantage of some degree of international comparability, contain some series breaks, some of which are quite large.

Although the literature dealing with structural breaks in cointegrating relationships is at a relatively early stage, it has tended thus far to confirm the intuition that an omitted structural break could result in failure to reject the null hypothesis of no cointegration when cointegration was in fact present. Gregory and Nason (1991) found that, for models with a single regressor, the Augmented Dickey-Fuller (ADF) test for cointegration loses considerable power when there is a break in the cointegrating vector. This suggests that when there is a structural break at a known date, it is desirable to include a shift dummy in estimating the cointegrating vector. Tests for unknown structural breaks in cointegrating relations have been proposed by Hansen (1991), but their properties are still being studied.

There have been a few studies that have examined structural breaks in cointegrating equations of money demand. For example, Hoffman and Rasche (1991) present recursive estimates of cointegrating vectors of money demand for the U.S. and Japan, using a technique suggested by Stock and Watson (1991), and examine the stability of the estimates. A study of Polish money demand by Lane (1992) includes dummies for possible structural shifts associated with major regime changes.

Since both financial innovation and changes in data definition may result in permanent shifts, they should be incorporated explicitly in the estimated cointegrating relations. In our study, we do this by including dummy variables for the dates of the shifts in estimating both the static and the dynamic equations. Breaks that were included in the study are shown in Table 1.

Table 1. Shift Dummies for M1 Demand Equations 1/

1. Germany

1978:1 - Boothe and Poloz (1987)--foreign hoarding of marks
1988:1 - Boughton (1991)--financial innovation.
1990:2 - Series break due to unification*

2. France

1977:4 - Series break*
1984:4 - Series break*

3. Italy

No documented shifts or series breaks

4. United Kingdom

1987:1 - Series break due to addition of Building Society deposits*

5. Japan

No documented shifts or series breaks

6. United States

1986:4 - Boughton (1991)--financial innovation: shifts in relative yields

7. Canada

1976:1 - Boothe and Poloz (1988)--financial innovation
1981:2 - Boothe and Poloz (1988)--financial innovation

1/ Asterisks are used to indicate the dummies that were included in the Dickey-Fuller regressions when testing for integration. All of the listed dummies were included in the final versions of the cointegrating vectors; a longer list of possible break points was included in preliminary tests, and some were eliminated given that they did not appear to contribute to cointegration.

4. Expected rates of depreciation

An important issue is the choice of a measure for the expected rate of depreciation. Previous work on currency substitution has measured expected exchange rate movements using either the forward premium or interest differentials--both of which are, however, poor predictors of actual spot rate movements. An alternative approach, using the actual future spot rate to represent the currently expected future rate, involves an errors-in-variables problem that cannot readily be handled in the absence of a plausible predictive model for the future exchange rate.

Another potential difficulty is that exchange rates are generally found to be difference-stationary, making a variable of the dimension of the forward premium an unlikely candidate for inclusion in a cointegrating relationship. Studies by Kremers and Lane (1990) and Monticelli and Strauss-Kahn (1991) have accordingly included the level of the exchange rate--which is generally found to be nonstationary--in estimating a cointegrating relationship. A similar result was found for M2 in the U.S. by McNown and Wallace (1992). The most obvious interpretation of this specification is that agents' expectations of future movements in exchange rates are based on its current level. This is inconsistent with rational expectations if the actual exchange rate is nonstationary, however, since nonstationarity implies that the current level of exchange rates conveys no information about future exchange rate movements. 1/ An alternative interpretation is that some shocks, such as institutional or policy developments, may affect both the level of exchange rates and the demand for money; in this case, the level of exchange rates is associated with the level of demand for money, but this may not be directly associated with expected exchange rate movements. It would also be difficult to discriminate between either of these interpretations and a third explanation according to which exchange rates appear in a reduced form equation for real balances because the monetary authorities use exchange rate movements as a guide to monetary policy.

Notwithstanding these caveats over their interpretation, in this study we include p-1 logs of nominal exchange rates, instead of the p-1 expected rates of depreciation, in each country's money demand equation (3) to capture the possibility of currency substitution.

5. The measure of money

The discussion of currency substitution leading up to EMU may potentially apply to both narrow and broad definitions of money, both of

---

1/ The evidence that exchange rates are nonstationary is not, however, iron-clad. Adams and Chadha (1991), in particular, cast doubt on this evidence by simulating a stochastic Dornbusch-style model of exchange-rate dynamics, showing that, in this setting, standard unit root and cointegration tests have low power in rejecting false null hypotheses.

which are of policy interest. Studies of aggregate money demand have examined both narrow (Kremers and Lane, 1990) and broad (Monticelli and Strauss-Kahn, 1991) definitions. In this study, we examine narrow money, leaving broader measures of money to be studied at a future time. Future work might also fruitfully examine the role of cross-border deposits (see Angeloni, Cottarelli, and Levy, 1991).

6. Multi-country aggregation

Aggregate variables were constructed for the four large EC countries (Euro-4), for the three participating in the exchange rate mechanism of the EMS for the 1980s (Euro-3), and for the G-7. Real income and money stocks were aggregated at 1985 purchasing-power-parity exchange rates published by the OECD. Consistent with this, price indices and interest rates were aggregated using as weights the shares of national income in aggregate income for the group of countries.

III. Empirical Results

1. Integration tests

The first step in the empirical work was to test the order of integration of the variables included in the study, using the Dickey-Fuller test (see MacKinnon, 1990). Data were taken from International Financial Statistics (IFS). 1/ In cases of breaks in the IFS data series, as discussed in the previous section, appropriately differenced shift dummies were included in the testing equation. The results are summarized in Table 2. For all seven countries, we find that liquidity ratios, real money stocks, real output, nominal interest rates and exchange rates are integrated of order 1(IGS)--that is to say, their first differences are stationary. There are two unusual results: (a) the GDP deflator was found to be I(0) for all seven countries, perhaps reflecting the fact that the 1972-90 period contains subperiods of both rising and falling inflation, with higher prices associated with lower inflation; and (b) consumer prices were found to be I(2) in all countries (except Germany and Japan, where they were I(1), perhaps reflecting the steady rise in indirect taxation during

1/ The one exception was Canadian M1, where the national definition (obtained from the CANSIM data base) was used in preference to the IFS data; previous studies have found the IFS definition to be unstable. The main difference between the two series is that the IFS definition includes interest-bearing checking accounts.

the sample period. The results for the multi-country aggregates are commensurate with those for each country. 1/

2. Testing for cointegration

The static equations were specified as follows. The dependent variable is the inverse of velocity, or the liquidity ratio, (m-p-y). 2/ The explanatory variables include a domestic nominal money market rate of interest, a domestic nominal long bond rate of interest, the six exchange rates, a constant, and a time trend. The equations for the four European countries also include nondomestic EMS output, while the non-European equations included total EMS output. Non-EMS aggregate output was included initially, but was dropped after preliminary investigation suggested it was highly collinear with the other two income variables. Finally, the equations include the dummy variables listed in Table 1.

The large number of variables in this general model creates a problem of specifying the appropriate critical values for cointegration tests; these have nowhere been published for such a large number of regressors. Our solution was to use a linear extrapolation of the critical values of the Dickey-Fuller statistic for multivariate models derived by Monte Carlo methods by Engle and Yoo (1987). The resulting critical values appear to be on the conservative side, since the critical values found by Engle and Yoo are a concave function of the number of regressors for a given sample size.

The results of the tests for cointegration for the seven countries using the sample period 1972-1990 are given in Table 3. Four versions of each equation are reported: the full maintained hypothesis, as described above; a second version that excludes the currency substitution variables--the six exchange rates and nondomestic Euro-4 income; a third version that includes the currency substitution variables but excludes the shift dummies, with the time trend treated as a shift dummy for this purpose; and a fourth version that excludes both the currency substitution variables and the shift dummies--that is, includes only a constant and the two interest rates.

The simplest version of the model, as reported in the fourth column, yields a cointegrating relation only for Italy. Adding shift and time trend variables, as shown in the second column, raises the ADF statistic

---

1/ In testing for integration here, and for cointegration in the next section, we focus on tests of significance at the 10 percent level, due to the Dickey-Fuller test's well-known problem of low power in rejecting the null hypothesis of nonstationarity. In presenting the dynamic results later in the paper, we use the (more conventional) 5 percent significance level.

2/ This specification was adopted after preliminary investigation showed that the implied restrictions of unit coefficients on prices and income in most cases could not be rejected by conventional hypothesis tests (although these tests are not strictly valid given the nonstationarity of the data) and did not seriously weaken the cointegration results.

Table 2. Tests for Integration, 1972:4-1990:4

(Dickey-Fuller Tests, p-values in percent) 1/

	Germany	France	Italy	U.K.	Japan	Canada	U.S.
m	100/0	100/0	100/15	100/0	100/1	100/0	100/2
p	0/na	1/na	0/na	1/na	0/na	1/na	2/na
(m-p)	100/0	81/0	94/0	93/0	100/0	75/0	95/0
y	100/0	100/0	100/0	100/0	100/1	100/1	100/0
(m-p-y)	36/0	97/0	99/0	66/0	98/0	100/0	99/0
RS	56/0	61/0	65/0	73/0	47/0	71/0	53/0
RL	73/0	78/0	75/0	75/0	74/0	84/0	75/0
CPI	100/2	99/33	100/28	100/10	100/8	100/33	100/26
S	12/0	76/0	98/0	36/0	18/0	73/0	na

	Aggregate (Euro-3)	Aggregate (Euro-4)	Aggregate (G-7)
m	100/0	100/0	100/2
p	97/21	2/na	3/na
(m-p)	90/0	81/0	56/0
y	100/1	100/1	100/1
(m-p-y)	98/0	99/0	100/0
RS	63/0	77/0	71/0
RL	78/0	77/0	79/0
CPI	100/16	100/31	100/36
S	98/0	98/0	90/0

1/ The first statistic in each cell is the probability value for a test of the null of a unit root in the level series; the second statistic tests the null of a unit root in the differenced series. Values less than 10 indicate rejection of the null at the 10 percent level.

Table 3. Cointegration Tests, 1970:4-1990:4

(Augmented Dickey-Fuller statistics, absolute values; estimated 10% critical value in parentheses)

	General Model	Excluding CS	Excluding Shifts	Excluding CS and Shifts
Germany	7.21(6.09)	4.50(4.32)	3.51(5.01)	0.58(3.34)
France	8.76(5.80)	6.75(4.32)	3.54(5.01)	2.33(3.34)
Italy	5.95(5.26)	2.60(3.69)	4.62(5.01)	4.96(3.34)
United Kingdom	5.80(5.52)	2.96(3.91)	4.72(5.01)	1.31(3.34)
United States	5.48(5.52)	2.05(3.91)	4.05(5.01)	2.48(3.34)
Japan	6.64(5.26)	1.90(3.69)	6.67(5.01)	2.47(3.34)
Canada	6.44(5.80)	4.46(4.11)	3.15(5.01)	2.57(3.34)
Euro-3	6.81(5.01)	5.93(4.77)	2.91(3.69)	2.62(3.34)
Euro-4	5.45(5.26)	5.49(5.01)	2.71(3.69)	2.56(3.34)
G-7	5.40(6.09)	5.00(5.80)	2.28(3.69)	1.15(3.34)

substantially for Germany, France, Britain, and Canada, and results in cointegration at the 10 percent level for Germany, France and Canada. Adding the currency substitution variables to these equations substantially increases the ADF statistics, as shown in the first column: cointegration is now found at the 10 percent level for all countries except the United States (for which the statistic is very close to the critical value). The third column completes the picture, by establishing that including the currency substitution variables without the shift dummies yields cointegration only for Japan. These results are suggestive of the importance of currency substitution in money demand.

The bottom part of Table 3 tests for a cointegrating aggregate money demand relationship for three groups of countries, namely the three of continental Europe (Euro-3), the four European countries (Euro-4), and the G-7 countries. For the G-7 none of the models appears to be cointegrated. For the Euro-3 and Euro-4 countries, we find that the shift dummies are needed to find cointegration but the currency substitution variables are not. Most importantly, an aggregate cointegrating relationship is found for the Euro-3 and Euro-4 aggregates with this data set; this is consistent with the results of previous studies cited in the introduction.

The results of a similar series of tests for the period of the EMS, 1978:4-1990:4, are given in Table 4. The pattern of results is slightly different from those of Table 3. As before, allowing for structural shifts and data breaks is important to the cointegration results. Including the relevant shift dummies but excluding currency substitution variables, as in column 2, we find cointegration only for Germany and France (and very nearly for Canada); adding the currency substitution variables to these equations produces cointegrating relations for all seven countries.

The results of cointegration tests for the aggregate variables over the EMS period are similar to those presented in Table 3. Cointegration evidently requires including the shift dummies, for all three aggregations. The currency substitution variables are not necessary for cointegration for the two European aggregates, but--in contrast to the results from the longer sample--their addition produces a cointegrating relation at the G-7 level.

Next, we present estimates of the cointegrating vectors for each country for the full sample period. Table 5(a) presents ordinary-least-squares estimates, which correspond to the cointegration results in Table 3. Table 5(b) presents estimates of the same system using seemingly unrelated regressions (SUR) estimation. Table 5(c) shows restricted SUR estimates, imposing the cross-equation restrictions implied by aggregation. 1/

Comparing the parameter estimates of Tables 5(a) and 5(b) shows that estimating the cointegrating vectors as a system using SUR does not greatly

---

1/ As always, we include 't' statistics as suggestive, even though nonstationarity precludes their use for formal statistical inference.

Table 4. Cointegration Tests, 1978:4-1990:4

(Augmented Dickey-Fuller statistics, absolute values; estimated 10% critical value in parentheses)

	General Model	Excluding CS	Excluding Shifts	Excluding CS and Shifts
Germany	8.11(5.80)	4.16(4.11)	3.36(5.01)	1.48(3.34)
France	8.29(5.52)	5.90(3.91)	7.66(5.01)	3.77(3.34)
Italy	6.55(5.26)	2.48(3.69)	6.50(5.01)	2.31(3.34)
United Kingdom	5.82(5.52)	3.35(3.91)	4.00(5.01)	2.27(3.34)
United States	5.82(5.52)	2.30(3.91)	4.94(5.01)	1.58(3.34)
Japan	8.31(5.26)	1.96(3.69)	8.64(5.01)	2.85(3.34)
Canada	6.39(5.52)	3.80(3.91)	5.92(5.01)	2.60(3.34)
Euro-3	5.14(4.54)	5.33(4.32)	2.53(3.69)	2.11(3.34)
Euro-4	6.32(4.77)	5.49(4.54)	2.56(3.69)	2.33(3.34)
G-7	5.58(5.26)	4.41(5.01)	2.68(3.69)	1.75(3.34)

Table 5(a). Estimated Cointegrating Vectors, 1972:4-1990:4, OLS

	Germany	France	Italy	U.K.	U.S.	Japan	Canada
RS	-0.007	0.010	-0.005	-0.004	-0.001	-0.007	-0.006
	(4.34)	(1.59)	(3.79)	(1.29)	(0.45)	(3.30)	(2.72)
RL	-0.010	-0.026	-0.003	-0.010	-0.019	-0.011	0.003
	(2.64)	(2.47)	(2.23)	(1.90)	(5.79)	(2.15)	(0.62)
y_E	-0.481	-0.605	1.142	-0.479	-0.976	0.629	0.142
	(2.23)	(1.21)	(5.85)	(1.21)	(4.28)	(3.15)	(0.47)
s_{fu}	-0.150	0.060	0.028	0.392	0.266	0.188	-0.000
	(2.83)	(0.37)	(0.43)	(2.38)	(3.93)	(2.71)	(0.00)
s_{iu}	-0.035	-0.116	-0.045	-1.023	-0.164	-0.222	-0.126
	(0.90)	(0.87)	(0.68)	(8.93)	(2.58)	(4.49)	(1.32)
s_{bu}	0.008	-0.098	-0.136	0.373	-0.145	0.003	0.091
	(0.20)	(0.91)	(3.52)	(3.96)	(3.04)	(0.06)	(1.80)
s_{gu}	0.089	0.156	0.069	0.312	-0.002	-0.118	0.064
	(1.49)	(1.03)	(1.05)	(2.02)	(0.03)	(1.86)	(0.85)
s_{ju}	-0.006	-0.005	0.032	-0.265	-0.016	0.161	-0.138
	(0.19)	(0.07)	(0.95)	(3.31)	(0.51)	(3.08)	(3.83)
s_{cu}	-0.228	0.343	0.182	-0.026	0.134	-0.161	-0.079
	(2.63)	(2.35)	(2.95)	(0.17)	(2.24)	(2.76)	(1.25)
TREND	0.006	0.004	-0.010	0.014	0.002	-0.003	-0.008
	(5.02)	(1.35)	(9.05)	(4.57)	(1.48)	(2.69)	(4.14)
CONST	5.426	7.870	-17.10	12.58	13.29	-9.781	-2.668
	(1.76)	(1.14)	(6.23)	(2.28)	(3.95)	(3.35)	(0.58)
D78G	0.071	-	-	-	-	-	-
	(5.61)	-	-	-	-	-	-
D88G	0.042	-	-	-	-	-	-
	(2.50)	-	-	-	-	-	-
D90G	0.114	-	-	-	-	-	-
	(9.07)	-	-	-	-	-	-
D77F	-	-0.095	-	-	-	-	-
	-	(2.81)	-	-	-	-	-
D84F	-	0.154	-	-	-	-	-
	-	(4.49)	-	-	-	-	-
D87B	-	-	-	0.613	-	-	-
	-	-	-	(15.3)	-	-	-
D86U	-	-	-	-	0.094	-	-
	-	-	-	-	(5.78)	-	-
D76C	-	-	-	-	-	-	-0.010
	-	-	-	-	-	-	(0.37)
D81C	-	-	-	-	-	-	-0.060
	-	-	-	-	-	-	(2.92)
SSR	0.014	0.088	0.023	0.113	0.021	0.023	0.026
SER	0.016	0.038	0.019	0.043	0.018	0.019	0.021
RBSQ	0.967	0.857	0.978	0.987	0.961	0.919	0.989
DW	1.515	2.101	1.377	1.291	1.126	1.551	1.492
ARCH	0.211	0.001	0.002	0.684	0.000	0.181	3.162

Table 5(b). Estimated Cointegrating Vectors, 1972:4-1990:4, SUR

	Germany	France	Italy	U.K.	U.S.	Japan	Canada
RS	-0.008	0.009	-0.004	-0.005	-0.000	-0.007	-0.006
	(6.15)	(1.66)	(3.75)	(2.07)	(0.26)	(4.11)	(3.31)
RL	-0.006	-0.024	-0.004	-0.012	-0.017	-0.008	0.000
	(1.95)	(2.73)	(3.02)	(2.63)	(6.38)	(1.65)	(0.02)
y_E	-0.347	-0.546	1.096	-0.385	-1.056	0.594	0.280
	(1.89)	(1.24)	(6.17)	(1.08)	(5.27)	(3.26)	(1.11)
s_{fu}	-0.159	0.048	0.024	0.346	0.288	0.204	-0.074
	(3.36)	(0.33)	(0.39)	(2.35)	(4.74)	(3.23)	(0.90)
s_{iu}	-0.015	-0.172	-0.053	-1.002	-0.208	-0.236	-0.030
	(0.45)	(1.46)	(0.89)	(9.77)	(3.79)	(5.28)	(0.38)
s_{bu}	0.016	-0.066	-0.131	0.350	-0.105	0.021	0.081
	(0.47)	(0.69)	(3.77)	(4.26)	(2.54)	(0.56)	(1.84)
s_{gu}	0.075	0.211	0.072	0.347	-0.015	-0.118	0.055
	(1.44)	(1.57)	(1.20)	(2.50)	(0.27)	(2.01)	(0.83)
s_{ju}	-0.021	-0.028	0.026	-0.247	-0.031	0.126	-0.128
	(0.81)	(0.44)	(0.88)	(3.48)	(1.09)	(2.76)	(4.04)
s_{cu}	-0.135	0.407	0.188	-0.030	0.121	-0.146	-0.096
	(1.89)	(3.14)	(3.35)	(0.22)	(2.28)	(2.75)	(1.72)
TREND	0.005	0.005	-0.010	0.014	0.003	-0.003	-0.009
	(4.74)	(1.80)	(9.64)	(5.28)	(2.10)	(3.04)	(5.75)
CONST	3.486	7.500	-16.37	11.05	14.82	-9.024	-5.210
	(1.33)	(1.23)	(6.53)	(2.23)	(5.02)	(3.39)	(1.37)
D78G	0.050	-	-	-	-	-	-
	(4.96)	-	-	-	-	-	-
D88G	0.046	-	-	-	-	-	-
	(3.54)	-	-	-	-	-	-
D90G	0.114	-	-	-	-	-	-
	(11.4)	-	-	-	-	-	-
D77F	-	-0.104	-	-	-	-	-
	-	(3.59)	-	-	-	-	-
D84F	-	0.124	-	-	-	-	-
	-	(4.19)	-	-	-	-	-
D87B	-	-	-	0.610	-	-	-
	-	-	-	(18.4)	-	-	-
D86U	-	-	-	-	0.090	-	-
	-	-	-	-	(6.89)	-	-
D76C	-	-	-	-	-	-	-0.029
	-	-	-	-	-	-	(1.43)
D81C	-	-	-	-	-	-	-0.049
	-	-	-	-	-	-	(3.02)
SSR	0.015	0.090	0.023	0.113	0.021	0.023	0.026
SER	0.014	0.035	0.018	0.039	0.017	0.018	0.019
RSQ	0.971	0.878	0.981	0.989	0.967	0.929	0.991
DW	1.398	2.045	1.337	1.316	1.064	1.515	1.469

Table 5(c). Estimated Cointegrating Vectors, 1972:4-1990:4, Restricted SUR

	Germany	France	Italy	U.K.	U.S.	Japan	Canada
RS	-0.008	-0.008	-0.008	-0.008	-0.001	-0.007	-0.005
	(9.50)				(0.58)	(4.34)	(2.83)
RL	-0.006	-0.006	-0.006	-0.006	-0.015	-0.005	-0.002
	(4.83)				(5.76)	(1.10)	(0.60)
y_E	-0.077	-0.077	-0.077	-0.077	-0.780	0.833	0.490
	(0.60)				(3.91)	(4.84)	(2.10)
s_{fu}	-0.180	0.279	-0.023	0.348	0.319	0.212	-0.082
	(3.43)	(2.14)	(0.29)	(2.56)	(4.94)	(3.30)	(1.00)
s_{iu}	0.001	-0.349	0.135	-1.043	-0.240	-0.256	-0.032
	(0.02)	(3.50)	(2.06)	(11.3)	(4.25)	(5.61)	(0.42)
s_{bu}	0.013	-0.013	-0.216	0.333	-0.080	0.040	0.091
	(0.42)	(0.18)	(5.30)	(5.02)	(1.92)	(1.08)	(2.14)
s_{gu}	0.098	0.110	0.088	0.439	-0.015	-0.091	0.071
	(1.86)	(0.82)	(1.21)	(3.44)	(0.25)	(1.54)	(1.05)
s_{ju}	-0.030	0.027	0.079	-0.284	-0.042	-0.105	-0.125
	(1.18)	(0.44)	(2.19)	(4.41)	(1.40)	(2.29)	(3.91)
s_{cu}	-0.106	0.320	0.002	0.005	0.129	-0.118	-0.077
	(1.64)	(2.44)	(0.03)	(0.04)	(2.28)	(2.20)	(1.36)
TREND	0.004	0.003	-0.005	0.013	0.001	-0.005	-0.011
	(4.38)	(1.72)	(4.97)	(8.34)	(0.89)	(4.35)	(6.88)
CONST	-0.046	4.694	-0.911	6.946	10.78	-12.29	-8.242
	(0.22)	(1.65)	(0.48)	(3.81)	(3.78)	(4.89)	(1.05)
D78G	0.029	-	-	-	-	-	-
	(3.15)	-	-	-	-	-	-
D88G	0.034	-	-	-	-	-	-
	(2.92)	-	-	-	-	-	-
D90G	0.114	-	-	-	-	-	-
	(11.9)	-	-	-	-	-	-
D77F	-	-0.078	-	-	-	-	-
	-	(2.72)	-	-	-	-	-
D84F	-	0.125	-	-	-	-	-
	-	(5.00)	-	-	-	-	-
D87B	-	-	-	0.602	-	-	-
	-	-	-	(19.9)	-	-	-
D86U	-	-	-	-	0.091	-	-
	-	-	-	-	(7.19)	-	-
D76C	-	-	-	-	-	-	-0.029
	-	-	-	-	-	-	(1.49)
D81C	-	-	-	-	-	-	-0.041
	-	-	-	-	-	-	(2.67)
SSR	0.018	0.109	0.038	0.118	0.024	0.024	0.027
SER	0.016	0.039	0.023	0.040	0.018	0.018	0.019
RSQ	0.966	0.851	0.968	0.989	0.962	0.927	0.990
DW	1.225	1.789	0.894	1.436	0.869	1.458	1.360

alter the results--with no differences in sign and little in magnitude. 1/ Table 5(c) reports results obtained by imposing the aggregation restrictions (viz. that coefficients on interest rates and on Euro-4 income be equal across countries). 2/ Comparing the estimates in 5(c) with those in 5(b), these restrictions do not appear to be grossly at variance with the data, but do noticeably alter all the parameter estimates. This impression is confirmed by testing the linear restrictions for the four European equations jointly; this yields a test statistic of 4.69, compared with a 5-percent critical value $F(9,242) = 1.91$. While this result is not conclusive, since nonstationarity violates the assumptions of the F test, they do suggest that the aggregation restrictions are not supported by the data.Next, we examine the joint significance of the variables included to reflect currency substitution. Tables 6(a) and 6(b) present system estimates omitting the currency substitution variables using restricted and unrestricted SUR, respectively. For the G-7 as a whole, in the unrestricted case (which appears to be more consistent with the data) the F-statistic is 15.48, compared with a 5-percent critical value $F(49,425) = 1.42$. Although again any inference is only tentative given nonstationarity, this result suggests strong empirical support for the role of the currency substitution variables. This finding is consistent with our earlier observation that the currency substitution variables contributed significantly to the finding of cointegration for several of the countries.

The results so far suggest that the data are not consistent with the aggregation restriction, and furthermore that currency substitution is an important determinant of the demand for money in the G-7 countries. This suggests that the finding of well behaved money demand equations at the aggregate level may have more to do with currency substitution than with common money demand parameters. A third possibility--which may also be related to currency substitution, although it may reflect some other omitted variable--is that there remains strong cross-equation correlations in the disturbances.

Table 7 presents some data relevant to this issue. In the spirit of Brittain (1981), we have calculated the sample correlations between the residuals of both the full model, and that with currency substitution variables omitted, both estimated in unrestricted form using SUR. Within Europe, we see evidence of strong positive correlations between the money demand residuals for France and the U.K. and between Italy and Germany; there is a strong negative correlation between the residuals for Germany and

---

1/ The SUR estimates, as is typical, have lower estimated standard errors, although, as noted earlier, these are not true standard errors given nonstationarity in the data.

2/ Notice that since the exchange rate variables appear in every equation, it is not necessary for the cross-equation effects within Europe to cancel out for the equations to be aggregatable. If they did not, this would only mean that it would be invalid to combine all the exchange rates into a single area-wide variable.

Table 6(a). Money Demand Excluding Currency Substitution, 1972:4-1990:4, SUR

	Germany	France	Italy	U.K.	U.S.	Japan	Canada
RS	-0.009	0.004	-0.009	-0.005	-0.002	-0.001	-0.000
	(5.10)	(1.10)	(5.49)	(1.70)	(0.90)	(0.26)	(0.24)
RL	-0.008	-0.015	-0.001	-0.026	-0.014	-0.010	0.013
	(2.43)	(2.73)	(0.87)	(4.66)	(3.99)	(2.09)	(4.62)
TREND	0.001	-0.001	-0.005	-0.001	-0.004	-0.003	-0.007
	(4.06)	(1.76)	(32.8)	(1.06)	(12.1)	(12.6)	(19.6)
CONST	-1.802	-1.251	-0.671	-1.515	-1.560	-1.071	-2.126
	(5.10)	(47.5)	(49.6)	(20.0)	(83.8)	(37.0)	(117.0)
D78G	0.027	-	-	-	-	-	-
	(2.83)	-	-	-	-	-	-
D88G	0.079	-	-	-	-	-	-
	(8.40)	-	-	-	-	-	-
D90G	0.144	-	-	-	-	-	-
	(10.7)	-	-	-	-	-	-
D77F	-	-0.069	-	-	-	-	-
	-	(3.57)	-	-	-	-	-
D84F	-	0.189	-	-	-	-	-
	-	(7.42)	-	-	-	-	-
D87B	-	-	-	0.867	-	-	-
	-	-	-	(32.5)	-	-	-
D86U	-	-	-	-	0.119	-	-
	-	-	-	-	(7.10)	-	-
D76C	-	-	-	-	-	-	-0.031
	-	-	-	-	-	-	(2.85)
D81C	-	-	-	-	-	-	-0.064
	-	-	-	-	-	-	(4.77)
SSR	0.037	0.139	0.061	0.396	0.093	0.093	0.047
SER	0.023	0.044	0.029	0.074	0.036	0.036	0.019
RSQ	0.930	0.812	0.950	0.962	0.852	0.717	0.991
DW	0.696	1.379	0.417	0.456	0.182	0.404	1.469

Table 6(b). Estimates Excluding Currency Substitution, 1972:4-1990:4, Restricted SUR

	Germany	France	Italy	U.K.	U.S.	Japan	Canada
RS	-0.009	-0.009	-0.009	-0.009	-0.002	-0.002	-0.002
	(9.78)				(1.47)	(1.00)	(1.45)
RL	-0.002	-0.002	-0.002	-0.002	-0.009	-0.002	0.010
	(2.18)				(3.57)	(0.52)	(4.00)
TREND	0.002	-0.001	-0.005	0.002	-0.005	-0.003	-0.007
	(7.79)	(1.15)	(33.3)	(3.16)	(15.5)	(11.7)	(23.5)
CONST	-1.859	-1.250	-0.651	-1.856	-1.586	-1.122	-2.128
	(192.)	(85.2)	(54.7)	(69.3)	(104.)	(44.7)	(130.)
D78G	0.011	-	-	-	-	-	-
	(1.35)	-	-	-	-	-	-
D88G	0.047	-	-	-	-	-	-
	(5.85)	-	-	-	-	-	-
D90G	0.124	-	-	-	-	-	-
	(11.9)	-	-	-	-	-	-
D77F	-	-0.075	-	-	-	-	-
	-	(3.98)	-	-	-	-	-
D84F	-	0.158	-	-	-	-	-
	-	(7.99)	-	-	-	-	-
D87B	-	-	-	0.794	-	-	-
	-	-	-	(29.5)	-	-	-
D86U	-	-	-	-	0.144	-	-
	-	-	-	-	(10.9)	-	-
D76C	-	-	-	-	-	-	-0.037
	-	-	-	-	-	-	(4.10)
D81C	-	-	-	-	-	-	-0.037
	-	-	-	-	-	-	(3.24)
SSR	0.053	0.169	0.060	0.558	0.103	0.099	0.060
SER	0.027	0.048	0.029	0.087	0.038	0.037	0.029
RSQ	0.902	0.776	0.950	0.949	0.835	0.699	0.979
DW	0.441	1.157	0.425	0.229	0.195	0.363	0.579

Table 7. Cross-Equation Residual Correlations

(a) Full Model, Unrestricted SUR Estimation

	Germany	France	Italy	U.K.	U.S.	Japan	Canada
Germany	1.00						
France	-0.14	1.00					
Italy	0.34	0.17	1.00				
U.K.	-0.26	0.28	0.11	1.00			
U.S.	-0.37	0.20	-0.30	0.35	1.00		
Japan	-0.13	0.18	-0.05	0.31	0.18	1.00	
Canada	0.46	-0.13	0.08	-0.31	-0.30	0.14	1.00

(b) Excluding Currency Substitution, Unrestricted SUR Estimation

	Germany	France	Italy	U.K.	U.S.	Japan	Canada
Germany	1.00						
France	-0.24	1.00					
Italy	0.43	-0.14	1.00				
U.K.	-0.18	0.23	0.07	1.00			
U.S.	-0.43	0.56	-0.26	0.38	1.00		
Japan	0.25	-0.21	0.27	0.21	-0.30	1.00	
Canada	0.52	-0.22	0.00	-0.41	-0.37	0.33	1.00

the U.K. However, while by conventional standards these correlations appear high, it is difficult to assess their importance to the aggregation issue in the absence of some sort of metric. We find even higher correlations outside the EMS, with the U.S. and Japan residuals being correlated with those of all of the remaining countries. The residuals of the Canada equation are highly positively correlated with those of Germany and Japan, and negatively correlated with those of the United States. These findings suggest that there may be an international aspect of money demand that is not well captured by including exchange rates and foreign income in money demand equations. They also tend to confirm the view, expressed at the beginning of this paper, that there may be important gains in efficiency in estimating European money demand equations in a system containing non-European equations as well. 1/

3. Dynamic error correction models

The second stage was to estimate dynamic error correction equations for each of the G-7 countries' real demand for money. The dynamic specification simply includes the contemporaneous first differences of all the variables in the cointegrating vector, as well as an error correction term derived from the unrestricted SUR estimates of the cointegrating equations. The use of such a general specification, without "testing down", was motivated by the need to use a common specification for all seven countries in which to test the aggregation restrictions. We also relaxed the previously-imposed unit coefficient on domestic income, recognizing that even if the long-run income elasticity of money demand is unitary, the elasticity relevant to short-run adjustment may be different. The resulting seven dynamic equations were then estimated using the SUR method.

The estimation results are summarized in Table 8, which reports the error correction coefficient and summary statistics for each version of the model. In the first panel we report the results of our full model, with no aggregation restrictions imposed, and with the error correction terms being based on the unrestricted SUR estimates shown in Table 5(b). Each equation demonstrates very significant and rapid error correction. The speed of adjustment ranges from 35 percent per quarter for the U.S. to more than 100 percent per quarter for France. The summary statistics are respectable, with only the U.S. equation showing some possible evidence of residual serial correlation.

1/ Because several of the equations are not cointegrated when the currency substitution variables are omitted, it is also relevant to ask whether the residuals of these equations, which are I(1), are cointegrated with one another--i.e. whether departures from the long-run money demand relationship in one country are reflected in adjustments in other countries. We have checked this, and have indeed found evidence of cointegration among these money demand residuals. This preliminary result invites further exploration.

Table 8. Error Correction Models - Summary Statistics, 1972:4-1990:4, SUR

	Germany	France	Italy	U.K.	U.S.	Japan	Canada
(a) Unrestricted, Full Model							
EC_{t-1}	-0.881	-1.088	-0.479	-0.431	-0.348	-0.777	-0.798
	(10.2)	(9.51)	(6.16)	(5.65)	(4.71)	(7.42)	(8.67)
SSR	0.010	0.078	0.014	0.035	0.007	0.019	0.017
SER	0.012	0.033	0.014	0.022	0.010	0.016	0.016
RSQ	0.756	0.594	0.467	0.923	0.542	0.545	0.522
DW	1.637	1.849	1.561	2.000	1.373	2.025	1.622
(b) Unrestricted Model, excluding Currency Substitution							
EC_{t-1}	-0.383	-0.763	-0.240	-0.104	-0.063	-0.213	-0.434
	(4.88)	(7.12)	(3.98)	(2.21)	(1.73)	(2.92)	(5.22)
SSR	0.016	0.114	0.017	0.060	0.009	0.030	0.025
SER	0.015	0.040	0.015	0.029	0.011	0.020	0.019
RSQ	0.587	0.412	0.368	0.868	0.403	0.265	0.308
DW	1.446	1.802	1.701	2.005	1.340	2.433	1.967
(c) Restricted, Full Model							
EC_{t-1}	-0.841	-0.965	-0.232	-0.539	-0.328	-0.800	-0.750
	(9.19)	(9.43)	(3.18)	(7.05)	(4.68)	(8.03)	(7.79)
SSR	0.012	0.085	0.017	0.041	0.007	0.020	0.020
SER	0.013	0.034	0.016	0.024	0.010	0.017	0.016
RSQ	0.697	0.556	0.352	0.911	0.528	0.511	0.465
DW	1.377	1.837	1.444	2.147	1.429	1.893	1.559
(d) Restricted Model, excluding Currency Substitution							
EC_{t-1}	-0.362	-0.648	-0.221	-0.082	-0.001	-0.199	-0.518
	(5.05)	(6.93)	(3.88)	(2.19)	(0.03)	(2.77)	(7.51)
SSR	0.021	0.127	0.017	0.061	0.008	0.031	0.029
SER	0.017	0.042	0.015	0.029	0.011	0.021	0.020
RSQ	0.480	0.341	0.384	0.864	0.439	0.240	0.276
DW	1.215	1.866	0.640	2.362	1.439	2.376	1.605
(e) Unrestricted, Full-Model EC, Dynamics excluding Currency Substitution							
EC_{t-1}	-0.887	-1.087	-0.470	-0.281	-0.305	-0.638	-0.752
	(9.42)	(9.74)	(5.62)	(3.61)	(4.34)	(5.48)	(7.13)
SSR	0.011	0.081	0.016	0.056	0.008	0.024	0.021
SER	0.013	0.033	0.015	0.028	0.011	0.018	0.017
RSQ	0.713	0.580	0.414	0.876	0.454	0.403	0.433
DW	1.503	1.874	0.513	1.834	1.207	1.887	1.806

The second panel removes the currency substitution variables from both the cointegrating vector and the short-run dynamics, while still not imposing aggregation restrictions. While significant error correction is still found, at least for all countries except the U.S., the speed of adjustment has declined substantially in all cases. Calculation of standard F-statistics to test for the joint significance of the currency substitution variables on an equation-by-equation basis yields the following results:

Germany	$F(14,42) = 2.06$.
France	$F(14,45) = 1.49$
Italy	$F(14,49) = 0.66$
U.K.	$F(14,48) = 2.46$
U.S.	$F(14,48) = 0.98$
Japan	$F(14,49) = 2.18$
Canada	$F(14,47) = 1.51$

The 5 percent critical values are all in the neighborhood of 1.92; thus, the currency substitution variables are statistically significant in the dynamic equations only for Germany, Britain, and Japan. However, a test of joint significance of the currency substitution variables for all seven countries--which is more powerful as it makes use of the fact that the equations for the seven countries were estimated simultaneously--yielded a test statistic of 1.71, compared with a critical value $F(98,328) = 1.30$, indicating that one can still reject the hypothesis that the currency substitution variables can be excluded from all seven equations jointly. Finally, we can test for currency substitution only in the four European countries; we find an F statistic of 1.69 compared with a critical value $F(56,184) = 1.41$, indicating that currency substitution is statistically significant for the four European countries as a group.

The third panel of Table 8 imposes the aggregation restrictions on the model with currency substitution variables; the error correction variables are therefore based on the restricted SUR estimates of Table 5(c). Comparing these results to those in the first panel, we note that the speed of error correction has declined slightly for France, U.S. and Canada, and significantly so for Italy. An F-test of the aggregation restrictions can be carried out for the G-7 countries as a group, using the fact that all seven equations were estimated jointly even though the restrictions directly constrain only four of the seven equations; this yields a test statistic of 2.02--implying rejection of the aggregation restrictions at the 5 percent level (critical value $F(21,328) = 1.60$). Thus, as was also suggested by the static results, the aggregation restrictions are not consistent with the data.

The fourth panel of Table 8 provides the most restricted results, where, in both the dynamic equation and the underlying cointegrating vector, currency substitution variables are excluded and aggregation restrictions imposed. The speed of error correction deteriorates substantially in this version of the model. Using the sums of squared residuals for all seven countries associated with these joint estimates, we can test the aggregation restrictions under the assumption that currency substitution is excluded from the equations: the aggregation restrictions can still be rejected by the data, with a test statistic of 2.40 (critical value F(15,420) = 1.70). We can also test for currency substitution in the model in which the aggregation restrictions have been imposed: here, in single-country tests the hypothesis of no currency substitution is rejected only for Germany (F(14,42) = 2.12), but is still rejected for the group of seven countries as a whole, with a test statistic of 1.61 (critical value F(98,349) = 1.29).

Panel 5 of Table 8 offers an intermediate hypothesis. We use the error correction variables from the full, unrestricted model, but exclude the currency substitution variables from the dynamics. Since we are interested in this hypothesis from a system-wide perspective, we formulate a test statistic for the system as a whole; this generates a test statistic of 1.69, which exceeds the 5 percent critical value of F(49,404) = 1.38. This suggests that currency substitution plays a significant role in the short-run dynamics of money demand as well as in the cointegrating relationship. (Inspection of the individual equation results suggest that it is particularly important for the U.K., Japan and Canada.)

Another step is to examine specifically whether intra-European exchange rates play a significant role in money demand. To do this, we test whether one can exclude other European exchange rates from each European country's equation, and exclude non-German European exchange rates from each non-European country's equation. 1/ In the version without aggregation restrictions, this yields a test statistic of 1.77, compared with a critical value F(42,328) = 1.43. These results confirm that intra-European exchange rates play a significant role in money demand.

Finally, in Table 9 we examine once again the cross-equation residual correlations, this time for the final dynamic specification. There continue to be some fairly high residual correlations in Europe, particularly between Italy and Germany, and Italy and the U.K. The U.S. and Canada residuals continue to be highly correlated with most of the others. These results are further suggestive of some international link in money demand.

In interpreting these results, it is important to bear in mind how little "data mining" they reflect: we have deliberately confined ourselves to using the same money demand specification for all seven countries, and to including all six exchange rates or none at all, and this essentially precludes any search for a "best fit" specification for each country. Despite this self-constraining approach, we find that the currency substitution variables--exchange rates and foreign income--do play a statistically significant role in money demand.

1/ In other words, we drop the franc, pound, and lira rates from German, U.S., Japanese, and Canadian equations; the deutsche mark, pound, and lira from the French equation; deutsche mark, franc and lira from the British equation; and deutsche mark, franc and pound from the Italian equation.

Table 9. Cross-Equation Residual Correlations

(Full Dynamic Model, Unrestricted SUR Estimation)

	Germany	France	Italy	U.K.	U.S.	Japan	Canada
Germany	1.00						
France	-0.12	1.00					
Italy	0.60	-0.05	1.00				
U.K.	-0.05	0.03	0.21	1.00			
U.S.	-0.29	0.15	-0.19	0.30	1.00		
Japan	-0.14	0.15	-0.26	0.07	0.06	1.00	
Canada	0.44	-0.17	0.37	-0.11	-0.26	0.22	1.00

IV. Conclusion

This paper has explored the foundations of cross-border monetary aggregation, comparing two alternative explanations for the success of cross-border aggregate estimates of money demand in the EMS. One explanation is simply that different countries' money demand equations are similar enough to make it appropriate to aggregate them. The other is based on currency substitution, which leads to variations in national money demands that are internal to a multi-country aggregate. Variations in money demand due to currency substitution may be associated either with observable exchange-rate movements or with unobservable variables that are embodied in the disturbance terms of individual countries' money demand equations.

The empirical analysis in the paper concentrated on testing these explanations in a multi-country setting. Multi-country aggregate money demand equations performed reasonably well for the European countries in the sample, but the data did not seem to be consistent with the aggregation restrictions in the static model, and rejected the formal aggregation restrictions in the dynamic framework.

These and other results point to a role for currency substitution, rather than just a similarity of different countries' money demand relationships, as an explanation of the good performance of cross-border monetary aggregation. Exchange rates proved important in achieving cointegration. In the dynamic equations, although the absence of currency substitution could not be rejected for many of the individual countries, currency substitution was shown to be significant for the G-7 countries as a group--a result of the greater power of hypothesis testing in the multi-country framework.

The results also tend to support the concern--as explained earlier in the paper--that exchange rates do not represent the effects of currency substitution very well, and thus that there may be determinants of currency substitution that are less easily represented empirically. This suggestion is reinforced by the cross-country correlations of error terms in money demand, which were significant, and often negative--suggesting that money demand may have been influenced by currency substitution in ways that are not so readily quantifiable, and possibly helping to explain the relatively small standard errors of some aggregate money demand equations.

The results highlight the possibility that a multi-country study may uncover evidence of currency substitution that is missed by the usual single-country studies. This work is obviously quite preliminary, and leaves wide scope for further research. One extension would be to re-examine the results with a broad monetary aggregate. Another would be to test for cointegration in a multi-country framework: a joint test of cointegration for all the countries in the panel might be more powerful than the usual tests for individual countries, particularly in a relatively small sample. Another related issue concerns the cross-country correlations of errors in money demand; 1/ these relationships could be explored further, perhaps yielding some illuminating results. A further unresolved question is whether the presence of exchange rates in money-demand equations really does reflect currency substitution, or whether it instead reflects the policy reaction function or some unobserved determinant of money demand.

If borne out by further work, the results are important. They suggest that there may be some good reasons that cross-country aggregate money demand equations appear to fit the data, lending some support to the use of such equations in analysis and policy. They also lend some support to the view that currency substitution may be important in the European Community, therefore making the implementation of national monetary policies increasingly difficult with increasing economic and monetary integration along the road to EMU.

1/ There is also the related finding, mentioned in a footnote, that different countries' money demand errors are cointegrated.

References

Adams, Charles and Bankim Chadha, "On Interpreting the Random Walk and Unit Root in Nominal and Real Exchange Rates," Staff Papers, International Monetary Fund (Washington), Vol. 38 (1991), pp. 901-20.

Angeloni, Iganzio; Cottarelli, Carlo; and Aviram Levy, "Cross-Border Deposits and Monetary Aggregates in the Transition to EMU," IMF Working Paper WP/91/114 (November 1991).

Artis, Michael J., "Monetary Policy in Stage Two of EMU: What Can We Learn from the 1980s?" mimeo, University of Manchester (1991).

Bekx, P. and Guiseppe Tullio, "A Note on the European Monetary System and the Determination of the DM-Dollar Exchange Rate," Cahiers Economiques de Bruxelles No. 123 (troisième trimestre 1989), pp. 329-43.

Bomhoff, Eduard J., "Monetary Policy and Inflation in the EC," mimeo, Rotterdam: Erasmus University (1991).

Boothe, Paul and Stephen Poloz, "Unstable Money Demand and the Monetary Model of the Exchange Rate," Canadian Journal of Economics, Vol. 21 (1988), pp. 785-98.

———, "Nominal and Real Exchange Rate Movements: Understanding the Deutschemark-Dollar Exchange Rate," Discussion Paper No. 87-7, Department of Economics, University of Alberta (1987).

Boughton, James M., "Long-Run Money Demand in Large Industrial Countries," Staff Papers, International Monetary Fund (Washington), Vol. 38 (1991), pp. 1-32.

Boyer, Russell S., "Nickels and Dimes," unpublished manuscript, Federal Reserve Board (1972).

———, and Geoffrey H. Kingston, "Currency Substitution under Finance Constraints," Journal of International Money and Finance, Vol. 6 (1987), pp. 235-50.

Brillembourg, Arturo and Susan M. Schadler, "A Model of Currency Substitution in Exchange Rate Determination, 1973-1978," Staff Papers, International Monetary Fund (Washington), Vol. 26 (1979), pp. 513-42.

Brittain, Bruce, "International Currency Substitution and the Apparent Instability of Velocity in some Western European Economies and in the United States," Journal of Money, Credit and Banking 13 (1981), pp. 135-55.

Engle, Robert F., and Clive W.J. Granger, "Cointegration and Error Correction: Representation, Estimation, and Testing," Econometrica, Vol. 35 (1987), pp. 143-59.

———, and B.S. Yoo, "Forecasting and Testing in Cointegrated Systems," Journal of Econometrics, Vol. 35 (1987), pp. 143-59.

Girton, Lance and Donald Roper, "Theory and Implications of Currency Substitution," Journal of Money, Credit and Banking, Vol. 13 (1981), pp. 12-30.

Gregory, Allan W. and James M. Nason, "Testing for Structural Breaks in Cointegrated Relations," Discussion Paper No. 827, Institute for Economic Research, Queen's University (July 1991).

Hoffman, Dennis L. and Robert H. Rasche, "Money Demand in the U.S. and Japan: Analysis of Stability and the Importance of Transitory and Permanent Shocks," mimeo (November 1991).

Kremers, Jeroen J.M. and Timothy D. Lane, "Economic and Monetary Integration and the Aggregate Demand for Money in the EMS," Staff Papers, International Monetary Fund (Washington), Vol. 37 (1990), pp. 777-805.

———, "European Monetary Union Raises Questions About Policy Targets and Indicators," IMF Survey, Vol. 21 (April 27, 1992(a)), pp. 136-39.

———, "The Implications of Cross-Border Monetary Aggregation," IMF Working Paper, forthcoming, August 1992(b).

Lane, Timothy D., "Household Demand for Money in Poland: Theory and Evidence," Staff Papers, International Monetary Fund (Washington), (forthcoming, 1992).

MacKinnon, James G., "Critical Values for Cointegration Tests," University of California-San Diego Discussion Paper 90-4 (1990).

McKinnon, Ronald I., "Currency Substitution and Instability in the World Dollar Standard," American Economic Review 72 (1982), pp. 320-33.

McNown, Robert F. and Myles S. Wallace, "Cointegration Tests of a Long-Run Relation Between Money Demand and the Effective Exchange Rate," Journal of International Money and Finance 11 (1992), pp. 107-14.

Melvin, Michael, "Currency Substitution and Western European Monetary Unification," Economica 52 (1985), pp. 79-92.

Monticelli, Carlo and Marc-Olivier Strauss-Kahn, "European Integration and the Demand for Broad Money," mimeo, Committee of Governors of EEC Central Banks (1991).

Pesaran, M.H.; Pierse, R.G. and M.S. Kumar, "Econometric Analysis of Aggregation in the Context of Linear Prediction Models," Econometrica 57 (1989), pp. 861-88.

Poloz, Stephen S., "The Transactions Demand for Money in a Two-Currency Economy," Journal of Monetary Economics 14 (1984), pp. 241-50.

———, "Currency Substitution and the Precautionary Demand for Money," Journal of International Money and Finance, Vol. 5 (1986), pp. 115-24.

Russo, Massimo, and Guiseppe Tullio, "Monetary Policy Coordination Within the European Monetary System: Is There A Rule?" in Policy Coordination in the European Monetary System, IMF Occasional Paper 61 (Washington: International Monetary Fund, September 1988).

Zellner, Arnold, "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias," Journal of the American Statistical Association Vol. 57 (1962), pp. 348-68.