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STRUCTURAL CHANGE IN THE EURO-DOLLAR MARKET: EVIDENCE FROM A TWO-EQUATION MODEL

by

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STRUCTURAL CHANGE IN THE EURO-DOLLAR MARKET: EVIDENCE FROM A TWO-EQUATION MODEL[1/]

I. Introduction

This paper describes a two-equation supply-and-demand model for 3-month Euro-dollar deposits, and discusses the results of estimating a reduced-form equation for the determination of the interest rate on such deposits. The objective is to emphasize the differences between the estimation results for the period 1966-68 and those for 1969-70. Multicollinearity among the explanatory variables complicates the interpretation of the estimates, and thus there is also a discussion of the tests developed by Farrar and Glauber for determining the degree and location of multicollinearity.

The Euro-dollar market is an international money market in which interest rates are determined by influences emanating from many countries. Monetary conditions in the United States are of particular significance to Euro-dollar rates, because of the importance of the United States in the world economy and because of the close substitutability between dollar deposits in -- and dollar loans from -- banks in the United States on the one hand, and Euro-banks on the other.

It is also true, however, that the relationships linking Euro-dollar rates to national money market rates in the United States and in Europe have not been constant over recent years. The importance

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of the U.S. money market as a determinant of Euro-dollar rates was much greater in 1969-70, when U.S. banks' borrowings of Euro-dollars were very large, than they had been in the preceding years 1966-68 when such borrowings were on a far smaller scale. This readily explains why, in the model developed in this paper, fluctuations in U.S. money market rates -- as typefied by the 3-month Treasury bill rate -- led to proportionately much larger fluctuations in the 3-month Euro-dollar rate in 1969-70 than in 1966-68. And largely because of U.S. banks' greater Euro-dollar borrowings in 1969-70, the fluctuations in the U.S. bill rate also explain more of the fluctuations in the Euro-dollar rate in the later of these two periods than in the earlier one. In contrast, key short-term interest rates in three national European money markets show up as less important in the second period than in the first in explaining changes in the Euro-dollar rate.

It might also be of interest to estimate the model for the period since the end of 1970 and compare the results with those for the two earlier periods. This has not been done largely because, while speculation on changes in the exchange rate for the U.S. dollar have been very important in determining Euro-dollar rates since 1970, the model used here does not include speculative forces among the explanatory variables.

While these findings should come as no surprise to students of international monetary events of the past decade, it is important to stress that linkages between Euro-dollar rates and money markets in individual countries can change. And past changes have great significance for any attempt to forecast Euro-dollar rates from projections of interest rates or other explanatory variables relating to national money markets. Estimates of relationships based on data for one period may be quite different from estimates obtained at a different time. One set of relationships will prove to be much better or much worse, as a forecasting tool, than others, depending on which period in the past the future most closely resembles. This paper underscores that point.

The remainder of this paper is presented in three sections. Section II develops the structural equations for the supply of and demand for 3-month Euro-dollar deposits. The estimated reduced-form equation for the 3-month Euro-dollar rate is presented in Section III, along with the main conclusions. The results of tests for multicollinearity are discussed in the final section.

II. The Structural Equations

Although the Euro-dollar market responds to monetary events around the world, practical considerations require that financial variables from only a restricted number of countries be included in the model, which simplifies the model from the geographical standpoint.

A. The supply equation

The supply equation relates the supply of 3-month Euro-dollar deposits to: 1) the rate paid on those deposits; 2) the interest rates on 3-month Treasury bills in the United States, 3-month local authority deposits in Britain, 3-month interbank loans in Germany, and 3-5 month bank deposits in Switzerland; 3) the premiums or discounts, relative to the spot rate, on the 3-month forward exchange rates of the pound sterling, German mark, and Swiss franc against the dollar; and 4) a dummy variable to represent the 10 per cent marginal reserve requirement on U.S. banks' foreign borrowings from September 1969 to November 1970.

The rate paid on Euro-dollar deposits enters the supply equation with a positive sign. The money market instruments involved are important outlets for bank funds in the respective countries. The U.S. Treasury bill and the Swiss bank deposit are also widely held by nonbank investors, both resident in and foreign to those countries. The local authority rate in Britain and the interbank loan rate in Germany move closely with rates paid by banks on large time deposits, and thus serve as good proxies for rates paid to nonbank investors. Thus, the interest rates employed as explanatory variables are rates received on instruments that are major competitors of Euro-dollars for investors' short-term funds. The expected signs of their coefficients in the supply equation are negative.

The forward exchange rates are included in the supply equation (a forward discount being considered as a negative premium) because most investors shifting into dollars from pounds, marks, or Swiss francs would cover forward at most times, and the premium (or discount) partly determines the covered yield for investors moving into Euro-dollar deposits in this way. However, it should be observed that the forward rates themselves are affected by (*inter alia*) changes in national money market rates relative to Euro-dollar rates. The resulting inverse correlation between the forward premiums (or discounts) and the national interest rates adds further to the multicollinearity among the regressors that already exists because of the fact that interest rates in the major industrial countries tend to move together. The expected coefficient signs are negative when the forward rates are expressed as premiums.

The dummy variable used to represent the 10 per cent marginal reserve requirement on U.S. banks' foreign borrowings has a value of 1 beginning with the week of September 4, 1969 and 0 for earlier weeks. Borrowings in excess of a reserve-free base became subject to the reserve requirement on that date. The expected sign of the coefficient is negative. The reserve requirement had the effect of increasing the total cost (i.e., inclusive of the cost of the reserve deposit) of Euro-dollars to U.S. banks, so that those banks borrowed fewer Euro-dollars than before, with a consequent reduction in the rate. The supply equation, definitions of the symbols, and the *a priori* signs of the coefficients of the supply function variables, are shown in Table 1.

B. *The demand equation*

The explanatory variables that appear in the demand equation for 3-month Euro-dollars are 1) the rate paid on 3-month Euro-dollar deposits; 2) the same interest rates and forward exchange rates that

Table 1. Structural Equations

Supply Equation

$$Q^s = k + a\ EDR + b\ TBR + c\ BLAR + d\ GILR +$$
$$+ e\ SBDR + f\ FPS + g\ FDM + h\ FSF + j\ RRD$$

Symbol	Variable[1/]	Expected Sign of Coefficient
EDR	3-mo. Euro-dollar deposit rate	Pos.
TBR	U.S. 3-mo. Treasury bill rate	Neg.
BLAR	British 3-mo. local authority deposit rate	Neg.
GILR	German 3-mo. interbank loan rate	Neg.
SBDR	Swiss 3-5-mo. bank deposit rate	Neg.
FPS	Forward pound sterling premium	Neg.
FDM	Forward Deutsche Mark premium	Neg.
FSF	Forward Swiss franc premium	Neg.
RRD	Reserve requirement dummy	Neg.

Demand Equation

$$Q^d = k' + a'EDR + b'TBR + c'BLAR + d'GILR +$$
$$+ e'SBDR + f'FPS + g'FDM + h'FSF +$$
$$+ m\ RQD + n\ QCD$$

Symbol	Variable[1/]	Expected Sign of Coefficient
EDR	As indicated for supply equation	Neg.
TBR	"	Pos.
BLAR	"	Pos.
GILR	"	Pos.
SBDR	"	Pos.
FPS	"	Pos.
FDM	"	Pos.
FSF	"	Pos.
RQD	Regulation Q dummy	Pos.
QCD	Quantity of CD's[2/]	Neg.

1/ In per cent per annum, except RRD, RQD, and QCD.
2/ In billions of dollars.

appear in the supply equation; and 3) two variables representing the impact of Regulation Q on U.S. banks' demand for Euro-dollars. The four interest rates reflect the incentives for banks in the particular countries to borrow Euro-dollars, or liquidate Euro-dollar placements, and use the funds in the domestic money market (after first going through the exchange market in Britain, Germany, or Switzerland). Also, changes in these interest rates serve as proxies for changes in the cost to nonbank borrowers of loans from domestic banks in domestic currency; such loans are the pricipal alternative to Euro-dollar loans for corporations and other nonbank borrowers.

The forward exchange rates are present to capture the effect on the demand for Euro-dollars on the part of borrowers who would convert loan proceeds into currencies other than the dollar and cover forward their dollar liability. In the demand equation, the expected signs of the coefficients of the Euro-dollar rate, national interest rates, and forward exchange rates are the reverse of the expected signs in the supply equation.

Two variables are needed to try to capture the effects of Regulation Q because the relationship between the Regulation Q ceilings and market rates of interest in the United States was not the same in 1969-70 as in 1966-68. Throughout the years 1969-70, rates of interest on large-denomination ($100,000 and over) certificates of deposit (CD's) issued by banks in the United States were at the ceiling levels allowed by Regulation Q. During 1969, the gaps between the Regulation Q ceiling rates and what CD rates would have been had there been no ceilings widened as U.S. monetary policy tightened. Investors allowed a large part of their CD holdings to run off, and the quantity outstanding of large-denomination CD's issued by prime New York banks declined from $23.5 billion at the end of 1968 to $10.3 billion in Mid-February 1970. As the funds raised by their CD issues contracted, U.S. banks' demand for Euro-dollars increased.

After mid-February 1970 this process was reversed as monetary policy eased; outstanding CD's rose again to $26.1 billion by the end of 1970, and the banks' demand for Euro-dollars diminished. For the 1969-70 period, we can take the outstanding volume of large-denomination CD's issued by prime New York banks to represent the effect of the Regulation Q ceilings -- in the context of monetary policy at the time -- on U.S. banks' demand for Euro-dollars. Although the volume of CD's was affected also by the rising trend of investors' wealth and by random factors, the impact of those influences was small compared with the effects of Regulation Q and shifts in monetary policy. The expected sign of the coefficient of this variable is negative.

In the 1966-68 period, rates paid by banks on CD's were at their Regulation Q ceilings at some times but not at other times. When rates were at the ceilings the banks' demand for Euro-dollars rose.

However, the gaps between the ceiling rates and hypothetical freely-negotiated rates were sporadic rather than continuous, and when they existed they were often small. Thus, the effect of Regulation Q on the quantity of CD's was not large enough, relative to the effects of other factors, to be able to use the quantity of CD's as a measure of the strength of banks' demand for Euro-dollars. Consequently, a dummy variable is used which has a value of 1 when CD rates were at their Regulation Q ceilings in 1966-68, and a value of 0 at other times. The anticipated sign of the coefficient of this Regulation Q dummy is positive. The demand equation variables and the expected signs of their coefficients are also shown in Table 1.

III. Estimation of the Reduced-Form Equation for the Euro-dollar Rate

When supply and demand are equated, the reduced-form equation for the rate of interest on 3-month Euro-dollar deposits is:

$$\begin{aligned} EDR = 1/(a - a') \,[\, & k' - k + (b' - b)\, TBR + (c' - c)\, BLAR + (d' - d)\, GILR + \\ & + (e' - e)\, SBDR + (f' - f)\, FPS + (g' - g)\, FDM + (h' - h)\, FSF + \\ & + j\, RRD + m\, RQD + n\, QCD \,] \end{aligned}$$

On the basis of the expected signs of the coefficients listed in Table 1, in the reduced-form equation the a priori signs of the quantity (a - a') and the successive quantities (b' - b) ... (h' - h) are positive. Thus, the coefficients of the interest rates and the forward exchange rates are expected to be positive. The anticipated coefficients of the reserve requirement dummy and the quantity of CD's remain negative while that of the Regulation Q dummy is again positive. The reduced-form equation for the quantity of 3-month Euro-dollar deposits is not shown since it is not relevant to the topic of the paper.

The reduced-form equation for the rate is estimated from weekly data for the two separate periods. However, observations were not taken over the final eight weeks of 1970 because of a change in the reserve requirement on U.S. banks' foreign borrowings. Effective in early November of 1970 the reserve ratio was increased from 10 to 20 per cent and the definition of the reserve-free base was somewhat modified.

A first estimation of the reduced-form equation gave evidence of a high degree of serial correlation in the residuals for both estimation periods. One or more explanatory variables is missing from the equation, which is hardly surprising given that the included variables reflect monetary conditions in only four countries. To correct for serial correlation and obtain minimum-variance estimators, the variables were transformed to the form $Y_t - p\,Y_{t-1}$, $X_{1t} - p\,X_{1t-1}$, $X_{2t} - p\,X_{2t-1}$, etc., on the assumption that the autoregressive structure of the disturbances is of the first order. The value of p was estimated by the Cochrane-Orcutt iterative process. The p values were .55 for 1966-68 and .87 for 1969-70. Estimation of the transformed equation yielded the results given in Table 2.

Table 2. Estimated Coefficients and t-Ratios

	1966-68 (N - 156)		1969-70 (N = 96)	
Variable	Coefficient	t-ratio	Coefficient	t-ratio
Constant	1.00	2.36	3.37	0.93
TBR	.24	2.44	.61	3.07
BLAR	.16	2.74	.29	1.72
GILR	.33	7.36	.04	0.30
SBDR	.18	2.42	.10	0.21
FPS	-.02	1.06	-.06	1.56
FDM	.30	6.98	-.01	0.53
FSF	.02	0.45	.07	0.99
RRD	--	--	-.28	0.81
RQD	.11	1.73	--	--
QCD	--	--	-.09	1.51
S.E.E.	.17		.32	
$\bar{R}^2$	.93		.92	
D.-W.	2.10		1.91	

Comparisons of the estimation results for the two periods show several striking differences. First, the standard error of estimate is nearly twice as large in 1969-70 as for 1966-68, because of the much greater variability of the Euro-dollar rate in the later period.

Second, the coefficient estimates indicate that a change of one percentage point in the U.S. Treasury bill rate caused the 3-month Euro-dollar rate to change by 61 basis points in 1969-70 compared with only 24 basis points in 1966-68. A much larger coefficient for the 1969-70 period is in fact anticipated, given that the use of the Euro-dollar market as a source of funds by banks in the United States was far heavier in the second period than the first. During 1966-68, U.S. banks' gross liabilities to their foreign branches -- through which virtually all Euro-dollar borrowings were obtained -- averaged $4.1 billion as measured by liabilities outstanding on the last Wednesday of each month. The comparable figure for 1969 and the first 44 weeks of 1970 was $11.8 billion. The estimated coefficient of the British local authority rate is also markedly greater in the second period than the first, while much smaller coefficients are given for the German interbank loan rate, the Swiss bank deposit rate, and the forward German mark.

While sampling error accounts for some of the differences between the two periods in these estimated coefficients, there appears to have been a structural change in the Euro-dollar market involving the parameters of the national interest rates and the forward exchange rates. A test can be made, using the residual sum of squares, of the hypothesis that the parameters of the interest rate and exchange rate variables were the same in the two periods.

The test procedure first requires a re-estimation of the equation over both time periods together. For the variables whose coefficients are being tested the data are pooled and a single coefficient estimated that applies to the combined time periods. For the remaining variables and the constants the data are kept separate and (as before) separate coefficients are estimated for the two periods. Such a re-estimation corresponds to the null hypothesis that the parameters of the interest rate and exchange rate variables were equivalent in the two periods. The residual sum of squares in this new regression, RSS^*, must be greater than RSS, the total residual sum of squares in the original regressions for the two periods separately. But is the difference large enough so that sampling error alone can be ruled out as the cause?

The following statistic has the F distribution:

$$F = \frac{(RSS^* - RSS)/n}{RSS/(T - K)}$$

where RSS and RSS* are as previously defined, n is the number of restrictions being placed on the parameters (i.e., the number of parameters being tested for equivalence in the two data sets), T is the number of observations, and K is the total number of parameters in the equation. This statistic increases in value as the quantity (RSS* - RSS) increases because of sampling error or because the null hypothesis is untrue. In this regression,

$$F = \frac{(14.09 - 4.69)/7}{4.69(252 - 12)} = 68.87$$

At the .99 confidence level the value of F with (7, 240) degrees of freedom is about 2.75. The test indicates we should reject the hypothesis that the parameters of the interest rate and exchange rate variables were the same in the two periods.

A third set of marked differences between the estimation results for the two periods concerns the relative importance of the four interest rate variables as factors explaining the fluctuations in the Euro-dollar rate. Comparing the second period with the first, we find a higher t-ratio for the U.S. Treasury bill coefficient, and lower t-ratios for the coefficients of the three European interest rates. Greater explanatory power of the U.S. Treasury bill in the second period stems from the larger coefficient. The reduced explanatory power of the European interest rates reflects a lower coefficient for the German interbank loan rate, a reduced variability of the British local authority rate, and both a smaller coefficient and a reduced variability for the Swiss rate. The estimates of the coefficients of the European interest rates are statistically significant in the 1966-68 period but not (at the .05 level) in the 1969-70 period. They are not statistically significant in the second period because of the high multicollinearity with the other explanatory variables; however, the marked declines in the t-ratios from the first period to the second were <u>not</u> caused by an <u>increase</u> in the degree of multicollinearity, on the basis of tests for that condition.

The estimated coefficients of the Regulation Q dummy, the quantity of CD's, and the reserve requirement dummy all carry the correct signs. In this regard the estimation results support the logic that 1) when CD rates in the United States were at Regulation Q ceilings in 1966-68 there was upward pressure on the Euro-dollar rate because of the presence of ceilings; 2) when investors let CD holdings run off in 1969-70 (again because of Regulation Q), and the quantity of CD's outstanding declined, this also put upward pressure on the Euro-dollar rate; and 3) the introduction of the reserve requirement on U.S. banks' foreign borrowings in 1969 had a downward impact on the Euro-dollar rate. The t-ratios imply that none of estimated coefficients of these variables is statistically significant at the .05 level (corresponding to a t-ratio of about 1.99 for both estimation periods), but the low t-ratios can be attributed to the high multicollinearity of each of these variables with the others in the regressor set. A most unsatisfactory aspect of the estimation results is the appearance of negative coefficients for the forward pound sterling in both periods and the forward German mark in one of them. The most likely explanation would seem to be the already-remarked upon absence from the equation of one or more important explanatory variables, a condition which imparts bias to the estimation of the coefficients of the included variables and which, in this instance, may have imparted a downward bias.[2/]

IV. Tests for Multicollinearity

Tests have been developed by Farrar and Glauber, using data routinely generated by computer regression programs, for measuring the degree of multicollinearity within a set of regressors as a whole, and also the degree to which a single variable within a regressor set may be multicollinear, either with the other variables as a group or with each of the others individually.[3/] These tests can be very useful for economists who deal with financial market data that, for cyclical reasons in particular, often move in phase with one another.

Farrar and Glauber's test for multicollinearity within a regressor set as a whole rests on the distribution of determinants of sample first-order correlation matrices of the explanatory variables. A first-order correlation matrix being the moment matrix when the data have been converted to standardized units, we denote its determinant as $|X'X|$. The following quantity, which we here call K, is distributed

2/ In addition, simultaneous-equations bias also affects these estimates. The forward exchange rates are not independent of the Euro-dollar rate and cannot be considered exogenous in any real sense. Simultaneous-equations bias also affects the estimate of the coefficient of the Swiss bank deposit rate since Swiss interest rates are strongly affected by developments in international markets.

3/ D. E. Farrar and R. R. Glauber, "Multicollinearity in Regression Analysis: the Problem Revisited", Review of Economics and Statistics, vol. 49, 1967, pp. 92-107.

approximttely as Chi Square with $1/2[n(n-1)]$ degrees of freedom:

$$K = -[N-1 - 1/6(2n + 5)] \log |X'X|$$

where N is the number of observations and n is the number of variables in the regressor set.

The values of K given by our data are approximately 1,155.2 for 1966-68 and 776.5 for 1969-70. At the .01 probability level, the values of Chi-Square with 28 degrees of freedom (with reference to K for 1966-68) and with 36 degrees of freedom (with reference to K for 1969-70) are about 48.3 and 71.4, respectively. It is clear that the variables are highly collinear.

If it can be reasonably ascertained by tests of hypotheses that one, or some, variables in a regressor set are multicollinear with the remainder, but that others are much less so or are not multicollinear at all, consideration can be given to the possibility of discarding the former, and perhaps substituting others in their place. The Farrar and Glauber test for the degree of multicollinearity of an individual variable vis-a-vis the remainder employs the elements on the principal diagonal of the inverse correlation matrix, which elements we designate by r^{ii}. The following quantity, which (after Farrar and Glauber) we call w, is distributed as F with N-n and n-1 degress of freedom:

$$w - (r^{ii} -1)(N-n)/(n-1)$$

where N and n are, again, the number of observations and the number of regressors.

For our regressors the values of w for the two periods are:

Variable	1966-68	1969-70
TBR	147.6	32.4
BLAR	93.2	64.8
GILR	197.9	237.8
SBDR	53.5	61.0
FPS	41.7	23.1
FDM	224.9	11.8
FSF	94.7	5.3
RRD	--	73.9
RQD	16.7	--
QCD	--	77.3

At the .01 probability level, the value of F with the appropriate degrees of freedom is approximately 2.7 for both estimation periods. Comparing the value of 2.7 with the values of w reported just above, we conclude that not a single explanatory variable is free of a very high degree of multicollinearity. While this is a dismaying conclusion, one positive aspect of the test results is the light they shed on the collapse of the t-ratios of the European interest rate coefficient estimates between 1966-68 and 1969-70. The test results suggest that although the degree of multicollinearity of the German and Swiss rates was a bit higher in 1969-70 than in 1966-68, the increases were hardly large enough to account for the very large declines in the t-ratios that occurred. For the British rate, the degree of multicollinearity evidently declined in the second period, and so we should not attribute the decline in the t-ratio to higher multicollinearity.