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Portfolio Substitution and the Reliability of M1, M2 and M3 as Monetary Policy Indicators

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Based on a single system of equations that contains income, prices, a market rate of interest, and the components of M3, we find that M1 became highly susceptible to adjustments in the public's portfolio of liquid assets in the 1980s, and thus is unlikely to be a reliable guide to monetary policy in the future. The behavior of the broader monetary aggregates has not changed significantly from the 1970s, and both M2 and M3 are broad enough to internalize most portfolio adjustments that are likely to occur. Therefore, they are likely to be more reliable as monetary policy indicators than M1, although the analysis does not imply that either will be as reliable as M1 once was.

Last February, Federal Reserve Chairman Paul Volcker testified before the Senate Banking Committee about the Federal Reserve's 1987 plans for monetary policy. An important element of those plans consists of the target ranges for growth in the monetary aggregates. In his testimony, the Chairman reported that the Fed had reaffirmed the 5½ to 8½ percent 1987 target ranges for growth in the broader monetary aggregates, M2 and M3, that had tentatively been set in July 1986.

Volcker also stated that the Fed had decided not to set a target range for the narrow aggregate M1. Instead, it will closely monitor the behavior of M1 ". . . in light of other information, including whether or not changes in that aggregate tend to reinforce or negate concerns arising from movements in M2 and M3."[1] Then, in its July 1987 meeting, the FOMC tentatively planned not to set a range for M1 in 1988. Thus, for the time being, M1 has been given a subordinate role in the formulation and implementation of monetary policy where, traditionally, it has received greater emphasis than the broader monetary aggregates.

The downgrading of M1's role in monetary policy for 1987 reflects concern about that aggregate's continued reliability as an indicator of monetary policy. Traditionally, M1 was considered a primary policy indicator, both by the Fed and by many outside observers, in part because it had the desirable property of containing most of the media of exchange in the economy, that is, currency and checkable deposits. Since M1 offered unique transactions services, the public's demand to hold that aggregate was not highly responsive to the kinds of portfolio considerations — for example, relative interest yields and terms-to-maturity — that determine the public's demand to hold the savings-type instruments that are in M2 and M3.

Because M1 had few close substitutes, its

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behavior was not substantially affected by difficult-to-predict portfolio substitutions, and, as a consequence, movements in M1 were dominated by changes in macroeconomic variables, such as income and prices, that are the concern of Fed policy.

Chairman Volcker's testimony cited two main sources of concern about M1's reliability as a monetary policy indicator. First, deposit-rate deregulation, which began in the case of M1 with the authorization of nationwide NOW accounts at the end of 1980 and was completed in March 1986, may have made M1 more of a savings-type aggregate. In such case, M1 most likely would have lost its unique transactions character and its relationship with income and prices might thus have become less predictable. Second, this change may have led to M1's highly unusual behavior over the past two years. In both 1985 and 1986, M1 grew extremely rapidly while economic growth was moderate and inflation was subdued. In contrast, M2 and M3 behaved much more in accordance with their historical relationships with income and prices.

This paper assesses the changes in the relationship between M1 and economic developments for 1985-86, and draws out the implications for the future reliability of that aggregate as a monetary policy indicator. The paper then assesses the reliability of M2 and M3 as alternative indicators for the Fed.

Based on a vector autoregression, our basic finding is that M1 became highly susceptible to adjustments in the public's portfolio of liquid assets in the 1980s. In particular, the rapid growth in M1 in 1985-86 appears to have been related to a large reduction in the public's demand to hold small time deposits. That change in demand probably was caused by reductions in spreads of yields on small time deposits compared with those on NOW and other more liquid accounts. Movements in M1 in 1985-86 therefore had little to do with general output and price trends. Given the nascent susceptibility of M1 to portfolio disturbances, it is unlikely to be a reliable guide to policy in the future.

The broader monetary aggregates were relatively accurate monetary policy indicators in 1985-86 primarily because they were broad enough to internalize the portfolio shifts that occurred. Moreover, our analysis suggests M2 and M3 should be able to internalize most portfolio reallocations that are likely to occur. Thus, our analysis strongly supports the Fed's recent action to downgrade M1 in favor of greater reliance on M2 and M3.

The remainder of the paper is organized as follows. In Section I, we summarize the major potential problems that can develop in the public's demand to hold money as the result of the financial deregulation in the 1980s. We then go on to review the empirical evidence on the demand for money in the 1980s, focusing special attention on the problems with M1 in 1985-86, as well as the stability of M2 and M3 in this period. In Section II, we use a statistical technique called vector autoregression to analyze the behavior of M1, M2, and M3, and their reliability as monetary policy indicators. Section III presents policy implications and conclusions.

I. The Demand for the Monetary Aggregates

Over most of the period since the mid-1970s, when the Federal Reserve began to express its monetary policy in terms of the monetary aggregates, M1 has received primary emphasis. M1 consists of the outstanding stock of currency and fully checkable deposits, and thus corresponds closely to the theoretical concept of "money" in macroeconomic theory. It has been found to be subject to a reasonable degree of control by the Federal Reserve, and, until recently, has been considered a more reliable leading indicator of real GNP and inflation than the more broadly defined monetary aggregates, M2 and M3, which include liquid savings instruments that do not function as fully as part of the medium of exchange.

An important necessary condition for M1's leading-indicator characteristic is that the public's demand to hold M1 is a stable function of a small number of macroeconomic variables that are of interest to monetary policymakers — income, prices and a market interest rate. M1 traditionally has been considered more likely than M2 and M3 to

have a stable and simple demand function because of M1's unique role as the main part of the medium of exchange, and because its rate of return has not been determined by market considerations but instead has been set by regulation. Such a narrow "medium-of-exchange" aggregate had a good chance of having a stable and relatively uncomplicated demand function because it had few close substitutes. At the same time, the constancy of its own yield meant that changes in the supply of M1 had predictable effects on the interest yields on other financial instruments. The deregulation of deposit interest rates and the introduction of new liquid instruments therefore have the potential to interfere with M1's usefulness for monetary policy by making the public's demand to hold that aggregate more difficult to predict.

In cataloging the effects of such financial market changes on money demand, it is useful to distinguish between the adjustment effects during the transition period after a change and the equilibrium effects, which persist even after full adjustment has been made. For example, deregulation of yields on M1 deposits initially would cause the demand for M1 to shift up as the public pursues the more attractive yields. This shift, in turn, would cause M1 growth rates to increase temporarily, relative to any given changes in income, prices and the market rate of interest, until the new, permanently higher, level of desired M1 balances is achieved. During such transition periods, monetary policy can go off course, since it is difficult to estimate the size, speed and duration of such demand shifts while they are occurring.

However, the problems for monetary policy caused by such transition effects are likely to be temporary since once the new equilibrium level of M1 is attained, the relation of M1 growth to its underlying determinants should return to its historical norm. Since deposit rate deregulation now is complete, these transition effects, which were of primary importance earlier in this decade, no longer are major issues.

Of more immediate concern are the permanent problems deposit-rate deregulation may have caused for M1-targeting if higher yields on M1 have led the public to use M1 as a savings vehicle to a greater degree than in the past. Such a change could contaminate M1's unique transaction character and cause it to become a closer substitute for other financial instruments. As a result, the public's demand to hold M1 might have become more highly responsive to changes in the spreads between M1's own rate of return and rates paid on a wide range of other financial instruments. Shifts in investors' preferences for various maturities and liquidity characteristics also could have larger effects on M1 demand.

In general, since M1 may have become more like financial assets held for investment purposes, changes in the demand for M1 could be dominated at various times by difficult-to-predict shifts in the composition of the public's portfolio, and only incidentally by changes in the variables that are of interest to the policymaker — income and prices. Such portfolio shifts would show up both as instability in estimated M1 demand functions and as unexpected shifts in reduced-form relationships between M1 and nominal GNP.

Deposit rate deregulation also could have made M1 demand more difficult to predict by making it depend on how depository institutions respond to movements in market yields in setting their offering rates both on transactions accounts and on other time and savings deposits that are substitutes for M1. Before deregulation, the "own-rate" on M1 was fixed by government fiat, as were the yields payable on most of its close substitutes. With deregulation, the speed and degree to which banks adjust deposit rates to follow market rates determine how sensitively the opportunity cost of M1 varies with market interest rates, opening up a whole new range of uncertainties for the policymaker. For any given elasticity of M1 demand with respect to the opportunity cost of holding it, the elasticity of demand with respect to market rates will be smaller the more rapidly banks adjust their rates on M1 deposits to changes in yields on market instruments. Thus, banks' deposit rate-setting behavior helps determine the overall relationship between a change in the market rate of interest and the demand for M1.

Deposit rate deregulation can affect the broader monetary aggregates as well. A recent example is the introduction of Money Market Deposit Accounts in December 1982, which caused M2 to grow extremely rapidly relative to M3 in a transition

period that lasted for two months. The introduction into the broader aggregates of instruments with interest rates that can vary freely with market rates undoubtedly has altered the behavior of those aggregates as the general level of rates has varied over the business cycle.

However, recent deregulation most likely has had smaller permanent effects on M2 and M3 than on M1 largely because the interest rate restrictions on the broader aggregates prior to deregulation were less severe than the prohibition of the payment of interest on M1. Prior to mid-1978, all of the time and savings deposits in M2 were subject to interest rate ceilings, but those ceilings were set well above zero. Then, in mid-1978, the deregulation of M2 began in earnest with the introduction of the small denomination six-month money market certificates, which had ceilings that vary with Treasury bill rates.

TABLE 1

Growth of Monetary Aggregates
(Annual Rates)

M1 Growth

	Actual	Simulated	Error
1985 H1	11.6	10.2	1.4
1985 H2	12.1	7.8	4.3
1986 H1	12.8	7.4	5.4
1986 H2	19.1	7.8	11.3
Mean Error			5.6
Root Mean Square Error			6.7

M2 Growth

	Actual	Simulated	Error
1985 H1	8.9	9.8	−0.9
1985 H2	7.1	6.6	0.5
1986 H1	8.1	7.3	0.8
1986 H2	10.0	6.4	3.6
Mean Error			1.0
Root Mean Square Error			1.97

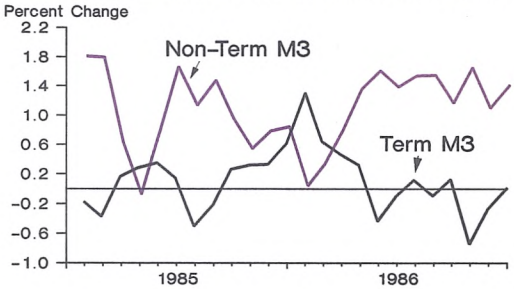
M3 Growth

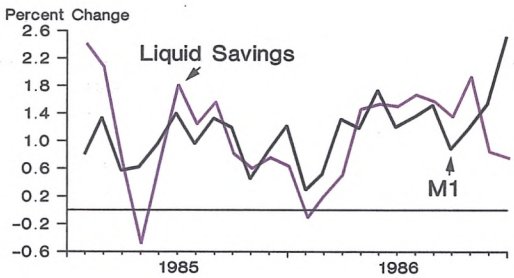
	Actual	Simulated	Error
1985 H1	7.4	10.1	−2.7
1985 H2	6.7	7.5	−0.8
1986 H1	8.6	8.1	0.5
1986 H2	9.0	6.3	2.7
Mean Error			−0.1
Root Mean Square Error			1.97

Large time deposits in M3 have been free of interest rate restrictions since the early 1970s.

In summary, significant proportions of M2 and M3 offered interest rates that were not far below market rates even before deregulation, so these aggregates were attractive savings vehicles for individuals in the earlier period as well. Thus, a priori, we would expect deposit rate deregulation to have had a smaller impact on the nature of these aggregates. Furthermore, M3 is likely to have been affected even less than M2, since M3 already contained accounts that were free of interest rate ceilings.

Chart 1
Monthly Growth Rates of M3 Components





Empirical Evidence on Money Demand

The evidence up to 1985 casts doubt on the hypothesis that the demand for M1 would be seriously affected by deregulation. When there were shifts in M1 demand (1974-76 and 1981), they were in the downward direction.[2,3] This suggests that these episodes of unusual M1 behavior occurred not as a result of deregulation, but rather because of deposit rate regulations that were still in place in a period of rapid inflation and high nominal market interest rates. Moreover, empirical tests for changes in the interest elasticity of M1 demand showed only a slight change — the elasticity had become slightly more negative.[4]

The first clear upward shift in M1 demand during the 1980s occurred over the last two years. On the surface, the timing of this shift is surprising since it occurred after deregulation was largely complete. We offer a tentative explanation for this timing below.

Table 1 shows the money demand simulations obtained from the San Francisco Money Market Model.[5] Except for the first few months in 1985, the model has consistently underpredicted M1 growth, so that the difference between the actual and simulated value of M1 has increased over time. M1 grew at an average annual rate of 13.9 percent from December 1984 to December 1986, while the model predicted mean annual growth of 8.3 percent.

The simulated value of M2 has tracked actual M2 more closely (see Table 1). For the two-year period ending in December 1986, M2 grew at an 8.5 percent annual rate, 1.0 percent more than the value predicted by the model. For the two-year period as a whole the model's simulation of M3 growth at an 8.0 percent annual rate is quite close to the actual rate of 7.9 percent.

The stability of the demand for the broader aggregates in combination with the upward shift in M1 demand suggests that M1 has been adversely affected by portfolio substitutions that were internalized within the broader monetary aggregates.

Chart 1 provides a perspective on these portfolio substitutions. The upper panel shows growth rates in the components of M3 that do *not* carry terms to maturity plotted against the components of M3 that do carry terms to maturity. This distinction is based on the liquidity of financial assets, which is an important characteristic of investors' demands for alternative assets. (See the discussion "Defining the

Monetary Aggregates" in the box.) The non-term M3 components include M1, overnight repurchase agreements and eurodollars, money market deposit accounts, passbook savings accounts, and money market mutual fund shares. The term components of M3 include small denomination (less than $100,000) time deposits, large denomination time deposits, and term repurchase agreements and eurodollars. The upper panel shows that the non-term component of M3 and the term component have moved in opposite directions, that is, they have behaved as substitutes. This is true of both trend growth and of the fluctuations in the growth rates of these components over this period.

The bottom panel of Chart 1 shows growth rates of M1 — a component of non-term M3 — and of the remainder of non-term M3. This latter component, which we call liquid savings, contains the instruments in M3 that are not fully checkable, that is, instruments that are not in M1 and do not have fixed terms to maturity. (For these and other monetary definitions see the box labeled "Monetary Aggregates.") Growth in the two non-term components, M1 and liquid savings, has been positively correlated during 1985 and 1986. In other words, M1 has behaved similarly to the liquid savings instruments in M2.

Taken together, these panels suggest that the distinction between term and non-term accounts has been an important margin of substitution within instruments in M3, whereas the distinction between checkable and non-checkable deposits has not been an important consideration over the last two years. The pattern of growth in the components of M3 is consistent with the idea that M1 may have been contaminated with savings balances and that its behavior may no longer be determined by medium-of-exchange characteristics only.

II. Portfolio Substitution

The evidence in Chart 1 is consistent with the idea that M1 has taken on the characteristics of a savings aggregate, but by no means does that evidence represent a rigorous test since it covers only two years of data and does not control for factors other than portfolio substitution that are likely to affect growth in the components of M3. In this section, we formally test the proposition that M1 has become more susceptible to portfolio shifts in the deregulated environment of the 1980s by estimating a vector autoregression (VAR).

Estimating a VAR is a method of examining the relationship between a set of variables and their past values. By imposing relatively few restrictions on the dynamic relationships between the variables in the model, a VAR, in effect, allows the data to speak for themselves. Statistical tests are used to check whether past values of a given variable are significant in a particular equation. The estimated equations can then be transformed to obtain "impulse response functions" that show how the variables respond over time to various shocks, or unpredicted movements, in the variables of the system. Finally, the relative importance of different shocks for predicting future values of the variables in the system can be estimated using "variance decompositions".

The VAR we estimated includes the variables that appear in conventional M1 demand equations (M1, real personal income, RPY, the implicit consumption deflator, DEF, and the 6-month commercial paper rate, R), and, in addition, the *quantities* of monetary assets believed to be close substitutes for M1.[6] We hoped that inclusion of these quantities, in combination with a market interest rate, would enable us to capture the combined effects of portfolio considerations in the demand for M1 — including changes in relevant interest rate spreads, changes in preferences for term-to-maturity and risk, as well as any other factors that consistently cause individuals to re-allocate their portfolios across various assets. We chose to include quantities rather than interest rate spreads because the quantities are likely to pick up the effects of changes in spreads *plus* other factors such as those mentioned above.

To illustrate the last point, in April 1987 there was a large movement in M1 that cannot be attributed to changes in interest rates. M1 increased by $11 billion, apparently because individuals moved

Defining the Monetary Aggregates

In the Federal Reserve's official definitions (lefthand brackets below) of M1, M2, and M3, the rationale for distinguishing the deposits in M1 from those in the broader aggregates is that the former are fully checkable.

The distinction between M2 and M3 is based on whether a deposit or other asset was commonly used by banks as a managed liability. Thus, for example, small denomination time deposits are part of M2 because they were not managed liabilities in 1980 when the definitions were instituted. Large denomination certificates of deposit are parts of M3, but not M2, because they were used as managed liabilities.

The results in this paper suggest that deregulation has blurred these distinctions. The introduction of interest-bearing accounts in M1 (NOWs and Super-NOWs) has led individuals to transfer savings balances into these accounts, thereby blunting the distinction between fully checkable accounts in M1 and other highly liquid savings-type accounts, such as MMDAs.

In addition, the lifting of ceilings on small time deposits has meant that banks are now in a position to meet their borrowing needs by varying rates on these accounts as well as by varying rates on large time deposits. Thus, both accounts now share the same characteristics of managed liabilities.

Under these circumstances, an alternative way to distinguish these accounts is by liquidity (righthand side brackets above). Accounts that have a fixed term to maturity may behave differently from those that do not. Indeed, our empirical analysis suggests that, in the 1980s, this distinction has been more important than the distinction between checkable and non-checkable accounts as well as the prevailing distinction between managed liabilities and the other deposit accounts in M3.

Monetary Aggregates: Components and Definitions
(Billions of Dollars)

Conventional Definitions			Components	Levels as of Dec. 1986	Definitions Used in Paper	
M3 ($3486.2)	M2 ($2798.4)	M1 ($730.5)	Currency	$183.5	M1 ($730.5)	Non-Term M3 ($1945.1)
			Demand Deposits	308.3		
			Other Checkable Deposits (includes NOWs)	232.3		
		NetM2 ($2067.9)	Overnight RP's and Eurodollars	75.9	Liquid Savings ($1214.6)	
			Money Market Deposit Accounts	571.3		
			Passbook Savings Deposits	366.2		
			General Purpose & Broker/Dealer Money Market Mutual Funds	207.5		
			Small Denomination Time Deposits	853.3	Small Time Deposits ($853.3)	Term M3 ($1541.1)
		NetM3 ($687.8)	Large Denomination Time Deposits	447.0	Large Term Accounts ($687.8)	
			Terms RP's and Eurodollars	163.8		
			Institution Only Money Market Mutual Funds	84.1		

funds from non-transactions accounts to pay taxes. To the extent that these funds were moved out of other accounts in M3, they should be picked up by our specification but not by a model that relied on interest rate spreads. (In theory, seasonal adjustments should remove such movements from the data. In practice, however, it is difficult to determine exactly how large such effects are likely to be.)

The specific monetary components we include, in addition to M1, are small time deposits, liquid savings, and large term accounts (see the box "Monetary Aggregates"). As will become evident, this set of monetary components permits us to analyze the important portfolio substitutions that have occurred in recent years between accounts with and accounts without terms to maturity. Further-

TABLE 2

Summary Statistics for Monetary Aggregates in VAR

Pre-Deregulation Period

Equation for:	Large Term Accounts	Small Time Deposits	Liquid Savings	M1
Marginal Significance Levels				
RPY	.14	.22	.36	.11
DEF	.38	.24	.67	.43
R	.07	.13	.20	.36
Large Term Accounts	.01	.27	.14	.96
Small Time Deposits	.60	.00	.13	.86
Liquid Savings	.99	.89	.00	.32
M1	.23	.48	.03	.03
Other monetary components*	.56	.60	.03	.56
$\bar{R}^2$	.75	.71	.87	.32
S.E.E.	.0105	.0029	.0030	.0034

Post-Deregulation Period

Equation for:	Large Term Accounts	Small Time Deposits	Liquid Savings	M1
Marginal Significance Levels				
RPY	.15	.95	.30	.27
DEF	.13	.73	.67	.09
R	.11	.00	.00	.01
Large Term Accounts	.33	.25	.15	.72
Small Time Deposits	.08	.00	.48	.00
Liquid Savings	.47	.19	.15	.00
M1	.04	.31	.42	.86
Other monetary components*	.07	.08	.38	.00
$\bar{R}^2$	.73	.96	.97	.49
S.E.E.	.0069	.0034	.0050	.0039

*For example, in the M1 equation, the null hypothesis is that past values of Small Time Deposits, Large Term Accounts, and Liquid Savings taken together have no influence on M1.

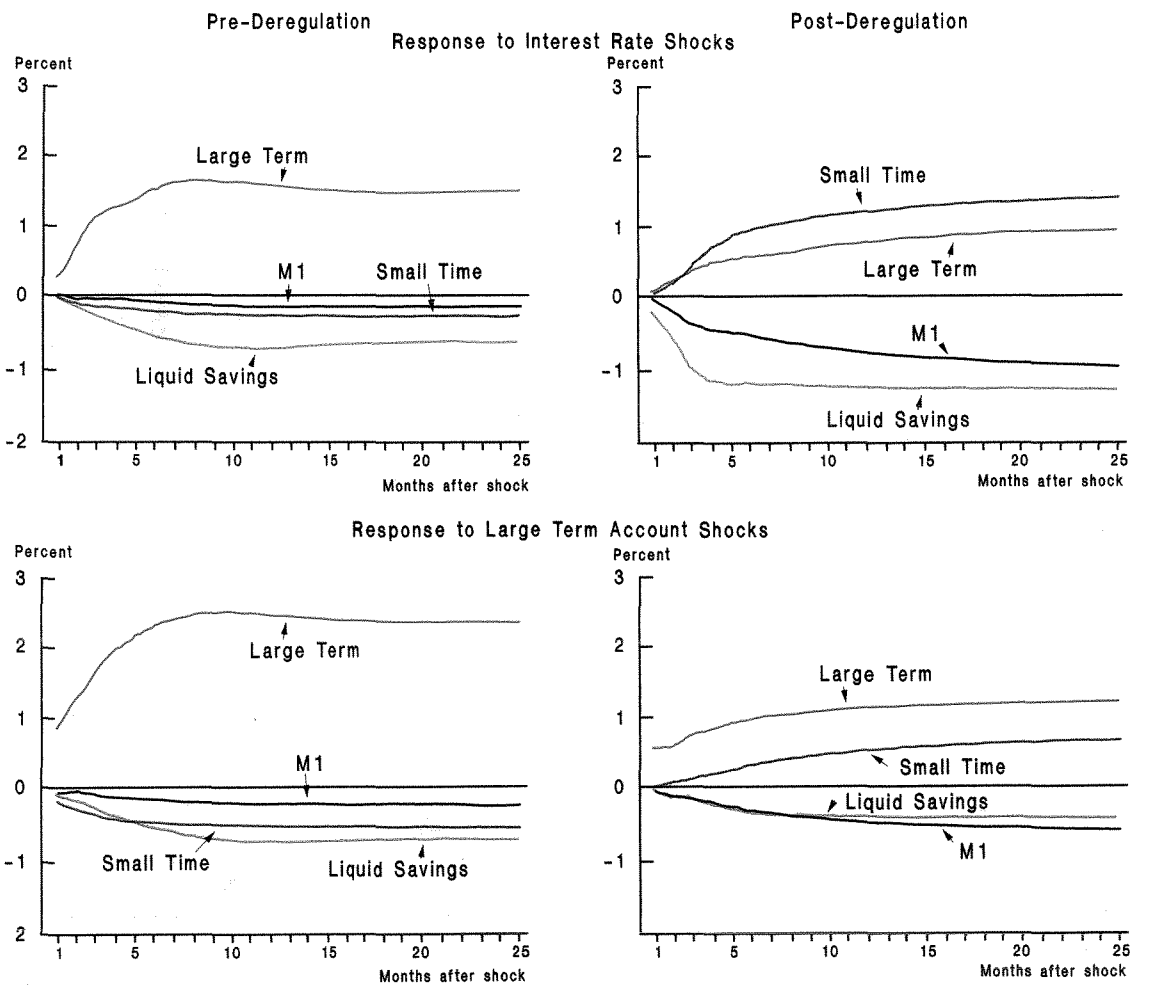
more, by aggregating these components, we can assess the effects of portfolio disturbances on the broader aggregates, M2 and M3.[7] (Note that M2 = M1 + small time deposits + liquid savings, and M3 = M2 + large term accounts.)

To analyze the effects of financial deregulation on the behavior of the monetary aggregates, we have defined two sample periods: the pre-deregulation period extending from January 1974 to June 1979 and the post-deregulation period extending from July 1981 to December 1986. The beginning date for the early period avoids the disturbances caused by the removal (in 1973) of interest rate ceilings on large time deposits. The sample ends in mid-1979 to avoid distortions from the change in Federal Reserve operating procedures later that year (see Spindt and Tarhan, 1987, for a description of the change). We have also included a dummy variable for the period up to June 1976 to capture the well-known downward shift in M1 demand over that period (see Judd and Scadding, 1982).

In the later sample, we omit the first six months of data for 1981 to avoid confusing the one-time portfolio reallocations that may have followed the introduction of nationwide NOW accounts with the interactions that may have occurred once the initial

Chart 2

Impulse Response Functions - Components of M3 in Levels



adjustment was complete. We also have included constant dummy variables for the months from December 1982 to February 1983 to take account of the one-time portfolio re-allocation following the introduction of MMDAs and Super-NOWs.

All variables are included as the first difference of logs. We use Sims' (1980) Chi-square test to determine the appropriate lag length for the VAR over both sample periods. Our tests reveal that in both samples a lag length of 2 months is statistically indistinguishable (at a 5 percent significance level) from lag lengths of 3 to 5 months.

Empirical Results

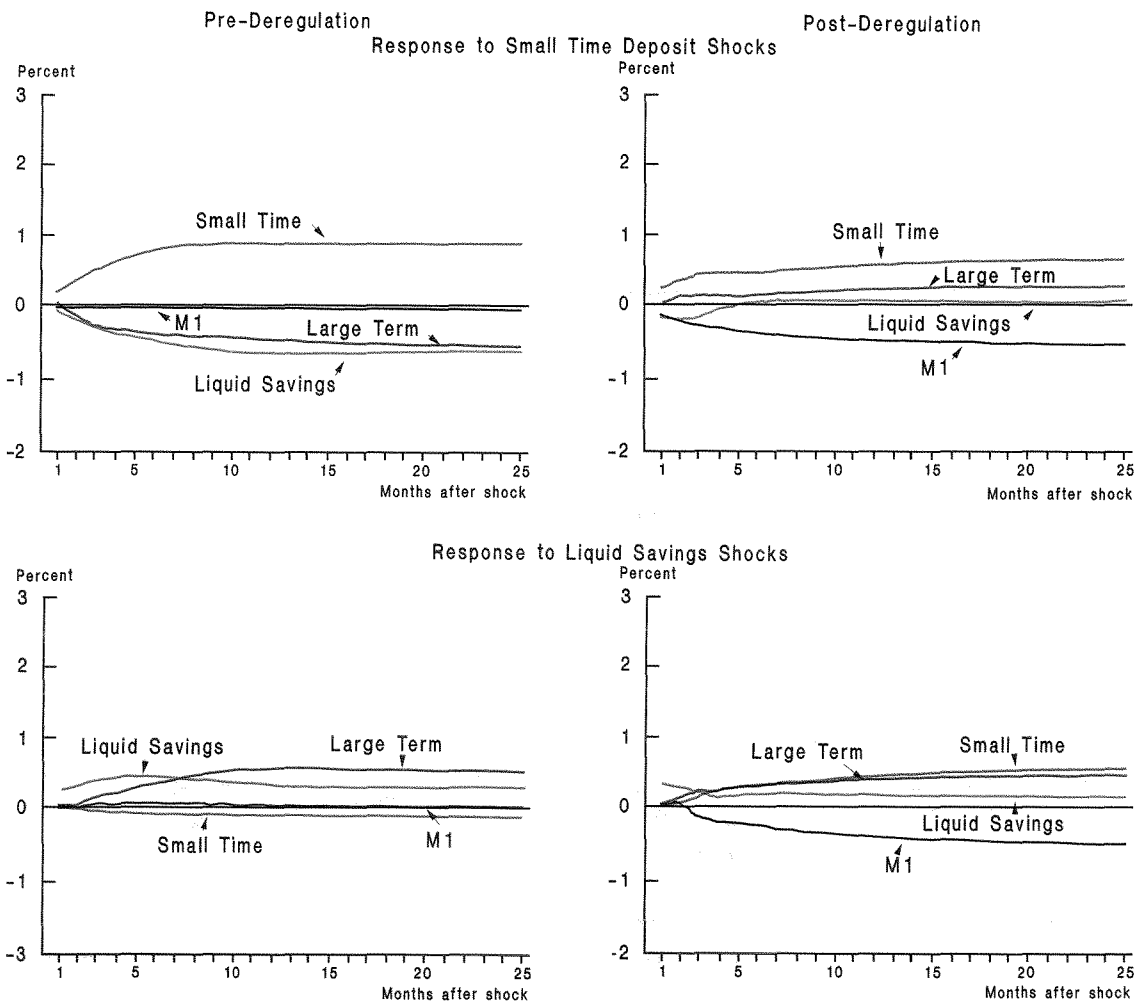
M1 and the Other Components of M3

The results from the VAR support the hypothesis that deregulation has changed the nature of the monetary aggregates. They are consistent with M1 having become more like savings-type assets in the period of deregulation, and hence having lost much of its transactions character.

Table 2 shows summary statistics from the estimated equations for the monetary components over the two sample periods. Abbreviations for the mon-

Chart 3

Impulse Response Functions - Components of M3 in Levels



etary variables are explained in the box "Monetary Aggregates." The marginal significance levels indicate which variables are important in predicting future values of the various components. According to convention, a significance level less than 0.05 suggests that past values of that variable *do* have an impact on the dependent variable.

In the post-deregulation period, past values of both small time deposits and liquid savings individually provide statistically significant information about M1. By contrast, during the pre-deregulation period, none of the other monetary components provides significant information about M1. For each component of M3 we also tested whether the remaining components of M3 taken together provide statistically significant information about future values of that particular component. For M1, the answer is yes after deregulation, but not before. There is evidence that the same is true for large term deposits and small time deposits, although there the results are weaker. (Correlations between the residuals obtained from the VAR, that is, the prediction errors in the equations, are shown in Table B1 of Appendix B.)

These results show that, in the post-deregulation period, movements in the various components of M3 (with the exception of the liquid savings component) are more closely related to one another than before — even after the effects of past changes in income, prices, and a market rate of interest have been taken into account.

The impulse response functions in Charts 2 and 3 show what typically happens to the levels of M1, liquid savings, small time deposits, and large term accounts over time when there is an unpredicted increase in selected variables, taking into account the full dynamic interactions estimated in the VAR. These responses are plotted in terms of the percent deviation of the responding variable from its initial level in response to a one-standard deviation change

TABLE 3

M1 Variance Decomposition

(Percentage Points)

Pre-Deregulation Period

Months Ahead	Forecast Standard Error	Real Income	Prices	Interest Rate	Large Term Accounts	Small Time Deposits	Liquid Savings	M1
0	.292	2	7	0	2	1	2	87
1	.328	4	6	3	2	1	2	82
3	.333	4	6	3	3	1	3	80
6	.337	4	6	4	3	1	3	78
12	.338	4	6	4	4	1	3	78

Post-Deregulation Period

Months Ahead	Forecast Standard Error	Real Income	Prices	Interest Rate	Large Term Accounts	Small Time Deposits	Liquid Savings	M1
0	.331	3	1	1	3	12	4	76
1	.388	3	11	13	3	12	3	55
3	.484	2	11	24	3	10	14	36
6	.516	4	11	24	6	10	13	32
12	.539	4	11	25	7	9	13	30

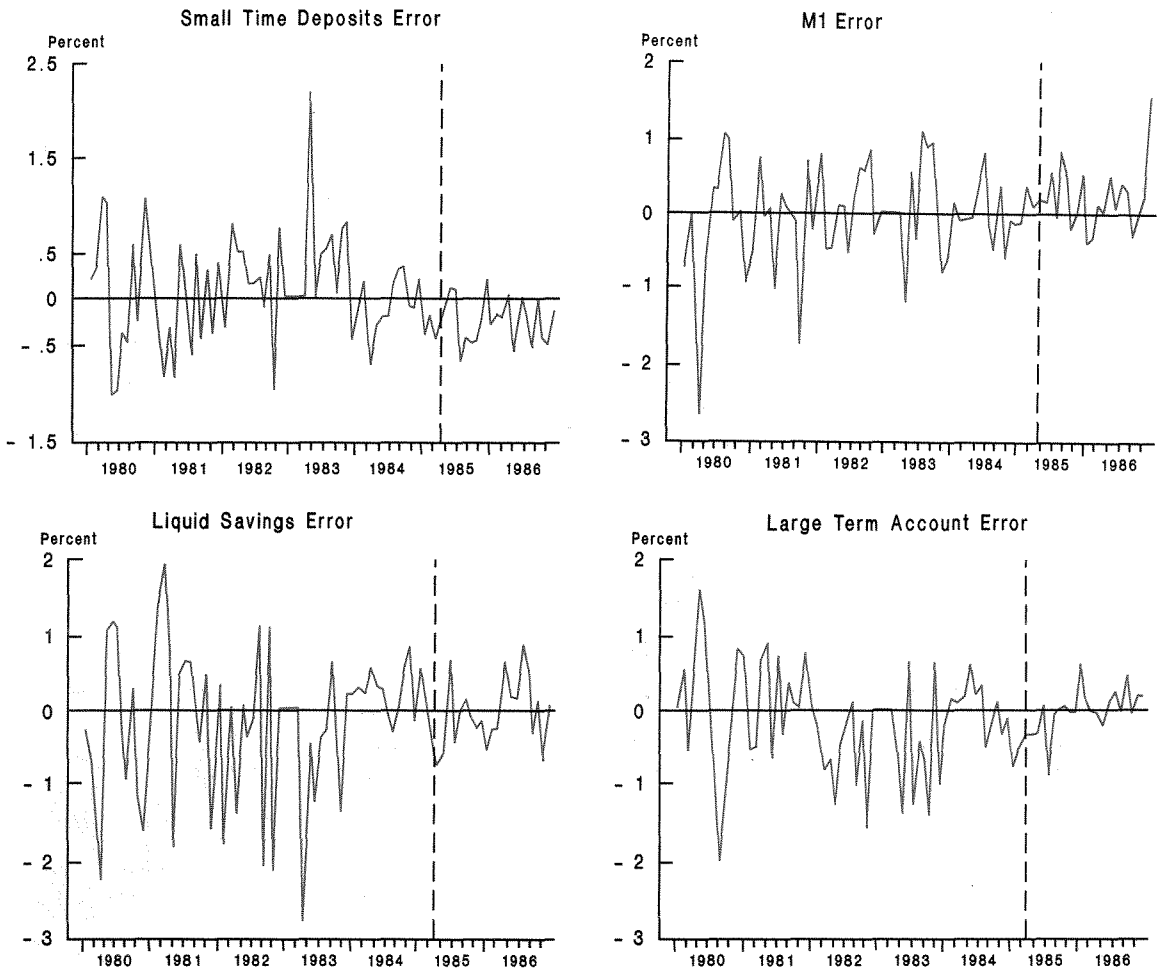
in the "shock" variable. Since our focus is on substitutions between different monetary components, we show the effect of interest rate shocks and shocks to the monetary components (large term accounts, small time deposits and liquid savings) only.[8]

The portfolio-substitution characteristics of M1 across the two periods are strikingly different. Consider, for example, the effects of interest rate shocks. Panel (a) of Chart 2 shows that in the pre-deregulation period, an unanticipated increase in the interest rate had only a small negative effect on the level of M1. In the second period, by contrast, the effect is noticeably larger, with the decline in M1 continuing for at least two years following the interest rate shock.

The response of M1 to shocks to the other monetary components also is markedly different in the two periods. In the pre-deregulation period, M1 stays close to its original level after a shock to any of the components of M3. In the post-deregulation period, by contrast, M1 decreases immediately following shocks to both large term accounts and small time deposits, and then keeps declining for approximately a year before stabilizing at the new lower level. M1 increases contemporaneously with a liq-

Chart 4

Errors in Projecting Growth Rates of M3 Components 1980:1 - 1986:12



uid savings shock but then falls and keeps declining for nearly a year as well.

The impulse response functions suggest that the reactions of M1 to portfolio shocks have undergone a number of changes after deregulation. M1 reacts noticeably more strongly to innovations in the market interest rate, large terms accounts, liquid savings, and small time deposits in the 1980s than in the pre-deregulation period. In the later period, shocks to large term deposits and small time deposits led to large, permanent changes in the level of M1; these shocks do not appear to have had a significant effect on M1 in the earlier period. Moreover, in the 1980s, M1 and liquid savings accounts react in the same direction and with the same dynamic pattern to interest rate and large term deposits shocks. Such behavior is much less evident in the 1970s.

The behavior of the term components, namely small time deposits and large term accounts, also shows a noticeable difference across the two periods. In the pre-deregulation period, these two components tended to move in opposite directions. In the post-deregulation period, they move in the same direction, which is usually opposite the movement in liquid savings and M1. The change in the behavior of small time deposits probably reflects the removal of the interest rate ceilings on them, which has allowed banks to use these accounts as a managed liability in the post-deregulation period. Small time deposits therefore behave more like the managed liabilities (such as, large certificates of deposit) in the large term accounts component of M3. As discussed below, this result has important implications for the stability of the broader monetary aggregate, M2.

Table 3 presents the variance decompositions for M1 over the two sample periods.[9] In the pre-deregulation period, innovations to M1 itself accounted for around 80 percent of the variance of the error in predicting M1. The interest rate variable accounted for no more than 4 percent of the forecast error variance of M1 at any forecast horizon, while the three monetary components — large term accounts, small time deposits and liquid savings — taken together accounted for only 5 percent of the M1 forecast error variance contemporaneously and did not account for any more than 8 percent at any forecast horizon. This situation is considerably different after deregulation. After the first few months, M1 accounts for only one-third of its own forecast error variance, while interest rate innovations account for around one-fourth. The other three components of M3 account for close to 20 percent of the contemporaneous forecast error variance of M1, and close to 30 percent as the horizon lengthens.

This evidence supports the hypothesis that under deregulation M1 has lost some of its unique characteristics as a transactions aggregate and has taken on the characteristics of a savings-type aggregate. M1 now appears to be much more susceptible to portfolio shocks than it was prior to deregulation and it responds to these shocks much more like the savings-type assets in liquid savings. (Judd and Trehan,

TABLE 4

M1 Variance Decomposition
1981:7 - 1985:3

(Percentage Points)

Months Ahead	Real Income	Prices	Interest Rate	Large Term Accounts	Small Time Deposits	Liquid Savings	M1
0	17	0	9	7	16	4	46
1	13	6	27	5	12	4	31
3	12	5	39	4	8	12	20
6	16	5	38	4	8	11	18
12	17	5	37	4	7	11	18

1987, show that this similarity in response is due to the similarity between NOW accounts and liquid savings.) Moreover, it appears that the term/nonterm distinction between monetary components, which is important for investors in choosing among savings-type assets, has become more significant than the transactions/nontransactions distinction.

The 1985-86 Episode

In Section I, we presented evidence showing that structural money demand equations systematically underpredicted M1 in April 1985 through the end of 1986. To be sure that the VAR results are not dominated by developments in 1985-86, we estimated the VAR over the period from July 1981 to March 1985. The M1 variance decomposition from the shorter period (Table 4) shows that the effect of innovations to the other monetary aggregates is similar to that obtained from the larger post-

Chart 5
Selected Interest Rate Differentials

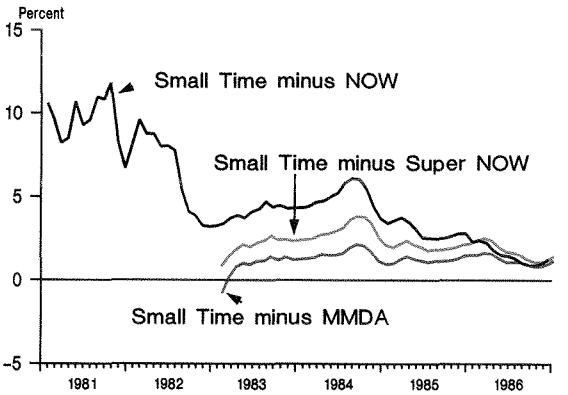


TABLE 5

M2 Variance Decomposition

(Percentage Points)

Pre-Deregulation Period

Months Ahead	Forecast Standard Error	Real Income	Prices	Interest Rate	Large Term Accounts	Small Time Deposits	Liquid Savings	M1
0	.156	5	0	0	35	2	33	23
1	.200	10	0	16	28	3	22	21
3	.251	7	7	17	32	3	16	19
6	.277	5	7	22	33	2	13	18
12	.293	5	7	22	32	2	13	18

Post-Deregulation Period

Months Ahead	Forecast Standard Error	Real Income	Prices	Interest Rate	Large Term Accounts	Small Time Deposits	Liquid Savings	M1
0	.170	0	4	9	3	0	66	17
1	.205	4	3	30	2	2	46	13
3	.240	7	2	36	2	6	35	11
6	.252	9	3	35	2	6	34	11
12	.253	9	4	35	2	6	34	11

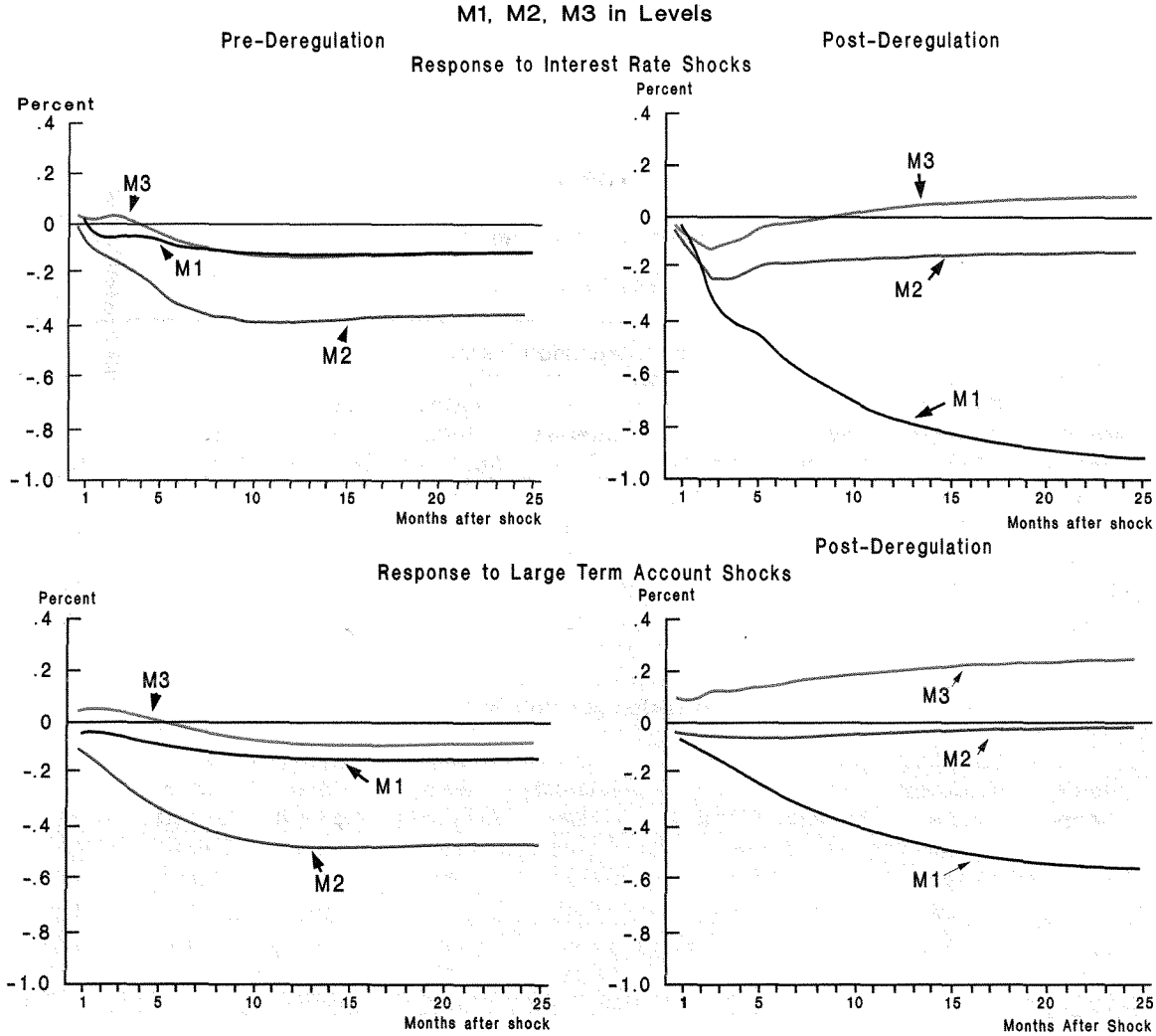
deregulation sample. Thus, M1 was sensitive to innovations in the other monetary aggregates even before 1985.

On the surface, the apparent sensitivity of M1 to changes in the other components of M3 throughout the 1980s contradicts the evidence from the structural M1 demand equations discussed above. If M1 had been contaminated with savings-type balances throughout the 1980s, why is there so little evidence of upward shifts in M1 demand until 1985? An answer is provided by Chart 4. This chart shows successive twelve-month-ahead errors made in predicting the growth rate of the monetary components M1, liquid savings, small time deposits, and large term accounts using the equations from the VAR and assuming actual values for the righthand-side variables. The projections for each year were based on the model estimated over the prior five years.

The panel in the top left corner shows the errors in predicting small time deposits. While the errors made by the equation are relatively large prior to 1985, they tend to be scattered around zero. That is, the errors do not appear to be systematically positive or negative.[10] However, the errors are almost uniformly negative beginning in the second quarter of 1985 (indicated by the dashed vertical line). This is

Chart 6

Impulse Response Functions - M1, M2, M3 in Levels



also the period when the demand for M1 equation began to underpredict M1 growth by a wide margin. Moreover, the overprediction of small time deposits in 1985-86 is consistent with the underprediction in M1 demand, given the negative response of M1 to an innovation in small time deposits shown earlier in the M1 impulse response functions. The bottom two panels of the chart show that there are no systematic errors in predicting liquid savings or large term accounts.

The results in Chart 4 provide a resolution of the apparent contradiction between the M1 demand results and the VAR results. It appears that M1 demand did not show sustained upward shifts related to deregulation prior to 1985 despite having been contaminated with savings-type balances because there were no large shocks to the monetary components prior to 1985. In other words, although the potential for instability in M1 had been increased by deregulation, actual instability did not show up until sizeable shocks actually occurred.

This evidence leaves open the question of why the large shocks to M1 occurred in 1985-86, after deregulation was largely complete. A plausible hypothesis relates the instability to declines in the spreads between yields on M1 and those on close substitutes. As shown in Chart 5, these spreads have declined sharply since the nationwide introduction of NOWs in 1981; the substantial drop in market rates relative to rates on NOWs and Super-NOWs beginning in the latter half of 1984 brought these spreads to all-time lows. The public may have shifted nontransactions balances from small time deposits into M1 in response to the decline in the yield on less liquid M1 substitutes relative to yields on NOWs.

Some analysts have argued that the very sharp response of M1 to this decline in yield implies that

TABLE 6

M3 Variance Decomposition

(Percentage Points)

Pre-Deregulation Period

Months Ahead	Forecast Standard Error	Real Income	Prices	Interest Rate	Large Term Accounts	Small Time Deposits	Liquid Savings	M1
0	.119	10	0	5	8	3	43	30
1	.131	14	2	4	9	2	39	29
3	.149	14	6	5	9	2	40	23
6	.166	12	7	12	11	2	34	21
12	.175	11	7	14	12	3	31	21

Post-Deregulation Period

Months Ahead	Forecast Standard Error	Real Income	Prices	Interest Rate	Large Term Accounts	Small Time Deposits	Liquid Savings	M1
0	.158	0	1	4	33	0	49	13
1	.176	1	1	11	27	6	41	12
3	.199	2	4	16	25	9	32	12
6	.214	3	6	18	22	9	32	11
12	.218	3	7	19	22	9	31	10

M1's interest elasticity has increased. (See Kretzmer and Porter, 1986.) Although this may be the case, it is too soon to tell. If the public were transferring balances to M1 because the yield differential earned for close cash management has become very small, the rapid growth in M1 may represent a transitional adjustment rather than a permanent change in the interest rate elasticity of M1 demand.[11] Indeed, the long run elasticity of M1 demand may even have declined: for money holders who have made the choice not to manage M1 balances actively, a small change in the yield on NOW accounts versus, say, the yield on small time deposits, would have little effect on their demand for M1.

The fact that two quite different interpretations of the 1985-86 episode are possible illustrates the recent nature of the "problems" with M1 demand, problems that do not allow a reliable estimate of the complex structural M1-demand relationships to test alternative hypotheses. Consequently, it will continue to be difficult to interpret movements in M1 in the foreseeable future.

M2 and M3

The analysis so far has focused on the interactions between M1 and the other components of M3. It also is of interest to examine what these interactions imply for the behavior of the broader monetary aggregates, M2 and M3, since the Fed established target ranges for those aggregates. Our results suggest that portfolio disturbances that disrupt the behavior of M1 do not tend to disrupt M2 and M3 as much because these other aggregates are broad enough to internalize the shocks.

We use the VARs shown in Table 2 to obtain results in terms of M2 and M3. This involved aggregating the impulse response functions for the various components obtained from the VAR and then constructing variance decompositions. The procedure followed is best illustrated by focusing on a specific case, say the response of M2 to an interest rate shock. Since the model is estimated in growth rates and since the various components of M2 are of different sizes in dollar levels, aggregation requires the use of weights for the growth rates of each of the components (M1, small time deposits, and liquid savings). The weight used for each component of M2 was the average ratio of the level of that component to the level of M2 over the sample period. The response of each of the 3 components of M2 to an interest rate shock was then multiplied by the corresponding weight and the resulting terms added to obtain the response of M2 to an interest rate shock. The same procedure was repeated to obtain the response of M2 to the other shocks to the system. The M2 forecast error variance decomposition was obtained from these responses in the usual manner.

Charts 6 and 7 present the effect of unexpected movements in interest rates, large term accounts, small time deposits, and liquid savings on the monetary aggregates M1, M2 and M3. As shown in Chart 6, prior to deregulation, an interest rate shock led to a permanent decrease in the level of all three aggregates. The decrease in the level of M2 was the largest, while M1 and M3 decreased by smaller, and roughly equal amounts. After deregulation, M1 decreases the most, while M3 actually returns to its pre-shock level. M2's post-deregulation response is only slightly smaller than its pre-deregulation response.

Second, the charts show that post-deregulation, M2 and M3 tend to move closely together in response to a shock to any of the monetary components. This is not surprising in view of our earlier demonstration that in the post-deregulation period, the responses of large term accounts to the portfolio innovations are similar to the responses of small time deposits.

The charts also show that the sensitivity of M1 to the other portfolio shocks has increased in the 1980s over the pre-deregulation period more than that of M2 and M3. Moreover, over the post-deregulation period, the response of M1 to any kind of innovation is substantially larger than the response of either M2 or M3.

Tables 5 and 6 present the standard error of the VAR forecasts and the variance decompositions for M2 and M3 respectively.[12] Table 5 shows that the error in predicting M2 more than a month into the future actually has declined after deregulation. However, the standard errors of the M1, liquid savings and small time deposit forecasts are all higher after deregulation. At a 3-month forecast horizon, for example, the standard error of the M1

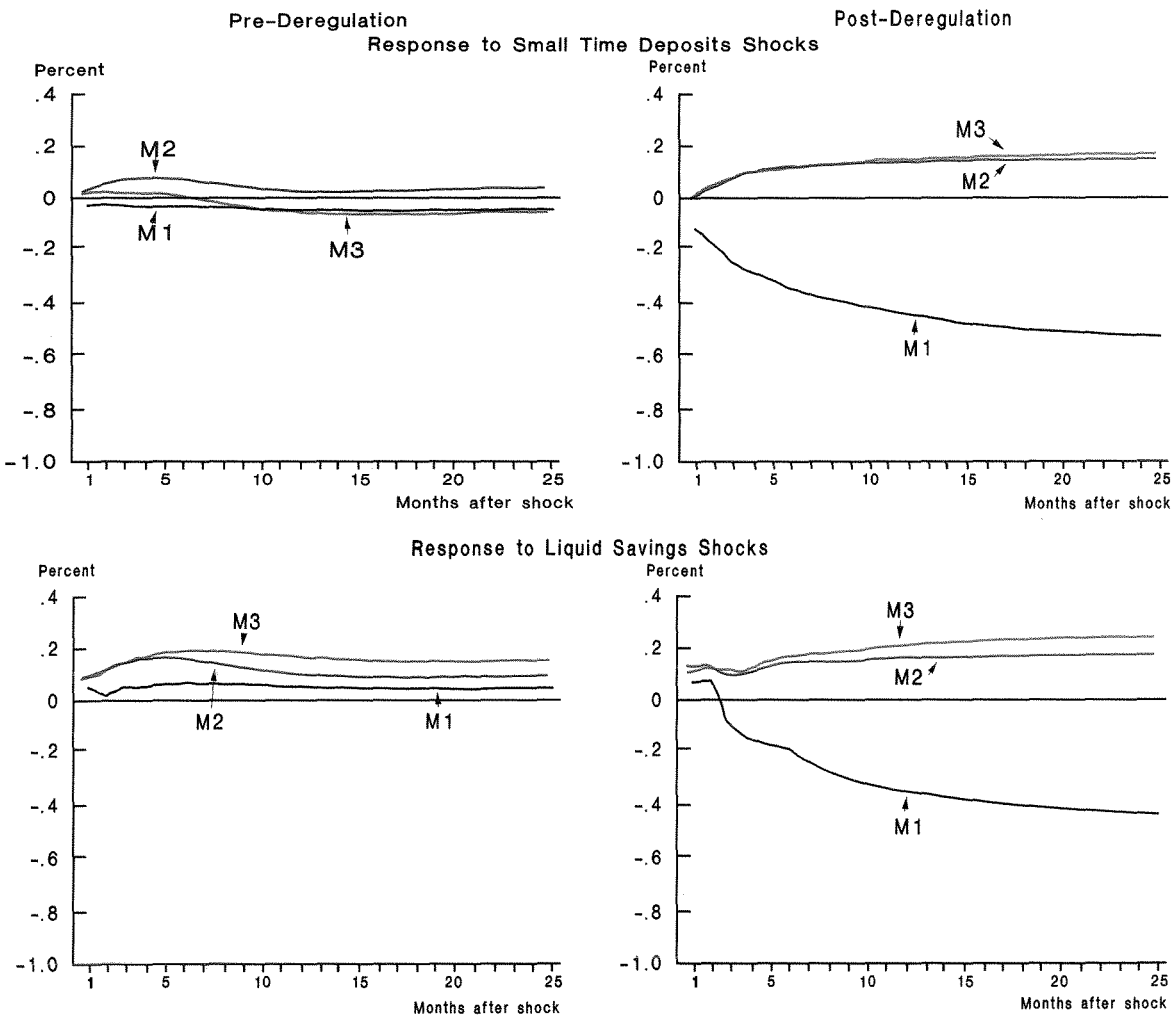
forecast was 0.33 prior to deregulation and 0.48 in the 1980s (see Table 3). The corresponding numbers for liquid savings are 0.48 and 0.78 and for small time deposits, 0.42 and 0.59. Thus, M2 has become easier to predict after deregulation not because its components are more "well-behaved", but because the unpredictable changes in its components tend to offset each other more than they did prior to deregulation.

By contrast, Table 6 shows that the forecast error variance of M3 has increased after deregulation. At the 3-month forecast horizon, for example, this variance has increased from 0.15 to 0.20. Underlying this is a substantial increase in the forecast error variance of large term accounts, which (at the 3-month horizon) has increased from 0.75 in the pre-deregulation period to 1.14 in the post-deregulation period. Notice also that the variance of the errors in predicting M3 is close to the variance of the errors in predicting M2 after deregulation, whereas earlier the former was noticeably smaller.

Our results suggest that M2 and M3 are about equally robust in the face of portfolio shocks. However, M2 traditionally has been preferred over

Chart 7

Impulse Response Functions - M1, M2, M3 in Levels



M3 on the grounds that M3 includes banks' managed liabilities, such as large certificates of deposit. (See, for example, Gramley, 1986.) Because very close substitutes for large term accounts exist in the credit market — such as commercial paper — it is argued that the demand for large term accounts is likely to be relatively unstable. As a result, movements in M3 are not likely to provide any information that is useful for policy purposes. Moreover, it is argued that since the instruments in M2 are not managed liabilities, that aggregate is less likely to be adversely affected by substitutions with credit market instruments.

However, the impulse response functions shown in Charts 2 and 3 contradict the latter assertion. They suggest that there is little difference in the behavior of small denomination time deposits (which are in M2) and large term accounts. This result is confirmed by a survey conducted by the Federal Reserve Bank of New York between November 1986 and January 1987 that concluded that "To banks, consumer CDs (what we have called small time deposits) are an alternative to funding through wholesale deposits" (our large time deposits).[13,14]

To summarize, our analysis of the conventional monetary aggregates suggests that deregulation appears to have had the greatest impact on M1, and that changes in the behavior of M2 and M3 have been relatively small. M1 appears to have become more susceptible to portfolio shifts, but these shocks to M1 generally are represented by portfolio re-allocations within the broader aggregates. In addition, M2 has become easier to predict in the post-deregulation period, even as its components have become more difficult to predict.

III. Policy Implications

Our results support the FOMC's decision to drop M1 from the set of variables being targeted. The increase in the degree of substitutability between M1 and other other components of M3 implies that the behavior of M1 is likely to be dominated by portfolio considerations, at least over the short run. Consequently, movements in M1 are not likely to provide useful information about variables such as prices and income, which are of interest to policymakers. Moreover, our results suggest that M2 and M3 are not as susceptible as M1 to being disturbed by portfolio shifts because they are broad enough to internalize most of those shifts. Thus, our results support the FOMC's decision to continue to establish target ranges for M2 and M3.

If M2 and M3 were the aggregates of choice, is there any evidence that favors greater emphasis on one rather than the other? Some analysts have argued that M2 is clearly superior for monetary policy purposes because M3 includes instruments that are used by banks as managed liabilities. Our results suggest no basis for preferring one over the other since small time deposits, which are in M2, now appear to be used by banks much like the managed liabilities in M3.

APPENDIX A

Definitions of Variables

Note to Table 1

CPRT	=	three-month commercial paper rate
DDLBL	=	second difference in the log of total loans of commercial banks, including loans sold to affiliates, and adjusted for the introduction of international banking facilities.
LM1	=	log of M1
LM2D1F	=	log of the non-M1 component of M2
LM3D1F	=	log of the non-M1 component of M3
LP	=	log of personal consumption expenditures deflator
LY	=	log of nominal personal income
TIME	=	1, 2, . . . 12 during January 1981 through December 1981.
TIME2	=	the square of TIME
TIME3	=	the cube of TIME
TIMEDR	=	1,2, . . . 13 during December 1982 through December 1983, zero elsewhere.
TIMEDR2	=	the square of TIMEDR

LM1 = A0 + A1*DDLBL + A2*(LY-LP)
+ A3*LP + A4*CPRT
+ A5*TIME + A6*TIME2
+ A7*TIME3 + A8*($LM1_{t-1}$ − LP)

A0	A1	A2	A3	A4	A5	A6	A7	A8
−0.0009	0.23	0.099	1.00	−0.00195	0.0023	−0.0005	0.00002	0.88
(0.008)	(2.96)	(5.31)		(−7.81)	(1.43)	(1.38)	(1.14)	(47.30)

$\bar{R}^2$ = 0.99

SE = 0.0045

DW = 1.77

RESTRICTIONS: A3 = 1.00

Sample Period: August 1976 - December 1984

LM2DIF = C0 + C1*CPRT + C2*LY + C3*TIMEDR + C4*TIMEDR2

C0	C1	C2	C3	C4	C5
−0.76	−0.0076	1.006	0.0075	−0.00028	−.00000529
(−1.90)	−3.122)	(19.31)	(2.05)	(−.418)	(−.154)

$\bar{R}^2$ = 0.999

SE = 0.0032

DW = 1.96

AUTO1 = 1.43 (17.32)

AUTO2 = −0.47 (−5.64)

RESTRICTIONS: Coefficients C1 and C2 estimated with a second order Almon distribution over lags t to t − 14 and t to t − 8, respectively, where the far end-point is tied to zero. Reported coefficients are for the sums of the lag distributions.

Sample Period: August 1976 - December 1984

LM3DIF = D0 + D1*CPRT + D2*LY + D3*TIMEDR + D4*TIMEDR2

D0	D1	D2	D3	D4	D5
−1.71	−0.007	1.19	0.000084	0.000081	−0.0000046
(4.80)	(−2.93)	(24.0)	(0.027)	(0.1333)	(−0.1511)

$\bar{R}^2$ = 0.0999

SE = 0.0026

DW = 1.97

AUTO1 = 1.53 (18.92)

AUTO2 = −0.55 (−6.45)

RESTRICTIONS: Coefficients D1 and D2 estimated with a second order Almon distribution over lags t to t − 14 and t to t − 8, respectively, where the far end-point is tied to zero. Reported coefficients are for the sums of the lag distributions.

Sample Period: August 1976 - December 1984

Appendix B

Table B1

Correlation Matrix of Residuals from VARS in Table 2

Pre-Deregulation Period

	Real Income	Prices	Interest Rate	Large Term Accounts	Small Time Deposits	Liquid Savings	M1
Real Income	1.00	−.38	−.10	.07	−.08	.31	.13
Prices		1.00	.01	−.01	.03	−.24	.19
Interest Rate			1.00	.28	−.06	−.12	.03
Large Term Accounts				1.00	−.61	−.30	−.11
Small Time Deposits					1.00	−.12	.01
Liquid Savings						1.00	.19
M1							1.00

Post-Deregulation Period

	Real Income	Prices	Interest Rate	Large Term Accounts	Small Time Deposits	Liquid Savings	M1
Real Income	1.00	−.49	−0.12	−.10	.12	−.08	.18
Prices		1.00	.04	−.06	.22	−.01	−.02
Interest Rate			1.00	.10	.22	−.42	−.11
Large Term Accounts				1.00	.01	−.13	−.21
Small Time Deposits					1.00	−.54	−.30
Liquid Savings						1.00	.34
M1							1.00

Table B2
M1 Variance Decomposition

Ordering: M1, Liquid Savings, Small Time Deposits, Large Term Accounts, R, DEF, RPY

Pre-Deregulation

Months Ahead	Real Income	Price	Interest Rate	Large Term Accounts	Small Time Deposits	Liquid Savings	M1
0	-	-	-	-	-	-	100
1	5	0	3	0	0	0	91
3	5	1	3	0	0	2	88
6	5	1	3	1	1	2	86
12	5	1	3	1	1	2	86

Post-Deregulation

Months Ahead	Real Income	Price	Interest Rate	Large Term Accounts	Small Time Deposits	Liquid Savings	M1
0	-	-	-	-	-	-	100
1	3	3	5	1	7	7	73
3	4	2	22	3	17	5	47
6	7	2	21	5	18	5	42
12	9	2	22	6	19	4	39

Table B3
M2 Variance Decomposition

Ordering: M1, Liquid Savings, Small Time Deposits, Large Term Accounts, R, DEF, RPY

Pre-Deregulation

Months Ahead	Real Income	Price	Interest Rate	Large Term Accounts	Small Time Deposits	Liquid Savings	M1
0	-	-	-	0	29	29	42
1	5	0	11	1	27	27	29
3	4	2	9	6	29	26	24
6	4	2	10	13	27	22	22
12	4	2	10	16	26	21	22

Post-Deregulation

Months Ahead	Real Income	Price	Interest Rate	Large Term Accounts	Small Time Deposits	Liquid Savings	M1
0	-	-	-	0	28	35	37
1	5	0	17	1	20	29	27
3	9	1	28	1	15	22	24
6	10	2	29	1	16	20	21
12	10	3	29	1	16	20	21

Table B4

M3 Variance Decomposition

Ordering: M1, Liquid Savings, Small Time Deposits, Large Term Accounts, R, DEF, RPY

Pre-Deregulation

Months Ahead	Real Income	Price	Interest Rate	Large Term Accounts	Small Time Deposits	Liquid Savings	M1
0	-	-	-	49	0	11	39
1	4	2	2	45	0	13	34
3	13	2	3	35	2	18	26
6	12	2	6	34	3	20	24
12	11	2	6	36	3	19	24

Post-Deregulation

Months Ahead	Real Income	Price	Interest Rate	Large Term Accounts	Small Time Deposits	Liquid Savings	M1
0	-	-	-	50	15	21	14
1	3	0	6	41	20	18	12
3	3	3	12	33	18	16	14
6	3	4	16	30	20	14	12
12	4	4	16	30	21	13	12

FOOTNOTES

1. Testimony of Paul A. Volcker, Chairman, Board of Governors of the Federal Reserve System, before the Committee on Banking, Housing and Urban Affairs, United States Senate, February 19, 1987, pg. 26. Also see, Board of Governors of the Federal Reserve System, "Monetary Policy Report to Congress Pursuant to the Full Employment on Balanced Growth Act of 1978," February 19, 1987.

2. See Keran (1983), Judd (1983), Judd and Motley (1984).

3. Disinflation seems to have caused greater problems than did deregulation for using M1 as an intermediate target of monetary policy. Disinflation after 1980 induced declines in nominal interest rates that led to temporary decreases in M1 velocity that contrasted with its steady upward trend in the preceding two decades. In fact, disinflation appears to account for all of the net reduction in M1 velocity in 1981 through 1983. Estimates using the San Francisco Money Market Model implied an M1 velocity growth trend of 0.8 percent per year in steady state, that is, when interest rates and inflation are constant and real GNP is advancing at its long-run potential rate of 3 percent. From the fourth quarter of 1980 to the fourth quarter of 1983, M1 velocity declined at an annual rate of 0.5 percent. Under the assumption that the expected inflation rate in any given month is equal to actual inflation over the previous twelve months, the coefficients in the model suggested that disinflation reduced the annual growth rate of M1 velocity by 1.7 percentage points in 1981 through 1983. Thus, without the disinflation that occurred in those years, M1 velocity would have increased at a 1.2 percent rate — close to its steady state trend.

Of course, these velocity declines would not have caused problems for monetary policy had they been anticipated. Unfortunately, they did seriously complicate the setting of monetary targets because, as often is the case, disinflation proceeded in unpredictable "fits and starts".

4. See Mehra (1986).

5. These simulation results rest on movements in the conventional money demand arguments of real income, an aggregate price index, and a nominal market rate of interest. As shown in Appendix A, the M1 equation also includes the growth in bank loans as an explanatory variable, but this non-traditional argument has little effect on the simulation results presented in the table. See "A Model of the Money and Bank Loan Markets," Federal Reserve

Bank of San Francisco, April 1987.

6. A similar model is estimated in Trehan and Walsh (1987). That model does not include small time deposits and liquid savings, but does include a forward rate of interest.

7. Even though Institution only Money Market Mutual Funds are more liquid than time deposits, we did not remove them from large term deposits to include them in liquid savings. Doing so would mean that we would no longer be able to aggregate the various components in a straightforward manner to obtain M2 and M3. The other alternative, including these accounts as a separate variable in the VAR, was rejected because it would increase the number of variables in the system without yielding any further insights.

8. The results were calculated under the following "ordering" of the model's variables: RPY, DEF, R, large term accounts, small time deposits, liquid savings, and M1. The ordering imposed upon the variables is a way of transforming the residuals from the VAR so that they can be interpreted as disturbances to specific variables in the system. This transformation is necessary because the residuals from the VAR tend to be correlated with each other. Consequently, the data can only be interpreted after the researcher has chosen some method of determining which variable is the causal factor behind the observed correlations.

By placing income first in our ordering, we are assuming that the entire contemporaneous correlation between unpredicted movements in income and other variables in the system is due to shocks to income. In other words, we assume that a shock to any of the other variables has no contemporaneous impact on income. Next, the entire contemporaneous correlation between DEF and the remaining variables in the system is assumed to be due to shocks to DEF. Similarly, while shocks to the interest rate have a contemporaneous impact on the monetary components in the VAR, shocks to the latter have no contemporaneous impact on the former, and so on.

The ordering we chose is equivalent to that imposed in studies of the money demand function, that is, contemporaneous shocks to income, prices, and interest rates are allowed to have an effect on money, but money is not allowed to affect the others. In principle, the results could be sensitive to the precise ordering imposed upon the system. Therefore, in Appendix B we present some results for the case where the ordering is the reverse of what we impose here. In general, our results are not very sensitive to this change.

9. In Table 3, the variables are ordered in the way they were for the impulse response functions, specifically, the ordering is RPY, DEF, R, large term accounts, small time deposits, liquid savings and M1. Table B2 in Appendix B reverses this ordering. While the reversal increases the share of M1 forecast variance explained by M1 innovations (or shocks) as expected, the change in the variance decomposition is not startling when compared to the original ordering. In the pre-deregulation period, interest rate innovations account for a maximum of 3 percent, while the other 3 components of M3 taken together account for a maximum of 4 percent of the M1 forecast error variance. Reversing the ordering leaves the share of interest rate innovations more or less unchanged in the post deregulation period as well. The share of the other components of M3 taken together is also approximately the same as under the original ordering. However, the share of small time deposits goes up somewhat and the share of liquid savings innovations is correspondingly smaller.

10. The equation does not, of course, predict the movements associated with the introduction of Super-NOWs and MMDAs. The errors in these months have been set to zero.

11. In terms of the Baumol-Tobin model of the demand for transactions balances, a larger proportion of cash holders may have reached cash-management "corner solutions".

12. The ordering is the same as before, that is, the variables are ordered RPY, DEF, R, large term deposits, small time deposits, liquid savings and M1. Results from the reverse ordering are shown in Tables B3 and B4 in Appendix B.

13. See Davis, Korobow and Wenninger.

14. More direct evidence on the extent of the potential problem with M3 is provided by a VAR we estimated that contained, in addition to the variables in the previous VAR (Table 2), assets included in the Fed's liquid asset measure, L, but not in M3 (for example, short-term treasury securities and commercial paper). We call these credit market instruments NetL. Under the hypothesized problem of M3, variations in large term deposits should be closely correlated to movements in NetL. For example, when banks raise interest rates on large time deposits to obtain more funds, individuals would respond by selling off short-term Treasury securities and commercial paper to acquire large time deposits. Further, since NetM2 is hypothesized to be less sensitive to these influences, it should be much less closely correlated with NetL. (NetM2 is the difference between M2 and M1 and equals the sum of our liquid savings and small time deposits components. See the box on "Monetary Aggregates." Note also that our large term accounts component is the same as the conventional NetM3).

An examination of the contemporaneous correlations between the residuals from the VAR estimated over the post-deregulation period does not support these hypotheses. The correlation between NetL and large term deposits is .01, between NetL and small time deposits is .1, and between NetL and liquid savings, −.25. The associated variance decompositions also do not suggest that there is a marked difference between NetM2 and NetM3. In particular, with NetL ordered before both NetM2 and NetM3, innovations to NetL account for approximately 3 percent of the forecast error variance of NetM2 and 5 percent of the forecast error variance of NetM3 for forecast horizons up to 2 years. Consequently, the evidence does not justify a preference for M2 over M3.

The result that innovations in NetL explain very little of the forecast error variance decomposition of NetM2 and large term deposits has another important implication, namely, that there appears to be little gain in going from M3 to a still broader aggregate. In other words, while the recent portfolio disturbances have not been internalized within M1, they do appear to have been internalized within M3 and, to a lesser extent, within M2.

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Interest Rate Linkages in the Pacific Basin

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Empirical estimates indicate that the degree of linkage between domestic real interest rates in Pacific Basin countries and that of the United States is comparable to the linkage between most European countries and the United States. Financial liberalization and other developments that have affected the determination of interest rates in the Pacific Basin region also are discussed.

The relation among real interest rates in different countries is an important issue for policymakers since the effectiveness of stabilization policies is determined largely by the extent to which domestic monetary and fiscal authorities can influence the domestic real rate relative to the world rate.

While a number of studies of interest rate linkages between the U.S. and European countries exist (von Furstenberg, 1983; Mishkin, 1984a, 1984b; Cumby and Obstfeld, 1984; and Cumby and Mishkin, 1986), similar studies for other parts of the world, particularly the developing regions, are scant (see Blejer and Khan, 1983). This relative neglect often has been justified by the rationale that competitive forces have played little role in the determination of interest rates in most other countries, and that controls and other market barriers impeded the development of any linkages.

With the recent liberalizing financial trend in many countries, however, particularly in the Pacific Basin, this rationale no longer seems justified. Moreover, as shall be discussed below, while barriers to international financial flows may prevent real interest rates from being equalized, linkages between rates in different countries may still exist.

The major purpose of this paper is to examine the extent to which domestic real interest rates in Pacific Basin countries have been linked to rates in the United States in recent years. The paper is organized as follows. Section I discusses factors affecting the relation of real interest rates among countries. Section II summarizes specific financial liberalization developments in the six countries examined in the empirical section of the paper: Hong Kong, Singapore, Malaysia, Japan, Taiwan, and Australia. These countries were chosen because each possesses a sufficiently long time series of a market-influenced interest rate.

Section III empirically analyzes relationships among real rates in the countries under study. This section first describes the methodology of generating estimates of *ex ante* real rates and of measuring the extent to which these rates are related to that of the United States. The methodology of Cumby and Mishkin (1986) is employed to obtain consistent estimates from *ex post* observations of real rates. It then presents and discusses the empirical results. Section IV provides a brief summary of conclusions.

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I. Theory of Real Interest Rate Linkage

A country's real interest rate is equal to its nominal interest rate minus the expected rate of inflation. The relation of real interest rates between two countries thus depends on the relationship of nominal interest rates through the interaction of their financial markets, on the relationship of price levels through the interaction of their goods markets, and, since their price levels are denominated in different currencies, on the exchange rate between their currencies.

To see this, define the *ex ante* foreign and U.S. real interest rates by

$$rr_j = i_j - \hat{p}_j^e \text{ and } rr_{us} = i_{us} - \hat{p}_{us}^e \qquad (1)$$

where rr_j (rr_{us}) and i_j (i_{us}) represent for country j (the U.S.) the expected real and nominal rates of return, respectively, at time t earned by holding the asset from time t to t + 1, and $\hat{p}_j^e$ ($\hat{p}_{us}^e$) denotes the expectation at time t of the inflation rate from t to t + 1, where time scripts are omitted.

Let s denote the nominal foreign exchange price of the dollar, p_j (p_{us}) the foreign (dollar) price of foreign (U.S.) goods, and $q = sp_{us}/p_j$, the real foreign price of the dollar. Note that a *rise* in s represents an increase in the amount of foreign currency necessary to buy a dollar and hence a *nominal foreign currency depreciation* or, correspondingly, a nominal appreciation of the dollar. A *rise* in q represents an increase in the relative foreign currency price of U.S. goods and hence a *real foreign currency depreciation* or, correspondingly, a real dollar appreciation. A real foreign depreciation occurs when a rise in nominal foreign currency value of the dollar and in U.S. prices exceeds the rise in foreign prices.

Adding and subtracting appropriately and using the definition of the U.S. real rate implies

$$\begin{aligned} rr_j &= i_j - \hat{p}_j^e + i_{us} - i_{us} + \hat{s}^e - \hat{s}^e + \hat{p}_{us}^e - \hat{p}_{us}^e \\ &= rr_{us} + (\hat{s}^e + \hat{p}_{us}^e - \hat{p}_j^e) + (i_j - i_{us} - \hat{s}^e) \\ &= rr_{us} + \hat{q}^e + (i_j - i_{us} - \hat{s}^e) \qquad (2) \end{aligned}$$

where $\hat{q}^e = \hat{s}^e + \hat{p}_{us}^e - \hat{p}_j^e$ denotes the expected change in the real exchange rate.

Equation 2 states that real interest rates may differ between countries because of two factors given by the last two terms on the righthand side of the expression. The first of these terms represents expected deviations from purchasing power parity (PPP) or, equivalently, expected real exchange rate movements. According to PPP, the nominal exchange rate is anticipated to change according to the anticipated differential in rates of inflation, leaving the real exchange rate constant. Thus, when foreign inflation exceeds U.S. inflation, a foreign currency depreciation is necessary to sustain purchasing power parity between foreign and U.S. currencies.

The last term represents deviations in uncovered interest parity (UIP). According to UIP, the anticipated rate of depreciation of the foreign currency should equal the nominal interest differential (presuming U.S. and foreign assets are otherwise comparable). Thus, an anticipated foreign currency depreciation should lead to a higher foreign interest rate to compensate for the expected currency loss associated with the anticipated depreciation, and thereby leave the overall return to investing in foreign assets equal to that from investing in U.S. assets.

The existence of deviations from PPP and UIP depends on a number of factors. Barriers to international trade may create PPP deviations by limiting the ability of goods market arbitrage to link domestic and foreign inflation rates and the exchange rate. PPP may not hold, even in the absence of goods market trade barriers, when domestic and foreign goods are not perfect substitutes. Moreover, deviations from PPP may also occur because of various factors affecting the equilibrium real exchange rate. Differential changes in taste, technology, or factor supplies can permanently influence relative price competitiveness among countries and therefore the real exchange rate between them. In addition, changes in monetary and fiscal policy and other economic demand and supply shocks can lead to fluctuations in real exchange rates and hence deviations from PPP.[1] To the extent that the effects of these policy changes average out over time,

however, the magnitude of this cause of real interest differentials diminishes.

Restrictions on international capital flows can inhibit the ability of financial market arbitrage to link domestic and foreign nominal interest rates and the exchange rate and thereby create deviations from UIP. UIP may not hold precisely even in the absence of financial market imperfections when domestic and foreign assets are not perfect substitutes. In this case, deviations would arise from the risk premium necessary to compensate investors for holding the asset with the higher risk.

To summarize, real interest rates are equal across countries only in the absence of deviations from PPP and UIP. They may differ because of deviations from PPP and/or UIP. Thus, for example, the foreign real rate can be below that in the U.S. in the case of an expected real appreciation of the foreign currency ($\hat{q}^e < 0$), a deviation from PPP, or because the foreign nominal return is less than the dollar equivalent return ($i_j < i_{us} + \hat{s}^e$), which is a deviation from UIP.

II. Pacific Basin Experiences

The discussion of the previous section implies that the degree of international linkage of real interest rates depends on the degree of integration of financial and goods markets as well as on expected changes in the real exchange rate. In recent years, the majority of countries in the Pacific Basin have undertaken steps to liberalize their domestic financial systems and to remove restrictions on international capital flows.[2] At the same time, these countries have been subject to various domestic and foreign disturbances that have influenced their real exchange rates. These disturbances include oil price changes, commodity export price shocks, and foreign economic policy changes, such as the U.S. fiscal expansion of the 1980s.

Since the process of financial liberalization has been the foremost economic development within most countries in the Pacific Basin region during the 1970s and 1980s, the individual experiences of the six countries examined in the empirical portion of this paper are briefly discussed below. These countries include: Hong Kong and Singapore, which liberalized earliest, in the early to mid-1970s; Malaysia and Japan, which began liberalization somewhat later, in the late 1970s; and Australia and Taiwan, which did not begin liberalization significantly until the 1980s.[3]

Hong Kong

Hong Kong has been one of the least restricted economies in the Pacific Basin. It formally abolished its last official exchange controls in December 1972, and, in general, now imposes no controls on international capital receipts or payments by residents or nonresidents.

Over the period 1979 to 1983, Hong Kong's financial system was subject to a number of changes. In February 1979, the government required the major note-issuing banks to back all reserve assets with either currency or foreign exchange assets. In April 1981, the banking system was restructured and withholding taxes on domestic assets were eliminated. In February 1982, withholding taxes on foreign currency deposits were abolished as well. In October 1983, interest withholding taxes on Hong Kong dollar deposits were eliminated, and the Hong Kong dollar, which had been allowed to float freely since November 1974, was pegged to the U.S. dollar. In addition, in the early 1980s, considerable uncertainty about the political future of Hong Kong occasionally influenced financial markets.

Singapore

Singapore began deregulating the pricing of most of its financial markets in July 1975 and completely liberalized foreign exchange transactions in June 1978. In principle, near perfect international capital mobility exists: residents are free to make transactions in any currency as well as to invest in any currency. While nonresidents are similarly free to

transact in Singaporean dollars, the authorities have sought to some extent to segment domestic money markets from the Asia dollar market — an offshore currency market where rates are freely determined (this practice differs from that of Hong Kong, which has not sought to limit nonresidents' use of local currency).

In addition, there is some historical evidence that on occasion Singapore has sought to limit the effects of U.S. interest rates on domestic rates by "moral suasion" (see Fry, 1985). Since 1975, the Monetary Authority of Singapore has officially pegged the Singaporean dollar to a trade-weighted basket of currencies.

Malaysia

Malaysia followed Singapore in the pursuit of a policy of financial deregulation. Starting in August 1973, certain nonbank interest rates were freed, and steps were taken to create more effective competition among commercial banks. In addition, the currency was allowed to float. In October 1978, measures were announced that reduced the extent of administrative guidance, that made bank interest rates more market-oriented, and that introduced several new instruments, such as bankers' acceptances and CDs. These steps significantly increased the responsiveness of deposit rates to the interbank rate. However, despite the fostering of price competition, allocative requirements on bank loans are still regularly imposed and priority sectors are favored with low interest rates.

Malaysia has a system that is generally free of exchange controls; its authorities impose virtually no restrictions on capital inflows or on capital outflows as long as they are not financed by local borrowing. However, the public is prohibited from dealing in foreign exchange unless there is an underlying "genuine" trade transaction. Moreover, commercial banks, which form the core of the foreign exchange market, are limited in the open positions they may undertake in foreign exchange transactions.

Japan

Japan has followed a gradual process of deregulation of both domestic and international financial transactions since the mid-1970s, including lifting interest rate ceilings and controls on international capital flows. In May 1979, foreigners were allowed for the first time to acquire gensaki securities — three-month repurchase agreements traded on one of the few markets in Japan with competitively determined interest rates.[5] Japanese banks were allowed to make short-term foreign currency loans to residents (impact loans) in June 1979 and long-term loans in March 1980. By freeing all international transactions, in principle, from direct government influence, amendments to the Foreign Exchange and Foreign Trade Control Law in December 1980 officially recognized the gradual process of de-control of capital flows that had already taken place. Nevertheless, the government has periodically used "moral suasion" to limit international capital transactions.

Efforts by the United States to induce the Japanese government to adopt a list of measures further liberalizing its capital markets resulted in the May 1984 Yen/Dollar Agreement. Subsequent reforms that have further facilitated increased international capital flows include the end of yen-dollar swap limits for foreign banks operating in Japan and the removal of the requirement that all forward exchange transactions be related to export and import merchandise transactions or remittances in June 1984.

Taiwan

Taiwan has been somewhat slower than the countries above in pursuing financial reform, although it too began establishing open money markets in the late 1970s. In April 1980, Taiwan relaxed official restrictions on bank lending rates. The rates are currently set by a bankers cartel, the Taipei Bankers' Association, which allows somewhat more flexible rate adjustment. In November 1980, more flexible interest rate adjustment was permitted on other bank instruments, including negotiable CDs and debentures.

Even as Taiwan has liberalized these aspects of its financial market, it has kept international capital movements greatly restricted. In December 1978, residents were permitted to hold foreign exchange deposits in designated banks and to buy and sell

foreign exchange through these banks. In February 1979, a foreign exchange market in which the exchange rate was allowed to float within pre-set limits was established. (The exchange rate was devalued in July 1978; a further devaluation occurred in August 1981.) In practice, the exchange rate is set by a small group of commercial banks together with the Central Bank.

Australia

Australia has only recently liberalized its financial markets although, in contrast to Taiwan, undertook reforms in quick succession. Not until December 1980 were some interest rate ceilings and quantitative guidelines on bank lending removed. However, by December 1983, Australia had floated its currency and abolished almost all foreign exchange controls.

III. Analyzing Real Interest Rates

In this section, we analyze real interest rate linkages between the United States and six Pacific Basin countries — Hong Kong, Singapore, Malaysia, Japan, Taiwan, and Australia. These countries were chosen because each possesses a domestic financial market that has been free enough to provide meaningful interest rate statistics. A comparison of findings involving these countries with those for developed countries provides useful evidence of the extent of international integration of asset and goods markets within the Pacific Basin.

Tests performed for the U.S. and other major industrial countries by Mishkin (1984a, 1984b), von Furstenberg (1983), Cumby and Obstfeld (1984), Mishkin (1984a, 1984b), and Cumby and Mishkin (1986) generally reject the hypothesis that real interest rates are equalized across countries.[6] However, Cumby and Mishkin have measured the extent to which real rates in the U.S., Canada, and Europe are linked and move together over time. They find that real rates have climbed dramatically from the 1970s to the 1980s in the U.S. and abroad, and that there is a significant positive association between movements in U.S. real rates and those abroad. This strong and statistically significant tendency for real rates to move together in different countries, even though the movement is not one-for-one, suggests that some degree of international linkage exists among the countries.

We proceed by discussing the econometric methodology of the tests employed, which were based on the work of Cumby and Mishkin (1986). As Cumby and Mishkin point out, the major difficulty in such tests is that the expected inflation rate, and hence the *ex ante* real interest rate, is unobservable. One must therefore take care in making statistical inferences about *ex ante* real rates from observed data. The methodology is described more fully below, and empirical results follow.

Methodology

Restating definition 1, the *ex ante* real interest rate associated with a given asset at time t is given by

$$rr = i - \hat{p}^e, \tag{3}$$

where i and rr represent the nominal and expected real rates of return, respectively, at time t earned by holding the asset from time t to t + 1, and $\hat{p}^e$ denotes the expectation at time t of the inflation rate from t to t + 1. The *ex post* real rate can be calculated by subtracting from the nominal interest rate the *ex post* inflation rate

$$eprr = i - \hat{p}, \tag{4}$$

where eprr represents the realized real return to holding an asset from t to t + 1, and $\hat{p}$, the *ex post* rate of inflation.

Relationships 3 and 4 imply that the *ex ante* real rate can be expressed as

$$rr = eprr + (\hat{p} - \hat{p}^e) = eprr + \varepsilon \tag{5}$$

where $\varepsilon = \hat{p} - \hat{p}^e$ represents the forecast error of

inflation. Thus the *ex ante* and *ex post* real rates differ only because of inflation forecast errors.

Since *ex ante* inflation expectations cannot be observed, *ex ante* real rates cannot be determined directly from the calculation of *ex post* rates. However, by inferring information about the relationship between expected inflation and other variables known at time t, it is possible to generate results about the *ex ante* real rate from regressions involving only *ex post* data.

More specifically, assuming rational expectations, that is, that expectations of future inflation at time t depend on all available information,

$$\hat{p}^e = E[\hat{p} \mid \theta] \tag{6}$$

and hence

$$E[\varepsilon \mid \theta] = 0, \tag{7}$$

where θ = all available information at time t. In other words, the forecast error of inflation is uncorrelated with any information available at time t. Correspondingly, 5 and 7 imply

$$rr = E[eprr \mid \theta] \tag{8}$$

that is, the *ex ante* real rate is given by the expected value of the *ex post* rate conditional on the information set θ or, equivalently, by the fitted linear regression relationship between the *ex post* rate and θ.

To take account of the fact that an econometrician does not know all the information available to agents, assume that the *ex ante* real rate formed at time t is linearly correlated with variables in the set X that can be observed by an econometrician at time t and are contained in the available information set θ. This implies

$$rr = XB + u, \tag{9}$$

where B is a vector of coefficients and u is a measurement error term such that $E[u \mid X] = 0$.[7]. Because rr is not observable by an econometrician either, equation 9 cannot be estimated directly. However, substituting equation 9 into equation 5 and re-arranging gives

$$eprr = XB + (u - \varepsilon) = XB + \eta \tag{10}$$

which, because both eprr and X are observable, can be estimated by ordinary least squares. Estimates of the *ex ante* real rate can then be obtained from the fitted values of this regression.[8]

The tests of interest rate linkage are constructed from the hypothesis

$$rr_j = a_j + b_j rr_{us} + \omega_j \tag{11}$$

where rr_j denotes the *ex ante* real rate in country j, rr_{us} that in the U.S., and ω_j is an error term. The hypothesis of equal real returns implies $a_j = 0$ and $b_j = 1$, while the hypothesis that there is no link between rates implies $b_j = 0$. Partial linkage is indicated if $0<b_j<1$.

Because the *ex ante* real returns are not observed, this regression equation cannot be estimated directly. However, using the expression for the *ex post* real rate in equation 5, one can rewrite equation 11 as

$$eprr_j = a_j + b_j eprr_{us} + (\omega_j - \varepsilon_j + b_j \varepsilon_{us}), \tag{12}$$

which depends only on observables. However, because the error term $\omega_j - \varepsilon_j + b_j\varepsilon_{us}$ is not uncorrelated with the explanatory variable $eppr_{us}$ ($eprr_{us}$ is realized at time t + 1 and is thus correlated with ε_{us}), an instrumental variables estimation method is necessary to obtain consistent estimates.

Consistency requires that the instruments used to estimate the *ex ante* U.S. real interest rate be uncorrelated with the error components in equation 12 — the inflation error terms in the foreign country and the U.S., ε_j and ε_{us}, and the linkage error ω_j. Choosing the instruments from the available information set θ implies by definition that they are uncorrelated with the expectational errors, ε_j and ε_{us}. To ensure that they are also uncorrelated with the linkage error ω_j, it is necessary to choose instruments that exert no additional influence on the interest rate in country j apart from their influence on the real rate in the U.S. As suggested by Cumby and Mishkin, a natural choice for instruments that satisfy these requirements are those variables in X that predict the U.S. *ex post* real rate well.

Empirical Results

The sample range in the empirical analysis consisted of quarterly data over the period 1974QIV to 1986QI (to 1985QIV for Malaysia). All data were obtained from the IMF *International Financial Statistics* or national sources. Where available, the rates used were end-of-period 90-day rates. More specifically, the 90-day Treasury bill rate was used for the

U.S., the 3-month gensaki rate for Japan,[9] and the 90-day commercial bill rate for Australia. For Taiwan, the short-term curb rate was employed,[10] and for Malaysia the overnight commercial bill rate.[11] In the case of Hong Kong, the mid-point of the low-high range of the overnight interbank rate in the last month of each quarter was used.

The variables in the information set X used instrumentally to estimate real rates in individual countries included a constant term, linear and quadratic time trend, the nominal interest rate, and three values of lagged inflation. The addition of other variables, such as money growth, was not found to provide any additional explanatory power, except for the case of Malaysia.

Quandt statistics (1960) and Chow tests were used to test for evidence of shifts in the stochastic structure of real interest rate levels. A regime shift was found for the U.S. from 1980QI to 1982QIII. This result is consistent with the findings of Huizinga and Mishkin (1986) and others of a shift in monetary policy behavior by the Federal Reserve in late 1979, with subsequent return to the original regime after the third quarter of 1982. For Japan a regime shift was found to occur in 1979QI. This shift may be identified as related to the greater focus of the Bank of Japan on monetary aggregates than on interest rates that purportedly began in July 1978 (see Hutchison, 1986).

Shifts found for other countries took place in Hong Kong in 1981QIV, Singapore in 1977QIII, Malaysia in 1980QII, and Taiwan in 1979QIV; although no significant shift was found for Australia. These shifts may be attributable to the effects of financial liberalization steps, although the cause is impossible to determine conclusively. It should be noted that these regime breaks cannot be determined precisely; breaks may have occurred before or after the periods indicated, and other breaks also may have occurred. The ones reported are those with F-statistics with less than 5 percent significance.

The final estimates of *ex ante* real rates were obtained by including in the regression equation multiplicative dummy terms for all variables in X; the dummy was set equal to 0 before the shift point

TABLE 1

Linkages with U.S. Real Interest Rates*

Country	a	b	$\bar{R}^2$	SEE	Q-sig
Hong Kong	.00 (.35)	.64 (2.62)	.17	.057	.15
Singapore	.03 (4.78)	.48 (2.86)	.33	.037	.44
Malaysia	.00 (.64)	.62 (3.49)	.30	.040	.05
Japan	.02 (3.66)	.46 (3.45)	.23	.031	.00
Taiwan	.21 (19.8)	.58 (2.46)	.70	.050	.96
Australia	.01 (1.38)	.38 (1.96)	.45	.040	.66

*T-statistics are in parentheses. All b coefficients are significantly different from 0 and 1 at the .05 level. Instruments used in all cases were a constant, the nominal interest rate in the United States, three lagged values of inflation in the United States, and time and time-squared trend variables. These variables were also included multiplied by a dummy variable that is set equal to 1 for 1980QI - 1982QIII and 0 otherwise. Intercept shift dummies included in final regressions are not reported.

and one at the shift point and after (except for the U.S. where it was set equal to 0 again after 1982QIII).

Charts 1 through 7 (appended) graph the *ex ante* real (and nominal) interest levels in each of these countries. Observe that the real interest rate appears to have risen in all cases in the 1980s in correspondence with the rise in the U.S. real rate. Note that in the case of Taiwan, interest rate levels are particularly high due to the higher transaction costs and risk associated with the interest rate measure employed — the curb rate.

Table 1 contains the results of linkage regressions for the six Pacific Basin countries with the United States. As discussed above, econometric considerations dictate the use of the information set X used to predict the U.S. real rate — a constant, linear and quadratic time trend, the nominal U.S. interest rate, and three values of lagged U.S. inflation, as well as multiplicative dummy terms involving these variables as instruments. Intercept dummy coefficients were also included for several of the countries to remove outlying observations from the sample, but are not reported.[12]

Of particular interest in Table 1 is the coefficient b that describes the amount of movement in the country's real rate for a given movement in the U.S. rate. The hypotheses that real rates are equal across countries, $a = 0$ and $b = 1$, or are fully linked across internationally, $b = 1$, are generally rejected. However, in all cases the hypothesis of no linkage between real rates in different countries, $b = 0$, is rejected as well. In all cases, the b coefficient lies between 0 and 1: Hong Kong has the highest coefficient at .64; Malaysia has a coefficient of .62; Singapore, .48; Japan, .46; Australia has the lowest coefficient, .38. Somewhat surprisingly the coefficient for Taiwan, at .58, appears somewhat high given the limited extent of financial liberalization in that country. None of the results appeared sensitive to correction for serial correlation.

It is interesting to compare these results with those obtained by Cumby and Mishkin for linkages between Canada, several European countries, and the U.S. over the period June 1973 to December 1983.[13] Using domestic money rates, they obtained figures for b of .91 for Canada, .77 for the United Kingdom, .63 for Italy, .58 for France, .52 for the Netherlands, .44 for Germany, and .16 for Switzerland. These results indicate that, for most Pacific Basin countries, the degree of linkage with the U.S. is less than that of Canada but comparable to that of most European countries.

To investigate the possibility that financial liberalization or other developments have influenced the degree of linkage over the sample period, tests for shifts in the estimated b coefficients were performed. One of the difficulties encountered in these tests is that, in most cases, the relaxation of financial controls has been gradual rather than abrupt. This makes it difficult to identify any single point in time that corresponds with a discrete change in the relationship between domestic and foreign rates. As a result, the usefulness of tests such as the Quandt statistic, which are best used for detecting the occurrence of discrete changes at particular points in time within a sample, is limited.

The approach adopted here was to introduce various dummy variables, both separately and multiplicatively, for periods of one or more quarters. The durations chosen correspond to dates on or over which financial liberalization measures were announced as well as dates on which shifts in domestic real interest rate determination had previously been identified.

Significant intercept dummies at times were found, but shifts in the b coefficients were not. Taking account of the intercept shifts and outlying observations generally improved the fit of the relationship without affecting the magnitude of the b coefficients. Thus, the analysis provided no evidence of changes in the degree of sensitivity to the U.S. real rate.

The lack of evidence of any change in the degree of interest linkage has several possible explanations. One explanation, of course, is that there may have been no actual change in the levels of linkage over the period studied. For some of the countries in the analysis, the interest rate used may have been determined relatively competitively over most of the sample period; for other countries, any change in the degree of international arbitrage may have occurred too late in the period to have been identified econometrically.

Second, the results may indicate that, while financial market liberalization has allowed domestic interest rates in most countries to be more competitively determined in relation to domestic economic conditions, remaining restrictions on international capital flows and intermittently applied government controls have effectively limited changes in the role of international factors.[14]

A third explanation lies in recognizing, as argued in Section I, that real interest rate linkages depend not only on international financial market arbitrage but also on linkages between prices in different countries through the interaction of goods markets. The latter may have masked the effects of interest rate liberalization. More specifically, it is possible that while financial market liberalization in the countries studied has resulted in smaller deviations from uncovered interest parity, thereby leading to closer real rate linkage, larger deviations from purchasing power parity associated with expected real exchange rate movements may have weakened the linkage. One can make a strong case for this possibility since, during the 1980s when the process of financial liberalization was in full swing in the countries under study, the real value of the dollar underwent a dramatic appreciation that generated a strong expectation of subsequent real dollar depreciation.

IV. Conclusion

This study has discussed developments affecting real interest rates in the Pacific Basin. In recent years, the countries in this region have allowed both domestic and foreign market forces to play a greater role in the determination of interest rates in their economies. Empirical estimates indicate that the degree of real interest rate linkage with the United States is comparable to that of most European countries. Efforts to detect any increase in the extent of this linkage over time were unsuccessful.

The result that the real interest rates of Pacific Basin countries analyzed in this study are not tied one-for-one to that of the United States implies that the monetary and fiscal authorities of these countries have some influence over their domestic real rates and some control of their stabilization policies. However, the existence of interest rate linkages indicates that, as with countries in more developed regions, economic market forces are at work integrating their financial and goods markets with those abroad. Thus, domestic economic conditions in the Pacific Basin area are sensitive to developments abroad.

Chart 1
United States Interest Rates

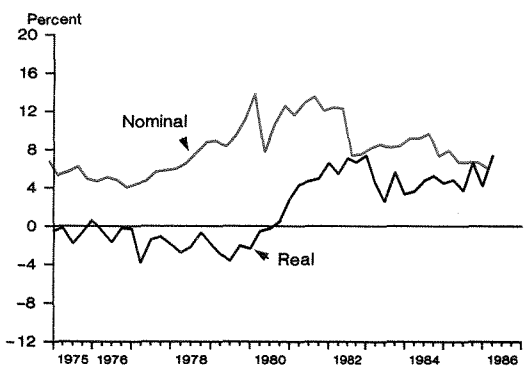


Chart 2
Japanese Interest Rates

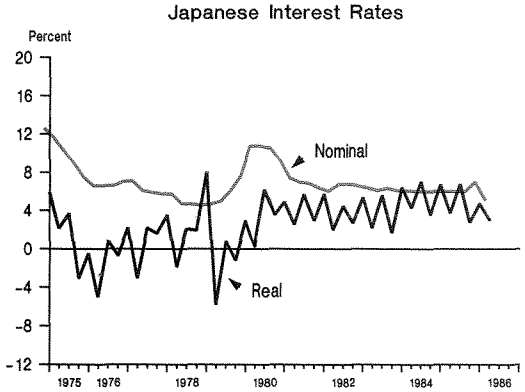


Chart 3
Hong Kong Interest Rates

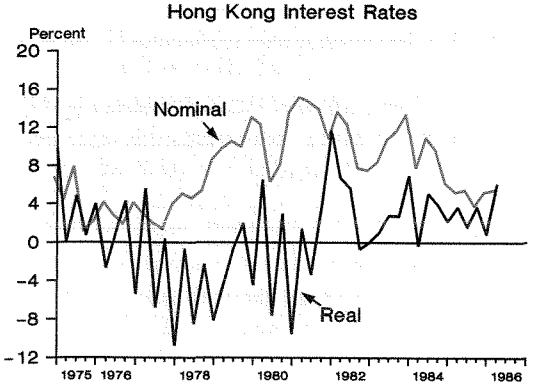


Chart 4
Singapore Interest Rates

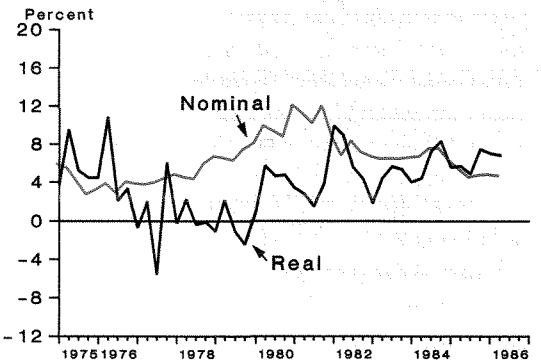


Chart 5
Malaysian Interest Rates

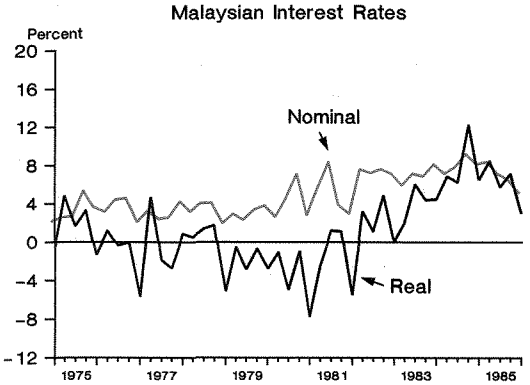


Chart 6
Taiwanese Interest Rates

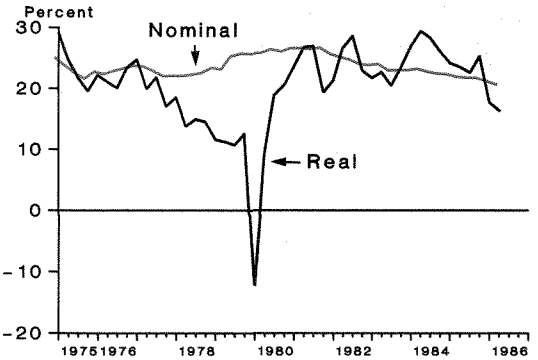
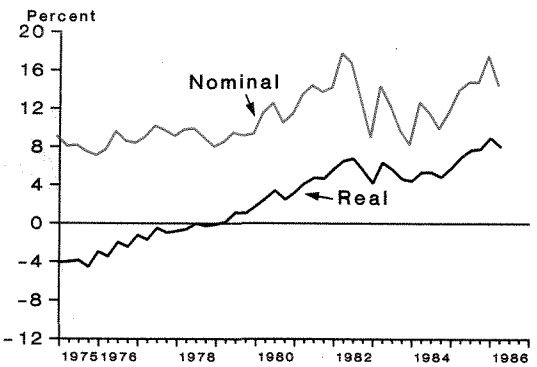


Chart 7
Australian Interest Rates



FOOTNOTES

1. Various explanations exist for the real exchange effects of disturbances. Some argue that labor and/or goods market rigidities imply that the adjustment to disturbances does not occur simultaneously, leading to short-run effects on real variables, such as real exchange rates (Dornbusch, 1976 and Obstfeld, 1985). Others attribute these effects to confusion about the source of these disturbances (Kimbrough, 1983; Flood and Hodrick, 1985; Glick and Wihlborg, 1986; Glick, 1986).

2. The appropriate order of liberalization of domestic and international restrictions is an important topic in the development economics literature. In some cases, particularly countries in Latin America, international controls were removed at the same time that domestic interest rates were allowed to rise at the very beginning of the liberalization process. Because this often resulted in large scale capital inflows (due to the return of funds involved in past capital flight in response to higher domestic rates as well as new borrowing from foreign financial institutions) that caused the domestic currency to appreciate, it has been argued that international liberalization, particularly of the capital account, should be delayed. See Edwards (1984) and Frenkel (1982). By contrast, countries in the Pacific Basin generally appear to have adopted a more gradual approach to liberalization.

3. Among other countries in the Pacific Basin, New Zealand experienced a brief period of interest liberalization between 1976 and 1981 that, after an abrupt reversal, was resumed in 1983. More cautious movements towards liberalization have occurred in Thailand. While Korea and the Philippines have also taken certain steps toward deregulation, they still continue to maintain restrictive controls on most financial transactions, particularly international financial transactions. Greenwood (1986) provides a survey of financial deregulation developments in seven East Asian countries, including Taiwan, South Korea, Hong Kong, Malaysia, Singapore, Thailand, and Indonesia. Also see Jao and Lee (1982).

4. It should be pointed out that, in general, the monetary and banking relationship between Singapore and Malaysia is not close, even though these countries were formerly one political entity, used the same currency (the Malay dollar), and had the same banking system.

5. The gensaki market evolved spontaneously in the mid-1970s with relatively little government intervention. In March 1976, Japan's Ministry of Finance formally acknowledged the existence of the gensaki market by laying down ground rules for trading. Many observers attribute Japan's policy reversal in the late 1970s, which allowed foreigners access to the gensaki and other markets, to a desire to encourage capital inflows at a time when the yen was beginning to depreciate.

6. Frankel (1986) contends that the primary source of the rejection of real rate equality for the industrialized countries is the failure of purchasing power parity since international goods market integration is far weaker than international financial market integration (or equivalently that goods in different countries are far from being perfect substitutes). However, others (Cumby and Obstfeld, 1984), have provided evidence in the case of developed countries against uncovered interest parity that is as strong as that against purchasing power parity.

7. Note that u is also in the information set θ because agents know the *ex ante* real rate even if the econometrician does not.

8. It should be noted that the regression residuals must not be heteroscedastic or serially correlated to yield correct standard errors for B. Furthermore, the estimates of rr obtained are good only when the variance of the u term is small. The variance would be small if no relevant information left out were highly correlated with X.

9. Gensaki transactions consist of the resale or repurchase of bonds at a fixed price after a fixed period, generally within 3 months. In essence, they are short-term capital transactions using bonds as collateral.

10. The curb market is an unofficial, largely unregulated financial market involving small borrowers and lenders. In the mid-1970s, the aggregate size of the curb market in Taiwan was as large as all other financial institutions put together. In 1980, it accounted for roughly 30 percent of total domestic assets (see Cheng, 1986, p. 151). Due to higher transactions costs, risk premiums, etc., the cost of funds in the curb market is substantially greater. No consistent series exist for rates on new instruments permitted in the late 1970s. Data for this series was obtained from monthly issues of the Hong Kong Monetary Authority.

11. Commercial paper rates are preferable to other interest series in Malaysia. Treasury bills are held mainly to satisfy minimum liquidity requirements and other portfolio restrictions imposed on commercial banks and other financial institutions and are sold at below-market yields. Similarly, interest rates on call loans to discount houses are influenced by the use of call loans in satisfying minimum liquidity requirements. Furthermore, the corporate bond market is extremely thin, and a consistent interest rate series is not available for the negotiable CDs introduced in 1978.

12. Individual intercept dummies were set equal to 1 for the following dates: Singapore, 75QI, 79QII; Malaysia, 75QI, 80QIV; Taiwan, 79QIV, 81QII, 78QIII-81QII; and Australia, 75QIII, 83QIV-86QI. The last dummy for Taiwan corresponds to a period of severe exchange market controls, whereas the last dummy for Australia corresponds to a period of rapid financial market liberalization.

13. The data set of Cumby and Mishkin, unlike that in this paper, involves overlapping observations. Because this leads to serially correlated errors, they use a two-step, two-stage least squares procedure developed by Cumby, Huizinga, and Obstfeld (1983). This procedure avoids problems associated with applying Cochrane-Orcutt-type techniques to models assuming rational expectations (see Flood and Garber, 1980).

14. For example, Frankel (1984) contends that, since 1979, covered interest parity through forward markets has held as closely for Japan as for the U.K., Germany, and Switzerland. By this criterion, he argues that Japan has been as open internationally as other developed countries, and disputes the claim that the Japanese still employ capital market restrictions.

However, Otani and Tiwari (1981), who analyzed capital

control distortions in the gensaki market over the period 1978QI to 1981QI, find evidence of capital flow restrictions even after such restrictions were supposedly eliminated. They found that from 1978QI - 1979QI, distortions were indeed on a declining trend — with almost no distortions from 1979QII - 1979QIV. However, they found that distortions increased in 1980QI and 1980QIII due to a Japanese government "request" that deposit institutions exercise restraint in accepting foreign exchange from the sale of foreign currency assets; distortions declined again beginning in 1980QIV. These results suggest that despite official policies, the Japanese government still retains the ability to influence capital flows when it so wishes.

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The Eurodollar Market and U.S. Residents

Ramon Moreno*

An empirical test confirms that, in the 1980s, eurodollar deposits held by U.S. residents were influenced slightly by the level of interest rates and the availability of monetary reserves available to the banking system. Total eurodollar deposits, however, do not appear to be sufficiently close substitutes for money, or to have been sufficiently large in volume even at their peak in the early 1980s, to affect U.S. interest rates. For purposes of monetary control, policymakers need not be concerned about the impact of domestic currency holdings of their nationals in the eurocurrency market.

The rapid development of international banking and the euromarket that started in the late 1960s generated extensive discussion about the implications for monetary policy. While concern about the inflationary implications of the euromarket has receded in the 1980s, the possibility that euromarket activity may limit the effectiveness of monetary instruments remains pertinent.

The U.S. is at once more and less vulnerable than other economies to the external influence of the euromarket. On the one hand, the U.S. is a "large" economy, and the volume of euromarket transactions in which U.S. residents are engaged remains small in comparison to domestic financial transactions. This is particularly true with regard to the eurodollar bank deposits of U.S. nonbank residents.

On the other hand, the few restrictions on capital movements, the use of the U.S. dollar as the major currency of denomination in the euromarket, and the size of eurodollar deposits held by U.S. residents in comparison to narrow domestic money, make the U.S. financial market more susceptible to external influences by enhancing the substitutability of euromarket assets for U.S. assets and hence the arbitrage activities of U.S. banks between the domestic market and the euromarket. The U.S. experience may thus indicate the susceptibility of a large economy to external influences when there are relatively few impediments to arbitrage between the domestic financial market and the euromarket.

Aside from promoting linkages between domestic and foreign capital markets by stimulating capital flows, it has been argued that the development of the euromarket may lead to the emigration of the intermediation activities of domestic banks to the euromarket.[1] Such emigration would have several implications. For economies seeking to target monetary aggregates, the appropriate definition of the aggregate may be complicated by the creation of potentially close substitutes in the euromarket. Moreover, even an appropriately defined aggregate may be less susceptible to direct control. The crea-

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tion of euromarket substitutes for domestic money may also weaken the ability of monetary policy to influence interest rates or exchange rates, or be associated with disturbances to asset preferences that increase the volatility of those rates.

The extent to which the eurodollar market affects U.S. financial markets, and interest rates in particular, has not been conclusively determined. The earlier structural models of the linkages between the euromarket and domestic economies, such as Herring and Marston (1977), assumed that U.S. interest rates are unaffected by foreign rates. This assumption is supported by some recent evidence. For example, an unpublished study using vector autoregressions by Genberg, Saidi and Swoboda (1982) found that U.S. domestic interest rates were generally not influenced by interest rates in foreign financial markets, although U.S. rates did have a weak influence on foreign rates.

However, by applying a vector autoregression to monthly data of the 3-month U.S. commercial paper and eurodollar deposits rates, Hartman (1984), found that while U.S. interest rates appeared to have been unaffected by foreign rates before 1975, between 1/5 to 2/3 of the variation in domestic rates can be traced to foreign sources from 1975 to 1978.[2] Using weekly data, Reinhart and Harmon (1986) found closer integration in the 1980s between the federal funds market and the overnight eurodollar market, and evidence that overnight eurodollar rates Granger caused the federal funds rate.[3]

An understanding of the linkages between the eurodollar market and domestic financial markets and the implications of the use of a national currency in international transactions is particularly relevant for economies that are expanding the scope of their international banking activities. The most notable example is Japan, which today faces issues similar to those the United States started to face in the 1960s as a result of the rapid growth of the eurodollar market. The growing internationalization of Japanese banking, the use of the yen in international transactions, and the possibility that Japanese residents may shift intermediation to an incipient euroyen market raise questions that may be clarified by the U.S. experience.

This paper will discuss the influences on the emigration of domestic banking activity to the eurocurrency market, and assess the potential implications of the emigration of domestic banking activity for domestic financial markets, specifically, for interest rates. The next section discusses how certain institutional features that characterize the euromarket and international banking activity explain the growth of these sectors, leading to the emigration of U.S. banking activity to the eurodollar market via the process of arbitrage. Section II examines the determinants of equilibrium in the eurodollar market. Section III assesses the potential implications for domestic interest rates and monetary policy of the shifting of domestic bank intermediation to the euromarket.

Using the framework developed in Section II, Section IV examines the actual growth of eurodollar deposits held by U.S. non-bank residents since the late 1970s. Section V contains an empirical test to ascertain the determinants of eurodollar deposit creation and the influence of the euromarket on domestic interest rates. The conclusion follows in Section VI.

I. International Banking and the Eurodollar Market

International banking can be described in several ways, but for our purposes, it will be useful to focus on two aspects:

1. The eurocurrency market, in which deposits and loans denominated in a given currency are offered outside the country where the currency is issued. The largest segment of the eurocurrency market is the eurodollar market, where transactions are denominated in U.S. dollars. U.S. banks and U.S. nonbank residents are active participants in the eurodollar market.

2. The cross-border activities of banks based in a given country, which form part of what is traditionally understood to be international banking. This includes lending by domestic banks to foreign residents, and foreign resident deposits in domestic banks.

Certain characteristics that historically have distinguished banking in the eurodollar market from domestic banking account for the rapid growth of the former. Unlike domestic deposits, eurodollar deposits are not subject to FDIC premia or to reserve requirements. For many years, eurodollar deposits also benefited from the absence of restrictions on interest paid that applied to domestic banking. These institutional advantages encouraged demand for eurodollar deposits, particularly during the inflationary 1970s.

However, under certain conditions, borrowing by U.S. residents from the eurodollar market is subject to reserve requirements,[4] and has affected the extent to which U.S. residents have used the eurodollar market as a source of funds. In the early 1970s, reserve requirements on eurodollar market borrowing were much higher than domestic reserve requirements, effectively discouraging such borrowing. In the mid-1970s, the reverse was true as the Federal Reserve sought to encourage borrowing from the eurodollar market to strengthen the value of the dollar.[5] Since the implementation of the Monetary Control Act of 1980, the reserve requirement on eurodollar borrowing has been 3 percent, the same as that on domestic CDs.

Banks operating in the eurodollar market generally do not issue checkable deposits, but they do issue a substantial volume of very short maturity liabilities held by U.S. nonbank residents. In further contrast to the domestic money market, where banks raise the bulk of their funds from nonbanks, interbank transactions account for about 70 percent of all eurodollar market transactions.

Although other currencies have gained some prominence in recent years, dollar-denominated deposits and loans offered outside the United States or in International Banking Facilities in New York, which are exempt from domestic banking regulations, still represent the bulk of eurocurrency market activity.[6] The settlement of dollar transactions originated by U.S. or foreign banks operating in the eurodollar market ultimately involves the transfer (using the Clearing House Interbank Payments System, or CHIPS) of reserves (that is, claims on the Federal Reserve) in the domestic U.S. banking market: Such reserve transfers typically involve U.S. banks, rather than the branches of foreign banks operating in the United States.[7]

Such close links between the domestic and the eurodollar markets lead observers to treat the latter as an extension of the U.S. banking system.[8] Since bank reserves are ultimately required in the settlement of claims originating in the eurodollar market, the availability of reserves will tend to influence the volume of eurodollar deposit creation. In addition, efforts to tap the domestic and eurodollar markets to acquire reserves imply that the markets for federal funds and overnight eurodollar deposits are closely connected by arbitrage, as are the markets for term domestic and eurodollar deposits.[9] These arbitrage activities are reflected in the eurodollar deposit holdings of U.S. residents and the international assets and liabilities of banks based in the U.S.

II. Understanding Eurodollar Deposit Creation

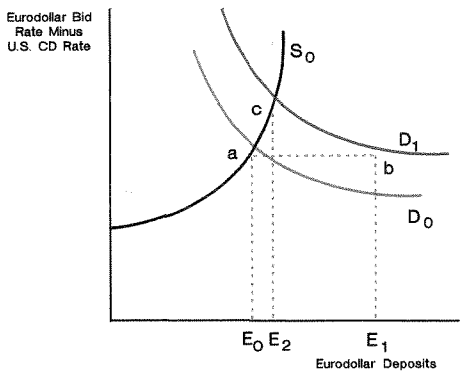
Eurodollar Supply and Demand

The arbitrage process described earlier is associated with the emigration of domestic banking activity to the eurodollar market.

The extent to which intermediation will shift from the domestic to the eurodollar market will depend on the interest rate paid on eurodollar deposits. At very high eurodollar deposit interest rates, the demand for eurodollar funds by banks will be small. As the differential between eurodollar rates and domestic U.S. rates approaches the difference in costs between dealing in the domestic and eurodollar markets, banks will be increasingly indifferent between operating in the domestic or eurodollar market, and the demand schedule will tend to flatten. The slope of the demand curve is determined by matching the marginal revenue from lending against the marginal cost of raising funds in the eurodollar markets at any given eurodollar rate.[10]

Domestic residents may be indifferent between holding domestic and eurodollar deposits when these deposits pay a premium over the domestic deposit rate sufficient to compensate them for the perceived risk of acquiring eurodollar assets. Beyond a certain point, however, depositors may require higher eurodollar rates to supply more funds to the eurodollar market, tracing an upward sloping supply schedule for eurodollar funds. The slope of the supply curve reflects the rate at which assetholders must be compensated for the perceived risk or inconvenience of banking in the eurodollar market. The equilibrium is shown by lines S and D in Chart 1.

Chart 1
Eurodollar Market Equilibrium



Determinants of Equilibrium

In an illuminating discussion of the supply and demand framework presented here, Giddy (1979), distinguished between two polar views of the eurodollar market: the *cost of regulation* view, which reflects the behavior of banks that demand eurodollar funds, and the *market price of risk* view, which reflects the behavior of assetholders who supply funds to the eurodollar market.

According to the cost of regulation view, the differential between the eurodollar and domestic deposit rate is set by banks to reflect the higher cost (reserve requirements and FDIC insurance premia) of funds in the domestic deposit market. Banks are then indifferent between demanding funds from the eurodollar or domestic deposit market. The perfectly elastic demand for funds determines the eurodollar rate, and a less than perfectly elastic supply of funds schedule is said to determine the volume of eurodollar deposits. In Giddy's version of the cost of regulation view, the demand schedule in Chart 1 would be a horizontal line.

In the *market price of risk view,* derived from portfolio management theory, the differential between the eurodollar and domestic deposit rates is set by depositholders to compensate them for the perceived risk of placing funds in the eurodollar market. Depositholders are then indifferent between placing funds in the eurodollar or domestic market. The perfectly elastic supply of funds determines the eurodollar rate, and a less than perfectly elastic demand schedule is said to determine the volume of eurodollar deposits. According to this view, the supply schedule in Chart 1 would be flat.

Giddy argues that the cost of regulation and market price of risk views are irreconcilable because market equilibrium cannot be determined when both demand and supply are infinitely elastic. One

way around this disturbing conclusion, which suggests that either banks or assetholders may not behave rationally, is that neither view need imply that the demand or the supply of funds are everywhere perfectly elastic.[11] This reasoning underlies the less than perfectly elastic segments illustrated in Chart 1.

The supply and demand framework introduced above does not explicitly state where the funds raised in the eurodollar market will ultimately be placed. Kreicher (1982) analyzed this question under the cost of regulation framework by discussing the two choices available to banks, namely to obtain funds from the domestic market to fund lending abroad (outward arbitrage) or to obtain funds from the eurodollar market to fund lending in the U.S. (inward arbitrage). When the cost of domestic funds (the domestic CD rates adjusted for reserve requirements and FDIC premia) is less than the return from depositing such funds in the eurodollar interbank market (the eurodollar bid rate), there is an incentive for outward arbitrage. In the process of bidding for funds, the differential between the domestic U.S. rate and the eurodollar rate will narrow until the incentive for outward arbitrage is eliminated. The cost of domestic funds thus imposes a ceiling on the eurodollar bid rate.

In contrast, when the cost of funds in the eurodollar market (the eurodollar offer rate adjusted for the cost of reserve requirements applied to borrowing from the eurodollar market) is less than the cost of funds in the domestic market, there is an incentive for obtaining funds in the eurodollar market to fund domestic lending. This case raises the possibility of a "round trip", whereby domestic residents place the funds in the eurodollar market and these funds are subsequently lent to domestic borrowers. Once more, the cost of funds in the domestic market, this time adjusted by the reserve requirements on eurodollar borrowing and the spread between the eurodollar bid and offer rates, places a floor on the eurodollar bid rate.

Between the two thresholds for inward or outward arbitrage is an "arbitrage tunnel" within which banks are largely indifferent between obtaining funds in the domestic market and the eurodollar market. When the differential between the eurodollar rate and the domestic rate is sufficiently large, the net foreign asset position of the U.S. banking sector would tend to be positive; the reverse would be true when the eurodollar interest rate is low enough to create an incentive for inward arbitrage. The recent U.S. experience in this regard is analysed in section IV.

III. Implications of Intermediation via the Euromarket

While the preceding analysis highlights some of the key features of eurodollar market equilibrium, it is a partial analysis because it does not explicitly discuss the impact eurodollar market activities may have on domestic interest rates. In general, the potential impact may be derived from macroeconomic considerations.

In the analysis of monetary policy in a closed economy, the existence of two assets, money and bonds, is typically assumed. Money here refers to currency and checkable deposits (M1) that pay a fixed (possibly zero) rate of interest, and bonds refer to a spectrum of interest-bearing assets. In this framework, monetary policy affects interest rates by changing the supply of money; changing the supply of money, in turn, requires changes in the yield on bonds (and hence, the relative yield on money) to induce the public to accept the new money supply. For example, a policy that shrinks bank reserves forces banks to reduce their deposit liabilities (and therefore money creation) to satisfy reserve requirements. The yield on assets that are alternatives to money must then rise to eliminate the resulting excess demand for money.

The extent to which interest rates will respond to the monetary policy objectives of the central bank depends on (1) the existence of close substitutes for money and (2) the tightness of the link between reserve creation by the Federal Reserve and domestic money creation by banks. If bonds were close substitutes for money, a small increase in their yield would suffice to eliminate the excess demand for money. The effect of a given change in reserves on interest rates in that case would be small. In a closed

economy, the tightness and predictability of the link between reserves and domestic money creation is strengthened by reserve requirements.

The growth of eurodollar deposits held by U.S. residents presents a potential problem for domestic monetary policy because it tends to weaken the two conditions needed for an effective monetary policy cited above. Eurodollar deposits are believed by some observers to be close substitutes for domestic money. Furthermore, because eurodollar deposits are not subject to reserve requirements, banks could potentially create a large volume of such deposits in a manner that offsets the monetary policy objectives of the Federal Reserve.

Money Substitutes

The argument that eurodollar deposits may be close substitutes for domestic money is analogous to arguments motivated by the financial innovation of the 1970s, namely, that certain domestic assets may, in various ways, reduce the demand for transactions balances. Because eurodollar deposits are of relatively short maturity, they could be close substitutes for domestic money. In addition, eurodollar deposits, particularly for the shortest maturities, may increase transactions efficiency (much like the domestic RP market), thus reducing the need for cash balances.

While domestic assets that are potential money substitutes have generated an enormous literature,[12] the evidence on the substitutability of eurodollar deposits for domestic money is thin. Studies of interest parity suggest a high degree of substitutability between assets of comparable maturity held in the U.S. and abroad,[13] with very small risk premia imposed on the assets held in industrial countries.

However, authors have generally not tested for the substitutability of eurodollar deposits for domestic money, limiting themselves instead to comparisons of the size of eurodollar deposit holdings of residents with measures of narrow domestic money.[14] The comparison implicitly assumes a high degree of substitutability between eurodollar deposits and domestic money but provides no direct evidence of such. An exception is Goodman (1984a), who found that the forecasting performance of two standard equations using narrow money (the Goldfeld money demand equation and the reduced form St. Louis equation) improved when eurodollar deposits of short maturity were included.[15] Goodman's results imply that shifting deposit activity to the eurodollar market would create substitutes for domestic money.

Tightness of Link to Monetary Reserves

Given that eurodollar deposits are, to some undetermined extent, substitutes for domestic money, the process by which eurodollar deposit creation may offset the intention of monetary policy is best seen by example. Consider a deflationary monetary policy which induces a rise in domestic interest rates in relation to those in the euromarket. If this policy were to raise loan rates by more than it raises deposit rates, and thereby increase the profit margins on lending, the rise in interest rates would create an incentive for banks to increase their intermediation. At the same time, however, by raising the cost of noninterest-bearing reserves, as well as domestic CD rates, the rise in domestic rates would tend to shift intermediation towards the eurodollar market, where the marginal cost of funds is comparatively lower. In Chart 1, these effects are illustrated by a rightward shift in the demand schedule for eurodollar funds to D_1.

Although the link between eurodollar deposits and monetary reserves may be weaker than the corresponding link between domestic deposits and reserves, the rightward shift in demand for eurodollar funds will still be limited by the following:

(1) *Liquidity Constraints:* While eurodollar deposits are not subject to reserve requirements (abstracting from reserve requirements on borrowing from the eurodollar market), banks eventually have to settle their eurodollar liabilities with dollar reserves.[16] When lending rates rise, a bank raising funds in the eurodollar market trades off the increased margins on lending these funds against the growing risk of illiquidity due to increasing intermediation. This trade-off should tend to limit the volume of loans and eurodollar deposit creation according to the availability of reserves created by the Federal Reserve, although the link is looser than in the case of the domestic market where reserve requirements are binding. The extent to which

reserve availability limits eurodollar deposit creation depends partly on the substitutability of eurodollar deposits for transactions balances and partly on the extent of maturity transformation in the eurodollar market;[17]

(2) *Loan Market Constraints.* Higher interest rates create adverse selection towards riskier borrowers and increase the probability of default.[18] These effects are generally associated with credit rationing, which limits the demand for funds on the part of banks;

(3) *Capital Constraints.* Intermediation in the eurodollar market tends to reduce capital-asset ratios. While the effect is reduced to the extent that such intermediation substitutes for intermediation in the domestic market, capital constraints have been a matter of great concern to banks in the 1980s.

For any given rightward shift in demand, motivating non-banks to place their funds in the eurodollar market bids up the eurodollar deposit rate. The rise in the rate would tend to reduce the margins on lending. This sequence may be seen as a movement from point b to point c in Chart 1 (with the differential increasing as the eurodollar rate rose). In fact, if the supply of eurodollar market funds were inelastic (for example, in times of great uncertainty abroad), eurodollar deposit rates could rise so far as to eliminate any advantage in raising funds in the eurodollar market.[19]

Our example thus suggests that the volume of eurodollar deposits will rise during periods when interest rates are high as long as the supply schedule for eurodollar deposits is not perfectly inelastic. This conclusion may have implications for domestic interest rates and monetary policy.

Consider now a shift in the supply of funds from domestic demand deposits to eurodollar deposits. The shift from reservable to non-reservable assets should lower the demand for reserves, and tend to lower domestic as well as eurodollar interest rates. A monetary authority seeking to stabilize output must offset such disturbances to interest rates caused by shifts in asset preferences. In general, the magnitude of shifts in the supply of funds between domestic demand deposits and the eurodollar market may be greater the greater the substitutability between those two assets, or smaller depending on the cost to assetholders of shifting to eurodollar deposits.

Inward and Outward Arbitrage

The extent to which a shift from domestic money towards eurodollar deposits will affect domestic interest rates will also depend on the extent of inward or outward arbitrage For example, if a rise in domestic interest rates were to create an incentive for inward arbitrage, banks may demand eurodollar deposit funds to lend at home. Such a "round trip" would tend to lower domestic interest rates and thus offset the impact of monetary policy. The effect on domestic interest rates would be attenuated if the differential between eurodollar and domestic interest rates were instead to create incentives to lend funds to the eurodollar market.

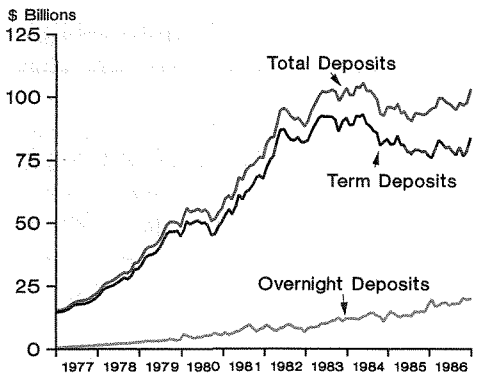
IV. U.S. Residents and the Eurodollar Market

We may now use the preceding heuristic framework to review the actual behavior of the eurodollar market and the reasons explaining the emigration of U.S. bank activity to the eurodollar market in the late 1970s and 1980s. Two indicators of the emigration of U.S. banking activity to the eurodollar market are the eurodollar deposit holdings of U.S. nonbank residents and the external asset position of U.S. banks compared to their foreign affiliates.[20]

Chart 2 shows the trend in the total, term, and overnight eurodollar deposit holdings of U.S. nonbanks with the foreign affiliates of U.S. banks since 1977. Overnight eurodollar deposits are included as part of M2, and term eurodollar deposits are part of M3 in U.S. monetary statistics.

Two features are apparent. First, after very rapid growth in the 1970s, total eurodollar deposits held by nonbank U.S. residents peaked in 1984 at approximately $105 billion, and declined subsequently. Overnight eurodollar deposits continued to grow, although they accounted for only 18 percent of total eurodollar deposits in 1986. Second, the size of eurodollar deposits held by U.S. residents is small in comparison to domestic monetary aggregates. At their peak, total eurodollar deposits were

Chart 2
Eurodollar Deposits of
U.S. Nonbank Residents



20 percent as large as M1 and 3.7 percent as large as M3.[21]

Note also that, for most of this period, there was little if any evidence of inward arbitrage, or a round trip in the form of eurocurrency market lending to U.S. residents via the banking sector, associated with these eurodollar deposits. Except for a brief episode between 1979 and 1980, U.S. banks have been net lenders to their foreign affiliates since 1977, as illustrated in Chart 3.[22]

The growth of the eurodollar market as a whole in the 1970s is often explained as a supply phenomenon: sharp increases in oil prices provided oil producers with a large supply of dollar funds which they preferred to place in the eurodollar market. However, the rapid growth of eurodollar deposits held by U.S. residents over the same period must mean that the demand for eurodollar funds — associated with the explosion in international lending starting in the 1970s — exceeded the increased supply of funds by oil producers. The growth trend was reversed by the 1982 debt crisis as declining expected returns on lending, and tightening capital constraints, lowered the demand for eurodollar funds.

Our earlier discussion suggests that, given the more favorable regulatory treatment that applies to the eurodollar market, eurodollar deposits must have grown in part because rising interst rates were associated with improved profit opportunities in lending, and relative interest rates favored intermediation via the eurodollar market. The information in charts 4 and 5 tend to confirm this explanation, as well as clarify the apparent absence of inward arbitrage.

Chart 4 illustrates the behavior of the 3-month eurodollar deposit rate and domestic CD rate. In line with our hypothesis, the fastest growth of eurodollar deposit holdings by nonbank residents occurred when interest rates were rising or at their highest levels, and eurodollar growth peaked in 1983, shortly after interest rate levels began their decline.

Chart 5 shows the difference between the 3-month eurodollar and the 3-month domestic CD rates. The top line, which is the unadjusted differential, represents the incentive to the nonbank sector to move deposits to the eurodollar market. It is remarkable that between 1979 and 1982, when the level of interest rates were at their highest, the spread between the eurodollar rate and the domestic deposit rates also peaked. The fact that eurodollar deposit growth continued at a fast pace over this period suggests that rising demand for eurodollar funds, presumably due to profit opportunities in lending, increased the unadjusted differentials between the eurodollar and domestic deposit rates. Since 1982, the spread between the eurodollar and domestic deposit rate has fallen significantly, and contributed to the contraction in eurodollar deposits held by U.S. residents.

Chart 3
Net Assets of U.S. Banks
Versus Their Foreign Branches

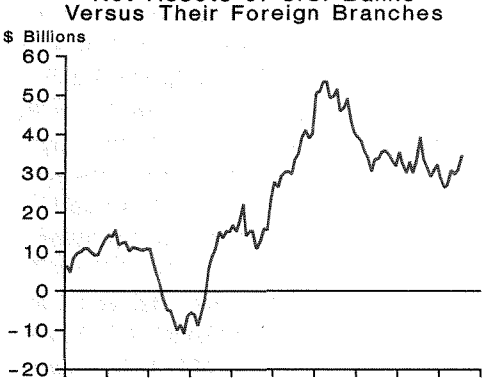
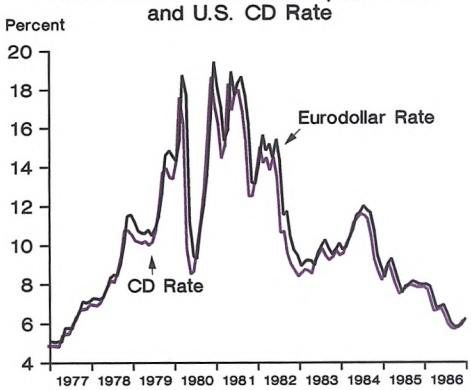


Chart 4
Three-Month Eurodollar Deposit Rate and U.S. CD Rate



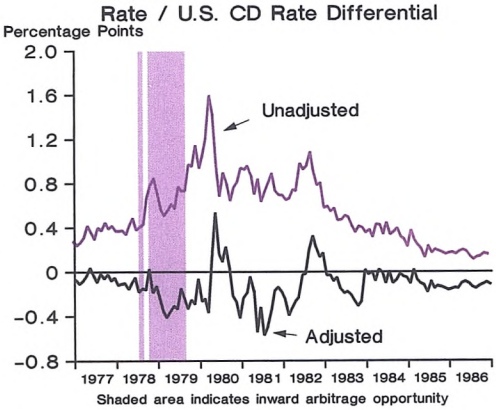
The reason that the funds raised in the eurodollar market were used for international rather than domestic lending is suggested by the bottom line of Chart 5, which represents the differential between the eurodollar bid rate and the domestic CD rate adjusted for reserve requirements. This differential reflects the incentive for banks to use the domestic market as a source of funds for lending to the eurodollar market, or the outward arbitrage cited earlier. When the differential is above zero, the eurodollar bid rate exceeds the tunnel ceiling discussed earlier, and banks have an incentive for outward arbitrage. When the differential is negative but sufficiently close to zero, banks are indifferent between using the eurodollar or the domestic market as a source of funds. When the differential is sufficiently low, the eurodollar bid rate falls below the tunnel floor, giving banks a possible incentive for inward arbitrage. The period in which this last case applied is illustrated by the shaded areas in Chart 5.[23]

Chart 5 shows that, for most of the ten years since 1977, banks have either been indifferent between tapping the domestic or eurodollar markets, or had an incentive for outward arbitrage. The exception is 1979, when the second oil price shock created a large supply of eurodollar funds. At that time, eurodollar market rates fell sufficiently below domestic CD rates to create an incentive for banks to use the eurodollar market to fund domestic loans. This timing roughly corresponds to the period when the net foreign asset position of domestic banks in comparison to their foreign affiliates turned negative (Chart 3).

To sum up, while the unadjusted differential of the deposit rates paid to the nonbank sector in the late 1970s (top line of Chart 5) appeared to encourage the shifting of deposits to the eurodollar market, the adjusted differential (bottom line of Chart 5), which reflects the cost of funds to the banks, simultaneously favored net lending abroad by the U.S. banking sector rather than the use of funds raised in the eurodollar market in the domestic market. Perhaps even more surprising is that, while the unadjusted differential between the domestic and eurodollar rate narrowed significantly since 1983 when the U.S. began importing unprecedented amounts of capital, the adjusted differential still reflected an outward arbitrage incentive for banks. This is confirmed by the rising net foreign assets of U.S. banks versus their foreign affiliates over the period.

While our discussion sheds some light on the behavior of eurodollar deposits over the past ten years, the importance of the various interst rate effects for eurodollar deposit holdings of U.S. residents is still unclear, as is the ultimate impact of eurodollar market on domestic interest rates. A more precise characterization of these effects requires more formal analysis.

Chart 5
Three-Month Eurodollar Deposit Rate / U.S. CD Rate Differential



V. Dynamic Relationships

In the absence of an elaborate structural model, the determinants of the behavior of eurodollar deposits over time and the implications of the euromarket for domestic interest rates (and therefore monetary policy), can be examined more systematically by performing a vector autoregression (VAR). A VAR takes a set of variable and regresses them on the lagged values of the same set of variable, thus indicating whether the dynamic relationships in the data appear to be consistent with the relationships postulated by our understanding of how the eurodollar market works. VARs may be interpreted as reduced forms of complex structural links, they assume limited knowledge of the precise nature of these links.

Three useful results may be obtained with VARs:

1. *Tests of Granger Causality.* A variable x is said to Granger cause another variable y if the lagged values of x improve the forecast of y. Granger causality does not imply causality in the behavioral sense understood in structural models (for example, that an increase in interest rates would cause money demand to fall), but does permit statements about whether two variables appear to be connected in a systematic way over time. While Granger causality tests are useful indicators, they do not show the extent to which lagged values of x will improve the forecast of y. This information is provided by two other results obtained from VARs.

2. *Variance Decompositions.* These decompositions indicate how much of the forecast error of a particular variable results from innovations in each variable included in the VAR.

3. *Impulse Response Functions.* Based on the moving average representation of the VAR, impulse response functions provide an explicit characterization of the dynamic response of a variable to an innovation to itself or other variables.

TABLE 1

Test of Granger Casuality

	Dependent Variables			
Explanatory Variables	**Nonborrowed reserves**	**3-month Treasury bill rate**	**Euro/domestic CD rate differential**	**Total Eurodollar deposits**
Nonborrowed reserves	3.0**	0.7	1.4	4.7***
3-month Treasury bill rate	1.7	7.5***	0.9	3.9**
Euro/domestic CD rate differential	3.1**	1.3	12.0***	0.6
Total Eurodollar deposits	1.1	0.3	1.7	7.5***
$\bar{R}^2$	.08	.26	.29	.21

F-statistics on the null hypothesis that the block of coefficients is zero.

*** significant at 1%

** significant at 5%

* significant at 10%

A four-variable VAR was estimated. The variables were nonborrowed reserves (used as a proxy for liquidity constraints that may affect deposit creation in the domestic and eurodollar markets), the 3-month U.S. Treasury bill rate (as a proxy for the level of domestic interest rates), the differential between the unadjusted 3-month eurodollar and domestic CD rates (representing the incentive for arbitrage between markets and the influence of eurodollar rates), and total eurodollar deposits held by U.S. residents (representing the shift in domestic intermediation towards the eurodollar market).[24]

The data are monthly, the variables expressed in differences of logs and lagged 1 to 3 months, and the estimation period is 1979:1 to 1986:12. Short lags were chosen on the belief that the arbitrage relationships we have been discussing take place over a very short span of time. The estimation period was chosen to focus largely on the behavior of eurodollar deposits in the 1980s, when the strong variation in interest rates provides a good potential experiment for the responsiveness of eurodollar deposits.[25]

The objective of our VAR study is to shed some light on the potential impact of eurodollar deposit

TABLE 2

Variance Decomposition

Forecast Horizon (months)	Percent of forecast error explained by: Nonborrowed reserves	3-month Treasury bill rate	Euro/domestic CD rate differential	Total Eurodollar deposits
Nonborrowed Reserves				
1	100.0	0.0	0.0	0.0
6	78.1	6.2	13.8	2.0
12	77.9	6.3	13.8	2.1
24	77.9	6.3	13.8	2.1
3-month Treasury bill rate				
1	10.1	90.0	0.0	0.0
6	12.2	77.7	7.7	2.3
12	12.2	76.6	8.7	2.4
24	12.2	76.6	8.7	2.4
Euro/domestic CD Rate Differential				
1	0.4	0.3	99.4	0.0
6	3.8	2.9	89.3	4.0
12	3.8	2.9	89.2	4.0
24	3.8	2.9	89.2	4.0
Eurodollar deposits				
1	0.0	4.0	0.1	96.0
6	11.6	14.8	2.4	71.3
12	13.1	14.6	2.5	69.8
24	13.1	14.6	2.5	69.7

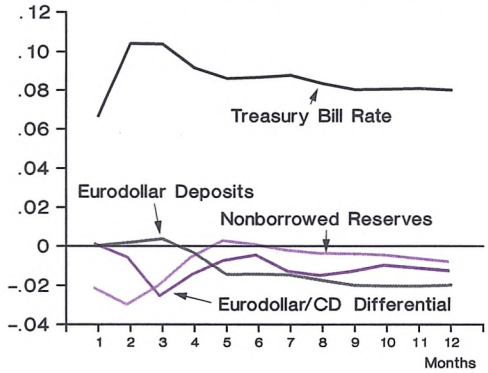
creation on domestic interest rates and on whether such eurodollar deposit creation could systematically offset the intention of monetary policy. Eurodollar deposit creation would do the latter if it were very responsive to interest rate behavior and relatively unfettered by the availability of reserves in the U.S. banking system. The dynamic links between the price (interest rate) and quantity variables should conform with the analysis presented earlier and may be interpreted as follows:

1. If U.S. interest rates were affected by the euromarket, eurodollar deposits as well as the eurodollar/domestic CD rate differential should Granger cause the U.S. Treasury bill rate, and should explain a large portion of its variance. If eurodollar deposits were to Granger cause the U.S. Treasury bill rate, one may infer that eurodollar deposits would be close substitutes for domestic money, and that, at the margin, such deposits would be large enough to have an impact on interest rates that is pertinent to domestic monetary policy.

2. If the volume of eurodollar deposit creation were responsive to interest rates, the U.S. Treasury bill rate, and the euromarket/domestic CD rate differential would Granger cause eurodollar deposits, and explain an important proportion of the variance in such deposits. In this case, eurodollar deposit creation may tend systematically to offset the direction intended by domestic monetary policy in the manner suggested earlier. In contrast, if eurodollar deposits were subject to liquidity constraints, nonborrowed reserves would Granger cause eurodollar deposits, and the extent of the offsetting effects on monetary policy will be correspondingly limited.

Table 1 reports the results of the VAR, with columns 2 and 4 being of direct interest. As can be seen in the second column of Table 1, under the specification adopted here only the lagged Treasury bill rate is statistically significant in forecasting the U.S. interest rate. In contrast to Hartman's results for the period 1975-1978, there is no evidence that the behavior of eurodollar interest rates, reflected by the interest differential between eurodollar and domestic rates, Granger cause domestic U.S. rates[26] in the 1980s. The fourth column of Table 1 reveals that eurodollar deposits are Granger caused by the domestic Treasury bill rate and nonborrowed reserves. However, the lagged values of the euromarket domestic CD rate differential are not significant.

Chart 6
Response of U.S. Treasury Bill Rate to One Standard Deviation Shock In:



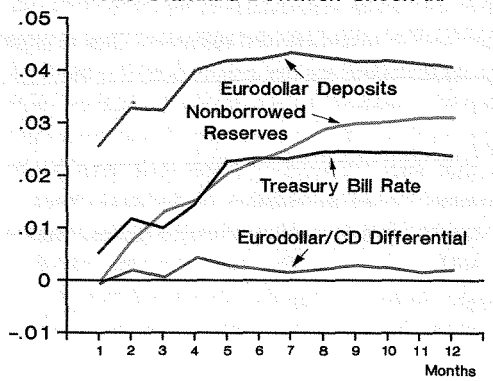
The variance decomposition and impulse response functions characterize the specific contributions of innovations in the different variables to the variation of each variable in turn. Such a characterization requires the innovations specific to each variable to be isolated. For example, the innovations in nonborrowed reserves must be treated separately from innovations to the U.S. Treasury bill rate. This cannot be done by looking at the residuals of the vector autoregression equations because such residuals are typically correlated with each other. The traditional procedure, in this case, is to construct a moving average representation of the vector autoregression that recovers innovations that are not correlated with each other.[27]

The variance decompositions reported in Table 2 show the percentage of the expected squared prediction error of each of the four variables in the system that is produced by an innovation in each of the variables in turn, for forecasts for 1 to 24 months ahead. The contribution of innovations in each variable is expressed as percentages. For example, in the last item under Nonborrowed Reserves, column 1, the portion of the 24-month ahead forecast error in nonborrowed reserves that is attributed to innovations in the eurodollar/domestic CD rate differential is divided by the total expected 24-month

ahead squared prediction error of nonborrowed reserves conditional on information available at the time the forecast is being made. This total error will depend on innovations in nonborrowed reserves, the U.S. interest rate, and the volume of eurodollar deposits, as well as on innovations in the eurodollar/domestic CD rate differential (recall that these variables are expressed in log differences). As can be seen, after 24 months, 78 percent of the error in nonborrowed reserves is due to innovations in nonborrowed reserves, and nearly 14 percent is due to innovations in the eurodollar/domestic CD rate differential.

In general, Table 2 shows that innovations in other variables play a limited role in explaining the standard error in the forecast of nonborrowed reserves, the U.S. interest rate, and the euromarket/domestic CD rate differential. The contribution of innovations in interest rates and nonborrowed reserves to the forecast error in total eurodollar deposits is also small.[28] After 24 months, innovations in the Treasury bill rate and nonborrowed reserves explain 15 and 13 percent, respectively, of the forecast error in total eurodollar deposits, as compared to 70 percent explained by innovations in eurodollar deposits.

Chart 7
Response of Eurodollar Deposits to One Standard Deviation Shock In:



The impulse response functions presented in Charts 6 and 7 illustrate the path of the response of the levels of the U.S. Treasury bill rate and total eurodollar deposits, respectively, to a 1 standard deviation shock in their own values and other variables in the system. The U.S. Treasury bill rate rises in response to a shock in the U.S. Treasury bill rate, but falls overall in response to a shock in nonborrowed reserves, the interest rate differential, and

TABLE 3

Covariance/Correlation Matrix

	Nonborrowed reserves	3-month Treasury bill rate	Euro/domestic CD rate differential	Total Eurodollar deposits
Nonborrowed reserves	0.8×10^{-3}	$-.32$	-0.6×10^{-1}	-0.5×10^{-2}
3-month Treasury bill rate	-0.6×10^{-3}	0.5×10^{-2}	-0.3×10^{-1}	.19
Euro/domestic CD rate differential	-0.5×10^{-3}	-0.5×10^{-3}	0.7×10^{-1}	-0.3×10^{-1}
Total Eurodollar deposits	-0.4×10^{-5}	0.3×10^{-3}	-0.2×10^{-3}	0.7×10^{-3}

eurodollar deposits. As indicated earlier, the effects of the last three are very small.

Total eurodollar deposits rise in response to a 1 standard deviation innovation to the U.S. Treasury bill rate and to nonborrowed reserves. This at least partly confirms our earlier suggestion that eurodollar deposit creation is positively associated with changes in domestic interest rates, but it also indicates that such deposit creation will tend to be constrained by the availability of dollar reserves.

In constructing a moving average representation of a VAR, which is the basis for the variance decompositions and impulse response functions, an assumption needs to be made as to the original source of observed disturbances. The present VAR assumes that disturbances to nonborrowed reserves are the primary source, followed by disturbances to the U.S. Treasury bill rate, the euromarket/domestic CD differential and eurodollar deposits. The sensitivity of the impulse response and variance decomposition results to the ordering adopted here depends on the covariation between the residuals of the equations, reported in Table 3. As can be seen, the correlations between the residuals are comparatively low, the highest being −32 percent for nonborrowed reserves and the U.S. Treasury bill rate. The results reported therefore are not very sensitive to the order assumed.

VI. Conclusions

Since the late 1970s, disturbances to U.S. interest rates and nonborrowed reserves influence eurodollar deposit creation. The effect of U.S. interest rates implies that eurodollar deposits may be created in a manner that offsets the intention of monetary policy. The effect of nonborrowed reserves implies that the extent of such offset will be curtailed by the availability of reserves. It should be stressed that these two effects are small. Eurodollar deposit holdings of U.S. residents are explained largely by the lagged values of those holdings.

In addition, any influence the euromarket has on domestic interest rates is negligible. Neither a proxy for the effect of the euromarket interest rate nor the volume of eurodollar deposits held by U.S. residents explains much of the variance in domestic U.S. interest rates. Specifically, total eurodollar deposits do not appear to be sufficiently close substitutes for money, or to be sufficiently large in volume even at their peak in the early 1980s, to have a strong influence on U.S. domestic rates. For purposes of monetary control, U.S. policymakers need not be concerned about the impact of domestic currency holdings of their nationals in the eurocurrency market.

This result may have implications for other large countries concerned about extending the scope of their international banking relationships. Of course, the internationalization of banking has other implications not fully explored here. Further research should seek to identify the importance of other channels that connect the euromarket to domestic financial markets, particularly, the eurobond market.

FOOTNOTES

1. See Mayer (1982). Similar reasoning underlies the framework used by Henderson and Waldo (1980, 1981).

2. The apparent absence of any influence of foreign rates on U.S. rates reported by Genberg, Saidi and Swoboda may be caused by two factors: (a) changes in the return on assets denominated in foreign currency affect exchange rate expectations in a way that diffuses the observed impact on U.S. rates, and (b) domestic interest rates and the rates in financial markets abroad are subject to such a wide variety of influences that no direct link between them may be apparent.

The absence of direct linkages between national financial markets in the U.S. and abroad does not rule out the possibility that interest rates in national financial markets abroad may influence eurocurrency market interest rates, which, in turn, may influence U.S. interest rates. Thus, the results of Genberg, Saidi and Swoboda may still be consistent with Hartman's (1984) results. However, as indicated later, Hartman's results do not appear to apply for the 1980s.

3. Overnight eurodollar rates Granger cause the federal funds rate if lagged values of the former improve the forecast of the latter. The test of Granger causality is discussed in a later section.

4. The eurocurrency liabilities of U.S. residents subject to reserve requirements are defined as the net interbank liabilities of U.S.-based banks versus those of banks operating in the euromarket and the borrowings of U.S. residents from branches of U.S. banks operating in the euromarket. AS discussed later, U.S. banks have been net creditors compared to their foreign branches over extended periods, so the reserve requirements in many cases do not apply.

5. In 1971, the reserve requirement on eurodollar borrowing was doubled to 20 percent; it was then reduced to 8 percent in June 1973. Over this period, reserve requirements on eurodollar borrowing were higher than the 5-8 percent reserve requirements on domestic CDs. From the last quarter of 1973 to 1978, the reserve requirement on eurodollar borrowing was progressively reduced to 0 to encourage borrowing from the eurodollar market in order to strengthen the value of the dollar, while the domestic CD requirement had risen to as high as 11 percent.

6. The share of dollar-denominated transactions in the euromarket has fallen in recent years. For example, lending denominated in U.S. dollars by banks in London — which is the major euromarket center — has fallen from a peak of 80 percent in 1983 to 72 percent in 1985, while the shares of transactions denominated in yen and deutschemarks have risen (to 7 and 10 percent respectively).

7. The reason is that foreign bank branch daylight overdrafts at the Federal Reserve are restricted, so foreign banks prefer to settle using deposits held with U.S. banks rather than with the reserves they have been required to hold with the Federal Reserve since 1978. Originally, foreign banks were not allowed to run daylight overdrafts. At present, foreign bank overdrafts are limited to 5 percent of their U.S. liabilities.

8. For example, Aliber (1979), points out: "The growth of the deposits of offshore banks can be thought of as the growth of the deposits of domestic branches not subject to reserve requirements . . . Banks do not hold separate reserves against offshore deposits because the reserves held against domestic deposits exceed normal liquidity needs . . ."

9. The arbitrage between the federal funds and overnight eurodollar market is discussed by Reinhart and Harmon (1987). The arbitrage between domestic and eurodollar CDs is highlighted by Johnston (1979) and Kreicher (1982).

10. The marginal conditions can be derived from the theory of the banking firm. The marginal revenue to be equated to marginal cost is the interest income from lending funds received by increasing eurodollar liabilities. For a given level of domestic deposits and interest rates, the marginal cost depends on the extent to which increasing eurodollar liabilities will affect desired holdings of (noninterest-bearing) reserves, the interest cost of the additional eurodollar liabilities, the expected penalty associated with the increased probability of becoming illiquid as eurodollar liabilities rise, and the marginal cost to the firm of an increase in its size. In a profit-maximizing equilibrium, the size of the banking firm, the share of the domestic and eurodollar market in loans and deposits, and the quantity of desired reserves are all determined simultaneously.

11. Such an approach would explain why the differential between the eurodollar deposit rate and domestic deposit rates of comparable maturity is not explained by the differential in the cost of funds in the two markets when there are large disturbances to asset preferences (for example, following the Herstatt Bank failure of June 1974). This implies that for sufficiently large changes in interest rates associated with shifts in the supply of eurodollar funds, the demand for eurodollar deposits is not perfectly elastic either.

12. See Judd and Scadding (1982).

13. For a recent discussion, see Frankel (1985).

14. For example, see Mayor (1982).

15. Goodman's definition of eurodollar deposits of short maturity includes overnight eurodollar deposits and either 20 percent or 40 percent of term eurodollar deposits held by U.S. residents (the latter is taken as the upper limit on eurodollar deposits under 8 days). Her equations are estimated quarterly from 1959 to 1974 and then simulated out-of-sample through the third quarter of 1982.

16. When foreign banks are involved, the settlement may first involve bank deposits held with U.S. banks. This eventually will result in the transfer of reserves.

17. Niehans and Hewson (1976) argued that banks largely match the maturities of their assets and liabilities in the euromarket, suggesting that the extent of maturity transformation, and therefore liquidity creation, is small. However, more recently, Sneddon-Little (1979) found that the extent of maturity transformation may be as large as for domestic banking.

18. See Stiglitz and Weiss (1981); or Sachs (1984).

19. One may also think of a leftward shift in the supply of funds schedule caused by the rise in domestic lending rates, which may or may not fully offset the rightward shift in demand.

20. These two indicators do not provide a complete representation of eurodollar activity that may be relevant for domestic monetary policy because the arbitrage activities of nonbank foreign residents between the domestic U.S. market and the eurodollar market are not considered. However, a large portion of the foreign resident holdings of eurodollars is unconnected with U.S. economic activity (for example, eurodollar entrepot operations). Since it is difficult, if not impossible, to ascertain that proportion of foreign eurodollar holdings that should be included in the analysis, we have confined our study to the emigration of intermediation by U.S. residents.

21. The analysis raises the question of whether it is appropriate to compare total eurodollar deposits with M1. Because of their short maturity, overnight eurodollar deposits are considered the closest substitutes for M1. However, a large proportion of eurodollar deposits are of very short maturity. Goodman (1984a), for example, assumes that up to 40 percent of eurodollar deposits mature in less than 8 days.

22. The pattern in the overall net foreign asset position of U.S. banks appears to be consistent with the pattern shown in Chart 3. Although the U.S. economy as a whole has been a net creditor from early this century up to the 1980s, total U.S. international banking liabilities typically exceeded assets up to the early 1970s. This was partly because the role of the dollar as a reserve currency resulted in the holding of significant dollar-denominated deposit holdings on the part of foreign governments. However, growing bank lending reversed this situation by the end of 1975. The net foreign assets of U.S. banks rose from $1.1 billion in that year to a peak of $130.2 billion in the first quarter of 1983, before falling to $42.1 billion in the first quarter of 1986. The decline reflected the 1982 debt crisis, which prompted U.S. banks to reduce the growth of their external lending, particularly to less developed countries, and that portion of growing U.S. borrowing that had been channeled through the banking sector.

23. The cost of domestic funds, which defines the tunnel ceiling, may be described by the formula: $c = (i+p)/(1-r_d)$, where c is the cost, i is the interest paid on the domestic deposit, p is the FDIC premium, and r is the reserve requirement on domestic deposits. The tunnel floor is described by: $f = [(i+p)(1-r_e)/(1-r_d)] - s$, where r_e is the reserve requirement on borrowing from the eurodollar market, and s is the spread between the eurodollar bid and offer rates. For a discussion of how these values are derived, see Kreicher (1982). Unlike Kreicher, statutory FDIC premia are used here.

24. Instead of taking the U.S. Treasury bill rate and the difference between the euromarket and domestic CD rates, we could have used a U.S. domestic rate and a comparable euromarket rate. The two series would have reflected both the effect of the overall level of the rates as well as the effect of the differential between them. Experiments with this alternative specification gave similar results.

25. Extending the estimation period to 1977 does not alter the basic results.

26. Hartman estimates a two-variable vector autoregression with the 3-month U.S. commercial paper rate and the 3-month eurodollar deposit rate and finds evidence that the 3-month eurodollar rate Granger caused domestic rates for the period 1974-1978. Direct estimates performed by the author using a similar bivariate system in levels and rates of change confirmed this finding, but indicated that, after 1979, the eurodollar rates do not Granger cause domestic rates. This is consistent with the results in the text. Reinhart and Harmon's (1986) finding that overnight eurodollar rates Granger cause the federal funds rate in the 1980s then indicates that the term structure relationship of the euromarket and domestic interest rates has changed. This warrants further investigation.

27. In vector autoregressions, variables that are not expected to have predictive values for other variables are put last. This assumption is reflected in the ordering of the equations reported in Table 1.

The procedure for isolating the innovations in each variable follows naturally from this assumption. The innovations to nonborrowed reserves were left unchanged. Any systematic relationship between the residuals in the nonborrowed reserves equation and the U.S. Treasury bill equation was then eliminated to obtain the innovations to be attributed to the U.S. Treasury bill rate. The innovations in the euromarket/domestic CD differential were then obtained by eliminating any systematic relationship with the residuals of nonborrowed reserves and U.S. Treasury bill equations. A similar process yielded the innovations in the eurodollar rate. As indicated later, the low correlation between the innovations suggests that the results are not very sensitive to the order assumed.

28. Recall that all variables are expressed in log differences.

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