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Risk and Interest Rates

Accelerating inflation and volatile interest rates, growing federal deficits and widespread deregulation have been among the primary influences on financial markets and financial institutions through the 1970s and early 1980s. The resulting risk and uncertainty have been major concerns of policymakers, corporate managers and investors, some of whose responses are explored by the authors in this *Review*.

In the opening article, Jack Beebe poses the question of whether the turbulent post-1979 economic and regulatory environment significantly increased the market's perception of bank capital risk. In particular, he cites the possible effects of rapidly rising inflation and interest rates, the change in October 1979 in the Federal Reserve's short-term operating procedure for influencing money, the imminent legislation to deregulate banks, credit controls imposed in the period from March-July of 1980, and the prospect of chronic federal deficits. To study the effects of these forces, Beebe compared changes in actual market measures of bank capital risk—both for bank debt and bank equity—for the two periods before and after October 1979.

With regard to debt risk, Beebe found that the risk premia for Moody's Baa bonds and for an equally weighted index of fifteen bank debt issues, both relative to Aaa corporate issues, were about the same in the 1974-79 period. During the post-1979 period, however, the bank bonds were considered less risky than the Baa's. On average, Beebe also found that bank-debt risk premia did not become more dispersed across banks of different sizes, and concludes that "bank debt issues have not been viewed as becoming more risky in the post-1979 period."

Using the standard deviation of equity returns over each of the two periods as a measure of equity risk, Beebe found that equity risk declined between the two periods and that the decline was greatest for the largest banks, even in comparison to the S&P 500.

Finally, Beebe calculated the sensitivity of bank stocks to the market price of risky assets (as measured by the S&P 500) in the two periods to see whether banks' ability to manage risk deteriorated after 1979. His results indicate that the sensitivity of bank equity returns to non-diversifiable, or market-related, risk declined in the post-1979 period compared to the earlier period and that the decline was statistically significant for more than half of the twenty banks in the $10 billion-plus size (large bank) group. Beebe concludes that capital risk was stable in the post-late-1979 period for banks of over $1 billion in assets.

In the second article, Randall Pozdena and Ben Iben examine a method for pricing options, and use two examples to show how this methodology can provide a useful perspective on investment analysis and problems of financial policy.

Their theory views the demand for options as a demand to construct riskless hedges—portfolios of options plus the underlying securities whose combined values are immune to changes in interest rates. The value of an option, i.e., what the investor will pay for it, therefore, depends on riskless returns elsewhere and the anticipated future behavior of the price of the underlying security. Rather than derive analytic expressions for options prices, the authors used numerical techniques to simulate the prices of options under different assumed scenarios for interest rates.

The authors applied their methodology to options on 10-year Treasury notes and to the valuation of early withdrawal provisions in fixed rate deposit instruments. The first application illustrates the ability of simple options pricing models to approximate the actual prices of traded options.

The second application highlights the use of the options pricing model to price more complex financial instruments. In particular, this application shows that the regulation of early withdrawal penalties may have prevented financial institutions from using the early withdrawal feature of their deposits to compete for funds against comparable instruments (such as T-bills) without withdrawal provisions.

Brian Motley, in the third article, tries to sort out the differential effects of money, inflation and government deficits on real, i.e., inflation-adjusted, interest rates in order to explain the post-1979 rise in real rates. Economic theory and popular opinion suggest that higher levels of federal borrowing would be associated with increases in real rates both because deficits have to be financed by the issue of securities to the public and because the expansionary effect of deficit spending on national income raises the demand for money. Likewise, a demand for money in excess of supply would put upward pressure on interest rates. A rise in inflation, however, is commonly argued to lower real interest rates.

Motley focused his study on short-term interest rates and applied a partial equilibrium model to explain the real interest rate in terms of four independent variables: a lagged inflation rate, a measure of the excess supply of money, a measure of the impact of government deficit spending on credit markets, and the ratio of actual to potential GNP. His dependent variable was the average rate on 91-day T-bills issued in the first month of each quarter from April 1958 to January 1982, adjusted for inflation.

His regression results for the entire period from the late 1950s to 1982 and for subperiods within led him to conclude that the popular explanations of the post-1979 rise in real rates do not find strong confirmation in the data. For example, while other studies of inflation and real rates in the period immediately after World War II found a significant inverse relationship, Motley's results duplicated this finding only for the 1970s. Moreover, he notes that even during that decade, "the effect was less significant when one took account of changes in the money supply and the federal deficit that took place at the same time."

Similarly, he found no support for "any simple direct causal link between the recent sharp increase in the federal deficit and high real rates." In the equation he estimated for the period of April 1970 to January 1982, the estimated coefficient on the federal borrowing variable was not statistically significant. Instead, his equation suggested that money shocks and changes in the inflation rate have been more closely related to real rates than has the federal deficit.

Motley concludes that "high rates appear to have been more closely linked to monetary policy—and to expectations of policy—than to fiscal policies that have produced federal deficits." Nevertheless, he claims that there is still a great deal to be learned "before we fully understand the causes of the recent explosion in real rates." In particular, econometric analyses based on data from earlier periods cannot incorporate the present situation in which an unprecedented (for peacetime) portion of government outlays are financed by borrowing rather than by taxation.

John Judd and Rose McElhattan explore the recent behavior of money and the economy in the last article, and present the idea of an "adjusted M1" to measure the effective force of monetary policy more accurately.

They use, as their starting point, the unexpectedly large drop in M1 velocity in late 1982. Some observers attributed the drop to an unstable money demand function, but Judd and McElhattan believe that the increase in the public's desire to hold M1 was a response to unexpectedly large drops in inflation and short-term interest rates. They argue, therefore, that the increase in M1 above the Federal Reserve's original targets in 1982 and early 1983 did not have the stimulatory effect on aggregate demand that the measured amount would suggest. Instead, a better representation of effective M1 would be actual M1 minus the increase in the public's demand for it, caused by the parallel decline in inflation and short-term interest rates.

The authors used the San Francisco money market model to estimate the increase in the public's demand for money. They then compared simulations of the FRBSF reduced-form macroeconomic model using actual M1 and the adjusted measure for the period 1982:1 to 1983:2. Simulations of M1 velocity, real GNP and inflation using the adjusted M1 proved more accurate than those using measured M1, which yielded large over-forecasts. Their results imply that monetary policy was effectively quite restrictive in 1982, became moderately expansionary in the first quarter of 1983, and was highly expansionary in the second quarter.

The authors warn that because the public's adjustment to lower levels of interest rates should have been complete by the end of the first quarter of 1983, a sustained expansionary money policy would lead "to hefty increases in spending and GNP and ultimately threaten to increase the rate of inflation." They therefore recommend a substantial slowdown in M1 growth over the next several years to hold the underlying rate of inflation to its present level. They add that their simulation suggests that "aggregate demand is likely to increase rapidly enough to sustain a recovery" even with this slower M1 growth.

Bank Capital Risk in the Post-1979 Monetary and Deregulatory Environment

Jack H. Beebe*

Since the early 1970s, economic risk—as reflected in uncertainty regarding real output, earnings, inflation, and interest rates—has been a major concern to corporate managers, investors, and policy makers. The banking sector has been no exception. In their role as intermediaries, bankers continually have had to monitor and manage risks due to unanticipated changes in inflation and interest rates, defaults, and liquidity. Bank risk has also been of particular importance to insuring agencies and bank regulators.

In structuring their portfolios, bank managers explicitly or implicitly, choose their risk exposure (an *ex ante* choice) with the expectation of earning a return commensurate with the expected risk. Current finance theory suggests that investors in debt and equity markets do not impose a uniquely optimal level of capital risk on individual banks or on the banking system because investors in capital markets can manage the risk of their total wealth by diversifying their portfolios.[1] Regulators also have no way of determining what level of bank risk is optimal. Thus, one cannot make judgmental statements about the level of risk observed.

However, bankers, investors, and regulators have a keen interest in knowing whether bank capital is perceived to have become more or less risky. For example, regulators become concerned when bank risk is increasing because the adverse consequences of bank failures may extend well beyond the losses to bank capital investors. At a minimum, non-insured depositors and insuring agencies bear some of the risk. But because of externalities associated with successive collapses in wealth or possible "runs" by non-insured depositors, the failure of one institution may increase the risk of other institutions. In the extreme, systematic failure can even affect the macroeconomic performance of the economy.

Beginning roughly in late 1979, a number of major developments had the potential of changing the perceived risk of bank capital. During 1979, the inflation rate accelerated sharply, putting upward pressure on market interest rates. By October of that year, the Federal Reserve had changed its monetary operating procedures by placing greater emphasis on controlling the quantity of money while allowing the federal funds rate to fluctuate over a wider range in the short run. Coinciding with the new operating procedure was a substantial increase in the volatility of market interest rates. Upward pressure on the level of interest rates also mounted with the prospect of chronic federal government deficits and monetary restraint.

In the latter half of 1979, momentum was building in Washington for landmark legislation to deregulate banks. By March 1980, Congress had passed the Depository Institutions Deregulation and Monetary Control Act, which, among other things, called for the removal of deposit-rate ceilings at banks and thrifts by 1986 and extended deposit insurance from $40,000 to $100,000 per account. From March through July of 1980, the Federal Reserve also imposed the Credit Control Program, which was directed largely at constraining the growth of bank credit. These developments taken together set the stage for what could have been perceived as a significant change in bank risk.

The purpose of this paper is to compare actual market measures of bank capital (debt and equity) risk in the pre- and post-October 1979 periods.[2] The paper examines whether or not there was a significant change in measured bank capital risk in the post-late-1979 era of monetary and fiscal policy uncertainty, interest-rate volatility and pending

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deposit-rate volatility. But because of the many factors affecting the market's perception of bank capital risk, neither the individual influences nor the extent to which a change in risk might have been due to government protection or increased deposit insurance can be determined.[3]

In summarizing the evidence comparing risk in the pre- and post-late-1979 periods, the picture is encouraging. For the latter period as a whole, there is no evidence of a significant rise in capital risk of banks with over $1 billion in assets. Measures of total capital risk changed little between periods, while the sensitivity of bank equity to overall stock-market risk actually declined between the two periods for most banks. (The decline was statistically significant for the group of largest banks—over $10 billion in assets.) On the whole, the largest banks reduced the risk exposures of their equities (elasticity of returns with respect to general stock price movements) far more than did the banks in the smaller groups ($1-5 billion and $5-10 billion).[4]

This paper is divided into three sections. In Section I, the theoretical underpinnings of the various measures of bank risk and the possible effects of the post-1979 economic and regulatory environment on bank risk are discussed. In Section II, the empirical evidence is presented. In Section III, conclusions are drawn.

I. Hypotheses of Bank Risk

In observing the capital risk of banks, it is important to distinguish between the *sensitivity* of bank capital risk to overall capital risk in the stock and bond markets (primarily a concept of *ex ante* risk posturing) and the actual level of bank capital risk observed (an *ex post* measure). For example, economic risk, as it impacts on earnings and interest rates, will affect capital values in the overall stock and bond markets. One question to be addressed is whether banks have positioned their portfolios, operations, and capital leverages to make their capital relatively sensitive or insensitive to such economic risks.

The single-index market model from the finance literature postulates that capital risk *sensitivity* can be represented by the equity "beta," or the measured sensitivity of the firm's (or portfolio's) equity return with respect to the return on the market bundle of risky assets, usually proxied by the return on a broad stock market index (originally, Sharpe, 1963). Precisely because it is measured in relation to a broad index of risky assets, beta represents sensitivity to commonly experienced, or non-diversifiable risk, and assets with a high beta should earn a return premium in the capital markets (originally, Sharpe, 1964).

The single-index model has since been extended to various multi-index models. One extension uses a two-index model in which the two indices are returns on a broad index of common stocks (e.g., the S&P 500) and returns on an index of default-free debt instruments (e.g., Treasury issues). The first index represents "non-diversifiable risk," which includes the risk associated with all factors that affect the stock market, such as expected earnings, interest rates, inflation, defaults, and so forth. (Since interest rates comprise one factor affecting the stock market, the two indices obviously are not independent.)

Bank equity is sensitive to all of the factors that affect the stock market, including interest rates. For example, banks are sensitive to "earnings risk" through possible defaults on their loans and investments, changes in loan demand, and potential variability in growth and profitability of their own (non-portfolio) operations. Bank portfolio returns also are subject to (nominal) interest rate risk because banks carry assets and liabilities that are usually contracted in nominal dollars and which normally differ in duration.[5] Bank equity values are sensitive also to interest rate risk because the real interest rate affects the discounting of future earnings. The question to be addressed is whether banks are positioned in such a way that their capital is relatively exposed to or insulated from the economy-wide sources of risk that are reflected in overall stock and bond market volatilities.

In this paper, risk *sensitivity* is measured in several ways: (1) by estimating the bank stock beta, which measures sensitivity to all commonly experienced non-diversifiable risk factors as they affect the S&P 500; (2) by estimating the sensitivity of bank stock returns to returns on 1-year Treasury bills (i.e., interest rate risk); and (3) by measuring whether bank stocks are responsive to Treasury bill returns beyond the sensitivity to interest rates already reflected in movements of the overall stock market (S&P 500).

While a bank may attempt to posture its risk sensitivity through discretionary *a priori* portfolio and operational policies, the risk inherent in the economic environment will determine how these policies translate into *ex post* measures of actual capital risk. For example, a bank could attempt to insulate itself *ex ante* from risk, but if total risk in the market were to rise, the bank's *ex post* capital risk actually could increase. Thus, the analysis examines not only the *elasticities* (sensitivities) of the prices of bank equities with respect to stock and T-bill prices, but also direct measures of bank-debt risk premia, bank equity returns, and the dispersion of those returns. These measures represent actual *ex post* bank risk as opposed to *ex ante* risk posturing.

Several forces in the post-1979 environment might have affected the capital risk of banks: (1) During 1979 and early 1980, there was a rapid acceleration in the rate of inflation and in the level of interest rates while the economy was operating roughly at capacity. Such developments in the past often have been followed by recessions. (2) In October 1979 the Federal Reserve changed its short-term operating procedure for monetary policy. (3) Beginning in late 1979, legislation (of unknown specifics at the time) to deregulate banks was becoming increasingly imminent, and resulted in the Depository Institutions Deregulation and Monetary Control Act of March 1980. (4) Credit controls were imposed during the March-July period in 1980, and their possible re-imposition must have presented some continued threat to the efficient operation of financial institutions. (5) Finally, the monetary-fiscal policy dilemma caused by tax changes and the prospect of chronic federal deficits began to surface in 1980 and 1981.

It is very difficult to say *a priori* how these events should have affected bank risk. For example, one cannot say unequivocally whether the Federal Reserve's change in operating policy should have diminished or increased either interest rate or real earnings risk. From a monetarist point of view, the *short run* variability of the federal funds rate and perhaps even other interest rates, economic activity, and real earnings might have increased, while the risk of major fluctuations would have abated. From a Keynesian point of view, variability of most interest rates, and perhaps real earnings, might have increased even in the longer run.

It is difficult to predict how deregulating consumer deposit ceilings also might have affected bank risk.[6] Ignoring the effect of deposit insurance for the moment, it is likely that removing consumer deposit ceilings might actually reduce bank risk in the long run because the shift from non-interest to interest payments on deposits presumably would enable a bank to shift from quasi-fixed factors of production—buildings and other convenience or nonprice concessions—to highly flexible factors—interest payments (Mingo, 1978 and Quick 1977).

While the deregulation of consumer deposit ceilings might have some effect in reducing bank risk by affording banks a more efficient and flexible means of attracting deposits, it might also increase the desired risk exposure of banks by increasing the likelihood that marginal liabilities would fall under the umbrella of deposit insurance. As a consequence of consumer deposit-rate deregulation, banks are freer to bid up the rates on *insured* deposits of up to $100,000 denomination. If marginal bank liabilities shift from non-insured to insured sources, the discipline imposed by lenders (i.e., depositors) is lessened. The deregulation of (insured) consumer deposits might then tend to increase the optimal *ex ante* risk exposure of a bank.

In part because there is no necessarily optimal level of risk for bank capital and in part because the several factors in the post-1979 environment might have either increased or decreased bank risk to varying degrees, any change in observed bank risk is simply an empirical question. The author's *a priori* expectation was that large banks probably attempted to reduce the *ex ante* exposures (sensitivities) of their capital to interest-rate and economic risk after the mid-1970s (Beebe, 1977).[7] The actual *ex post* risk to be observed in the post-1979 period was an open question.

II. Evidence of Risk

Month-end closing prices of common equity were obtained from Data Resources, Inc. (DRI) for 91 large bank holding companies and banks (henceforth referred to as "banks") ranging in total assets (year-end 1981) from $1 billion to $121 billion. The choice of institutions was based on the availability of stock data that indicated frequent trading[8]: 52 banks had assets of $1-5 billion, 19 had assets of $5-10 billion, and 20 had assets of $10-121 billion.

Secondary-market month-end quoted yields were obtained for 15 debt issues of 15 different bank holding companies and banks.[9] The institutions associated with the 15 issues ranged in size from $1.7 billion to $121 billion, with 8 in the $1-5 billion group, 2 in the $5-10 billion group, and 5 in the $10+ billion group.

In the following analysis, evidence on bank debt and equity *ex post* capital risk is presented first (Charts 1 and 2 on debt and Tables 1 and 2 on equity). Then the more complex regression analysis of *ex ante* risk posturing follows (Tables 3-5).

Debt Risk

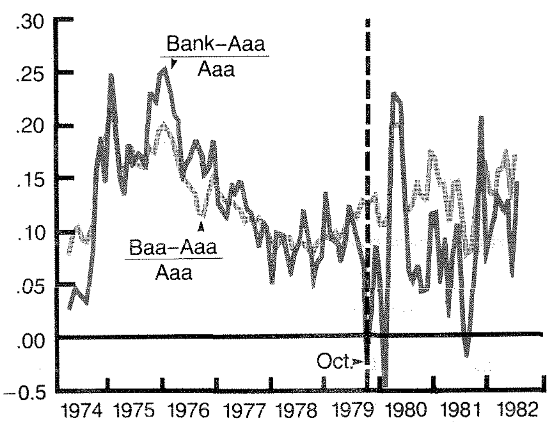
Chart 1 shows the risk premia for Moody's Baa bonds and for an equally weighted index of the fifteen bank debt issues, both relative to Aaa corporate issues.[10] Throughout most of the 1974-79 period, the bank bonds on average were considered by the market to be about as risky as Baa bonds. However, during the post-1979 period, the bank bonds were considered to be less risky than Baa's. In fact, the post-1979 period shows very little increase in the average risk premium for these 15 bank debt issues, with the exception of the Credit Control period (March-July, 1980) and possibly a small increase in 1982.

Chart 2 reports the *cross-sectional* coefficient of variation of yields within the 15-bank-bond index. (The coefficient of variation is the standard deviation divided by the mean. It measures the extent to which the risk premia differ across the fifteen banks.) Interestingly, the cross-section dispersion of yields increased markedly immediately after October 1979 and through the Credit Control period when the cross-sectional dispersion reached its high 1975 level. After the Credit Control period, however, the dispersion of bank yields (risk premia) has remained well below that of the turbulent 1974-1976 period.

Charts 1 and 2 taken together indicate that, since 1979, bank-debt risk premia (for these 15 large banks) have neither risen significantly on average nor become more dispersed across the banks, except during the period of Credit Controls. One may conclude, then, that these bank debt issues have not been viewed as becoming more risky in the post-1979 period.

Chart 1

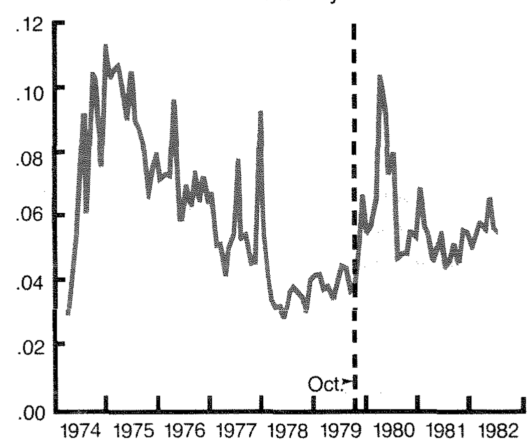
Bank/Aaa and Baa/Aaa Debt Risk Premia



Aaa and Baa yields are end-of-month. Bank bond index is an equally weighted end-of-month yield of fifteen major bank debt issues.

Chart 2

Dispersion of Bank Debt Yields About Their Monthly Means



Monthly cross-section coefficient of variation (standard deviation divided by mean) of month-end yields for fifteen major bank debt issues.

Equity Returns

Table 1 shows equity returns (excluding dividends) for the pre- and post-1979 periods.[11] In the 1972-79 period, bank equity returns were very close to those on the S&P 500, although the large-bank group performed moderately better than the small-bank group.[12] In the post-1979 period, the group of $1-5 billion banks performed considerably better than the S&P 500, and the two groups of larger banks, considerably poorer. But within the post-1979 period, there was a distinct break in stock price behavior, with a persistent decline in the stock market beginning in December 1981 and continuing throughout the sample period. The two groups of large banks registered a decline in stock prices that was much more severe than that of the S&P 500, an indication that the market might have reassessed the expected earnings of the largest banks beginning in late 1981.

Equity Risk

The standard deviation of equity returns over a period of time is commonly used as a measure of equity (total) risk. Table 2 presents standard deviations of monthly equity returns (excluding dividends) for the bank groups for the pre- and post-1979 periods. Between the two periods, the standard deviation of equity returns declined for all three groups of banks. The decline was greatest for the group of largest banks; for this group, the standard deviation declined even in comparison to that of the S&P 500.[13] The table indicates that the total equity risk of the largest banks declined both absolutely and relatively in the post-1979 period. As indicated by the regression results reported below, this lower risk can be interpreted in part as the consequence of discretionary policies taken by the largest banks either prior to or during the post-1979 period.

Table 1
Bank Equity Returns

(Monthly Percentage Returns at Annual Rates, Excluding Dividends[1])

		1979:10–1982:07		
	1972:08–1979:09	Full Period	1979:10–1981:11	1981:12–1982:07
All Banks	−0.5%	2.1%	12.0%	−27.5%
$1-5 billion	−1.5	6.2	14.5	−16.7
$5-10 billion	0.3	−3.4	6.1	−29.0
$10+ billion	1.1	−3.5	10.9	−38.7
S&P 500	0.3	0.7	6.9	−22.0

[1] Monthly percentage returns are calculated for each bank over the period. Equally-weighted cross-section average returns are calculated for each group of banks. Geometric mean returns for the group indices are then calculated for the sample periods.

Table 2
Bank Equity Risk

(Standard Deviations of Monthly Percentage Returns at Monthly Rates[1])

	1972:08–1979:09		1979:10–1982:07	
	Standard Deviation	Relative to S&P 500[2]	Standard Deviation	Relative to S&P 500[2]
All Banks	8.05%	1.71	7.82%	1.75
$1-5 billion	7.91	1.68	7.81	1.75
$5-10 billion	8.37	1.78	8.23%	1.85
$10+ billion	8.11	1.72	7.46	1.67

[1] Standard deviations of monthly percentage returns (at monthly rates) are calculated for each bank over the period. Period averages are then calculated using equal weights for each bank in the group. Returns exclude dividends.

[2] The standard deviation of bank returns divided by the standard deviation of returns on the S&P 500 (excluding dividends).

Risk Posturing

The above measures of *ex post* debt and equity risk are the combined consequence of risk posturing by banks and total risk in the stock and bond markets. The risk sensitivity measures reported below, although measured on an *ex post* basis, are interpreted as exposures to total risk, and hence the result of *ex ante* risk posturing. (As noted later, one could argue also that they are the consequences of implied regulatory protection.)

As described earlier, the single-index stock market model employs the equity beta as a measure of non-diversifiable, or market-related, risk. Specifically, beta is a measure of the elasticity of equity prices with respect to the price of the market basket of risky assets, normally proxied by the stock market (here by the S&P 500, exclusive of dividends).[14] Because it is a measure of sensitivity to non-diversifiable risk factors, the magnitude of beta can be interpreted as being the consequence of *ex ante* discretionary policies employed to manage capital risk.

For the individual bank, the single-index stock market model for the full sample period with a shift in beta at 1979:10 is as follows:

$$BK_t = \alpha + \beta SP_t + \beta_s(SP_t \times D) + e_t \qquad (1)$$

where

BK_t = monthly stock price percentage return (excluding dividends) for the individual bank (closing prices for the last trading day of the month)

SP_t = monthly percentage return (excluding dividends) on the S&P 500 (closing prices for the last trading day of the month)

α = "excess return," excluding dividends for the period in question—i.e., in excess of the return earned for taking on non-diversifiable risk, as measured through beta

β = the elasticity of bank-stock prices with respect to the S&P 500

β_s = shift in β at 1979:10

D = 0, 1 dummy to estimate the shift in β (D = 1 for the second subperiod)[15]

e_t = standard error, interpreted as nonmarket-related, or residual, risk

Equation (1) was estimated separately for each of the 91 banks.[16] The individual bank results were then summarized in Table 3 by reporting the *median* values of the parameter estimates, t-statistics and regression statistics for (1) all 91 banks, (2) the 52 banks in the $1-5 billion size class, (3) the 19 banks in the $5-10 billion size class, and (4) the 20 banks in the $10+ billion size class. In addition, the *percentages* of significant t-statistics are reported along with *median*- t-values.

Table 3
Bank Equity Risk Related to the S&P 500

(Median Values of Individual-Bank Regressions—
1972:08–1982:07, with Dummy Shifts at 1979:10)

	α^1	β_0^2	β_1^2	β shift[3]	R^2	D.W.	σ^1
All Banks	.09	.90	.76	−.13	.28	2.15	6.48
	(.16;3%)	(6.11;100%)	(2.94;91%)	(−.45;20%)			
$1-5 billion	.10	.84	.79	−.03	.24	2.17	6.67
	(.17;4%)	(5.46;100%)	(2.91;92%)	(−.11; 8%)			
$5-10 billion	.09	.97	.84	−.13	.32	2.14	6.80
	(.16;5%)	(6.64;100%)	(3.28;95%)	(−.48;16%)			
$10+ billion	.04	1.16	.63	−.48	.36	2.16	6.26
	(.07;0%)	(8.05;100%)	(2.54;85%)	(−1.74;55%)			

Subscripts refer to pre- and post-1979:10. Figures in parentheses are median t-statistics (against the null hypotheses that the coefficients are zero) and percentages of individual t-statistics that exceed the 5-percent critical level using a one-tailed test (two-tailed for α)—t-critical = 1.66 for one-tailed tests.

[1] Units are monthly percentage changes, nonannualized.

[2] Elasticity of bank-stock price with respect to the price of the S&P 500.

[3] Because the values reported are group medians, the reported shift coefficients do not necessarily equal the differences between the period coefficients.

The results for beta are quite striking. Beta was higher for the largest banks than for the other banks in the first subperiod. By the second period, beta was actually lower for the largest banks than for the smaller banks, and for the largest banks its decline between subperiods was statistically significant. (For the shift coefficient, the median t-value was −1.74 compared with a critical value of −1.66, and 55% of the individual t-values were significant.) This evidence is consistent with the hypothesis that the largest banks (over $10 billion in assets) postured their portfolios to insulate their capital from non-diversifiable, or market-related, risk.[17]

The estimate of beta conveys the sensitivity of bank-stock prices to real economic activity, interest rates and all other "common factors" that impinge on equity prices. The fact that such factors are numerous, complex, and correlated—and that we do not have a reliable structural model to sort them out—means that we cannot identify the individual factors that explain beta. However, we can examine the sensitivity of bank equity capital to interest-rate risk. Tables 4 and 5 present these results.

The regression for sensitivity to interest rate risk is:

$$BK_t = \alpha + \gamma TB_t + \gamma_s (TB_t \times D) + e_t \quad (2)$$

where

BK_t = monthly stock price percentage return for the individual banks (closing prices for the last trading day of the month)

TB_t = monthly percentage return on 1-year Treasury bills for the holding period from the first to the second month of the life of the T-bill (calculated from closing yields on the last trading day of the month)[18]

α = average elasticity-adjusted return differential, excluding bank dividends, between T-bills and bank stocks

γ = elasticity of bank-equity prices with respect to the price of 1-year Treasury bills

γ_s = shift in γ at 1979:10

D = 0, 1 dummy to estimate the shift in γ (D=1 for the second subperiod)

e_t = standard error of the regression

Table 4
Bank Equity Risk Related 1-Year Treasury Bills

(Median Values of Individual-Bank Regressions—1972:08–1982:07, with Dummy Shifts at 1979:10)

	α^1	γ_0^2	γ_1^2	γ shift[3]	R^2	D.W.	σ^1
All Banks	−1.64	2.95	1.99	− .88	.05	2.03	7.74
	(−1.62;44%)	(1.84;58%)	(2.40;88%)	(−.60;12%)			
$1-5 billion	−1.38	2.18	1.95	− .37	.04	2.04	7.78
	(−1.36;29%)	(1.36;42%)	(2.39;87%)	(−.25; 0%)			
$5-10 billion	−1.91	3.95	2.06	−1.58	.06	1.98	7.86
	(−1.70;58%)	(2.18;74%)	(2.63;89%)	(−1.17;32%)			
$10+ billion	−1.93	3.61	1.92	−1.86	.05	2.10	7.63
	(−1.97;70%)	(2.42;85%)	(2.28;90%)	(−1.18;25%)			
S&P 500[4]	−1.11	2.55	0.85	−1.70	.05	1.99	4.51
	(−1.89)	(2.70)	(1.72)	(−1.82)			

Subscripts refer to pre- and post-1979:10. Figures in parentheses are median t-statistics (against the null hypotheses that the coefficients are zero) and percentages of individual t-statistics that exceed the 5-percent critical level using a one-tailed test (two-tailed for α)—t-critical = 1.66 for one-tailed tests.

[1] Units are monthly percentage changes, nonannualized.
[2] Elasticity of bank-stock prices with respect to the price of the S&P 500.
[3] Because the values reported are group medians, the reported shift coefficients do not necessarily equal the differences between the period coefficients.
[4] Estimates reported are for a single regression on the index for the S&P 500, and thus are not median values.

Equation (2) postulates that bank stock prices are affected by T-bill prices (i.e., the inverse of interest rates) with a possible change in the elasticity at October 1979. In equation (2), BK and TB are monthly holding-period *returns* on bank stocks and 1-year Treasury bills, respectively. For debt instruments, holding-period returns are inversely correlated with interest rates (yields). Since stock prices generally are inversely correlated with interest rates (yields), we should expect stock prices to be *positively* correlated with returns on debt instruments (i.e., the sign on γ is expected to be *positive*.) Treasury bills are used as the representative debt instrument because they are default-free and are pure discount instruments (that is, they bear no coupons), and hence, have a constant duration regardless of the level of interest rates.[19]

In Table 4, results from equation (2) are presented for the 91 individual banks and for the S&P 500. These results show that interest rates have a significant effect on the equity prices of banks and the S&P 500 in both periods. For the bank stocks, interest rate sensitivities do not increase in the post-1979 period, and tend to decrease for some of the banks in the two larger size groups. (The R^2 is surprisingly small for all regressions, however, indicating that interest rates explain only a small portion of stock-price variance.)

Interest rates ought to affect bank stock returns in at least two ways. First, if banks make contracts whose payment streams are fixed in nominal dollars (e.g., fixed-rate mortgages), then unexpected changes in *nominal* rates should affect the market value of the bank's portfolio depending upon the extent to which interest rate risk is more or less hedged. Second, unexpected changes in the *real* interest rate should affect the present value of expected dividends attributable to taking on risk, generating information needed for lending, and providing operational services. The latter effect is similar to that impacting on all equities, not just bank stocks, and the extent to which only the real rate affects equities depends on the extent to which real corporate earnings are hedged against inflation.

In the bottom line of Table 4, it is apparent that S&P 500 returns are sensitive to interest rates. The sensitivities are significant in both periods, and there is a significant downward shift in the relationship.[20] The large downward shift in interest-rate risk sensitivity for the S&P 500 between the two subperiods is perplexing. Since equity valuation ought to be sensitive generally to changes in the *real* interest rate, two possible explanations come to mind. Either there was a structural shift in the way the market evaluated the effect of *real* interest rate changes on the present value of equities after 1979, or the market attributed a larger proportion of *nominal* interest rate volatility after 1979 to changes in the inflation premium. Although some research has concluded that variability of inflation premia has caused much of the variability in debt yields since October 1979, other research disagrees. The downward shift in the S&P 500's sensitivity to interest rates requires further study.[21]

In light of the results for the S&P 500 in Table 4, it is possible that much of the response of bank stocks to interest rates is felt through a change in the discount rate applied to the expected dividend stream rather than through any specific effect of interest rates on banks' portfolios. To test this hypothesis, the right-hand variables for returns on the S&P 500 and 1-year T-bills were entered simultaneously within a single regression:

$$\begin{aligned} BK_t = {} & \alpha + \beta SP_t + \beta_s(SP_t \times D) \\ & + \gamma TB_t + \gamma_s(TB_t \times D) + e_t \end{aligned} \quad (3)$$

where the variables are defined as before.

Equation (3) postulates a two-factor market model in which bank stock prices are related not only to "common factors" as reflected in the S&P 500 but also to an additional "interest rate" factor beyond that already reflected in the S&P 500. Although multi-index models often are estimated by first orthogonalizing the right-hand variables relative to one another, this method causes an unjustifiable upward bias in the t-statistics and, therefore, the method of ordinary least squares is used in this paper.[22] (As suggested by the low R^2 of .05 in the bottom row of Table 4, multi-collinearity between SP and TB should not present an estimation problem).

The results reported in Table 5 help to confirm the implication that arises from comparing the bank stock results of Table 4 with the S&P 500 results: that the interest rate effect on bank stock prices is not very different from the general effect of interest rates on common stocks. Although γ in Table 5 is positive in both periods, it is significant only in the second period. Moreover, its magnitude is reduced from the estimates in Table 4, and it adds little explanatory power over the regressions on beta alone in Table 3.[23] The perplexing behavior of interest rates in the latter period generally makes it difficult to speculate on the economic reasoning behind the results in Table 5.

Table 5
Bank Equity Risk Related to the S&P 500 and 1-Year Treasury Bills

(Median Values of Individual-Bank Regressions—
1972:08–1982:07, with Dummy Shifts at 1979:10)

	α^1	β_0^2	β_1^2	β_{shift}^3	γ_0^4	γ_1^4	γ_{shift}^3	R^2	D.W.	σ^1
All Banks	−.60	.90	.64	−.21	.65	1.39	.65	.29	2.19	6.50
	(−.69;12%)	(5.93;100%)	(2.55;82%)	(−.67;25%)	(.53; 9%)	(1.94;66%)	(.50; 9%)			
$1-5 billion	−.42	.82	.65	−.13	.31	1.38	1.13	.25	2.19	6.63
	(−.46;10%)	(5.31;100%)	(2.46;83%)	(−.48;15%)	(.22; 2%)	(1.91;69%)	(.88;12%)			
$5-10 billion	−.82	.88	.80	−.21	1.42	1.43	.10	.34	2.17	6.58
	(−.77;21%)	(6.05;100%)	(2.79;89%)	(−.85;16%)	(.85;21%)	(2.01;68%)	(.06; 5%)			
$10+ billion	−.93	1.13	.54	−.58	1.23	1.29	−.05	.39	2.15	6.21
	(−1.03;10%)	(7.62;100%)	(2.23;75%)	(−2.02;60%)	(.95;15%)	(1.84;55%)	(−.03; 5%)			

Subscripts refer to pre- and post-1979:10. Figures in parentheses are median t-statistics and percentages of individual t-statistics that exceed the 5-percent critical level. (One-tailed tests for negative shift for β and positive shift of γ; two-tailed test for α)—t-critical = 1.66 for one-tailed tests.

[1] Units are monthly percentage changes, nonannualized.
[2] Elasticity of bank-stock prices with respect to the price of the S&P 500.
[3] Because the values reported are group medians, the reported shift coefficients do not necessarily equal the differences between the period coefficients.
[4] Elasticity of equity prices with repect to the price of 1-year Treasury bills.

III. Summary and Conclusions

The evidence presented here indicates that the post-1979 economic and regulatory environment did not significantly increase the capital risk of banks (and bank holding companies) with over $1 billion in assets. With the exception of the Credit Control period (March-July 1980), the risk premium on debt capital of the fifteen institutions rose very little above its low level of 1977-79 and remained well below the high debt-risk premium period of 1975-76. Moreover, the standard deviations of equity returns for the 91 institutions with assets of $1-121 billion were lower on average in the post-late-1979 period than in the 1972-1979 comparative period. For the largest institutions ($10+ billion), the standard deviation of equity returns even declined in comparison to that of the S&P 500.

The sensitivity of bank equity to common risk factors, as measured by the equity beta, also declined in the post-1979 period compared to the earlier period, and the decline was statistically significant for over half of the twenty banks in the $10+ billion size group. For the twenty largest banks, the median beta declined from 1.16 to 0.63. This evidence suggests that investors perceived the capital of these banks to be more insulated from common risk factors (economy-wide interest-rate, earnings, and bankruptcy risk) in the post-1979 period than in the earlier period.

Although bank equities are sensitive to interest rates, the sensitivity did not increase in the post-1979 period, and declined significantly for some of the banks in the two larger size groups. However, the general stock market sensitivity to interest rates declined significantly, and by a comparatively greater amount. After taking account of the change in general sensitivity of the stock market to interest rate volatility, as reflected in beta, the specific sensitivity of bank stocks to interest rates was reduced considerably, and was statistically significant only in the post-1979 period. Given the perplexing behavior of interest rates in the latter period, it is difficult to draw firm conclusions regarding changes in the effect of interest rates on bank stock prices.

The post-late-1979 period is regarded generally as having been a turbulent period for inflation, economic activity, interest rates, and banking deregulation. The evidence of stable capital risk for banks of over $1 billion in assets (and declining betas for the $10+ billion banks) is encouraging, although not necessarily surprising in view of the fact that banks with assets over $1 billion are regarded generally as being relatively well-insulated from interest rate risk and the adverse consequences of deregulation.

The result could be attributed to investor perceptions that regulators (particularly the insuring agency) and legislators increasingly protected the capital holders of large banks, or to discretionary policies by the managements of these banks to reduce the risk of their capital by altering their portfolios, operations, and capital leverages. Although one cannot determine from the data whether the relative stability of bank capital risk is due to perceived regulatory protection or discretionary policies by bankers, the author is inclined to suspect the latter (Beebe, 1977).

FOOTNOTES

1. Because investors in capital markets can manage the risk of their total wealth by diversifying their portfolios, the capital markets do not dictate a unique set of preferences, and hence an optimal level of risk, *vis-a-vis* any single investment or group of investments such as bank debt or equity.

2. The data end in July 1982 simply because they were assembled in the Fall of that year. Passage of the Garn-St Germain Act would not have affected the data, as its passage was not anticipated prior to about September 1982.

3. For example, it is possible that investors simply perceived banks as being more protected by government policies in the turbulent post-1979 period and hence bank capital values became less volatile than they otherwise would have been.

4. The evidence turned up what appears to have been an increase in bank capital risk beginning in 1982. This development is not examined in the paper because the sample period ends in July 1982. It is the subject of a subsequent study by the author.

5. See especially Flannery (1981 and 1982) and Flannery and James (1982 and 1983) on interest rate risk of banks. The impetus of much of this paper comes from their work.

6. There is a longstanding, albeit unpersuasive, argument that the removal of deposit ceilings would have caused bankers to preserve earnings spreads by investing in riskier assets. Benston (1964) calls this postulated effect the "profit-target" hypothesis, as opposed to the "profit-maximum," hypothesis. See Mingo (1978) for a discussion.

It is unlikely that the profit target hypothesis had merit even at a time when most or all of banks' liabilities were subject to ceiling rates. Even if deposit ceilings were binding on all bank liabilities, profit-maximizing banks would raise additional funds by bidding up the marginal cost of funds to market-equivalent yields through non-interest concessions. Deposit ceilings would lower the marginal cost of funds for profit-maximizing banks only if the ceilings somehow also lowered the yield on all the non-bank alternatives available to depositors (both personal and commercial)—an unlikely prospect.

Particularly in recent years, however, deposit ceilings have pertained only to some bank liabilities, and banks clearly have paid explicit interest at market rates in the unregulated commercial deposit and non-deposit markets for their marginal funds. It is difficult, therefore, to argue that removing deposit ceilings would lead banks into riskier assets, as removing the ceilings would change only the average cost of funds, not the marginal cost.

7. In an earlier paper, the author examined the aggregate bank portfolio over the post-WWII period in an effort to explain how banks had employed active liability management to affect their growth and risk postures (Beebe, 1977). A clear picture emerged that both growth and non-diversifiable risk exposure of large banks accelerated during the 1960s and early 1970s. (The average equity beta of large banks rose from 0.5 to 1.1 between the late 1950s and early 1970s.) The author postulated that in response to the riskier economic environment of the mid-1970s, large banks might reduce their risk exposure. This result is borne out in the present study, as the beta for banks over $10 billion in assets declined from 1.2 to 0.6

8. The author thanks Chris James of the University of Oregon for providing the names of DRI banks with well-behaved stock price series. The list of banks in this study differs from the samples in the various studies done by Mark Flannery and Chris James. They restricted their sample to holding companies with identifiable lead banks. The present study consists of holding companies and banks

that are listed by Compustat and that have monthly stock price data dating back to 1972 in the DRI database.

9. Month-end quoted yields were obtained from Moody's Bond Record, and information on the bonds, from Moody's Bank and Finance Manual. Reliable data were available for only 15 bank holding companies and banks. The bonds were issued between February 1971 and March 1974. All had call options after 10 years at par or slightly above, and all carried coupons such that they initially sold approximately at par. Eleven had initial maturities of 25 years and four had maturities of 30 years.

There is a dearth of regularly traded bank debt issues in the secondary market. Even for these 15 issues, which Moody's considered to be frequently traded, statistical analysis of the monthly returns indicated that the bonds were not always traded at month-end. Serially correlated errors in the returns with respect to the returns on broad bond indices implied average lags of over a week, a sign of infrequent trading and/or data that are based on bids rather than actual trades. For this reason, bank bond risk premia are reported only in graphical form.

10. In Charts 1 and 2, risk premia were divided by the level of interest rates because the change in yield (or yield differential) is directly proportional to the level of yields for any given holding period percentage return.

The increased variance after October 1979 in the Bank/Aaa differential in Chart 1 may be due to short-run discrepancies caused by infrequent trading of bank bonds during the period of great day-to-day volatility in bond prices. Aaa and Baa rates are for the last trading day of the month. Although reported bank bond rates are also quoted for the last trading day of the month, statistical tests indicated infrequent trading throughout the entire sample period, in that yields lagged behind those of the broad indices (See footnote 9).

11. Bank equity data are common stock prices as of closing on the last trading day of the month. Monthly percentage returns are calculated as percentage changes in price. Returns exclude dividends because dividend data were not available. Lack of dividend data seriously affects calculations of *average* returns (as in Table 1) but has little effect on the measures of the *variability* of returns used in the regressions and reported in Tables 2-5.

12. Differences in dividend policies are unknown to the author. Dividend differentials could have a substantial effect relative to such a small discrepancy.

13. Because the S&P 500 is a portfolio of diversified stocks, its standard deviation understandably is below the average standard deviations of its component issues and of the individual bank issues. While the absolute level of the bank standard deviations relative to that of the S&P 500 conveys no meaning, changes over time are meaningful.

14. Given the wide variations of price returns using monthly data, omitting dividends affects estimated betas only slightly. Returns are sometimes expressed in excess of the risk-free rate of return, a nuance that also has little effect on empirical results. Ideally, in place of the S&P 500, one would use returns of a value-weighted index of all risky assets, including debt and real estate. Such an index does not exist.

15. The t-statistics for β in the second period (β_1 in Table 3) were obtained by running the same specification, substituting (0, 1) multiplicative dummies for both of the subperiods. This technique was used to obtain second-period t-statistics in Tables 4 and 5 also.

16. All of the regressions in the paper (Tables 3-5) were run with and without the Credit Control period (March-July, 1980). The omission of these months made almost no perceptible difference, and so the regressions reported in the paper include the Credit Control period.

17. In work reported earlier, the author argued that such a shift might occur. (See footnote 7.)

18. TB in equation (2) is the 1-month return on a *new* 1-year Treasury bill held for one month only. Month-end effective yields (not discount yields) are from the DRI-FACS database with back data from Bank of America. The formula used to convert yields to monthly returns at monthly rates is:

$$\left\{ \left[\frac{1 + \frac{Y_t}{100}}{1 + \frac{Y_{t+1}}{100}} \right]^{11/12} - 1 \right\} \times 100.$$

19. It is known that for bonds with fixed coupons, the duration (the present-value-weighted effective maturity of all the payments—coupons and principal) varies inversely with the level of interest rates. This effect would alter a relationship between BK and coupon-bearing bonds, and thus would make interpretation of γ difficult. A T-bill has only a single payment at maturity and hence its duration is always its stated maturity, regardless of changes in the level of rates. The duration of TB at the beginning of each monthly holding period is a constant value of 12 months, regardless of the level of interest rates.

20. One has to take care in interpreting the higher t-statistics and lower standard error for the S&P 500 equation compared with the individual bank equations in Table 4. Part of the higher significance results from the fact that the S&P 500 index represents a diversified portfolio.

21. The perplexing behavior and interpretation of interest rates in the post-late-1979 period has been explored by Evans (1981) and others. His study and others do not fully explain post-1979 interest rate behavior.

22. There are several papers analyzing stock prices using orthogonalization, or more generally, principal components. All are subject to the criticism of overrated significance. (For an interpretation of these methods, see Fogler, John, and Tipton, 1981). Recently, papers by Flannery and James (1982 and 1983) have found significant effects of interest rates on bank stock prices. These papers use only that portion of stock market returns *orthogonal to debt returns* in an equation like that of equation (3). The measured interest rate elasticity is then the total effect (direct and through the stock market) of the interest rate on bank

stocks. Orthogonalization sidesteps the fact that SP and TB are jointly determined in a structural model of the economy. Besides overstating the resulting t-statistics, it ignores possible structural changes between these two important macroeconomic, endogenous variables. The significant shift variable in the S&P 500 equation in the bottom line of Table 4 indicates structural change between interest rates and the stock market between the two superiods.

23. The R^2 values are improved very little over those reported using beta alone (Table 3). F tests on the 91 individual bank regressions to test the significance of adding the interest rate parameters—i.e., testing for improved regression fit for the specification in Table 5 over that in Table 3—show critical F-values (95 percent confidence) in 25 of 91 cases.

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Pricing Debt Instruments: The Options Approach

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As interest rates have become more volatile, participants in financial markets have become more aware of the need to accommodate interest rate uncertainty in the design of their portfolios. This increased awareness has led to a rise in the demand for mechanisms capable of transferring interest rate risk between the parties to a transaction.

One of these mechanisms is the trading of options on debt securities such as Treasury bills and Treasury notes. These instruments, traded on organized exchanges, give the holder the option to buy or sell a debt security at a predetermined price within a specific time frame. As such, they help a market participant avoid the effect of interest rate risk on the value of his portfolio. However, the investor in debt options must be able to determine whether the option is "over-" or "underpriced" from his standpoint compared to the price determined by the market.

A similar observation may be made concerning the pricing of liability products by depository institutions. Fixed rate bank or savings and loan time deposits, for example, traditionally offer a fixed return over the term with significant penalties for premature liquidation. In a period of volatile interest rates, the choice of the combination of the deposit rate and the early withdrawal penalty can critically affect the marketability of the fixed rate deposit instrument in comparison to a more nearly variable rate instrument such as money market mutual fund shares.

Thus, financial institutions, like investors in debt securities, also face the difficulty of determining the appropriate price of an option—in their case, the early withdrawal option inherent in their fixed rate deposits. There is certainly some "price" at which a financial institution with a given set of interest rate expectations would be willing to market a deposit with given early withdrawal features. But many financial institutions may not have enough confidence in their ability to translate their interest rate forecasts into appropriate prices.

The purpose of this paper is to present the results of some new experiments with a debt instrument pricing methodology. The methodology is based on options theory and recently developed pricing techniques. Its application is illustrated first by pricing the recently approved "put" options on government securities and comparing simulated results with market outcomes. The methodology is then used to illustrate the applicability of options pricing in an indirect context, namely, that of evaluating policy regarding early withdrawal penalties on deposit liabilities. In each case, options are involved and the methodology relates the "prices" of these instruments to interest rate forecasts. The empirical estimates presented are not intended to apply directly to a particular options pricing problem. They are intended instead to illustrate the sensitivity of rational debt instrument prices to interest rate forecasts (and the features of the instruments) and the usefulness of the options perspective to both investment analysis and policy problems.

Two specific results come from our analysis. First, in the simulation of options on Treasury notes, the options prices obtained by the pricing model are good approximations of the prices at which options on Treasury notes have recently traded. Second, our estimates of early withdrawal option prices suggest that the combination of regulated rates and the penalty structure that existed in the 1970s (particularly on fixed rate deposit instruments of less than one year) may have put depository institutions at a severe competitive disadvantage in marketing their deposit services against other instruments in the marketplace.

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The remainder of the paper is divided into four sections. In the first, the basic theory of options pricing is presented. The second section expands this discussion and focuses on the pricing of options on debt securities. In addition, we present the methodology incorporated in our computations in this section. The valuation methodology is tested by pricing Treasury note options. In the third section, the methodology is applied to the valuation of early withdrawal penalties. The fourth section concludes the paper with a discussion of the policy implications and limitations of current pricing methodologies.

I. Options Theory

We often think about options in the context of marketed options, such as those on corporate shares traded on organized exchanges since 1973, or options on certain Treasury securities that have been traded on selected U.S. exchanges since 1982. In its most general form, however, an option is simply a contract—or stipulation within a contract—that gives the owner of the option the right to trade in some asset at a defined price any time on or before a given date (the "exercise" date). From this perspective, many conventional financial agreements contain options, and these implicit options can be analyzed in the same fashion as explicitly traded options.

For example, a corporate bond that is issued with a call provision giving the corporation the right to buy the bond back at a stipulated price, in essence, contains an option. Specifically, it contains a call option because it gives the *owner* (the corporation) the right to acquire ("call away") an underlying security (the bond) from the lender (who would also be called the option *writer*). The price stipulated in the bond indenture is called the *exercise* price.

Similarly, the ability to withdraw funds from a deposit account gives the depositor the option to force the borrower of the funds (the depository institution) to buy back the deposit instrument—in options terminology, to "put" the deposit on the borrower. The early withdrawal feature is thus a *put option* owned by the depositor.

Whether or not a particular option is traded in the market as an independent security, it should have value. If it is also part of a more complicated securities contract, it should influence the price of the underlying securities contract. Indeed, options in some sense are the fundamental building blocks of more complex financial instruments. Thus, even a complete instrument could be valued if it were decomposed into its constituent options, each of which would be a simpler instrument and easier to value.

Pricing Options

The price of an option, whether explicitly traded as a separate security or not, depends upon expectations of future economic conditions as these affect the value of the underlying security. In the abstract, the prospective and contingent nature of options would appear to make evaluation of an option extremely difficult because future conditions are never known with certainty. Nonetheless, financial economists have devised methods of evaluating such contingent claims.

The analytical breakthrough in this area came in 1973 with the work of Black and Scholes.[1] They reasoned that an option could be valued by inference from the value of portfolios that contained the option. Specifically, Black and Scholes used the idea of a riskless hedge—a portfolio consisting of the option and its underlying security constructed to yield the riskless return. The price that the investor will be willing to pay for the options necessary to construct a riskless version of such a hedge will depend upon the riskless return available elsewhere as well as the anticipated scenario of the stock price movements.

Although the underlying security may take on a wide range of values, Black and Scholes were able to derive an analytical formula for the price of an option on corporate stock by relying on very general assumptions about the stochastic nature of stock price movements, the current price of the stock, and an assumed riskless real rate of return.[2] Although the user of this formula must provide the estimates of the variability of the stock's future price movements, the implication of the Black/Scholes work is that the price of the option is otherwise unambiguous.

The Black/Scholes formula applies only to options on corporate stock, but the notion of inferring options values from riskless hedges and alternative future values of the underlying security has enabled other researchers to apply the idea to the valuation of options on debt securities as well. The application of options valuation to these instruments, however, is somewhat more complex because the value of the underlying security is likely to move in a complex fashion as interest rates change. In other words, although it may be reasonable to assume that interest rates move in a random fashion about some trend, for example, it is not reasonable to assume that the value of debt securities moves similarly. If the underlying instrument is a bond, for example, the response of the value of a new bond to movements in interest rates may be very complex depending upon the bond's features (e.g., the number and timing of coupon payments); nevertheless, the value of the bond is virtually known with certainty toward the end of the bond's life.

As a result, it is difficult to derive a purely analytical debt option valuation methodology, except for specific underlying securities.[3] The generalizable approaches thus tend to consist of numerical approximation techniques.

Numerical Approximation

Numerical approximation techniques rely upon the observation that a continuous process (such as movements in the value of a security) can be divided into discrete steps without losing the essential features of the process. Since there are theoretical relationships between certain discrete statistical processes and continuous statistical processes, the valuation can be made to depend upon a few simple parameters, much in the spirit of the original Black/Scholes analytical approach.

An example may help to clarify this point. Let us assume that risk-free nominal interest rates move in equally probable discrete steps or jumps (either up or down) and that the magnitude of the movements up or down does not change over time. In Chart 1, for example, we show alternative paths for the interest rate over three future time periods, assuming that a jump "up" always multiplies the interest rate by a factor of 1.1 and a jump "down" by .9. This tree of movements in interest rates can be translated into a tree of prices for a debt instrument because its value in any given period depends upon the path which interest rates may take between now and some future time period. By working backwards from the date the instrument matures (when the value of the bond is known with certainty), all values of the debt corresponding to each interest rate value on the interest rate tree can be computed.

With the tree of values of the underlying debt, the *value* of the option on the debt instrument, were it to be exercised, can be computed for each branch of the tree as well. With this information and the basic notion of a riskless hedge, it will be shown below that it is possible to derive the option's appropriate *price* at any branch of the tree.[4] Thus, if the discrete interest rate movement process could be shown to approximate a continuous process in a reasonable fashion, options on instruments with quite complex features could be valued.

This approach to pricing options has been used by a number of analysts,[5] but most notably by Rendleman and Bartter.[6] The arithmetic of the computations is quite simple. The contribution of these authors was in relating this simple binary interest rate movement process to the continuous movement that can be expected in the real world. In particular, they showed that the "up" and "down" jump ratios can be manipulated to incorporate various underlying assumptions about the trends in interest rates and the variance of their movement about that trend.

The numerical approximation technique, therefore, yields a valuation methodology that uses inputs that are almost as simple as those required by the original Black/Scholes formula for corporate stocks—only forecasts of the trend and variance of interest rates need be provided. Once the precise features of the underlying security and its option are imbedded in the procedure, the value of the option under different interest rate movement scenarios can be computed easily.[7]

II. Valuing Options on a Bond

In this section, we will make our presentation more specific by pricing a put option on a coupon bond. A coupon bond is a general instrument and procedures applicable to it are broadly applicable to other instruments. For ease of exposition, we focus on a specific option and bond: a put option with the same life as the underlying bond. In other words, lives of the option and the bond are both assumed to be T periods. Later on, we will use the methodology to value bond options that are actually traded, in which case the option life is shorter than the bond maturity. We emphasize, however, that the procedure is a very general one despite the simplifying assumption of the example. Our numerical approximation technique is a modification of the methodology of Rendleman and Bartter[8] and involves a sequence of modelling steps beginning with the specification of the process of interest rate movements.

Interest Rate Pattern

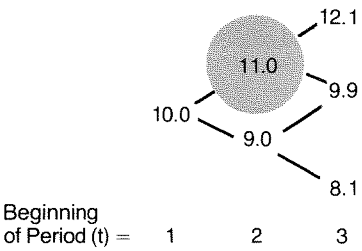
We will use the following example to illustrate the process. As in other examples discussed earlier, we shall assume that the short term risk-free interest rate one period in the future can take one of two values: Z^- denoting a fall in the interest rate and Z^+ denoting a rise in the interest rate. (In this paper a plus superscript indicates an increase in a variable and a minus superscript a decrease). The risk-free interest rate in period t takes one of the following values:

$$I^-_t = Z^- I_{t-1}$$
$$I^+_t = Z^+ I_{t-1}$$

We assume further that the values of Z^- and Z^+ are constant over time, and that each year there are only a finite number of times that interest rates can move (N). In addition, the life of the bond is assumed to expire at the beginning of the T + 1 year. In the general case, a binomial tree would generate 2^{TN} values in the last period. However, since we assume that the Z^+ and Z^- ratios remain constant over time and that the relationship between interest rates over time is multiplicative, we obtain the following interest rate tree which has only TN values in the final period:

Chart 1

Interest Rate Tree



To find values for Z^+ and Z^-, we need to make assumptions regarding the statistical properties of interest rate movements. If we assume that the probabilities of the two states are constant over time, then the logarithm of Z (denoted z) can be said to be drawn from a binomial distribution with annual mean of

$$M = N\,[Z^+W + Z^-(1-W)]$$

and annual variance of

$$S^2 = N[(Z^+-Z^-)^2\,W\,(1-W)]$$

where

N = Number of periods per year and
W = Probability of Z^+.

The result is important for two reasons. First of all, for large N and for W = .5 (an assumption employed in our work), the binomial distribution approaches that of the lognormal. This means that under these assumptions, the interest rate jump process approximates a state of the world in which the instantaneous riskless interest rate follows a lognormal distribution. Second, if one knows M and S one can solve for Z^+ and Z^-.

On a more intuitive level, M can be thought of as a measure of the annual geometric drift[9] of the mean interest rate, while S is a measure of the dispersion of interest rates around the mean. The drift and dispersion parameters, a part of the option pricing process, must be forecast by the pricer of the option. In the empirical work that follows, we obtain simple forecasts of the drift and dispersion of the interest rate by econometrically estimating the historical drift (and dispersion about that drift) of short-term interest rates.[10] We vary these parameters considerably in our analysis.

The purpose of employing an empirically derived forecast is simply to provide a benchmark for the various values of the mean and drift employed. These values are by no means offered as sophisticated or definitive forecasts.

Bond Pricing Under Uncertainty

In pricing the bond, we employ the pure expectations hypothesis under which, at any time t, the bond should be priced so that its expected return (over time t−1 to t) is the rate earned on a default-free discount bond. That is, its value in period t−1 should be equal to its expected value (plus any coupons) in period t, discounted at the risk free rate, or

$$D_{t-1} = \frac{E(D_t) + C/N}{(1 + I_{t-1})^{1/N}}$$

where

D_t is the bond price in period t
$E(D)_t$ is the expected bond price in period t
C is the annual coupon payment
N is the number of periods per year.

Since the expected bond price in the terminal period (that is, T+1) is its face value ($100), the bond pricing formula for period T is:

$$D_T = \frac{100 + C/N}{(1 + I_T)^{1/N}}$$

As discussed earlier, the interest rate in period T can take on T possible values. Thus, there are T possible bond prices in this period. In the preceding periods, the expected bond price is the discounted average of the two possible bond prices in the next period. The bond prices can then be determined recursively using a tree of the same form as the interest rate tree.

Pricing the Option

Now we have all of the elements necessary for pricing the option. As stated earlier, the basic pricing method is based upon the notion that one can form a riskless hedge by purchasing the right combination of a bond and its option. If the price of the bond increases or decreases, that of the option will move in the opposite direction, offsetting the effect of the bond price movements in the yield of the portfolio, at least for small bond price changes. In the case of put options, for every $1 invested in a bond at time t − 1, the number of put options that should be purchased is

$$\frac{(H_t^- - H_t^+)}{(V_t^+ - V_t^-)}$$

where

$$H_t^+ = (D_t^+ + C/N)/D_{t-1}$$
$$H_t^- = (D_t^- + C/N)/D_{t-1}$$

and

V_t^+ = value of option if the price of the bond increases,

V_t^- = value of option if the price of the bond decreases,

Simply stated, this formula tells us that as the possible variability in bond prices increases (i.e., as D_t^+ and D_t^- diverge) so does the need for a hedge. If there were no possibility of variation in bond prices, H_t^+ would equal H_t^- and no options would be needed to form a riskless hedge.[11]

Since the joint investment is riskless, the option should be priced to earn the riskless rate of interest. Rendleman and Bartter have shown that this price is

$$P_{t-1} = \frac{V_t^+ [(1+I_{t-1})^{1/N} - H_t^-] + V_t^- [H_t^+ - (1+I_{t-1})^{1/N}]}{(H_t^+ - H_t^-)(1 + I_{t-1})^{1/N}}$$

To use this formula, we must first calculate the value of the option (V) in each period. In doing so, we must consider the alternatives facing the option holder at the beginning of each period. If he exercises the option, its value is just the difference (call it VEXER) between the exercise price and the market price of the bond. Otherwise, the option's value is the price at which he could sell it. Since the investor is assumed to be rational, the value of the option to the investor will be the larger of these two numbers.

We know that the price of the option is zero in the last period of its life, since it cannot be exercised after it has expired. And we know VEXER because the price of the bond and the exercise price are known for each period. Thus, by beginning the option pricing process in the last period of the option's life, it is possible to use the pricing formula above to determine the option price one period earlier. We repeat this process until we reach period 1 and obtain the initial price of the option.

Options on Treasury Notes

As a simple test of the methodology presented above, we will use the valuation technique to price a real world instrument. There are a number of options on currently traded government debt securities that could be priced using this technique, but we have chosen options on 10-year Treasury notes being traded on the American Stock Exchange (AMEX) because the features of these options are most like those of the hypothetical instrument described.

Before proceeding with the demonstration, some differences between the Treasury note options and our hypothetical options should be noted. First, the options on T-notes which Amex is trading are available with March, June, September, and December exercise dates, with the option expiring the Saturday following the third Friday of the expiration month. This differs from the hypothetical instrument discussed above in that the life of the option is not the same as that of the bond. Second, the bond pays interest semiannually, while the equivalent coupon in our hypothetical model is paid continuously. Third, in the real world, costs such as brokerage and settlement fees must also be considered.

To keep the exposition as straightforward as possible, we will not attempt to incorporate all these differences into our model. Instead, we will employ the model as outlined in the previous section, with the exceptions that we shall assume the life of the option to be 3 months and, of course, give the note a 10-year maturity instead of the arbitrary maturity used before. Finally, there are several exercise prices for the option offered in the AMEX instrument. These are stated as if the value of the underlying instrument were \$100. For simplicity, we employ only the exercise prices 96, 100, and 104 dollars because they are the major exercise prices on recently traded instruments.

Interest Rates and Option Prices

As we have already stated, the primary function of an option is to protect the owner against future interest rate fluctuations. In the case of a put option on a T-note, for example, the owner is protected against upward movements in interest rates. Given that expected interest rate changes play such a central role, two features of these changes should each be a major factor in determining the price of an option: the magnitude of expected changes and their associated uncertainty. In other words, the higher one expects interest rates to rise during the life of the option, and the more uncertain one is about future interest rates, the more one would value protection against such fluctuation and the higher the price one would be willing to pay for the option. Thus, one of the factors which we shall test is the sensitivity of the price of the option on the T-note to different interest rate scenarios. These results will then be compared to the prices of options actually traded.

Table 1
Estimated Interest Rate Drift and Dispersion: Varous Periods, 1978–1983

Estimation Period (Year, Month)	**Drift (M)**	**Dispersion (S)**
81.04 - 83.03	−.10	.42
81.02 - 83.01	−.06	.41
80.11 - 82.10	.02	.40
80.08 - 82.07	.08	.34
80.05 - 82.04	.10	.33
80.02 - 82.01	.16	.34
79.11 - 81.10	.24	.29
79.08 - 81.07	.23	.28
79.05 - 81.04	.18	.22
79.02 - 81.01	.23	.20
78.11 - 80.10	.25	.21

Source: see text

Analysis and Results

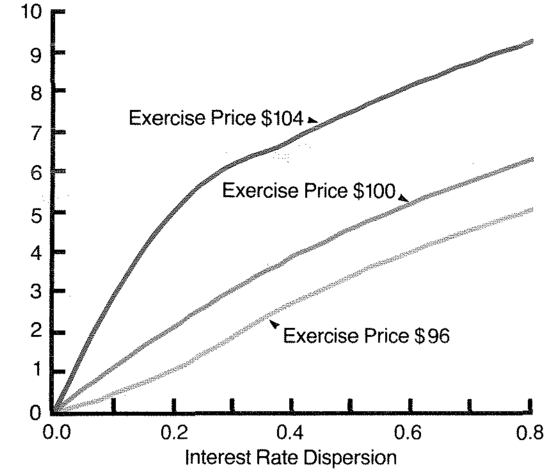
Although we are not attempting to price particular options, the sensitivity analysis is more useful when based on a realistic interest rate range. To devise a forecast for interest rate movements that simulates what the market may be using, we use a simple time-series econometric model and extract from it the two main parameters of the option pricing model, M and S.[12] The first parameter represents the trend or drift followed by the interest rate, while the second represents the variability of uncertainty about the forecasted trend. The results of this estimation process for various periods are presented in Table 1. Because T-note options were first traded in late 1982 and we wish to value the instruments as of December 1982, we choose the values .02 for M and .40 for S from the table. The final parameter needed is the initial interest rate. We use 8.53 percent because it was the interest rate on one-month commercial paper in December 1982.

The sensitivity analysis performed uses these parameters. We start the analysis by allowing the forecast dispersion, S, to change while holding the trend or drift term, M, constant. The results from the exercise are presented in Chart 2, and are consistent with simple intuition about options pricing. First, as expected, the option price increases as interest-rate dispersion increases. Second, and also as expected, the option has no value even when there is a positive interest rate trend. The latter indicates that even an expected rise in interest rates would not give an option value if the rise were known with certainty.

Next, we vary the trend term while holding the

Chart 2

Option Price/Interest Rate Dispersion with Historic Interest Rate Trends*



*This graph assumes that the underlying instrument has a face value of $100.

dispersion term constant. The results, presented in Chart 3, are again what one would expect. The price of the option increases when the trend is toward higher interest rates, since the likelihood of the option being exercised profitably is higher when interest rates are expected to rise. One should note that even with a negative trend term, the option will have a positive value if the dispersion term is large enough. This means that market participants may wish to purchase an option to protect themselves against the possibility that interest rates may rise when they expect rates to fall, if they were not certain interest rates will in fact fall.

Finally, we compare the option prices estimated by the model with those actually traded. The price of the note and its option calculated from the model using the forecasted interest rate parameters (i.e., M = .02 and S = .40) with strike prices of 96 and 100 are $2.73 and $3.88 per $100 of face value of underlying note, respectively. The prices of options on a similar note actually traded on AMEX on December 21, 1982, were $.87 and $2.69, respectively. Clearly, the model produces simulations that are within the same order of magnitude as the actual prices of the options traded.

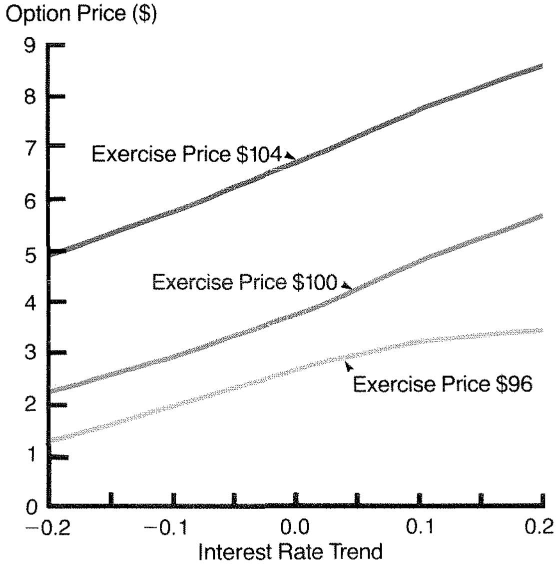
Some differences between actual and simulated prices should not be surprising. For one, the model does not incorporate transactions costs. The exclusion of such costs tends to bias th[illegible] tions upward, since the net proceeds of exercising the option would otherwise be lower by the amount of the costs. Transactions costs are particularly important in light of the current thinness of the existing AMEX options market.

A second possible source of divergence is our forecast of interest rate trend and dispersion. As the previous section on sensitivity analysis indicates, the option prices calculated by the model are greatly affected by the interest rate parameters used. Thus, if our forecast of interest rate trend and dispersion is different from that of the market, then the option price calculated by the model will differ from the actual option price. In this regard, however, we have another piece of data to corroborate the results: the price of the underlying T-note. The simulated note prices are within one percent of the prices of the notes underlying the actual options traded. This does not guarantee that our forecast parameters are correct, but it does suggest that the model is at least pricing the option and the note consistently.

A more subtle potential problem with the model is that by employing the pure expectations hypothesis, it leaves no room for specifying the utility

Chart 3

Option Price/Interest Rate Trend with Historic Interest Rate Dispersion*



structure of wealth. That is, the degree of risk-aversion is not a parameter of the model. Although explicit inclusion of a risk aversion parameter in the bond pricing formulae may be desirable (and, indeed, has been tried by other investigators), the addition of a third parameter makes our presentation more cumbersome and is unlikely to yield radically different results when applied to short-term instruments.[13]

In light of the imperfect means available to incorporate the factors relevant to options pricing, the Rendleman-Bartter model, on the whole, approximates the real world reasonably well.

III. An Application to Early Withdrawal Penalties

Besides simulating the prices of traded options on debt securities, the options pricing methodology developed in Section II can be applied to more general policy issues regarding debt instruments. An example is the evaluation of early withdrawal penalty features of fixed rate deposit instruments.

Fixed rate deposits, unlike other instruments of the same maturity offered in the marketplace, include an early withdrawal provision that allows the depositor to liquidate the account and obtain the par value of the account less a pre-stipulated penalty. In the presence of uncertainty regarding future interest rates, the early withdrawal provision should increase the value that investors place on the underlying instrument, while the pre-payment penalty, which exercising the provision entails, should have a negative effect. Thus, the early withdrawal structure as well as the rate structure are important factors in pricing a deposit account in relation to other investment opportunities.

Historically, early withdrawal penalties and deposit rates were largely determined by regulation. Deposit rates were either regulated directly or linked by regulation to a market rate. The latter mechanism allowed deposit rates to reflect, at least partly, changing market conditions. This was not true of pre-payment penalties which were determined without any attempt to measure the effect of the penalty structure on the marketability of fixed rate deposit instruments. Thus, the regulation of pre-payment penalties prevented banks from tailoring the interest rate and pre-payment features offered on their deposit accounts to investors' interest rate risk/return preferences.

Valuation Method

The option to withdraw funds from a deposit account is a put option on a debt security. The security is a deposit account which pays coupons whose magnitudes are determined by the deposit rate. The holder of such an account—one that permits early withdrawal—essentially owns the option to "put" this "bond" on the depository institution for an exercise price equal to the principal value of the account less any predetermined penalty. (We assume there is zero risk of default on the part of the institution.)

The value of such an option derives from the possibility of a larger than expected rise in interest rates. That is, if the rise in interest rates makes the yield on the fixed rate deposit less than the yields of competing instruments, the market value of the deposit account will fall below its par value. Since the early withdrawal option enables the depositor to get back the par value of his deposit, he may, depending on the penalty associated with early withdrawal, profit from exercising the option.

In such a context, the exercise price (X) can be considered the deposit's principal amount (F) minus the early withdrawal penalty (E). The value or proceeds of the exercise (VEXER) are then $X - D - F - E - D$ where D is the market value of the deposit. The price of the early withdrawal option can then be determined using the general option value formula described earlier.

This valuation method is applied here to hypothetical deposit accounts whose deposit rates and early withdrawal penalties are tied to the yield on risk-free market instruments. A comparable real-world example, of course, is the 6-month money market certificate (MMC) introduced in 1978. Its deposit rate is fixed for the six-month period and is linked to the yield on newly issued Treasury bills in the week the deposit is created. It presently has an early withdrawal penalty of 3 months interest. We will also include valuation of the early withdrawal options on one-year, 2½-year, and 4-year deposit instruments in our analysis. We assume that the yields for all of these instruments are linked to discount-type Treasury security yields of similar maturity (an assumption that departs from reality but makes our analysis more consistent across instruments.)

There are three major steps involved in valuing the early withdrawal option on such instruments. First, since the deposit rates are linked to market yields, it is necessary to simulate the Treasury security yield using the (assumed) market interest rate tree. We use the bond valuation approach described in Section II to price the relevant Treasury security and to obtain the appropriate implicit yield.

The second step in the process is to link the implicit yield to the deposit instrument, since we assume that the deposit rate is linked to this yield by regulation. We use the implicit yield to derive the stream of "coupons" offered by the MMC account as well as the interest penalty. In keeping with the actual practice in the case of MMCs, we assume that the deposit pays simple interest only, so the "coupon" or periodic interest payment is constant throughout the instrument's life. Thus, the deposit can be seen as a "bond" which pays a constant coupon each period and returns the principal amount at the end of its life. Finally, using this representation of the deposit and the early withdrawal penalty, we price the early withdrawal put option using the formulae described earlier.

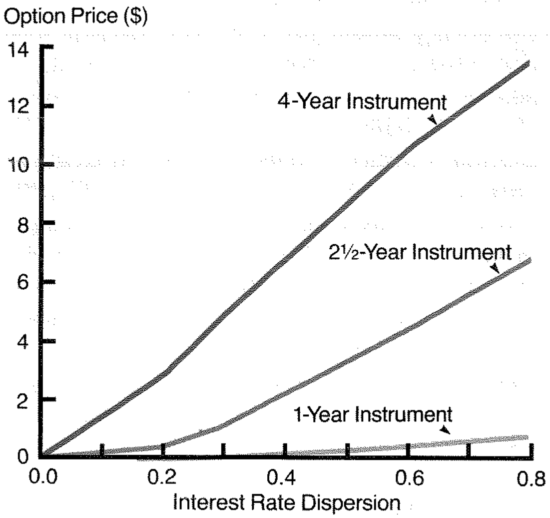
Assumed Penalty Structure

Current early withdrawal penalty policy requires, in most cases, a sacrifice of 3 months interest on the 6-month and one-year instruments and a sacrifice of 6 months simple interest on instruments greater than one year in maturity. Since one of the goals of the analysis is to examine the interaction between regulated rates and early withdrawal penalties, these penalty structures are the ones assumed in our analysis.

Using the valuation techniques and assumptions described above, the prices of the par-value withdrawal options inherent in our hypothetical deposit instruments result from a variety of interest rate and penalty environments. For reference purposes, we employ M = .2 and S = .3. As Table 1 indicates, these values are consistent with the "forecasts" produced by our simple econometric model in the

Chart 4

Option Price/Interest Rate Dispersion with Current Penalty and Historic Interest Rate Trend*



*This graph assumes that the underlying instrument has a face value of $100.

1979 to 1981 period. We also employ a starting interest rate of 12 percent, which is approximately the rate that prevailed in late 1981.

Effects of Interest Rate Uncertainty

Chart 4 demonstrates the effect of interest rate uncertainty (dispersion) on the value of the early withdrawal option (using the assumed penalty structure and a historic forecast of drift of .2). Only the 1-year, 2½-year, and 4-year instruments are sensitive to changes in uncertainty in a broad range around the historic dispersion of .3. The withdrawal feature on the 6-month instrument takes on zero value throughout except at high uncertainty levels. (We will see later that this is due to the very high penalty implicit in the 6-month instrument.)

In general, however, the greater the uncertainty about interest rate movements the greater is the value of the early withdrawal option inherent in a deposit-type instrument. The value of the option is also greater, at any given level of uncertainty, for a longer maturity deposit. Both are results that we would expect to follow from the very nature of an option as a hedge against an uncertain world. The more uncertain that world or the longer the investment must be in place, the more valuable the option to liquidate becomes.

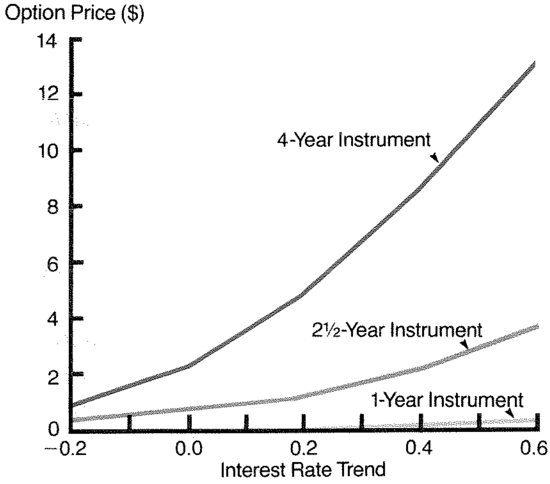
From the standpoint of the policy behavior of financial institutions, it is obvious that, if they could, they should pay lower rates of interest (or find other ways of charging for the option) during periods of high interest rate volatility, everything else being equal. At the historic dispersion, the 2½-year certificate contains an option worth approximately $1.25 per $100 of face value. The 4-year certificate contains an option worth approximately $4.75 per $100 of face value. Whether charged "up front" or in the form of lower deposit rates, such options represent a valuable service provided by depository institutions and should be an important source of income and an important means of differentiating the deposit product from other financial instruments.

Effects of Interest Rate Drift

Chart 5 illustrates the effect of another important interest rate forecast parameter: anticipated drift in interest rates. The more widely held is the view that interest rates are going to rise (i.e., the greater is the forecast of drift), the greater is the value of an option to liquidate (and reinvest). Holding the level of uncertainty (dispersion) at its historic level and using the current withdrawal penalty structure, we find that by varying the drift, the early withdrawal option indeed increases dramatically in value as anticipated drift increases. This is particularly true for the instruments of longer maturity.

Chart 5

Option Price/Interest Rate Trend with Current Penalty and Historic Dispersion*



We can conclude that during periods of widely anticipated (but uncertain) increases in interest rates (such as the late 1970s), long-term deposit-type instruments with withdrawal options should be very attractive in comparison to their bond-market competition paying roughly comparable rates. (Recall that the deposit rate on these instruments is linked to the yield offered by a government debt security.)

In addition, we can surmise that if anticipated drift is significantly negative (i.e., interest rates are anticipated to fall sharply over the life of the instrument), the value of the early withdrawal option rapidly approaches zero. This, too, is a common sense consequence of the nature of the early withdrawal option. Within a declining rate scenario, the exercise of the option prior to maturity would expose the investor to investment alternatives with lower returns than the existing instrument. The option is thus less likely to be of value to the investor.

Even under conditions of zero anticipated drift, the early withdrawal options on the 1-, 2½- and 4-year instruments have positive value in an uncertain world. For the 4-year instrument, the option's value is approximately $2.50 for every $100 in deposit value, representing a significant feature of par-value deposits that should not be ignored in pricing these instruments competitively.

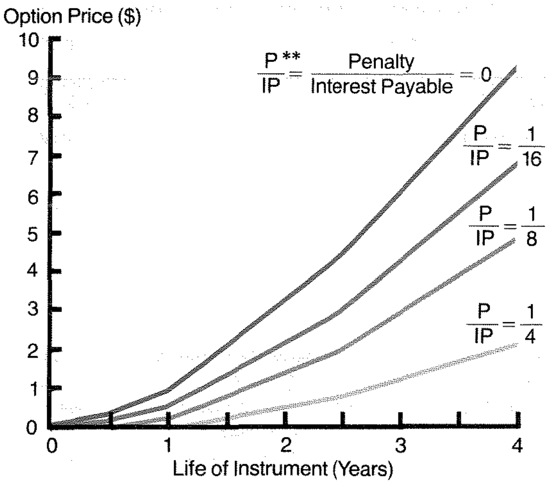
Effects of Early Withdrawal Penalties

Note that in all of the previous figures, the option price of the shortest term deposit instruments reacted least (if at all) to changes in drift and dispersion. To some extent, this is to be expected. The shorter the intended term of the investment, the less important the option to liquidate and reinvest in response to changing economic conditions. However, a less obvious but major factor in the behavior of the 6-month and 1-year instruments is the prevailing penalty structure. The current penalty structure appears to eliminate the distinction between par-value deposit instruments and bonds for those deposit instruments whose yields are linked to Treasury market yields. This is illustrated clearly in

Chart 6

Option Price/Penalty with

Historic Interest Rate Trend and Dispersion*



*This graph assumes that the underlying instrument has a face value of $100.

**The assumption here is that the penalty for early withdrawal is a constant fraction of the total interest payable. For example, for a two-year instrument with a penalty of six months' interest, P/IP = ¼.

Chart 6 where the valuation of the early withdrawal option on all four instruments (at the historic drift and dispersion) for a variety of early withdrawal penalties expressed in terms of months of simple interest is plotted. Even at penalties considerably smaller than those presently enforced, the early withdrawal option has no value for deposits of less than one year.

Calculations from the options model suggest that at the conventional penalty of 3 months' interest, the early withdrawal option has zero value for the 6-month deposit. In fact, the penalty must be reduced to approximately a ½ month's interest before it takes on a non-zero value. This suggest that, for our simulated interest rate uncertainty, the existing penalty structure on the 6-month instrument prevented banks from using the pre-payment option to differentiate their deposit account from bond-like instruments available on the marketplace and, therefore, to compete for funds. It also restricted the ability of investors to choose between instruments offering a higher return and those offering protection against interest rate risk but with a lower return.

Obviously, our valuations depend critically upon interest forecast assumptions and ignore transactions costs and convenience aspects of deposit-type instruments and their alternatives. Nonetheless, the results do strongly suggest that under conditions of rising interest rates and high levels of uncertainty, the existing structure of early withdrawal penalties on short-term instruments (combined with regulated rates) has been extremely onerous. It may have contributed to the difficulties that depository institutions faced in the late 1970s and early 1980s in competing effectively against money market funds and direct investment in Treasury securities.

V. Conclusion

This paper has applied a simple option-pricing model to two instruments: traded options on Treasury notes and fixed rate deposit instruments. The first application illustrated the importance of interest rate forecast parameters to the valuation of traded options. An investor (or seller) of such options can use such pricing techniques to help relate his view of the future path of interest rates to option prices and, thereby, to help him take positions in the options.

The second application illustrates the usefulness of the options perspective to setting general policies regarding deposit-instrument pricing. Although the option pricing exercises were based on somewhat hypothetical instruments, they highlight the sensitivity of proper instrument prices to the features of the instrument and to alternative future interest rate scenarios.

A specific implication of the simulations is that the regulation of early withdrawal penalties prevented financial institutions from using the early withdrawal feature of their deposits to compete for funds. That is, they were prevented by the prohibitively high penalty structure from using the early withdrawal option to enable them to offer a lower return on their deposit accounts than those of comparable instruments (such as T-bills) without withdrawal provisions. Our analysis of MMC rates provided empirical evidence to support this point at least in the case of the 6-month instrument. Despite the fact that the regulated deposit rate was simply a *ceiling* rate (that is, the institutions could offer a lower rate if they desired), virtually all MMCs in recent years have been marketed at the ceiling rate. This suggests that under the regulated penalty structure (and the interest rate environment), the early withdrawal option was not an attractive investment feature.

Whatever the specific nature of financial instruments, the increased complexity of financial markets will require more sophisticated and careful accommodation of interest rate risk. The options perspective appears to be a useful and practical mechanism for analyzing the effects of alternative future interest rate paths on financial instruments and their markets. Although much work needs to be done to improve options pricing models, our exercises with one model suggest that they are likely to have broad applications for financial institutions managing their portfolios in a highly competitive and uncertain world.

FOOTNOTES

1. Fisher Black and Myron Scholes, "The Pricing of Options and Corporate Liabilities," **Journal of Political Economy**, May 1973, pp. 637–654.

2. More precisely, it is a function of the current price of the underlying stock, the life of the option, the variance of the continuously compounded annual rate of return on the stock, the exercise price and the continuously compounded riskless rate of return. The stochastic assumption is that the continuously compounded rate of return follows a normal distribution with constant variance. (See Black and Scholes, **op. cit.**).

3. Some of the complexity of the analytical pricing approach is revealed by the work of Michael Brennan and Eduardo Schwartz, "Savings Bonds, Retractable Bonds and Callable Bonds," **Journal of Financial Economics**, August 1977, pp. 67-88.

4. This process is elaborated upon below.

5. William Sharpe appears to have been the first to suggest the general type of numerical approximation technique presented here (albeit in the context of options on stock) in his text **Investments**, (Prentice-Hall), 1978, pp. 366-371. A useful review of numerical techniques, however, is presented in Robert Gerske and Kuldeep Shastri, "Valuation by Approximation: A Comparison of Alternative Option Valuation Techniques," **Working Paper 13-82**, University of California, Los Angeles, August 1982.

6. Richard Rendleman, Jr. and Brit Bartter, "The Pricing of Options on Debt Securities," **Journal of Financial and Quantitative Analysis**, March 1980, pp. 11-24.

7. See Rendleman and Bartter or Geske and Shastri, **ibid.**

8. The major theoretical changes are a continuous-time discounting procedure and a slightly different time-dating convention necessitated by the computer simulation program written by the authors. However, to assist readers in relating this paper to the work of Rendleman and Bartter, similar terminology and nomenclature are employed where possible. We wish to thank Dr. Rendleman for his helpful comments at several points in this adaptation of their work.

9. It is important to emphasize the difference between arithmetic and geometric drift. Since arithmetic drift, A, is equal to $(M+S^2)/2$, readers must be cautious about the empirical inferences drawn about the sensitivity analysis presented in this paper. Constant arithmetic drift—the conventional notion of "flat" interest rate evolution—is not the same as constant geometric drift when there is some dispersion about the drift. In this paper, the sensitivity analysis is presented in terms of the original parameters of the model, namely M and S, rather than in terms of arithmetic drift to illustrate better the sensitivity of the model to its specified parameters.

10. The interest rate parameters are obtained from a regression of the general form

$$\ln (i_t/i_{t-12}) = a + u$$

where i_t is the monthly commercial paper rate, a is a parameter, and u is an error term. The coefficient a is interpreted as the estimated geometric drift M and the standard error of the equation is interpreted as the dispersion parameter S.

11. This computation is conventionally referred to as the "hedge ratio." Instinctively, the variable H is the gain anticipated between periods t-1 and t in the holding of the underlying security and V is the value of the associated option. Both V and H will depend upon the interest rate state that actually evolves. If the difference in the gain on the underlying security between states differs from the offsetting movements that would occur in the option value, the proportion of options to underlying instruments in the portfolio must be changed accordingly.

12. See footnote 10. The values presented were estimates using a time series dated 11/80 to 10/82.

13. See Richard Rendleman, "Some Practical Problems in Pricing Debt Options," Duke University, August 1982, Mimeo.

Real Interest Rates, Money and Government Deficits

Brian Motley*

In the last five years both long- and short-term interest rates have reached levels not seen in U.S. economic history since the Civil War. Yields on long-term corporate bonds never exceeded 7 percent in the one hundred years before 1970 but ratcheted steadily upward after that year, reaching double-digit levels by 1979. Similarly, when the yield on short-term commercial paper reached 10.9 percent in 1979, it exceeded the previous record high which had stood since 1873.

It is generally agreed that these historically high interest rates reflected the unusually rapid inflation experienced during the 1970s. Economic theory and common observation suggest that both borrowers and lenders in loan markets are influenced by the rate of inflation in determining the rate of interest. If the prices of goods and services are rising at ten percent a year and a loan is negotiated at fifteen percent, the true cost of the loan to the borrower—in terms of purchasing power over goods and services—and the true return received by the lender are only five percent. Presumably, it is this inflation-adjusted or *real* rate of interest that borrowers and lenders negotiate. If the rate of inflation were to decline, but all the factors determining the *real* interest rate were to remain unchanged, the *nominal* interest rate offered by borrowers and accepted by lenders would also decline. For example, if the inflation rate were to fall from ten percent to five percent, the nominal rate of interest would decline correspondingly from fifteen percent to ten percent.

Empirical evidence supports these theoretical expectations. Chart 1 shows the nominal yield[1] on 91-day Treasury bills, the rate of inflation over three-month spans as measured by the official consumer price index, and the realized real interest rate computed as the difference between these two series.[2] From this chart, it is clear that in the quarter-century after 1953, variations in the nominal short-term rate were associated closely with changes in the rate of inflation and, thus, the real rate did not vary much from its long-run average level of around one percent.

However, Chart 1 also suggests that the close link between inflation and short-term interest rates may have broken down after 1979. Although the rate of inflation declined in response to the Federal Reserve System's policy of slowing monetary growth after 1979, nominal interest rates remained high. Even after the sharp decline in rates beginning in mid-1982, the nominal Treasury bill yield averaged 8.55 percent in December 1982. As measured by the consumer price index, the rate of inflation during the three-month period beginning in that month was slightly less than one-half of one percent, so that the real yield realized by holders of these bills was just over 8 percent. From Chart 1, we can see that a real rate of 8 percent is extremely high by historical standards.

In this article, we consider a number of factors which economic theory and popular opinion suggest may be important in determining short-term real interest rates and examine whether they are capable of explaining the recent experience of high real rates. The principal conclusion is that, at least over the sample period examined in this study, high real rates appear to have been more closely linked to monetary policy—and to expectations of policy—than to fiscal policies that have produced federal deficits.

Focus on Short-Term Rates

Throughout our study, we focus on *short-term* rather than long-term interest rates for several reasons, some purely practical and others funda-

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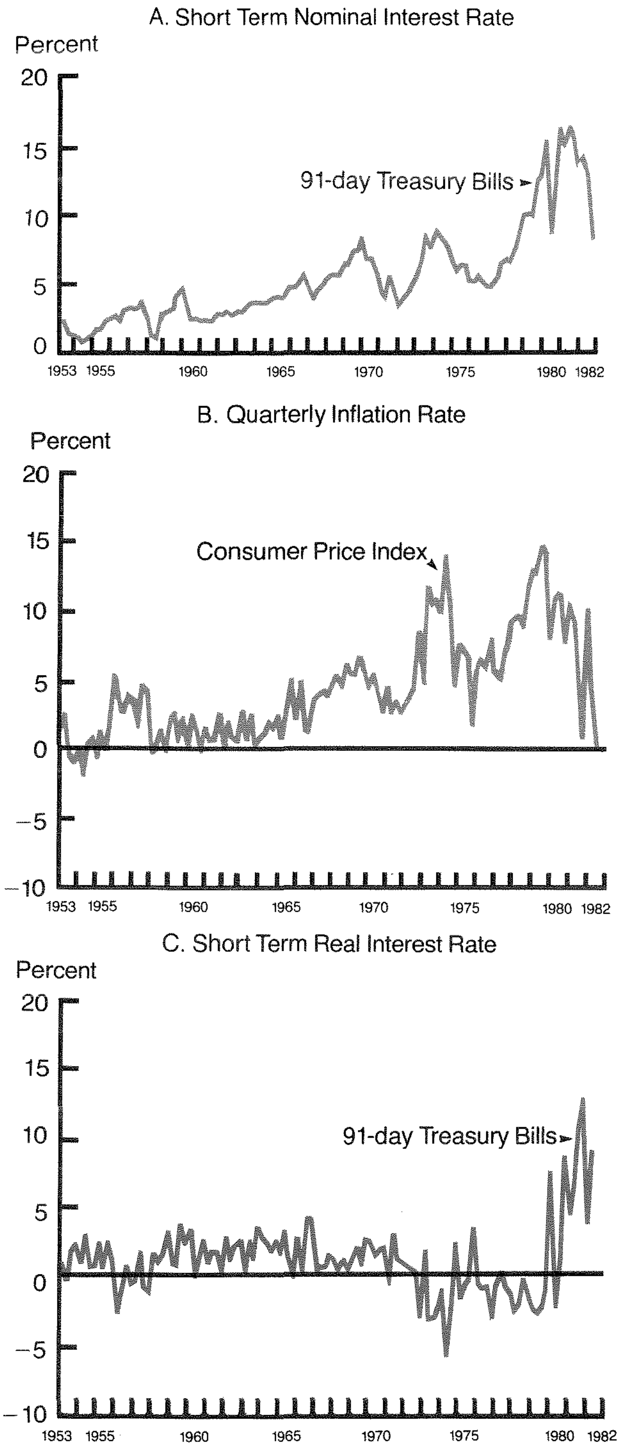
Chart 1

Comparison of Nominal and Real Interest Rates and Inflation (1953–1982)



mental. The principal *practical* reason arises from the fact that in determining the nominal interest rate on a financial asset, investors will take account of the rate of inflation which they *expect* to occur over the life of that asset. That is, the nominal rate will be set so that the real rate which is expected to emerge will adequately compensate investors for holding the asset. However, because those inflation expectations are not observable, the real rate required by investors also is not observable.

This measurement problem, in principle, affects both short-term and long-term securities, but may be less serious for short-term assets. Except in periods when the rate of inflation is changing rapidly, investors should be able to predict the prices of the goods and services they buy and sell over the next three months quite accurately. The differences between predicted and realized rates of inflation should therefore be quite small. By contrast, inflation forecasting over a longer time horizon is a much more difficult undertaking. Divergences between expected and realized inflation rates in such long-term forecasting are therefore likely to be larger. In other words, whereas the realized, or *ex post*, real rate on short-term securities should be a reasonably good approximation of the rate which investors required *ex ante* when they acquired the securities, the same is less likely to be true for longer-term securities. Because of this measurement problem, it is more difficult to test hypotheses regarding the determinants of long-term real rates than it is for those of short-term rates.

Traditionally, economists have argued that changes in the financial side of the economy mainly affect the real side through their effect on *long-term* interest rates. The interest-sensitive components of aggregate demand consist primarily of residential construction and plant and equipment spending. Since these components represent purchases of long-lived physical assets, economists have argued that they should respond to changes in the yield on long-term financial assets because this return represents the appropriate opportunity cost of funds used to purchase such assets. This argument would imply that although hypotheses with regard to short-term rates are easier to test, they are less important to policy-makers than those concerned with long rates.

In fact, however, there are good *fundamental* reasons—in addition to the practical technical reason discussed above—justifying this article's emphasis on short-term rates.

The first reason is that changes in short-term rates tend to be reflected in long rates. A household or business wishing to invest its funds for a long period may, if it wishes, hold a sequence of short-term securities rather than a single long-term security. Conversely, an investor wishing to invest for a short period may purchase a long-term security and resell it before maturity. Hence, long-term and short-term securities are to some extent substitutes, and as a result, their rates of return tend to move together.[3]

A second reason for focusing on short-term rates is that in recent years the share of short-term borrowing in the total of all funds raised in the nation's capital markets has increased. Of the $85 billion raised by private domestic non-financial borrowers (excluding residential mortgages) in 1971, almost 70 percent represented corporate and municipal bonds and non-residential mortgages. Ten years later, the amount raised had risen to $225 billion but the share of long-term financing had declined to 42 percent. Conversely, commercial paper, bankers' acceptances and bank loans increased from 13 percent to 46 percent of the total over this ten-year period.

A final reason for studying short-term rates is that, in some sense, their behavior since 1979 has been more surprising than that of long rates. The failure of nominal long rates to decline in line with inflation may be explained by arguing that, although the *current* inflation rate has declined, investors are still worried about *future* inflation, so that long-term *ex ante real* rates are not particularly high by historical standards. Although this argument is difficult to test empirically[4] because, as noted earlier, long-term inflation expectations and hence *ex ante* real rates are not observable, it is not implausible. This argument cannot, however, be applied to short-term rates because short-term inflation rates clearly have come down substantially. When investors set an 8.55 percent rate of return on 3-month Treasury bills in December 1982, it would have required an expected inflation rate of close to 7 percent for the real rate on those bills to be at its long-run average level. The *realized* inflation rate was almost zero over the 3-month period beginning in December 1982. It seems very unlikely that expectations of inflation were that far off the mark. Thus, it is virtually certain that the *ex ante* real rate was exceptionally high by historical standards. This unusual behavior requires an explanation.

What Determines the Real Interest Rate?

The real interest rate represents the return which investors expect to earn on holdings of securities. Each investor decides how many securities to hold by comparing this return with that available on alternative assets. The principal alternatives are money, which often yields no explicit return, and physical assets, such as business plant and equipment and residential housing, which provide a return in the form of productive services.

Although each investor chooses how to allocate total wealth among these various assets, in the aggregate, all securities outstanding must be held. This means that the interest rate must be such that the entire outstanding stock of securities is willingly held by investors. The rate of interest, therefore, is determined by the *demand* to hold securities and the available *supply* of securities.[5]

Before discussing these factors in detail, one methodological point should be mentioned. In this paper, the interest rate is treated as being determined by the supply of and demand for securities. As we shall see, a variety of macroeconomic variables influence these supplies and demands. But these variables are themselves affected by the interest rate. For example, the demand to hold securities, and hence the interest rate, is influenced by the level of nominal GNP. But conversely, the interest rate affects the level of nominal GNP through its effect on the spending decisions of households and businesses. In turn, the level of GNP influences other macroeconomic variables, such as the government deficit, which may affect interest rates.

In a complete model of the economy, the interest rate would be determined simultaneously with other macroeconomic variables such as income, the government deficit, and the inflation rate. In such a "full equilibrium" model, the level of nominal GNP, for example, both affects and is affected by the level of interest rates. The model used here, however, is a "partial equilibrium" one and seeks to explain the real interest rate in terms of other macroeconomic variables without exploring the feedback effects of changes in interest rates on those variables.

There is ample precedent for this procedure. The well-known IS/LM paradigm, for example, is a complete model of the economy which determines both the level of income and the interest rate. Within this framework, the LM curve is essentially a model which determines the interest rate in terms of income and the IS curve describes the feedback from the interest rate to the level of income. The equations estimated here are analogous to the LM curve since the level of income is taken as one of the determining variables. Factors influencing interest rates via the IS curve (fiscal policy, for example) do so through their effect on the level of income.

Within this broad framework, economists have two ways of approaching the determination of interest rates: The *liquidity-preference approach* which focuses attention on the decision between holding securities and holding money, and the *demand for capital approach* which emphasizes the decision between holding (or issuing) securities and holding productive capital.

In the liquidity-preference approach the rate of interest is regarded as "the reward for parting with liquidity."[6] In this approach, the key characteristic of money is that it is used to make payments so that the demand to hold it is closely related to the level of nominal income. But the demand for money also depends on the opportunity cost of holding it. In equilibrium, this opportunity cost must be such that in the aggregate the stock of money is willingly held. When the stock of money is willingly held, this implies that the same is true of the stocks of other assets.

Until recently, money was distinguished by the fact that it yielded no explicit return, so the cost of holding it was simply the interest rate which could be earned on alternative non-money assets such as securities. This meant that the interest rate on securities had to be such that the public was willing to hold the existing stock of money. If, for example, the level of income were to rise with no increase in the total stock of money, individual investors would seek to increase the level of their money-holdings by selling securities. Since all securities must be held in the aggregate, security prices would fall and interest rates would rise until investors stopped trying to switch out of securities into money. Conversely, if the level of income were to remain unchanged and there were an increase in the supply of money, individual investors would tend to push down interest rates as they sought to reduce their money holdings and to increase their holdings of securities.

Although the recent deregulation of the financial system has eroded the unique characteristic of money as an asset which provides no explicit return, it remains true that the yield on monetary assets is less flexible than that on securities. As a result, rates on securities continue to do most of the adjusting to equate the supply of money to the demand for money.

Whereas the liquidity preference approach emphasizes the choice between holding money and holding securities, the *demand for capital approach* emphasizes the decision between holding productive capital and holding securities, and argues that the nominal rate of interest on securities must be such that wealth holders are willing to hold the existing quantities of these two types of earning assets. If, for example, the expected return to productive capital rises, businesses and households will wish to hold fewer (or issue more) securities in order to hold more capital. Since all outstanding securities must be held, this will tend to drive up yields on securities.

Frequently, this argument is expressed in *flow* rather than in stock terms, and the interest rate is explained in terms of the supply of lendable funds out of current saving relative to the demand for funds to finance private capital formation and the government's deficit. When the demand for funds increases relative to the available supply, their price, which is the interest rate, tends to rise.

The liquidity-preference and productive-capital approaches to interest rates focus on different aspects of the process of interest-rate determination. The liquidity preference approach emphasizes substitutions between money and securities whereas the capital model stresses the choice between securities and physical assets. Each approach suggests that certain variables will have predictable effects on security prices and interest rates. The variables most often considered by both economists and market commentators are changes in the money supply relative to the demand, changes in the inflation rate and changes in the government's deficit.

Consider first the effects of monetary changes, better analyzed in terms of the liquidity preference paradigm. An increase in the demand to hold money with no change in the available supply puts upward pressure on interest rates. To be more specific, the amount of money investors want to hold depends positively on recent levels of nominal income and negatively on short-term interest rates. In a given month, money demand may rise as a result of past or present increases in personal income or as the delayed result of *past* declines in interest rates. If the supply of money does not rise to match such an increase in demand, the *current* interest rate must rise to restore equilibrium in the money market. Conversely, if the supply of money increases by more than the demand, interest rates will decline.

Since the stock of money is a policy variable determined largely by the central bank, the liquidity preference approach implies that the central bank can make a significant impact on the general level of nominal interest rates. A policy-induced increase in the stock of money will, *ceteris paribus*, tend to lower interest rates.

In the short run, the stock of money also may increase as a result of a rise in the amount of commercial bank lending. The public is willing to hold this money for a short while with little or no change in interest rates but will eventually seek to get rid of these excess money holdings.[7] When they do so, interest rates will tend to decline.

The effects of inflation and government deficits on interest rates are better examined in terms of the demand for capital approach since inflation affects the nominal returns to holding productive capital relative to those on securities, while deficits require changes in the supply of securities.

Consider first the effect of a change in the rate of inflation. Since wealth-owners are concerned with the *real* return on their portfolios of securities, the nominal interest rate which they require will be equal to the real rate they demand plus the rate of inflation they expect. Conversely, the return which issuers of securities will pay will be equal to the real rate they offer plus the inflation rate they expect. Hence, if the real rate is constant, a given change in the rate of inflation will cause an equal change in the nominal rate since both lenders and borrowers will accept such a change.[8]

However, inflation also may affect the *real rate* itself. In that case, a change in the rate of inflation would result in a larger or smaller change in the *nominal* rate. In fact, a number of writers on the determinants of real interest rates have found a significant *negative* relationship between the past rate of inflation and the current *real* interest rate on securities. Their finding implies that a given change in the inflation rate leads to a *smaller* change in the nominal rate.

A theoretical argument underlying this empirical finding is that more rapid inflation leads investors to want to hold more of their wealth in the form of tangible capital and less in the form of financial assets because the nominal returns on capital vary with the price level whereas the returns on securities and money are fixed in nominal dollars. This increased demand for capital has the effect of driving up its price and lowering its yield. The shifting of household savings into residences and the resulting steep increase in house prices during the 1970s may have been an example of this phenomenon. More rapid inflation also lowers the real return to holding money, because the nominal return on money is fixed.[9] Finally, since inflation reduces the real rates of return on both money and capital, the real interest rate on *securities* must also decline if investors are to remain willing to hold the existing stocks of money and capital. This argument apparently was first developed by James Tobin[10]; hence the result frequently is called the Tobin effect.

In the years up to 1979, inflation increased sharply; since that year, it has declined dramatically. The Tobin effect would predict that real rates would fall during the 1970s and rise subsequently. Thus, casual observation of the recent behavior of interest rates would support Tobin's argument. There may, however, be other explanations for recent interest rate movements, and we can sort through them only by formal econometric testing.

A prominent alternative explanation for these interest rate movements is that increases in the federal deficit have tended to drive up real interest rates. The sharp rise in real rates since 1980 has coincided with the emergence of federal deficits which are larger and apparently more long-lasting than any in recent U.S. history. This does not, of course, *prove* that the high rates have been caused by the high deficits. Indeed, the reverse may be the case because an important source of these deficits has been a sharp increase in government interest payments.[11] Nonetheless, a theoretical explanation of why deficits will drive up interest rates is readily available. Interest rates must rise in order to induce the public to hold the government securities which the Treasury issues when it runs a deficit.

Suppose, for example, the government reduces tax rates without cutting its outlays. The Treasury must issue securities to make up for its loss of tax revenues. Although the tax reduction means that the public has higher after-tax income, the public may not want to loan all of these additional funds to the Treasury. Hence, the demand for loanable funds by the government rises by more than the supply of funds, causing their price—the interest rate—to rise.[12] In slightly different language, the rise in the interest rate is necessary to induce the public to hold a larger share of its asset portfolio in the form of government securities.

Such a tax reduction also leads to an increase in aggregate demand for goods and services which, through the familiar Keynesian multiplier process, causes an increase in nominal national income. This income effect also will tend to raise interest rates. At higher income levels the transactions demand to hold money is greater and if this demand for money is not accommodated by the Federal Reserve, interest rates must rise to restore equilibrium between the supply of and the demand for money. In addition, at higher levels of income, businesses may become more optimistic about the likely future return on new investment projects and hence more willing to issue securities in order to finance such projects. These additional claims on the nation's capital markets drive interest rates further up. An analogous argument may be made that an increase in government outlays will drive up interest rates.

These last arguments frequently are summarized by saying that interest rates are influenced by the *high-employment* deficit rather than the *actual* deficit. The high-employment deficit is a measure of the setting of fiscal policy. A more expansionary fiscal policy—represented by an increase in the high-employment deficit—tends to raise interest rates through its effect on current and prospective future GNP. However, our earlier argument that actual deficits tend to raise interest rates *does not depend on* their having this effect of raising aggregate demand and hence nominal income. Because an increase in the *actual* deficit must be financed by the issue of more government securities to the public, it causes interest rates to be higher at any *given* level of GNP. If income does rise, this provides a second (logically distinct) reason for expecting interest rates to rise.[13]

Conversely, the argument that only the high-employment deficit matters implies that an increase in the actual deficit which reflects a cyclical decline in GNP rather than a shift in fiscal policy will not raise interest rates. This argument ignores the point that actual deficits—however they arise—must be financed by the issue of securities and hence cause interest rates to be higher than they otherwise would be. In this case, however, the upward pressure on interest rates associated with this deficit-financing tends to be offset by the downward pressure from the decline in GNP.[14]

The sharp increase in the federal deficit since 1979 has been widely blamed for the recent high level of real interest rates. It is important, therefore, for us to test rigorously the hypothesis that, if other things remain unchanged, an increase in government borrowing causes interest rates to rise. An obvious empirical problem in this test is that those other things do not remain unchanged in the actual world. In particular, the size of the deficit both affects and is affected by the level of business activity in the economy, and this activity in turn influences and is influenced by interest rates.

To distinguish those effects of deficits related to financing by the issue of securities to the public from those due to the link between deficits and the level of income, we include the gross national product relative to potential GNP as an additional variable in the empirical equations estimated below. In addition, we measure government borrowing as a proportion of potential GNP in order to adjust for the long-run growth in the economy and, hence, in the supply of private savings available to finance the deficit. The coefficient on the government borrowing variable, therefore, may be interpreted as representing the effect of deficits while holding the level of income constant.

In recent years, high interest payments on the existing federal debt have boosted the size of the federal deficit. In fact, the government has been borrowing in order to pay interest on its outstanding debt. A number of economists[15] have argued that to the extent that these interest payments result from high nominal rates caused by inflation, the additional Treasury borrowing should have no effect on *real* rates. Their reason is that inflation reduces the real value of government debt outstanding and that wealth-owners would be willing to purchase additional securities to maintain the real value of their stocks of securities with no change in their real rate of return.

In the empirical work reported below a crude correction for this effect is made by simply deducting government interest payments from measured Treasury borrowing. This deduction is too large since not *all* interest payments represent inflation, but the actual proportion of interest payments that represent inflation-induced increases in nominal rates cannot be measured precisely.[16]

The upshot of this section is that at any given level of GNP, there are reasons to expect real interest rates to be higher if the money supply is smaller in comparison to demand, if the inflation rate is lower, or if the government deficit is larger. Each of these events has occurred since 1979. Nonetheless, formal empirical tests are required to determine which, if any, of these various effects we have identified was the *primary* cause of high interest rates.

Measuring the Real Rate of Interest

On a given date the real rate of interest on a security is equal to the nominal rate minus the rate of inflation that investors *expect* to materialize over the maturity of the security. Put differently, the nominal rate which is determined in the financial markets is equal to the real rate which investors require *ex ante* when they purchase the security plus the rate of inflation they expect. Symbolically,

$$r = i - p^e \qquad (1)$$

where r is the real rate, i is the nominal rate and p^e is the expected inflation rate.[17] It was the determination of this *ex ante* real rate which the theory of the preceding section sought to explain.

As stressed earlier, the empirical problem with this formulation is that the expected rate of inflation is not an observable variable and hence neither is the required or *ex ante* real rate. After the security matures, of course, the actual inflation rate becomes known and the investor can calculate the real rate actually realized. The realized or *ex post* real rate is written:

$$r^{ep} = i - p \qquad (2)$$

where r^{ep} is the *ex post* real rate and p is the actual rate of inflation.

The difference between the *ex ante* real rate demanded by investors when they set the nominal rate and the *ex post* rate they actually receive is equal to the error investors made in forecasting inflation. By substracting equation (1) from equation (2) we find:

$$r^{ep} - r = p^e - p = u \qquad (3)$$

where u is the error which investors made in their forecast of inflation.

To test the various hypotheses advanced in the last section concerning the determinants of the *ex ante* real rate r, we must solve the problem of having data only on the *ex post* rate, r^{ep}. Fortunately, the theory of efficient markets provides a framework for attacking this problem.[18]

An efficient market is one in which participants use all available information in determining prices. Since the markets for short-term government securities are highly competitive, it is generally assumed that they are efficient in this sense. Participants who did not take advantage of all available information would earn lower profits than, and ultimately be driven out of business by, competitors who did.

This assumption of market efficiency implies that when the nominal interest rate is set, investors use all the information available to them both to determine the real interest rate they demand and to form their expectations of the future inflation rate. What this means is that the inflation-forecast error, u, is a random variable that is independent of all the other variables that determine the real rate. It is independent because the other variables were necessarily *known* when the market set the nominal rate while u reflects information that was *unknown* at that time. By exploiting this implication of the theory of efficient markets, we can investigate the determinants of the *ex ante* real interest rate and test the hypotheses outlined in the previous section, despite the fact that the *ex ante* interest rate is not directly observable.

To illustrate the procedure, let X represent the factors that theory suggests determine the *ex ante* real rate and assume that the relation between X and that rate is a linear one. Then

$$r = a + bX + v \qquad (4)$$

where v is a random error which is independent of X and essentially captures the variables that affect r but that have been inadvertently left out of X.

Combining Equations (3) and (4) gives

$$r^{ep} = a + bX + v + u \qquad (5)$$

The dependent variable in this equation is the *ex post* real rate that is observable. The combined error term, v + u, represents both errors in determining the real rate, v, and errors in predicting inflation, u. Both of these errors are independent of X so that least-squares estimation of Equation (5) will yield unbiased estimates of the parameters of Equation (4). Notice that although the efficient markets hypothesis implies that u is not autocorrelated, it says nothing about the characteristics of v. Hence, in our empirical work, the combined error term is assumed to be autocorrelated.

Empirical Results

Equations have been estimated in the form of Equation (5) for various sample periods. The nominal interest rate is the average rate on 91-day Treasury bills, issued in January, April, July and October, and converted to a bond equivalent basis. The inflation rate is represented by the annualized change in the logarithm of the consumer price index over 3-month spans beginning in those same months. The dependent variable in the estimated equations is the *ex post* real interest rate defined as the difference between the Treasury bill rate and the inflation rate. Notice that both the bill rate and the inflation rate refer to non-overlapping time periods.

The vector X was taken to include the following independent variables: the lagged inflation rate (PLAG), the excess supply of money (XMONEY), a measure of the impact of government deficit spending on credit markets (FEDDEF), and the ratio of current to potential GNP (INCOME). These variables are designed to capture the theoretical considerations outlined earlier.

Lagged inflation refers to the rate of price change over the three-month period ending in the month preceding the interest rate observation (December, March, June, and September). Similarly, the other three variables are quarterly data for the calendar quarters ending in those same months. Thus, market participants would have had information on each of these four variables when the nominal interest rate was set. For example, when the nominal interest rate was set in January, investors would have had information on the rate of inflation over the three months that ended in December, and data on the excess supply of money, the government deficit, and the level of GNP in the fourth quarter of the previous year. The variables, therefore, satisfy the conditions required for the application of the efficient markets hypothesis.

Our theoretical discussion suggested that an increase in the expected rate of inflation will lead to a decline in the real interest rate. As evidence of this Tobin effect, several authors[19] have found a statistically significant inverse relation between the current real interest rate and the past rate of inflation and have interpreted this finding as evidence of this effect. Although, strictly speaking, the Tobin effect implies a relationship between the real interest rate and the *expected future* inflation rate, it is difficult to test this hypothesis in the efficient market framework so that lagged inflation is used as a proxy for expected inflation. We have tried to replicate the results of these other authors before considering other possible influences on the real rate suggested by theory. The relevant equations are shown in Table 1. In an attempt to capture the possible influence of lagged variables, the error terms in these equations were assumed to follow a fourth-order autoregressive process.

The earlier studies generally used a relatively long sample period that encompassed the sixties and seventies. Hence, it is comforting to find that using a similar long period—April 1958-October 1979—we were able to reproduce their conclusion. The estimated equation shown in the first column of Table 1 implies that if the quarterly rate of inflation increases by one hundred basis points, the real rate for the succeeding quarter declines 30 basis points, or, to put the same point slightly differently, if the higher inflation rate is expected to continue in the future, the nominal rate will rise 70 basis points. Clearly, if this result holds up when the sample period is extended beyond 1979 and when additional variables are added to the equation, it will help to explain why falling inflation rates have been associated with rising real interest rates.

The remaining columns of Table 1 show the regression results when the long sample period is divided into two shorter periods—April 1958-January 1970 and April 1970-October 1979, and when the latter period is extended to January 1982. The first of these equations shows only a small, and not statistically significant, effect of inflation on the real rate during the 1958-1970 period. The effect during the 1970s is larger and highly significant, implying that the negative relationship between inflation and the real rate found in other studies (and apparently confirmed by the results in the first column), in fact, represents only the experience of the seventies. Given the much lower inflation rate experienced in the sixties, the result is not surprising. If there are transactions costs associated with rearranging asset portfolios to hold more tangible assets and fewer financial assets, modest changes in the inflation rate may not induce any response.

The last column of Table 1 shows the estimated equation when the sample period is extended to January 1982. Again, the estimates show a negative relation between inflation and the real rate, suggesting that the Tobin effect continued to hold up after the Federal Reserve changed its operating procedures. This result suggests that the decline in the rate of inflation after 1979 may have been at least partially responsible for the upward movement in real rates. However, the structure of the autoregressive process on the residuals was sharply different in this extended sample period, suggesting that some new variable(s) began to influence real rates after 1979.

The theoretical discussion argued that increases in the supply of money relative to the demand to hold it tend to lower interest rates. Our excess supply of money variable is designed to capture this effect. We derived the variable by, first, estimating a demand for money equation in which money demand in any quarter depends on current and past values of the interest rate and of nominal personal income and on the current quarter's increase in outstanding bank loans. The parameters of this equation for various sample periods are shown in Table 2. The inclusion of the bank loans variable is based on the work of Judd and Scadding[20] who

Table 1
Inflation and Real Rates

Independent Variables	Sample Periods Apr 1958–Oct 1979	April 1958–Jan 1970	Apr 1970–Oct 1979	Apr 1970–Jan 1982
CONSTANT	0.020 (5.20)	0.018 (7.94)	0.011 (1.35)	0.004 (0.32)
PLAG	−0.30 (5.17)	−0.06 (0.79)	−0.28 (3.19)	−0.24 (2.06)
RHO1	−0.17 (1.63)	−0.13 (0.97)	−0.21 (1.41)	0.15 (1.01)
RHO2	0.12 (1.21)	0.05 (0.39)	0.06 (0.38)	0.30 (2.24)
RHO3	0.30 (2.90)	0.08 (0.64)	0.29 (2.06)	0.62 (4.36)
RHO4	0.13 (1.25)	−0.22 (1.74)	0.31 (2.11)	0.30 (1.82)
R-SQUARED	0.395	0.08	0.34	0.53

RHO1, RHO2, RHO3, RHO4 are fourth order autocorrelation coefficients.

argue that when banks increase their lending, members of the public receive additional bank deposits (money), some of which they are willing to hold *temporarily* until they rearrange their portfolios to add to their earning assets. Thus, the demand to hold money also depends on recent increases in bank lending.

In a given quarter, the demand to hold money may rise as a result of past or present increases in personal income or as the delayed result of *past* declines in interest rates. If such a rise in demand is not matched by a corresponding increase in the supply of money, the interest rate must rise to restore equilibrium in the market. Since members of the public do not adjust their money-holdings instantanously, this interest-rate change may be spread over several months. Similarly, to the extent that there is a rise in the stock of money as a result of an addition to the volume of bank lending, the rise will tend to drive down interest rates in later months because members of the public are only willing to hold this additional money temporarily.

To capture these effects of money on interest rates, the estimated coefficients of the money demand equation are used to predict what the quantity of money demanded in a given quarter would have been if the interest rate had remained the same as the preceding quarter and if there had been no change in

Table 2
Quarterly Demand for Money Equations

Independent Variables	Sample Periods: 1956:4–1969:4	1968:4–1979:4	1968:4–1982:4
CONSTANT	0.689 (1.165)	−1.795 (1.70)	0.264 (0.49)
TIME DUMMY^2		−0.00074 (0.406)	−0.0014 (0.71)
TIME DUMMY^3		0.00013 (0.332)	0.00 (0.00)
TIME DUMMY^4		0.00002 (0.728)	0.00001 (0.37)
LOG REAL PERSONAL INCOME*	0.685 (7.58)	1.054 (6.79)	0.750 (8.98)
LOG CONSUMER PRICE INDEX**	0.608 (3.41)	0.656 (7.12)	0.721 (23.7)
LOG COMMERCIAL PAPER RATE*	−0.029 (3.24)	−0.047 (2.86)	−0.033 (3.17)
LOG BANK LOANS (QUARTERLY CHANGE)	0.224 (2.38)	0.048 (0.76)	0.107 (1.30)
RHO	0.943 (20.6)	0.910 (14.6)	0.671 (6.83)

*Coefficients are sums of four-quarter distributed lags.
**Coefficient is sum of eight-quarter distributed lag.

TIME DUMMY = 0, 1956(4) − 1974(3);
= 1,2,3,. . . ,8, 1974(4) − 1976(3)
= 8 1976(4) − 1982(4)

The dummy variable is raised to the second, third and fourth powers to allow the implicit constant term in the equation to vary smoothly.
RHO = First Order Auto Regression Parameter

the volume of bank loans. The difference between this quantity and the actual supply of money is the excess supply of money, XMONEY.[21] Increases in this variable are expected to be associated with declines in the interest rate in the subsequent month. Notice that because the demand for money is made to depend on nominal income, this variable captures the effect of changes in income on interest rates via the transactions demand for money.

Two alternative measures of FEDDEF, the variable representing the impact of government borrowing on credit markets, were used: the overall federal government deficit shown in the national income and product accounts and the total of government and agency securities issued to the public (excluding the Federal Reserve system). Each variable was deflated by potential GNP and each was measured both inclusive and exclusive of Treasury interest payments. The second variable, which measures more directly the impact of federal borrowing on the credit markets, fit the data slightly better. For this reason, only equations using the second definition of this variable are reported below.

The final variable in the estimated equation is the level of GNP relative to potential. This variable captures any effect on interest rates of cyclical variations in real income in addition to those operating through the transactions demand for money. Also, it enables us to interpret the coefficient on FEDDEF as representing only the effect of financing changes

Table 3
Determinants of Real Interest Rates

Independent Variables	Sample Periods: Apr 1958 – Jan 1970		Apr 1970 – Oct 1979		Apr 1970 – Jan 1982	
CONSTANT	0.148	0.149	0.089	0.092	0.550	0.572
	(1.81)	(1.82)	(0.63)	(0.66)	(1.62)	(1.69)
PLAG	0.213	0.216	−0.113	−0.101	0.362	0.369
	(1.85)	(1.88)	(1.10)	(0.97)	(2.13)	(2.17)
FEDDEF1	0.141		0.369		0.027	
	(1.10)		(1.73)		(0.090)	
FEDDEF2		0.137		0.377		−0.011
		(1.09)		(1.78)		(0.038)
XMONEY	−1.006	−1.006	−0.168	−0.147	1.368	1.380
	(3.23)	(3.23)	(0.175)	(0.15)	(1.70)	(1.72)
INCOME	−0.134	−0.133	−0.104	−0.102	−0.576	−0.600
	(1.58)	(1.57)	(0.73)	(0.72)	(1.63)	(1.69)
RHO1	0.083	0.086	−0.112	−0.105	0.713	0.716
	(0.63)	(0.65)	(0.76)	(0.71)	(4.50)	(4.52)
RHO2	0.250	0.248	0.005	0.002	−0.147	−0.150
	(1.94)	(1.93)	(0.39)	(0.01)	(0.80)	(0.82)
RHO3	0.178	0.177	0.307	0.303	0.387	0.385
	(1.40)	(1.39)	(2.40)	(2.36)	(2.11)	(2.09)
RHO4	−0.178	−0.178	0.430	0.426	−0.055	−0.059
	(1.41)	(1.41)	(3.11)	(3.08)	(0.33)	(0.36)
R-SQUARED	0.17	0.18	0.36	0.36	0.48	0.48

FEDDEF1 includes and FEDDEF2 excludes government interest payments.

in the deficit, holding the level of income constant. An increase in real income tends to raise the anticipated return on real assets because businesses become more optimistic. This will tend to drive up interest rates as businesses seek to borrow to finance capital investment. At the same time, however, the supply of savings typically rises during a business cycle upswing and mitigates the upward pressure on interest rates. Thus, the sign of the coefficient on the INCOME variable is not determinate on the basis of economic theory.

Table 3 shows the results of adding these three variables to the equations estimated in Table 1. Since the INCOME variable is defined as the ratio of actual to potential GNP it is equal to one when the economy is operating at potential. Hence, the estimated value of the interest rate when the economy is at full employment and when there is no inflation, no federal borrowing and no excess money is represented by the sum of the constant term and the coefficient on the INCOME variable. This value was close to 1½ percent in the sixties and was negative in the seventies. Over the 1970-82 sample period, this value was even more negative—between −2½ and −3½ percent, implying that the high real rates actually observed were associated with changes in one or more of the independent variables in the equation and not with a shift in the intercept.

Both in the 1960s and in the 1970s, the coefficient on government borrowing is estimated to be positive. Thus, as theory would suggest, increases in federal borrowing at given levels of income were associated with higher real interest rates. The effect was smaller—and not statistically significant—in the earlier sample period when government borrowing was much smaller relative to the size of the economy. These results are hardly affected when government interest payments are excluded from total government borrowing. Apparently interest rates were influenced by total government borrowing, regardless of whether the funds were used to make interest payments on earlier borrowings. This result casts some doubt on the argument that deficits caused by high nominal Treasury interest payments do not drive up the real rate.

The last two columns of Table 3 display the results of extending the sample period to January 1982. Despite the widespread belief that the high levels of real interest rates after 1979 were the result of the sharp increase in federal borrowing, the coefficients on FEDDEF in these equations are small and insignificant. Thus, statistical analysis does not confirm the popular view that high real interest rates in recent years have been due to the increased volume of Treasury borrowing.[22]

A similar lack of stability in the coefficients was found with respect to the inflation and money variables. As the first column of Table 3 shows, during the 1958-1970 period, increases in the excess supply of money had a strongly negative impact on real interest rates: This is the result which traditional Keynesian liquidity-preference theory would predict.

In the subsequent decade, changes in monetary conditions had no perceptible influence on real rates. The estimated coefficient on XMONEY in the second column of Table 3, although negative, is small and not statistically significant. The most plausible explanation of this result is that it reflects the growing recognition by the public of the role of money in the inflation process. As investors come to realize that increases in the money supply lead to higher prices and, if sustained, to faster inflation, the net effect of monetary changes on interest rates becomes ambiguous.

Increases in the inflation rate were associated with increases in the real rate during the first sample period. Our analysis of the Tobin effect would lead us to expect the contrary. Until 1965, however, the average inflation rate was very low so that changes in the rate may not have led the public to alter its inflation expectations. Hence, increases in PLAG may have captured the effect of increases in the *level* of prices, which tend to raise interest rates when the money stock is held constant, rather than of increases in the *expected inflation* rate, which tend to lower real rates via the Tobin effect. During the 1970s, however, the estimated equation indicates that increases in the inflation rate were associated with higher nominal but lower real rates, as the Tobin effect would predict. However, this result is not significant at conventional probability levels when the influences of other variables are incorporated into the equation.

When the sample period is extended beyond October 1979, the estimated coefficients both on PLAG and on XMONEY are significantly positive.

Real rates *rose* when either the inflation rate increased or the supply of money grew faster than the demand. Since this extended period was one in which the Federal Reserve was strictly limiting money growth with a view to ending inflation, this result—which does not accord with the predictions of standard macroeconomic theory—suggests security markets interpreted increases in either money growth or inflation as signals of impending tightening of policy by the Fed; interest rates consequently rose. As previously indicated, the Treasury's borrowing had no significant impact on the real rate during this period when the effects of inflation and monetary policy were controlled for.

Summary and Conclusion

In recent years, real interest rates have risen sharply. It is widely argued that the need to finance increasing government deficits combined with a tight monetary policy on the part of the Federal Reserve System have been the principal reason for this development. In this paper, the formal theory underlying these arguments has been explained. This theory also suggests that a reduction in the rate of inflation will be associated with increased real rates.

An inescapable problem in testing hypotheses about the real interest rate is that when the market sets the nominal interest rate, it does so on the basis of an expected rate of inflation. Wealth-holders determine the nominal interest rate by adding their expected inflation rate to the *ex ante* real rate which they demand. However, the outside observer of the market cannot measure this *ex ante* rate; he can only measure the *ex post* rate that emerges. Nonetheless, by making use of the theory of efficient markets, it is possible to test hypotheses about the determinants of the *ex ante* rate using data on the *ex post* rate.

A number of studies by other authors have found that there was a significant inverse relationship in the post-war period between the rate of inflation and the real rate. Since the inflation rate has fallen since 1979, this relationship—if it continued to hold—would imply that real rates should have risen. However, the empirical results of this paper suggest that this relation only held during the seventies and that even during this decade the effect was less significant when one took account of change in the money supply and the federal deficit that took place at the same time.

Higher levels of federal borrowing were associated with increases in real rates during the 1970s. However, the empirical results do not support the proposition that there is any simple direct causal link between the recent sharp increase in the federal deficit and high real rates. In the equation estimated for the period between April 1970 and January 1982, for example, the estimated coefficient on the federal borrowing variable is small and not statistically significant. In fact, this equation suggests that money shocks and changes in the inflation rate have been more closely related to real rates than has the federal deficit. However, in this period high rates were associated with high inflation and positive monetary shocks rather than the reverse, probably because these factors were interpreted as signals of likely Federal Reserve policy in the near future.

Thus, the statistical analysis in this paper of the various factors which economic theory and popular opinion suggest as possible causes of the post-1979 rise in real rates does not strongly confirm any one of them. The results suggest that there is a great deal more to be learned before we fully understand the causes of the explosion in real rates.

A situation in which a substantial portion of government outlays are financed by borrowing rather than by taxation is unprecedented in peacetime. Hence, we should not be surprised that econometric analysis of data from an earlier period fails to provide a good guide to the current situation. This suggests that in formulating policy, we should be guided by the predictions of economic theory even though that theory has yet to be confirmed by empirical evidence.

FOOTNOTES

1. Throughout this paper, yields are measured on a bond-equivalent basis in order to make them consistent with rates of inflation.

2. Holders of Treasury Bills pay attention to the inflation rate they *expect* to occur over the maturity of the bill. Chart 1 shows the inflation rate which *actually occurred*. Over long periods, however, the rate of inflation which investors expect should not diverge too far from the actual rate. Hence the *realized* real return on bills should be a good proxy for the real rate which their holders *anticipated*.

3. The reader will recognize this argument as a simplified form of the expectations theory of the term structure of interest rates.

4. For one attempt to measure real long-term interest rates, see Charles Pigott, "Measuring Real Interest Rates Using the Term Structure and Exchange Rates," in a forthcoming issue of the **Economic Review**.

5. Notice that both the supply and the demand refer to the *stock* of securities. However, if these stock supplies and demands are equal at two successive dates, then the new securities *issued* between these dates must have been willingly *purchased* by investors. Some economists, and most market commentators, prefer to think of the interest rate as equating the *flow* of new issues by borrowers with the demand by investors to add to their holdings of securities.

6. J.M. Keynes, **The General Theory of Employment, Interest & Money**, New York, Harcourt Brace & Company, 1936, (p. 167).

7. For a more detailed exposition of this argument see John P. Judd and John L. Scadding, "Liability Management, Bank Loans and Deposit 'Market' Disequilibrium," **Economic Review**, Federal Reserve Bank of San Francisco, Summer 1981.

8. If nominal interest incomes are taxable, nominal rates will rise proportionately more than inflation, since investors will demand that their *after-tax* real incomes be protected against the effects of rising prices.

9. Notice that the deregulation of interest rates on monetary assets may weaken this effect in the future.

10. For an exposition of the argument in the context of a complete model of asset markets, see James Tobin, "A General Equilibrium Approach to Monetary Theory," **Journal of Money, Credit and Banking**, Vol 1, Number 1, (February 1969).

11. In the 1982 fiscal year the federal government had an overall deficit of $123.9 billion, while net interest payments were $82.5 billion.

12. Some economists have argued that as long as government *outlays* have not changed, members of the public will recognize that a cut in their *current* tax liabilities will have to be offset by an increase in their (or their children's) *future* tax liabilities. Thus, they will not change their level of consumption and will be willing to invest their increased savings in securities in order to provide for those future tax liabilities. Hence the supply of loanable funds increases by as much as the demand so that the interest rate is unaffected. David Ricardo was an early exponent of this view so that economists who take this position are frequently described as neo-Ricardians. Although there is some empirical evidence for this position, most economists believe the argument assumes a greater degree of rationality and forsightedness than most households possess. For an extensive discussion of this issue, see Robert J. Barro, "Are Government Bonds Net Wealth," **Journal of Political Economy**, Vol. 82, No. 6 (1974).

13. In terms of the traditional IS/LM paradigm, the increase in the interest rate which results from the expansionary effect of an increase in the high employment deficit on nominal income is represented by an upward shift of the IS curve. The increase which results from the fact that actual deficits must be financed by the issue of securities is represented by an upward shift of the LM curve. The public will be willing to hold a larger share of its portfolio in the form of securities (and hence a smaller share in the form of money or physical capital) only if interest rates on securities rise. For an early explanation of this distinction see William L. Silber, "Fiscal Policy in IS-LM Analysis: A Correction." **Journal of Money, Credit and Banking,** Vol. II (November 1970). More extensive discussions of the role of government deficits are provided in L.H. Mayer, "The Balance Sheet Identity, the Government Financing Constraint and the Crowding-Out Effect," **Journal of Monetary Economics** Vol. 1 (January 1975) and Brian Motley, **Money, Income and Wealth**, Lexington, Mass: D.C. Heath and Co., 1977. Chapter 6.

14. An exogenous cyclical downturn is represented by a downward shift of the IS curve, which, by itself, tends to lower interest rates. The upward pressure on rates caused by the associated rise in the deficit to be financed is represented by an upward shift of the LM curve. Hence, the net effect on interest rates cannot be predicted *a priori* on the basis of economic theory.

15. Adrian W. Throop, "Changing Fiscal Policy II," **Weekly Letter**, Federal Reserve Bank of San Francisco, January 16, 1981. Brian Horrigan and Aris Protopapadakis, "Federal Deficits: A Faulty Gauge of Government's Impact on Financial Markets," **Business Review**, Federal Reserve Bank of Philadelphia, March/April 1982.

16. For one attempt to measure the effect of inflation on the Treasury's interest-costs, see Throop, *op. cit.* An alternative approach which directly measures the decline in the real value of the government debt, is used by Horrigan and Protopapadakis, *op. cit.*

17. This formulation assumes that investors are risk neutral and hence do not require a risk premium to cover the fact that the inflation rate is uncertain.

18. For a detailed exposition of this argument, see Frederick S. Mishkin, "The Real Interest Rate: An Empirical Investigation," **Carnegie-Rochester Conference Series on Public Policy,** 15, (1981).

19. See, for example, Frederick S. Mishkin, *op. cit.,* John H. Makin, "Real Interest, Money Surprises and Anticipated Inflation," Working Paper 878, National Bureau of Economic Research, (December 1981).

20. John P. Judd and John L. Scadding, *op. cit.*

21. The stock of money in a given quarter t may be written

$$M^s_t = a_t + b\text{INCOME}_t + c\text{INTEREST RATE}_t + d\Delta\text{BKLOANS}_t + e_t$$

where a_t includes the effects of all lagged variables on money demand as well as the constant term, and e_t is the residual between the actual money stock and the fitted money demand. Then

$$\text{XMONEY}_t = M^s_t - (a_t + b\text{ INCOME}_t + c\text{INTEREST RATE}_{t-1}) = c\,(\text{INTEREST RATE}_t - \text{INTEREST RATE}_{t-1}) + d\Delta\text{BKLOANS} + e_t$$

22. This result does not, however, mean that real rates would not have been lower if fiscal policy had been less expansionary, but only that—given the level of nominal income which resulted from that policy—the additional impact on interest rates of the associated deficits was small.

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The Behavior of Money and the Economy in 1982-83

John P. Judd and Rose McElhattan*

In 1982, M1 velocity unexpectedly declined at a 5-percent rate in contrast to its 3-percent average rate of increase over the previous twenty years. As a result, the Federal Reserve de-emphasized M1 in its conduct of monetary policy, and allowed that monetary aggregate to grow at a rapid 8½-percent rate for the year compared to its target range of 2½ to 5½ percent. But even with this change in policy, nominal income rose only moderately and real income declined.

A paper in the Spring *Economic Review* assessed what went "wrong" with velocity in 1982.[1] One possibility it considered was that the public's demand to hold money balances "shifted" upward in the sense that, for given interest rates, income, and prices, the public wanted to hold more money than historical relationships would have predicted. However, the article presented evidence from the San Francisco money market model suggesting that the demand for M1 was stable, and that the decline in velocity largely is explained by the sharp parallel drop in short-term interest rates and inflation in 1982. In sum, the drop in interest rates raised the quantity of money demanded by the public, and the Federal Reserve responded by allowing money to grow faster than originally targeted. This drop in interest rates was roughly equal in size to the surprisingly sharp decline in inflation that occurred in 1982. Thus, the declines in nominal interest rates and inflation meant that inflation-adjusted, or *real*, short-term interest rates remained high and depressed total spending in the economy. As a result, GNP grew very slowly or declined. The combination of fast M1 growth and slow income growth meant that velocity actually fell. Thus the earlier article presented evidence that the decline in velocity was consistent with a stable demand for money relationship, representing an increase in the quantity of money demanded because of lower interest rates and inflation, rather than an unstable money demand function.

This analysis suggests that a good deal of the growth in M1 over 1982 and early 1983 did not have a stimulatory effect on aggregate demand because it represented an increase in the quantity of money demanded, rather than an autonomous increase in the supply of money. In other words, effective money growth—effective in the sense of measuring the thrust of monetary policy—was lower than actual, or measured, money growth during the period. We attempted to measure this effective growth by subtracting from measured M1 an estimate of the increase in the public's demand for M1 caused by the decline in short-term interest rates that paralleled the decline in inflation. This estimate came from the M1 demand equation in the San Francisco money market model. The results suggest that whereas measured M1 increased at a rapid 11 percent rate over 1982/Q3-1983/Q1, adjusted M1 grew at only a 1½ percent rate.

If the analysis behind these estimates were correct, adjusted M1 should be a better indicator of monetary policy in 1982-1983 than measured M1. To see if this is the case, the FRBSF Research Department's macroeconomic model (which predicts real GNP and inflation from reduced-form equations on M1 and other variables), was simulated over the period 1982/Q1-1983/Q2 using adjusted M1 and, alternatively, actual M1. The results of this experiment confirmed the above analysis of events in 1982-83. Simulations of velocity, real GNP and inflation using adjusted M1 were more accurate than those using measured M1, which yielded large over-forecasts of all three macroeconomic variables.

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These results have an important policy implication. They suggest that although monetary policy was quite restrictive in 1982, it became moderately expansionary in 1983/Q1 and highly expansionary in 1983/Q2. The money market model suggests that the public's demand for money had fully adjusted to the new lower levels of interest rates by the first quarter of 1983, while money growth continued to grow rapidly. It expanded, for example, at a fast 12½ percent rate in the second quarter of 1983. With the adjustments in money demand over, one could expect the growth in velocity to revert to a more commonly observed range. Such a rebound in velocity suggests that it would be desirable for M1 growth to slow down in the last half of 1983. Otherwise, there would be hefty increases in spending which ultimately would threaten to increase the rate of inflation.

The remainder of this paper is divided into four sections. Section I briefly reviews the discussion in the earlier paper on what went "wrong" with velocity in 1982-83. The estimates of adjusted M1 growth are presented in Section II. Section III contains a discussion of the simulations of macroeconomic variables. Finally, conclusions and policy implications are presented in Section IV.

I. What Went "Wrong" with Velocity in 1982-83?

One possible explanation for the unexpected change in velocity in 1982 is that there was an upward shift in the public's demand for money, that is, that increasing quantities of M1 were demanded by the public for given levels of prices, real GNP and interest rates. This alleged shift has been attributed to a precautionary motive for holding money caused by the economic uncertainty of the recession.[2] This would be a plausible hypothesis if the evidence showed that the demand for M1 did shift upward in 1982. However, simulations of the M1-demand equation in the San Francisco Money Market Model[3] suggest that the demand for M1 was stable. The M1 equation predicted annualized growth of 10.2 percent in 1982/Q1-1983/Q1 when actual growth was 10.3 percent. (*Ex ante* forecasts made during the year produced nearly identical results.) Thus, the rapid M1 growth can nearly all be "explained" by the determinants of M1 demand; these results provide no indication of a shift in the money demand relationship.

If the demand for M1 did not shift, what explains the rapid growth of that aggregate in the period considered? An analysis of the simulations indicates that the largest contributions were made by the declines in the commercial paper rate in the third and fourth quarters. These drops by themselves caused M1 to grow an annual rate of about 11.8 percent between August 1982 and February 1983, compared to a contribution of a 0.4 percent rate of decline in M1 over the preceding seven months. Apparently, most of the sharp increase in M1 growth between 1982/Q2 and 1983/Q1 is explained by the drop in nominal interest rates.

Lower Inflation

Given that the demand for M1 does not appear to have shifted, an alternative explanation of the decline in velocity in 1982 is required. The Federal Reserve Bank of San Francisco staff has argued that the unexpectedly rapid decline in inflation provides an explanation.[4] This explanation rests on the distinction between nominal, or market interest rates, and real, or inflation-adjusted interest rates. The level of spending on goods and services depends on the real rate of interest. In contrast, the public's demand for M1 depends on the nominal rate of interest. To illustrate the significance of this dichotomy for developments in 1982-83, assume that the rate of inflation falls and that this is reflected in an equal decline in nominal interest rates. In this circumstance, the real rate of interest would be unchanged, implying that the decline in nominal interest rates would *not* stimulate additional growth in real GNP. However, the public's demand for money would grow more rapidly, for a time, in response to the drop in nominal interest rates. As a result, money growth would accelerate in comparison to GNP growth, implying a decline in the growth of velocity.

This stylized scenario is a rough approximation to the events that occurred in 1982 as whole.[5] The GNP deflator rose at an 8.9 percent rate in 1981, then fell suddenly to a 4.4 percent rate in 1982, for a decline of 4.5 percentage points in the rate of inflation. The commercial paper rate fell about the same amount, dropping 4.1 percentage points from 12.9 percent in the fourth quarter of 1981 to 8.8 percent in the fourth quarter of 1982. The very rapid growth in M1 associated with the drop in nominal interest rates did not stimulate the economy because real interest rates were not reduced substantially for the year as a whole. Thus, real GNP over this period fell on average at a 0.9 percent rate.

II. Adjusted M1 Growth

In the midst of a decline in velocity as large as that in 1982, growth in M1 obviously would not be a good indicator of the impact of monetary policy. A macroeconomic model that exploits the historical relationship between money and income would likely have over-predicted nominal income and, thus, velocity in 1982. The analysis in the preceeding section suggests a way to correct for this problem by adjusting the growth in M1 downward, and then using the adjusted M1 growth rates to predict income on the basis of historical money-to-income relationships.

How should these M1-adjustments be calculated? A significant part of the desired adjustment should be calculated as the growth in M1 caused by a drop in nominal interest rates that paralleled the drop in inflation. Since interest rates and inflation both declined by about the same amount, we calculated the adjustment as the M1 growth due to the full drop in interest rates in the last half of 1982. We then subtracted these adjustments from actual M1 growth to obtain what can be called *adjusted M1 growth*.

The figures for adjusted M1 growth are presented in Table 1 on a quarterly average basis. Two aspects of the figures are worth emphasizing. First, the adjustments are quite large in 1982/Q3-1983/Q1, and convert rapid measured M1 growth of 11.1 percent into very slow growth in adjusted M1 of 1.7 percent. Second, the decline in interest rates in the latter part of 1982 affected M1 growth only temporarily, specifically for three quarters. Because money growth will rise relative to GNP growth only as long as the public's demand for money is stimulated by *declines* in interest rates, the effects on money growth dissipate once interest rates stabilize at new lower levels. The exact timing depends on the lags in the demand for money.

The M1-demand equation used suggests that interest rates affect the public's demand for money for about six months. According to the equation, a one-time decline in the commercial paper rate in any given month causes M1 to accelerate relative to GNP (that is, causes velocity growth to fall) contemporaneously and for the next five months. This suggests that M1 growth induced by the decline in interest rates in 1982 should have played itself out by the second quarter of 1983. In fact, the commercial paper rate fell sharply in the third and fourth quarters of 1982. By the second quarter of 1983, these interest rate changes should have had only minor effects on M1 growth, and should not have required any adjustment in that growth after the first quarter. Thus this analysis suggests that the rapid measured M1 growth in the second quarter accurately indicated the thrust of policy in that quarter.

Table 1
Growth in M1 at Annualized Rates
(Quarterly Average Basis)

	Measured	Adjustments	Adjusted M1 Growth
1982/Q1	10.5	0.0	10.5
Q2	3.2	0.0	3.2
Q3	6.1	-5.4	0.7
Q4	13.1	-14.7	−1.6
1983/Q1	14.1	-8.2	5.9
Q2	12.3	0.0	12.3

III. Using Adjusted M1 in Macroeconomic Simulations

The unusual experience with inflation and velocity in 1982 and early 1983 resulted in large errors from macroeconomic forecasting models in general. Many models, including that of the FRBSF, were thrown off-track, and overestimated actual velocity, real GNP and inflation during that period. If the above explanation for the macroeconomic developments of the past year and a half were correct, adjusted M1 should be a significantly more accurate indicator of monetary policy than actual M1. One way to check the validity of the M1-adjustments, and therefore the underlying explanation of events in 1982-83, is to use them in the FRBSF Research Department's macro-model to simulate events over the 1982-83 period.

The model is a reduced form representation of the U.S. economy and includes equations for real GNP growth and inflation as functions of M1 and the high employment deficit.[6] Velocity is not estimated directly but is obtained by subtracting (exogenous) M1 growth from the sum of the predicted growth in real GNP and predicted inflation.

The model was estimated over 1966-81, and then simulated over 1982/Q1-1983/Q2 with measured M1 and, alternatively, with adjusted M1 to see which yielded results closer to the actual events of the period. As shown in the charts below, adjusted M1 produces simulated values for inflation, real GNP and velocity that are reasonably close to actual developments, whereas actual M1 produces large over-forecasts.

Chart 1 shows actual velocity and dynamic model simulations with observed and adjusted M1. With observed M1, the model follows the general pattern of velocity from mid-1966 until 1982. The 1982-83 period is unusual in that the model substantially overestimated velocity for a *sustained* period of time. Historically, when large simulation errors occurred, they abated within one to two quarters. Thus, the recent errors made with actual M1 are unusual because of their size and because they persisted so long. In contrast, the M1 adjusted simulations produce errors well within the range of those experienced in the past. The same observations hold for the real GNP and inflation simulations (not shown). Using adjusted M1 improved the model's simulation accuracy not only for nominal GNP (and thus velocity), but also for the split between inflation and real GNP growth.[7]

Charts 2 through 4 show a detailed view of actual

Chart 1

M1 Velocity

1966:2–1983:2

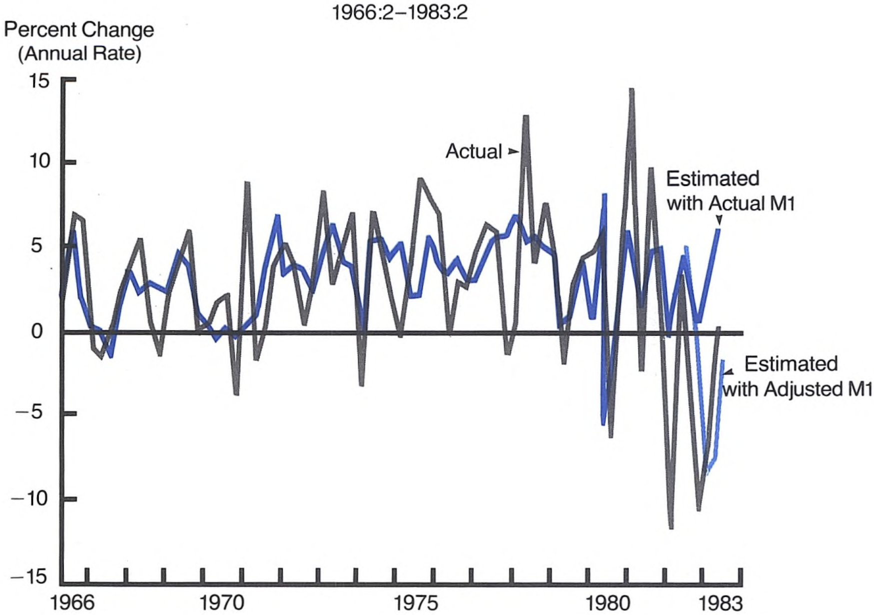


Chart 2

M1 Velocity

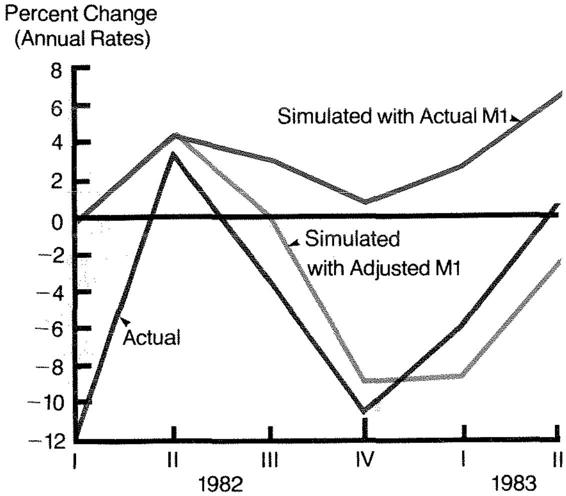


Chart 3

Real GNP

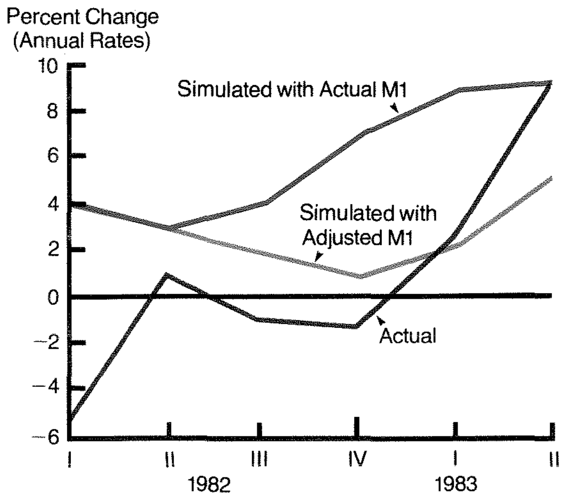
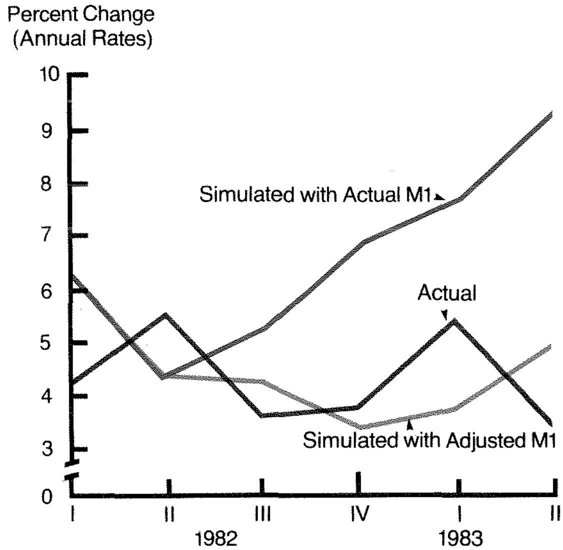


Chart 4

GNP Implicit Price Deflator—Inflation Rates



and model simulations of velocity, real GNP growth and inflation from 1982/Q1 to 1983/Q2. The simulated values for velocity growth in Chart 2 using observed M1 are much higher than actual values for the entire period. In contrast, the simulation with adjusted M1 closely follows the actual course of velocity and captures both the dramatic decline in velocity in the second half of 1982 and the increase during the first half of 1983. The model still makes a larger error in 1982/Q1, but, overall, forecast errors for the growth rate of velocity were reduced from an average overforecast of 8.2 percentage points between 1982/Q3 and 1983/Q2 with actual M1 to 0.2 percentage points with adjusted M1.

The model forecasts of real GNP considerably overstated the strength in the economy in 1982 and early 1983. In contrast, the simulations with adjusted M1 tracked actual activity more closely, with the exception of 1983/Q2 in which adjusted M1 underestimates the strength of the economy. On average, both simulations overforecasted real GNP growth in the period 1982/Q3-1983/Q2. But the average forecast error was only 0.2 percentage points with adjusted M1 in contrast to 5.0 percentage points with actual M1. Similar observations apply to inflation. Forecast errors were reduced from an average overforecast of 3.2 percentage points in the case of simulations with actual M1 to 0.01 percentage point with adjusted M1 during 1982/Q3-1983/Q2.

IV. Policy Implications

The conclusion that the behavior of velocity in 1982 may be attributed to the (surprisingly) sharp drop in inflation and nominal interest rates has an important implication for monetary policy in 1983. With this explanation, there is good reason to believe that velocity will return to more commonly observed rates of change in the second half of 1983. As noted earlier, the 1982 decline in interest rates should affect M1 growth (and thus velocity growth) only temporarily. Money will rise relative to GNP only as long as the public's demand for money is stimulated by *declines* in interest rates. Once interest rates stabilize at new lower levels, the effects on money growth should dissipate according to the lags in the demand for money. Thus, by the second quarter of 1983, these interest rate changes should have only minor effects on M1 growth and velocity. This implies that M1 growth needs to be reduced substantially from its 12-percent rate in the second quarter to avoid a highly expansionary effect.

In July 1983, the Federal Reserve announced a revision in the 1983 target range for M1. It replaced the original 1983 range of 4 to 8 percent for the entire year with a 5 to 9 percent range for the second half of 1983. By establishing a second quarter base, the Federal Reserve accommodated the rapid 12 percent growth in M1 in the second quarter. If M1 were to grow at the 9 percent upper boundary of its new range, for example, average M1 growth over the period 1983/Q1-1983/Q4 would be ten percent.

The macroeconomic model was simulated assuming 9 percent M1 growth in the second half of 1983, followed by growth of 8 percent in 1984 (the upper boundary of the 4 to 8 percent range tentatively established for that year by the FOMC) and 7 percent in 1985. The figures represent a gradual reduction in M1 growth in 1984-85 that is consistent with a policy of minimizing the adverse effects of lower money growth on the economy. Our simulation suggests that the rate of inflation would be 5½ percent in the second half of this year, followed by increases to 6½ percent and 7½ percent in 1984 and 1985 respectively. If M1 growth were held to the 7 percent mid-point of the range for the second half of this year, followed by growth of 6 percent in 1984 and 5 percent in 1985, the inflation rate would be held to about 5 percent over the entire period.

Thus, a substantial slowdown in M1 growth appears to be required over the next several years to hold the underlying rate of inflation at its present level. Moreover, the simulation suggests that even with this slower M1 growth, aggregate demand is likely to increase rapidly enough to sustain a recovery. Velocity is estimated to grow at 4½ percent rate in the last half of 1983 and 1984, leaving room for real GNP to grow at a 5½ percent rate.

FOOTNOTES

1. John P. Judd, "The Recent Decline in Velocity: Instability in Money Demand or Inflation?, **Economic Review**, Federal Reserve Bank of San Francisco, Spring 1983, pp. 12-19.

2. This possibility is raised, for example, in "Record of Policy Actions of the Federal Open Market Committee", meeting held on August 24, 1982.

3. The model is presented in John P. Judd, "A Monthly Model of the Money and Bank Loan Markets", **Working Papers in Applied Economic Theory and Econometrics**, Number 83-01, Federal Reserve Bank of San Francisco, May 1983.

4. See Michael W. Keran, "Velocity and Monetary Policy in 1982, **Weekly Letter**, Federal Reserve Bank of San Francisco, March 18, 1983.

5. Inflation fell early in 1982, whereas interest rates fell in the third quarter. This consideration complicates the explanation of events without altering the fundamental explanation given in the text. See the article cited in footnote 1 for a discussion of these points.

6. A feature of the model, which is not generally found in other reduced form models, is that both real GNP and inflation react in a cyclical manner to changes in monetary policy. Ultimately only the level of prices and the inflation rate are affected by changes in money. This property is often referred to as the neutrality of money. In particular, about two years after an initial change in monetary growth, inflation will overshoot its sustainable, long-run value and then slowly return to that value within the next two-to-three years. The reason for this is that following a permanent change in money growth, inflation initially will change more slowly than the money supply. Consequently, the public's holdings of real money balances will be disturbed leading to adjustments in the public's holdings of both real and financial assets. For instance, it takes about two years before a decrease in money growth is matched by a decrease in the inflation rate, according to the model. But by that time, real money balances are far below their longer-term desired value. The continued adjustment in real money balances will sustain cyclical movement in both inflation and real GNP until both nominal and real quantities are at their new, longer-run values consistent with the lower monetary growth.

Rose McElhattan, "The Response of Real Output and Inflation to Monetary Policy", **Economic Review**, Federal Reserve Bank of San Francisco, Summer 1981, pp. 45-70, and "On Federal Deficits and their Economic Impact", **Economic Review**, Federal Reserve Bank of San Francisco, Summer 1982 pp. 6-17.

7. OPEC price shocks have been important determinants of short-term changes in the overall rate of inflation. The inflation model allows for this in 1974 and 1975, but does not include the substantial oil price increases in 1979 and 1980 when the relative price of oil increased around 15 percent and 30 percent, respectively. This exclusion is related to the relatively large under forecasts of inflation during that time. On the other hand, real oil prices declined about 5 percent in 1982 and no doubt have been responsible for some of the overforecast of inflation in that year.