DALLASFED

Economic Review

Federal Reserve Bank of Dallas
January 1983

The answer depends on whether the region is well integrated with the U.S. financial system. Interest rates charged by southwestern banks on commercial loans are strongly correlated with the rates charged by banks in New York City, the financial center of the country. This indicates a high degree of integration, which implies that the Southwest is not short of capital.

Nominal interest rates have adjusted slowly to changes in inflation in recent years, resulting in low real interest rates during the early 1970's and high real rates since 1979. History shows that this sluggishness is not a new development. The relationship between interest rates and inflation over the past three decades is similar in many respects to the relationship observed by Irving Fisher for 1890–1927. Interest rates have typically followed inflation with long distributed lags, and real interest rates have been persistently high or low for extended intervals.

Is the Southwest Short of Capital?

*By Dale K. Osborne**

The Southwest has been growing faster than the country as a whole for a couple of decades and is frequently described as "capital-short." This term is harmless enough if it means only that the Southwest is a net borrower from the rest of the country, for being a net borrower goes hand in hand with growing faster. But at times the term seems to mean more, to suggest that the capital "shortage" is a defect to be remedied lest it hinder the region's further development. This latter sense of the term is appropriate only if the region is not well integrated into the U.S. financial system.[1]

All regions would be perfectly integrated if credit conditions never changed, for then interest rates on a given financial instrument would be the same in all regions. A difference in such rates could exist only if the cost of obtaining information kept lenders in the low-rate region economically separated from borrowers in the high-rate region. In known static conditions, one or both of these parties would willingly incur the start-up costs of ending the separation. A party that thus obtained information about the other, or provided information about itself, would recapture its start-up costs by borrowing more cheaply or lending more dearly. For example, if interest rates on business loans of a given type were lower in Pittsburgh than in Dallas, the Pittsburgh bankers could open loan offices in Dallas in order to compete for the more profitable lending. The very exploitation of such opportunities for profit would eventually erode them away, and the only sustainable relation between interest rates on a given instrument in the various regions would be equality.

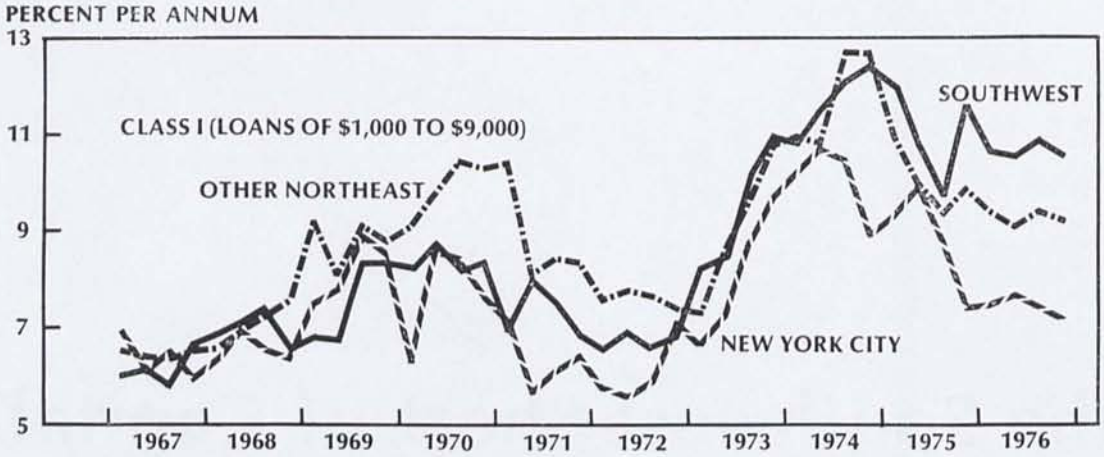
In practice, credit conditions change frequently and interest rates approach their new equilibrium values at different speeds. Regional differentials might occur, and their durations might be difficult to predict. Borrowers and lenders might not be sure how long a favorable opportunity elsewhere will

* *Dale K. Osborne is Director of the Center for Financial Institutions at Oklahoma State University and a consultant at the Federal Reserve Bank of Dallas.* *Research for this article was partially supported by the College of Business Administration at OSU.*

1. Here we abstract from usury laws and other artificial impediments to the movement of capital.

Chart 1

Interest Rates on Long-Term Business Loans



SOURCE: *Federal Reserve Bulletin.*

last, even if they know of it. Pittsburgh bankers will have to exercise considerable judgment about the duration of a gap between Dallas and Pittsburgh rates and might fear that the gap would vanish before a proposed Dallas office could become operational; they might refuse to incur the start-up cost unless the gap were considerable.

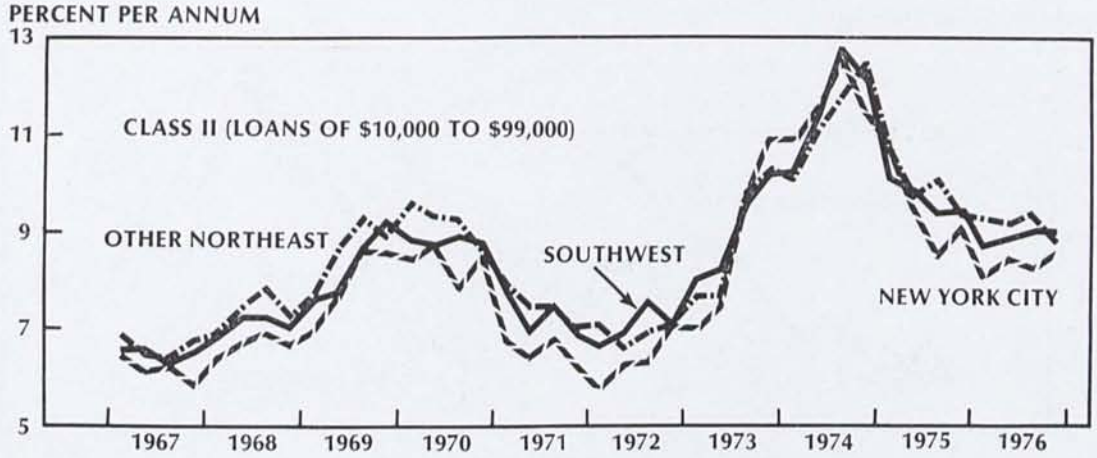
But even in the real world of uncertainty about the future and incomplete information about the present, regional differences in interest rates call forth actions that tend to diminish them. The Pittsburgh bankers would not have to open an office in Dallas in order to profit from higher rates there. They could simply dispatch a traveling loan officer to Dallas. Or they could increase their participation in the loans made by Dallas bankers; and if for some reason they held back, bankers in other regions could increase their participations in Dallas loans and decrease their participations in Pittsburgh loans. In either case, the increased flow of credit to Dallas and the decreased flow to Pittsburgh would diminish the gap.

Indeed, it is tempting to believe that, at least with respect to the business loans of banks, the various regions of the country are financially integrated into one market. In any region the interest rate on a given type of business loan (given the maturity, default risk, collateral, compensating balance arrangements, and all other pertinent terms of the loan) is primarily determined by the marginal cost of funds. This cost is the rate on Federal funds, large certificates of deposit, or other unregulated instruments and is the same in every region. (It differs among banks according to the market's perception of their risks, but these depend on the banks' balance sheets and not on their locations.) Therefore, bankers in all regions can "afford" to lend at the same rate and will be forced to do so if their attempts to exploit inelasticity in the regional demand for loans attract funds from regions where the loan demand is more elastic. If loan offices, traveling loan officers, and participations bring enough funds into a region to move interest rates and if they are attracted by sufficiently small regional differentials, they will equalize the rates. The profit-seeking actions of banks thus tend to integrate the regions.

If the regions are financially integrated, differential regional demands for or supplies of capital have no effects on regional growth rates. The various regions are as one so far as finance is concerned, howsoever they might differ in cultural, political, fiscal, or other respects. Rapidly growing regions will attract capital from other regions, and no

Chart 2

Interest Rates on Long-Term Business Loans



SOURCE: *Federal Reserve Bulletin.*

region will suffer from a shortage of capital.

Therefore, to claim that the Southwest is short of capital is really to claim that it is poorly integrated with the U.S. financial system. This poor integration would have to derive from inadequacies in the commercial lending of banks. (Lending to regional enterprises by the capital markets is clearly not a regional matter, for these markets are national or international in scope, and lending to consumers has comparatively little obvious bearing on regional development.) Such inadequacies would cause interest rates on commercial loans by southwestern banks to be weakly related to the interest rates on commercial loans by banks in New York City, the banking center of the country. A weak relation between these rates would thus suggest that the Southwest is financially segregated from the banking center and that the frequent complaints of a capital shortage might have some substance. But a *strong* relation between the rates will suggest that the region is financially integrated with the banking center and is short of capital only in the sense that IBM is short—namely, that it is a net borrower.

As there is no precise criterion for a "strong relation," it is necessary to settle for a comparison. The relation between New York rates and southwestern rates may be compared with the relation between New York rates and other northeastern rates. If there is no difference, the indicated conclusion is that Southwest banking is integrated with New York banking as well as Northeast banking is. Because the Northeast is the closest region to New York (and not only geographically), its financial integration with New York may be regarded as a standard of comparison.

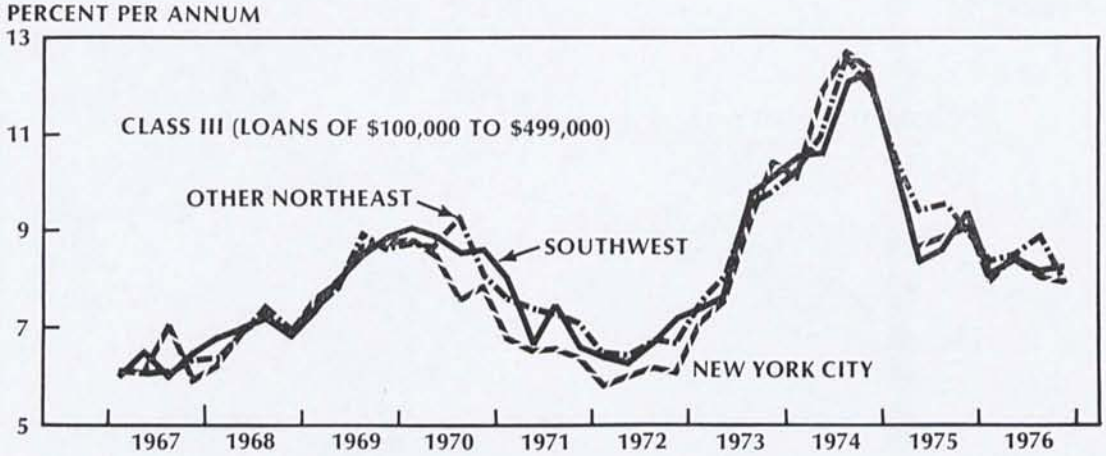
Two ways of evaluating the relations between rates in New York City and the other regions are explained below. To anticipate the findings, Southwest banking does indeed appear to be integrated with New York banking as well as Northeast banking is. The findings thus give no support to the notion that the Southwest is short of capital.

The data

The data come from a survey conducted quarterly by the Federal Reserve Board from 1967 to 1976, covering 126 banks in 35 reporting centers in the United States. The 35 centers were allocated to six geographic regions, and weighted-average interest rates were reported for each region. The three regions of interest to us are New York City, "Other Northeast" (Boston, Hartford and Providence, Buffalo, Nassau County in New York, Rochester, Newark, and Philadelphia), and "Southwest" (Dallas

Chart 3

Interest Rates on Long-Term Business Loans



SOURCE: *Federal Reserve Bulletin.*

and Fort Worth, Houston, Oklahoma City and Tulsa, Denver, Kansas City, St. Louis, Louisville, and Memphis—the last three of which, regrettably for our purposes, are not ordinarily regarded as southwestern cities).

The survey covered loans in three maturity classes and five size classes. The maturity classes are short term (one year or less), long term (over one year), and revolving credit.[2] Only the long-term loans are analyzed here, as these are the loans that bear most directly on questions of regional development.

The five size classes are:

Class	Amount of loan
I	$1,000 to $9,000
II . . .	$10,000 to $99,000
III . . .	$100,000 to $499,000
IV . . .	$500,000 to $999,000
V . . .	$1 million and over

2. See the *Federal Reserve Bulletins* of May 1967 and June 1971 for descriptions of the survey. Essentially all the surveyed banks had business loans totaling at least $40 million in 1967. The survey was revised in 1971, but close examination of the data shows enough continuity for our purposes. Regional data on interest rates are available for years earlier than 1967 and later than 1976, but only for the years 1967–76 are the data broken down by maturity and size classes.

The data are plotted in the five charts. Only the movements of the rates are germane. The rates can differ in their levels because of regional differences in the noninterest terms of lending (collateral, compensating balance arrangements, and so on), for which we have no information. But the rates must move together if the regions are really integrated.[3] The charts give a visual impression that the rates do indeed tend to move together. The tendency is weaker in Class I, but this fact may indicate that the reported rates reflect actual transactions instead of just "tracking the prime rate" (as would be the case if, for example, the bank clerks filling out the survey forms yielded to the temptation to write in the prime rate or some other fictitious figure instead of inspecting the records).

In any case, these visual impressions cannot be relied upon to decide the question. The large swings in rates during the sample period tend to dominate the graphs and to tempt the viewer into hasty conclusions. A statistical analysis may help us to resist

3. For a thorough discussion of financial integration and its evaluation, see Peter B. Kenen, *Capital Mobility and Financial Integration: A Survey*, Princeton Studies in International Finance no. 39 (Princeton: Princeton University, Department of Economics, International Finance Section, 1976), 9–30.

RESULTS OF TESTS FOR REGIONAL INTEGRATION IN LONG-TERM BANK BUSINESS LOANS

	Coefficients of correlation with New York City, by loan-size classes				
	I	II	III	IV	V
Contract interest rates					
Other Northeast	.769	.951	.961	.935	.948
Southwest	.723	.969	.961	.947	.945
Implied risk premiums					
Other Northeast	.488	.880	.904	.830	.878
Southwest	.346	.926	.896	.867	.866
Number of observations	38	40	40	40	40

NOTE: Sample period = 1967–76.
SOURCE OF PRIMARY DATA: *Federal Reserve Bulletin.*

this temptation.

Statistical analysis

A straightforward correlation analysis of the data confirms the visual impressions given by the charts. The results of this analysis, based on the contract interest rates, are shown in the upper part of the table. The correlations between New York and Southwest rates and the correlations between New York and Other Northeast rates are quite high, being greater than .93 for all sizes of loans except those in Class I. Moreover, in *every* size class the Southwest–New York correlation does not differ significantly from the Northeast–New York correlation at the 5-percent level by Fisher's Z test.[4] If this correlation analysis is the correct method of testing the hypothesis of regional integration, the conclusion is clear: Southwest banking and Northeast banking are equally well integrated with New York City banking.

4. Fisher's Z test transforms a correlation coefficient, r, into a variable, Z, by the equation

$$Z = [\ln(1 + r) - \ln(1 - r)]/2.$$

This variable is almost normally distributed, with its standard error equal to $1/\sqrt{(n - 3)}$, where n is the number of sample observations. The test then proceeds in the usual manner of a t test.

Correlation analysis of the contract rates is appropriate if integration implies a linear relation between the rates in different regions—that is, if the rates R_{1t} and R_{2t} in Regions 1 and 2 at time t obey a relation such as

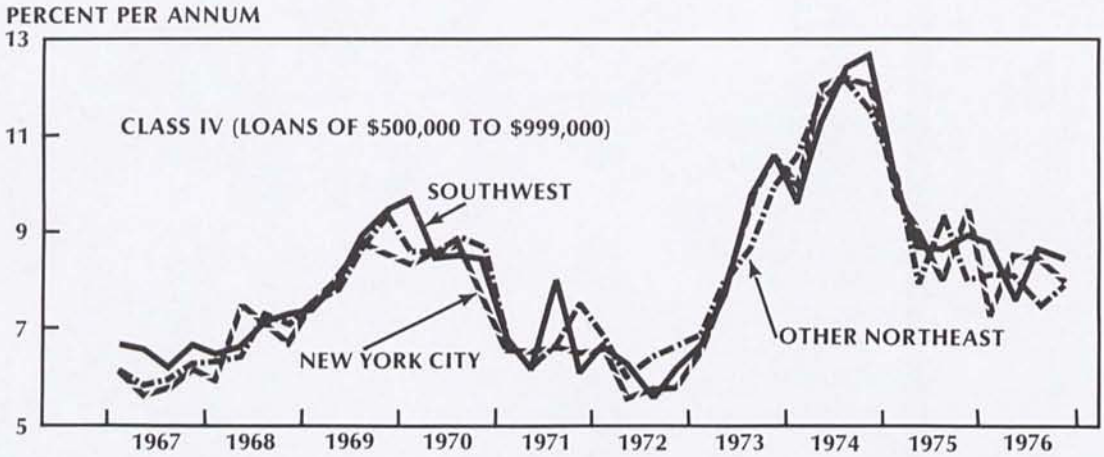
$$(1) \qquad R_{1t} = a + bR_{2t} + u_t, \qquad b > 0,$$

where a and b are the coefficients of the relation and u_t is a random deviation averaging zero and uncorrelated with R_{2t}. This kind of relation can obtain if the characteristics of borrowers are essentially the same regardless of the regions from which they borrow, so that regional differences in rates spring only from noninterest terms of lending.

Suppose, for instance, that Region 1 lenders impose no compensating balance requirements but Region 2 lenders impose a requirement of 10 percent, so that the effective rate in Region 2 is 10/9 of the contract rate. Suppose further that all other terms are identical in both regions. If integrated, the regions have the same effective rate, and the Region 2 contract rate is 9/10 of the Region 1 contract rate. The coefficient b in equation 1 then equals 10/9. Alternatively, suppose that all noninterest terms are identical except that Region 1 lenders impose a prepayment penalty while Region 2 lenders impose no such penalty but, instead, increase their contract rates by a percentage point. Then the Region 2 con-

Chart 4

Interest Rates on Long-Term Business Loans



SOURCE: *Federal Reserve Bulletin.*

tract rate exceeds the Region 1 rate by 1 point, and the coefficient a in equation 1 equals -1.

A combination of these alternative suppositions yields nonzero values for both coefficients in equation 1. These values cannot be further specified—beyond ($b > 0$)—because of possible intraregional variations in all noninterest terms of lending, so the correlation analysis reported above is appropriate under the suppositions just set forth.[5]

An alternative set of suppositions leads, however, to a different form of relation between the rates of integrated regions. As these suppositions cannot be rejected out of hand, they force us to a second test of the integration hypothesis.

Specifically, it might be supposed that bank loans are amenable to analysis by the capital asset pricing model (CAPM) or the options model of corporate debt (OMCD).[6] As explained in the Appendix, these models are normally applied to secondary trading in corporate equity and corporate debt, respectively, not to the pricing of bank loans. But the fundamental substitutability of all financial instruments makes it possible that bank loans obey a risk-return relation similar to that which governs tradable instruments. A defensible test of the integration hypothesis must either admit this possibility or prove it false. In our case, to admit it is simpler.

As shown in the Appendix, if Regions 1 and 2 are integrated, both the CAPM and OMCD imply that the rates R_{1t} *and* R_{2t} obey the relation

$$(2) \quad R_{1t} - R_t = a + b(R_{2t} - R_t) + u_t, \qquad b > 0,$$

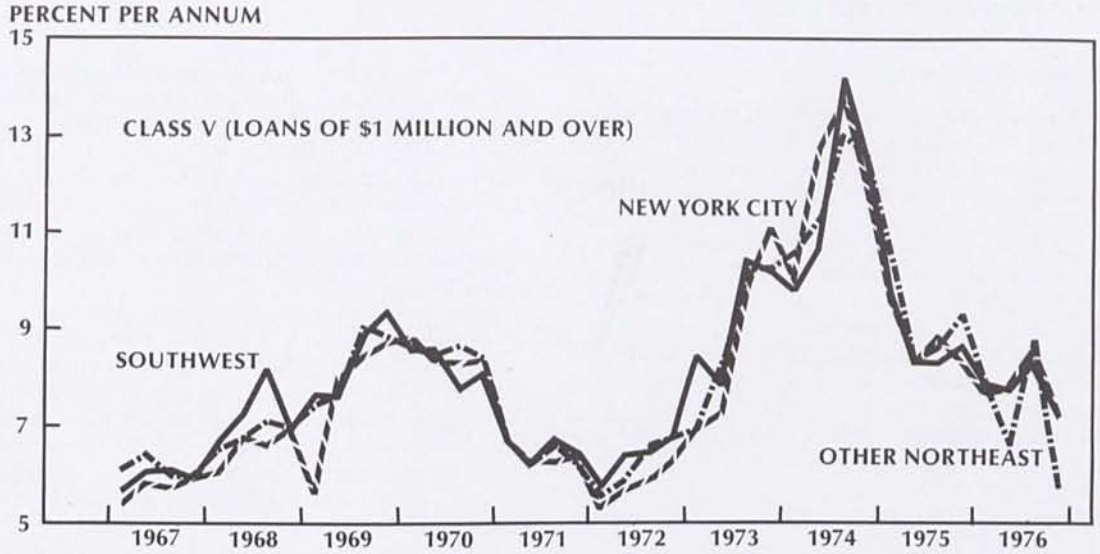
where R_t is a risk-free rate. Neither the CAPM nor the OMCD determines the values of a and b beyond the requirement that b must be positive if the regions are integrated. The indicated statistical test of the integration hypothesis is a correlation analysis identical to the analysis reported above except that it deals with the implied risk premiums $(R_1 - R)$ and $(R_2 - R)$ instead of the contract rates R_1 and R_2. For this analysis the risk-free rate R is taken to be the yield on three-year constant-maturity U.S. Treasury issues. The results (shown in the lower part of the table) are qualitatively the same as those based on the contract rates. The correlations are low in Class I, are high in Classes II

5. For a regression analysis based on an equation similar to equation 1, see Robert E. Keleher, "Regional Credit Market Integration: A Survey and Empirical Examination," Federal Reserve Bank of Atlanta, Working Paper Series (Atlanta, 1979).

6. Both models are sketched in the Appendix. For thorough expositions, see Kenneth Garbade, *Securities Markets* (New York: McGraw-Hill Book Company, 1982), chaps. 12, 18, 19.

Chart 5

Interest Rates on Long-Term Business Loans



SOURCE: *Federal Reserve Bulletin.*

through V, and do not differ significantly (at the 5-percent level) in any class.

Concluding remarks

It is not our purpose to judge the suppositions that lead to equations 1 and 2 or to choose between the equations on any other grounds. Our purpose is to test the integration hypothesis, for which it is only necessary to show that the hypothesis passes the test no matter which of the equations is true.[7] These equations, representing both of the known testable models of the relations between interest rates in integrated regions, determine the variables to be used in appropriate correlation analyses. In both analyses the Southwest–New York correlations are insignificantly different (at the 5-percent level) from the Other Northeast–New York correlations, indicating that the Southwest and Other Northeast regions are equally well integrated with New York City.

While the Southwest and Other Northeast appear to be equally well integrated with New York regarding long-term loans of all sizes, both regions are poorly integrated with New York regarding the smallest loans (under $10,000). These loans are not as important as the larger loans with respect to regional development. The findings thus offer no support to the notion that southwestern development may be hindered by a capital shortage.

7. Equations 1 and 2 might not exhaust the possibilities, for the arbitrage pricing theory (Stephen A. Ross, "The Arbitrage Theory of Capital Asset Pricing," *Journal of Economic Theory* 13 [December 1976]: 341–60) implies a linear relation between the risk premiums ($R_k - R$) in two *or more* regions:

$$R_{1t} - R_t = a + b_2(R_{2t} - R_t) + \ldots + b_n(R_{nt} - R_t) + u_t, \qquad b_2, \ldots, b_n > 0.$$

This theory, however, is not yet developed to the point of determining the number of regions. A test of the integration hypothesis with this theory must wait until that number is determined.

Appendix

The Models Used in the Second Test of the Integration Hypothesis

Capital asset pricing model

The CAPM is based on the mean-variance model of portfolio choice, according to which all investors (1) want high expected returns and low risk and (2) identify risk with the standard deviation of possible returns. On the further assumptions that all investors (3) regard the distributions of returns as invariant to their decisions on the composition of their portfolios, (4) have the same beliefs about these distributions, (5) face no transaction costs, and (6) may hold an asset on which the return is certain (this return being the "risk-free" rate), the mean-variance model implies that every investor should hold a portfolio consisting of the riskless asset and a share of the "market portfolio" of all risky assets, the relative proportions of which depend on the investor's aversion to risk.

The expected return on this portfolio is E_p,

$$E_p = x_m E_m + (1 - x_m)R,$$

where x_m is the proportion of the portfolio devoted to the market portfolio m, E_m is the expected return on m, and R is the risk-free rate. The standard deviation on this portfolio is σ_p,

$$\sigma_p = x_m \sigma_m,$$

where σ_m is the standard deviation of m (for the standard deviation of the risk-free rate is zero). From this equation we can substitute σ_p/σ_m for x_m in the first equation of this appendix, obtaining

$$\text{(A.1)} \qquad E_p - R = \frac{\sigma_p}{\sigma_m}(E_m - R).$$

This equation shows the risk-return combinations available to investors that choose optimally. It is analogous to the budget constraint in elementary demand theory.

The CAPM is a model of equilibrium expected returns on the securities in the market portfolio. Its key assumptions are: (1) equation A.1 is the invariant budget constraint of each investor, (2) the market portfolio is unchanging, and (3) equilibrium is approached by a Walrasian *tatonnement* process that permits no trades at disequilibrium prices. The model's key result is an equation very much like A.1 except that it applies to individual assets:

$$E_i - R = \frac{r_i \sigma_i}{\sigma_m}(E_m - R),$$

where r_i is the correlation between the possible returns on asset i and those on the market portfolio. This equation is usually written as

$$\text{(A.2)} \qquad E_i - R = \beta_i (E_m - R),$$

where $\beta_i (= r_i \sigma_i / \sigma_m)$ measures the undiversifiable risk of asset i relative to the risk of the market portfolio.

Although the CAPM is a one-period model, it may be applied to security returns in the real, multiperiod world if the autocorrelation of the possible returns is small. As this autocorrelation is negligible for equities but not for debt, the CAPM is usually applied to the equity market and not the debt market. Moreover, the CAPM deals with assets traded in active secondary markets, and this is a second reason why it might not apply to bank loans.

Nevertheless, bank loans are substitutes for equities as sources of funds to the borrowers, they are substitutes for Government securities as uses of funds by the bankers, and Government securities are substitutes for equities in the financial markets. Hence we cannot summarily reject the CAPM as the model of bank lending rates in integrated regions but must, for safety, test the integration hypothesis conditional on this model.

On the basis of equation A.2 and the integration hypothesis, the expected rate of return, E_{ikt}, on the ith loan in region k at time t may be expressed as

$$\text{(A.3)} \qquad E_{ikt} - R_t = \beta_{ikt}(E_{mt} - R_t), \qquad \beta_{ikt} > 0.$$

Taking the average value for n loans in region k at time t and putting

$$E_{kt} = \frac{1}{n} \sum_{i=1}^{n} E_{ikt}$$

and

$$\beta_{kt} = \frac{1}{n} \sum_{i=1}^{n} \beta_{ikt},$$

equation A.3 implies

$$\text{(A.4)} \qquad E_{kt} - R_t = \beta_{kt}(E_{mt} - R_t).$$

From A.4, expressions for the means of the expected returns on loans in Regions 1 and 2 can be written, and these together yield

$$\text{(A.5)} \qquad E_{1t} - R_t = \frac{\beta_{1t}}{\beta_{2t}}(E_{2t} - R_t).^{1}$$

The data are average contract rates R_{kt}, which are related to the E_{kt} by

$$\text{(A.6)} \qquad R_{kt} = E_{kt} + d_{kt},$$

where d_{kt} is the average deviation of the contract rate from the expected rate of return (in a region) and is very likely to be positive. A.5 and A.6 together imply

1. The inspiration for equation A.5 is Pao L. Cheng and Robert R. Grauer, "An Alternative Test of the Capital Asset Pricing Model," *American Economic Review* 70 (September 1980): 660–71.

$$R_{1t} - R_t = \left[d_{1t} - d_{2t} \frac{\beta_{1t}}{\beta_{2t}} \right] + \frac{\beta_{1t}}{\beta_{2t}} (R_{2t} - R_t).$$

If the beta ratio is constant over time and the term in brackets is constant except for random deviations, this equation has the same form as equation 2 of the text.

Options model of corporate debt

The OMCD treats a corporation's equity as a call option on the corporation's assets, taking the exercise price of the option to be the face value of the corporation's debt and the expiration date of the option to be the maturity date of that debt. On this reasoning, the equity may be valued by a model of option prices, such as the Black-Scholes model.[2] The implied value of the equity may then be inserted, along with the value of the assets, into the corporation's balance sheet identity to give the market value of the debt. The market value of the debt, in conjunction with its face value and maturity, then gives an expression for the promised yield of the debt.

To treat equity as a call option is to recognize that stockholders face the following alternatives when the debt matures t years from now: (1) Pay the face amount F to the creditors and keep control of the assets A; this is conceptually like exercising an option to buy A for F. (2) Default on the debt and let the creditors have the assets; this is conceptually like allowing the option to expire. The key assumption of the OMCD is that investors will value the equity with these choices in mind.

The Black-Scholes equation gives the equity an aggregate value S,

$$S = A\phi(x) - Fe^{-rt}\phi(y),$$

where ϕ is the standard normal distribution function, r is the rate on riskless assets of the same maturity as the corporation's debt, and

$$x = \frac{\ln(A/F) + t(r + v^2/2)}{v\sqrt{t}}$$

$$y = x - v\sqrt{t}$$

v = the standard deviation of the logarithms of the possible values of the assets.

The equation for S, together with the balance sheet identity in assets (A), debt (D), and S,

$$A = D + S,$$

yields the following aggregate market value for the debt:

$$D = A\phi(-x) + Fe^{-rt}\phi(y). \tag{A.7}$$

The coefficient of $\phi(y)$ in this equation is what the debt would be worth if it were certain to be repaid. Let us therefore define D_f,

$$D_f = Fe^{-rt},$$

as the value of riskless debt of the same maturity as the corporation's debt. Then we can rewrite A.7 as

$$D = D_f[\phi(-x)/L + \phi(y)], \tag{A.8}$$

where

$$L = D_f/A.$$

Assuming continuous compounding, the promised yield R_i on the corporation's debt is

$$R_i = \frac{\ln(F/D)}{t}. \tag{A.9}$$

Substituting A.8 into A.9 and noting that

$$\ln(D_f) = \ln(F) - rt,$$

we obtain

$$R_i - r = \frac{-\ln[\phi(-x)/L + \phi(y)]}{t}. \tag{A.10}$$

Strictly speaking, all the variables in this equation are specific to corporation i, so each should be indexed by i:

$$R_i - r_i = \frac{-\ln[\phi(-x_i)/L_i + \phi(y_i)]}{t_i}. \tag{A.11}$$

Pick some arbitrary maturity T and define

$$a_i = t_i/T$$

$$\alpha_i = -\ln[\phi(-x_i)/L_i + \phi(y_i)]/a_i.$$

Then A.11 can be expressed more simply as

$$R_i - r_i = \alpha_i/T. \tag{A.12}$$

This equation, like equation A.2, expresses the premium ($R_i - r_i$) as the product of two factors, a general factor—in this case, T—and a factor specific to the borrower.

Not all bank loans are made to corporations, nor are they traded in secondary markets. But marketable corporate debt is a substitute for other instruments in the financial markets, so the reasoning that prompted our consideration of the CAPM is fully applicable to the OMCD.

Suppose that A.12 holds for the ith loan in region k

2. See Fischer Black and Myron Scholes, "The Pricing of Options and Corporate Liabilities," *Journal of Political Economy* 81 (May/June 1973): 637–54.

at time t,[3] so that

$$R_{ikt} - r_{ikt} = \alpha_{ikt}/T$$

and, in terms of regional averages,

$$R_{kt} - r_{kt} = \alpha_{kt}/T.$$

Sequentially putting ($k = 1$) and ($k = 2$) and substituting, we obtain

$$R_{1t} - r_{1t} = \frac{\alpha_{1t}}{\alpha_{2t}}(R_{2t} - r_{2t}). \tag{A.13}$$

3. From this point forward, t is a date and not an interval, as it was in the exposition of the OMCD.

As the average maturities are probably not the same in both regions, the average appropriate risk-free rates r_{1t} and r_{2t} probably differ. Write

$$r_{kt} = R_t - c_{kt},$$

where, as before, R_t is "the" risk-free rate; then

$$R_{1t} - R_t = \left[c_{1t} - \frac{\alpha_{1t}}{\alpha_{2t}} c_{2t}\right] + \frac{\alpha_{1t}}{\alpha_{2t}}(R_{2t} - R_t).$$

If the alpha ratio has a constant value b and the term in brackets varies randomly about an average value a, the preceding equation may be written as equation 2 of the text.

Interest Rates and Inflation: An Old and Unexplained Relationship

*By John H. Wood**

The failure of nominal interest rates to fall as rapidly as the rate of inflation has meant very high observed real interest rates during the early 1980's. This experience has been the mirror image of the early 1970's, when observed real rates were low because nominal rates failed to keep pace with rising inflation. We should not be surprised by these events, for they are typical of American experience. The tendency of interest rates to respond slowly and incompletely to changes in the rate of inflation has been well documented, most notably by Irving Fisher in 1930 but also by several writers who have examined the period since World War II.[1] However, an opposing hypothesis regarding the relationship between interest rates and inflation has recently been advanced. According to the efficient markets model, nominal interest rates anticipate rather than lag inflation.[2]

The primary objective of the research reported in this article has been to discover whether the connections between interest rates and inflation experienced since the early 1950's have, in fact, differed significantly from those observed by Fisher. It will be seen that the similarities are greater than the differences. The secondary objective has been to compare the abilities of the Fisher model and the efficient markets model to explain the data, both before 1930 and after 1950. It will be seen that the former always outperforms the latter but that neither model does very well.

* *John H. Wood is a visiting scholar at the Federal Reserve Bank of Dallas, on leave from Northwestern University.* *This article has benefited from many helpful suggestions by Scott Ulman.*

1. Irving Fisher, *The Theory of Interest* (New York: Macmillan Co., 1930; reprint, New York: Augustus M. Kelley, 1965), chap. 19. Also see, for example, William E. Gibson, "Price-Expectations Effects on Interest Rates," *Journal of Finance* 25 (March 1970): 19–34; William P. Yohe and Denis S. Karnosky, "Interest Rates and Price Level Changes, 1952–69," *Review*, Federal Reserve Bank of St. Louis, December 1969, 18–38; and Thomas J. Sargent, "Commodity Price Expectations and the Interest Rate," *Quarterly Journal of Economics* 83 (February 1969): 127–40. Additional references, in a slightly different context, are given in footnote 12 below.

2. Some support for an efficient markets model that incorporates perfect information and a constant expected real rate of interest has been presented for the tranquil 1953–71 period by Eugene F. Fama, "Short-Term Interest Rates as Predictors of Inflation," *American Economic Review* 65 (June 1975): 269–82.

The remaining sections of this article begin with a statement of the simple theoretical framework that has served as the starting point for the empirical work of Fisher as well as for later tests of the efficient markets model. This common theory consists simply of the statement that any risk-free nominal rate of interest is approximately the sum of an expected real rate of interest and an expected rate of inflation. The next section reproduces Fisher's famous conclusion that during the 19th and early 20th centuries, interest rates responded slowly to changes in rates of inflation, sometimes with lags extending to 30 years. The application of Fisher's method to 1953–82 produces results that are similar in most respects to those obtained for the period before 1930. That is, *relations between interest rates and inflation since 1953 are similar to those that prevailed before 1930.*

The explanatory powers of the Fisher and efficient markets models are compared for 1915–27 and 1953–82 (as well as for the subperiods 1953–71 and 1971–82), and in every case Fisher's approach is superior. The data always correspond more closely to the model in which interest rates respond to past inflation than to the model in which interest rates anticipate inflation. But these results give little solace to advocates of the Fisher approach, for both models contain debilitating defects. Neither produces results that pass the most elementary econometric tests, and both suffer from incomplete or inconsistent theoretical specifications.

The concluding section emphasizes that the results obtained by Fisher and reproduced in this article contain no clear implications for monetary policy. In particular, the observation that nominal interest rates respond slowly and incompletely to changes in the rate of inflation does *not* imply that the Federal Reserve can control expected or realized real rates of interest through alterations in the rate of inflation. No such implication can validly be drawn until a complete and consistent model of interest rates and inflation becomes available.

The common underlying model

The Fisher and efficient markets models are both founded on the following relation:[3]

$$(1) \qquad (1 + R_t^e) = (1 + r_t^e)(1 + p_t^e).$$

R_t^e may be understood as the nominal (dollar) rate of return expected from an investment in a fixed-income security between dates t and $(t + 1)$, r_t^e as the real rate of return expected from a physical asset during the same period (for example, the harvest return to seed corn or the services provided by a house or a machine), and p_t^e as the expected rate of change in the price of that physical asset between t and $(t + 1)$. If the value of the goods or services, net of cost, produced by a machine during a year is expected to be 5 percent of the beginning-of-year value of the machine ($r_t^e = .05$) and the price of the machine is expected to appreciate 10 percent during the year ($p_t^e = .10$), then investors will be indifferent between an investment in the machine and an investment in a fixed-income security if and only if the expected rate of return on the latter is

$$R_t^e = (1.05)(1.10) - 1 = .155.$$

Most empirical studies have simplified equation 1 by (1) using a high-grade, fixed-income security with term to maturity equal to the period of observation so that the rate of return is certain (or nearly so) and R_t may be substituted for R_t^e and (2) applying the following linear approximation:

$$(2) \qquad R_t = r_t^e + p_t^e.$$

If all prices vary in the same proportion, then the real rate of return (gain in purchasing power) for a fixed-income security is

$$(3) \qquad \tilde{r}_t = R_t - \tilde{p}_t = r_t^e + (p_t^e - \tilde{p}_t),$$

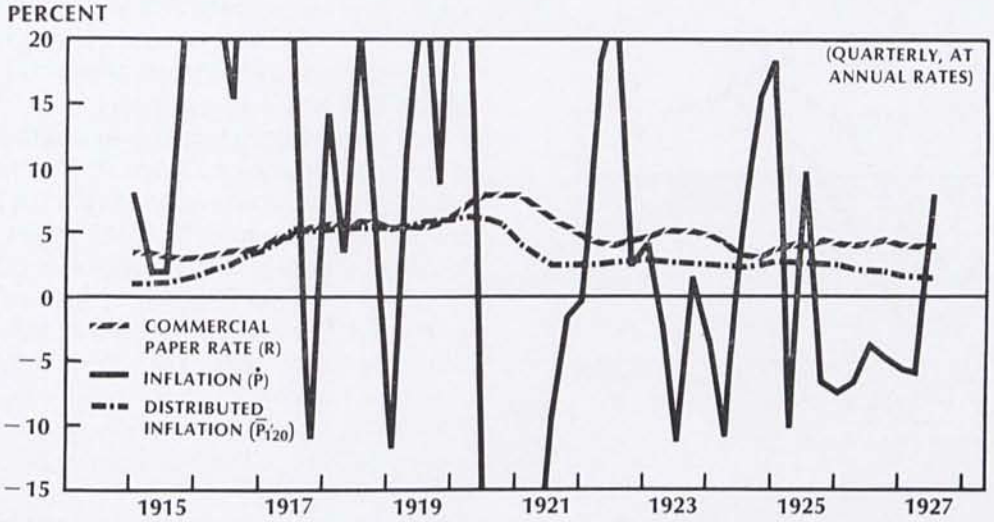
where the tildes denote random variables, $\tilde{p}_t$ is the rate of inflation that actually occurs during the investment period, and $\tilde{r}_t$ is the real rate of return actually realized on the fixed-income security.

Continuing the numerical example, suppose the expectations ($r_t^e = .05$) and ($p_t^e = .10$) apply to 1983 and are held as of December 31, 1982, so that the yield to maturity on 52-week U.S. Treasury bills quoted on that date is, using the approximation in equation 2, ($R_t = .15$). Now suppose the rate of inflation between December 31, 1982, and December 31, 1983, turns out to be 5 percent instead of the predicted 10 percent. This means that the real rate of return on 52-week bills actually realized during 1983 is, from equation 3,

3. Equation 1 assumes no risk aversion and, in taking the expectation of the right-hand side, ignores the covariance between r and p.

Chart 1

Commercial Paper Rate, Inflation, and Fisher's Distributed Inflation



SOURCE OF PRIMARY DATA: Fisher, *Theory of Interest*, 532–33.

(4) $r_t = .15 - .05 = .05 + (.10 - .05) = .10$

instead of the predicted ($r_t^e = .15 - .10 = .05$).

The best-known tests of the efficient markets model[4] have assumed that relation 1 or the linear approximation 2 is valid, the expected real rate ($r_t^e = r^e$) is a constant, and inflationary expectations correctly incorporate all available information. Thus, equation 3 may be written

(5) $$\tilde{r}_t = r^e + (p_t^e - \tilde{p}_t),$$

where p_t^e is an unbiased predictor of $\tilde{p}_t$ so that forecast errors ($p_t^e - \tilde{p}_t$), and therefore realized real rates $\tilde{r}_t$, are not serially correlated. For example, we should not observe persistently high or persistently low real rates.

An alternative expression of the efficient markets model is

(6) $$R_t = r^e + p_t^e = r^e + \tilde{p}_t + \tilde{u}_t,$$

where $\tilde{u}_t = (p_t^e - \tilde{p}_t)$ is the inflation forecast error. The correlation between observations on R_t and the realized rate of inflation $\tilde{p}_t$ should be at least as high as the correlation between R_t and any other set of variables because p_t^e correctly utilizes all available information and, therefore, $\tilde{u}_t$ represents irreducible errors. Fisher began his empirical work with an equation very much like the modern efficient markets model expressed in equation 6.

Interest rates and inflation before 1930

Fisher examined annual and quarterly data on interest rates and inflation in the United States and several other countries during the 19th and early 20th centuries and concluded that interest rates (1) tended to be much less volatile than inflation and (2) contrary to equation 6, were poor predictors of inflation.[5] The first conclusion was based on data like those in Chart 1, which presents quarterly observations during 1915–27 on the commercial paper rate (R) and the rate of change of the wholesale price index (P).[6] ($\bar{P}'_{120}$ will be discussed shortly.) The

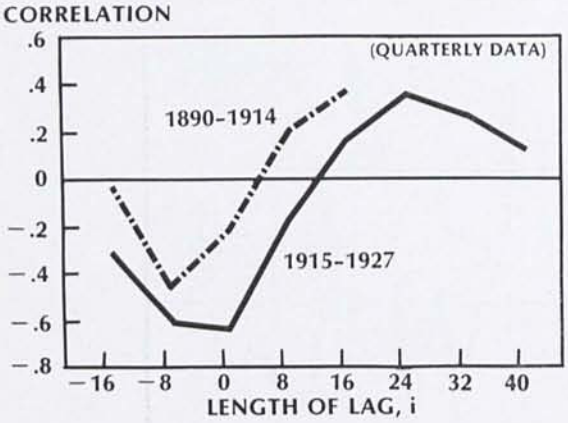
4. Especially see Fama, "Short-Term Interest Rates."

5. Fisher's data and results are presented in *Theory of Interest*, chap. 19 and appendix to chap. 19.

6. The sources of these data are given in Table 1. R is a quarterly average of daily figures, and $\dot{P}$ is the rate of change of quarterly averages of monthly wholesale price index data. Both R and $\dot{P}$ are expressed in annual rates. Ideally, observations on

Chart 2

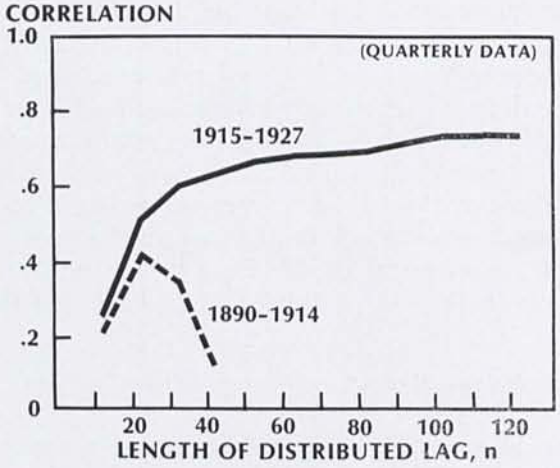
Correlations Between R_t and P'_{t-i}



SOURCE: Fisher, *Theory of Interest*, Chart 50.

Chart 3

Correlations Between R_t and $\overline{P}'_{n,t}$



SOURCE: Fisher, *Theory of Interest*, Chart 51.

second conclusion followed from the low correlations obtained by Fisher in his test of equation 6. Examples of these correlations are presented in Chart 2, which shows that the relationship between the commercial paper rate and future (as well as past) rates of inflation was weak. In fact, the relationship was often negative, instead of positive as suggested by the efficient markets theory.[7]

Fisher's next step was to see whether the influence of inflation on interest rates might be "*distributed in time*—as, in fact, must evidently be true of any influence."[8] Chart 3 shows correlations between the commercial paper rate (R) and weighted averages (distributed lags) of past rates of inflation (P') for lags (n) up to 120 quarters. These correlations are higher than those in Chart 2 and reach a maximum of .738 for 1915–27 "only when a total of 120 quarters, or 30 years, is included in the period subject to the influence of price changes upon R."

The regression equations corresponding to some of Fisher's correlations (n = 20, 70, 120 for 1915–27) are reported in equations 1.1 through 1.3 of Table

---

R should be for a specific date t and should be compared with the rate of change of a price index between dates t and $(t + 1)$, as prescribed by the discussion following equation 1. However, the only available price indexes are based on data collected throughout some period of time. $\dot{P}$ is used in Chart 1 and elsewhere to indicate an average rate of inflation between two *periods* of time, as distinct from p in equations 1 through 6, which indicates the rate of inflation between two *points* in time. R and r are used to indicate nominal and real interest rates in both cases. Consistency required the interest rates used by Fisher to be averages over time periods (quarters) corresponding to his price data.

7. Fisher's variables and lag distributions were specified somewhat differently than those commonly used today, largely because computational expenses forced him to use linear forms. He approximated the rate of inflation during the tth quarter by

$$P'_t = 2\,\frac{(P_{t+1} - P_{t-1})}{P_t},$$

where P_t is the average wholesale price index during the tth quarter. These approximate rates of inflation enter Fisher's distributed lags with arithmetically declining weights:

$$\overline{P}'_{n,t} = \frac{(n-1)P'_{t-1} + (n-2)P'_{t-2} + \ldots + P'_{t-(n-1)}}{1 + 2 + \ldots + (n-1)}.$$

8. The quotations in this paragraph are from Fisher, *Theory of Interest*, 419, 427. In all quotations from Fisher, the emphasis is Fisher's and R is substituted for Fisher's i.

Table 1
INTEREST RATES AND INFLATION, 1915-27

Equation	n	Without a time trend						With a time trend						
		$\bar{P}'_{n,t}$	P'_{t-1}	$\dot{P}_{t-1}$	$\dot{P}_t$	Constant	$\bar{R}^2$/DW	$\bar{P}'_{n,t}$	P'_{t-1}	$\dot{P}_{t-1}$	$\dot{P}_t$	T	Constant	$\bar{R}^2$/DW
1.1 . . .	20	.04				4.70	.06/.11	-.04				.01	3.33	.05/.11
		(.02)*				(.18)*		(.02)*				(.01)	(1.78)	
1.2 . . .	70	.31				3.60	.45/.17	.38				-.03	-.33	.54/.21
		(.05)*				(.23)*		(.05)*				(.01)*	(1.28)	
1.3 . . .	120	.62				2.75	.55/.21	.66				.01	.87	.57/.22
		(.08)*				(.29)*		(.08)*				(.01)	(1.14)	
1.4 . . .			-.04			4.94	.39/.22		-.04			-.03	8.37	.48/.32
			(.01)*			(.14)*			(.01)*			(.01)*	(1.17)*	
1.5 . . .				-.03		4.96	.20/.25			-.03		-.02	8.07	.26/.38
				(.01)*		(.16)*				(.01)*		(.01)*	(1.42)*	
1.6 . . .					-.03	5.00	.31/.34				-.04	-.03	8.57	.40/.55
					(.01)*	(.15)*					(.01)*	(.01)*	(1.28)*	
1.7 . . .												-.01	5.50	-.02/.12
												(.01)	(1.52)*	

Dependent variable = R_t (In percent, at annual rates)

R_t = quarterly average of the commercial paper rate reported in Fisher, *Theory of Interest*, 532.

Explanatory variables (In percent, at annual rates)

$\dot{P}_t$ = rate of change in the wholesale price index between quarters t and $(t + 1)$. (The WPI is reported for 1890-1927 in Fisher, *Theory of Interest*, 533, and for 1884-89 in the *Statistical Bulletin* of the Standard Statistics Company, 219. The two sets of data used different base years and were linked using their average ratio in 1913.)

P'_t = variable in footnote 7 converted to percentages; computed from the same data as $\dot{P}_t$.

$\bar{P}'_{n,t}$ = variable in footnote 7 converted to percentages; computed from the same data as $\dot{P}_t$.

T = a trend variable that takes the values 1, 2, ..., 52.

NOTE: n is the length of the distributed lag, in quarters.
$\bar{R}^2$ is the coefficient of determination adjusted for degrees of freedom.
DW is the Durbin-Watson autocorrelation test statistic.
Figures in parentheses are standard errors of the regression coefficients; * indicates significant difference from zero at the 5-percent level.

Table 2
PEAKS AND TROUGHS FROM 1915 TO 1925 FOR INFLATION, FISHER'S LONGEST DISTRIBUTED LAG, AND THE COMMERCIAL PAPER RATE

Variable	Peak	Trough	Peak	Trough	Peak
Inflation ($\dot{P}$)	1917:Q2	1921:Q1	1922:Q3	1923:Q3	1925:Q1
Fisher's longest distributed lag ($\overline{P}'_{120}$)	1920:Q2	1922:Q1	1923:Q1	1924:Q3	1925:Q2
Commercial paper rate (R)	1920:Q3	1922:Q3	1923:Q4	1924:Q3	1925:Q4

SOURCE: Chart 1.

1.[9] Equation 1.4 shows the regression of R on Fisher's inflation variable (P') lagged only one period. The correlation coefficient of .64 (as distinct from the adjusted coefficient of correlation, $\overline{R}^2$, in the table) is close to the approximate value of .60 indicated in Chart 2. Equation 1.5 is identical to equation 1.4 except that the previous rate of inflation ($\dot{P}$) is used instead of Fisher's approximation (P').[10] (P' and $\dot{P}$ are defined in footnote 7 and Table 1.) Equation 1.6 is the regression of R during the tth period on the rate of inflation between periods t and $(t + 1)$ and roughly corresponds to the efficient markets equation 6. The regressions on the right-hand side of Table 1 show that except for the constant terms, the results are essentially unaltered by the addition of a trend variable.

The most troublesome aspects of these regressions are the high residual autocorrelations indicated by the low Durbin-Watson ratios. A complete theory of interest rates and inflation must explain these autocorrelations, and later sections will consider how they might be implied by the Fisher and efficient markets models.

Fisher summarized his results as follows:

> By assuming a distribution of effect of price changes over several years according to the form described above, the relationship between price changes and interest rates which was only faintly revealed by the first direct comparisons is clearly revealed. The high correlation coefficients obtained by means of the method of distributing the influence of P' and R show that the theory . . . conforms closely to reality, especially during periods of rather marked price movements.
>
> Furthermore the results and other evidence, indicate that, over long periods at least, interest rates *follow* price movements. The reverse, which some writers have asserted, seems to find little support. (*Theory of Interest*, 423, 425)

This passage follows Fisher's presentation of annual data, but his statements were also meant to apply to results based on quarterly data, such as those in Charts 1, 2, and 3 and Table 1. The closer correspondence between R and $\overline{P}'_{120}$ than between R and $\dot{P}$ is seen clearly in Chart 1, particularly during the 1915–25 decade of "rather marked price movements." Not only was the variance of R much

9. The correlation coefficients of these equations are almost, but not quite, the same as Fisher's. For ($n = 120$), for example, the correlation coefficient for equation 1.3 is .749, compared with Fisher's .738. Another near duplication of this result was obtained by Arthur Laffer and J. Richard Zecher, "Anticipations About the Value of Money—Much Ado About Nothing?" (University of Chicago, 1971, Mimeographed), and is reported in John Rutledge, *A Monetarist Model of Inflationary Expectations* (Lexington, Mass.: D. C. Heath and Company, Lexington Books, 1974), 20n. Also, the correlation coefficient of −.64 for equation 1.4 is close to that indicated in Chart 1 for a lag of one-fourth of a year.

10. The qualitative nature of Fisher's conclusions is not altered by the substitution of the exact rate of inflation $\dot{P}$ for his approximation P', as indicated by a comparison of equations 1.4 and 1.5 and by a comparison of equation 1.3 with the following regression equation, which is also based on quarterly data from 1915 to 1927:

$$R = \underset{(.311)}{1.641} + \underset{(.061)}{.649}\,\overline{P}_{120},$$

$$\overline{R}^2 = .689;\ \text{DW} = .267.$$

where $\overline{P}_{120}$ is defined as in footnote 7 except that $\dot{P}$ instead of P' is used.

Table 3
INTEREST RATES AND INFLATION, 1953:Q1–1982:Q1

Equation	n	Without a time trend						With a time trend						
		$\bar{P}'_{n,t}$	P'_{t-1}	$\dot{P}_{t-1}$	$\dot{P}_t$	Constant	$\bar{R}^2$/DW	$\bar{P}'_{n,t}$	P'_{t-1}	$\dot{P}_{t-1}$	$\dot{P}_t$	T	Constant	$\bar{R}^2$/DW
2.1 . . .	20	.65				3.32	.58/.21	.21				.06	-58.31	.69/.29
		(.05)*				(.28)*		(.08)*				(.01)*	(9.98)*	
2.2 . . .	70	1.02				3.22	.67/.27	.54				.04	-40.73	.71/.31
		(.07)*				(.24)*		(.14)*				(.01)*	(11.26)*	
2.3 . . .	120	1.45				3.21	.69/.29	.85				.04	-35.83	.72/.32
		(.09)*				(.24)*		(.20)*				(.01)*	(11.30)*	
2.4 . . .			.40			4.12	.36/.26		.10			.07	-70.30	.68/.30
			(.05)*			(.32)*			(.04)*			(.01)*	(6.94)*	
2.5 . . .				.32		4.37	.34/.48			.10		.07	-69.28	.69/.34
				(.04)*		(.31)*				(.03)*		(.01)*	(6.46)*	
2.6 . . .					.26	4.60	.24/.38				.03	.08	-76.18	.67/.30
					(.04)*	(.33)*					(.03)	(.01)*	(6.53)*	
2.7 . . .												.08	-79.56	.67/.28
												(.01)*	(5.54)*	

Dependent variable = R_t (In percent, at annual rates)

R_t = quarterly average of the four- to six-month prime commercial paper rate until September 1979 and of the average of three- and six-month prime commercial paper rates thereafter.

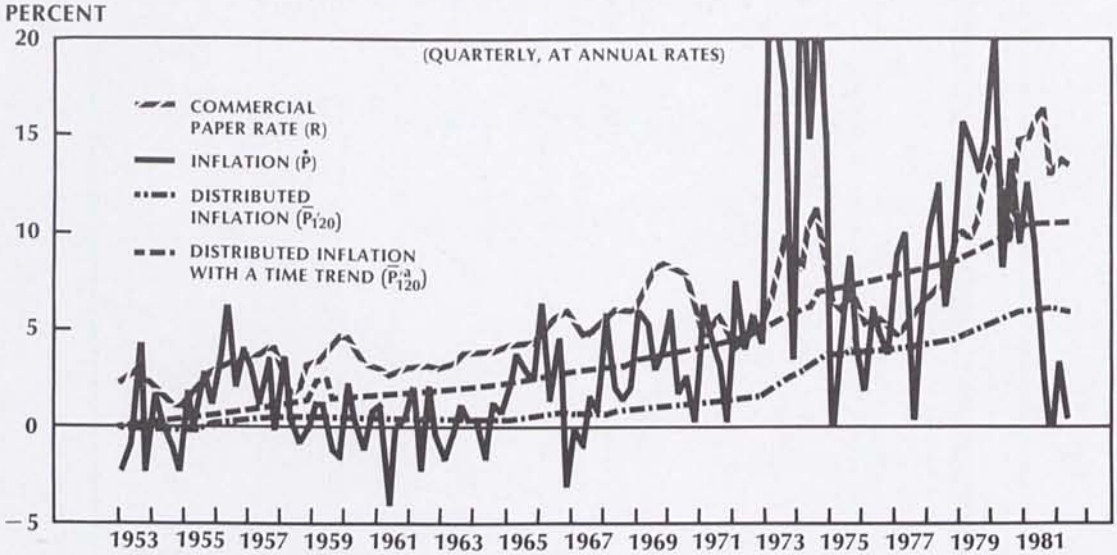
Explanatory variables (In percent, at annual rates)

Same definitions as in Table 1.

NOTE: n is the length of the distributed lag, in quarters.
$\bar{R}^2$ is the coefficient of determination adjusted for degrees of freedom.
DW is the Durbin-Watson autocorrelation test statistic.
Figures in parentheses are standard errors of the regression coefficients; * indicates significant difference from zero at the 5-percent level.
SOURCES OF PRIMARY DATA: *Federal Reserve Bulletin.*
Survey of Current Business.

Chart 4

Prime Commercial Paper Rate, Inflation, Fisher's Distributed Inflation, and Distributed Inflation Adjusted for a Time Trend



SOURCES OF PRIMARY DATA: *Federal Reserve Bulletin.*
Survey of Current Business.

closer to $\overline{P}'_{120}$ than to $\dot{P}$, but the peaks and troughs of R corresponded more closely to those of $\overline{P}'_{120}$ than to those of $\dot{P}$ (Table 2).

These results are famous. But their interpretation is controversial. Some of the proposed interpretations will be discussed later, after it is shown in the next section that for whatever reasons, the phenomena observed by Fisher have recurred in the period since 1953.

Interest rates and inflation since 1953

The results of applying Fisher's approach to the 1953–82 period are presented in the regression equations in Table 3, which are identical to the equations in Table 1 except in the choice of sample period. Results for the subperiods 1953:Q1–1971:Q2 and 1971:Q3–1982:Q1 are shown separately, in Table 4, because of the contention that the earlier subperiod is most favorable to the efficient markets model.[11] The estimates in Tables 3 and 4 are similar to those for 1915–27. Specifically, the rate of interest is more closely correlated with past than future inflation, and of all the Fisher variables tried, the longest distributed lag ($\overline{P}'_{120}$) again proved the most effective. Fisher's version of the efficient markets model performs better during 1953–82 and 1953–71 than during 1915–27 and 1971–82, as may be seen in equations 1.6, 2.6, 2.13, and 2.20 of Tables 1, 3, and 4. Nevertheless, the estimates for all periods suggest that in contradiction to the efficient markets model, the usefulness of the rate of interest as a predictor of inflation may be improved by the addition of past rates of inflation and, since 1953, a trend variable.

The results produced by Fisher's rough-and-ready approach have turned out to be impressively robust under a variety of conditions. They are consistent with the results of more sophisticated tests (and refutations) of the efficient markets model, even during 1953–71, as well as with the results of other models that have (1) different types of lag structures—for example, geometrically declining weights instead of Fisher's arithmetically declining weights;

11. By Fama, "Short-Term Interest Rates."

Table 4

INTEREST RATES AND INFLATION, 1953:Q1–1971:Q2 AND 1971:Q3–1982:Q1

Equation	n	Without a time trend						With a time trend						
		$\bar{P}'_{n,t}$	P'_{t-1}	$\dot{P}_{t-1}$	$\dot{P}_t$	Constant	$\bar{R}^2$/DW	$\bar{P}'_{n,t}$	P'_{t-1}	$\dot{P}_{t-1}$	$\dot{P}_t$	T	Constant	$\bar{R}^2$/DW
							1953:Q1–1971:Q2							
2.8	20	1.19 (.14)*				2.80 (.21)*	.49/.15	.61 (.12)*				.05 (.01)*	−3.13 (.70)*	.75/.32
2.9	70	3.12 (.25)*				1.90 (.21)*	.68/.25	1.58 (.43)*				.04 (.01)*	−2.31 (1.03)*	.74/.31
2.10 . . .	120	4.37 (.31)*				1.94 (.19)*	.73/.29	3.33 (.75)*				.02 (.01)	.07 (1.24)	.73/.29
2.11 . . .			.47 (.10)*			3.45 (.22)*	.24/.28		.18 (.06)*			.06 (.01)*	−4.57 (.72)*	.73/.38
2.12 . . .				.31 (.08)*		3.67 (.22)*	.17/.41			.12 (.05)*		.06 (.01)*	−4.74 (.72)*	.72/.44
2.13 . . .					.27 (.08)*	3.72 (.22)*	.12/.35				.11 (.05)*	.06 (.01)*	−4.88 (.72)*	.72/.42
2.14 . . .												.06 (.01)*	−4.61 (.74)*	.66/.26
							1971:Q3–1982:Q1							
2.15 . . .	20	.51 (.14)*				4.66 (1.18)*	.23/.24	.08 (.14)				.19 (.04)*	−14.88 (4.21)*	.49/.39
2.16 . . .	70	1.00 (.16)*				4.14 (.82)*	.47/.36	−.08 (.72)				.22 (.14)	−17.32 (13.84)	.49/.40
2.17 . . .	120	1.52 (.23)*				4.24 (.76)*	.50/.38	.74 (1.38)				.10 (.18)	−6.30 (18.25)	.49/.39
2.18 . . .			.14 (.10)			7.40 (1.02)*	.02/.21		.18 (.06)*			.21 (.03)*	−18.42 (3.57)*	.57/.52
2.19 . . .				.13 (.07)		7.36 (.86)*	.05/.26			.15 (.05)*		.20 (.03)*	−17.78 (3.44)*	.59/.66
2.20 . . .					.04 (.07)	8.24 (.88)*	−.02/.21				.09 (.05)	.21 (.03)*	−17.53 (3.78)*	.52/.53
2.21 . . .												.20 (.03)*	−15.89 (3.73)*	.50/.40

Dependent variable = R_t (In percent, at annual rates)

Same definition as in Table 3.

Explanatory variables (In percent, at annual rates)

Same definitions as in Table 1.

For notes and data sources, see Table 3.

(2) different periods of observation—monthly, quarterly, and annual averages of interest rates and prices, in addition to observations on interest rates at specific points in time instead of averages, as by Fisher; (3) different types of securities, long-term and short-term as well as private and U.S. Government; and (4) different price indexes, consumer and wholesale.[12]

The most notable difference between Table 1 and Tables 3 and 4 is the importance of the trend variable (T) in the later results. The failure of Fisher's distributed lag ($\overline{P}'_{120}$) to keep up with the rising trend in R is seen clearly in Chart 4. Nevertheless, variations in R continued during 1953–82 (as during 1915–27) to be more closely associated with variations in weighted averages of past inflation than with contemporaneous inflation—as indicated by the correlations in Tables 3 and 4 and the movements in R, $\dot{P}$, and $\overline{P}'^{a}_{120}$ in Chart 4, where the last variable is $\overline{P}'_{120}$ with the addition of the trend estimate in equation 2.3.

But these estimates are rendered suspect by the low Durbin-Watson statistics, which indicate strong autocorrelations in the residuals of all the regressions reported in Tables 1, 3, and 4. These autocorrelations suggest that both the Fisher and efficient markets equations have been misspecified or incompletely specified. Possible sources of these inadequacies are discussed in the following sections, which present critiques of the three best-known models of interest rates and inflation: the efficient markets model and two interpretations of the Fisher equation.

Fisher's interpretation of the Fisher equation

Fisher's equation may be expressed in the following form:[13]

$$R_t = a + \sum_{i=1}^{n} w_i \dot{P}_{t-i}, \tag{7}$$

where his highest correlation was achieved with the longest lag, n being 120 quarters. This apparently "fantastic" result suggested to Fisher that interest rates in, say, 1927 were affected by events as far removed as 1897. He did not present a complete explanation of interest rates and inflation but pointed out that "the effects of bumper wheat crops, revolutionary discoveries and inventions, Japanese earthquakes, Mississippi floods, and similar events project their influence upon prices and interest rates over many future years even after the original causal event has been forgotten" (*Theory of Interest*, 428). Notice that most, perhaps all, of these dynamic forces are likely to affect nominal interest rates by causing changes in both expected real rates and expected rates of inflation.

Fisher went on to discuss earlier studies, by himself and others,[14] suggesting that inflation influences the volume of trade, with the influence distributed over a long period, and that the volume of trade influences the rate of interest, again with the influence distributed over a long period. The accumulation of these and other lags, such as the delayed response of the banking system to increased loan demands, almost persuades us of the plausibility of the 30-year lags between inflation and interest rates shown in Tables 1, 3, and 4. Perhaps more important, the dynamic interactions of the various factors suggest that several more or less systematic influences on the rate of interest have been omitted from the regressions in those tables—which may explain the high serial correlation of the variations in R left unexplained by the regressions.

A later interpretation of the Fisher equation

Most subsequent writers have given a narrower and more precise interpretation than Fisher to his equation.[15] The most common version of the Fisher ap-

12. These include, in addition to the studies listed in footnote 1, Douglas Joines, "Short-Term Interest Rates as Predictors of Inflation: Comment," *American Economic Review* 67 (June 1977): 476–77; and Charles R. Nelson and G. William Schwert, "Short-Term Interest Rates as Predictors of Inflation: On Testing the Hypothesis That the Real Rate of Interest Is Constant," *American Economic Review* 67 (June 1977): 478–86.

13. As noted in footnote 7, Fisher used the approximation P' instead of the exact rate of inflation $\dot{P}$, and his weights, w_i, were constrained to decline arithmetically and to sum to unity. However, more general weighting schemes using $\dot{P}$ have yielded results similar in most respects to Fisher's. (See the references in footnotes 1 and 12.) The main difference is that most recent studies have reported estimates of the w_i with sums less than unity.

14. See the references in Fisher, *Theory of Interest*, 439–49.

15. This point has been stressed by Rutledge, *Monetarist Model of Inflationary Expectations*, 21.

proach interprets the constant term in equation 7 as a constant expected real rate of interest and treats the result as equivalent to equation 2:

$$(8) \qquad R_t = r_t^e + p_t^e = r^e + \sum_{i=1}^{n} w_i \dot{P}_{t-i},$$

where the two symbols for inflation, p and $\dot{P}$, are used interchangeably.

Equation 8 embodies the following hypotheses:

H.1. *Equation 2 holds. That is, the nominal rate of interest is the sum of the expected real rate of interest and the expected rate of inflation.*

H.2. *Expected inflation is a weighted average of past rates of inflation.*

H.3. *The expected real rate of interest is a constant, r^e.*

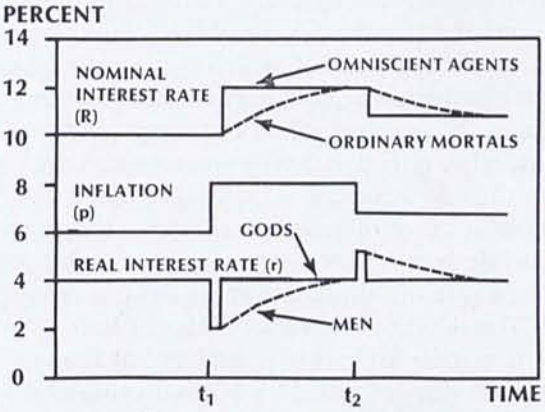
If actual inflation is the weighted average of past rates of inflation indicated in equation 8, then inflationary expectations are correct, and this interpretation of the Fisher equation is equivalent to the efficient markets model.[16] In light of the empirical results presented by Fisher and others, however, it can be shown that these hypotheses, and therefore equation 8, are inconsistent with all but the most naive all-the-people-can-be-fooled-all-the-time models. The failure of nominal interest rates to keep pace with inflation means that either inflationary expectations have been systematically wrong or expected real rates of interest are not constant but vary systematically with inflation. The validity of equation 8 and hypotheses H.1, H.2, and H.3 can be maintained only by adopting the first explanation, insisting on a constant expected real rate, and assuming that investors do not learn. Specifically, systematic movements in realized real rates cannot induce revisions of expected real rates—the opposite of rational expectations.

The efficient markets model

The efficient markets model is expressed in equations 5 and 6 and hypothesizes that equation 2 holds, expectations correctly incorporate all

Chart 5

Responses of Omniscient and Less Than Perfect Markets to Unexpected Changes in Inflation



available information, and the expected real rate of interest is constant. The difference between this and the preceding model is that H.2 is replaced by

H.2′. *Expectations correctly incorporate all available information.*

This model is valid only under an extremely restrictive set of conditions. For example, a constant expected real rate of interest requires either that nothing affecting saving or investment ever changes or that the changes cancel one another so that the saving and investment functions always intersect at the same expected real rate of interest. The virtual impossibility of these conditions becomes obvious upon consideration that the variables affecting saving and investment include aggregate output, population, technological change, the capital stock, and taxes. Furthermore, all changes in the economic structure tending to affect the rate of inflation, such as shifts in the goals of monetary policy or in the demand for money, must be completely, correctly, and immediately incorporated into expectations. That is, the "available information" in H.2′ includes a complete knowledge of the structure of the economy.

The importance of the latter requirement for the validity of the efficient markets model is illustrated

16. This discussion has been influenced by Thomas J. Sargent, "Rational Expectations, the Real Rate of Interest, and the Natural Rate of Unemployment," *Brookings Papers on Economic Activity*, 1973, no. 2:429–72.

in Chart 5. The figure begins with a situation in which the expected real rate of interest is 4 percent, both actual and expected inflation are 6 percent, and the nominal rate of interest is 10 percent so that the realized real rate of interest equals the expected real rate.[17] Now suppose that for some reason, perhaps because of a change in the goals of monetary policy, there is a sudden jump in the rate of inflation to 8 percent, which persists for a period of time (between t_1 and t_2). The dashed, curved lines describe the response of an economy composed of agents who, although intelligent, require time to learn the new structure. Expected inflation and nominal interest rates adjust slowly to the change in p while people attempt to determine whether the new rate of inflation is permanent or temporary. The realized real rate of interest falls from ($r = R - p = 10 - 8 = 2$ percent) at time t_0 and then rises slowly toward its original value of 4 percent as the market adjusts to new information. These curves are consistent with the data in Charts 3 and 4 and also with the estimates reported in Charts 1 and 2 and Tables 1, 3, and 4.

The values of r and R described by the solid lines between t_1 and t_2 show the adjustment of an almost instantly omniscient market. Participants did not foresee the rise in inflation but rapidly adjust to the new situation. R quickly reflects the new p, causing r to return to 4 percent almost immediately after the unexpected decline. If people were omniscient about the future as well as the present, R would have moved simultaneously with p so that r would not have deviated from 4 percent.

The dashed and solid lines to the right of t_2 show adjustments of omniscient and other markets to an unexpected reduction in inflation. Again, slow learning produces high serial correlation in the realized real rate, while omniscience generates random and uncorrelated variations in r around 4 percent.

Summary and (the absence of) implications for monetary policy

This article has reported evidence that the tendency for changes in interest rates to lag changes in the rate of inflation has been as pronounced recently as it was during the 19th and early 20th centuries. But this does not mean that the central bank, even with precise control of the rate of inflation, can control real interest rates. The causes of observed relations between interest rates and inflation have not been determined. Neither of the principal competing explanations is well specified, and both have produced results that are econometrically deficient. Fisher's own cursory explanation appears in some ways the most satisfactory, possibly because it is less specific and, therefore, less subject to refutation. Nevertheless, there is considerable appeal in his argument that variations in inflation and interest rates have been the joint effects of a wide variety of real and monetary disturbances and that monetary disturbances themselves have often been responses to real forces.

Suppose Fisher's explanation is correct and that the central bank now decides to initiate a monetary policy designed to achieve a rate of inflation consistent with some particular real interest rate. Such a policy cannot be successful, except by accident, for at least two reasons. First, the present state of economic knowledge does not include an explanation of the forces affecting real interest rates that are outside the central bank's control. Second, there is little or no evidence upon which estimates of the public's response to the new monetary policy might be based. Even if there existed econometric models that approached satisfactory explanations of past relationships, those models would not apply to the new economic structure.[18] For example, the public's behavior in a world in which the central bank systematically pursues a new monetary policy designed to achieve specific real rates of interest may be quite different from past behavior.

This point should become clear once it is remembered that none of the results reported above can be interpreted to refute the usual concept of efficient markets, according to which observed prices and interest rates correctly reflect all *available* information. This hypothesis is placed under an unsupportable burden when tested jointly with the

17. These are averages. Actual values vary randomly about the lines shown in the figure.

18. This point is made in the often-cited but never-applied paper by Robert E. Lucas, Jr., "Econometric Testing of the Natural Rate Hypothesis," in *The Econometrics of Price Determination Conference*, ed. Otto Eckstein (Washington, D.C.: Board of Governors of the Federal Reserve System, 1972), 50–59.

hypotheses of perfect information and a constant expected real rate. It is quite conceivable that interest rates might, at one time, respond slowly to a mixture of reliable and possibly unreliable information about the behavior of the central bank and the determinants of expected real rates of return and, at another time, respond quickly and vigorously to clear information that the central bank is attempting to control interest rates.