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Do Interest Rates Help Predict Inflation?

The primary responsibility of a central bank is to preserve the value of its nation's currency. In the United States, the Federal Reserve System attempts to meet this responsibility by pursuing monetary policies that promote economic growth without fueling inflation. Achieving sustained noninflationary growth is complicated by the fact that changes in monetary policy affect the economy with a lag. Thus, the successful conduct of monetary policy requires reliable forecasts of both inflation and economic activity.

A plot of the three-month U.S. Treasury bill rate and subsequent quarterly inflation suggests that interest rates may contain information about future inflation (*Figure 1*). Indeed, recent research indicates that movements in interest rates are helpful in predicting inflation (Bernanke 1990; Fama 1990; Mishkin 1990a, 1990b; Frankel and Lown 1991). Interest rate movements may, therefore, provide the Federal Reserve with information useful in conducting monetary policy. In fact, some monetary policymakers (Johnson 1988) have advocated a strategy for conducting policy based on monitoring several financial variables, including interest rates.

Figure 1
Three-Month Treasury Bill Rate and CPI Inflation

SOURCES OF PRIMARY DATA: Board of Governors, Federal Reserve System; U.S. Bureau of Labor Statistics.

While the studies cited above have addressed the question of whether interest rates, *by themselves*, help predict inflation, more relevant to policymaking is the question of whether *adding* interest rates to traditional models for forecasting inflation yields any improvement in the models' forecasting ability. This article examines whether interest rates provide information about inflation beyond that contained in traditional models. For two reasons we focus on inflation as measured by the consumer price index (CPI). First, existing studies of the predictive content of interest rates use the consumer price index almost exclusively. Second, because they are not distorted by transitory shifts in the composition of output, fixed-weight indexes like the consumer price index give a more accurate picture of near-term changes in the cost of living than do variable-weight indexes.

The first section of the article reviews the economic intuition underlying the connection between interest rates and inflation. The second section presents evidence of the power of interest rates, by themselves, to predict near-term inflation. Consistent with previous studies, we find that although interest rates are quite helpful in explaining movements in inflation during the 1960s and

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Table 1
Inflation and Interest Rates

		Marginal Significance Level				Number of Lags				
	DV	*3M*	*3MFF*	*10Y3M*	*JOINT*	DV	*3M*	*3MFF*	*10Y3M*	$\bar{R}^2$
A.	π	.000	.034	.012	.000	3	1	6	5	.899
B.	π	.733	.920	.059	.296	3	1	1	1	.618
C.	$\Delta\pi$	.006	.000	.483	.000	8	8	5	1	.493
D.	$\Delta\pi$	.146	.862	.671	.168	2	2	1	1	.265

Sample periods

A. 1959:1–1979:4
B. 1980:1–1991:2
C. 1959:1–1979:4
D. 1980:1–1991:2

Definitions

DV = dependent variable in the regression.
π = change logarithm of the consumer price index.
$\Delta\pi$ = change in π.
3M = interest rate on three-month Treasury bills.
3MFF = difference between *3M* and the federal funds rate.
10Y3M = difference between the interest rate on ten-year Treasury bonds and *3M*.
JOINT = marginal significance level from a test of the hypothesis that the coefficients of all interest rate variables are equal to zero.

NOTE: All regressions were carried out using the RATS regression package, Version 3.0.

1970s, the explanatory power of interest rates markedly deteriorates in the 1980s. The third section of the article specifies traditional inflation-forecasting models and examines whether including interest rates in these models results in additional explanatory power. We find that short-term interest rates *do* possess marginal explanatory power in the pre-1980 sample. Furthermore, this increased explanatory power does *not* disappear during the 1980s. Indeed, we find that long-term interest rates also become significant during the 1980s. The fourth section of the article examines the real-time forecasting performance of the most general of our inflation models. Four versions of this general model are considered—versions meant to explain the level of inflation and the change in inflation, both with and without the help of interest rates. We find that better inflation forecasts are obtained from models that explain the change in inflation than from models that explain the level of inflation. Moreover, we find that interest rates improve our ability to predict near-term changes in inflation. We conclude by interpreting our findings and discussing their implications for policy.

The relationship between interest rates and inflation

In general, the expected real return on a loan equals the nominal return less the expected rate of inflation. Turning this relationship around,

$$(1) \qquad \pi^e_t = i_{t-1} - r^e_{t-1},$$

where i_{t-1} is the market interest rate at time $t - 1$, r^e_{t-1} is the expected real interest rate at time $t - 1$, and π^e_t is the expected rate of inflation between period $t - 1$ and period t. If the expected real interest rate is constant, then movements in expected inflation will be reflected, one for one, in movements in the market interest rate. More generally, as long as the expected real interest rate is not correlated with the market interest rate, analysts can infer a 1-percentage-point increase in expectations of inflation from a 1-percentage-point increase in the market interest rate. Of course, insofar as analysts are able to find variables that control for movements in the expected real interest rate, they will be able to improve the accuracy of their estimates of expected inflation. However, even exact estimates of expected inflation are of little use unless expected inflation is, in turn, an accurate indicator of *realized* inflation.

Similarly, the expected *change* in inflation is

$$(1') \qquad \pi_t^e - \pi_{t-1} = (i_{t-1} - i_{t-2}) - (r_{t-1}^e - r_{t-2}),$$

where π_{t-1} represents the realized rate of inflation between period $t-2$ and period $t-1$ and where $(r_{t-2} \equiv i_{t-2} - \pi_{t-1})$ is the *ex post* real rate of return on a loan made in period $t-2$ that matures in period $t-1$. If expected changes in the real interest rate are not correlated with changes in the market interest rate—as will be the case, for example, when the real interest rate follows a random walk—then a 1-percentage-point increase in the market interest rate can be used to infer a 1-percentage-point increase in expectations of the change in inflation. Variables correlated with the expected change in the real interest rate will allow analysts to control for the change in the real rate and thereby improve their forecasts of the market expectation of the change in inflation. This market expectation may or may not be a good predictor of the actual change in inflation.

Before moving on to further analysis of the additional predictive content of nominal interest rates, we briefly review the evidence that movements in nominal interest rates, by themselves, can help predict future inflation or future changes in inflation.

Inflation and interest rates: the existing evidence

A study by Fama (1975) first showed that interest rates might be useful for predicting inflation. For the period from 1953 through 1971, Fama found that the level of one- to six-month Treasury bill rates provided information about future inflation beyond that contained in lagged values of inflation. Additionally, Fama's results suggested that all the variation in one- to six-month nominal Treasury bill rates during this period was due to variation in expected inflation, rather than variation in expected real interest rates.

Hess and Bicksler (1975) showed that Fama's finding of a constant real rate of interest was specific to the sample period he examined. However, Fama's other result—that market interest rates provide information about future inflation beyond that obtained from lagged values of inflation—has been confirmed by subsequent studies (Fama and Gibbons 1982, 1984).

Table 1 demonstrates the usefulness of interest rates in explaining inflation and changes in inflation. Line A, for example, summarizes results obtained when quarterly CPI-inflation data from the first quarter of 1959 through the fourth quarter of 1979 are regressed on three lagged values of inflation and several interest rate measures.[1] The interest rate measures are the three-month Treasury bill rate, six lags of the difference between the three-month Treasury bill rate and the federal funds rate, and five lags of the difference between the ten-year Treasury bond rate and the three-month Treasury bill rate.[2] If the expected real interest rate were constant over the 1959–79 period (apart from white noise) and if market

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[1] *Inflation is measured as the logarithmic difference of the data series CPI-UX (U.S. Bureau of Labor Statistics), which treats housing costs on a rental-equivalence basis. Two dummy variables were included in the regressions to capture the impact of the Nixon Administration wage and price controls. The first dummy variable is unity over the actual period of price controls (1971:3–1972:4), and the second dummy variable is unity over the period immediately following the price controls (1973:1–1974:4).*

[2] *All interest rates are quarterly averages. We used Akaike's final prediction error (FPE) criterion to choose the appropriate lag length for each right-hand-side variable. The FPE statistic (Akaike 1969) measures a regression's mean-square prediction error. We used the FPE statistic, along with a methodology outlined by Hsiao (1981), to determine the order in which lag-length selections were made. A maximum of eight lags was allowed.*

expectations of inflation differed from realized inflation by only a white-noise error, then equation 1 would imply a coefficient of unity on the three-month Treasury bill rate and zero coefficients on all other right-hand-side variables. In fact, the coefficient on the three-month T-bill rate is estimated precisely and is within one standard error of unity, but lagged inflation and the interest rate spreads also have significant explanatory power for inflation.[3] Apparently, *ex post* real returns were correlated with both lagged inflation and lagged interest rate spreads over the 1959–79 period.

A number of studies have suggested that the relationship between interest rates and inflation has broken down or, at least, changed since 1979.[4] This shift in the interest rate–inflation relationship is illustrated on line B of Table 1, which presents results from a regression of inflation on lagged inflation and several interest rate measures over the period from the first quarter of 1980 through the second quarter of 1991. Note that over this later sample period, none of the interest rate measures help to explain movements in inflation.

Similar results are obtained when one substitutes the *change* in inflation for the *level* of inflation in the regression equations. During the pre-1980 period, both the level of the three-month Treasury bill rate and the spread between the three-month Treasury bill rate and the federal funds rate have significant marginal explanatory power for changes in inflation (line C). After 1979, this explanatory power disappears (line D).

What accounts for the changed relationship between market interest rates and inflation since 1980? Broadly speaking, only two explanations are possible. Either the relationship between actual inflation and expected inflation or the correlation between movements in nominal interest rates and movements in real interest rates must have been different during the 1980s compared with the 1970s. Evidence exists to support each of these views (which, after all, are not mutually exclusive). Thus, for example, Evans and Lewis (1991) and Raymond and Rich (1992) have presented empirical results suggesting that inflation policy is subject to discrete "regime shifts."[5] During the 1970s, according to these two studies, there may have been a systematic tendency for realized inflation to exceed expectations of inflation. This apparent bias in expectations would be rational if, over this period, people had felt that the Federal Reserve might soon adopt a stronger anti-inflationary stance. Beginning in late 1979, according to many observers, the Federal Reserve did indeed launch a campaign to bring down the rate of inflation. Therefore, the seeming bias in inflationary expectations likely was eliminated, or even reversed in sign, after 1979. Thus, a plausible case can be made for a sudden shift in the relationship between expected inflation (the inflation incorporated into market interest rates) and realized inflation (the inflation we are attempting to explain in our regression equations).

The view that the correlation between nominal interest rates and real interest rates may have been altered has received indirect support from empirical studies documenting a shift in the relationship between nominal interest rates and real economic activity—a shift that apparently occurred at about the same time as the shift in the relationship between nominal interest rates and inflation. Bernanke (1990) documents the changed relationship between interest rates and real activity and discusses financial innovations that may have been responsible for the change. Expected real returns, though not directly observable, are thought to be closely related to movements in real economic activity (Chapman 1991).

In summary, existing studies indicate that over some sample periods, interest rates and interest rate spreads have provided information useful in explaining or predicting movements in inflation. However, these studies have only examined whether market interest rates have explanatory or predictive power beyond that evident in the history

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[3] *The estimated coefficient on the three-month Treasury bill rate is 1.115, with a standard error of 0.215.*

[4] *See, for example, Clarida and Friedman (1984), Huizinga and Mishkin (1986), Bernanke (1990), Fama (1990), Mishkin (1990a, 1990b), and Jorion and Mishkin (1991). The change in the relationship between interest rates and inflation is also evident in Figure 1.*

[5] *Also see Romer and Romer (1989) and Balke and Fomby (1991).*

of inflation itself.[6] In the analysis that follows, we adopt a more stringent test of the usefulness of interest rates in predicting inflation. In particular, we examine whether market interest rates provide information about price movements beyond the information included in variables traditionally used to forecast inflation. Besides interest rates, the variables we consider are measures of money growth, the velocity of money, the relative price of energy, productivity-adjusted wages, and output-market slack. We first estimate empirical models that rely solely on these non-interest-rate variables, then test whether adding interest rates to the models significantly improves their performance.

Specification of traditional inflation models

Most economists would agree that over the long term, inflation is determined by the rate of money growth relative to the rate of potential output growth. There is considerably less consensus about the factors that influence near-term movements in inflation. Two paradigms, the monetarist and Phillips-curve approaches, have dominated the empirical literature on near-term movements in inflation. In the monetarist paradigm, inflation is caused by money-supply growth in excess of money-demand growth—in other words, by "too much money chasing too few goods." In monetarist models, past money growth is the primary determinant of near-term movements in inflation. The Phillips-curve paradigm, in contrast, attributes near-term movements in inflation to variations in excess demands on the labor or output markets. In Phillips-curve models, variables that proxy for the gap between current output and the full-employment level of output play an important role in determining inflation.

We estimate variants of both monetarist and Phillips-curve models, as well as a general model that draws upon both paradigms. Estimating several inflation models allows us to determine whether our results are robust with respect to model specification. Testing for robustness is important, given the current lack of consensus about which inflation paradigm is superior.

A monetarist model of inflation. A typical monetarist model of inflation takes the form

$$(2)\qquad \pi_t = a + \sum_i b_i \pi_{t-i} + \sum_i c_i \hat{M}_{t-i} + \sum_i d_i \hat{E}_{t-i},$$

where π is inflation, M is money growth, $\hat{E}$ is an energy-shock variable, and the lowercase letters denote parameters to be estimated. We use the logarithmic difference of the M2 monetary aggregate as our measure of money growth and use the growth rate of the producer price index for fuels and energy relative to the overall producer price index as our energy-shock variable.[7] All data are quarterly, running from 1959 through the second quarter of 1991.

Before equation 2 can be estimated, several technical issues need to be addressed. The first concerns appropriate lag lengths for the right-hand-side variables in the equation. Choosing a model with lags that are too short can result in biased estimates, while choosing lags that are too long can result in inefficiency. We relied upon Akaike's (1969) final prediction error (FPE) criterion to select the appropriate lag length for each right-hand-side variable in our regressions.

A second technical issue is the stationarity of the regressors in equation 2. If any of its right-hand-side variables have nontrivial trends, then misleading conclusions may result from hypothesis testing. For this reason, Dickey–Fuller tests were used to ensure that all right-hand-side variables entered in (2) are stationary.[8] These tests gave ambiguous results for the stationarity of inflation. Therefore, (2) was estimated twice: once with inflation as the dependent variable and once with the change in inflation as the dependent variable.[9]

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[6] *The exception is Bernanke (1990), who also includes a history of the U.S. Commerce Department's index of leading indicators.*

[7] *We also examined monetarist models using the St. Louis monetary base, rather than M2, and found no qualitative differences in results. Separately, we examined models in which the energy-shock variable was the growth rate of consumer energy costs relative to overall consumer prices, rather than the growth rate of producer energy costs relative to overall producer prices. Again, we found no qualitative differences in results.*

[8] *A time series random variable is said to be stationary if its distribution does not depend on time.*

[9] *Differencing a random variable that is nonstationary with a single unit root ensures stationarity.*

Table 2

Traditional Inflation Models

A. Monetarist Model

	Marginal Significance Level			Number of Lags			
DV	DV	$\dot{E}$	$\dot{M}$	DV	$\dot{E}$	$\dot{M}$	$\bar{R}^2$
π	.000	.000	.003	3	8	1	.833
$\Delta\pi$	.000	.000	.002	2	8	1	.433

B. Phillips-Curve Model

	Marginal Significance Level				Number of Lags				
DV	DV	$\dot{E}$	*GAP*	*V2*	DV	$\dot{E}$	*GAP*	*V2*	$\bar{R}^2$
π	.000	.000	.013	.303	3	8	1	2	.829
$\Delta\pi$	.000	.000	.001	.006	2	8	6	2	.476

C. General Encompassing Model

	Marginal Significance Level						Number of Lags						
DV	DV	$\dot{W}$	$\dot{E}$	*GAP*	*V2*	$\dot{M}$	DV	$\dot{W}$	$\dot{E}$	*GAP*	*V2*	$\dot{M}$	$\bar{R}^2$
π	.000	.018	.000	.093	.194	.001	3	6	8	1	2	1	.856
$\Delta\pi$	.000	.251	.000	.024	.114	.000	2	1	8	1	1	1	.473

Sample period: 1959:1–1991:2

Definitions

$\dot{E}$ = change in the logarithm of the relative price of energy in the producer price index.
$\dot{M}$ = change in the logarithm of the M2 monetary aggregate.
GAP = difference between the logarithm of GNP and the logarithm of potential GNP.
V2 = logarithm of the velocity of M2.
$\dot{W}$ = change in the logarithm of the ratio of compensation per hour to output per hour in the nonfarm business sector.

NOTE: For further explanations, see Table 1.

Results are presented in Table 2, part A.

The explanatory power of the monetarist models is quite high. Clearly, both lagged money growth and lagged energy prices help explain movements in inflation. In neither regression is serial correlation or heteroskedasticity of the errors a problem. Furthermore, traditional *F* tests do not provide evidence of a structural break in either model.[10]

A Phillips-curve model of inflation. One motivation for the Phillips-curve inflation model is presented by Hallman, Porter, and Small (1991). An attractive feature of their approach is that it makes explicit the importance of money growth for long-term trends in inflation, while allowing excess demand for output to influence move-

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[10] *Godfrey–Breusch Lagrange-multiplier tests were used to check for serial correlation. We used a version of White's test to examine for heteroskedasticity. The breakpoint for these and other F tests was the first quarter of 1960.*

ments in inflation over the near term.

Hallman et al. write inflation as a function of lagged inflation and of the gap between the current price level, P, and the long-run equilibrium price level, P^*.[11] The equilibrium price level is defined as the price level consistent with the current outstanding stock of M2, the average velocity of M2 ($V2^*$), and the current value of potential, or full-employment, real output.[12] Formally,

$$(3) \qquad P^* \equiv M2 + V2^* - Q^*,$$

where Q^* is potential real output and all variables are in logarithmic form.

According to the equation of exchange, $P = M2 + V2 - Q$, where $V2$ is the current velocity of M2 and Q is the current level of output. Clearly, if the velocity of M2 tends to revert to $V2^*$ and if output tends to revert to Q^*, then the price level will converge to P^*. Hallman, Porter, and Small argue that this convergence is described by the equation

$$(4) \qquad \Delta\pi = -b(P - P^*),$$

where $\Delta\pi$ is the change in inflation and b is a fixed, positive parameter. From the equation of exchange, (4) can be rewritten as

$$(5) \qquad \Delta\pi = -b[(V2 - V2^*) - (Q - Q^*)]$$

or, more generally, as

$$(6) \qquad \Delta\pi = a - bV2 + c(Q - Q^*),$$

where a is defined as $bV2^*$. Equations 5 and 6 are equivalent if c equals b.

We estimated not only a version of the Phillips-curve model with the change in inflation as the dependent variable, as in equation 6, but also a version with the level of inflation as the dependent variable. In both cases, lagged values of the dependent variable were allowed to enter as right-hand-side variables. We used gross national product as our measure of output. Estimates of potential output came from the Board of Governors of the Federal Reserve System. As with the monetarist models, an energy-shock variable and dummy variables for the Nixon wage and price controls were included in the regressions. The Akaike criterion was used to select lag lengths, and Dickey–Fuller tests were applied to ensure stationarity of the right-hand-side variables. Like Hallman, Porter, and Small, we found that both M2 velocity and the output gap are stationary. Heteroskedasticity and serial correlation did not appear to be a problem.[13] Results are presented in Table 2, part B.

The explanatory power of the inflation-level version of the Phillips-curve model, as measured by its $\bar{R}^2$, is similar to that of the corresponding monetarist model. The inflation-change version of the Phillips-curve model, on the other hand, has somewhat greater explanatory power than does the corresponding monetarist model. Each right-hand-side variable in the Phillips-curve model makes a significant contribution to the explanation of the change in inflation. Every right-hand-side variable except the velocity of money makes a significant contribution to the explanation of the *level* of inflation.

A general encompassing model of inflation. The final inflation model we estimate includes both monetarist and Phillips-curve variables. The

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[11] *Strictly speaking, the Hallman–Porter–Small derivation goes through only if P is an implicit deflator for some measure of aggregate output. As a practical matter, however, movements in the consumer price index are highly correlated with those in the implicit gross national product deflator and gross domestic product deflator. Consequently, one might reasonably expect that the set of variables that helps explain movements in the implicit deflators would also help explain movements in the CPI.*

[12] *Mehra (1989) advocates an alternative definition of the long-run equilibrium price level. Mehra's analysis leads to an inflation equation that includes the change in money's opportunity cost as a right-hand-side variable. Because changes in the opportunity cost of holding money are highly correlated with changes in interest rates, Mehra's analysis provides a rationale for including interest rate measures in the inflation equation that is an alternative to the rationale sketched earlier in this article.*

[13] *F tests yielded strong evidence against the structural stability of the Phillips-curve model estimated in levels form but no evidence against structural stability of the model estimated in changes form. Accordingly, although we present results for both forms of the model, we place greater emphasis in our analysis on results obtained from the inflation-change regressions.*

Table 3
Interest Rates and the Monetarist Model

A. Interest Rate Variables

	1959:1–1979:4							1980:1–1991:2						
	Marginal Significance Level				Number of Lags			Marginal Significance Level				Number of Lags		
DV	*3M*	*3MFF*	*10Y3M*	*JOINT*	*3M*	*3MFF*	*10Y3M*	*3M*	*3MFF*	*10Y3M*	*JOINT*	*3M*	*3MFF*	*10Y3M*
π	.032	.089	.148	.025	1	4	1	.165	.011	.043	.000	4	3	2
$\Delta\pi$	.122	.032	.468	.034	1	4	1	.978	.016	.000	.000	1	3	2

B. Non-Interest-Rate Variables

	1959:1–1991:2						
	Marginal Significance Level			Number of Lags			
DV	DV	$\dot{E}$	$\dot{M}$	DV	$\dot{E}$	$\dot{M}$	$\bar{R}^2$
π	.000	.000	.001	3	8	1	.876
$\Delta\pi$	.000	.000	.001	2	8	1	.564

motivation for estimating a general model of this type comes from recent findings that models including both monetarist and Phillips-curve characteristics significantly outperform narrower models (Haslag and Ozment 1991; Mehra 1990).

Besides lagged values of the dependent variable (either the level of inflation or the change in inflation), money growth, and the output gap, we include lagged values of M2 velocity, lagged energy-price shocks, and lagged values of a measure of labor costs as right-hand-side variables.[14] Dummy variables for the Nixon wage and price controls complete the model. There is no evidence of a structural break in the general model, regardless of whether the model is formulated in terms of the level of inflation or the change in inflation. There is also no evidence of serial correlation or heteroskedasticity. Results are presented in Table 2, part C.

According to the table, the general model explains a somewhat higher proportion of the variation in the level of inflation than do the monetarist and Phillips-curve models. Most of this incremental explanatory power comes from productivity-adjusted wages. The inflation-change version of the general model performs no better than does the corresponding Phillips-curve model. However, money growth helps significantly in explaining variations in both the level of inflation and the change in inflation, and the velocity variable is now insignificant in the changes regression. In the changes regression, unlike the inflation-level regression, wage growth contributes little explanatory power.

Additional information content of the interest rate variables

To examine the marginal information content of interest rates for future inflation, we added

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[14] *The labor-cost measure is defined as the growth rate of compensation per hour relative to output per hour in the nonfarm business sector. Mehra (1990) and Haslag and Ozment (1991) include similar labor-cost measures in their analyses.*

lagged values of three interest rate measures to the right-hand sides of our inflation models. These measures were the level of the three-month Treasury bill rate (*3M*), the spread between the three-month Treasury bill rate and the federal funds rate (*3MFF*), and the spread between the ten-year Treasury bond rate and the three-month Treasury bill rate (*10Y3M*). The three-month rate was included because economic theory suggests that the rate incorporates market expectations of inflation over the coming quarter (compare with equation 1). The spread between the ten-year bond rate and the three-month bill rate was included because previous research indicates that this spread is closely related to future growth in real economic activity and, hence, might control for movements in expected real interest rates (Bernanke 1990; Estrella and Hardouvelis 1991). The spread between the three-month Treasury bill rate and the federal funds rate was included partly for completeness and partly because the federal funds rate is the interest rate that is most nearly under the control of the monetary authority.

In each regression equation, both the constant term and the coefficients on the interest rate variables were allowed to differ between the pre-1980 and post-1979 sample periods.[15] This split was introduced because formal *F* tests indicated that the coefficients on some interest rate variables in the monetarist and Phillips-curve models shifted beginning in 1980. A split was allowed even in the general model, which showed no evidence of a structural shift, because we wanted to examine whether interest rates played a less important role in explaining movements in inflation during the 1980s than during the 1960s and 1970s. (Recall that in regressions involving only interest rates and the lagged level of inflation or change in inflation, we found evidence that the marginal explanatory power of interest rates declines after 1979.) Coefficients on non-interest-rate variables were constrained to be equal across the entire 1959–91 period.

We found that in the pre-1980 period, the short end of the interest rate yield curve has substantial marginal explanatory power for both the level of inflation and the change in inflation, while the long end of the yield curve does not. In the post-1979 period, *both* short-term and long-term interest rates help to explain movements in inflation. Our general encompassing model with interest rates apparently dominates the interest-rate-augmented monetarist and Phillips-curve models, not only in terms of its structural stability but also in terms of its ability to explain inflation. In the general model, a yield curve that is steep at its long end tends to signal low, and declining, near-term inflation.

Impact of interest rates on the monetarist model. According to Table 3, adding interest rates to the monetarist model of the level of inflation raises the $\bar{R}^2$ of the regression equation to 0.88. Over the pre-1980 period, the three interest rate measures are jointly significant at well under the 5-percent level. Over the post-1979 period, the joint significance level falls to 0.02 percent, indicating that the marginal explanatory power of interest rates increased during the 1980s. Most of the marginal explanatory power of interest rates over the early sample period is accounted for by the level of the three-month interest rate, though the spread between the three-month rate and the federal funds rate is also significant at the 10-percent level. The spread between the ten-year and three-month interest rates—representing the slope of the long end of the yield curve—does not contribute significant marginal explanatory power until the 1980s.[16]

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[15] *Lags on the non-interest-rate variables were held fixed at lengths determined by Akaike's FPE criterion as applied to the monetarist, Phillips-curve, and general models without interest rates. The Akaike criterion was applied separately to the pre-1980 and post-1979 interest rate variables to determine the optimal number of lags of these variables to be included in the regression equations.*

[16] *One explanation for this result—and similar results reported later in the article—can be provided within the context of a model (such as that of Mehra 1989, 1990) in which the opportunity cost of holding money is one determinant of inflation. During the 1960s and 1970s, when deposit rate ceilings were generally binding, the opportunity cost of holding money principally varied with short-term interest rates. Once deposit rate ceilings were abolished, banks were free to change deposit rates in response to movements in loan rates—which are relatively long-term—and the opportunity cost of holding money became a function of the spread between long-term and short-term market rates.*

Table 4
Interest Rates and the Phillips-Curve Model

A. Interest Rate Variables

	1959:1–1979:4							1980:1–1991:2						
	Marginal Significance Level				Number of Lags			Marginal Significance Level				Number of Lags		
DV	*3M*	*3MFF*	*10Y3M*	*JOINT*	*3M*	*3MFF*	*10Y3M*	*3M*	*3MFF*	*10Y3M*	*JOINT*	*3M*	*3MFF*	*10Y3M*
π	.020	.018	.314	.011	3	4	1	.082	.778	.012	.011	1	1	1
$\Delta\pi$	.542	.422	.774	.413	1	2	1	.589	.026	.001	.001	1	3	2

B. Non-Interest-Rate Variables

	1959:1–1991:2								
	Marginal Significance Level				Number of Lags				
DV	DV	$\hat{E}$	*GAP*	*V2*	DV	$\dot{\hat{E}}$	*GAP*	*V2*	$\bar{R}^2$
π	.001	.000	.766	.055	3	8	1	2	.856
$\Delta\pi$	.000	.000	.019	.004	2	8	6	2	.567

Table 5
Interest Rates and the General Encompassing Model: Split-Sample Interest Rate Coefficients

A. Interest Rate Variables

	1959:1–1979:4							1980:1–1991:2						
	Marginal Significance Level				Number of Lags			Marginal Significance Level				Number of Lags		
DV	*3M*	*3MFF*	*10Y3M*	*JOINT*	*3M*	*3MFF*	*10Y3M*	*3M*	*3MFF*	*10Y3M*	*JOINT*	*3M*	*3MFF*	*10Y3M*
π	.015	.051	.990	.007	1	3	1	.049	.002	.097	.000	1	3	2
$\Delta\pi$	.596	.037	.700	.093	1	4	1	.877	.013	.001	.001	1	3	2

B. Non-Interest-Rate Variables

	1959:1–1991:2												
	Marginal Significance Level						Number of Lags						
DV	DV	$\dot{W}$	$\dot{\hat{E}}$	*GAP*	*V2*	$\dot{M}$	DV	$\dot{W}$	$\dot{\hat{E}}$	*GAP*	*V2*	$\dot{M}$	$\bar{R}^2$
π	.586	.012	.000	.628	.022	.003	3	6	8	1	2	1	.895
$\Delta\pi$	.000	.286	.000	.621	.751	.001	2	1	8	1	1	1	.561

When interest rates are added to monetarist variables in an attempt to explain *changes* in inflation, the R^2 of the monetarist equation rises from 0.43 to 0.56. Collectively, the interest rate measures help significantly in explaining changes in inflation during both the early and the late sample periods. As in the inflation-level regression, the bulk of interest rates' marginal explanatory power during the early sample period comes from the short end of the yield curve. During the 1980s, the long end of the yield curve also makes a significant contribution.

Impact of interest rates on the Phillips-curve model. Results for the Phillips-curve model (*Table 4*) are qualitatively similar to those for the monetarist model. Including interest rates in the Phillips-curve equation for the level of inflation raises the equation's $\bar{R}^2$ from 0.83 to 0.86 and raises the R^2 of the Phillips-curve equation for the change in inflation from 0.48 to 0.57. In the levels regression, only short-term interest rates have significant marginal explanatory power in the early sample period, while it is principally the slope of the long end of the yield curve that helps explain movements in inflation during the 1980s. In the regression for the change in inflation, none of the interest rate measures are statistically significant during the early sample period, but the slopes of both the short end and the long end of the yield curve have substantial explanatory power during the 1980s.

Impact of interest rates on the general encompassing model. Including interest rates in the general encompassing model of inflation raises the $\bar{R}^2$ of the levels regression from 0.86 to 0.89 and raises the R^2 of the changes regression from 0.47 to 0.56. (Compare Table 5 with Table 2.) In both the pre-1980 and the post-1979 segments of the 1959–91 sample period, measures of short-term interest rates help substantially in explaining movements in the level of inflation and the change in inflation. In contrast, the slope of the long end of the yield curve is of little help in explaining movements in the level of inflation or the change in inflation until after 1979. Table 6 shows that when the coefficients of the interest rate variables are constrained to be constant over the sample period, all three interest rate measures make a statistically significant contribution to both the level-of-inflation and the change-in-inflation regressions.

Including interest rates among the right-hand-side variables in the regression equations for the general encompassing model has important effects on the explanatory power of both the output gap and the velocity of money. The explanatory power of the output gap for the level of inflation is weakened by the inclusion of interest rates, while that of velocity is markedly strengthened.[17] (Compare Tables 5 and 6 with Table 2.) In the inflation-change version of the general encompassing model, adding interest rates markedly reduces the explanatory power attributable to the output gap. The velocity variable remains insignificant.

Inflation and the slope of the yield curve. Is a steep yield curve a signal of high inflation or of low inflation? Is a steep yield curve a signal of rising inflation or of falling inflation? One can determine the long-run effect of a change in the steepness of the yield curve on predicted inflation, or on the predicted change in inflation, by using the sum of the coefficients attached to lagged values of the interest rate spread. In our estimate of the *levels* version of the general encompassing model, this sum of coefficients is 0.891 (with standard error 0.346) for the spread between the three-month rate and the federal funds rate and is –0.403 (with standard error 0.175) for the spread between the ten-year rate and the three-month rate. Thus, a three-month interest rate that is high relative to the federal funds rate signals a *high* near-term rate of inflation, while a ten-year interest rate that is high relative to the three-month rate signals a *low* near-term rate of inflation.

One interpretation of these results is that bond market participants expect the Federal Reserve to raise the federal funds rate quickly when near-term inflation threatens to be high. Because the three-month rate is more responsive to expected near-term movements in the federal funds rate than is the ten-year rate, the prospect of an increase in the federal funds rate raises the

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[17] *This statement also applies to the Phillips-curve model. (Compare Table 4, part B, with Table 2, part B.)*

Table 6

Interest Rates and the General Encompassing Model: Unified-Sample Interest Rate Coefficients, 1959:1–1991:2

A. Interest Rate Variables

	Marginal Significance Level				Number of Lags		
DV	*3M*	*3MFF*	*10Y3M*	*JOINT*	*3M*	*3MFF*	*10Y3M*
π	.001	.011	.004	.000	5	3	3
$\Delta\pi$	.017	.011	.002	.001	2	2	2

B. Non-Interest-Rate Variables

	Marginal Significance Level						Number of Lags						
DV	DV	$\hat{W}$	$\dot{E}$	*GAP*	*V2*	$\hat{M}$	DV	$\hat{W}$	$\dot{E}$	*GAP*	*V2*	$\hat{M}$	$\bar{R}^2$
π	.021	.000	.000	.289	.002	.000	3	6	8	1	2	1	.891
$\Delta\pi$	.000	.196	.000	.518	.134	.000	2	1	8	1	1	1	.548

three-month rate relative to both the current funds rate and the ten-year rate.[18]

In the regression explaining *changes* in inflation, inflation tends to rise more slowly in the future, the steeper is the long end of the yield curve. Thus, the sum of the estimated coefficients attached to lagged values of the spread between ten-year and three-month interest rates is –0.368, with standard error 0.158. Again, a possible interpretation is that the Federal Reserve is thought to be more likely to drive down near-term interest rates when inflationary pressures are waning than when inflationary pressures are building.

The following section analyzes the forecasting performance of the general encompassing models of the level of inflation and the change in inflation. The analysis compares the forecasting performance of models with interest rates with the forecasting performance of the corresponding models without interest rates. We confine our attention to the general models because they encompass the monetarist and Phillips-curve models and because the coefficients on the interest rate variables in the general models—unlike the other models—are stable across the entire sample.

Out-of-sample forecasts

The out-of-sample forecasting exercises we conduct are one-quarter-ahead static forecasts of inflation as generated by the general encompassing models. The forecasts are real-time in the sense that they are generated using only information available at the time of the forecasts. Furthermore, the parameter estimates of the models are updated each period as new information becomes available. However, the lag structures of the models were selected by using data from the entire sample. (Specifically, the lags used in the forecasting

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[18] See McNees (1989, 33). Alternatively, a large spread between long-term and short-term interest rates may signal a low opportunity cost of holding money and, hence, a low velocity of money. A low velocity of money tends to imply a low equilibrium price level for any given money supply, putting downward pressure on near-term inflation. The problem with this explanation is that velocity is already included as a separate right-hand-side variable in the level-of-inflation regression.

Table 7

Forecasting Performance of the General Encompassing Model

	With Interest Rates		Without Interest Rates	
	π	$\Delta\pi$	π	$\Delta\pi$
Mean error	–.278	–.255	–.235	–.130
Mean absolute error	1.445	1.175	1.303	1.211
Root-mean-square error	1.836	1.465	1.697	1.574

NOTE: Based on one-period-ahead forecasts from 1980:1 through 1991:2.
All statistics are multiplied by 100; for example, a mean error of –0.255 represents an error of –0.255 percentage point.

models are the same as those in Table 6.)

Table 7 presents forecast results for the level of and the change in inflation obtained from the general encompassing models with and without interest rates. In every case, the forecast period runs from the first quarter of 1980 through the second quarter of 1991. None of the mean errors are statistically different from zero, indicating that the forecasts are unbiased. Root-mean-square errors are lower for forecasts based on regressions in the change in inflation than for forecasts based on regressions in the level of inflation.[19]

Table 8 presents the results of formal encompassing tests. (For an explanation of forecast encompassing tests, see the box titled "Forecast Encompassing," page 15.) These tests confirm that the inflation-change versions of the general model yield significantly more accurate forecasts of inflation than do the corresponding inflation-level versions. Thus, forecast errors of the inflation-change models help explain the forecast errors of the inflation-level models but not vice versa (Table 8, lines A and B). Comparing the inflation-change models, the model with interest rates encompasses the model without rates, but the model without rates fails to encompass the model with rates (Table 8, line C). Consequently, the forecasting performance of the model with interest rates is unambiguously superior to that of the model without interest rates. In particular, interest rates contain information useful in predicting near-term movements in inflation.

Discussion

Previous research has shown that the slope of the interest rate yield curve can serve as a useful predictor of long-term changes in inflation. Attempts to extract information about *near*-term movements in inflation from interest rates have proven to be less successful—especially for the 1980s. *A priori*, one might have expected the marginal information content of interest rates to shrink as additional explanatory variables were included on the right-hand side of the inflation regression. Apparently, however, the variables that might have been expected to be most competitive with market interest rates actually help the analyst to control for unobservable movements in expected real interest rates. Thus, supplementing interest rates with traditional inflation-predicting variables makes it easier to extract the information about near-term inflation that is hidden in the yield curve.

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[19] *By way of comparison, McNees (1992) reports the inflation-forecasting performance of an anonymous "prominent forecaster" for the period from the first quarter of 1980 through the first quarter of 1992. The mean error, mean absolute error, and root-mean-square error for this forecaster were 0.1, 1.2, and 1.7 percentage points, respectively (McNees 1992, Table 2).*

Table 8

Encompassing Tests

	Independent Variable	Dependent Variable	*t* Statistic
A.	$(\pi - \pi^I) - (\Delta\pi - \Delta\pi^I)$	$\pi - \pi^I$	2.710*
		$\Delta\pi - \Delta\pi^I$	.192
B.	$(\pi - \pi^F) - (\Delta\pi - \Delta\pi^F)$	$\pi - \pi^F$	5.146*
		$\Delta\pi - \Delta\pi^F$	.696
C.	$(\Delta\pi - \Delta\pi^I) - (\Delta\pi - \Delta\pi^F)$	$\Delta\pi - \Delta\pi^I$	2.685*
		$\Delta\pi - \Delta\pi^F$	.458

Definitions

$\pi - \pi^I$ = forecast error from the level-of-inflation model without interest rates.
$\Delta\pi - \Delta\pi^I$ = forecast error from the change-in-inflation model without interest rates.
$\pi - \pi^F$ = forecast error from the level-of-inflation model with interest rates.
$\Delta\pi - \Delta\pi^F$ = forecast error from the change-in-inflation model with interest rates.

* Significant at the 1-percent level.

In the existing literature, a steep yield curve signals rising inflation. Here, however, short-term rates that are low relative to long-term rates are a signal of *falling* inflation over the near term. Bond-market traders possibly believe that policymakers are more inclined to drive down short-term interest rates, steepening the yield curve, when the near-term outlook for inflation is favorable than when the near-term outlook for inflation is unfavorable. This interpretation of our empirical results would imply that a shift in the monetary authority's response to changes in the near-term inflation outlook would lead to a shift in our parameter estimates. In particular, if the Federal Reserve were to begin to rely more heavily on the slope of the yield curve as a guide for monetary policy, policymakers might find that the estimated relationship between the slope of the yield curve and near-term inflation would change. While interest rates historically have contained information helpful in predicting near-term inflation, this historical relationship is no guarantee that movements in market interest rates can be used successfully to guide policy.

Forecast Encompassing

The idea underlying the Chong and Hendry (1986) forecast encompassing test is not complicated. Let y denote the variable being forecast, and let y^f_1 and y^f_2 denote forecasts generated by two competing models. Consider the regression equation

$$(B.1) \qquad y = \alpha y^f_1 + (1-\alpha) y^f_2 + \epsilon,$$

where ϵ is a random error term. If α does not equal zero, then y^f_1 contains useful information for forecasting y that is not contained in y^f_2, and model 1 is said to "encompass" model 2. If α does not equal 1, then y^f_2 contains useful information for forecasting y that is not contained in y^f_1, and model 2 encompasses model 1. If model 1 encompasses model 2 but model 2 does not encompass model 1 (that is, if α equals 1), then model 1 is clearly superior for forecasting purposes. If model 1 is encompassed but is not encompassing (that is, if α equals zero), then it is model 2 that has clear superiority.

An easy way to test for forecast encompassing is to estimate each of two rearrangements of equation B.1:

$$(B.1') \quad y - y^f_1 = (1-\alpha)[(y - y^f_1) - (y - y^f_2)] + \epsilon$$

and

$$(B.1'') \quad y - y^f_2 = \alpha[(y - y^f_2) - (y - y^f_1)] + \epsilon.$$

In equation B.1′, if the estimated value of $(1-\alpha)$ is significantly different from zero, then α is significantly different from unity, and model 2 encompasses model 1. Similarly, if the estimated value of α in equation B.1″ differs significantly from zero, then model 1 encompasses model 2. If $(1-\alpha)$ is significantly different from zero but α is not, then model 2 contains information about y beyond that contained in model 1, while model 1 contains no information about y beyond that contained in model 2. In this case, model 2 is clearly superior for forecasting purposes. Similarly, if α is significantly different from zero while $(1-\alpha)$ is not, then model 1 is clearly superior.

In Table 8, we first test whether forecasts of inflation derived from models of the change in inflation encompass forecasts of inflation obtained from models of the level of inflation. (Implicit in any one-period-ahead forecast of the change in inflation is a one-period-ahead forecast of the level of inflation.) The t statistics reported on lines A and B of Table 8 confirm that forecasts of inflation derived from the change-in-inflation regressions are superior to forecasts obtained from the level-of-inflation regressions. Finally, the t statistics reported on line C of Table 8 indicate that in predicting inflation, forecasts derived from change-in-inflation regressions with interest rates are superior to forecasts derived from change-in-inflation regressions without interest rates.

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