Does Higher Inflation Lead to More Uncertain Inflation?

A. Steven Holland

IN recent years, many countries have experienced "stagflation," a period of high and rising inflation and unemployment. Over this time, higher inflation increasingly has come to be blamed for higher unemployment and reduced growth of real output. This contrasts sharply with previously held notions that there was either a long-run tradeoff between inflation and unemployment or a "natural rate of unemployment" regardless of the inflation rate.

One reason why many people have changed their minds about inflation's impact on the economy is the presumed impact of "inflation uncertainty." Many now argue that there is greater uncertainty about future prices during periods of higher inflation.[1] This increased uncertainty leads to a less efficient allocation of resources.

The best-known statement of this view came from Milton Friedman in his Nobel Lecture. Briefly stated, Friedman argued that greater inflation uncertainty shortens the average duration of contracts and reduces the efficiency of the price system. These two forces combine to lower the growth rate of real output and potentially increase the rate of unemployment.[2] Thus, if reducing inflation produces sufficiently larger output growth and lower unemployment in the long run, it is a worthwhile venture, even if doing so would produce a large short-term loss of output and rise in unemployment.[3] While Friedman's discussion primarily concerns the variability of inflation — not necessarily identical to the notion of inflation uncertainty — it is clear that he considers them to be closely related.

This argument can be split into three separate hypotheses: (1) higher inflation leads to greater variability of inflation; (2) greater inflation variability implies greater uncertainty about future inflation; and (3) greater inflation uncertainty has a detrimental effect on economic activity. For policymakers to be concerned about the relevance of hypothesis 3, they must believe that they can influence the level of inflation uncertainty. Hypotheses 1 and 2 state that they can do this by controlling the rate of inflation. If exogenous factors, such as energy shocks, are primarily responsible for greater inflation uncertainty, then policymakers can do little to affect it.

This article focuses on the validity of the first two hypotheses, which together imply that higher inflation leads to greater inflation uncertainty. Besides analyzing the causes of inflation uncertainty, an assessment of its potential effects is presented as well.

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[1] Some have suggested that uncertainty begins to increase once the rate of inflation rises above some threshold. For example, see Logue and Willett (1976) and Hafer and Heyne-Hafer (1981).

[2] Friedman (1977). He suggests that the natural rate hypothesis holds for the very long run (a period of decades), because the economy's institutional structure for dealing with inflation eventually will adjust to eliminate the real effects of inflation.

[3] To determine whether the long-term benefits of anti-inflation policies would offset the short-term costs, one must consider the timing of the output effects and the rate at which future output gains are discounted. See Meyer and Rasche (1980).

Since energy shocks have been the single most important factor accounting for temporary price level changes, this article also investigates the impact of changes in the relative price of energy on both the rate of inflation and the level of inflation uncertainty.[4] Energy shocks and inflation uncertainty should be positively associated, because the magnitude and timing of the effects of an energy shock on the rate of inflation are bound to be viewed with uncertainty.

WHAT IS INFLATION UNCERTAINTY?

Inflation uncertainty arises from a lack of complete knowledge about how future price levels are determined. Of course, an individual typically will have enough information to make some forecast of future inflation rates. A given estimate of next period's inflation can be thought of as the mean of some underlying probability distribution.

The forecaster's inflation uncertainty may be estimated by looking at the size of some specified confidence interval for his forecast. For example, a person may have predicted at the end of 1982 that 1983 inflation had a 90 percent probability of being between 3 percent and 5 percent. If the same individual's 90 percent confidence interval for 1984 inflation (forecast at the end of 1983) is wider, say 4 percent to 7 percent, then his uncertainty about 1984 inflation is greater than it was for 1983 inflation.

The analysis presented here deals with inflation uncertainty for a representative individual. Though the level of an individual's uncertainty about inflation is not directly observable, ways of estimating it have been suggested in the literature. One of these is to use the variance or standard deviation of the errors made in forecasting inflation. A forecaster is trying to predict the outcome of a process that has both systematic and random components. With an unbiased forecast of the inflation rate, the variance of the forecast errors indicates the importance of the random component and can be considered an estimate of the level of inflation uncertainty.[5] An implicit assumption in this type of analysis is that the variance need not be constant but may vary over time.

[4]See Tatom (1981).

[5]It is the *ex ante*, not the *ex post*, variance of forecast errors that is relevant. Estimates of the latter, however, are commonly used as proxies for inflation uncertainty. See, for example, Klein (1978), Engle (1983), and Pagan, Hall and Trivedi (1983).

WHY DOES INFLATION UNCERTAINTY MATTER?

The real effects of inflation uncertainty arise in part because inflation expectations enter into the contracting process. Any contract that provides for payment in nominal rather than real terms incorporates an expectation of future inflation. If actual inflation ends up higher than was expected when the contract was made, a redistribution of wealth occurs: those making the contracted nominal payments gain and those receiving them lose. If actual inflation is lower than was expected, the opposite wealth redistribution occurs.

When there is greater inflation uncertainty, risk-averse individuals will attempt to shorten the duration of contracts to reduce the risk of loss caused by deviations of actual from expected inflation. More frequent negotiation of contracts will divert economic resources to the contracting process from other, previously more efficient uses.[6]

As the accompanying insert demonstrates, greater inflation uncertainty increases the risk associated with both saving and investing, since both require a contract of some kind. Individuals faced with greater inflation uncertainty may choose to reduce both their planned savings and investment. The result is likely to be lower long-term real economic growth.

Another potential real effect of inflation uncertainty is reduced efficiency of the price system in allocating resources. The basic idea is this: the more uncertain is inflation, "the harder it becomes to extract the signal about relative prices from the absolute prices."[7] Because individual prices adjust to unexpected inflation at different rates due to the presence of long-term contracts and the costs of adjusting prices, relative prices may be temporarily distorted.[8] They also may be incorrectly perceived, because information does not flow smoothly across markets. As a result, economic efficiency is reduced, producing lower output growth

[6]Indexation of contracts can reduce (though not totally eliminate) the risk associated with contracting, and one would expect indexation to increase as inflation uncertainty increases. For a theoretical analysis of indexation in this context, see Gray (1978). Klein finds evidence that an increase in "long-term price uncertainty" leads to a reduction in the average term to maturity of outstanding corporate debt.

[7]Friedman, p. 467. Again, Friedman's discussion is in terms of inflation variability; if this variability were anticipated, however, adjustments could be made that reduce or eliminate this effect. His discussion of this effect is based on the work of Hayek (1945) and Lucas (1973) among others.

[8]See Bordo (1980) and Sheshinski and Weiss (1977).

How Inflation Uncertainty Creates Greater Risk for Savers and Investors

To see how greater inflation uncertainty affects savings and investment, consider the consequences of an unexpected price level increase for a saver. The expected real rate of return (r^*) on savings can be written:

$$(1)\quad r^* = i - \dot{p}^*,$$

where i is the nominal rate of return (assumed to be constant) and $\dot{p}^*$ is the expected rate of inflation. There is risk to the saver, because the realized real rate of return (r) will only equal the expected real rate if the actual inflation rate ($\dot{p}$) equals the expected inflation rate. The difference between the realized and expected real rates can be written as:

$$(2)\quad r - r^* = -(\dot{p} - \dot{p}^*).$$

Using the variance of the difference between the actual and expected real return as a measure of risk and the variance of inflation forecast errors as an estimate of inflation uncertainty, inflation uncertainty and risk are equated:[1]

$$(3)\quad \text{var}(r - r^*) = \text{var}(\dot{p} - \dot{p}^*).$$

The effect of greater risk on the flow of savings is not clear a priori. The greater risk could reduce the savings of risk-averse individuals and, as a consequence, reduce the actual amount of investment as well. If a person's goal in saving is to assure a given level of real wealth in the future, however, greater risk could actually lead to increased savings.

For investment in physical capital, the analysis is not as straightforward, because the nominal rate of return (i) varies to some degree with the rate of inflation. A deviation of actual from expected inflation does not necessarily indicate that the realized real rate is different from the expected real rate of return. Therefore, the effect of inflation uncertainty on investment risk depends on how the nominal rate of return is expected to respond to a change in the rate of inflation. This response may also be viewed with uncertainty. If investors are risk averse, then risk-increasing inflation uncertainty will reduce investment and lower output growth in the long term.

[1]A similar analysis can be carried out for other types of contracts. For example, if one considers wage contracts, the risk measure is the variance of the actual less the expected real wage.

and possibly higher unemployment than if all relative prices were correctly perceived.[9]

The notion that greater inflation uncertainty leads to reduced economic growth and higher unemployment has been supported by empirical research. Mullineaux finds some measures of inflation uncertainty to have a negative effect on the growth of industrial production and a positive effect on unemployment; Levi and Makin get similar results for employment growth. Furthermore, Blejer and Liederman find that increased dispersion of relative price changes leads to a significant reduction in real GNP and increased unemployment.[10]

WHY SHOULD HIGHER INFLATION LEAD TO GREATER INFLATION UNCERTAINTY?

The relationship between higher rates of inflation and inflation uncertainty is based more on empirical regularities than on theoretical rationale. Beginning with Okun in 1971, several researchers have found that there are significant positive correlations between rates of inflation and the variability of inflation across countries and across time for a given country. Others

[9]Carlton (1981) discusses in detail the impact of inflation uncertainty on the organization of markets. He concludes that (p. 19):

> . . . in response to inflationary uncertainty, we expect to see fewer contracts with fixed prices for long time-periods, fewer customized goods, greater use of standardized goods sold in a liquid market, a move from outside contracting of customized goods to internal production through vertical integration, and a move from vertical integration to reliance on standard quality goods sold in a liquid market where "the market" price is easy to observe. All of these changes are undesirable from an efficiency standpoint.

[10]See Mullineaux (1980), Levi and Makin (1980), and Blejer and Leiderman (1980). Evans (1983) finds an unstable price level to have a negative effect on real GNP growth, and Able (1980) finds a negative impact of inflation variability on the rate of investment.

have found a positive relationship between inflation variability (or inflation itself) and proxies for inflation uncertainty, the latter including the dispersion of inflation expectations across survey respondents and the variance of estimated inflation forecast errors. The insert on pages 20 and 21 provides a summary of findings from previous studies.

The theoretical rationale centers on the hypothesis that a more inflationary economy produces greater uncertainty about the future direction of government policy, causing greater uncertainty about future inflation. Okun states that the application of fiscal and monetary policies is apt to be less consistent (i.e., predictable) during inflationary times because of the difficulty in reducing inflation without causing unacceptably high rates of unemployment and interest.[11] In a similar vein, Friedman states that:

> A burst of inflation produces strong pressure to counter it. Policy goes from one direction to the other, encouraging wide variation in the actual and anticipated rate of inflation. And, of course, in such an environment, no one has single-valued anticipations. Everyone recognizes that there is great uncertainty about what actual inflation will turn out to be over any specific future interval.[12]

One can argue that an inflationary economy creates an environment in which major policy changes become more likely and the effects of such policy changes become more uncertain. To support this argument, one need only look at some of the policy measures taken or proposed in recent years at least partially in response to an inflationary economy: deregulation of financial institutions, wage and price controls, indexation of income taxes and changes in methods for implementing monetary policy.

Table 1
Two Models of Inflation Expectations: II/1954–III/1983

	(1)	(2)
Intercept	0.108	0.376
	(0.40)	(1.46)
$\dot{p}_{t-1}$	0.285	0.210
	(3.35*)	(2.59*)
$\dot{p}_{t-2}$	0.099	0.100
	(1.17)	(1.26)
$\dot{p}_{t-3}$	0.309	0.261
	(3.92*)	(3.56*)
$\dot{M}_{t-1}$	0.109	0.125
	(2.47*)	(3.05*)
$\dot{M}_{t-2}$	0.023	0.037
	(0.48)	(0.84)
$\dot{M}_{t-3}$	0.022	0.026
	(0.44)	(0.56)
$\dot{M}_{t-4}$	0.102	0.107
	(2.08*)	(2.31*)
$\dot{p}^e_{t-1}$	—	0.017
		(1.43)
$\dot{p}^e_{t-2}$	—	0.039
		(3.10*)
$D1_t$	−1.017	−0.936
	(−1.85*)	(−1.85*)
$D2_t$	2.022	1.189
	(3.98*)	(2.35*)
$\bar{R}^2$	0.770	0.804
SE	1.33	1.23
h	1.46	0.50

t-statistics in parentheses.
*Significant at the 5 percent level (one-tailed test).

INFLATION FORECASTS AND THE VARIANCE OF ERRORS

The discussion above suggests that the variance of errors in forecasting inflation could be used as one measure of inflation uncertainty. If the variance of the forecast errors remains constant over time, so does the level of inflation uncertainty. One way to determine whether inflation uncertainty has changed over time is to test for non-constant variance (i.e., heteroscedasticity) in the residuals from a model of inflation expectations.[13]

First, we need an inflation expectations model that provides unbiased forecasts over both lower and higher inflation periods; we can then test whether the error variance is larger for the higher inflation period. A model obtained by regressing the quarterly growth rate of the GNP deflator ($\dot{p}$) on its own lagged values, lagged values of the growth rate of M1 ($\dot{M}$), and dummy variables for periods of wage-price controls and their aftermath (D1 and D2) is given by equation 1 in table 1.[14] The equation was estimated using data from II/1954–III/

[11]See Okun (1971).

[12]Friedman, p. 466.

[13]This is the approach suggested by Engle (1982) and Pagan, Hall and Trivedi.

[14]All growth rates are expressed in annualized log differences. D1 has a unity value during the control period of III/1971–I/1973 and zero otherwise. D2 represents the period during which controls were being phased out, taking a unity value for the period I/1973–I/1975 and zero otherwise.

Table 2
Tests for Inflation Uncertainty Using Regression Models of Inflation Expectations

$$(1)\quad e_t^2 = \underset{(1.80^*)}{0.732} - \underset{(-0.259)}{0.035\,\dot{p}_{t-1}} + \underset{(1.17)}{0.163\,\dot{p}_{t-2}} - \underset{(-1.03)}{0.144\,\dot{p}_{t-3}} + \underset{(1.67^*)}{0.225\,\dot{p}_{t-4}}$$

$$R^2 = 0.082 \qquad SE = 2.24 \qquad DW = 2.13$$

$$(2)\quad e_t^2 = \underset{(2.25^*)}{0.881} - \underset{(-0.42)}{0.055\,\dot{p}_{t-1}} + \underset{(0.942)}{0.127\,\dot{p}_{t-2}} - \underset{(-1.04)}{0.140\,\dot{p}_{t-3}} + \underset{(1.39)}{0.180\,\dot{p}_{t-4}}$$

$$R^2 = 0.040 \qquad SE = 2.17 \qquad DW = 2.00$$

t-statistics in parentheses.
*Significant at the 5 percent level (one-tailed test).

1983, and the number of lags was chosen using standard t and F tests. When we divide the sample into a lower inflation period, II/1954–IV/1967, and a higher inflation period, I/1968–III/1983, we can reject the hypothesis that the error variance is the same in both periods.[15] As expected, the variance is higher in the period of higher inflation.[16]

Another test of the constancy of the variance of the forecast errors over time is obtained by regressing the squared value of the inflation forecast error for period t (e_t^2) estimated from equation 1 on the variables thought to cause changes in the variance. When four lagged values of the inflation rate are used, the estimated equation yields the results shown in equation 1 in table 2. The results indicate, once again, that inflation affects the variance of forecast errors using this model of expected inflation.[17] The effect over four quarters is both positive (as indicated by the sum of the coefficients of the lagged values of the inflation rate [0.209]) and statistically significant at the 5 percent level.[18]

Relative Energy Price Changes and Expected Inflation

The above result seems to suggest rather strongly that a higher inflation rate is associated with more inflation uncertainty. This conclusion must be carefully viewed, however; the results are quite sensitive to the way in which the model of inflation expectations is specified. In particular, if one considers the possibility that individuals anticipate some impact of a higher relative price of energy on the rate of inflation, then inflation does not affect the variance of the errors. An estimated inflation expectations model that incorporates two lagged values of the change in the relative price of energy is presented in equation 2 of table 1.[19] When the sample was divided into the same lower and higher inflation periods as before (and the impact of energy prices is taken into account), the hypothesis that the error variance is the same in both periods cannot be rejected at the 5 percent level of significance.[20]

Furthermore, as equation 2 in table 2 shows, lagged values of the inflation rate do not affect the squared inflation forecast error estimated from equation 2 in table 1.[21] Therefore, when this inflation expectations model is used, there is no indication that higher inflation is associated with greater inflation uncertainty.

[15]The average quarterly rate of growth of the GNP deflator between II/1954 and IV/1967 was 2.18 with a maximum of 4.57 and a minimum of −0.87; for I/1968–III/1983, the average growth rate of the GNP deflator was 6.31 with a maximum of 11.41 and a minimum of 2.83. The value of the calculated F-statistic ($F_{53,47} = 1.77$) from the Goldfeld-Quandt test is statistically significant at the 5 percent level. For an explanation of this test for heteroscedasticity, see Goldfeld and Quandt (1965).

[16]A Chow test does not indicate that the structure of the model is different for the two periods. The Chow test statistic is $F_{10,98} = 0.705$, far below the level required for statistical significance at the 5 percent level.

[17]The test statistic TR^2 (where T is the number of observations) has a χ^2 distribution with degrees of freedom equal to T minus the number of regressors. This statistic is used to test for heteroscedasticity. In equation 1 in table 2, $TR^2 = 9.62$, which is statistically significant at the 5 percent level. This test is suggested by Engle (1982).

[18]The t-statistic for the sum of the coefficients is 2.59. Additional lagged values of $\dot{p}$ up to a total of 12 had no effect. Lagged values of the rate of inflation are used instead of the current rate, because the rate for period t is not known at the time the forecast is made. This procedure of regressing squared residuals on a set of variables as a test for heteroscedasticity is suggested by Breusch and Pagan (1979).

[19]The relative price of energy is defined as the ratio of the "fuels and related products and power" component of the producer price index (PPI) to the business sector deflator. See Tatom for a slightly different model of the inflation rate itself (rather than expected inflation).

[20]The Goldfeld-Quandt F-statistic is $F_{51,45} = 1.47$.

[21]Neither the value of TR^2 (4.72) nor the sum of the coefficients of lagged inflation (0.112, $t = 1.44$) are statistically significant at the 5 percent level.

Previous Research on the Relationships among Inflation Rates, Inflation Variability and "Inflation Uncertainty"

Article	Countries Studied	Time Periods	Major Findings
Okun (1971)	17 industrialized OECD countries	1951–1968	High correlation between the average annual percentage increase in the GNP deflator and the standard deviation of annual inflation rates.
Gordon (1971)	same as Okun	1960–1968	Smaller correlation than in Okun. Also, if five relatively small countries are omitted, correlation disappears.
Logue and Willett (1976)	41 industrialized and nonindustrialized countries	1949–1970	Inflation rates of no more than 2–4 percent cause no problem of increased variability of inflation.
Jaffee and Kleiman (1977)	same as Okun United States (survey)	1951–1971 1955–1971 (survey)	(a) Positive correlation across countries between inflation and its variance, though correlation is weak during 1960s. (b) Positive relationship between mean and standard deviation of inflation rates expected in the SRC survey.
Foster (1978)	40 countries	1954–1975	Large correlations between inflation and the average absolute change in inflation.
Cukierman and Wachtel (1979)	United States	1948–1975 1955–1976	Variance of expected inflation across individuals is positively related to variance of actual inflation using both the Livingston and SRC surveys.
Taylor (1981)	7 large industrialized countries	1954–1979	Strong correlation (except during 1960s) between average inflation and its standard deviation, which is at least partially due to association between average inflation and inflationary shocks.
Fischer (1981)	United States	1806–1979 1954–1976 (survey) 1950–1980 (survey) 1948–1980	(a) Positive relationship between inflation and its variability. (b) Variance of expected inflation across individuals is positively associated with actual, expected and unanticipated inflation using the Livingston and SRC surveys. (c) No significant association between the rate of inflation and the variance of residuals from a forecasting equation of the inflation rate.

Frohman, Laney and Willett (1981)	United States	1954–1976	Positive relationship between both actual and expected inflation and the variance of expected inflation across individuals using the Livingston survey.
Hafer and Heyne-Hafer (1981)	same as Logue and Willett, excluding Chile	1970–1979	Inflation and its variability are positively related; may require rates as high as 9 percent.
Pagan, Hall and Trivedi (1983)	Australia	1973–1981 1968–1982	Inflation affects variance of errors in forecasting, as measured by squared estimated forecast errors.
Engle (1983)	United States	1947–1979	Inflation does not affect squared value of estimated forecast errors. Past values of squared forecast errors do.

INDIVIDUAL INFLATION UNCERTAINTY AND THE VARIABILITY OF INFLATION EXPECTATIONS AMONG INDIVIDUALS

The preceding tests illustrate one of the major problems involved in trying to estimate an individual's uncertainty about future inflation: estimates can be sensitive to one's assumptions about the nature of the information used to forecast inflation. In this section, we use a different approach to estimating inflation uncertainty based on very different assumptions about the way individuals form inflation expectations.

In contrast to the models of inflation expectations estimated previously, individuals may use considerably more information to forecast inflation rates than the past growth rates of such aggregates as the price level and money supply. For example, each forecaster may have personal information regarding the historical relationship between the price of a specific product and the general price level. This specialized information is likely to be too costly for all individuals to obtain. If there is greater heterogeneity in the inflation signals that forecasters receive from this type of market-specific information, then greater dispersion of individual inflation forecasts can result. An individual who observes a wider variety of predictions of next period's inflation rate (through published sources, for example) may become more uncertain about the accuracy of his own forecast, especially if he believes that different forecasts are based on information he does not have.[22]

In the analysis to follow, it is assumed that greater dispersion of inflation forecasts among individuals leads to increased inflation uncertainty. Therefore, we use measures based on the variability of responses to the Livingston survey of inflation expectations to further investigate the relationship between inflation and inflation uncertainty.[23]

The standard deviation of the individual inflation forecasts from the Livingston survey is the first proxy for inflation uncertainty. Chart 1 shows the actual inflation rate over the forecast period and the mean and standard deviation of six-month inflation forecasts from the first half of 1954 to the first half of 1983. The shaded areas of the chart represent periods of energy shocks.[24] The chart indicates that both energy shocks

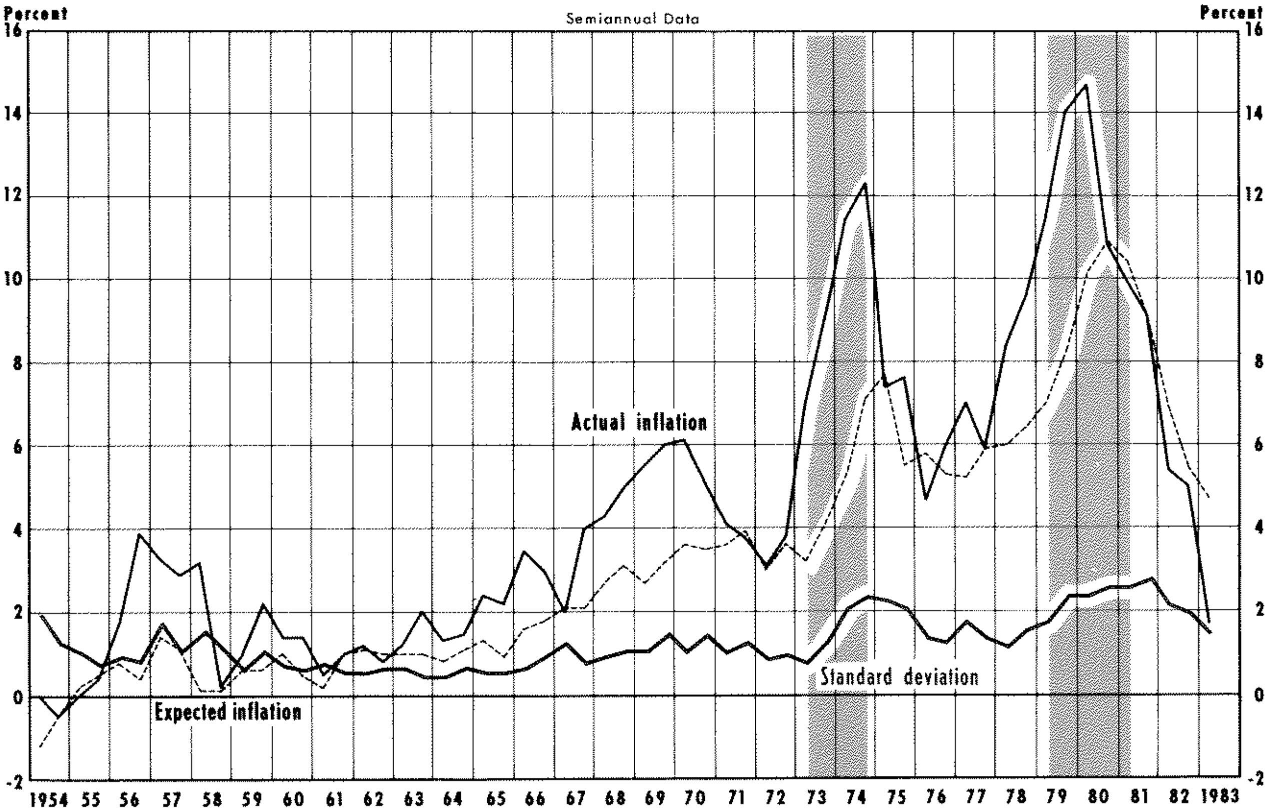
[22]This kind of partial information framework is used by Cukierman and Wachtel (1982). There is, however, an alternative explanation for increased variability of individual inflation forecasts: forecasters may all use the same information but in different ways. This would not necessarily imply greater inflation uncertainty for a particular individual since each forecaster could be just as certain as he ever was about the accuracy of his forecast.

[23]Joseph Livingston of *The Philadelphia Inquirer* conducts a survey each spring and fall, requesting respondents to indicate their predictions about a number of economic indicators including the consumer price index (CPI). Because the survey results published, for example, in June contain predictions for the following December, Livingston refers to them as six-month-ahead forecasts as does this article. (The survey also includes 12-month forecasts, which are not used here.) Because the respondents to the June survey are thought to know only the April CPI, however, they are actually predicting an eight-month rate of change. For a detailed discussion of the Livingston expectations data, see Carlson (1977). This article uses the data in Carlson's revised form updated to the present.

[24]The periods of energy shocks are the first half of 1973 to the second half of 1974, and the first half of 1979 to the first half of 1981. The quarterly deflator for fuels and related products and power divided by the business sector deflator grew at an annual rate of 22.9 percent from IV/1972 to IV/1974 and 23.4 percent from I/1979 to II/1981.

Chart 1

Actual Inflation, Expected Inflation and Standard Deviation of Six-Month Inflation Forecasts



Shaded areas represent periods of energy price shocks.
Latest data plotted: First half 1983

and inflation may have a positive impact on inflation uncertainty. All three series rose substantially during periods of energy shocks, and there are significant positive correlations between the uncertainty measure and the other two series in other periods.[25]

The root-mean-squared error (RMSE) of the individual forecasts of inflation from the survey serves as the second proxy for inflation uncertainty. An examination of chart 1 indicates that the survey mean inflation expectation is biased; it consistently underpredicts the inflation rate over most of the sample period. The RMSE of the inflation forecasts incorporates these errors. The squared value of this variable is the sum of the variance of inflation expectations across survey respondents (the standard deviation squared) and the squared forecast error using the survey mean as the expected inflation rate.[26] The use of this variable

[25]The correlation coefficient between the standard deviation and the expected inflation rate is 0.787 for the entire period and 0.667 for the period omitting the two energy shock periods. Between the standard deviation and the actual inflation rate, the correlations are 0.724 and 0.597, respectively. These figures are all statistically significant at the 5 percent level.

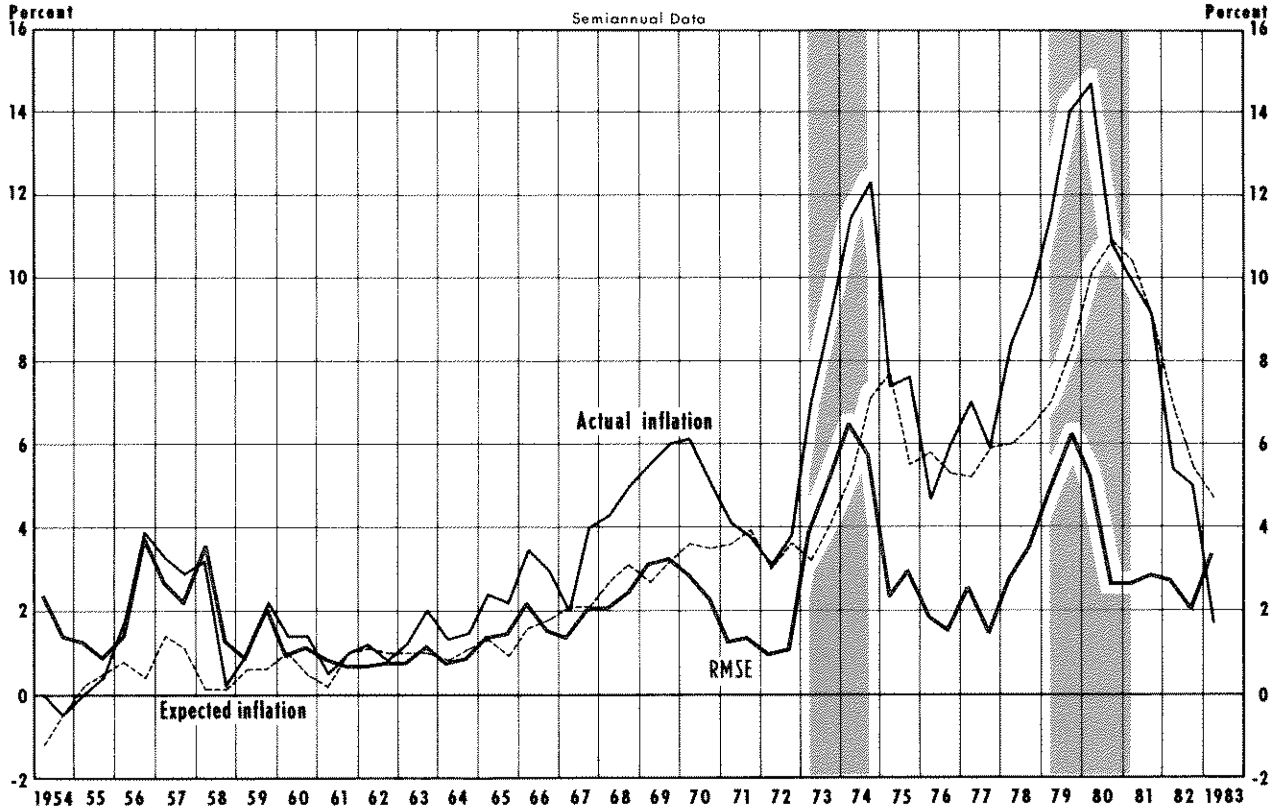
[26]The mean-squared error of the forecasts can be written:

$$MSE_t = \frac{1}{n}\sum_{i=1}^{n}(\dot{p}^*_{it} - \dot{p}_t)^2$$
$$= (\bar{\dot{p}}^*_t - \dot{p}_t)^2 + \frac{1}{n}\sum_{i=1}^{n}(\dot{p}^*_{it} - \bar{\dot{p}}^*_t)^2,$$

where n is the number of forecasters, $\dot{p}^*_i$ is the expected rate of inflation for the ith forecaster, and $\bar{\dot{p}}^*$ is the mean expected inflation rate among the forecasters. The first term on the right-hand side of the equation is the squared forecast error, and the second is the variance of individual inflation expectations. We use the square root of this variable and the standard deviation of expectations because regressions using the mean-squared error and the variance exhibited heteroscedasticity.

Chart 2

Actual Inflation, Expected Inflation and Root-Mean-Squared Error of Six-Month Inflation Forecasts



Shaded areas represent periods of energy price shocks.
Latest data plotted: First half 1983

as a measure of inflation uncertainty assumes that there is greater inflation uncertainty, holding constant the variance of inflation expectations, when a large mean forecast error occurs than when a small mean forecast error is observed.[27]

Chart 2 plots the RMSE along with the actual inflation rate and the mean expected inflation rate from the survey. Again there is a positive association between the uncertainty measure and the other two series, with the largest increases in RMSE occurring during periods of energy shocks.[28] As chart 2 shows, the RMSE is considerably more variable than the standard deviation over the sample period. The most interesting difference in the two series, however, is their behavior during the energy shock periods: the standard deviation remains higher than normal throughout each of the energy shock periods and does not decline until the period is over; the RMSE peaks, then declines substantially while relative energy prices are still rising. Therefore, these two measures imply different responses of inflation uncertainty to energy shocks.

INFLATION AND THE VARIABILITY OF INFLATION FORECASTS

This section provides more detailed evidence on the effects of inflation and energy shocks on the two measures of inflation uncertainty discussed above. Table 3 presents results from regressions based on six-month inflation forecasts. The data used are from the same sample period shown in the charts.

[27]The standard deviation of the forecasts has one advantage over RMSE as a proxy for inflation uncertainty: it does not contain any *ex post* information. $RMSE_{t+1}$ includes the actual inflation rate from period t+1, $\dot{p}_{t+1}$.

[28]The correlation coefficient between RMSE and the expected inflation rate is 0.559 for the entire sample period and 0.433 for the period exclusive of the periods of energy shocks. Between RMSE and the actual rate of inflation, the correlations are 0.826 and 0.658, respectively.

Table 3
Tests for Inflation Uncertainty Using Livingston Survey Data

	(1) $SD_{t+1}\|I_t$	(2) $RMSE_{t+1}$
Intercept	0.802 (8.32*)	1.407 (4.32*)
$\dot{p}_t$	0.103 (5.40*)	0.267 (3.66*)
$\dot{p}_{t-1}$	—	−0.038 (−0.57)
$\dot{p}_{t-2}$	—	0.180 (2.64*)
$\dot{p}_{t-3}$	—	−0.223 (−3.06*)
Sum	—	0.186 (2.69*)
$\dot{p}^e_{t+1}$	—	0.023 (1.84*)
$\dot{p}^e_t$	0.006 (1.42)	0.000 (0.02)
$\dot{p}^e_{t-1}$	0.003 (0.73)	−0.024 (−1.75*)
$\dot{p}^e_{t-2}$	0.014 (3.54*)	—
Sum	0.023 (2.55*)	−0.001 (−0.01)
ρ	0.389 (3.25*)	0.448 (3.85*)
$\bar{R}^2$	0.769	0.663
SE	0.30	0.84
DW	2.05	1.91

t-statistics in parentheses.
*Significant at the 5 percent level (one-tailed test).

Inflation's Effect on the Standard Deviation of Forecasts

In equation 1, the dependent variable is $SD_{t+1}|I_t$, which is the standard deviation of inflation expectations for period t+1 as calculated from responses to the Livingston survey at period t.[29] The most recent six-month rate of inflation known to the forecasters, $\dot{p}_t$, has a positive and strongly significant effect on the standard deviation of the forecasts. Lagged values of this variable had no significant effect. The value of the intercept implies that, in the absence of inflation or changes in the relative price of energy, the standard deviation of inflation forecasts would be about a 0.8 annualized percentage rate. The coefficient for $\dot{p}_t$ indicates that for every 1 percentage-point increase in the annual rate of inflation, the standard deviation increases by about 0.1 percentage point. Therefore, with 8 percent inflation, the standard deviation would be twice as high as with zero inflation.

The three most recent values of the annualized six-month change in the relative price of energy ($\dot{p}^e$) also have a significant positive impact on this measure of inflation uncertainty.[30] A 1 percent increase in this variable leads to an increase in the standard deviation of 0.023 percentage points over three six-month periods. In other words, an energy shock affects this measure of inflation uncertainty for up to 18 months. A 20 percentage-point increase in the relative price of energy — not uncommon in the last decade — causes the standard deviation of inflation expectations to increase by about 0.45 percentage points.[31]

Inflation's Effect on the Root-Mean-Squared Error of Forecasts

Equation 2 presents results using the RMSE of inflation forecasts for period t+1 ($RMSE_{t+1}$) as the dependent variable.[32] The conclusion that inflation exerts a positive influence on inflation uncertainty is the same as in equation 1, although the impact occurs over four six-month periods. The sum of the coefficients of current and lagged inflation is positive and significant. Over 24 months, a 1 percentage-point increase in inflation leads to an increase in RMSE of about 0.19 percentage points. Although this is about twice the impact that

[29]The variable is written $SD_{t+1}|I_t$ to indicate that it is based on forecasts of period t+1 inflation given an information set from period t, I_t.

[30]The series for the inflation rate and changes in the relative price of energy are constructed to include the most recent numbers known by the forecaster, so monthly data are used. The spring forecaster is assumed to know the April levels of the CPI and the relative price of energy, so the six-month rate of change is calculated between October and April. For the fall forecast, the rate is calculated between April and October. The denominator in the relative energy price variable for monthly data is the finished goods component of the PPI.

[31]The regressions also were run with a somewhat different dependent variable, the standard deviation across individuals of the expected *level* of the CPI divided by the mean expected level. This is the coefficient of variation of the CPI level forecasts. The results were similar to those for the standard deviation of the inflation *rate* forecasts. The coefficient of variation of the inflation rate forecasts is clearly an inappropriate variable to use, since, as the expected inflation rate approaches zero, the coefficient of variation approaches infinity.

[32]$RMSE_{t+1} = \sqrt{(SD_{t+1}|I_t)^2 + (\bar{\dot{p}}^*_{t+1}|I_t - \dot{p}_{t+1})^2}$.

inflation had on the standard deviation, the constant term is nearly twice as high in this equation; thus, the impacts actually are quite similar. The initial impact of inflation on RMSE is much greater than it is on the standard deviation, but this effect is partially offset after 24 months have passed.

The impact of relative energy price changes is quite different in this regression than it was in equation 1. The initial impact on the uncertainty measure is positive, but the effect is totally offset 12 months later.[33] Consequently, if the relative price of energy were to increase by the same amount each period, it would cease to have any effect on the RMSE after 12 months. In contrast, for the standard deviation of expectations to stabilize, the level rather than the growth rate of the relative price of energy must stabilize.[34]

In both equations, the effect of higher inflation on the measure of inflation uncertainty is positive and permanent. There is no indication that, over time, forecasters come to be just as certain about higher rates of inflation as they were about lower rates. This evidence supports the hypothesis that higher inflation leads to more uncertain inflation.

CONCLUSION

Researchers have compiled considerable evidence suggesting that the rate and variability of inflation are positively related and a lesser amount of evidence linking these variables to inflation uncertainty. This article has explored the relationship between the rate of inflation and the level of inflation uncertainty in greater detail, looking also at the impact of energy shocks on inflation uncertainty.

The empirical results presented here are somewhat mixed and are sensitive to the method chosen for measuring inflation uncertainty. On the one hand, a model of inflation expectations was introduced and estimated for which the variance of the estimated inflation forecast errors is related to the rate of inflation. A different inflation expectations model — one incorporating the effects of changes in the relative price of energy on expected inflation — led to the opposite conclusion. On the other hand, there are positive relationships between the rate of inflation and the standard deviation and root-mean-squared error of inflation forecasts taken from the Livingston survey. Energy shocks also affect these two measures of inflation uncertainty, but in quite different ways.

Because the results of empirical tests based on inflation forecasting models are sensitive to the specification of the model, the usefulness of these results is questionable. Therefore, uncertainty measures based on the variability of "observed" inflation forecasts or forecast errors should be given more attention. In this article, these measures indicate that inflation uncertainty can be reduced if the rate of inflation is reduced.

In light of recent evidence that greater inflation uncertainty has a detrimental effect on the levels of economic activity and unemployment, the reduction of inflation uncertainty is an important potential benefit of anti-inflation policies.

[33]The inclusion of the variable $\dot{p}^e_{t+1}$ in the regression is not meant to imply that forecasters know the value of this variable, only that it affects $RMSE_{t+1}$.

[34]The regressions in table 3 also were run with several other independent variables, none of which was statistically significant at the 5 percent level. These included current and lagged values of the absolute value of unanticipated inflation (based on the survey mean expectation), a dummy variable for the period of wage and price controls, and a time trend. In regressions excluding the relative price of energy, the estimated effects of inflation on the uncertainty measures were somewhat larger.

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