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Inflation and Uncertainty: Tests for Temporal Ordering

A SUBSTANTIAL BODY of evidence indicates that the rate of inflation is positively associated with inflation uncertainty, both across countries and for the United States over time. Holland (1984) reviews the earlier studies, while Froyen and Waud (1987), Zarnowitz and Lambros (1987), Ball and Cecchetti (1990), Evans (1991), Evans and Wachtel (1993), and Brunner and Hess (1993) provide more recent evidence. These studies leave an important question unanswered, however: Does an increase in the rate of inflation *cause* an increase in inflation uncertainty? If it does, one can reasonably conclude that greater uncertainty—which many have found to be negatively related to economic activity—is part of the costs of inflation.[1]

Currently available methods are not fully capable of answering this question. It may be possible, however, to discover whether an increase in the rate of inflation *precedes*, that is, "Granger causes," an increase in inflation uncertainty. Using three different tests for temporal ordering, I find that it does.

MODELS OF THE INFLATION-UNCERTAINTY RELATIONSHIP

A number of recently developed models imply a positive association between the rate of inflation and inflation uncertainty. Each implies a particular temporal ordering between the two variables.

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1. Holland (1993b) discusses the controversy about whether the inflation rate and inflation uncertainty are positively correlated and about whether inflation uncertainty and economic activity are negatively correlated. The paper also provides a list of studies of these relationships for the United States.

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In Devereux's (1989) model, as real shocks become more variable relative to nominal shocks, the optimal degree of indexation declines. A reduction in the degree of indexation increases the output and employment effects (and the benefits to the government) of creating surprise inflation. If the variability of real shocks is the predominant cause of inflation uncertainty, then inflation uncertainty and the mean rate of inflation are positively correlated. The mean inflation rate rises only after the degree of indexation falls. Assuming that changes in the degree of indexation take time to occur, greater inflation uncertainty precedes higher inflation.

Holland's (1993b) comment on Evans and Wachtel's (1993) paper suggests a reason why inflation may precede uncertainty. The comment provides an example of the more general point made by Holland (1993a): uncertainty about the parameters of the inflation process can lead to a link between the inflation rate and inflation uncertainty. Evans and Wachtel specify an inflation process of the form:

$$\Pi_t = a_t + b_t\Pi_{t-1} + \epsilon_t \, , \tag{1}$$

where Π is the inflation rate, ϵ is a mean-zero i.i.d. disturbance, and a and b are time-varying parameters that reflect changes in the inflation regime. In their model, one regime implies that the inflation rate is stationary so that $b_t < 1$ and no restrictions apply to a_t. The other implies that the inflation rate is a random walk without drift so that $b_t = 1$ and $a_t = 0$. They do not specify the length of the period in their model, but they estimate it using quarterly data.

In his comment Holland shows that in such a model, the conditional variance of inflation, that is, inflation uncertainty, is

$$E(\Pi_t - \Pi_t^*)^2 = E(a_t - a_t^*)^2 + E(b_t - b_t^*)^2(\Pi_{t-1})^2 + E(\epsilon_t)^2 \, , \tag{2}$$

where * denotes expectation conditional on information from period $t - 1$. If regime changes cause unpredictable changes in the persistence of inflation, then $E(b_t - b_t^*)^2 > 0$ and lagged inflation squared is positively related to inflation uncertainty. An increase in the rate of inflation (or deflation) would precede an increase in inflation uncertainty.

Several authors contend that if reducing inflation causes an increase in the rate of unemployment, a high rate of inflation would produce greater uncertainty about the future direction of government policy and therefore future rates of inflation. Ball's (1992) model formalizes this idea in the context of a repeated game between the monetary authority and the public. In the model, exogenous shocks cause low-inflation equilibria to break down occasionally. Two policymakers alternate power stochastically, only one being willing to create a recession to disinflate. Both try to keep inflation low if it is already low. The public is uncertain which one will be in power in the future. Thus, with a low rate of inflation the policy choice is certain and with a high rate of inflation the policy choice is uncertain. Inflation causes uncertainty and would precede it at least slightly.

Cukierman and Meltzer's model explains the positive association between inflation and inflation uncertainty across countries, but can also be applied to a given country over time. Governments differ in the stability of their objectives, which can be summarized by the trade-off between a desire to expand output through monetary surprises and a desire to keep the rate of inflation low. The policymaker is free to determine the accuracy of monetary control and does not necessarily choose the most effective control variable. If there is a great deal of political instability, the policymaker chooses monetary control procedures that are less precise, so that uncertainty about money growth and uncertainty about inflation are higher. The reason is that greater ambiguity about the conduct of monetary policy makes it easier for the government to create the monetary surprises that increase output. This causes rates of money growth and inflation to be higher on average. In other words, greater uncertainty about money growth and inflation *causes* a higher mean rate of inflation. If there are different policy regimes within a given country over time, their model can be applied to explain a positive relationship between the inflation rate and inflation uncertainty over time for a given country. Increases in uncertainty would precede increases in inflation at least slightly.

Both the Devereux and the Cukierman and Meltzer models imply that any costs due to inflation uncertainty cannot be considered part of the welfare costs of inflation because inflation does not cause inflation uncertainty. The models of Evans and Wachtel, Holland, and Ball, on the other hand, imply that greater inflation uncertainty is part of the welfare costs of inflation because inflation causes uncertainty.

TIMING OF THE DATA

The most commonly used proxies for inflation uncertainty in the United States across time are measures of the dispersion of inflation forecasts across respondents to surveys. Findings based on such measures indicate that inflation uncertainty has adverse effects on employment and output. Because much of the interest in inflation uncertainty is the result of these findings, it seems appropriate to use such measures here. I use the survey of professional economic forecasters conducted by Joseph Livingston of *The Philadelphia Inquirer* and the survey of households conducted by the Survey Research Center (SRC) of the University of Michigan. For the Livingston survey, the proxies for inflation uncertainty are the standard deviation of the six- and twelve-month forecasts of CPI inflation made in June and December of each year. For the SRC survey, the proxy is the standard deviation of the twelve-month forecasts of the rate of change of "prices" made each month.[2] There are no usable surveys over either shorter or longer time horizons.

A more theoretically accurate measure of inflation uncertainty is the size of the confidence interval for individual inflation forecasts. Using a limited time span of observations from the ASA-NBER survey, Zarnowitz and Lambros (1987) show that one tends to get the same results with individual confidence intervals as with the

2. The root-mean-squared-error (RMSE) of inflation forecasts is sometimes used instead of the standard deviation. The standard deviation, however, is more appropriate for the tests presented in this paper.

standard deviation of forecasts. I choose not to use the ASA-NBER survey, however, because of the limited time span. I therefore must assume that the standard deviation of the Livingston and SRC forecasts are closely related to the average size of individual confidence intervals.

In this study, the timing of the data is of utmost importance in that one must be careful that forecasters actually observed an increase in inflation before altering their levels of uncertainty. The Livingston surveys are conducted in June and December. For example, respondents to the survey of June 1990 were asked to forecast the CPI for both December 1990 and June 1991. According to Carlson (1977), however, they were unlikely to have access to data from May in time for the June survey (or data from November in time for the December survey). Thus, the "six-month" forecasts are really eight-month forecasts and the "twelve-month" forecasts are really fourteen-month forecasts.

The standard deviation of the six-month forecasts from the June 1990 Livingston survey is taken to represent the average level of uncertainty felt during the period January 1990 to June 1990 about the rate of inflation destined to occur through December 1990. Consecutive estimates of "six-month uncertainty" do not overlap even though consecutive estimates of expected inflation (not used in this paper) do. Likewise, the standard deviation of the twelve-month forecasts from June 1990 represent the average level of uncertainty felt during the period January 1990 to June 1990 about the rate of inflation destined to occur through June 1991. Thus, estimates of "twelve-month uncertainty" are semiannual and consecutive estimates do not overlap.

In examining the temporal ordering of inflation and uncertainty, I specify the timing of the data so that the inevitable biases that occur work *against* finding that inflation precedes uncertainty. Any inflation deemed to have "preceded" the uncertainty measured in June 1990 must have been observable to forecasters prior to the survey of December 1989. Thus, for the June 1990 survey, inflation "lagged one period" is that known to have occurred between the June 1989 and December 1989 surveys: the inflation rate between April 1989 and October 1989. "Current" inflation is that known to have occurred between the December 1989 and June 1990 surveys: the inflation rate between October 1989 and April 1990. Estimates of the inflation rate are also semiannual and do not overlap.

For the tests based on the Livingston survey, I use the sample period 1954H1 to 1990H2 (first half of 1954 to second half of 1990). The choice of sample period reflects a desire to avoid both the aftermath of World War II and the Korean War and to be comparable to most other studies. Cosimano and Jansen (1988), among others, have argued that the period before 1954 should be excluded because of a structural break in the inflation series around 1954. In a later section of this paper, I examine the robustness of the results to changes in sample period.

The SRC survey has been conducted since the mid-1940s, but respondents were not asked for a point estimate of expected inflation until the mid-1960s. Prior to 1978 the surveys were conducted quarterly, and since 1978 they have been conducted monthly. Using the quarterly data presents a serious problem with timing.

Surveys were conducted throughout the quarter, meaning some respondents had access to more recent CPI data than others.[3] For that reason, I examine only the monthly data. The sample period is January 1978 to December 1990.

The forecasts are for twelve months and the standard deviation from the June 1990 survey is taken to represent the average level of uncertainty felt during June 1990 about the rate of inflation destined to occur through June 1991. For the June 1990 survey, all respondents are assumed to have known the CPI for April 1990. Thus, inflation "lagged one period" is that known to have occurred between the April 1990 and May 1990 surveys: the inflation rate between February 1990 and March 1990. "Current" inflation is measured between March 1990 and April 1990.

TEMPORAL ORDERING

The standard test for temporal ordering, or Granger causality, examines whether lagged values of a variable X help to explain the current value of another variable Y over and above the explanation provided by lagged values of Y, assuming that both X and Y are stationary. If X and Y are not stationary and not cointegrated but ΔX and ΔY are stationary, then the test requires replacing X with ΔX and Y with ΔY. Two nonstationary series are cointegrated if some linear combination of the two is stationary. They are then said to have a common stochastic trend: they tend to move together over long periods of time. If X and Y are cointegrated, then a more comprehensive test for temporal ordering described by Engle and Granger (1987) allows for a relationship between the two variables stemming from their common stochastic trend. Specifically, if two variables are cointegrated, then the lagged *level* of one may help to explain the current *change* in the other even if lagged changes do not. In other words, if X and Y have a common trend, the current change in X may be caused partly by X moving into alignment with Y. This is referred to as error correction. Engle and Granger show that if X and Y are cointegrated, Granger causality must exist between them in at least one direction, though two-way Granger causality is also possible.

The error-correction model is

$$\Delta X_t = \alpha + \lambda \epsilon_{t-1} + \Sigma_{i=1} \beta_i \Delta X_{t-i} + \Sigma_{i=1} \psi_i \Delta Y_{t-i} + u_t \,, \tag{3}$$

where ϵ_{t-1} is the lagged value of the residual from the cointegrating equation:

$$X_t = \theta + \xi Y_t + \epsilon_t \,. \tag{4}$$

In other words, the value of ϵ in one period represents the error to be "corrected" (at least partially) in the next period. The null hypothesis that Y does not precede X is rejected if either the ψ_is are jointly significant or if λ is significant. If X and Y are

3. This information was obtained in a telephone conversation with Denise Polcyn of the Survey Research Center.

positively related, then λ would be negative: an abnormally high value of X relative to Y results in a reduction in X.

RESULTS FOR TWELVE-MONTH UNCERTAINTY FROM THE LIVINGSTON SURVEY

In this section I discuss the results based on twelve-month inflation uncertainty from the Livingston survey. The results based on six-month uncertainty from the Livingston survey and twelve-month uncertainty from the SRC survey are discussed in the section on robustness. The six- and twelve-month Livingston measures have a correlation coefficient of .91. It would be desirable to have measures over longer horizons, but the close association between the six- and twelve-month horizons may indicate that the horizon is not critical.

As is often the case with postwar data, one cannot say with confidence whether the series are stationary or nonstationary (or cointegrated if nonstationary). I perform the augmented Dickey-Fuller test for stationarity (see Dickey and Fuller 1979, 1981) on the inflation and uncertainty series. In general, the tests do not reject nonstationarity but they are known to have low power. Johansen's (1988) maximum-likelihood procedure indicates cointegration between the inflation rate and inflation uncertainty. Engle and Granger's (1987) residual-based method, however, yields mixed results.[4]

I therefore perform the tests for temporal ordering based on three different assumptions: (1) inflation and uncertainty are stationary, (2) inflation and uncertainty are nonstationary but not cointegrated, and (3) inflation and uncertainty are cointegrated. In all cases, a search is conducted over four lagged values and the regression with the highest adjusted R^2 is presented. For the selected regressions, in no case does an LM test detect serial correlation of the residuals.

Table 1 presents the results in levels and is based on Assumption 1. In column 1, the dependent variable is inflation uncertainty (*UNCERT*) and in column 2 it is the inflation rate (*INFL*). In column 1, four lagged values of *INFL* have a significant positive effect on *UNCERT*. The F-statistic is significant at the 1 percent level and the sum of the coefficients is positive and significant ($t = 2.90$). In column 2, three lagged values of *UNCERT* have a significant effect on inflation since the F-statistic is significant at the 5 percent level. The sum of the coefficients, however, is negative but significant at only the 12 percent level ($t = -1.57$). The results in Table 1 suggest strongly that higher inflation precedes greater inflation uncertainty and weakly that greater uncertainty precedes *lower* inflation. One possible reason for greater inflation uncertainty to precede lower inflation is that an increase in inflation uncertainty is viewed by policymakers as costly, inducing them to reduce inflation in the future.

Table 2 presents the results in first differences and is based on Assumption 2. In column 1, three lagged values of the first difference of inflation ($\Delta INFL$) have a

4. For details of these results, contact the author. The software program Microfit 3.0 by Pesaran and Pesaran (1991) is used for this and all other tests performed for this paper.

TABLE 1

TESTS FOR TEMPORAL ORDERING BETWEEN *INFL* AND *UNCERT* BASED ON THE ASSUMPTION OF STATIONARITY, 1954H1 TO 1990H2

Dependent Variable	(1) *UNCERT*	(2) *INFL*
Intercept	.32	1.97
	(.12)	(.68)
$UNCERT_{t-1}$	.27	1.09
	(.14)	(.81)
$UNCERT_{t-2}$	.06	−.47
	(.14)	(.81)
$UNCERT_{t-3}$	−.08	−1.81
	(.14)	(.76)
$UNCERT_{t-4}$	.27	—
	(.14)	
F (significance of lagged *UNCERT*)	5.34	2.91
$INFL_{t-1}$	.09	.54
	(.02)	(.12)
$INFL_{t-2}$	−.01	.23
	(.02)	(.14)
$INFL_{t-3}$	.00	.39
	(.02)	(.14)
$INFL_{t-4}$	−.03	−.26
	(.02)	(.11)
F (significance of lagged *INFL*)	5.01	24.7
R^2	.61	.74

Standard errors are in parentheses.

TABLE 2

TESTS FOR TEMPORAL ORDERING BETWEEN *INFL* AND *UNCERT* BASED ON THE ASSUMPTION OF NONSTATIONARITY BUT NO COINTEGRATION, 1954H1 TO 1990H2

Dependent Variable	(1) $\Delta UNCERT$	(2) $\Delta INFL$
Intercept	−.04	.06
	(.04)	(.22)
$\Delta UNCERT_{t-1}$	−.52	.90
	(.14)	(.78)
$\Delta UNCERT_{t-2}$	−.31	.44
	(.16)	(.92)
$\Delta UNCERT_{t-3}$	−.29	−1.28
	(.14)	(.97)
$\Delta UNCERT_{t-4}$	—	−1.67
		(.82)
F (significance of lagged $\Delta UNCERT$)	5.52	1.97
$\Delta INFL_{t-1}$	.08	−.28
	(.02)	(.13)
$\Delta INFL_{t-2}$	.05	−.01
	(.03)	(.16)
$\Delta INFL_{t-3}$	.04	.31
	(.02)	(.16)
F (significance of lagged $\Delta INFL$)	4.38	5.33
R^2	.24	.32

Standard errors are in parentheses.

TABLE 3

TESTS FOR TEMPORAL ORDERING BETWEEN *INFL* AND *UNCERT* BASED ON THE ASSUMPTION OF COINTEGRATION USING AN ERROR-CORRECTION MODEL, 1954H1 TO 1990H2

Dependent Variable	(1) $\Delta UNCERT$	(2) $\Delta INFL$
Intercept	.01	.10
	(.04)	(.23)
EC	−.40	.05
	(.11)	(.11)
$\Delta UNCERT_{t-1}$	−.38	1.03
	(.13)	(.83)
$\Delta UNCERT_{t-2}$	−.34	.43
	(.15)	(.92)
$\Delta UNCERT_{t-3}$	−.46	−1.37
	(.14)	(.99)
$\Delta UNCERT_{t-4}$	−.23	−1.76
	(.12)	(.85)
F (significance of lagged $\Delta UNCERT$)	4.07	1.90
$\Delta INFL_{t-1}$	.05	−.31
	(.02)	(.15)
$\Delta INFL_{t-2}$	.05	−.02
	(.03)	(.16)
$\Delta INFL_{t-3}$	.05	.31
	(.02)	(.16)
$\Delta INFL_{t-4}$	—	−.15
		(.14)
F (significance of lagged $\Delta INFL$)	2.12	5.00
R^2	.38	.32

Standard errors are in parentheses.

significant positive effect on the first difference of uncertainty ($\Delta UNCERT$). The sum of the coefficients has a t-statistic of 2.87. In column 2, four lagged values of $\Delta UNCERT$ have an impact on $\Delta INFL$ that is significant only at the 11 percent level. The sum of the coefficients is negative but not significant ($t = -.61$). Except for the weaker evidence of a negative effect of lagged uncertainty on inflation, the results are essentially the same as in Table 1.

Table 3 presents the results of estimating the error-correction model from equation (3) and is based on Assumption 3. The cointegrating equation is estimated using the Johansen method. Normalized, that equation is

$$UNCERT_t = .34 + .16 INFL_t \tag{5}$$

or

$$INFL_t = -2.10 + 6.18 UNCERT_t \,. \tag{6}$$

The row denoted EC in Table 3 contains the coefficients of the error-correction terms, the lagged residuals from the appropriate version of the cointegrating equation. As in Tables 1 and 2, the results indicate strongly that higher inflation precedes greater inflation uncertainty and weakly that greater inflation uncertainty precedes lower inflation. In column 1 the error-correction term is negative as expected and strongly significant ($t = -3.75$). Three lagged values of $\Delta INFL$ have positive coefficients that are jointly significant only at the 11 percent level, but the sum of the coefficients is significant at the 2 percent level ($t = 2.41$). In column 2 the error-correction term is positive though not nearly significant. Four lagged values of $\Delta UNCERT$ are jointly significant at the 12 percent level, and the sum of the coefficients is negative but not statistically significant ($t = -.64$).

ROBUSTNESS

Davis and Kanago (1992) argue that the standard deviation of inflation forecasts should be divided by one plus the inflation rate to get a more accurate reflection of inflation uncertainty. Using their measure does not alter the results. Using OLS instead of Johansen's method to estimate cointegrating equations also does not alter the results.

In column 2 of Tables 1 through 3, the first lagged value of uncertainty always has a positive coefficient. The negative coefficients are for the longer lags, but they are not always individually significant. I reestimated the equations without the longer lags to see if the results would change. They did only in that there was no indication of a negative effect of lagged uncertainty on inflation. There also was no indication of a significant positive effect, the largest t-value being 1.20.

The results are essentially the same for six-month inflation uncertainty based on the Livingston survey. The evidence of a negative effect of lagged uncertainty on inflation, however, is somewhat stronger. Significance levels are 8–9 percent instead of 11–12 percent, which means that rejection of the hypothesis of no relationship would occur for a critical significance level of 10 percent. Other authors, for example, Evans, Ball, and Cecchetti, and Brunner and Hess, have found differences in the relationship between uncertainty and inflation between short-term and long-term uncertainty. My results, however, are not directly comparable to theirs because they typically use horizons of less than six months for short-term uncertainty and more than twelve months for long-term uncertainty.

For the twelve-month Livingston uncertainty measure, the results are not at all sensitive to inclusion of the pre-1954 data. Using all three forms of the tests for temporal ordering, I find strong evidence that higher inflation precedes greater inflation uncertainty and weak evidence that greater inflation uncertainty precedes lower inflation. For the six-month Livingston uncertainty measure, the evidence that greater uncertainty precedes lower inflation is weaker than in the shorter sample period.

One of the possible explanations for higher inflation preceding greater uncertainty centers on Evans and Wachtel's model of uncertainty about the inflation regime. They find that over the period 1954–67 there is virtually no uncertainty about the inflation regime. In that case, as Holland's comment on their paper shows, one would expect higher inflation to precede greater inflation uncertainty only after 1968. I therefore split the sample into two subperiods: 1954H1 to 1967H2 and 1968H1 to 1990H2. The findings are broadly consistent with the Evans and Wachtel model, but for the earlier subperiod are sensitive to assumptions about stationarity and cointegration. For 1954–67, the influence of lagged inflation on inflation uncertainty is generally not statistically significant (though in one case it is significant at the 8 percent level) and not always of the right sign. There also is evidence in some specifications that greater uncertainty precedes *higher* inflation. For 1968–90, the findings are essentially the same as in the full sample, except that the evidence that greater uncertainty precedes *lower* inflation is stronger.

The results of tests that use the twelve-month inflation uncertainty from the SRC survey (monthly data from January 1978 to December 1990) also indicate that higher inflation precedes greater uncertainty. For the tests based on assuming stationary series (levels), however, the sum of the coefficients of lagged inflation in the regression for uncertainty, though positive, is only significant at the 11 percent level ($t = 1.60$). But the evidence against stationarity of the series is fairly strong (as these things go). For both inflation and uncertainty, maximization of adjusted R^2 in an augmented Dickey-Fuller test regression implies a choice of eleven lagged values of the first difference of the series. For inflation, the Dickey-Fuller τ-statistic is -1.50 and for uncertainty it is -1.22, compared to a critical value of -2.88. Thus, nonstationarity is not close to being rejected for either series. For the tests assuming nonstationary, noncointegrated series (first differences without error correction), the evidence that higher inflation precedes greater uncertainty is stronger. The sum of the coefficients of lagged inflation in the regression for uncertainty has a t-statistic of 2.44. There is no evidence of cointegration using either the Johansen or the Engle-Granger method, so I do not estimate an error-correction model.

The major difference between the SRC and the Livingston results is that for the SRC data there is no evidence at all that greater uncertainty precedes lower inflation. In both sets of tests using the SRC data, lagged uncertainty has a positive, though insignificant, cumulative effect on inflation (the highest t-statistic is .73).

CONCLUSION

For the postwar United States, increases in the rate of inflation tend to precede increases in the level of inflation uncertainty. The finding suggests that higher inflation uncertainty is part of the welfare cost of inflation. One possible explanation—due to Ball (1992)—is that a high rate of inflation increases uncertainty about future monetary policy. People are not certain whether the Fed is willing to bear the cost of a recession to disinflate. Another—due to Evans and Wachtel (1993) as extended by Holland (1993b)—is that people are uncertain about the persistence of inflation, so that the farther away from zero is the inflation rate the more uncertainty there is about future inflation.

The first explanation implies that a higher rate of *deflation* would not affect inflation uncertainty. The second implies that a higher rate of deflation would increase inflation uncertainty. A study of inflation uncertainty during deflationary episodes is needed.

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