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Interest Rates, Uncertainty and the Livingston Data

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ABSTRACT

The observed relationship between the standard deviation of forecasts and past forecast errors as found in the Livingston survey suggests the interpretation of the standard deviation as a measure of inflation uncertainty. The mean and the standard deviation for the inflation rate forecast found in the Livingston survey, furthermore, are used as regressors in a reduced-form interest rate equation. The results indicate a large negative effect of such uncertainty on interest rates. The inclusion of the uncertainty measure and commonly omitted lagged values of all variables in our analysis of data leads to more theoretically plausible estimated effects of money growth and expected inflation on interest rates than do standard estimates.

IT IS WIDELY AGREED that expectations regarding future inflation have important effects on nominal interest rates. A popular and successful technique for examining these effects involves the use of a survey of price level forecasts conducted by J. A. Livingston [2, 3, 9, 15, 18, among others]. The individual forecasts and the then current price level presumably known to the forecasters are used to calculate a mean annualized rate of expected inflation which is used as a regressor in an interest rate equation.

More recently, a number of analysts have attempted to extract more information from the Livingston data by identifying the standard deviation of individual forecasts with the degree of uncertainty afflicting the average respondent [1, 16, 20]. In each study the standard deviation is simply included as an additional regressor in the same equation.

This type of exploitation of the Livingston data is potentially interesting. Empirical evidence on the interaction of expected inflation and uncertainty with regard to inflation and the interest rate has obvious relevance to theories of interest rate determination and potentially useful policy implications. Perhaps more importantly, evidence that a useful measure of inflation uncertainty exists over an extended period would be welcomed by those who wish to empirically examine numerous theories about the effects of uncertainty on the economy.[1]

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[1] Expected inflation and uncertainty of various kinds have long been conjectured to influence the choice among assets. Recently Klein [14] has examined the effect of uncertainty regarding future inflation on the demand for money. Preliminary theoretical work has been performed regarding the demand for "indexed" assets which indicates a potentially important role for inflation uncertainty.

Variations of an influential model by Lucas [17] suggest that uncertainty about the course of overall prices versus relative prices is a principal determinant of the degree to which unanticipated changes in demand affect income and employment. To date, all empirical studies have been forced to use the assumption that such uncertainty is constant over the sample period.

Unfortunately, previous work has not provided persuasive evidence that a workable outline of this interrelationship has been uncovered. In addition, the usefulness of the standard deviation of responses as a measure of uncertainty has been examined only to the extent that this variable yields an acceptable "t" ratio when placed on the right-hand side of an estimated interest rate equation.

This paper is intended to correct and extend the results of these previous investigations. Our purpose is twofold: (1) to provide evidence that the Livingston data yield an internally consistent and useful measure of inflation uncertainty; and (2) to estimate the parameters describing the relationship between interest rates, expected inflation, and uncertainty in an appropriate way. To these a methodological issue is added: to illustrate that the role of lagged values of the regressors in a "Fisher equation" must be examined if reliable information on parameters is to be gained.

The paper is divided into four sections. In Section I we examine the internal consistency of identifying the standard deviation of Livingston responses with uncertainty. In Section II we present a simple macromodel which serves as a framework for our empirical estimates presented in Section III. A concluding section follows.

I. The Livingston Data and Uncertainty

Previous studies have found that the standard deviation of the individual Livingston forecasts, σ_t, provides significant explanatory power on the right-hand side of an estimated interest rate equation. The results to be presented in this paper differ substantially in detail and are based on a different methodology, but they confirm the existence of a significant effect. Such results may be interpreted as evidence of an effect of uncertainty with regard to future inflation on interest rates which is separable from the effect of the consensus of expectations. Whether this interpretation is to be taken seriously depends on the validity of regarding σ_t as a measure of uncertainty. This practice remains empirically unexamined.[2]

The standard deviation among individual forecasts of inflation is, strictly speaking, a measure of the dispersion of opinion rather than a measure of the confidence in which those opinions are held. Nevertheless, it is reasonable to suppose that situations in which future inflation is thought to be more difficult to predict will, in general, be situations in which individual predictions will differ more widely. In the absence of alternative measures of uncertainty,[3] we can examine the internal consistency of this interpretation of the data. The question

[2] Barnea, Dotan, and Lakonishok [1] present a theoretical discussion of the plausibility of this interpretation. Wachtel [20] presents a descriptive analysis of the Livingston responses which touches upon changes in the population of responders and the kurtosis of the responses. Levi and Makin [16] do not examine this issue.

[3] Klein uses the variance of inflation about a moving average estimate of the mean as a proxy for uncertainty. This is, strictly speaking, a measure of variability rather than uncertainty. As one moves from a peacetime to a war economy, the inflation rate may increase dramatically, leading to a high measured variance even if the increase was regarded as highly predictable. Likewise, a change in political leadership may lead to substantial ex ante uncertainty, even when ex post inflation is rather uniform.

which we wish to answer in this regard is: is the relationship between the mean expected rate of inflation, π_t^e, actual future inflation, π_{t+1}, and σ_{t+1} consistent with the relationship between a forecast, the success of the forecast, and confidence in future forecasts?

If expected inflation may be viewed as a point forecast, uncertainty with regard to inflation may be viewed as a measure of the length of the confidence interval the forecaster draws about his point estimate. The length of that interval may depend upon external events. For instance, the onset of war or a period of expected political instability may lengthen the interval. However, it also seems reasonable to suppose that the length of the interval will be influenced by the degree to which recent forecasts have missed the mark. That is, periods in which forecasters are badly in error are likely to be followed by periods in which forecasters have less confidence in their current forecasts.

A simple model of this process can be constructed by assuming that one component of uncertainty, S_t, can be described as a weighted average of squared past errors. For individual k this component of his uncertainty at time t can be formulated:

$$s_{kt} = \sum_{i=1}^{\infty} (1-\lambda)\lambda^{i-1}(\pi_{t+1-i} - \phi_{kt-i})^2 \qquad 0 < \lambda < 1 \tag{1}$$

where ϕ_{kt-i} is the forecast by individual k at time $t - i$ for inflation between $t - i$ and $t + 1 - i$, and π_{t+1-i} is the subsequently observed inflation rate.

If the s_{kt} are averaged over N forecasters, we can construct S_t, an index of average uncertainty for the group of forecasters. Some manipulation of this expression yields:

$$S_t = \sum_{k=1}^{N} s_{kt}/N = \sum_{i=1}^{\infty} (1-\lambda)\lambda^{i-1}(E_{t+1-i}^2 + \sigma_{t-i}^2)^2 \tag{2}$$

where $E_t = \pi_t - \pi_{t-1}^e$ is the difference between actual inflation (between $t - 1$ and t) and the mean forecast for the same period and $\sigma_t^2 = \sum_{k=1}^{N} (\pi_t^e - \phi_{kt})^2/N$.

The respondents to the Livingston survey may be considered the N forecasters, and the mean past errors, E_{t-i}, can be calculated by comparing the mean forecasts with actual subsequent inflation. If σ_t is indeed an appropriate measure of uncertainty, movements in an index such as S_t should explain a substantial part of the movements in σ_t. More mechanically, one should be able to find a value for λ such that the generated S_t series has a timepath similar to the timepath of σ_t.

To examine this prospect, we have constructed alternative series for S_t using the eight-month forecasts from the Livingston data[4] and values for λ of 0.1, 0.2, . . . , 0.9. The best results were produced for 0.4 although the timepaths differed little for $\lambda = 0.3$ and $\lambda = 0.5$. The timepaths of σ_t and $\sqrt{S_t}$ over the period 1952–77 are shown in Figure 1. An *OLS* regression of σ_t on $\sqrt{S_t}$ using this sample was performed with the following results:

$$\underset{}{\sigma_t} = \underset{(3.31)}{0.266} + \underset{(12.84)}{0.409\sqrt{S_t}} \qquad R^2 = .77$$

These results formalize a fact which can be seen in Figure 1: σ_t and $\sqrt{S_t}$ move

[4] See Carlson [4] for an interpretation of the horizons involved with these data.

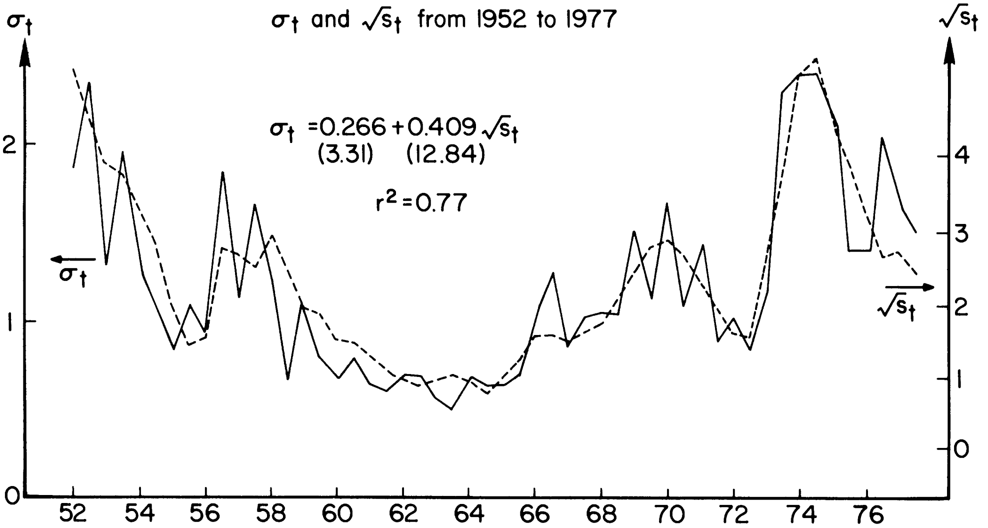

Figure 1. The Standard Deviation of Inflation Forecasts and the Square Root of the Weighted Average of Squared Past Forecast Errors

together rather closely.[5] It should be emphasized that although both variables are generated, at least in part, by responses to the same survey, they are in no way constrained to be similar. S_t depends on past responses and actual inflation; σ_t depends only on current responses. Given the crudeness of the procedure which generates S_t, these results indicate a substantial consistency of this interpretation.[6]

II. A Model of Interest Rate Determination

This section outlines a simple macromodel which can be used to catalogue the effects of uncertainty and other variables on interest rates.

[5] The square root of the weighted average of past squared errors, $\sqrt{S_t}$, is more comparable in concept with σ_t than S_t. We have checked the possibility that past levels of σ_t which enter into the calculation of S_t have forced a good fit because of serial correlation in the σ_t series. When σ_t is excluded from the right-hand side of (2), the altered S_t series yields the following regression result:

$$\underset{}{\sigma_t = \underset{(5.7)}{.411} + \underset{(12.5)}{.426}\sqrt{S_t}} \qquad R^2 = .76$$

Past values of σ_t alter the scale of S_t but not its pattern over time.

[6] Consistency provides comfort rather than proof. Nevertheless, it is hard to find a reason why σ_t and $\sqrt{S_t}$ should resemble each other except for the reason given above. It should be noted that neither variable is highly trended so their resemblance is not caused by a common trend. Neither does the explanatory power of σ_t in an interest rate equation to be reported in Section III arise from its resemblance to some highly trended excluded variable.

The Model

The model is as follows:

$$y_t = y_{ct} + \alpha_0 + \alpha_1 r_t + \alpha_2 \pi_t^e + \alpha_3 \sigma_t + \epsilon_t \tag{3}$$

$$m_t = \beta_0 + y_t + \beta_1 r_t + \beta_2 \sigma_t + \theta_t \tag{4}$$

$$\pi_t = \pi_t^e + \gamma(y_t - y_{ct}) + \eta_t \tag{5}$$

$$m_t = \mu_t - \pi_t + m_{t-1} \tag{6}$$

$$y_{ct} = g_t + y_{ct-1} + \delta(\sigma_t - \sigma_{t-1}) \tag{7}$$

The variables y_t, y_{ct}, and m_t are logarithms of real output, real capacity output, and real money balances, respectively; g_t, μ_t, and π_t are the exponential rates of growth (between $t-1$ and t) of real capacity output, nominal money balances, and prices, respectively; r_t, π_t^e, and σ_t are the nominal interest rate, the rate of inflation expected between t and $t+1$, and the uncertainty regarding that expectation, respectively. ϵ_t, θ_t and η_t are disturbance terms with zero means.

Equation (3) is an *IS* curve with $\alpha_1 < 0$ and $\alpha_2 > 0$. As the interest rate rises or the expected inflation rate falls, the demand for output falls relative to capacity. If $\alpha_1 = -\alpha_2$, a constant rate of capacity utilization (reflected in $y_t - y_{ct}$) is consistent with only one real interest rate (given σ_t and ϵ_t). The sign of α_3 depends on the way in which uncertainty with regard to future inflation affects expenditure patterns. Wachtel [19] has found evidence that uncertainty of this kind leads to increased saving. Levi and Makin [16] suggest that investment depends inversely on inflation uncertainty. Either effect implies $\alpha_3 < 0$ but neither effect is theoretically unambiguous.

Equation (4) is an *LM* curve with $\beta_1 < 0$. For convenience we have assumed a unitary elasticity of the demand for real balances with respect to real output. This assumption eliminates any secular trend in the velocity of money in a growing economy. Klein [14] has argued that uncertainty about future inflation decreases the "quality" of the services provided by money. The direction of the effect of this decrease is theoretically ambiguous but both Klein [14] and Frazer [6] have found evidence for a positive effect, implying $\beta_2 > 0$.

Equation (5) is an expectations-augmented Phillips curve with $\gamma > 0$. Output exceeds (falls short of) capacity as inflation exceeds (falls short of) the rate which had been expected for that period.

Equation (6) is an identity. Equation (7) is in one sense an identity: it defines the rate of growth of capacity in the absence of a change in uncertainty, g_t. This variable may be considered as exogenous and stochastic with a positive mean. The inclusion of the final term (with $\delta < 0$) is motivated by the proposition presented most prominently by Friedman [8] that uncertainty about future inflation decreases economic efficiency and, hence, capacity output. The first difference form of our uncertainty effect means that an increase σ_t produces a once-and-for-all decrease in capacity but produces no change in the ongoing trend growth rate which accrues to the (decreased) current base. We believe this formulation is consistent with the spirit of Friedman's proposition.

The model contains no equation describing the formation of expected inflation. This omission anticipates the use of survey data for expected inflation. As with virtually all work based on the Livingston data, we treat π_t^e as exogenous.[7] The effects of expected inflation will be examined. All aspects of its formation, including its "rational" characteristics will not be examined.

Interest Rate Determination

The determination of the interest rate in this model may be examined in three stages: first, Equations (3) through (7) may be solved to eliminate y_t, y_{ct}, m_t, and π_t producing a reduced-form expression:

$$r_t = d_0 + d_{10}\pi_t^e + d_{20}\sigma_t + d_{30}(\mu_t - g_t) + \text{lagged terms} + \text{disturbances} \tag{8}$$

where

$$d_{10} = -(1 + \alpha_2(1+\gamma))/(\beta_1 + \alpha_1(1+\gamma)) > 0,$$

$$d_{20} = -(\delta + \beta_2 + \alpha_3(1+\gamma))/(\beta_1 + \alpha_1(1+\gamma)) \lesseqgtr 0,$$

and

$$d_{30} = 1/(\beta_1 + \alpha_1(1+\gamma)) < 0.$$

Second, repeated substitution of Equations (3) through (7) into (8) will, in principle, eliminate all lagged values of y_t, y_{ct}, m_t, and π_t yielding an expression for the final form:

$$r_t = d_0 + \sum_{i=0}^{\infty} d_{1i}\pi_{t-i}^e + \sum_{i=0}^{\infty} d_{2i}\sigma_{t-i} + \sum_{i=0}^{\infty} d_{3i}(\mu_{t-i} - g_{t-i}) + \text{disturbances} \tag{9}$$

where d_{10}, d_{20}, and d_{30} are given above the the remaining d_{ji} ($j = 1, 2, 3$; $i = 1, 2, \ldots$) can be expressed as functions of the parameters of (3) through (7).

Third, the signs and magnitudes of the individual d_{ji} cannot be determined without knowledge of the specific parameter values of the structural equations, but we may obtain information about the pattern of lagged responses by examining a steady state. To do this, suppose that μ, g, π^e, and σ are constant over an extended period and the disturbances jointly equal to zero. Without further defining the formation of expectations, we can assume that $\pi^e = \pi$ in such a state. The structure of the model is consistent with a constant r, π, and y when all of the exogenous variables are constant. Inspection of the structural equations reveals that

$$r = -\alpha_0/\alpha_1 - (\alpha_2/\alpha_1)\pi^e - (\alpha_3/\alpha_1)\sigma \tag{10}$$

and

$$\pi^e = \pi = \mu - g \tag{11}$$

in this situation. If (9) describes the general relationship between r_t and the exogenous variables, it must reduce to (10) in the special case described above.

[7] An interesting exception to this practice is provided in Lahiri [15]. There π_t^e is viewed as an imperfect observation on the "actual" expected inflation rate, π_t^*. The interest rate equation and the equation describing the formation of π_t^* are then jointly estimated to purge the former from "errors in variables" problems.

This correspondence requires that

$$d_0 = -\alpha_0/\alpha_1; \qquad \sum_{i=0}^{\infty} d_{1i} = -\alpha_2/\alpha_1; \qquad \sum_{i=0}^{\infty} d_{2i} = -\alpha_3/\alpha_1 \quad \text{and} \quad \sum_{i=0}^{\infty} d_{3i} = 0.$$

The absence of β_j, γ, and δ terms in (10) and the zero sum for the d_{3i} illustrate the fact that the long-run determinants of the nominal interest rate in this model are limited to the exogenous variables and parameters which enter into the expenditure schedules. All monetary influences have only short-run effects except insofar as they affect expected inflation.

The long-run effect of expected inflation on the interest rate is positive (unitary if $\alpha_1 = -\alpha_2$) and may be larger or smaller than the positive instantaneous effect d_{10}. The instantaneous effect of uncertainty on the interest rate is of indeterminant sign. The likelihood that it will be negative is increased as (1) $\delta < 0$ as hypothesized, (2) $\beta_2 < 0$ contrary to the evidence mentioned above, and/or (3) $\alpha_3 < 0$ consistent with speculation and evidence mentioned above. The long-run effect depends only on the sign of α_3 and will, therefore, be negative if uncertainty decreases expenditures on net. Note that if the money demand and efficiency effects are minor ($\beta_2 \simeq \delta \simeq 0$), the long-run uncertainty effect will be of the same sign as the instantaneous effect but larger in magnitude ($| -\alpha_3(1 + \gamma)/(\beta_1 + \alpha_1 (1 + \gamma)) | < | -\alpha_3/\alpha_1 |$).

Before proceeding to the next section, it is worthwhile mentioning that virtually all studies which use the Livingston data estimate an equation of the form

$$r_t = a_0 + a_1\pi_t^e + \sum_{j=1}^{K} b_j q_{jt} + \text{disturbance} \tag{12}$$

where the q_{jt} are contemporaneous values of other variables presumed to affect interest rates.

It is possible to interpret such an equation as a version of (8) or (9) in which the lagged values of all right-hand side variables have been impounded in the disturbance term. Such an estimating equation is virtually guaranteed to exhibit serial correlation among the disturbance terms, but correction for serial correlation remains the exception in Livingston data studies.

More importantly, the likely serial correlation in the right-hand side variables themselves suggests a high probability that the contemporaneous values of these variables will be correlated with the lagged values of the same variables sequestered in the disturbance term. The inconsistency of commonly used estimating techniques under these conditions represents a serious drawback. Extreme assumptions regarding parameter values may be sufficient to assure that lagged values do not belong in such an equation ($d_{ji} = 0$ for $i > 0$ in (9)), but there seems to be no reason to assume these conditions a priori. The role of lagged values is easily examined at the cost of some degrees of freedom.

III. Some Empirical Results

In this section we present empirical estimates of the effects of expected inflation and uncertainty regarding future inflation on interest rates. Our estimating equation is a truncated version of (9) from the preceding section. It has been modified in two ways: (1) since the growth rate of capacity output excluding uncertainty effects, g_t, is difficult to observe, we have relegated its effects to the disturbance term; and (2) we have limited the number of lagged right-hand side variables to a finite amount.

Some experimentation was used in selecting the number of lagged terms to be included. A large number were initially allowed, then the number was reduced until further reduction seemed inappropriate. The somewhat arbitrary rule of thumb we applied required that the last lagged term included be insignificant, and the next to last term be of at least marginal significance as measured by a "t" ratio. We were deliberately generous in our allowance for lagged terms because we feel that the costs of including too many are less than the costs of including too few.[8]

The interest rates used were the market yields on 3 month, 3 to 5 year, and 10 year Treasury debt. The Livingston data give rise to semiannual observations on π_t^e and σ_t for April and October from 1947. The period over which the estimation is performed is 1952–77. There are, therefore, sufficient observations to estimate the equation over this period with at most 10 lagged values for π_t^e and σ_t. Observations on r_t and μ_t are constructed so as to be contemporaneous with the Livingston observations.[9]

The estimating equation we found suitable included 5 lags (2½ years) for π_t^e, 9 lags (4½ years) for μ_t, and 10 lags (5 years) for σ_t:[10]

$$r_t = a_0 + \sum_{i=0}^{5} a_{i+1}\pi_{t-i}^e + \sum_{i=0}^{9} b_{i+1}\mu_{t-i} + \sum_{i=0}^{10} c_{i+1}\sigma_{t-i} + e_t \tag{13}$$

To illustrate the roles of the lagged values and the separate variables five regressions were run for each interest rate. The regressions were run with, (a) no lagged terms; (b) no μ_t or σ_t terms; (c) no μ_t terms; (d) no σ_t terms; and (e) all terms included. Table I reports summary statistics and estimates for $a_0, a_1, \ldots, a_6$ from regressions (a), (b), and (e). Table II reports the estimates for $b_1, b_2, \ldots, b_{10}$ from regressions (a), (c), and (e). Table III reports the estimates for $c_1, c_2, \ldots, c_{11}$ from regressions (a), (d), and (e).

The results support the proposition that lagged values of the right-hand side variables belong in an interest rate equation, particularly for long-term rates. The introduction of lagged values of π_t^e not only raises the cumulative contribution of expected inflation (as measured by the sum of the $\hat{a}_i$), but also raises the estimated coefficient of current expected inflation, $\hat{a}_1$, in all cases. Based on "t" ratios, a 99 percent confidence interval about $\hat{a}_1$ does not include 1 in any of the

[8] Our view of the costs is as follows: if we include "too many" lags, we lose some degrees of freedom which produces a decrease in efficiency. If we include "too few," we leave out potentially important variables which are likely to be correlated with included variables, which leads to inconsistent estimates. The latter would appear to be the more important difficulty to avoid.

[9] The sample period begins at the same point as the original investigation of the Livingston data by Gibson [9]. These interest rates were also used in the Gibson study. The observations on interest rates are monthly averages for April and October. The rate of money growth is the annualized rate of growth of $M2$ over the 6 month period ending in the month in question. Estimates using $M1$ provided similar results with slightly poorer fits.

[10] In general, estimates using the 3 month rate called for the inclusion of fewer lagged terms according to the rule-of-thumb above. In order to facilitate comparisons across the different interest rate equations, we have included the same (larger) number of lags for each.

Table I

Estimates of the Contemporaneous and Lagged Effects of Expected Inflation on the Interest Rate

	3 month rate			3 to 5 year rate			10 year rate		
	(a) no lags	(b) π^e only	(e) complete	(a) no lags	(b) π^e only	(e) complete	(a) no lags	(b) π^e only	(e) complete
$\hat{a}_0$	4.179	2.541	4.336	6.484	3.118	5.172	6.542	3.306	4.363
	(5.94)[a]	(6.08)	(3.10)	(5.19)	(10.9)	(6.09)	(5.19)	(18.2)	(12.1)
$\hat{a}_1$	.527	.551	.625	.216	.275	.476	.202	.260	.358
	(3.98)	(3.25)	(3.37)	(1.72)	(1.91)	(3.08)	(2.74)	(3.64)	(4.40)
$\hat{a}_2$	—	.238	.168	—	.300	.338	—	0.98	.124
		(1.32)	(1.00)		(2.04)	(2.15)		(1.39)	(1.44)
$\hat{a}_3$	—	0.66	.205	—	.099	−.218	—	.168	−.028
		(0.36)	(1.21)		(0.66)	(1.29)		(2.32)	(0.31)
$\hat{a}_4$	—	−.383	−.314	—	−.054	−.101	—	.004	−.037
		(2.08)	(2.29)		(0.36)	(0.78)		(0.05)	(0.52)
$\hat{a}_5$	—	.229	.344	—	.130	.433	—	.044	.256
		(1.39)	(2.63)		(1.19)	(3.87)		(0.85)	(4.30)
$\hat{a}_6$	—	−.060	−.047	—	.023	.077	—	.092	.110
		(0.41)	(0.36)		(0.23)	(0.76)		(1.88)	(2.03)
$\sum_{i=1}^{6} \hat{a}_i$	.527	.641	.979	.216	.773	1.007	.202	.667	.783
	(3.98)	(4.69)	(3.90)	(1.72)	(8.37)	(5.65)	(2.74)	(11.9)	(9.77)
R^2	.883	.848	.972	.469	.921	.984	.968	.970	.993
DW	2.20	1.94	1.52	2.38	1.92	2.38	2.19	2.07	2.14
$\hat{\rho}$	.84	.63	.77	.95	.60	.66	.97	.68	.55

All equations have been corrected for first-order serial correlation by a Cochrane-Orcutt Technique.
[a] Numbers in parentheses are "t" statistics.

equations. The cumulative effect is virtually equal to 1 for the complete equation using 3 month and 3 to 5 year rates. For the analogous equation using the 10 year rate, the estimated cumulative effect is significantly less than 1, although it is nearly twice as large as the estimated contemporaneous effect, $\hat{a}_1$.[11]

OLS estimates similar to Gibson's which contain only current values for π_t^e (not shown) give point estimates for a_1 of .71, .77 and .64 for the respective interest

[11] For each interest rate there is a problem associated with the time horizon of expectations. The expected inflation rate which is presumably most relevant is the inflation expected over the horizon corresponding to the maturity of the debt. The Livingston data provide forecasts of inflation over 8 month and 14 month horizons. The 8 month forecasts were used in the short-term interest rate equations. The 14 month forecasts were used with the long-term rates. The alternative combinations were also used but yielded a poorer fit in each case. The noticeably lower cumulative effect of π_t^e on the 10 year rate may simply indicate that the 14 month expected rate of inflation is a poor proxy for the 10 year expected rate of inflation.

Table II

Estimates of the Contemporaneous and Lagged Effects of Money Growth on the Interest Rate

	3 month rate			3 to 5 year rate			10 year rate		
	(a)	(d)	(e)	(a)	(d)	(e)	(a)	(d)	(e)
	no lags	π^e, μ only	complete	no lags	π^e, μ only	complete	no lags	π^e, μ only	complete
$\hat{b}_1$	−.193	−.175	−.191	−.141	−.116	−.156	−.046	−.032	−.059
	(5.35)[a]	(5.54)	(5.70)	(5.49)	(3.97)	(5.88)	(3.13)	(1.96)	(4.15)
$\hat{b}_2$	—	.086	.065	—	.004	−.037	—	−.003	−.030
		(2.56)	(1.84)		(0.15)	(1.32)		(0.19)	(2.03)
$\hat{b}_3$	—	−.020	−.032	—	.002	−.048	—	−.006	−.034
		(0.57)	(0.88)		(0.06)	(1.63)		(0.37)	(2.27)
$\hat{b}_4$	—	.134	.137	—	.066	.055	—	.024	.021
		(3.79)	(3.93)		(2.14)	(2.09)		(1.42)	(1.56)
$\hat{b}_5$	—	.033	.038	—	.053	.018	—	.040	.020
		(0.87)	(1.02)		(1.58)	(0.61)		(2.10)	(1.39)
$\hat{b}_6$	—	.053	.074	—	.016	.003	—	−.001	−.004
		(1.31)	(1.87)		(0.46)	(0.09)		(0.05)	(0.27)
$\hat{b}_7$	—	.022	.029	—	.036	.028	—	.021	.022
		(0.56)	(0.74)		(1.06)	(0.95)		(1.11)	(1.51)
$\hat{b}_8$	—	−.033	−.018	—	.001	.016	—	.002	.016
		(0.80)	(0.39)		(0.02)	(0.48)		(0.12)	(0.93)
$\hat{b}_9$	—	−.102	−.075	—	−.048	−.027	—	−.028	−.012
		(2.81)	(1.85)		(1.41)	(0.86)		(1.49)	(0.70)
$\hat{b}_{10}$	—	−.041	−.022	—	.011	.033	—	.004	.011
		(1.20)	(0.57)		(0.35)	(1.16)		(0.25)	(0.72)
$\sum_{i=1}^{10} \hat{b}_i$	−.193	−.044	.005	−.141	.026	−.116	−.046	.022	−.048
	(5.35)	(0.20)	(0.02)	(5.49)	(0.15)	(0.80)	(3.13)	(0.22)	(0.74)

All equations have been corrected for first-order serial correlation by a Cochrane-Orcutt technique.
[a] Numbers in parentheses are "t" statistics.

rates. Clearly, the serial correlation in the π_t^e series has caused part of the effects of (excluded) past expected inflation to be attributed to current expected inflation. OLS regressions lead to an overestimate of the contemporaneous effect and an underestimate of the cumulative effect of expected inflation.

As indicated in Table I, expected inflation appears to affect the short-term rate with a shorter lag than the long-term rates. This pattern is repeated for the other right-hand side variables as indicated in Tables II and III.

The necessity of including lagged values of the right-hand side variables and attempting to correct for autoregressive disturbances is further demonstrated by

Table III

Estimates of the Contemporaneous and Lagged Effects of Uncertainty on the Interest Rate

	3 month rate			3 to 5 year rate			10 year rate		
	(a)	(c)	(e)	(a)	(c)	(e)	(a)	(c)	(e)
	no lags	π^e,σ only	complete	no lags	π^e,σ only	complete	no lags	π^e,σ only	complete
$\hat{c}_1$	0.54 (0.23)[a]	.153 (0.35)	−.461 (1.66)	.073 (0.50)	−.137 (0.53)	−.429 (2.40)	−.060 (0.72)	−.130 (1.09)	−.311 (3.25)
$\hat{c}_2$	—	.369 (0.86)	−.193 (0.65)	—	−.362 (1.33)	−.406 (2.05)	—	−.156 (1.24)	−.242 (2.43)
$\hat{c}_3$	—	−.479 (1.2−)	−.357 (1.21)	—	−.208 (0.78)	−.004 (0.02)	—	.042 (0.34)	.110 (1.18)
$\hat{c}_4$	—	−.578 (1.42)	−.305 (1.21)	—	−.016 (0.74)	−.001 (0.01)	—	−.025 (0.25)	.006 (0.09)
$\hat{c}_5$	—	−.109 (0.26)	−.209 (0.78)	—	.227 (0.71)	.201 (0.99)	—	.055 (0.37)	.058 (0.54)
$\hat{c}_6$	—	−.034 (0.08)	−.148 (0.55)	—	−.325 (1.16)	−.420 (2.23)	—	−.076 (0.59)	−.123 (1.25)
$\hat{c}_7$	—	−.276 (0.87)	−.333 (1.69)	—	−.292 (0.93)	−.187 (0.88)	—	−.227 (1.57)	−.139 (1.22)
$\hat{c}_8$	—	−.192 (0.61)	−.467 (2.29)	—	.112 (0.38)	−.281 (1.46)	—	.043 (0.32)	−.104 (1.01)
$\hat{c}_9$	—	.130 (0.45)	.063 (0.31)	—	.331 (1.11)	.280 (1.42)	—	.216 (1.58)	.136 (1.28)
$\hat{c}_{10}$	—	−.004 (0.13)	.022 (0.10)	—	−.265 (0.87)	−.010 (0.47)	—	−.200 (1.44)	−.093 (0.83)
$\hat{c}_{11}$	—	−.061 (0.20)	.155 (0.76)	—	−.088 (0.34)	−.267 (1.56)	—	−.129 (1.07)	−.166 (1.89)
;$\sum_{i=1}^{11}\hat{c}_i$	.054 (0.23)	−1.116 (1.48)	−2.333 (2.30)	.073 (0.50)	−.623 (2.12)	−1.615 (3.53)	−.060 (0.72)	−.589 (2.55)	−.868 (4.66)

All equations have been corrected for first-order serial correlation by a Cochrane-Orcutt technique.
[a] Numbers in parentheses are "t" statistics.

the estimated effects of money growth summarized in Table II. Estimates which include no lagged values, (*a*), yield a large, significantly negative estimated coefficient for current money growth, $\hat{b}_1$, for each interest rate. OLS estimates of the same equation (not shown) yield values which range from near zero for the 10 year rate to marginally significant negative values for the others. The former estimates might lead one to believe that money growth has a permanent effect on interest rates separate from any influence operating through expected inflation.

The latter estimates might lead one to believe that money growth has little independent effect at all. Estimates for the complete equation, (e), reveal that, while the initial effects are negative and significant, the cumulative effect (as measured by the sum of the $\hat{b}_i$) is insignificantly different from zero for each interest rate as predicted by (9). As was the case with π_t^e, OLS estimates using only current values pick up a mixture of contemporaneous and lagged effects.

The "liquidity effect," as measured by the initial negative values for the $\hat{b}_i$, is completed more quickly for the short-term rate (within 6 months versus 18 months). The magnitude of the cumulative effect before positive terms appear is comparable for each interest rate. This aspect of our results may be compared with those of Gibson [10, 11] who regressed interest rates on current and lagged money growth in an attempt to assess the combined "liquidity," "income," and "expectations" effects suggested by Friedman [7]. Our estimates control for the expectations effect so that the $\hat{b}_i$ presumably reveal the liquidity and income effects only.

The estimates for the effects of uncertainty, as summarized in Table III, also indicate the importance of lagged right-hand side variables. Estimates from the complete equation, (e), indicate large and, in the case of the long-term rates, significantly negative contemporaneous effects followed by a preponderance of negative lagged effects. The cumulative effect (as measured by the sum of the $\hat{c}_i$) is significantly negative for each interest rate. Rather large estimated coefficients appear far back in the lag structure and it is possible that, for the long-term rates, the lagged effects may not be complete after the 10 period (5 year) horizon we have allowed.

Since uncertainty with regard to inflation may influence interest rates via several routes, it is not possible to use the $\hat{c}_i$ to precisely identify individual effects. More formally, the d_{2i} of (9) which we have estimated as the $\hat{c}_i$, do not provide easily obtained estimates of the parameters of the structural equations (3) through (7). The discussion in Section II suggests that the cumulative effect may be taken as an estimate of $-\alpha_3/\alpha_1$. If so we may infer that α_3 is negative, i.e. increased uncertainty with regard to inflation decreases demand. This result is consistent with previous work mentioned in Section II. The large and significantly negative initial values, $\hat{c}_1$ and $\hat{c}_2$, may be interpreted as evidence of a large impact of contractionary effects on demand and/or the reinforcing negative effect of a presumed decrease in efficiency on supply as suggested in Section II. The presumed positive effects proceeding from increased money demand are not in evidence. Harrod [12], drawing from Keynes [13], has gone as far as to suggest that the observed relationship between interest rates and measures of π_t^e is entirely due to such a monetary effect, and the underlying correlation between π_t^e and uncertainty with regard to inflation. Our results indicate that the effect of uncertainty on money demand is either obscured by a larger nonmonetary effect or is itself negative.

All of the estimates indicate the crucial nature of the choice of right-hand side variables. The addition of μ_t and σ_t terms to the (b) equation to produce the complete equation, (e), yields a considerable increase in the estimated cumulative effect of π_t^e. The addition of μ_t or σ_t terms separately to produce the (c) and (d) equations yields little change in the estimated cumulative effect of π_t^e (not shown).

The estimated liquidity effect, as measured by $\hat{b}_1 + \hat{b}_2 + \hat{b}_3$, is magnified by the addition of σ_t terms. This sum changes from $-.109$, $-.110$, and $-.041$ for the respective interest rates in Equation (*d*) to $-.158$, $-.241$, and $-.123$ in Equation (*e*). In a somewhat more dramatic fashion, the estimated contemporaneous and cumulative effects of σ_t become more negative as μ_t terms are added. As one moves from (*c*) to (*e*) in Table III, each $\hat{c}_1$ becomes more negative by more than twice the original standard error, and similar changes occur in the sum of the $\hat{c}_i$. The pattern of results suggests a relationship between current uncertainty with respect to inflation, and past accelerations and decelerations in the rate of money growth which obscures the estimated effect of either when the other is not controlled for. Such a relationship is plausible in light of the influence money growth has been shown to have on current and subsequent inflation.

A direct comparison of these results with previous efforts to include σ_t in an interest rate equation is difficult. Each previous study has (1) excluded lagged values; (2) failed to correct for serial correlation among the disturbances; and (3) not used money growth as a right-hand side variable. Nevertheless, some mention is in order. Both Barnea, Dotan, and Lakonishok [1] and Wachtel [20] estimate equations of the form $r_t = a_0 + a_1\pi_t^e + a_2\sigma_t$ using OLS over a variety of rather short sample periods. The result in which both are principally interested is a positive and significant value for $\hat{a}_2$. Wachtel also experiments with an interactive term, $\sigma_t^2 \cdot \pi_t^3$. Levi and Makin [16] make a more ambitious effort and estimate a number of equations using a variety of interest rates and sample periods. An illustrative result is[12]

$$\underset{}{r_t} = \underset{(9.9)}{3.58} + \underset{(8.4)}{1.00}\pi_t^e - \underset{(3.4)}{.128}(y_t - y_{t-1}) - \underset{(4.0)}{1.02}\sigma_t \quad R^2 = .69 \quad DW = 1.30$$

These results are the only ones which "confirm" our own in the sense that a significantly negative effect for σ_t is discovered.

IV. Conclusion

Our results indicate that the Livingston data provide a measure of uncertainty regarding future inflation which is internally consistent and plays an important explanatory role in the determination of interest rates. Increased uncertainty of this kind tends to lower interest rates with a substantial lag.

12 We show the 1950–70 sample period which was in some ways the best for this equation. This was the only sample for which the inclusion of $y_t - y_{t-1}$ and σ_t substantially alters $\hat{a}_1$ and the only one for which $\hat{a}_1$ approaches 1. The wide disparity between these results and the others is not unusual for slight variations of the sample when OLS methods are used and monetary effects are not controlled for. We have reproduced the Levi and Makin [16] results and then re-estimated the same equation: (1) using OLS but using the sample 1952–70; and (2) using the same sample but using a correction for first order serial correlation. The results are, respectively:

$$r_t = \underset{(5.0)}{2.02} + \underset{(12.1)}{1.166}\pi_t^e \underset{(0.9)}{-.032}(y_t - y_{t-1}) + \underset{(0.4)}{.109}\sigma_t \qquad R^2 = .81$$

$$r_t = \underset{(3.6)}{3.72} + \underset{(1.0)}{.181}\pi_t^e + \underset{(0.8)}{.025}(y_t - y_{t-1}) + \underset{(0.3)}{.074}\sigma_t \qquad R^2 = .82 \quad \hat{\rho} = .89$$

Two results of methodological interest need to be emphasized. First, a potentially useful measure of one type of uncertainty seems to be available over a 30 year period and could be used for empirical work in a number of areas. Second, the extraction of useful information from interest rate equations seems to require the inclusion of lagged values of all right-hand side variables unless their role can be reasonably excluded a priori or by lack of explanatory power.

Although this paper has not been directly concerned with the execution of monetary policy, one concluding comment is suggested by the results of the last section. Our results indicate that uncertainty of this type has a substantial effect on interest rates and is itself entangled with current and past money growth. This suggests that changes in the rate of money growth engender "uncertainty" effects on interest rates in addition to the already familiar effects. Such an effect is likely to be complex and can be added to the other difficulties encountered when a monetary authority implements policy in the form of interest rate "targets." It could be argued that the existence of this effect has had something to do with the lack of success of such strategies over the last few decades, culminating in the ostensible abandonment of interest rate targets in October 1979 [5].

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