Inflation and inflation uncertainty

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This article examines whether higher inflation has been associated with greater inflation uncertainty in the United Kingdom during the post-war period, using various descriptive and econometric estimates of uncertainty. Though the results cannot establish conclusively whether there has been a causal link, they do suggest that the level of inflation and inflation uncertainty are positively correlated. If inflation uncertainty is costly, this provides a potential justification for directing policy at establishing and sustaining an environment of low inflation.

Introduction

One of the most important costs of inflation is thought to be the uncertainty it generates about future inflation. This uncertainty potentially introduces various distortions into economic behaviour by, among other things, making it more difficult for economic agents to distinguish between (real) relative price movements and (nominal) inflationary ones; adding risk premia to longer-term nominal bonds and increasing the real cost of capital; and encouraging unproductive investment in real assets as a hedge against unanticipated inflation.(1) These effects are likely to inhibit the allocative efficiency of the price mechanism, thereby reducing economic welfare and possibly growth. (These costs of inflation uncertainty are additional to those related to anticipated inflation, as discussed in the article on pages 274–84.)

At least as far back as Okun (1971) and Friedman (1977), it has been claimed that higher inflation itself leads to greater inflation uncertainty. If this proposition is correct, it provides a strong justification for a policy aimed at securing low, and so more stable, inflation. But the findings from the vast body of literature looking at this relationship, using data both across country and over time, are far from conclusive. Though it is fairly well established that high rates of inflation are associated with greater inflation variability, the link with inflation uncertainty—the unpredictability of future inflation—is less clear-cut (see for example Driffill, Mizon and Ulph (1990)).(2)

The aim of this article is to present some evidence on the association between UK inflation and inflation uncertainty during the post-war period. Since inflation uncertainty is not directly observable, we consider various proxies, including descriptive measures of inflation variability and econometric estimates of uncertainty derived using an ARCH (autoregressive conditional heteroskedasticity) model approach.(3) Though the framework adopted does not allow any conclusive inference to be drawn about causality, the results support the view that inflation uncertainty is positively associated with the level of inflation.

Why might inflation uncertainty increase with the level of inflation?

The best-known exposition of the link between inflation and inflation uncertainty appears in Friedman's Nobel lecture on 'Inflation and Unemployment' (1977), though similar arguments were advanced earlier by Okun (1971) in his article on 'The Mirage of Steady Inflation'. In an often-quoted passage, Friedman proposed the following explanation for expecting a relationship between inflation and inflation variability or uncertainty:

> '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 recognises that there is great uncertainty about what actual inflation will turn out to be over any specific future interval.'

More recently, Ball (1992) has formalised this basic intuition in a game-theoretic setting. In his theoretical model, two types of policy-maker alternate in power. One policy-maker cares solely about inflation, the other about inflation and unemployment; but agents in the economy do not know which type of policy-maker is in charge. (The real-world equivalent of this might be that people do not know what the true preferences of the authorities are.) When inflation is low, there is no difference between the actions of either policy-maker: both act to maintain low inflation. But when inflation is high, there is a difference. One policy-maker would be prepared to pay the temporary

(1) These and other costs of inflation were discussed in the then Governor's inaugural London School of Economics, Bank of England lecture (Leigh-Pemberton (1992)). A recent review of the literature on this subject appeared in Briault (1995).
(2) This is a particularly important distinction from the perspective of measuring the costs of inflation uncertainty because it is clearly the possibility of unexpected inflation outcomes, rather than its variability *per se*, that is most important. For example, provided that it can be accurately predicted, inflation need have no effect on the real cost of capital.
(3) This work is described more fully in Joyce (1995).

unemployment costs of disinflating the economy; the other would not. And since the public does not know which type of policy-maker is in charge, uncertainty about future inflation increases.

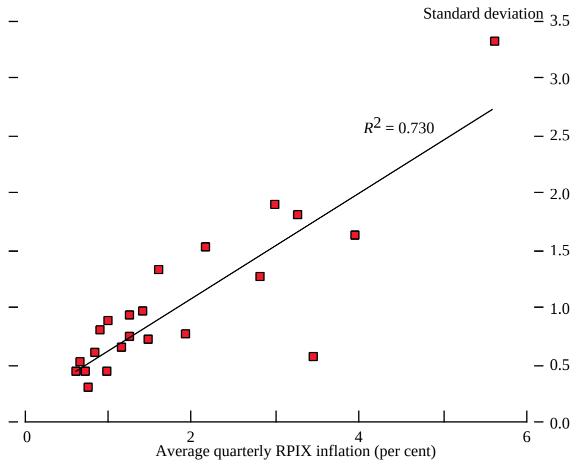
There are other possible theories that imply a causal relationship from inflation to inflation uncertainty, but a correlation could also arise for reasons quite unconnected with causality, and there are several theoretical models with this property. For example, in Devereux (1989), a correlation between the level and the variability of inflation arises through the common influence of the variability of 'real' disturbances.[1] Indeed, there is some empirical evidence that the historical association between the level and volatility of US inflation may partly reflect the independent influence of energy price shocks (see Holland 1984).

Inflation and inflation variability

The early literature on the inflation-uncertainty relationship measured uncertainty using various descriptive measures of inflation variability, such as the variance or standard deviation. The difficulty with using such measures is that they may bear little relation to uncertainty if variations in inflation are predictable. Nevertheless, for completeness and as a cross-check on the ARCH model-based estimates of inflation uncertainty that follow, some descriptive measures of UK inflation variability and how they relate to inflation are considered below.

Chart 1 plots the standard deviation of underlying quarterly (RPIX) inflation against average inflation for non-overlapping four-quarter periods, using the available data back to 1975.[2] The least-squares regression line plotted through the data suggests that there is a positive relationship between the two series, though its strength is clearly sensitive to one outlying observation (for 1975[3]).

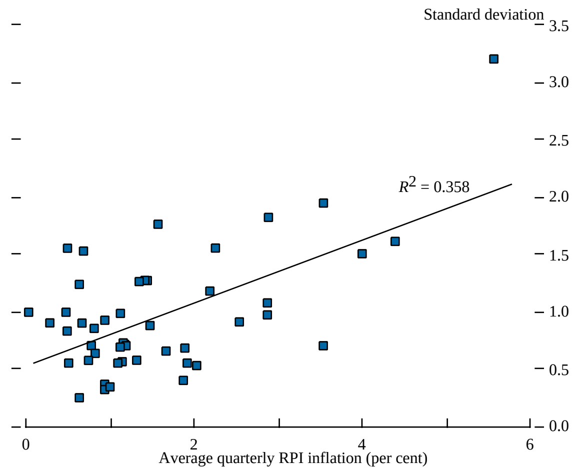
Chart 1
Standard deviation and average level of RPIX inflation,[a] over non-overlapping four-quarter periods



(a) Derived from quarterly data, 1975 to 1996.

The fairly short sample period used in Chart 1 is dictated by the availability of data for RPIX. To extend the sample back for the post-war period, the rest of this article focuses on RPI inflation data.[4] Chart 2 repeats the same analysis as in Chart 1 using these data back to 1950. The association is somewhat weaker for this longer sample, but still positive, suggesting that higher inflation tends to be more volatile over quite short horizons.

Chart 2
Standard deviation and average level of RPI inflation,[a] over non-overlapping four-quarter periods



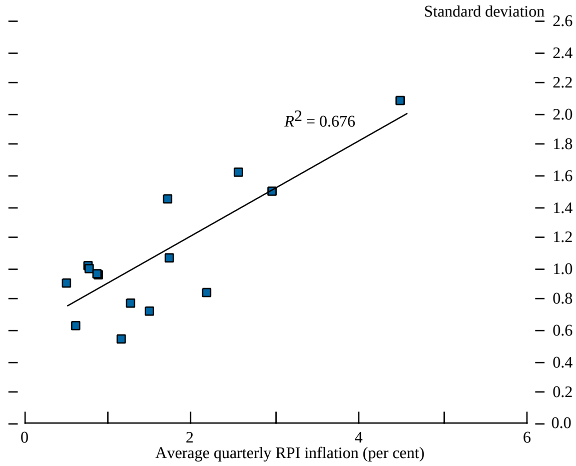
(a) Derived from quarterly data, 1950 to 1996.

It is sometimes argued that, in measuring the costs of inflation, longer-run uncertainty about inflation is more important, because this form of uncertainty is most relevant to the risk involved in entering long-term nominal contracts (see for example Ball and Cecchetti (1990)). By averaging over longer periods, it is possible to examine whether longer-run variability is more associated than shorter-run variability with the level of inflation. Charts 3 and 4 therefore consider the same relationship but using twelve-quarter and twenty-quarter periods. Though comparison of the charts provides some evidence for there being a stronger relationship over longer horizons, in each case the correlation is positive and statistically significant.

So on the basis of this simple descriptive analysis, it seems that during the post-war period higher inflation in the United Kingdom has been associated with greater inflation variability.

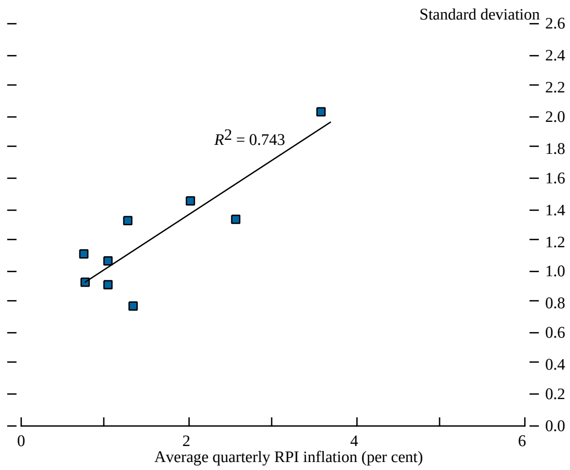
(1) This arises in the following way. As the variance of real shocks increases, the level of wage indexation in the economy is assumed to fall and the monetary authorities are assumed to have a greater incentive to create inflation surprises to engineer higher output. This raises average inflation. At the same time, the greater variability of real shocks also leads to higher variability in output and inflation. Hence the correlation, without causation, between average inflation and inflation variability.
(2) Throughout this article, inflation is measured using the conventional logarithmic approximation, so that any one quarter's inflation rate is calculated as 100 multiplied by the logarithmic difference between the retail price index for that quarter and that for the previous quarter. End-quarter (final-month) data are used throughout.
(3) The high variability of inflation during 1975 partly reflects a large change in VAT in that year.
(4) An alternative method of extending the sample would be to splice together the series for RPIX and RPI. None of the results illustrated here is changed significantly by doing so, but using RPI throughout has the benefit of consistency.

Chart 3
Standard deviation and average level of RPI inflation,[a] over non-overlapping twelve-quarter periods



(a) Derived from quarterly data, 1950 to 1994.

Chart 4
Standard deviation and average level of RPI inflation,[a] over non-overlapping twenty-quarter periods



(a) Derived from quarterly data, 1950 to 1994.

Inflation and inflation uncertainty

As already noted, finding a link between the level of inflation and inflation variability need not imply a relationship between inflation and inflation uncertainty. Unfortunately, measuring inflation uncertainty is problematic because it is not directly observable. In previous studies, researchers have typically used proxies based on survey data (often measures of the dispersion of inflation forecasts among individual survey respondents, see for example Holland (1984)) or the variance or standard deviation of the forecast errors from an econometric model of inflation, assuming that the latter is representative of the implicit model being used by economic agents to forecast inflation. For the period considered here, there are no suitable survey data with which to measure inflation uncertainty, so an econometric approach is adopted.

The measures of inflation uncertainty used are derived from the estimation of various forms of ARCH model for UK post-war inflation. (Further background on ARCH models is given in the box on page 288.) ARCH models provide a natural framework for measuring inflation uncertainty and, though now more commonly associated with the finance literature, were in fact first applied in this way (see for example Engle (1982 and 1983) and Bollerslev (1986)). An ARCH model takes the form of a regression model (here for quarterly inflation) which is estimated subject to an assumption that the model's conditional error variance (here the variance of errors in predicting inflation—a natural analogue of uncertainty) changes over time in a particular way. The ARCH acronym relates to the fact that uncertainty (the conditional variance of the variable) is assumed to depend only on the size of past squared errors in predicting the variable being modelled. So when applied to modelling inflation, the use of an ARCH model assumes that inflation uncertainty depends only on the size of past squared errors in forecasting inflation. This assumption is appropriate where both large and small forecasting errors occur in clusters, which has been observed to be the case with inflation.

Recent extensions of the ARCH framework—motivated primarily by the inability of these simple models to explain important features of financial data[1]—have resulted in a variety of models that allow uncertainty about the future value of a variable (its conditional variance) to respond differently according to whether the model over or under-predicted the level of the variable in previous periods. These developments are useful in estimating inflation uncertainty, because some of the arguments for expecting higher inflation to lead to greater inflation uncertainty might suggest that higher-than-expected inflation ('bad news') could generate more uncertainty about future inflation than lower-than-expected inflation ('good news'). Asymmetric ARCH models allow this hypothesis to be tested.

To apply the ARCH approach, a model of the level of inflation first needs to be estimated. The results described below are based on a simple autoregressive model in which the level of inflation in each quarter was explained by the behaviour of inflation in previous quarters and seasonal factors (to allow for the fact that the RPI figures are not seasonally adjusted).[2] This approach is obviously restrictive, since it assumes that the relevant information set for forecasting inflation is both limited and timeless—it cannot therefore make any allowance for the effects on uncertainty arising from different monetary regimes. Nevertheless, this model appears to explain the level of inflation reasonably well on most statistical criteria. However, the prediction errors from this model show the

(1) In particular, the 'leverage' effect, whereby an unexpected stock price fall produces a bigger increase in volatility than an equivalent price rise.
(2) Adjustments were also made for the effect of two particularly large VAT changes in 1975 and 1979, implicitly assuming that these were perfectly anticipated and therefore did not lead to additional inflation uncertainty. Details are contained in Joyce (1995).

ARCH models

Autoregressive conditional heteroskedasticity (ARCH) models were originally introduced by Engle (1982). In broad terms, the approach involves estimating a regression model, subject to an assumption that the model errors follow a specific form of heteroskedasticity (or non-constant error variance). More specifically, in the simplest case of an ARCH(1) model, the error term is specified as conditional normal, with the variance a time-varying function of the one-period lagged squared errors. Thus, if the dependent variable is described by a first-order autoregression, the complete AR(1)-ARCH(1) model can be written as

$$y_t = \alpha + \beta y_{t-1} + \varepsilon_t \qquad (1)$$

$$\varepsilon_t | \Omega_{t-1} \sim N(0, h_t) \qquad (2)$$

$$h_t = \gamma_0 + \gamma_1 \varepsilon_{t-1}^2 \qquad (3)$$

where y_t is the level of the variable being modelled, h_t is its conditional variance, ε_t is a random error, and α, β, γ_0 and γ_1 are parameters.

Estimation of this model is possible using maximum likelihood techniques, subject to initial starting values for the lagged squared forecast error.

An extension of the model to include the lagged dependent variable in the conditional variance equation—termed 'generalised ARCH' (or GARCH)—was subsequently suggested by Bollerslev (1986). Thus equation (**3**) becomes

$$h_t = \gamma_0 + \gamma_1 \varepsilon_{t-1}^2 + \delta h_{t-1} \qquad (4)$$

The order (or number of lags) of the ARCH or GARCH process can in principle be extended to any value, but in many applications a GARCH model including only the first period lags of h_t and e_t^2 has been found to be adequate (this is known as a GARCH(1,1) model).

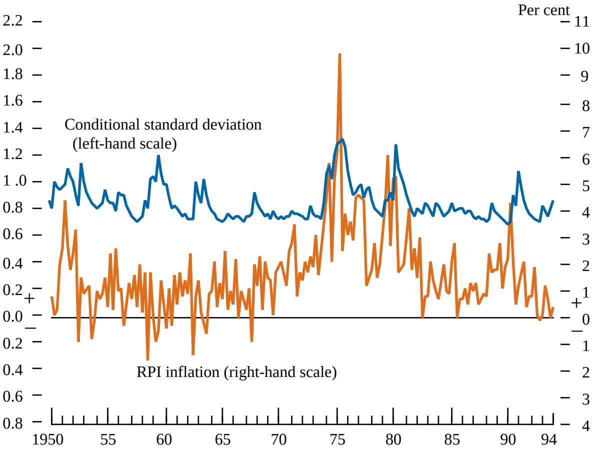
For modelling inflation uncertainty, standard ARCH and GARCH models have the undesirable feature that they impose a symmetry restriction on the lagged errors, which implies that good news and bad news have identical effects on uncertainty. In fact, in the empirical work reported in this article, a variety of asymmetric models were found to be superior in fitting UK inflation data. The text reports results from the best-fitting asymmetric models, the exponential GARCH (EGARCH) model (due to Nelson (1990)) and the GJR model (proposed by Glosten, Jagannathan and Runkle (1993)), both of which allow higher-than-expected inflation in the previous quarter to increase measured inflation uncertainty by a greater amount than lower-than-expected inflation.(1)

(1) For further discussion of asymmetric ARCH models, see Engle and Ng (1993).

clustering which is consistent with there being ARCH effects. The conditional error variance of the model was therefore modelled in terms of various types of ARCH process. The analysis shows that asymmetric models that allow this conditional variance to respond more sharply to previous under-predictions of inflation are slightly superior in fitting the data.

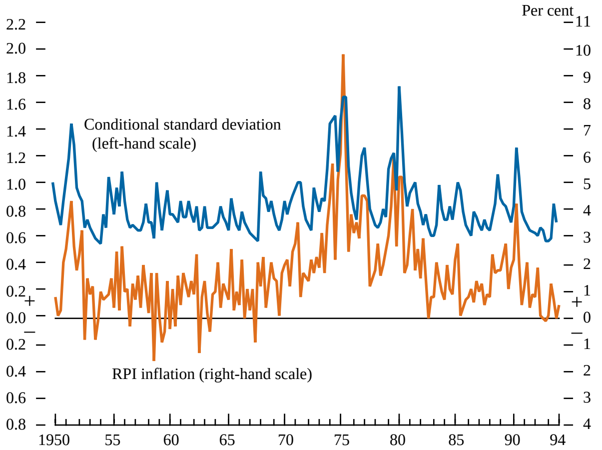
Charts 5, 6 and 7 plot measures of short-run inflation uncertainty (expressed in terms of the one-quarter-ahead conditional standard deviations) from three slightly differently ARCH models against post-war quarterly RPI inflation.(1) The uncertainty measure shown in Chart 5 is

Chart 5
Quarterly RPI inflation and estimated inflation uncertainty from GARCH model



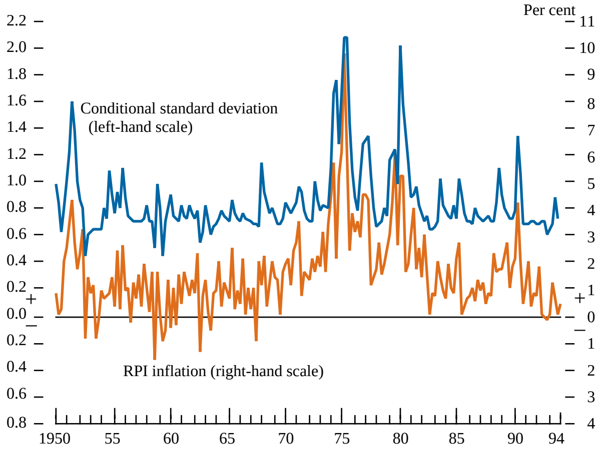
from a generalised ARCH (GARCH) model that imposes the symmetry restriction that the forecast of the next period's inflation volatility responds only to the size of this period's inflation news, ignoring whether inflation was higher or lower than expected. By contrast, Charts 6 and 7 show uncertainty derived from two models—the exponential GARCH (EGARCH) model and the GJR model (see the box for further details)—that allow the next period's expected

Chart 6
Quarterly RPI inflation and estimated inflation uncertainty from EGARCH model



(1) The choice of a short-run measure of inflation uncertainty is dictated by the use of the ARCH framework, since the set-up of these models implies that over longer-run horizons the conditional variance must converge to the constant unconditional variance of the model.

Chart 7
Quarterly RPI inflation and estimated inflation uncertainty from GJR model



inflation volatility to respond differently according to whether this period's outturn for inflation was higher or lower than expected.

All three measures of inflation uncertainty (shown in blue on each chart) track inflation (the orange line) reasonably closely during the post-war period. Thus inflation and inflation uncertainty in the 1990s have both been at low levels, broadly similar to those achieved on average in the 1950s and 1960s. The two periods of greatest uncertainty were in the mid 1970s, when inflation reached its post-war peak, and in the early 1980s.

But despite these broad similarities, it is noticeable that the uncertainty measures based on the models that discriminate between the effects of good and bad inflation news are much more sensitive to movements in inflation than the model that imposes the restriction that all news generates the same amount of uncertainty. This is brought out very clearly in the scatter plots in Chart 8, 9 and 10, which show the correlation between lagged inflation and estimated uncertainty from each of the three models. As is shown by

Chart 8
Estimated inflation uncertainty from GARCH model and lagged quarterly RPI inflation

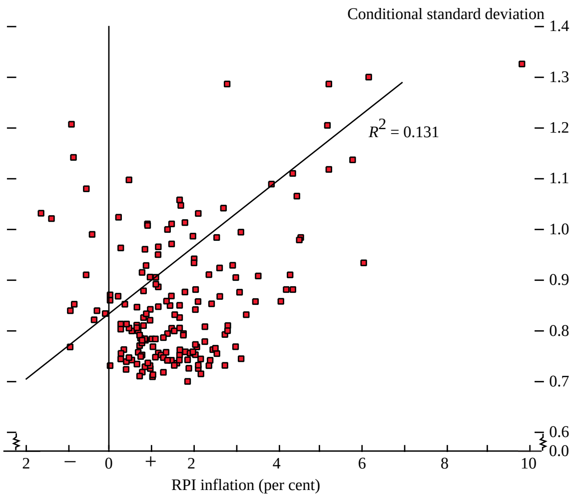
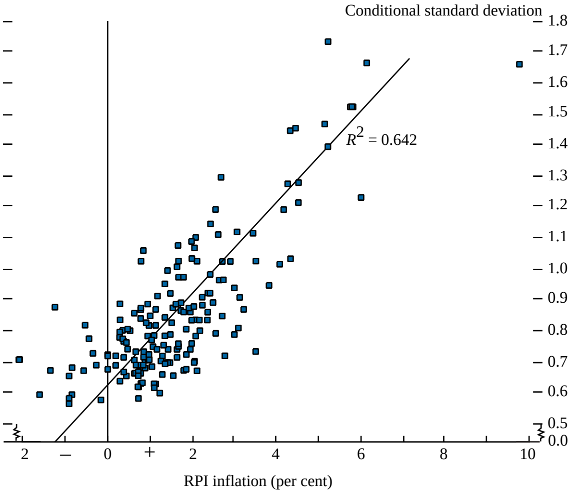
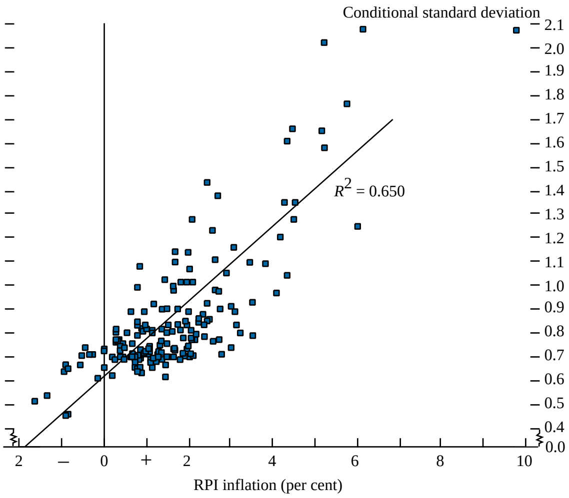


Chart 9
Estimated inflation uncertainty from EGARCH model and lagged quarterly RPI inflation



the statistical fit of the associated regression lines, though there is a clear positive relationship in each case, there is a much stronger association between lagged inflation and measured uncertainty based on the asymmetric EGARCH and GJR models. This finding, which mirrors that of Brunner and Hess (1993) for the United States using a slightly different asymmetric approach, emphasises the importance of allowing positive and negative inflation shocks to have different effects on expected volatility.

Chart 10
Estimated inflation uncertainty from GJR model and lagged quarterly RPI inflation



Conclusions

The aim of this article has been to review some evidence on post-war inflation in the United Kingdom to see whether it is consistent with the claim that higher inflation is associated with greater inflation uncertainty. The descriptive analysis presented supports the existence of a positive relationship between the level of inflation and various measures of inflation variability during this period. More interestingly perhaps, the econometrically derived estimates of inflation uncertainty also appear to be associated with the level of inflation, and these correlations are greater when uncertainty is modelled in what seems *a priori* to be a more plausible way, allowing it to respond differently to good and bad inflation shocks. Clearly, these estimates of inflation uncertainty are subject to the limitations of the modelling approach adopted, which may not correspond to that used by households and firms in the economy. Moreover, since no allowance is made for other factors in the models employed, the findings cannot establish conclusively that there is a causal link between the level of inflation and inflation uncertainty. One must therefore be cautious in drawing policy inferences. Nevertheless, the balance of the evidence is consistent with there being a positive association, which suggests there may be benefits—in terms of the costs of uncertainty—in directing policy at establishing and sustaining an environment of low inflation.

References

Ball, L (1992), 'Why Does High Inflation Raise Inflation Uncertainty?', *Journal of Monetary Economics*, 29, pages 371–88.

Ball, L and Cecchetti, S G (1990), 'Inflation and Uncertainty at Short and Long Horizons', *Brookings Papers on Economic Activity*, 1, pages 215–54.

Bollerslev, T (1986), 'Generalised Autoregressive Conditional Heteroscedasticity', *Journal of Econometrics*, 31, pages 307–27.

Briault, C (1995), 'The costs of inflation', *Bank of England Quarterly Bulletin*, Volume 35, February, pages 33–45.

Brunner, A D and Hess, G D (1993), 'Are Higher Levels of Inflation Less Predictable? A State-Dependent Conditional Heteroscedasticity Approach', *Journal of Business and Economic Statistics*, Vol 11, No 2, pages 187–97.

Devereux, M (1989), 'A Positive Theory of Inflation and Inflation Variance', Economic Enquiry, Vol XXVII, pages 105–16.

Driffill, J, Mizon, G E and Ulph, A (1990), 'Costs of Inflation', in Friedman, B M and Hahn, F H, *The Handbook of Monetary Economics*, Volume II, North Holland.

Engle, R F (1982), 'Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation', *Econometrica*, 50, pages 987–1,007.

Engle, R F (1983), 'Estimates of the Variance of US Inflation Based Upon the ARCH Model', *Journal of Money*, *Credit and Banking*, Vol 15, pages 286–301.

Engle, R F and Ng, V K (1993), 'Measuring and Testing the Impact of News on Volatility', *The Journal of Finance*, Vol XLVIII, No 5, pages 1,749–78.

Friedman, M (1977), 'Nobel Lecture: Inflation and Unemployment', *Journal of Political Economy*, 85, pages 451–72.

Glosten, L, Jagannathan, R and Runkle, D (1993), 'On The Relation Between the Expected Value and the Volatility of the Nominal Excess Return on Stocks', *The Journal of Finance*, Vol XLVIII, No 5, pages 1,779–801.

Holland, A S (1984), 'Does Higher Inflation lead to More Uncertain Inflation', Federal Reserve Bank of St Louis, February.

Joyce, M A S (1995), 'Modelling UK Inflation Uncertainty: The Impact of News and the Relationship with Inflation', Bank of England, *Working Paper Series*, No 30.

Leigh-Pemberton, R (1992), 'The case for price stability', *Bank of England Quarterly Bulletin*, Volume 32, November, pages 441–48.

Nelson, D (1990), 'Conditional Heteroscedasticity in Asset Returns: A New Approach', *Econometrica*, Vol 59, pages 347–70.

Okun, A M (1971), 'The Mirage of Steady Inflation', *Brookings Papers on Economic Activity*, 2, pages 485–98.