TRANQUILITY, VOLATILITY, AND CORE INFLATION

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ABSTRACT
This paper investigates the behavior of inflation over the recent past with primary focus on volatility, not the level of inflation. Over the past 60 years, the inflation rate has shown periods of tranquility as well as periods of volatility. Recent evidence suggests that inflation, after a period tranquility during the 1990s, became more volatile early in the new century (perhaps even as early as 1999)—prior to the current run-up in the energy and food sectors. Evidence of the increased volatility is presented and the volatility is modeled with a relatively simple autoregressive conditional heteroskedasticity (ARCH) model. We also attempt to offer some explanation for the recent volatility.

INTRODUCTION
The autoregressive conditional heteroskedasticity (ARCH) model was developed by Robert Engle [3] to explain volatility “clustering,” that is, periods in which the variance of a time series is tranquil and other periods in which the variance of the series is more volatile. The ARCH model and its extension, generalized ARCH (GARCH), have been applied to numerous economic and financial series. These models are important in identifying periods of volatility and they also aid in producing more realistic interval forecasts. In a prior paper [6], we found evidence of ARCH effects for the Consumer Price Index (CPI). That index includes food and energy prices, components known to be more volatile that the general index. Excluding food and energy prices from the CPI results in what is known as “core” inflation—a measure many economists favor as a measure of overall price stability. Because it is widely recognized that the very recent past has been characterized by volatility in food and energy prices, it is prudent to test core inflation for volatility. That, then, is the objective of this project.

DATA, METHOD, PRELIMINARY RESULTS
We collected the monthly measure of the Consumer Price Index (CPI) excluding energy and food prices for the period January 1957 to March 2009. The measure of inflation is the monthly log difference in the core CPI at annual rates. That series is shown in Figure 1.

Casual observation of Figure 1 suggests that inflation was quite volatile in the 1970s and early 1980s. Periods of tranquility seem to be evident beginning in the mid-eighties. It is well known that simple inspection of the variance of a series can be misleading when the series is autocorrelated. To correct for this, we fit an autoregressive model to the inflation rate. The lags were chosen using standard penalized likelihood model selection criteria. The form of the autoregressive model can be represented as follows:

\[ \text{INFL}_t = a_0 + \sum_{i=1}^{p} b_i \text{INFL}_{t-i} + e_t \]  

where \( \text{INFL} \) is annualized monthly inflation, \( t \) indexes time, \( e_t \) is a white noise disturbance term and the \( b_i \) \( (i = 1, \ldots, p) \) are the lag coefficients, and \( p \) indicates the order of the lags. The two standard penalized likelihood selection criteria are the Akaike information criterion (AIC) and the Schwarz information criterion (SIC) represented as follows:
where \( k \) is the total number of estimated coefficients in the VAR, \( T \) is the number of usable observations, and \( \sigma \) is the scalar estimate of the variance of the equation's disturbance term. If the \( AIC \) and the \( SIC \) differed on the number of lags, each indicated model was estimated, with evidence presented here for the most parsimonious model. The \( SIC \) chose \( p = 6 \), and we present additional evidence based on that model.

Figure 1: Monthly Core Inflation at Annualized Rates

Figure 2 depicts the residuals from the autoregressive model for inflation, with the same periods of volatility and tranquility evident, with the possible addition of a spike in the variance at about 1960.

Testing for volatility is usually accomplished by analysis of the squared residuals from an autoregressive model, such as depicted in Figure 3. The reasoning for testing the squared residuals is simple. The residuals from the autoregressive model (see Figure 2) will be serially uncorrelated as a result of the autoregressive lag fit. Those residuals are, however, not independent. Small (in absolute value) residuals are likely to be followed by additional small residuals, and large residuals are likely followed by other large residuals—that is the meaning of volatility clustering.
Figure 3 shows the same clustering effect for the squared residuals. To test for ARCH errors, a second regression was run:

$$e_t^2 = c_0 + \sum_{i=1}^{p} d_i e_{t-i}^2 + \nu_t$$

(4)
where \( e_i^2 \) represents the squared residuals from equation 1, and the \( d_i \) (\( i = 1, \ldots, p \)) are lag coefficients and \( p \) again indicates the order of the lags. If there are no ARCH effects, then equation 4 will have little explanatory power, i.e., \( R^2 \) will be very low. The existence of ARCH effects can be tested in two ways. First with a sample of \( T \) residuals, \( TR^2 \) is distributed as \( \chi^2 \) with \( p \) degrees of freedom. Alternatively, an F-test that all \( d_i \) coefficients are jointly zero will also indicate whether or not ARCH effects are present. The SIC chooses 3 lags for equation 4.

The estimated equation for (4) is:

\[
\hat{e}_t^2 = 2.70 + 0.023 \hat{e}_{t-1}^2 + 0.18 \hat{e}_{t-2}^2 + 0.17 \hat{e}_{t-3}^2
\]

\[R^2 = 0.0637\]
\[T = 617\]

The null hypothesis of no ARCH effects can be written:

\[H_0: d_1 = d_2 = d_3 = 0 \text{ (there are no ARCH effects)}\]
\[H_1: \text{ some } d_i \neq 0 \text{ (there are ARCH effects)}\]

As expected, the null hypothesis is rejected resoundingly for either the \( \chi^2 \) test (\( \hat{\chi}^2 = 41.12 \), p-value = 0.0000), or the F-test (\( F_{(df = 3, 613)} = 14.97 \), p-value = 0.0000). We conclude that the process of inflation is subject to ARCH effects. Thus we have confirming statistical and visual evidence that small squared residuals tend to be followed by small squared residuals, and large squared residuals are more often followed by other large squared residuals.

**OTHER RESULTS**

The ARCH errors model is typically estimated simultaneously with the autoregressive model of inflation by maximum likelihood methods. That estimation also yields an estimate of the variance of the series, typically known as the \( h \) series. Again choosing \( p = 6 \) for the autoregressive presentation for inflation, and \( p = 3 \), for the variance of the series, we present the portion of the equation that represents the variance (here, \( h \)) of the inflation series (here we are less interested in the autoregressive parameters of the estimate of inflation, since many alternative inflation forecasting models are possible):

\[
h_t = 1.41 + 0.17 \hat{e}_{t-1}^2 + 0.40 \hat{e}_{t-2}^2 + 0.15 \hat{e}_{t-3}^2
\]

\[(2.76) \quad (6.06) \quad (2.65)\]

where \( h \) is the estimated conditional variance in inflation and the numbers in parentheses are t-statistics.

Figure 4 represents the conditional variance of inflation based on the ARCH model estimated by maximum likelihood methods. Two things from Figure 4 are striking for recent inflation. First, consistent with prior results, there was a marked period of tranquility, beginning near 1985 and lasting through the most recent data. This result is in marked contrast to our prior work on “headline” inflation—where we found that a new period of volatility began in approximately 1999 and extended through the current period.

As a final visual for the effects on forecasting of the increase in volatility, we offer Figure 5, an estimate of 95% error bands for inflation forecasts. In the graph, we limit the time period to the 1990s until the end of the dataset and, for simplicity, we assume a 2.5% forecast of inflation.
In the graph, it is once again clear that the variance in inflation, and hence the 95% confidence interval around inflation forecasts was relatively narrow from the early 1990s and has had no tendency to widen during the last ten or so years, again in contrast to our earlier findings.

To summarize the results of this section, we find in favor of ARCH effects for the inflation series. The statistical and visual evidence are (we think) very clear. That result is interesting, but not particularly
surprising. We do find surprising that the extremely tranquil period through most of the 1990s extends through the end of the data period.

ECONOMIC EVENTS AND INFLATION

The tranquil period of the 1990s can be considered a part of The Great Moderation. This term, coined by Stock and Watson [7], refers to the simultaneous reduction in the volatility of inflation and real output that began in 1984. Bernanke [1] popularized this moniker and explained that economists attribute its occurrence to structural changes in the economy, improved monetary policy, and good luck. Structural changes include the smaller share of output attributed to durable goods production, improvements in inventory management, and increased openness in international trade and capital flows. The change in monetary policy refers to the increased emphasis on fighting inflation that began in 1979. Good luck took the form of fewer exogenous shocks, such as oil and other commodity price increases and financial crises. The empirical evidence on the relative importance of these three classes of causes of decreased economic volatility is decidedly mixed and it remains an important area of research.

As noted above, our earlier research documented an increased volatility of headline inflation over the past few years. The terrorist attacks on New York and Washington, wars in Afghanistan and Iraq, oil and food price shocks, and the bursting of two speculative bubbles can all be classified as exogenous shocks. The fact that the earliest of these shocks, namely the precipitous decline in stock prices in 2000, occurred in the year after the current period of “headline” inflation volatility began is surprising and interesting to us.

Core inflation, on the other hand, shows no tendency at all to increased volatility since the early 1990s. Such a result may indicate that monetary policy maintained relative price and variance stability even during a period of new macroeconomic shocks to the economy.

CONCLUSIONS

This research finds in favor of modeling inflation as an ARCH process, consistent with much other research on inflation. Our primary findings in this paper include the following three conclusions. First, the decline in core inflation variance that began in the 1980s extends through the current period. Second, the increased variance in headline inflation that followed the period of 1990s is notably absent from the core inflation series. Third, the increased volatility noted in headline inflation is likely due solely to energy and food sectors.

REFERENCES


