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Authors	Jeremy M. Piger, and Robert H. Rasche
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Federal Reserve Bank of St. Louis, Research Division, P.O. Box 442, St. Louis, MO 63166

Inflation: Do Expectations Trump the Gap?*

Jeremy M. Piger
Federal Reserve Bank of St. Louis

Robert H. Rasche
Federal Reserve Bank of St. Louis

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Abstract: We measure the relative contribution of the deviation of real activity from its equilibrium (the gap), "supply shock" variables, and long-horizon inflation forecasts for explaining the U.S. inflation rate in the post-war period. For alternative specifications for the inflation driving process and measures of inflation and the gap we reach a similar conclusion: the contribution of changes in long-horizon inflation forecasts dominates that for the gap and supply shock variables. Put another way, variation in long-horizon inflation forecasts explains the bulk of the movement in realized inflation. Further, we find evidence that long-horizon forecasts have become substantially less volatile over the sample period, suggesting that permanent shocks to the inflation rate have moderated. Finally, we use our preferred specification for the inflation driving process to compute a history of model-based forecasts of the inflation rate. For both short and long horizons these forecasts are close to inflation expectations in surveys and market data.

Keywords: Inflation persistence, Inflation forecast, Phillips Curve

JEL Codes: C32, E31

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* Piger: Research Department, Federal Reserve Bank of St. Louis, P.O. Box 442, St. Louis, MO 63166 (piger@stls.frb.org); Rasche (corresponding author): Research Department, Federal Reserve Bank of St. Louis, P.O. Box 442, St. Louis, MO 63166 (rasche@stls.frb.org). The views expressed here are those of the authors and do not necessarily reflect official positions of the Federal Reserve Bank of St. Louis, the Federal Reserve System, or the Board of Governors.

1. Introduction

The Phillips Curve is one of the most widely recognized concepts in modern macroeconomics, and is widely used as both a theoretical construct and empirical tool. At the core of the Phillips Curve is a relationship between inflation and the real activity "gap", defined as the deviation of real economic activity from its equilibrium level. The within-sample statistical support for such a relationship in U.S. data over the post-war period is well documented in a number of studies, primary among them the work of Robert Gordon over the past 20 years (Gordon, 1982, 1997, 1998). In particular, the gap is strongly statistically significant as an explanatory variable for inflation, and this significance is robust to a broad range of specifications of the Phillips Curve. More recently, a number of papers have evaluated the out-of-sample forecasting performance of the Phillips curve. Here the evidence in favor of the gap as a driver for inflation is more mixed, with some papers documenting a substantial out-of-sample relationship, (e.g. Stock and Watson, 1999), while others find that inflation forecasts from a Phillips curve are not better than those from simple benchmark models such as a random walk or an autoregression (e.g. Atkeson and Ohanian, 2001; Orphanides and Van Norden, 2003). Clark and McCracken (2003) provide a thorough exploration of the in-sample vs. out-of-sample performance of the Phillips Curve.

In this paper we revisit the importance of the gap as an explanatory variable for U.S. inflation over the post-war period. However, rather than measure importance with statistical significance, we instead focus on the relative contribution of the gap and other potential inflation drivers, such as changes in long-horizon inflation forecasts and "supply shock" variables, for explaining the realized inflation rate. The initial analysis uses a specification for the inflation driving process similar to that espoused by Gordon (1982, 1997, 1998). Subsequently we investigate a specification that replaces the distributed lag on the inflation rate present in the Gordon specification with a time-varying intercept that follows a random walk process. We show that this time-varying intercept (TVI) model can be restated in terms of the forward forecast of the inflation rate and distributed lags on the gap and supply shock variables. The results from both the Gordon and TVI specifications are clear: Changes in long-horizon inflation forecasts dominate the gap and supply shock variables in the determination of actual inflation.[1]

We then turn to more detailed analysis of the TVI model-based inflation forecasts. To begin, we allow for a sequence of structural breaks in the variance of shocks to the random walk intercept. The estimates display a hump-shaped pattern, with the variance rising substantially during the late 1960s and the 1970s from its value in the 1950s and early 1960s, falling substantially in the early 1980s, and falling again in the early 1990s to its lowest level observed over the post-war period. This suggests that the size of permanent shocks to the inflation rate have varied substantially over the sample period.[2] Next, we use the TVI specification to construct histories of both short (one-month ahead) and long (10-year ahead) inflation forecasts and compare these to survey-based inflation forecasts. The model-based forecasts are quite close to the survey measures of expected inflation, suggesting that the TVI model provides a good description of the evolution of expectations. Given this success, we then use the model-based measures of expected inflation to derive time series estimates of *ex ante* real interest rates at various horizons for the past 50 years.

The remainder of the paper proceeds as follows: Section 2 presents results for the Gordon-type Phillips Curve specification, while Section 3 describes the TVI model and presents

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[1] This result is reminiscent of findings in the bond pricing literature that suggest changes in long-horizon inflation expectations are the dominant source of variation in long-horizon bond yields (e.g. Gürkaynak, Sack and Swanson, 2003; Rudebusch and Wu, 2004).

[2] Using a model with stochastic volatility, Stock and Watson (2006) also find substantial variability in the variance of shocks to the stochastic trend of inflation.

results from this specification. Section 4 compares the measures of inflation forecasts from the TVI model to survey-based measures of expected inflation and presents new estimates of *ex ante* real interest rates over the post-war period using the model-based inflation forecasts. Section 5 concludes.

2. Results from the Gordon-Type Specification

2.1 Model specification and estimation

We begin with the specification that is featured in various analyses conducted by Robert Gordon:

$$\pi_t = a(L)\pi_{t-1} + b(L)D_t + c(L)X_t + \varepsilon_t \tag{1}$$

This model relates the rate of inflation to a long (typically 24 quarter) distributed lag on inflation, a distributed lag on either the unemployment rate or the deviation of the unemployment rate from a time-varying NAIRU (an index of excess demand, D_t,) distributed lags on various supply shock variables including changes in relative import prices, changes in the relative price of food and energy, and/or deviations of productivity from trend, and dummy variables for the beginning and termination of the Nixon price controls in the early 1970s (a vector of supply shocks, X_t). The distributed lag on inflation, $a(L)\pi_{t-1}$, is generally interpreted as "reflecting the influence of several past years of inflation behavior on current price-setting, through some combination of expectation formation and overlapping wage and price contracts." (Gordon, 1998, p. 303)

Our specification differs from that in Gordon (1998) in that 1) it measures the gap using the "output gap", defined as the percentage deviation of real GDP from potential GDP as measured by the CBO, 2) it uses four lags on all variables (in contrast to the 24 lags on inflation used by Gordon), and 3) it does not include the productivity deviations present in the Gordon specification. We use changes in import prices relative to the GDP price index and changes in the "core" PCE price index relative to the PCE price index as does Gordon. All the estimations follow Gordon and exclude a constant term.[3] We construct parallel analyses for the CPI, the PCE price index and the GDP price index, each of which is measured in quarterly percentage changes at annual rates. Our estimates over the same 1962:Q1 – 1998:Q2 sample period used in Gordon (1998) are shown in Table 1. The distributed lag variables are specified so that the estimated sum of the lag coefficients appears in bold as the coefficient on the first variable (the first variable in each lag distribution is in levels, all subsequent variables are first differences).

In each of the three regressions the sum of the estimated coefficients on lagged inflation is not significantly different from unity and indeed never differs from 1.0 by more than 0.01. The estimated sum of the coefficients on the output gap ranges from 0.12 to 0.16 and, consistent with prior research, is highly significant for all three price indices. The estimated sum of the coefficients on changes in relative import prices ranges from 0.15 to 0.28 and is significant in two of the three equations. The sign of the sum of the estimated coefficients on changes in the relative price of food and energy is not consistent across the three equations, and is not significant in any equation, though the impact effect of this variable is always large and significant.

2.2 Stability

We investigate the robustness of these results in Figures 1-3, where we construct forward and backward recursive regressions for each of the three measures of inflation. In the forward

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[3] Some initial regressions were constructed that included the constant term. The estimated constant was insignificant and the estimates of the parameters of interest were unaffected by its omission.

recursions the sample period always begins in 1962:Q1. Initially the sample ends in 1970:Q1 and then is extended one quarter at a time through 2005:Q1. The graphs show the sum of the lag coefficients on each of the four regressors. Once the sample gets sufficiently long, around 80 quarters, the long-run coefficients on each of the variables settles down. However, for sample periods of less than 80 quarters the estimated long-run coefficients on the output gap, changes in relative import prices and changes in relative food and energy prices are very sensitive to additional observations. For very short sample periods (24 to 40 quarters) the sum of the lagged inflation coefficients in the CPI regression is substantially less than 1.0, but as the sample length is increased the estimate becomes very stable at close to 1.0. For the PCE and GDP measures of inflation the sum of the lagged inflation coefficients becomes close to 1.0 even for very short samples. In some cases the sum of these estimated coefficients even exceeds 1.0 implying, on the face of it, an explosive process.

In the backward recursive regressions the sample size increases from the most recent observations. In all cases the end of the sample is fixed at 2005:Q1 and the beginning of the sample is initially 1994:Q3 and then shifted backward a quarter at a time until 1962:Q1. In these experiments the estimated coefficients on the change in relative import prices and the change in the relative price of food and energy are highly unstable across sample periods that use only the data from the late 80s and 90s, regardless of the measure of inflation chosen. Over these same sample periods the estimated coefficient on the sum of the output gap terms is very small relative to the estimated value in the longer sample periods. Finally the sum of the estimated lag coefficients on inflation is fairly close to 1.0 regardless of the length of the sample period in the backward recursive regressions.

2.3 How much does the gap contribute to explaining the inflation process?

In this subsection we investigate the relative contribution of the output gap for explaining inflation dynamics. We begin this analysis with Figure 4. The panels in this figure illustrate the "marginal adjusted R^2" defined as:

$$1.0 - \frac{s^2_{withgap}}{s^2_{nogap}}$$

where $s^2_{withgap}$ is the squared standard error of estimate from the regression with all the regressors including the distributed lag on the output gap and s^2_{nogap} is the squared standard error of estimate from the regression that excludes the distributed lag on the output gap. For short sample periods, probably not surprisingly given the instability of the coefficient estimates noted above, this statistic is quite variable for the forward recursive regressions for the three measures of inflation. For the PCE and GDP measures of inflation for some samples the statistic is even negative, indicating that the other regressors account for a higher percentage of the variance of inflation in the absence of the gap terms than does the full regression specification including the gap terms. For the longer sample regressions using the PCE or GDP measures of inflation, the marginal contribution of the gap terms to accounting for the variance of inflation is quite low; on the order of 8 to 10 percent.

For the CPI measure of inflation the picture is different. The highest marginal contribution of the gap terms occurs for the shorter sample periods (late 60s and 70s) where at times the statistic exceeds 0.30. For the longer samples the statistic is generally around 0.14, substantially larger than computed for the other two measures of inflation but still indicating relatively little marginal explanatory power for the output gap terms.

The marginal adjusted R^2 from the reverse recursive regressions present a contrast to the statistics for the forward recursive regressions, but do not alter the conclusion that the marginal explanatory power of the output gap terms is minimal. The results for the CPI and GDP measures of inflation are highly variable as the sample size changes. In contrast, the results for the PCE measure of inflation are negative for the samples that involve only the most recent years of data.

Another way to address this question is to compare the values of the terms $a(L)\pi_{t-1}$, $b(L)D_t$, $c(L)X_t$ and ε_t for a regression over the entire sample period. These are shown in Figure 5-7 for regressions constructed on the sample 1962:1 – 2005:1. The message from these graphs is apparent and consistent with the analysis above: the output gap (and supply shock variables) accounts for only a minor portion of fluctuations in inflation in this specification regardless of the measure of inflation. In summary: for this model, expectations, as proxied by a distributed lag on inflation whose coefficients sum to 1.0, trump the gap!

3. Results from the Time-Varying Intercept Specification

Suppose that the distributed lag on inflation in the Gordon specification represents a proxy for long-horizon expected inflation that is specified to appear with a coefficient of 1.0 so that the long-run Phillips curve is vertical:

$$\pi_t = 1.0\pi_t^e + b(L)D_t + c(L)X_t + \varepsilon_t \qquad (2)$$

Alternatively this equation can be thought of as specifying a time-varying intercept (the expected rate of inflation) on a vector of 1.0's:

$$\pi_t = 1.0 z_t + b(L)D_t + c(L)X_t + \varepsilon_t \qquad (3)$$

We assume that z_t follows a random walk:[4]

$$z_t = z_{t-1} + \mu_t \qquad (4)$$

Equation (4) implies that, assuming stationarity of D_t and X_t, the infinite-horizon forecast of inflation is equal to z_t (see Beveridge and Nelson, 1981). Thus, z_t has the interpretation of the long-horizon inflation expectation.[5]

We estimate the model in (3) and (4) via maximum likelihood using the Kalman filter. The estimates of the model parameters are shown in Table 2 for the sample period 1962:Q1 to 2005:Q1. Table 2 also shows the standard error of the estimate for the Gordon equation estimated over the same sample period, which demonstrates that the time-varying intercept specification is competitive with the Gordon specification.

We focus our analysis on an expanded version of the time-varying intercept specification, the results of which are presented in Table 3. First, we extend the sample period back in time to include data subsequent to the end of the Korean War. Since the core PCE data are not available before 1959, we recompute the relative change in food and energy prices using CPI data. The "core CPI" is available starting in 1957. Prior to 1957 we use the all items CPI less food rather than the "core CPI". The two series are highly correlated in the late 1950s, since energy prices were not highly volatile until the early 1970s. Prior to 1987 we compute the relative change in food and energy prices using CPI data on a 1967=100 base, not seasonally adjusted, and apply

[4] This is similar to Gordon's specification of the time-varying NAIRU in his 1997 and 1998 papers.
[5] Equation (4) assumes that the shocks to long-horizon inflation expectations are frequent and continuous. An alternative is that shocks to long-horizon inflation expectations are infrequent and discrete. For an example of such a specification for modeling U.S. inflation see Levin and Piger (2002, 2006).

the current seasonal factors for these years using the 1982-84 base year data. We do this to avoid the truncation problems that affect the computation of CPI inflation rates in the early part of the sample period when the base year is 1982-84 = 100 (see Kozicki and Hoffman, 2004).

Second, we allow for structural breaks in the variance of the innovations to the time-varying intercept process to occur at several points in the sample that align with well known macroeconomic and monetary events. The first break is allowed to occur at the beginning of the Great Inflation, which we date to the first quarter of 1967. The second break is meant to capture the beginning of the large reduction in U.S. macroeconomic volatility that has been observed over the past two decades. Based on the findings of Kim and Nelson (1999) and McConnell and Perez-Quiros (2000), we date the beginning of this "Great Moderation" to the first quarter of 1984. We date the third break at the first quarter of 1994 when the FOMC started releasing information on changes in the intended federal funds rate at the close of FOMC meetings.

As Table 3 demonstrates, for all three measures of inflation the estimated variance of the innovations to the time-varying intercept increases sharply during the Great Inflation, falls to 40-50 percent of its 1953-66 value during the first decade of the Great Moderation, and then declines by roughly 50 percent of the value in the 1984-93 period during the most recent decade (see Figure 8 for a plot of the estimated innovations). This pattern for the volatility of shocks to the random-walk intercept suggests that the size of permanent shocks to the inflation rate have varied substantially over the sample period, and that such shocks are now quite small from a historical perspective. The latest decline in volatility is consistent with the notion that long-horizon inflation expectations have become better "anchored" during the period of increasing FOMC transparency, although this is not necessarily evidence of a causal relationship between increased transparency and lower volatility of long-term inflation expectations.

The estimates of the time-varying intercept and the contributions of the gap and supply shocks from the estimates in Table 3 are shown in Figures 9-11 for the three measures of inflation. These graphs indicate that the time-varying intercept term dominates the variation in all three measures of inflation. The only cases where the distributed lags on the output gap and the supply shock terms account for a substantial portion of the inflation rates are in 1973-4 and to a lesser extent in 1979-80. Finally, Figure 12 demonstrates that the estimated autocorrelations of estimated residuals of the PCE and GDP inflation equations are very small, though there is some autocorrelation in the residuals of the CPI inflation equation.

In Table 4 another set of regressions with a time-varying intercept are reported, but in this case the CBO measure of the output gap has been replaced by the difference between the unemployment rate and a time-varying estimate of the NAIRU. We follow Gordon (1997) and model the NAIRU as a random walk and constrain the standard deviation of the error term in this process to 0.2. In addition a restriction on the level of the NAIRU is required in order to identify this process in the presence of the time-varying intercept term. We have restricted the NAIRU to equal the unemployment rate in 1995:1, consistent with Figure 3 in Gordon (1997). These results are substantially the same as those obtained with the CBO output gap, suggesting that our conclusions about the contribution of the gap are not sensitive to whether it is measured as an output or unemployment gap.

4. TVI Model-Based Inflation Forecasts

The TVI specification in equations (3-4) can be rewritten in terms of the forward expectation of the inflation rate and distributed lags on the gap and supply shock variables, a specification that has much in common with the "New Keynesian" formulation of the Phillips curve (Clarida, Gali and Gertler, 1999). To begin, rewrite equation (3) as:

$$\pi_t = z_t + \sum_{i=0}^{N} \alpha_i \begin{bmatrix} D_{t-i} \\ X_{t-i} \end{bmatrix} + \varepsilon_t \tag{5}$$

where a_i is a vector of coefficients taken from the lag polynomials $b(L)$ and $c(L)$ and N is the lag order of these lag polynomials. Incrementing the time index in equation (5) by one quarter and taking conditional expectations yields:

$$E_t[\pi_{t+1}] = E_t[z_{t+1}] + \alpha_0 E_t \begin{bmatrix} D_{t+1} \\ X_{t+1} \end{bmatrix} + \sum_{i=1}^{N} \alpha_i \begin{bmatrix} D_{t+1-i} \\ X_{t+1-i} \end{bmatrix}, \tag{6}$$

Assume that $\begin{bmatrix} D_{t+1} \\ X_{t+1} \end{bmatrix}$ can be modeled as a stationary VAR process:[6]

$$\begin{bmatrix} D_{t+1} \\ X_{t+1} \end{bmatrix} = \sum_{i=0}^{J} \beta_i \begin{bmatrix} D_{t-i} \\ X_{t-i} \end{bmatrix} + v_{t+1}\,. \tag{7}$$

Then:

$$E_t[\pi_{t+1}] = z_t + \alpha_0 \sum_{i=0}^{J} \beta_i \begin{bmatrix} D_{t-i} \\ X_{t-i} \end{bmatrix} + \sum_{i=1}^{N} \alpha_i \begin{bmatrix} D_{t+1-i} \\ X_{t+1-i} \end{bmatrix}. \tag{8}$$

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[6] Our forecasting model for $(D_{t+1}, S_{t+1})'$ is a restricted four lag VAR. Estimates of an unrestricted VAR, $(I - \beta(L))(D_{t+1}, S_{t+1})' = v_{t+1}$ indicated a lower triangular structure for $\beta(L)$ when the three variables are ordered 1) relative food and energy price changes, 2) relative import price changes and 3) the output gap. This structure was imposed to generate our forecasts.

Since $\begin{bmatrix} D_t \\ X_t \end{bmatrix}$ is assumed to be stationary, $\lim_{M\to\infty} E_t\pi_{t+M} = z_t$. Thus z_t represents the long horizon inflation forecast from the model and, in the sense of Beveridge and Nelson (1981), represents the long-run or permanent component of inflation. Likewise, $\alpha_0\sum_{i=0}^{J}\beta_i\begin{bmatrix} D_{t-i} \\ X_{t-i} \end{bmatrix} + \sum_{i=1}^{N}\alpha_i\begin{bmatrix} D_{t+1-i} \\ X_{t+1-i} \end{bmatrix}$ is then the one-period ahead transitory component of expected inflation.[7]

The inflation forecast error from the TVI specification is given by:

$$\pi_{t+1} - E_t[\pi_{t+1}] = \mu_{t+1} + \alpha_0[\begin{bmatrix} D_{t+1} \\ X_{t+1} \end{bmatrix} - \sum_{i=0}^{J}\beta_i\begin{bmatrix} D_{t-i} \\ X_{t-i} \end{bmatrix}] + \varepsilon_{t+1} = \mu_{t+1} + \alpha_0 v_{t+1} + \varepsilon_{t+1}. \qquad (9)$$

Thus unpredicted inflation is the sum of three terms: 1) the innovation to long-horizon inflation expectations, 2) the one-period ahead forecast error for $\begin{bmatrix} D_{t+1} \\ X_{t+1} \end{bmatrix}$, and 3) the residual of the "Phillips curve." When $\alpha_0 = 0$ the one-period ahead unexpected inflation is just $\pi_{t+1} - E_t[\pi_{t+1}] = \mu_{t+1} + \varepsilon_{t+1}$.

Finally, given the expression for $E_t[\pi_{t+1}]$, the "Phillips Curve" can be rewritten as the sum of the forward prediction of the inflation rate and distributed lags on the gap and supply shock variables:

$$\pi_t = E_t[\pi_{t+1}] - \alpha_0\sum_{i=0}^{J}\beta_i\begin{bmatrix} D_{t-i} \\ X_{t-i} \end{bmatrix} + \sum_{i=0}^{N-1}[\alpha_i - \alpha_{i+1}]\begin{bmatrix} D_{t-i} \\ X_{t-i} \end{bmatrix} + \alpha_N\begin{bmatrix} D_{t-N} \\ X_{t-N} \end{bmatrix} + \varepsilon_t. \qquad (10)$$

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[7] By constructing multistep dynamic forecasts of $(D_{t+i} X_{t+i})'$ the entire path of the transitory component of expected inflation can be estimated.

In Figures 13a – 15a the actual inflation rates are plotted against the one-period ahead projections $E_{t-1}\left[\pi_t\right]$ using the estimated coefficients from Table 3. The middle panels of each figure (13b – 15b) show the differences in the series from the top panels – the one-period ahead inflation forecast errors.[8] Finally, the lower panels of each figure (13c – 15c) show the first 12 autocorrelations of the computed one-period ahead inflation forecast errors. Note that for all three inflation measures the autocorrelations are very small indicating that there is little predictive content in the history of the forecast errors for future forecast errors.

In Figure 16 we compare our estimates of the one-period ahead inflation rate with various survey measures of expected inflation. There are two surveys that are available for CPI inflation: the one-quarter ahead inflation forecast from the Survey of Professional Forecasters (available from 1981:3 through 2005:1) and the one-quarter ahead inflation forecast from the Blue Chip (available from 1985:1 through 2005:1). The inflation forecast measure from the TVI model is plotted in black in all three panels of Figure 16. The forecasts from the Survey of Professional Forecasters are plotted in blue (SPF 1-quarter) and the forecasts from the Blue Chip are plotted in Green (BC1-quarter). There is one survey available for GDP inflation: the one-quarter ahead forecast from the Survey of Professional Forecasters (available from 1968:4 through 2005:1). This is plotted in blue (SPF 1-quarter) in the bottom panel of Figure 16. From the early 1980s, the TVI estimates track the respective survey measures quite closely. In particular for CPI inflation the major spikes in the time-varying intercept estimates of inflation are mirrored in the timing, and in many cases in the amplitude by spikes in the SPF 1-quarter measure. The Blue Chip CPI inflation forecasts are less volatile than the other two measures, but again the major

[8] For purposes of these graphs, we incorporate the effects of the Nixon price control dummy variables, Nixon_On and Nixon_Off. While these variables were constructed by Gordon *expost*, we believe it is reasonable to assume that at the time individuals expected some impact on inflation in the short run of the implementation and removal of the controls.

spikes in this series mirror the timing of the major spikes in the series derived from the time-varying intercept model.

This visual impression is confirmed by heteroskedasticity and autocorrelation consistent regressions of the inflation forecast from the TVI model $E_{t-1}[cpi_t]$ on the corresponding survey measure. For the sample period 1981:3 – 2005:1 the regression with the Survey of Professional Forecasters measure is:

$$\underset{}{E_{t-1}cpi_t} = \underset{(0.45)}{0.06} + \underset{(0.14)}{1.08}spf\_cpi_t + \varepsilon_t \qquad \overline{R}^2 = .68,\ see = 1.13, dw = 2.00$$

while for the sample period 1985:1 – 2005:1 the regression with the Blue Chip measure is:

$$E_{t-1}cpi_t = \underset{(0.37)}{0.19} + \underset{(0.11)}{1.00}bc\_1Q_t + \varepsilon_t \qquad \overline{R}^2 = .49,\ see = 0.94, dw = 2.16$$

In both regressions the estimated constant term is not significantly different from zero and the estimated coefficient of the survey measure is not significantly different from one. The estimated standard errors of the residuals of these regressions are fairly large, but the Durbin-Watson statistics do not indicate any first-order serial correlation.

For the GDP inflation measure we have data to compare with a survey starting in late 1968. There are substantial differences in the two measures in the late 1960s and then again in 1973. The latter period is strongly influenced by our decision to include the estimated effect of the removal of the price controls in the TVI measure of expected inflation. After 1973 the two measures track quite well, though the spikes in the time-varying coefficient measure are not as well aligned with the survey data as is the case with the CPI inflation rate. A regression of the TVI measure ($E_{t-1}gdp_t$) on the survey measure over sample period 1968:4 – 2005:1 is:

$$E_{t-1}gdp_t = -0.07 + 1.09 spf\_gdp_t + \varepsilon_t \qquad \bar{R}^2 = .78,\ \ see = 1.20, dw = 1.12$$
$$\qquad\quad (0.22) \quad (0.07)$$

Again the estimated constant term is not significantly different from zero nor is the estimated coefficient on the survey measure of GDP inflation significantly different from one. The estimated standard error of the residuals is comparable to that found for the CPI inflation regressions, but in this case the Durbin-Watson statistic suggests that substantial first-order serial correlation remains in the estimated residuals.

The estimated time series of the time-varying intercept (the permanent component of inflation) are shown in Figure 17. The series for all three inflation rates are quite similar, though the one derived from the CPI is more volatile than the other two up to the "Great Moderation" period. The estimates suggest that long-term expected inflation rose sharply in the late 60s from less than 2 percent in 1964 to over 4 percent in 1968. All three series level off in the late 60s and decline a bit in the early 70s before the first energy shock. From 1973 until 1982 all the series trend up. From 1982-85 the trend is reversed and the series level out around 4 percent for the remainder of the 80s. After 1990 all the series again trend down through the mid 90s, after which they level out around 2 percent.

The final line (SPF_10) plotted on Figure 17 is the 10-year ahead CPI inflation forecast from the Survey of Professional Forecasters. The general trend in the long-term expected CPI inflation from the TVI model tracks that in the survey data quite well for the period for which the latter series are available: 1991:4 through 2005:1. A regression of the model generated data on the survey data shows:

$$Z\_cpi = -0.83 + 1.23 Spf\_\inf \qquad \bar{R}^2 = .86,\; see = 0.24, dw = 0.63$$
$$\quad (0.21)\;\; (0.08)$$

The constant in the regression is significantly less than zero and the coefficient on the survey data is significantly greater than one. These results are driven by the constant value of the survey data over the past five years. Nevertheless the relationship between the two series is quite close as judged by the large $\bar{R}^2$ and the low estimated standard error of the residuals.

Goodfriend (1993) hypothesizes four periods of "inflation scares" during the 1980s. These periods are December 1979 through February 1980, June 1980 through October 1981, May 1983 through August 1983 and March 1987 through October 1987. He defines "a significant long-rate rise in the absence of an aggressive funds rate tightening an inflation scare since it reflects rising expected long-run inflation" (p.8). Hence his inflation scares are inferred from the behavior of long-term rates relative to short-term rates. Since we have a measure of long-term inflation expectations that is derived independently of any information on the behavior of interest rates, the estimates can be used as an independent check on Goodfriend's inflation scare hypothesis. The approximate periods designated as inflation scares are shaded in Figure 17.[9] Our measure of long-term expected CPI inflation jumps up sharply in the first three designated inflation scares. There are no sharp increases in our measures of long-term expected PCE or expected GDP inflation for the first two designated inflation scares. For the third inflation scare, the measure of expected long-term PCE inflation jumps up, but this follows a short-lived downward spike of almost the same magnitude. The measure of expected long-term GDP inflation continues on a downward trend during the third inflation scare. Finally, none of

[9] The shaded periods are only approximate since Goodfriend worked with monthly data and our models are estimated on quarterly data.

our measures of long-term expected inflation exhibit any major movement during the fourth period designated as an inflation scare. Hence our measures of long-term expected inflation, particularly those for GDP and PCE inflation, do not provide strong evidence in favor of the inflation scare hypothesis.

As an alternative check on whether the estimated time-varying intercept is a reasonable proxy measure for long-term expected inflation, we can subtract the estimated z_t for each of the three inflation equations from a long-term rate of interest to get an estimated *ex ante* long-term real rate. We use the 10 year Treasury bond rate for this purpose. These estimates are shown in Figures 18a-c. The horizontal line is drawn for reference at 2 percent. In recent history there are two comparison measures. Beginning in 1991 the Survey of Professional Forecasters reported survey responses for a 10 year-ahead CPI inflation rate. The difference between the 10 year nominal rate and these survey responses is plotted as the blue line in Figures 18a-c. Since 1997 the U.S. Treasury has issued long-term indexed bonds. The yield on these bonds is shown as the green line in Figures 18a-c.[10]

Regressions of the implied long-term real rates from the TVI model on the implied long-term real rate from the Survey of Professional Forecasters over the sample period 1991:4-2005:1 are:

$$\underset{}{ltrate - Zcpi} = \underset{(0.12)}{0.15} + \underset{(0.05)}{1.00}\left[ltrate - spf\_10\right] \qquad \overline{R}^2 = .90,\ see = 0.27, dw = 0.45$$

$$\underset{}{ltrate - Zpce} = \underset{(0.08)}{0.55} + \underset{(0.04)}{1.05}\left[ltrate - spf\_10\right] \qquad \overline{R}^2 = .92,\ see = 0.24, dw = 0.40$$

[10] The comparisons are only exact in Figure 21a since the Survey of Professional Forecasters refers to the CPI and the TIPS are indexed to the CPI.

$$ltrate - Zgdp = \underset{(0.06)}{0.51} + \underset{(0.02)}{1.10}[ltrate - spf\_10] \qquad \bar{R}^2 = .98,\ see = 0.13, dw = 1.05$$

Strictly speaking only the first of these three regressions is an exact comparison, since the survey data refer the CPI. In that regression the estimated constant term is not significantly different from zero, and the estimated coefficient on the survey measure of the real long-term rate is not significantly different from one. Hence the two measures appear on average to differ by an insignificant constant (with the model-generated estimate larger) and to move up and down together during the sample period. The same conclusion is appropriate for the model based measure of the long-term real rate based on PCE inflation relative to the long-term real rate derived from the survey data, though in this case the average difference is significantly different from zero. The regression with the long-term real rate derived from the model based estimate of long-term GDP inflation moves significantly more than one-for-one with the real rate derived from the survey data.

A second comparison of real rates is provided by the Treasury indexed bond data, though only for a short time period: 1997:1 – 2005:1. The real long-term rates derived from our model of long-term expected inflation for all three measured inflation rates do not move significantly differently from one-for-one with the TIPS rate over this sample period.

$$ltrate - Zcpi = \underset{(0.24)}{0.22} + \underset{(0.08)}{0.84}tips \qquad \bar{R}^2 = .69,\ see = 0.48, dw = 0.35$$

$$ltrate - Zpce = \underset{(0.22)}{0.44} + \underset{(0.07)}{0.92}tips \qquad \bar{R}^2 = .77,\ see = 0.43, dw = 0.34$$

$$ltrate - Zgdp = \underset{(0.22)}{0.57} + \underset{(0.07)}{0.89}tips \qquad \bar{R}^2 = .73,\ see = 0.46, dw = 0.33$$

In all three cases the estimated standard error of the residuals of the regressions are larger than the estimated standard error of the residuals from the corresponding regression with the survey based measures of the long-term real rate. This may suggest a closer relationship between our model-based estimates and the survey based estimates than between the model-based estimates and the TIPS rates, but the differences may only reflect the relatively short sample period during which the TIPS rates are available.

The model can be used to generate multiperiod inflation forecasts for any horizon. As the horizon gets longer the forecast of the transitory component of inflation goes to zero and the forecast converges on the estimated permanent component of inflation. The forecasts for inflation one to four quarters ahead can be combined to generate a one-year ahead inflation forecast. This forecast is subtracted from the one-year constant maturity Treasury rate to produce a one-year ahead estimated *ex ante* real rate. These model based one-year real rates are plotted in Figure 19a-c along with one-year real rates derived using Michigan, Survey of Professional Forecasters and Blue Chip survey measures of future CPI and GDP inflation rates. For the CPI measures, the model-based real rates track the survey-based measures very closely since the 1980s when the survey data start. The model-based measure for GDP inflation tracks the measure derived from the Survey of Professional Forecasters since the mid 1970s.

Finally, we can use the model-based estimates of one-period ahead expected inflation and a three month interest rate to construct an *ex ante* three month real rate. The nominal rate that we use for these calculations is the secondary market rate on three month Treasury bills. In Figure 20a-c we compare the term structure of real interest rates. In each panel of that figure the black line is the one-quarter ahead real rate computed from our models, the blue line is the model-based one-year ahead real rate, and the green line is the model-based long-term (10 year) real rate discussed in the previous section. The results in the three panels are quite consistent. In each case the real term structure appears very flat throughout the 1960s. In the 1970s the real term structure became positively sloped. The really interesting period is that of the early 1980s – the period of the New Operating Procedures. During this period the model based estimates imply that the real term structure shifted up rapidly, but that the term structure remained essentially flat for the entire period. There is no evidence that the estimated real term structure inverted during this period, though the nominal term structure became sharply inverted at the time. Beginning in the early 80s the real term structure is almost always positively sloped and is the steepest in 1990-2 and since 2000. In those two periods real rate spreads in the 1-10 year range became quite large, but those in the 3-month to 1-year range remained relatively small.

5. Conclusion

We have presented evidence regarding the relative contribution of the real activity "gap" and other potential inflation drivers, such as changes in long-horizon inflation expectations and supply shock variables, for explaining the U.S. inflation rate over the post-war period. Our results suggest that realized inflation is dominated by variation in long-horizon expected inflation, while the gap and supply shock variables play only a very limited role. These results are robust to alterative specifications for the inflation driving process and measures of inflation and the gap.

Our preferred model specification is one in which inflation is determined by a random walk permanent component (which represents the long-horizon inflation expectation), a distributed lag on the real activity gap, and a distributed lag on supply shock variables. Model-based inflation forecasts align closely with forecasts obtained from surveys at all horizons during the years for which the survey data is available. This suggests that our model of the inflation driving process does a very good job of reproducing whatever process is driving survey measures of future inflation. Results from this model also suggest that the variance of the process that generates changes in long-term expected inflation has changed over time. Interestingly, this variance has become very small over the last 10 years of the sample, suggesting that long-term expected inflation has become much better "anchored" in the past decade.

Taken together, the evidence presented here suggests that the key to understanding the inflation process is to understand what drives changes in long-horizon inflation expectations. To this end, further research focused on attempting to relate these changes to "news" could prove especially fruitful.

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Table 1: Gordon-Type Regressions

	CPI	PCE	GDP
π_{t-1}	**1.01**	**1.00**	**1.00**
	(0.02)	(0.02)	(0.02)
$\Delta\pi_{t-1}$	-0.64	-0.67	-0.63
	(0.09)	(0.09)	(0.09)
$\Delta\pi_{t-2}$	-0.58	-0.44	-0.49
	(0.09)	(0.10)	(0.09)
$\Delta\pi_{t-3}$	-0.18	-0.27	-0.33
	(0.08)	(0.09)	(0.09)
Gap_t	**0.16**	**0.12**	**0.13**
	(0.04)	(0.03)	(0.04)
ΔGap_t	0.07	0.07	0.01
	(0.11)	(0.08)	(0.10)
ΔGap_{t-1}	0.13	0.01	0.01
	(0.11)	(0.08)	(0.10)
ΔGap_{t-2}	0.13	-0.01	0.08
	(0.11)	(0.08)	(0.10)
ΔGap_{t-3}	0.06	-0.12	0.08
	(0.11)	(0.08)	(0.10)
Δ *Rel Import Prices*$_t$	**0.15**	**0.19**	**0.28**
	(0.11)	(0.09)	(0.11)
Δ^2 *Rel Import Prices*$_t$	-0.07	-0.05	-0.42
	(0.11)	(0.08)	(0.10)
Δ^2 *Rel Import Prices*$_{t-1}$	0.05	0.08	-0.17
	(0.09)	(0.07)	(0.09)
Δ^2 *Rel Import Prices*$_{t-2}$	0.08	0.10	-0.05
	(0.08)	(0.06)	(0.08)
Δ^2 *Rel Import Prices*$_{t-3}$	0.08	0.13	0.03
	(0.06)	(0.05)	(0.06)
Δ *Rel Fd & Energy Prices*$_t$	**-0.15**	**0.20**	**-0.41**
	(0.90)	(0.71)	(0.86)
Δ^2 *Rel Fd & Energy Prices*$_t$	4.43	2.95	2.28
	(0.85)	(0.66)	(0.81)
Δ^2 *Rel Fd & Energy Prices*$_{t-1}$	3.36	2.08	1.68
	(0.88)	(0.68)	(0.77)
Δ^2 *Rel Fd & Energy Prices*$_{t-2}$	2.95	0.98	0.63
	(0.81)	(0.63)	(0.66)
Δ^2 *Rel Fd & Energy Prices*$_{t-3}$	1.25	0.23	0.17
	(0.63)	(0.47)	(0.51)
NIXON_ON	-1.50	-1.19	-1.00
	(0.58)	(0.46)	(0.56)
NIXON_OFF	2.77	1.06	1.13
	(0.63)	(0.51)	0.60
$\overline{R}^2$	0.90	0.91	0.86
Mean Inflation Rate	4.63	4.15	4.12
Std Error of the Inflation Rate	3.11	2.59	2.52
Standard Error of the Estimate	0.97	0.77	0.93
Durbin-Watson Statistic	2.13	2.06	2.14

Table 2: Time-varying Intercept Model with CBO Gap

	CPI	**PCE**	**GDP**
Standard Deviation of Intercept	0.58	0.37	0.35
	(0.08)	(0.05)	(0.05)
Gap_t	0.18	0.02	0.00
	(0.10)	(0.06)	(0.00)
Gap_{t-1}	0.00	0.00	0.01
	(0.00)	(0.00)	(0.07)
Gap_{t-2}	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
Gap_{t-3}	0.13	-0.12	0.07
	(0.12)	(0.08)	(0.00)
Gap_{t-4}	0.04	0.25	0.07
	(0.11)	(0.08)	(0.09)
Δ *Rel Import Prices*$_t$	0.12	0.13	-0.20
	(0.06)	(0.04)	(0.04)
Δ *Rel Import Prices*$_{t-1}$	0.07	0.09	0.06
	(0.06)	(0.04)	(0.05)
Δ *Rel Import Prices*$_{t-2}$	0.07	0.02	0.07
	(0.07)	(0.05)	(0.05)
Δ *Rel Import Prices*$_{t-3}$	0.03	0.05	0.11
	(0.06)	(0.04)	(0.05)
Δ *Rel Import Prices*$_{t-4}$	0.00	0.04	0.05
	(0.05)	(0.04)	(0.04)
Δ *Rel Fd & Energy Prices*$_t$	2.83	1.97	1.30
	(0.33)	(0.23)	(0.25)
Δ *Rel Fd & Energy Prices*$_{t-1}$	0.35	0.40	0.68
	(0.34)	(0.23)	(0.25)
Δ *Rel Fd & Energy Prices*$_{t-2}$	0.19	0.21	0.01
	(0.36)	(0.24)	(0.19)
Δ *Rel Fd & Energy Prices*$_{t-3}$	0.19	0.03	-0.03
	(0.35)	(0.23)	(0.24)
Δ *Rel Fd & Energy Prices*$_{t-4}$	0.08	0.24	0.29
	(0.27)	(0.22)	(0.25)
NIXON_ON	-0.84	-0.81	-1.27
	(0.97)	(0.65)	(0.67)
NIXON_OFF	3.03	2.10	2.54
	(0.79)	(0.50)	(0.59)
Log Likelihood	-276.16	-209.47	-225.91
Standard Error of the Estimate	0.90	0.64	0.78
Standard Error of the Estimate (Gordon equation)	0.93	0.74	0.90

Table 3: Time-varying Intercept Model with CBO Gap and break in the Variance of the Intercept in 1967, 1984 and 1994

	CPI	PCE	GDP
Standard Deviation of Intercept 53-66	0.79	0.47	0.52
	(0.15)	(0.12)	(0.15)
Standard Deviation of Intercept 67-83	1.92	1.06	0.75
	(0.19)	(0.16)	(0.21)
Standard Deviation of Intercept 84-93	0.36	0.26	0.22
	(0.09)	(0.06)	(0.08)
Standard Deviation of Intercept 94-05	0.15	0.12	0.09
	(0.05)	(0.06)	(0.08)
Gap_t	-0.01	-0.09	-0.10
	(0.07)	(0.07)	(0.09)
Gap_{t-1}	0.10	0.22	0.13
	(0.09)	(0.09)	(0.10)
Gap_{t-2}	0.03	0.03	-0.03
	(0.10)	(0.09)	(0.11)
Gap_{t-3}	0.10	-0.11	0.03
	(0.10)	(0.09)	(0.12)
Gap_{t-4}	-0.07	0.06	0.01
	(0.08)	(0.07)	(0.09)
Δ *Rel Import Prices*$_t$	0.10	0.07	-0.23
	(0.04)	(0.04)	(0.05)
Δ *Rel Import Prices*$_{t-1}$	-0.002	0.08	0.11
	(0.04)	(0.04)	(0.05)
Δ *Rel Import Prices*$_{t-2}$	0.04	-0.03	0.01
	(0.04)	(0.05)	(0.05)
Δ *Rel Import Prices*$_{t-3}$	-0.06	0.04	0.09
	(0.04)	(0.04)	(0.05)
Δ *Rel Import Prices*$_{t-4}$	0.03	-0.01	0.02
	(0.04)	(0.04)	(0.05)
Δ *Rel Fd & Energy Prices*$_t$	3.26	2.14	1.36
	(0.21)	(0.18)	(0.22)
Δ *Rel Fd & Energy Prices*$_{t-1}$	0.21	0.01	0.17
	(0.21)	(0.13)	(0.23)
Δ *Rel Fd & Energy Prices*$_{t-2}$	-0.07	0.01	0.20
	(0.21)	(0.32)	(0.22)
Δ *Rel Fd & Energy Prices*$_{t-3}$	0.32	-0.21	0.03
	(0.21)	(0.19)	(0.33)
Δ *Rel Fd & Energy Prices*$_{t-4}$	-0.18	0.30	0.41
	(0.21)	(0.18)	(0.22)
NIXON_ON	-0.36	-0.31	-1.51
	(1.75)	(1.08)	(0.96)
NIXON_OFF	3.37	2.20	2.46
	(1.16)	(0.73)	0.71
Log Likelihood	-290.16	-249.08	-277.11
Standard Error of the Estimate	0.40	0.47	0.66

Table 4: Time-varying Intercept Model with Time-varying NAIRU and break in the Variance of the Intercept in 1967, 1984 and 1994

	CPI	PCE	GDP
Standard Deviation of Intercept 53-66	0.96	0.39	0.54
	(0.15)	(0.10)	(0.15)
Standard Deviation of Intercept 67-83	1.92	1.04	0.74
	(0.19)	(0.15)	(0.21)
Standard Deviation of Intercept 84-93	0.35	0.24	0.22
	(0.07)	(0.08)	(0.08)
Standard Deviation of Intercept 94-05	0.18	0.14	0.13
	(0.06)	(0.06)	(0.07)
$NAIRU\ Gap_t$	0.20	0.21	-0.08
	(0.23)	(0.19)	(0.19)
$NAIRU\ Gap_{t-1}$	-1.24	-0.91	-0.01
	(0.25)	(0.27)	(0.25)
$NAIRU\ Gap_{t-2}$	1.12	0.04	-0.22
	(0.35)	(0.28)	(0.36)
$NAIRU\ Gap_{t-3}$	-0.61	0.72	0.58
	(0.34)	(0.29)	(0.37)
$NAIRU\ Gap_{t-4}$	0.13	-0.47	-0.44
	(0.23)	(0.19)	(0.23)
Δ *Rel Import Prices*$_t$	0.11	0.06	-0.24
	(0.04)	(0.04)	(0.05)
Δ *Rel Import Prices*$_{t-1}$	0.001	0.10	0.13
	(0.04)	(0.04)	(0.04)
Δ *Rel Import Prices*$_{t-2}$	0.06	-0.05	0.01
	(0.04)	(0.04)	(0.05)
Δ *Rel Import Prices*$_{t-3}$	-0.07	0.03	0.10
	(0.04)	(0.04)	(0.05)
Δ *Rel Import Prices*$_{t-4}$	0.01	-0.02	0.03
	(0.04)	(0.04)	(0.04)
Δ *Rel Fd & Energy Prices*$_t$	3.34	2.06	1.36
	(0.21)	(0.18)	(0.22)
Δ *Rel Fd & Energy Prices*$_{t-1}$	0.16	-0.13	0.13
	(0.20)	(0.18)	(0.23)
Δ *Rel Fd & Energy Prices*$_{t-2}$	-0.21	-0.01	0.17
	(0.21)	(0.12)	(0.22)
Δ *Rel Fd & Energy Prices*$_{t-3}$	0.29	-0.14	0.03
	(0.19)	(0.18)	(0.22)
Δ *Rel Fd & Energy Prices*$_{t-4}$	-0.17	0.26	0.34
	(0.20)	(0.18)	(0.22)
NIXON_ON	-0.42	-0.25	-1.51
	(1.69)	(1.09)	(0.94)
NIXON_OFF	2.98	1.82	2.33
	(1.13)	(0.73)	(0.69)
Log Likelihood	-285.18	-241.45	-276.46
Standard Error of the Estimate	0.23	0.43	0.64

Figure 1

CPI Inflation Rate -- Gordon Equation

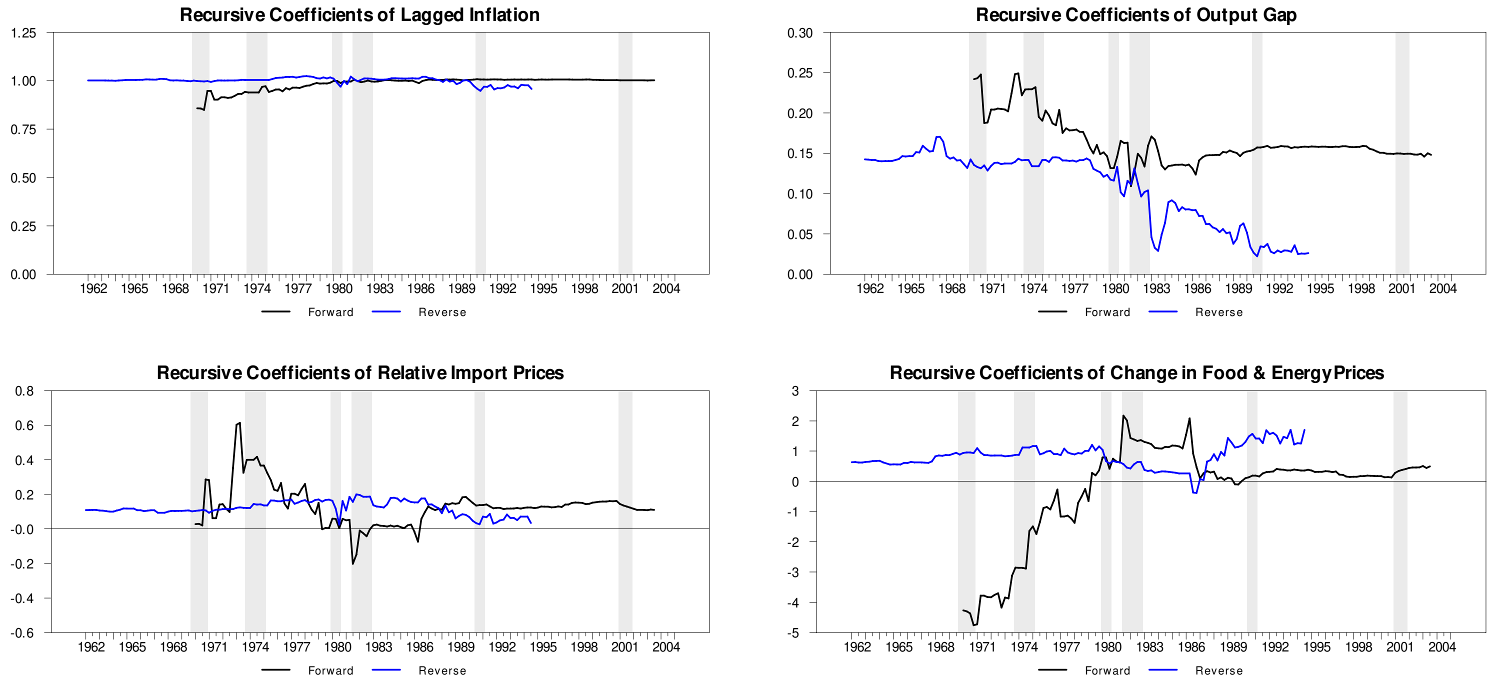


Figure 2

PCE Inflation Rate -- Gordon Equation

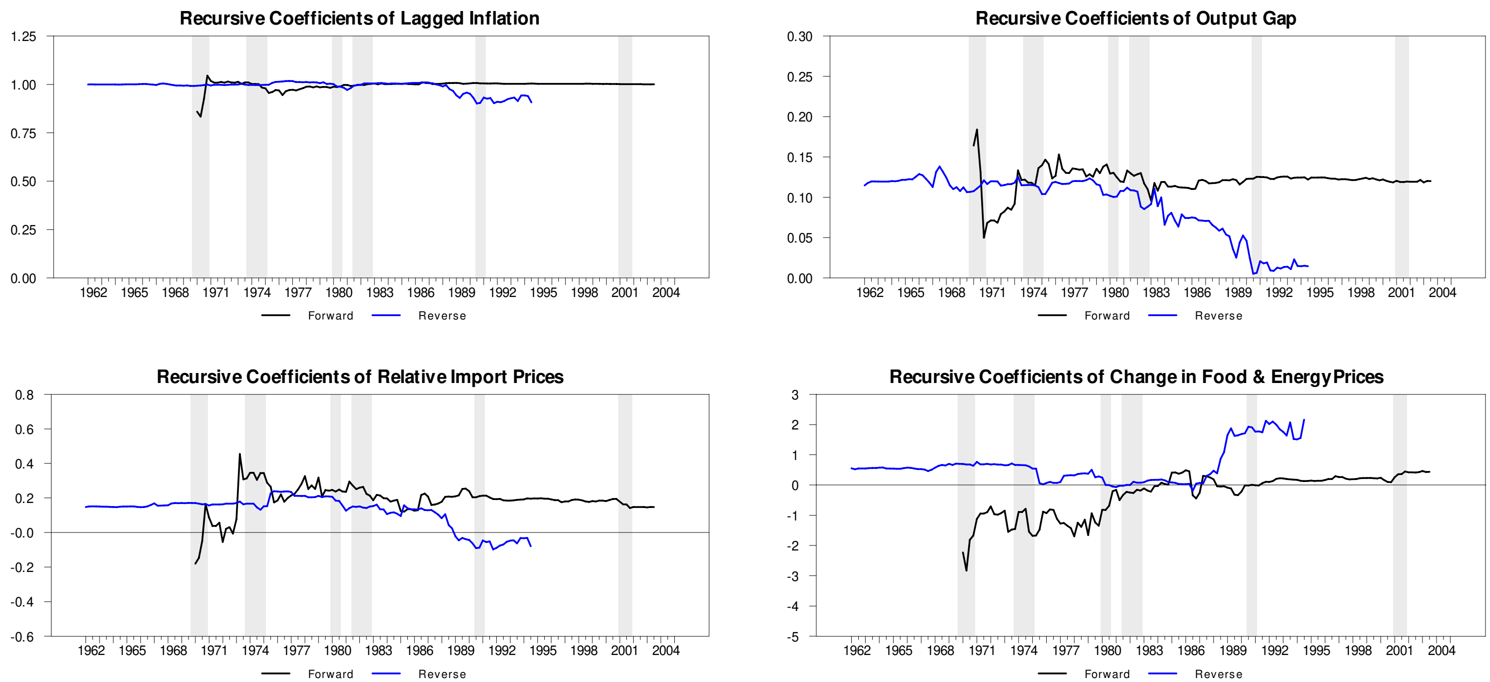


Figure 3

GDP Inflation Rate -- Gordon Equation

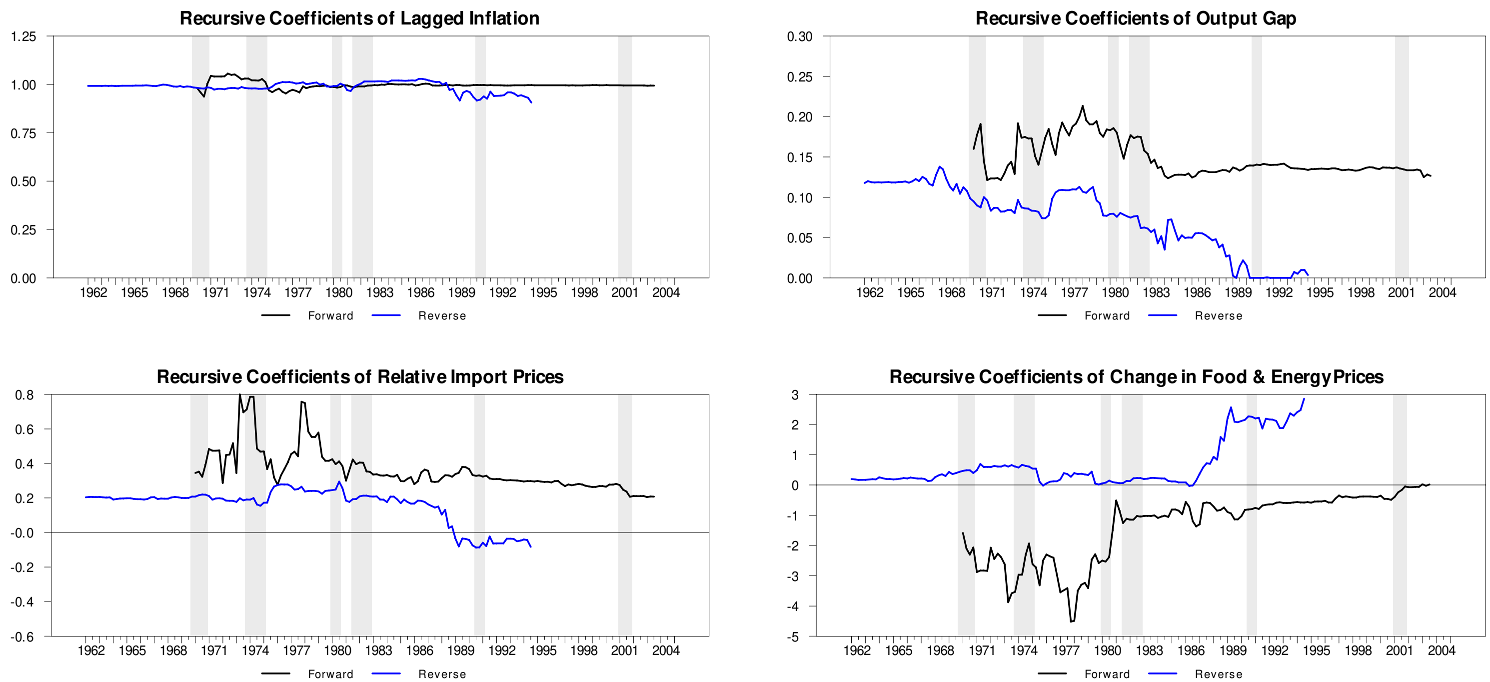


Figure 4

Marginal R Squares of Recursive Regressions

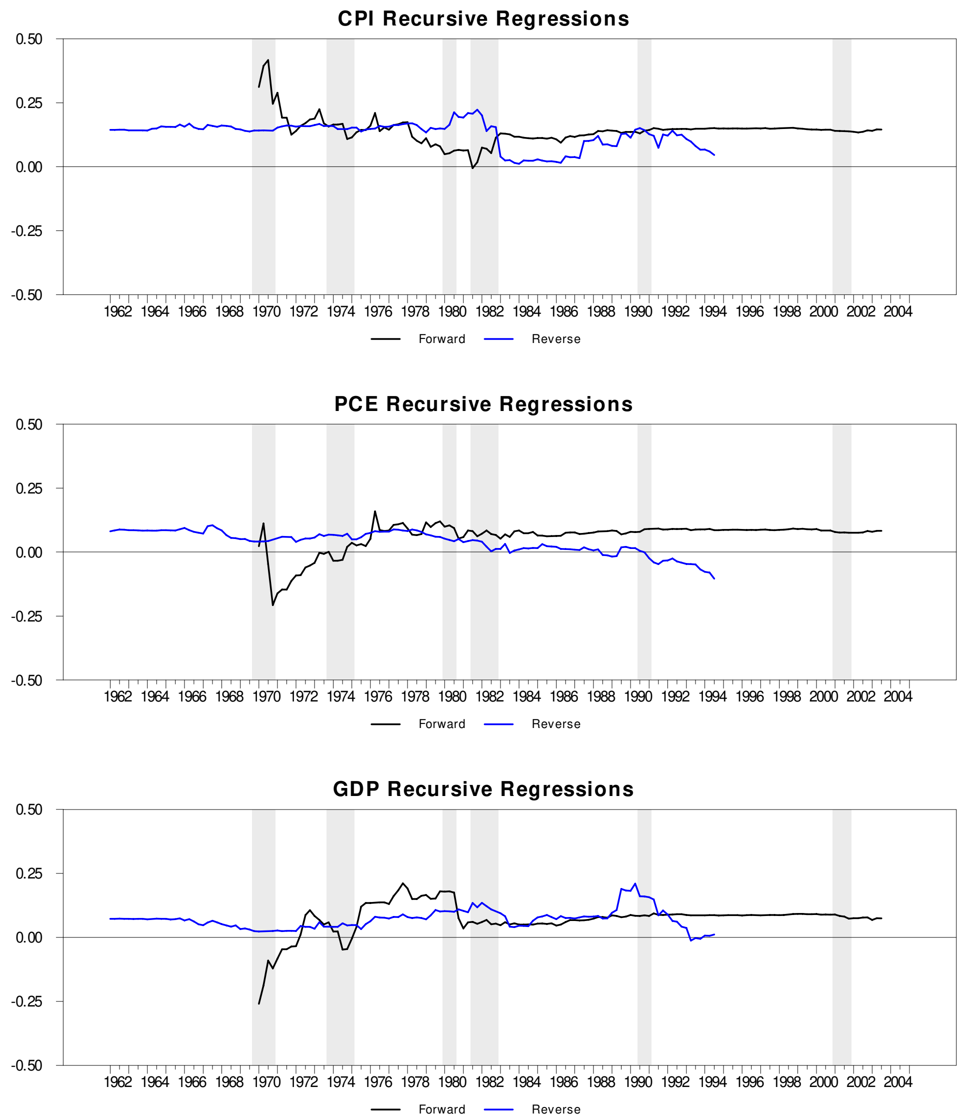


Figure 5

CPI Inflation: Gordon Equation: Sample Period 1962:1 - 2005:1

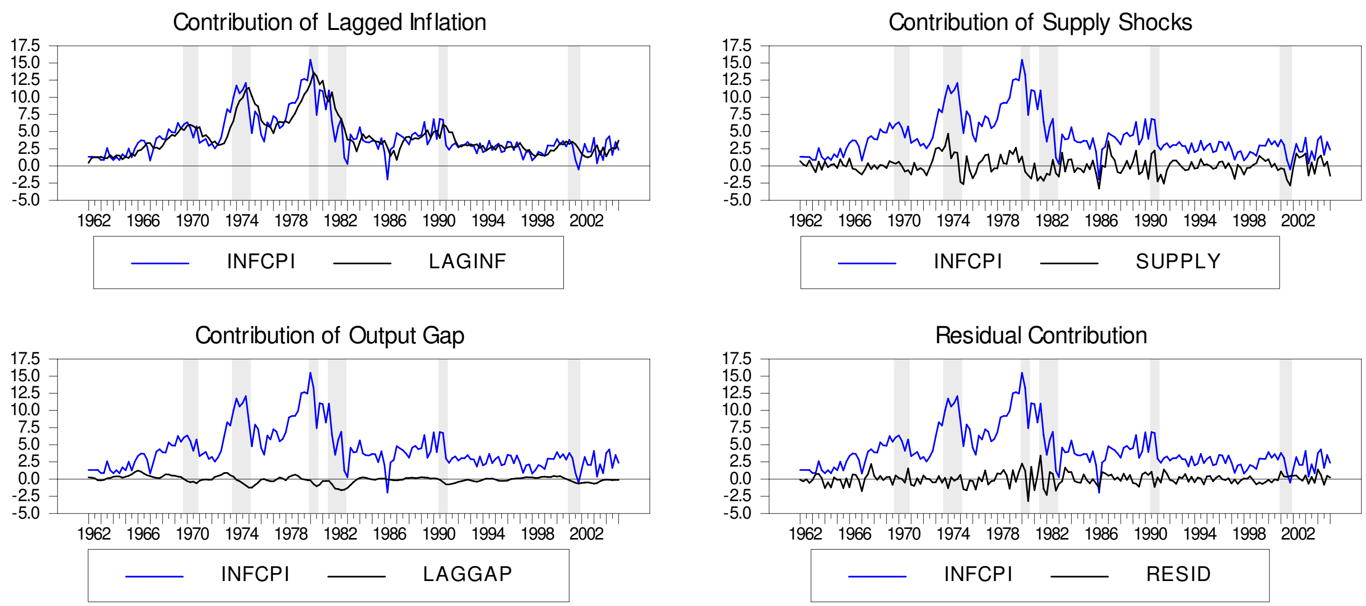


Figure 6

PCE Inflation: Gordon Equation: Sample Period 1962:1 - 2005:1

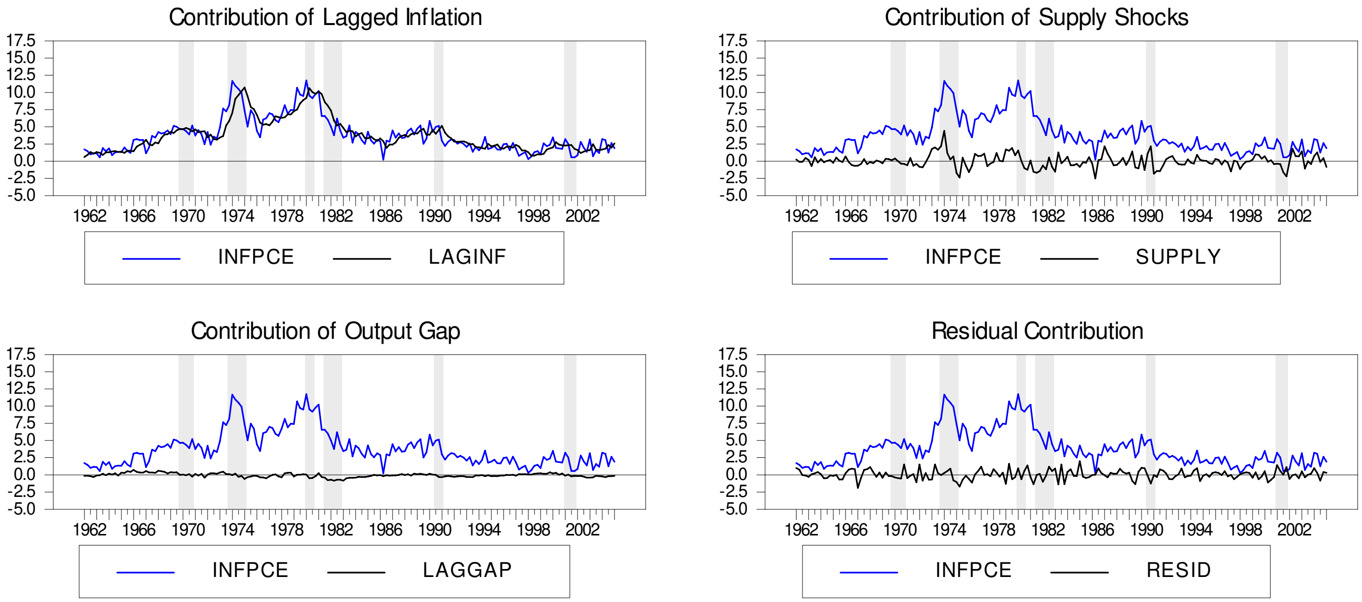


Figure 7

GDP Inflation: Gordon Equation: Sample Period 1964:2 - 2005:1

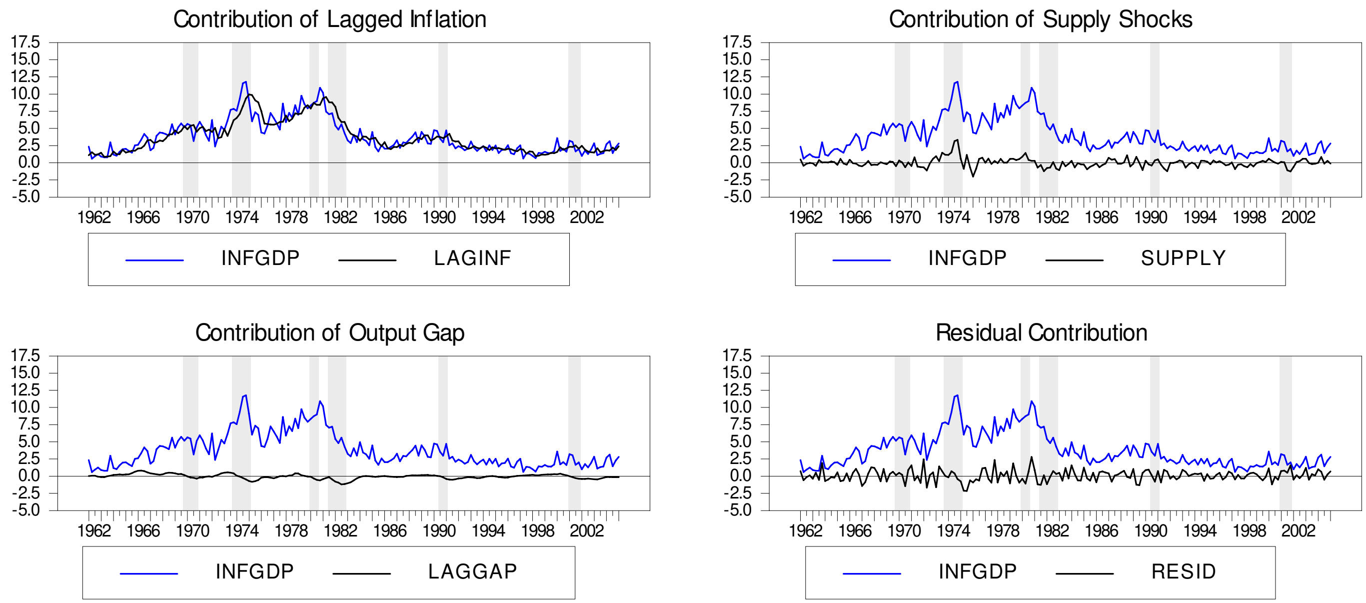


Figure 8

Shocks to Permanent Inflation

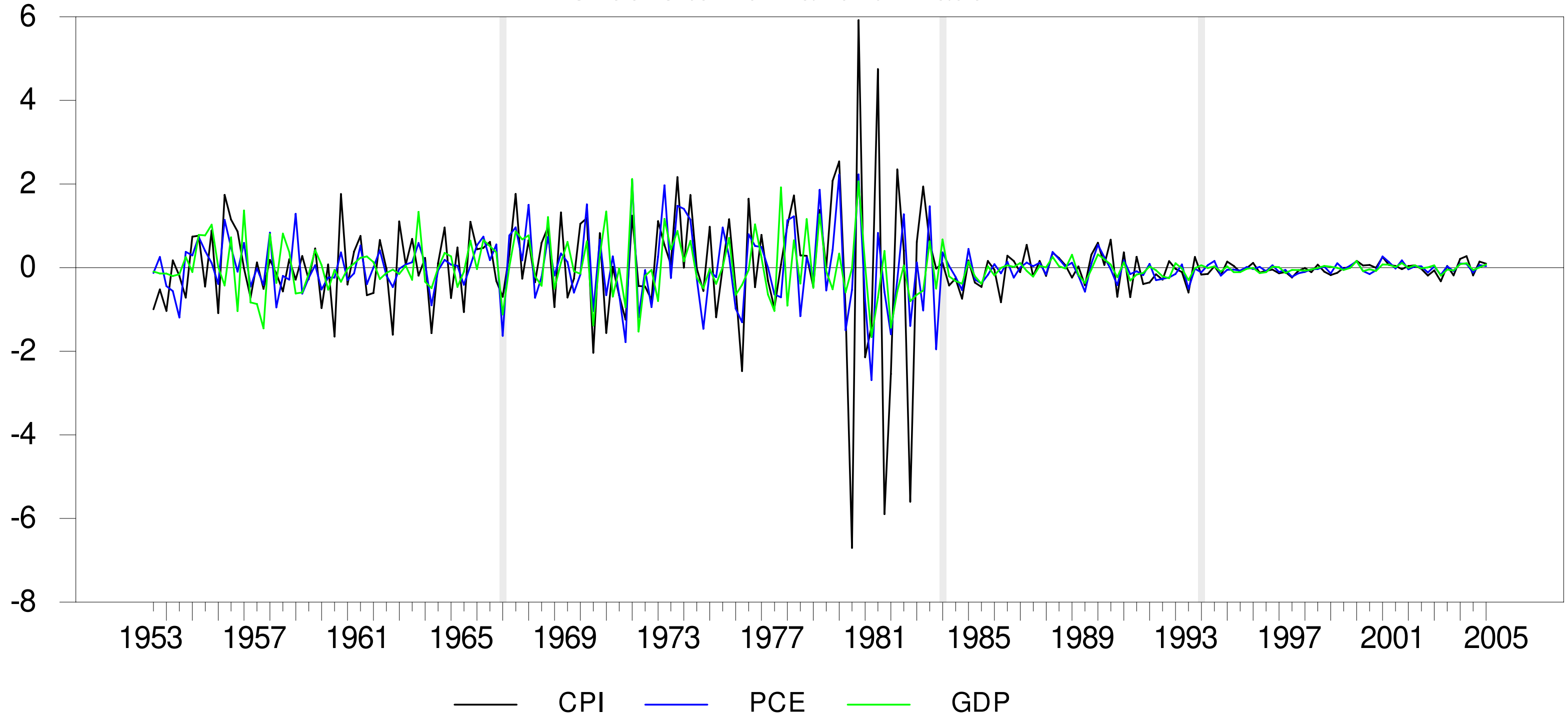


Figure 9

One-Period Ahead CPI Inflation Components

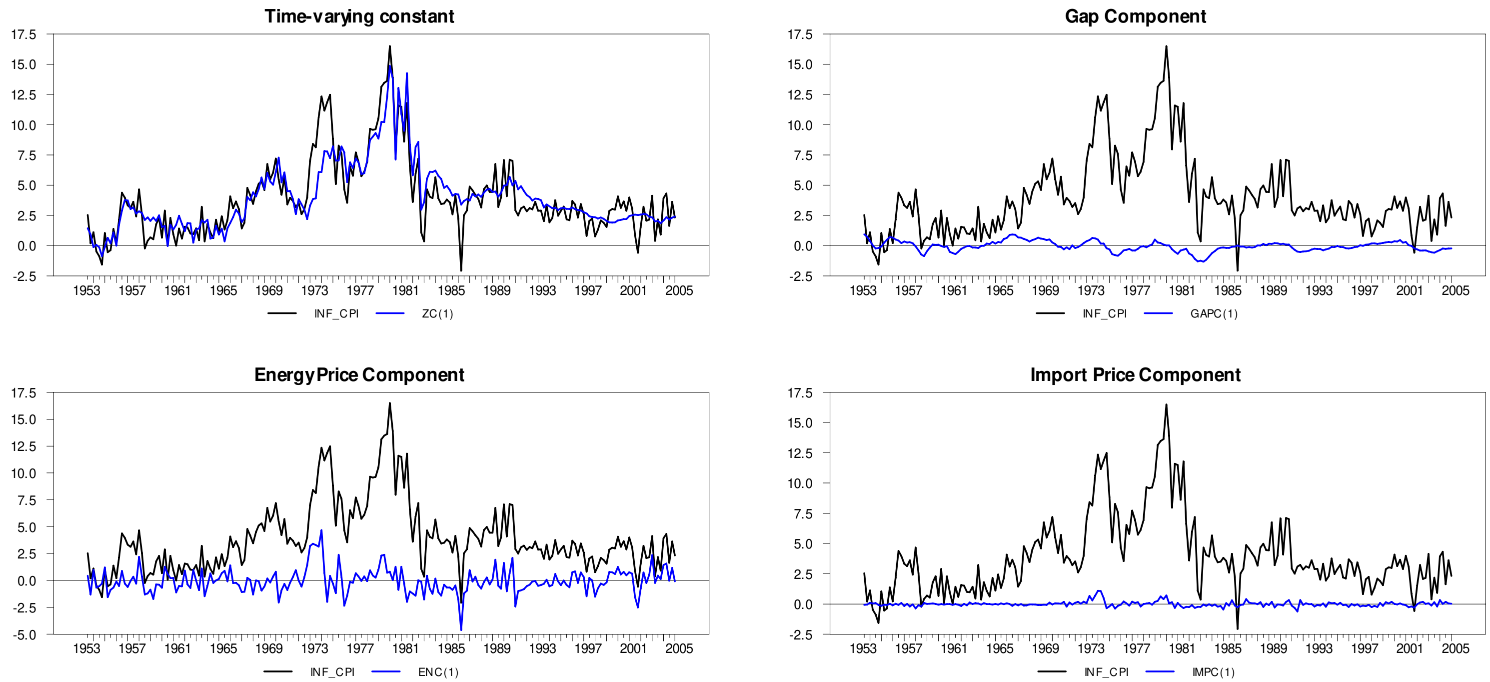


Figure 10

One-Period Ahead PCE Inflation Components

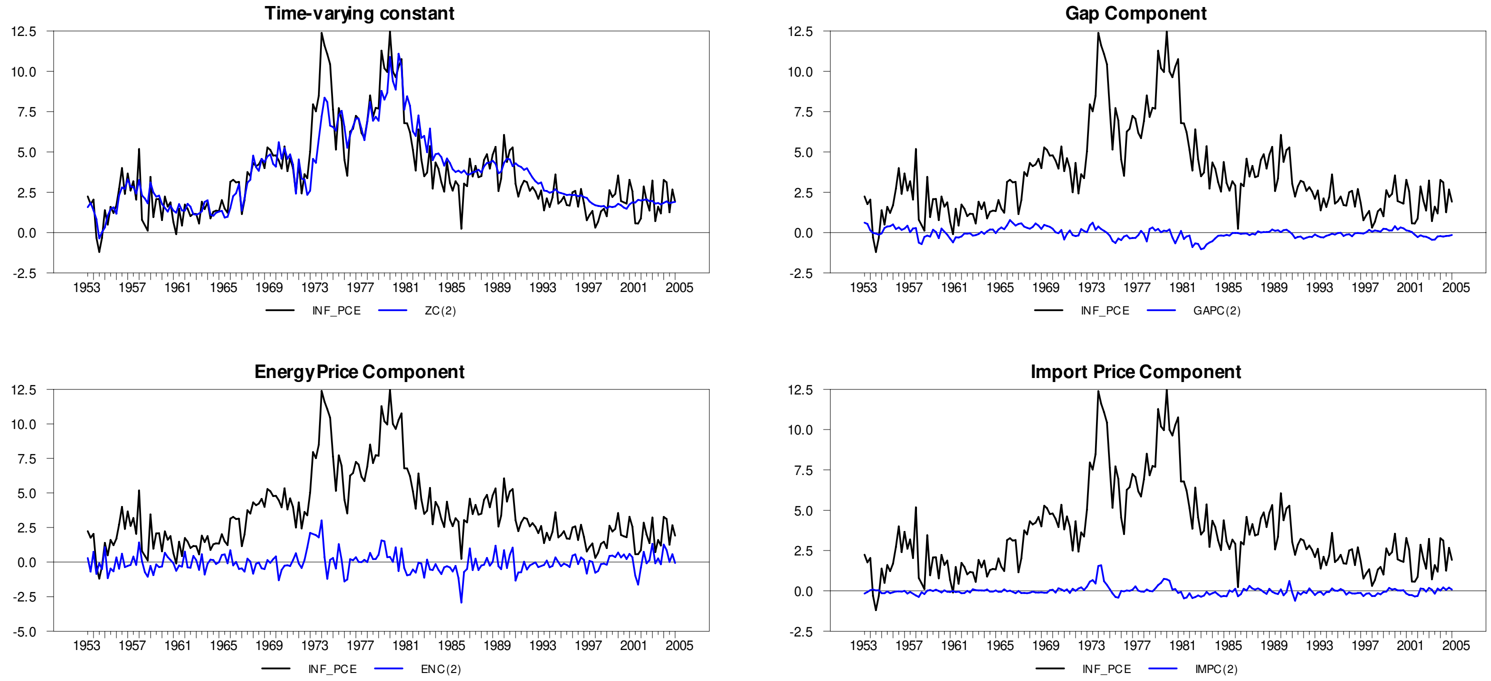


Figure 11

One-Period Ahead GDP Inflation Components

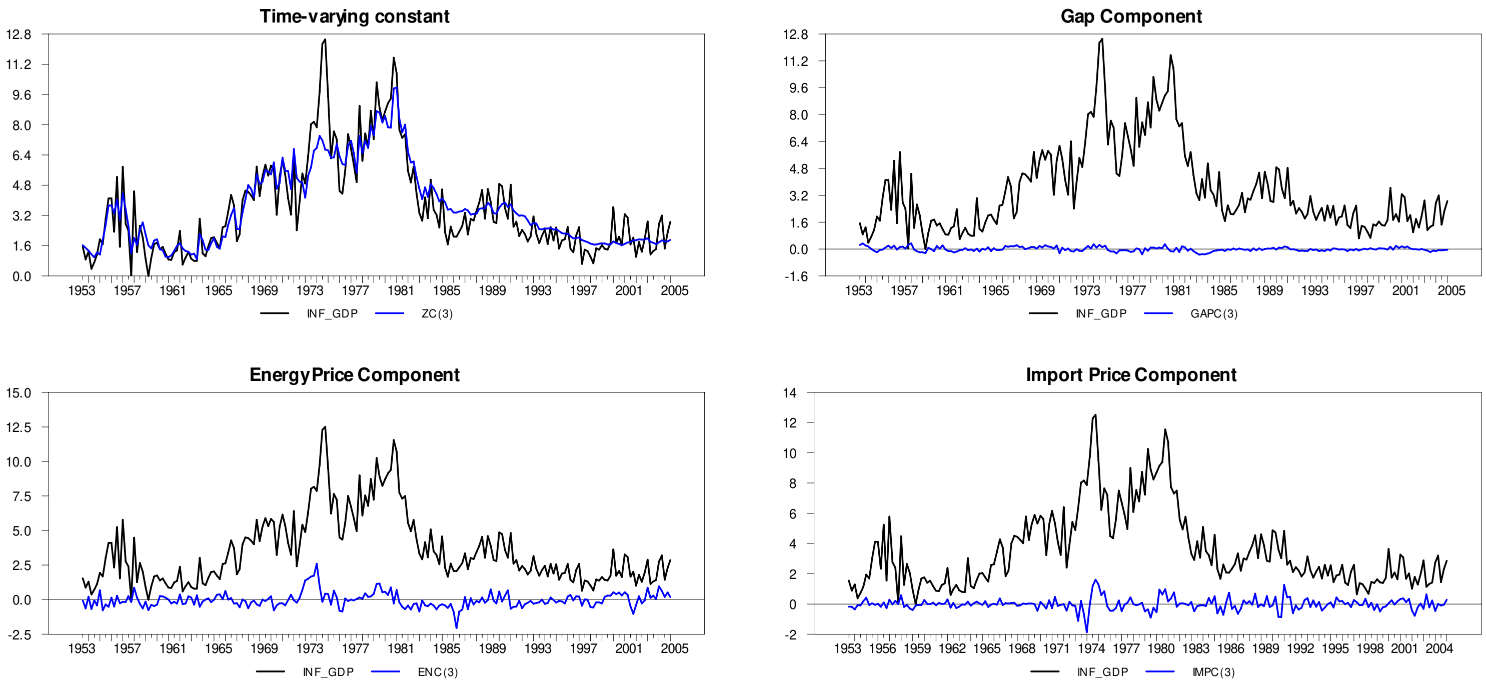
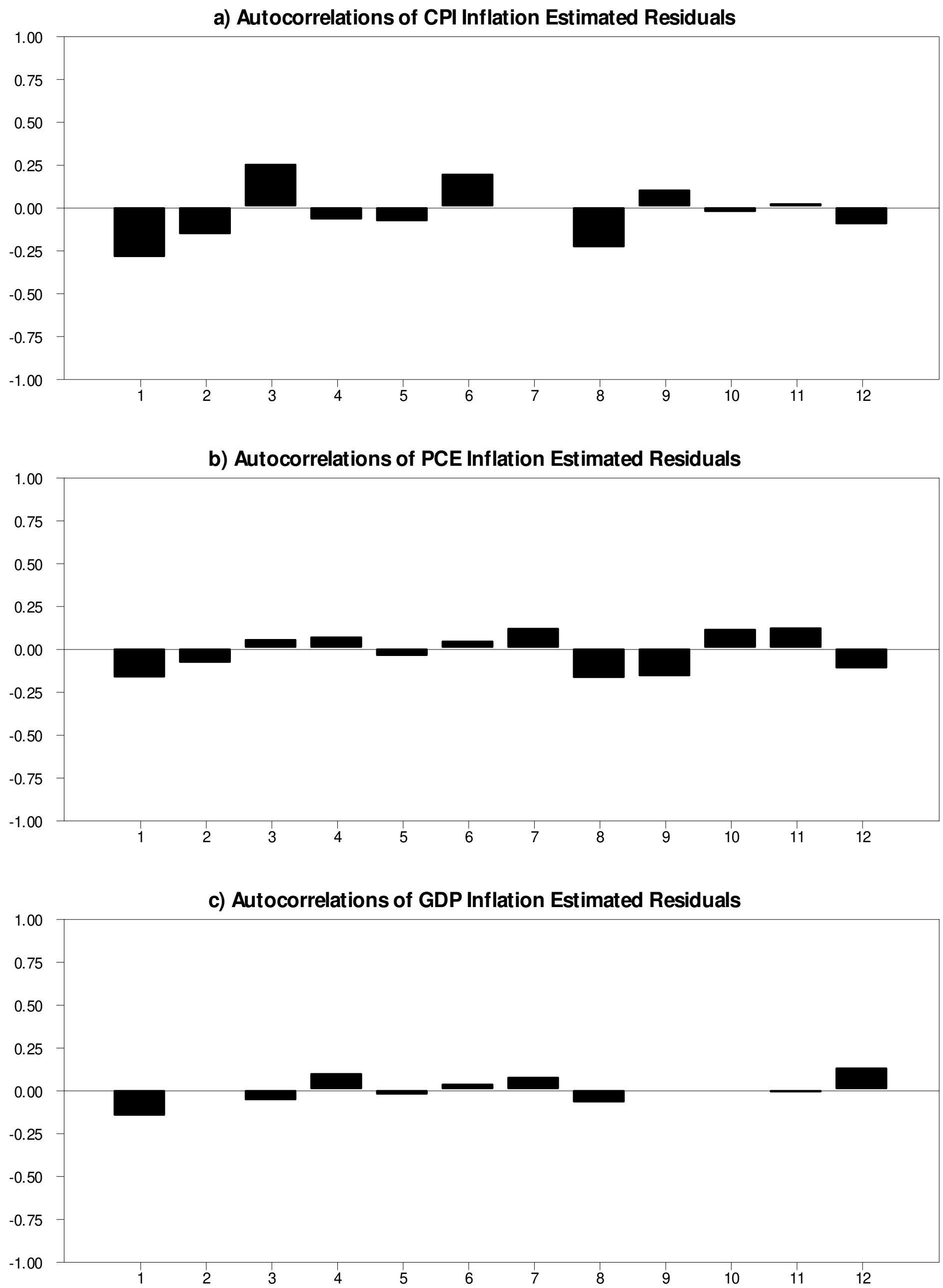


Figure 12



a) Autocorrelations of CPI Inflation Estimated Residuals
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
1 2 3 4 5 6 7 8 9 10 11 12
b) Autocorrelations of PCE Inflation Estimated Residuals
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
1 2 3 4 5 6 7 8 9 10 11 12
c) Autocorrelations of GDP Inflation Estimated Residuals
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
1 2 3 4 5 6 7 8 9 10 11 12

Figure 13

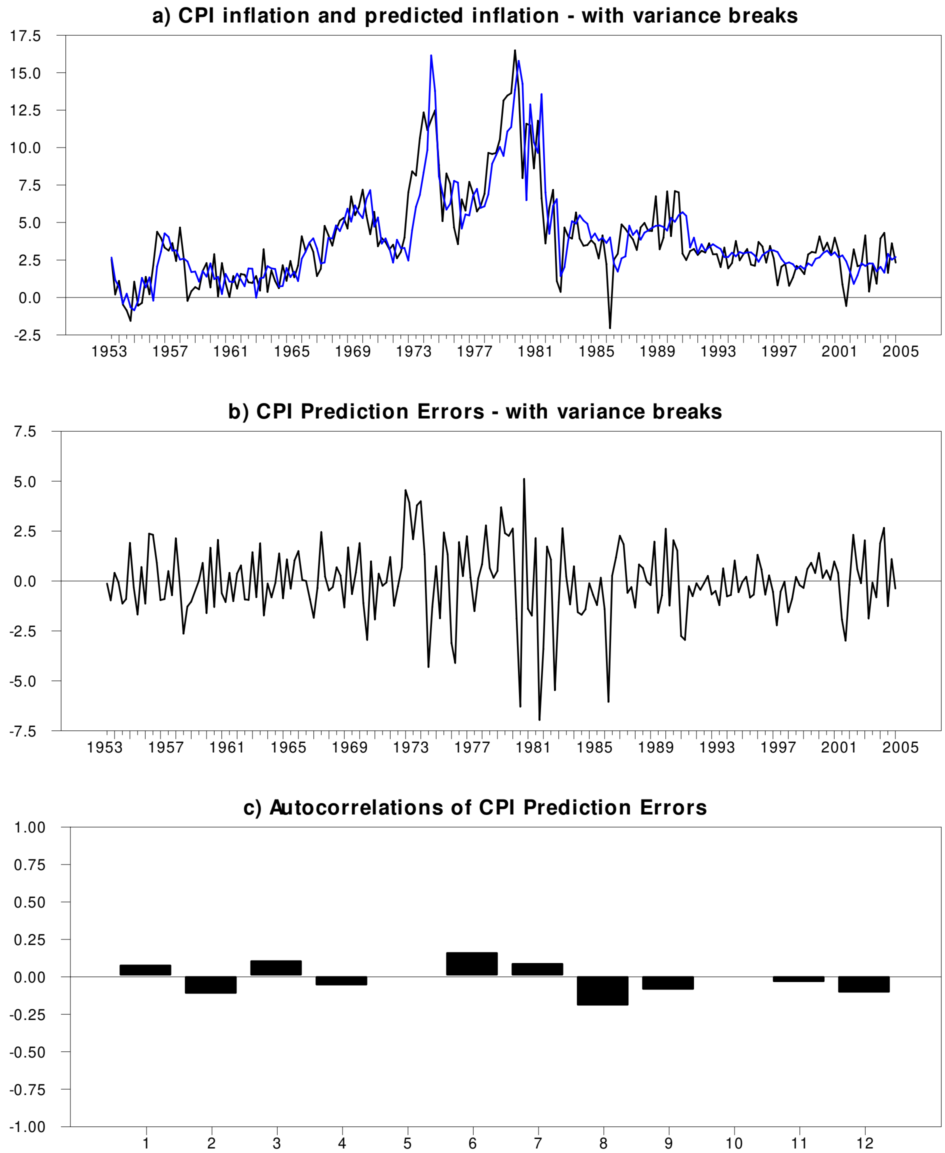

a) CPI inflation and predicted inflation - with variance breaks
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
-2.5
1953 1957 1961 1965 1969 1973 1977 1981 1985 1989 1993 1997 2001 2005
b) CPI Prediction Errors - with variance breaks
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
1953 1957 1961 1965 1969 1973 1977 1981 1985 1989 1993 1997 2001 2005
c) Autocorrelations of CPI Prediction Errors
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
1 2 3 4 5 6 7 8 9 10 11 12

Figure 14

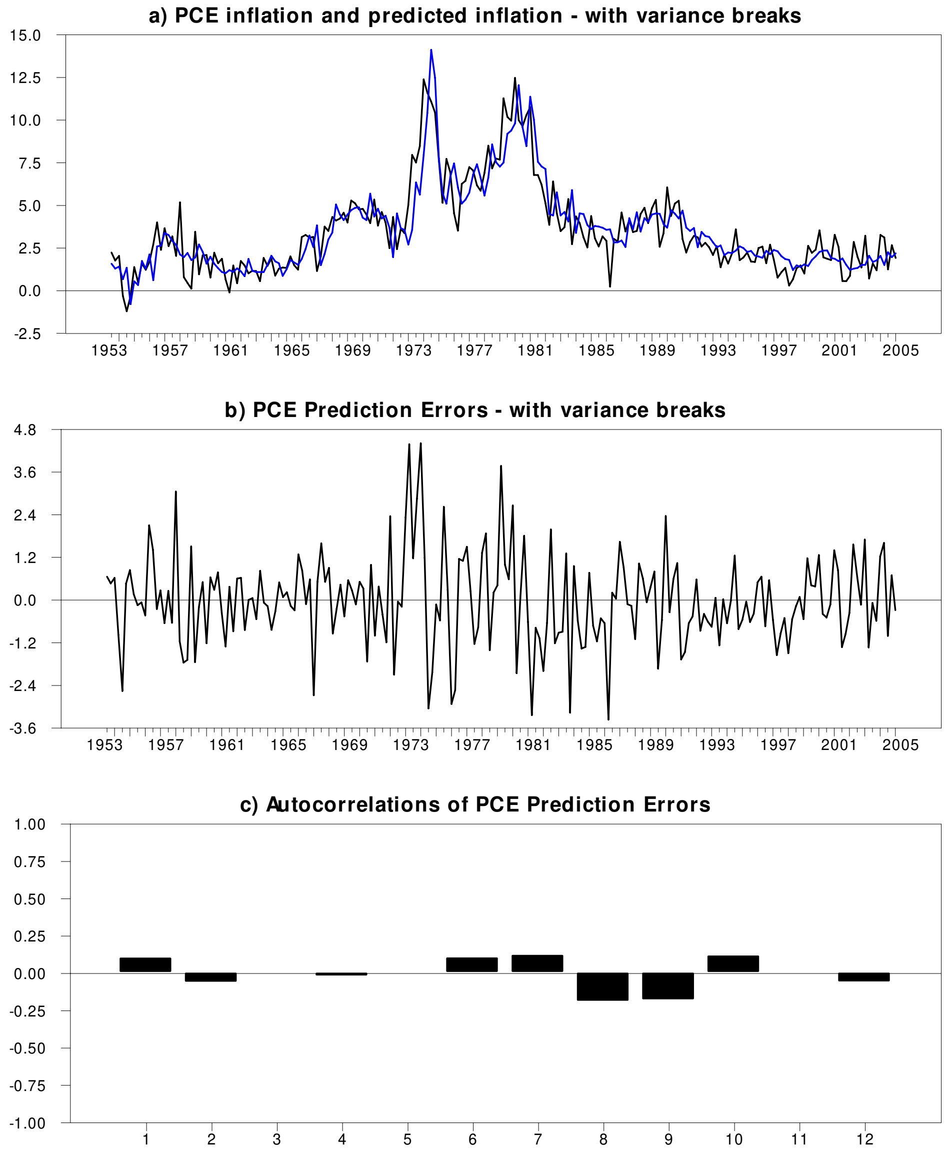

a) PCE inflation and predicted inflation - with variance breaks
15.0
12.5
10.0
7.5
5.0
2.5
0.0
-2.5
1953 1957 1961 1965 1969 1973 1977 1981 1985 1989 1993 1997 2001 2005
b) PCE Prediction Errors - with variance breaks
4.8
3.6
2.4
1.2
0.0
-1.2
-2.4
-3.6
1953 1957 1961 1965 1969 1973 1977 1981 1985 1989 1993 1997 2001 2005
c) Autocorrelations of PCE Prediction Errors
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
1 2 3 4 5 6 7 8 9 10 11 12

Figure 15

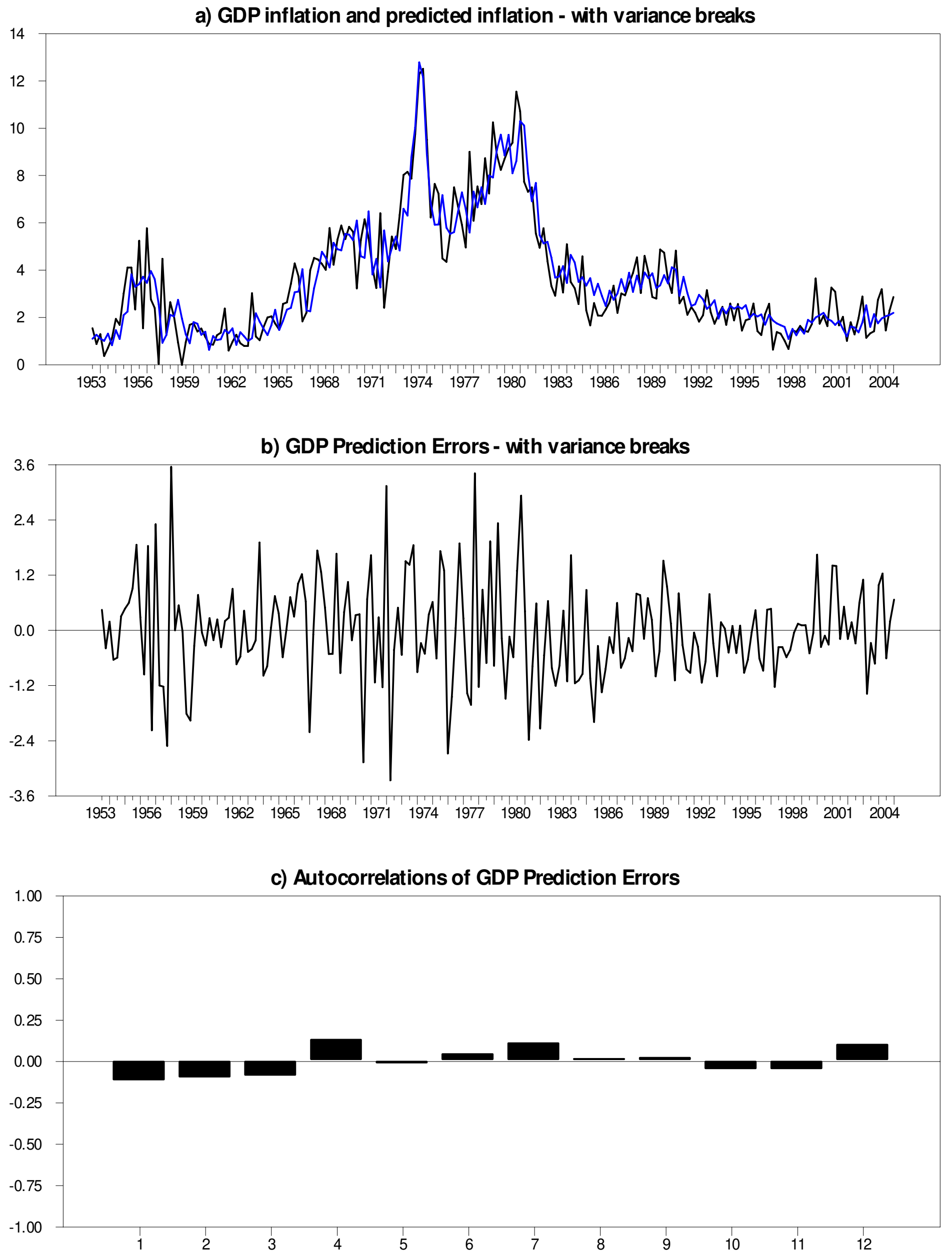
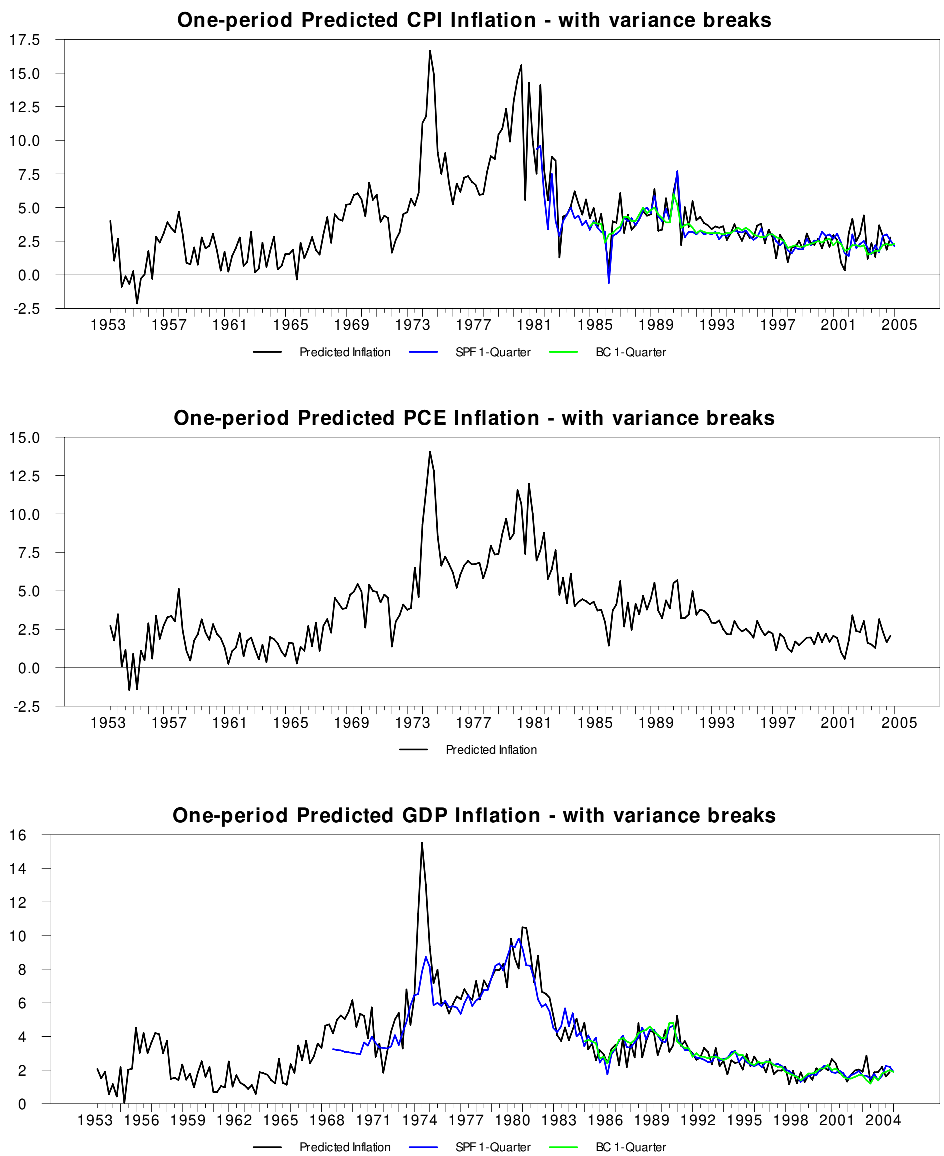
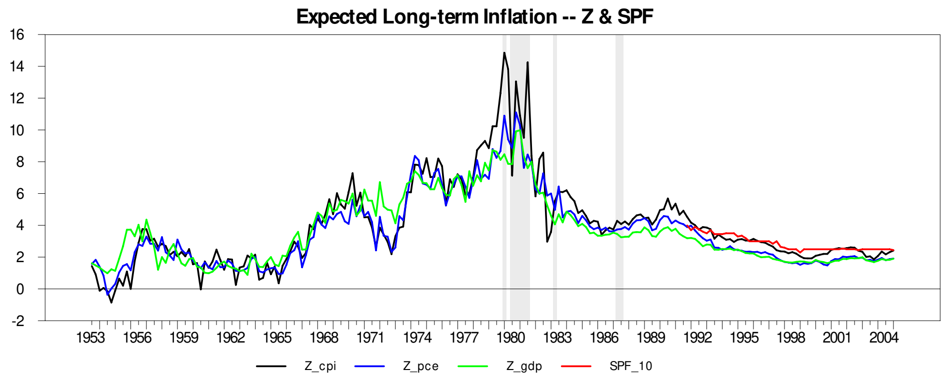

a) GDP inflation and predicted inflation - with variance breaks
14
12
10
8
6
4
2
0
1953 1956 1959 1962 1965 1968 1971 1974 1977 1980 1983 1986 1989 1992 1995 1998 2001 2004
b) GDP Prediction Errors - with variance breaks
3.6
2.4
1.2
0.0
-1.2
-2.4
-3.6
1953 1956 1959 1962 1965 1968 1971 1974 1977 1980 1983 1986 1989 1992 1995 1998 2001 2004
c) Autocorrelations of GDP Prediction Errors
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
1 2 3 4 5 6 7 8 9 10 11 12

Figure 16



One-period Predicted CPI Inflation - with variance breaks
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
-2.5
1953 1957 1961 1965 1969 1973 1977 1981 1985 1989 1993 1997 2001 2005
Predicted Inflation
SPF 1-Quarter
BC 1-Quarter
One-period Predicted PCE Inflation - with variance breaks
15.0
12.5
10.0
7.5
5.0
2.5
0.0
-2.5
1953 1957 1961 1965 1969 1973 1977 1981 1985 1989 1993 1997 2001 2005
Predicted Inflation
One-period Predicted GDP Inflation - with variance breaks
16
14
12
10
8
6
4
2
0
1953 1956 1959 1962 1965 1968 1971 1974 1977 1980 1983 1986 1989 1992 1995 1998 2001 2004
Predicted Inflation
SPF 1-Quarter
BC 1-Quarter

Figure 17



Expected Long-term Inflation -- Z & SPF
16
14
12
10
8
6
4
2
0
-2
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
Z_cpi
Z_pce
Z_gdp
SPF_10

Figure 18

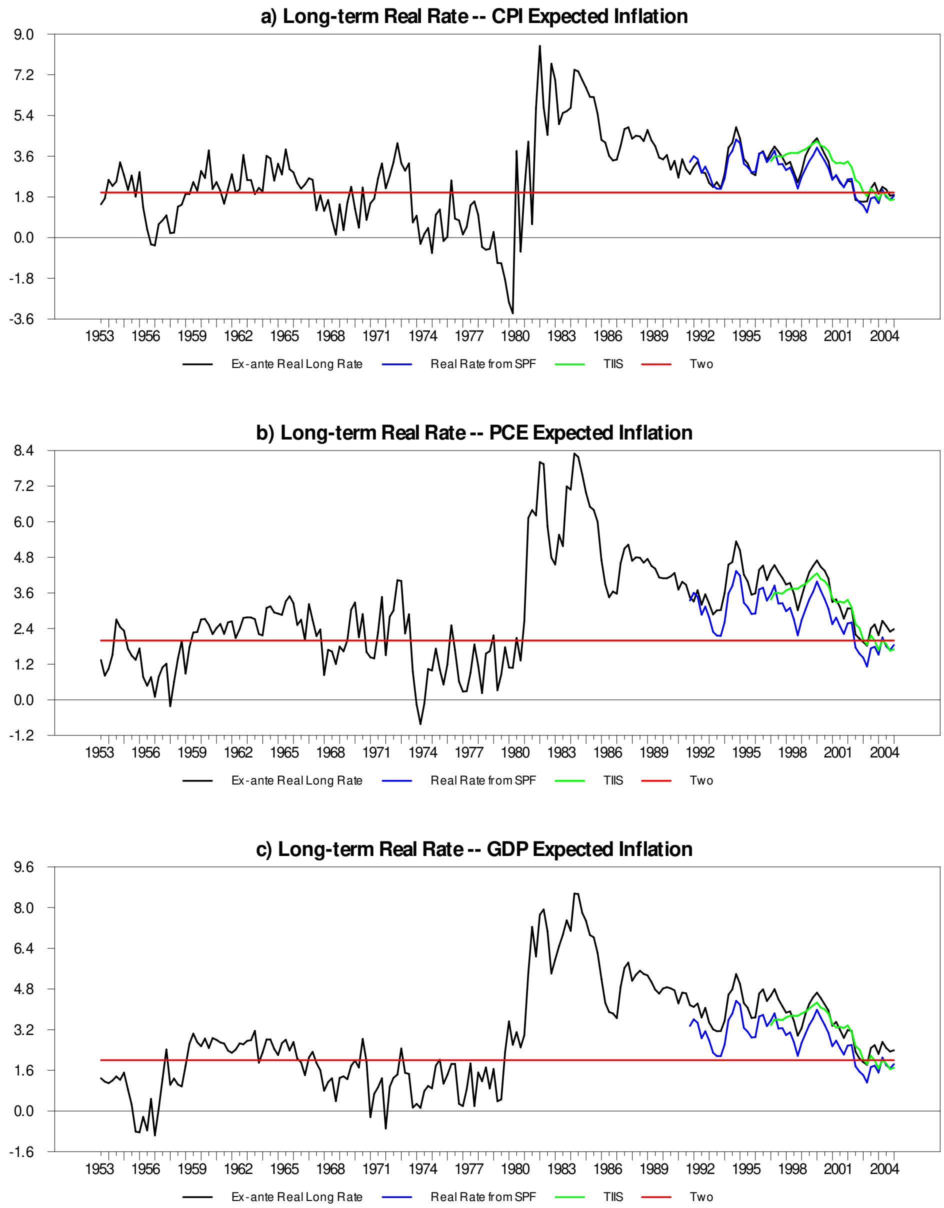

a) Long-term Real Rate -- CPI Expected Inflation
9.0
7.2
5.4
3.6
1.8
0.0
-1.8
-3.6
1953 1956 1959 1962 1965 1968 1971 1974 1977 1980 1983 1986 1989 1992 1995 1998 2001 2004
Ex-ante Real Long Rate
Real Rate from SPF
TIIS
Two
b) Long-term Real Rate -- PCE Expected Inflation
8.4
7.2
6.0
4.8
3.6
2.4
1.2
0.0
-1.2
1953 1956 1959 1962 1965 1968 1971 1974 1977 1980 1983 1986 1989 1992 1995 1998 2001 2004
Ex-ante Real Long Rate
Real Rate from SPF
TIIS
Two
c) Long-term Real Rate -- GDP Expected Inflation
9.6
8.0
6.4
4.8
3.2
1.6
0.0
-1.6
1953 1956 1959 1962 1965 1968 1971 1974 1977 1980 1983 1986 1989 1992 1995 1998 2001 2004
Ex-ante Real Long Rate
Real Rate from SPF
TIIS
Two

Figure 19

One-Year Exante Real Treasury Rate

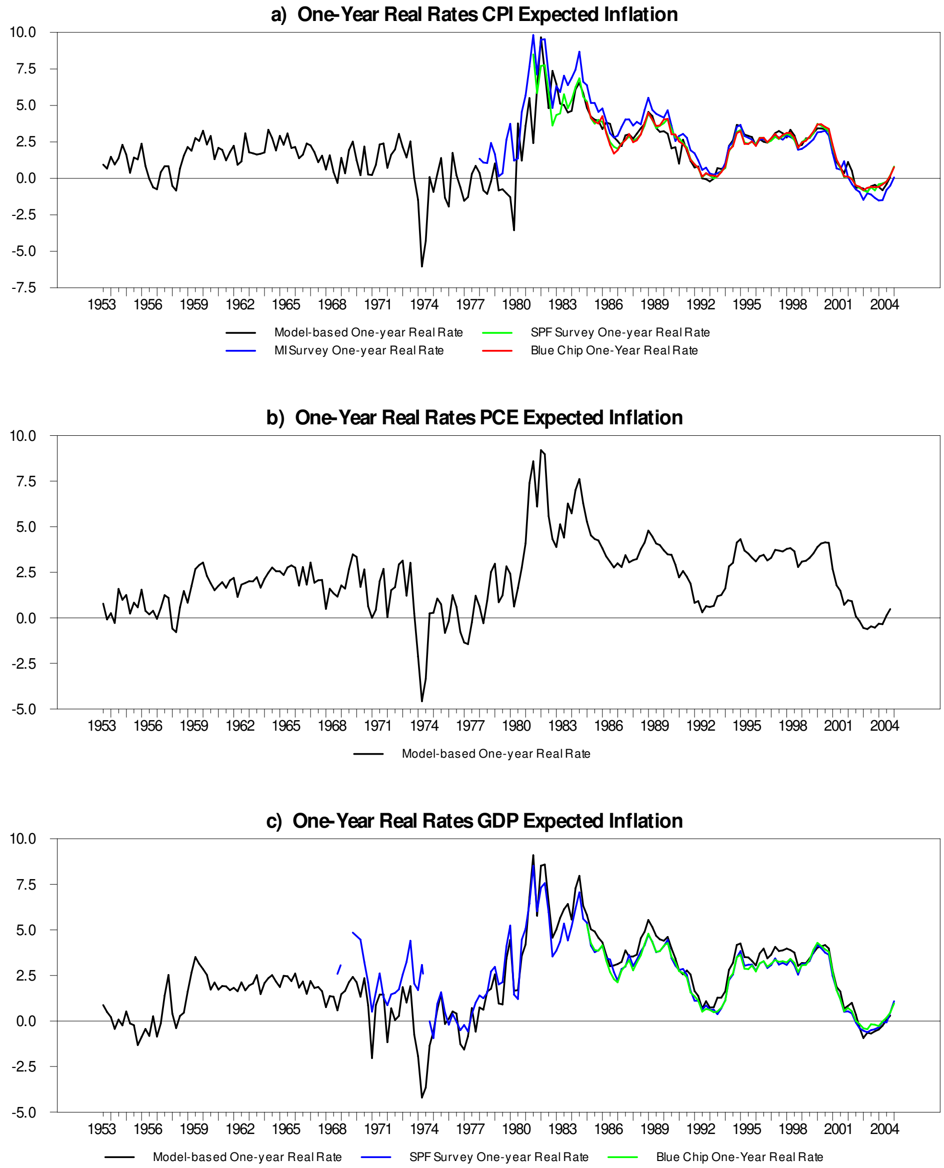
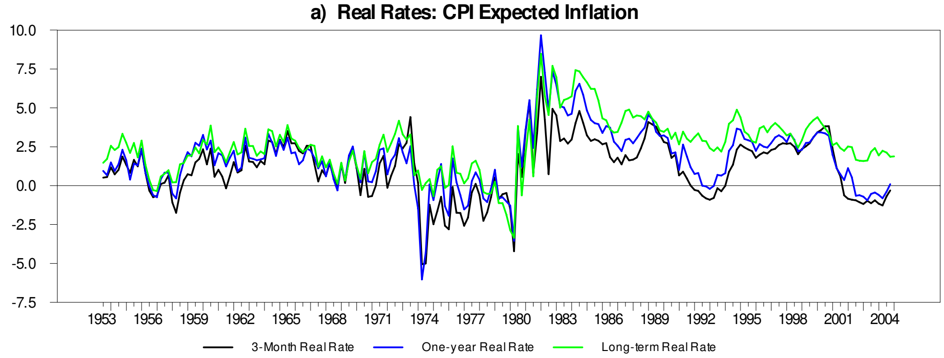


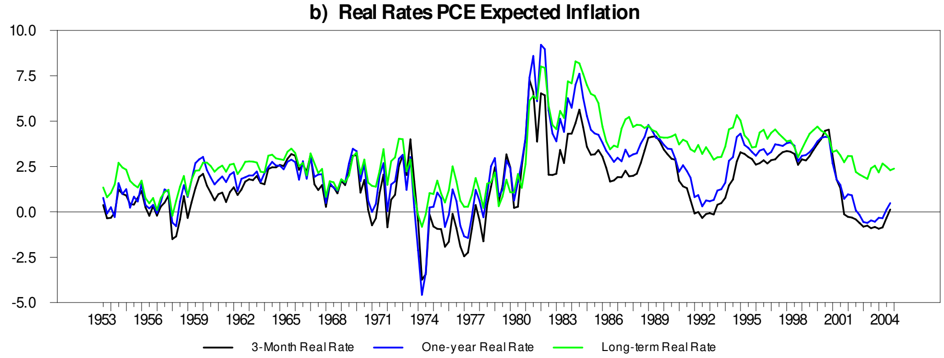
Figure 20

Real Treasury Rate Term Structure

a) Real Rates: CPI Expected Inflation



b) Real Rates PCE Expected Inflation



c) Real Rates GDP Expected Inflation