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Abstract

This paper provides a review of the concept of core inflation and evaluates the performance of several proposed measures. We first consider the rationale of a central bank in setting its inflation goal in terms of a selected rate of consumer price growth and the use of a core inflation measure as a means of achieving this long-term policy objective. We then discuss desired attributes of a core measure of inflation, such as ease of design, accuracy in tracking trend inflation, and predictive content for future movements in aggregate inflation. Using these attributes as criteria, we evaluate several candidate series that have been proposed as core measures of consumer price index (CPI) inflation and personal consumption expenditure (PCE) inflation for the United States. The candidate series are inflation excluding food and energy, inflation excluding energy, and median inflation, as well as exponentially smoothed versions of aggregate inflation and the aforementioned individual series.

For PCE inflation, we examine quarterly data starting in 1959. Unlike previous research, we confine our analysis to the methodologically consistent CPI index, which is only available starting in 1978. We find that most of the candidate series, including the familiar ex-food and energy measure, demonstrate the ability to match the mean rate of aggregate inflation and track movements in its underlying trend. In the within-sample analysis, we find that core measures derived through exponential smoothing, in combination with simple measures of economic slack, have substantial explanatory content for changes in aggregate inflation several years in advance. In the out-of-sample analysis, however, we find that no measure performs consistently well in forecasting inflation. Moreover, we document evidence of some parameter instability in the estimated forecasting models. Taken together, our findings lead us to conclude that there is no individual measure of core inflation that can be considered superior to other measures.

Key words: core inflation, inflation target, consumer price index, personal consumption expenditure index

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I. Introduction

In recent years much discussion about inflation in the United States has focused on "core" measures. Core inflation is typically viewed as aggregate inflation excluding the contribution of price changes from food and energy, although alternative concepts have been proposed. The standard rationale for confining attention to a more narrow measure of inflation is that the excluded components are "volatile" and add noise to price data. However, volatility is a common feature in economic data and there are many possible ways to remove it, such as averaging the data over several periods. Consequently, what is the merit of constructing an alternative index to reduce the volatility of incoming inflation data? That is, what is the usefulness of focusing attention on near-term movements in a truncated price measure?

This paper provides a review of "core" inflation and formally evaluates several proposed measures. We first consider the reasons why movements in aggregate price measures are interesting, especially to policymakers. The discussion also serves as a reminder that monetary policy price **goals** could be geared toward stabilizing movements in an aggregate—not "core"—price measure. As a practical matter, we offer various arguments as to why the goal could also be expressed in terms of household price measures such as the Consumer Price Index (CPI) or the Personal Consumption Expenditures (PCE) index.

We next turn our attention to the use of a core measure to mark progress to an ultimate inflation goal. In terms of the older literature on policy formulation, a core inflation measure may be thought of as an intermediate **target** for policy. Achievement of a target would be a necessary, but not a sufficient condition for success in attaining a policy goal. Within this framework, the discussion moves to the features of a core inflation measure. A useful core inflation measure could have a number of desirable attributes: Ease of design, a similar mean to the goal inflation series, an ability to track the underlying trend in the goal series, and an ability to forecast the goal series. In light of these desirable attributes, there seems to be no compelling a priori reason to exclude food and energy prices. Thus, the choice or identification of a preferred measure of core inflation appears to be an open empirical question.

Using the desired attributes as a basis for evaluation, we then undertake a formal investigation of various proposed core measures of CPI and PCE inflation. The candidate series include the popular ex-food and energy measures, ex-energy measures, median measures, as well as exponentially smoothed versions of aggregate (total) inflation and the aforementioned individual series. The empirical analysis yields mixed results. In general, the candidate measures do a good job reproducing the mean and tracking the trend of aggregate inflation. The within-sample analysis (confined to data from 1959 forward for the PCE series and data from 1978 forward for the methodologically consistent CPI series) shows that the exponentially smoothed series tend to contain important explanatory content for future changes in the goal measures, especially when combined with simple measures of economic slack. In the out-of-sample analysis, though, no series does a consistently good job forecasting aggregate inflation. Moreover, the findings document some evidence of instability in the structures of the underlying estimating models. Thus, while there are a number of viable candidates for core inflation, in the sense of filtering out noise in aggregate inflation and monitoring its current underlying trend, there is no individual measure that dominates others in terms of forecasting performance.

II. Motivation and Concepts

Thinking about Inflation Goals

Just about all Central Banks have some sort of mandate to achieve price stability. Systematic, ongoing changes in the aggregate price level, whether increases (inflation) or declines (deflation), even when they are anticipated, impose costs on economies. These costs basically arise from the reallocation of resources associated with the continual change in aggregate prices (for instance, increases in financial transactions to avoid holding cash during inflationary periods).[1] Importantly, the costs are not directly related to movements in any sort of truncated or "core" price measure—they stem from systematic changes in the prices of all goods and services produced or purchased.[2]

As a practical matter, inflation goals are often linked to movements in a price measure for consumer goods and services. Prices for many of the capital goods purchased by businesses are extremely difficult to measure, as are the prices for many of the products produced by governments (for instance, public education). A consumer-oriented price measure likely does a reasonable job capturing the

[1] There are other (likely larger) costs that arise if the inflation or deflation is unanticipated.

[2] An open point is whether the proper measure of aggregate inflation for such computations should concentrate on a price index encompassing the underlying characteristics of goods and services, or one focused on the posted price of the composite goods and services actually purchased in the marketplace. In other words, should the included "car" price measure be the cash price at which actual motor vehicles are exchanged, or should it be the price as computed by statisticians (using hedonic or other methods) of a unit with standardized characteristics? This is not an easy question to answer, partly because some of the costs connected to aggregate price changes include the "menu cost" of altering posted prices (or correspondingly, the cost of changing the characteristics of products being sold to avoid changing the posted price).

component of aggregate price movements that may affect economic efficiency. Again, a consumer price measure used for this purpose would most likely include as broad an array of goods and services as possible.

Another reason for a Central Bank to be concerned with movements in a consumer price measure is that many formal indexing arrangements, notably for wages and government taxes and benefits, are connected to indexes of consumer prices. Such arrangements always involve somewhat arbitrary reallocations of income across groups. While they indeed protect some real incomes from being reduced by inflation, it is at the expense of some reduction in economic efficiency. In principle, these costs exist even if increases in consumer prices were completely offset by reductions in other prices so as to leave a broad economy-wide index unchanged. So there is some pragmatic logic to policy concentrating its attention on inflation in its consumer component.

Given a general desire to stabilize consumer inflation, a Central Bank may want to quantify such a goal in terms of a stated level of (positive) price growth, perhaps along with a specified tolerance range around the goal. An actual goal of no price change may not be practicable, given concerns about measurement error in prices, as well as the general perception of an asymmetry in which the costs of price deflation exceed those of price inflation. Once a goal is set, the issue then becomes one of achieving it.

Marking Progress to an Inflation Goal

If a Central Bank is given or allowed to set an inflation goal, then the Bank and others need some criteria to gauge actual performance vis à vis the goal. The current logic of focusing on a core price measure is the belief that there is a significant amount of transient noise in the movement of aggregate consumer prices. This noise complicates the task of comparing incoming movements in price indexes to a longer-term goal. Filtering out this transient component gives a better sense of the underlying trend in prices, and thus a better sense of how a current measure of price change compares to the longer-term goal.

A useful way to think about this issue is the old "targets and goals" approach to policy formulation. Price stability is a **goal** of monetary policy, with a broad consumer measure possibly serving as the price index to be stabilized over the long-run. The performance of a core price measure would then serve as a way to monitor progress toward the goal, with the stabilization of a core price measure being a **target** of policy. A similar approach to policy formulation was evident in discussions centering on the use of monetary aggregates to target nominal GDP. Specifically, it was previously argued that stabilization of nominal GDP growth may be a good goal for monetary policy, because in the long-run stable low nominal GDP growth could be consistent with full employment and price stability. If there is a stable money demand function, then stabilization of the growth of a monetary aggregate would ultimately be consistent with stable nominal GDP growth. The progress toward achieving a nominal GDP growth goal could then be gauged by observing the growth of a targeted monetary aggregate.

The previous discussion recognizes that the feasibility of using a monetary aggregate to influence and control the path of nominal GDP depends on these variables displaying a stable relationship. Indeed, while the Federal Reserve adopted a policy in 1979 that placed major emphasis on achievement of monetary growth targets, it became evident in the early and middle 1980s that satisfactory rates of real output growth and inflation were occurring even though the monetary aggregates were behaving in an unanticipated fashion. Consequently, instability in the link between monetary aggregates and GDP ultimately led to an abandonment of the strategy of targeting growth of the money supply. For present purposes, the analogy is that aggregate inflation may look acceptable in spite of a core measure being outside a target range or, conversely, that achieving success in terms of a target range for a core inflation measure may not by itself ensure a similar outcome for consumer prices.

In summary, it is our opinion that stable low growth of a core price measure should not be viewed as a direct "goal" of policy, but at most as an intermediate "target". This treatment could also temper any criticism that a Central Bank's decision to ignore certain price changes in the conduct of monetary policy indicated a lack of concern for the impact of the price changes on the general public.[3] Moreover, the previous discussion underscores the importance of examining whether a core price measure displays a reliable relationship to broad consumer price goals.[4]

<u>Development of the "Core" Inflation Concept</u>

The core inflation concept originated in the early 1970s. An early (and likely initial) construction, associated with the late Otto Eckstein, was the appropriately weighted growth of unit labor and capital

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[3] That is, the tension that could arise from the public's concern with changes in the cost of living and the Bank's focus on a measure that deviates from a cost-of-living index.
[4] Of course, it can be argued that achievement of any preset price target is valuable in and of itself if it enhances the credibility of a Central Bank. Over the long-run, though, one suspects that Central Bank control over a variable that has little connection to broader policy goals has limited value.

costs, which was viewed as a proxy for "the trend rate of increase of the price of aggregate supply" (Eckstein, 1981, p. v). The logic of focusing on such a measure was straightforward: If the aggregate price index were to grow at this rate, then the employment of labor and capital would be stabilized. However, the practical use of this core inflation concept would appear to be limited. First, there is the sheer difficulty of observing labor and capital costs in a timely fashion. Second, even if one wishes to readily distinguish between the supply and demand factors influencing aggregate prices, it is not clear on a conceptual basis why this is the correct way to do so. As Eckstein himself noted, demand affects labor and capital costs. Consequently, there is no real presumption that policy could stabilize inflation at the currently observed core rate, since future changes in the core rate would not be independent of current policy decisions.

The more familiar core inflation measure as aggregate price growth excluding food and energy appears to have first been analyzed in a systematic fashion in a 1975 paper by Robert Gordon (Gordon, 1975b). Gordon was investigating the relative importance of demand and cost factors in U.S. inflation. His aggregate (p. 620) "'core' price equation" was estimated for final sales prices excluding food and energy.[5] Given that movements in food and energy prices, especially in the early 1970s, often reflected developments outside of the evolution of domestic U.S. demand and supply factors, this measure was useful for his analysis. The name "core inflation" began to be attached to price measures excluding food and energy, perhaps reflecting its rough similarity to Eckstein's measure, as well as Gordon's usage of the word. In 1978, the Bureau of Labor Statistics began to report monthly growth of both the Consumer Price Index (CPI) and the Producer Price Index (PPI) excluding food and energy.

An interesting aspect of this evolution is that the early studies of Eckstein and Gordon were somewhat comparably aimed at understanding the relative importance of demand and cost factors in the dynamics of <u>economy-wide inflation</u>. The modern usage of the core concept focuses on the growth in <u>consumer prices</u>. It is not at all clear that one can produce a core measure of consumer inflation that can be used to help distinguish between aggregate domestic supply and demand factors. A large portion of consumer purchases are for imported products, and a large portion of domestic supply is devoted to producing capital goods, exports, government output, and goods and services purchased by governments. Moreover, the usual rationale for the exclusion of food and energy costs from core price calculations (that they are influenced by world commodity markets) holds most strongly for the raw commodity elements of these products. Consumer-level prices for food and energy will be often influenced by domestic distribution costs as well as growth in aggregate demand, and will not always directly reflect exogenous forces affecting commodity markets.

III. Evaluation and Proposed Measures of Core Inflation

Performance Criteria

In any event, the initial Eckstein identification of "core" inflation with the underlying cost trend for aggregate supply has been abandoned. Instead, the usage now appears to be limited to a concept of household inflation trimmed of transient movements. Aside from series removed of energy and food price changes, some alternative core measures that have been proposed include aggregate series removing just energy (Clark, 2001), "median" price series (Bryan and Cecchetti, 1994), and exponentially smoothed versions of aggregate price indexes (Cogley, 2002).[6]

In some instances, the rationale for the proposed core measure appears to be construction of a readily observable variable that lines up well with the current underlying trend in household inflation. However, this is not the only criterion one could use. We propose a larger set, similar to those discussed in Wynne (1999) keeping in mind our proposition that core inflation may be thought of as an intermediate target for an aggregate inflation goal[7]:

1. Transparency of construction. It may be helpful to build a core price measure in a straightforward, relatively easy fashion. This facilitates communication of the concept in the policy dialogue.
2. Similarity of means. A useful core measure might have a comparable mean to the goal inflation variable over a long period of time.

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[5] In a slightly earlier piece, Gordon (1975a) referred to 1973-74 inflation as made up of several components, including (p. 184) "underlying 'hard-core' inflation".

[6] Clark motivates his measure of core inflation on the grounds that food prices, at least at the consumer level, are likely to react to many of the same forces that influence other retail prices, while energy price changes contain a large element of transient commodity price shifts. For the core measure proposed by Bryan and Cecchetti, the median price increase in a period is the price rise for that product for which half the expenditures in the period are for products whose prices are rising just as much or more rapidly, and half for products whose prices are rising just as much or more slowly.

[7] Wynne (1999), like Bryan and Cecchetti (1994), also notes that at times the rationale for the construction of a core index has appeared to be identifying the common, non-idiosyncratic component of price changes due to the effects of monetary policy. If such is the case, then it is not altogether clear why one would confine the measure to elements of household price indexes.

3. Tracking trend inflation. A core measure should display a close coherence to the underlying trend of the goal inflation measure.
4. Forecasting ability. Current information on the core price measure should provide information about future developments in the inflation goal.

Candidate Core Inflation Measures

With these four criteria in mind, we now address the construction of candidate measures of core inflation. For the analysis, we restrict our attention to inflation measures that would be plausible goals for core measures to target. We select two: Quarterly growth in the Personal Consumption Expenditures (PCE) chained price index, and quarterly growth in the methodologically consistent Consumer Price Index (CPI). In recent years the PCE has gained considerable prominence in U.S. monetary policymaking at the expense of the CPI, and it would surely be sensible to analyze the PCE in parallel with the CPI.[8]

The PCE index is produced in the course of constructing the National Income and Product Accounts data, and starts in 1959.[9] The methodologically consistent CPI is a less familiar price index. Basically, it is a reconstruction of the CPI designed to, as far as is possible, utilize current procedures to compute the prices of individual products. The major, but by no means sole, difference from the standard CPI is the extension of the current "rental equivalence" method of computing homeowners costs to data prior to 1984. The key advantage of using such a series is that it controls for any impact on the statistical results that may result from changes in the methods used to construct the CPI. A major disadvantage is that the series starts only in 1978, truncating the time period available for the analysis.[10]

Not surprisingly, as Chart 1 illustrates, the aggregate methodologically consistent series has differed from the standard published series. The divergence is most notable, and quite striking, prior to 1984, when the measurement of homeownership costs in the standard CPI was changed to the owners equivalent rent concept used for the entire history of the methodologically consistent series. We believe that it makes more sense to analyze a more consistently constructed price series.

For each of the two goal inflation series, we examine seven candidate "core" inflation measures:

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[8] For example, FOMC participants now twice a year report their projections of growth in the PCE index excluding food and energy rather than for the CPI excluding food and energy.

[9] We use the vintage of data available before the 2005 annual mid-year revision of the recent numbers.

1. The goal inflation series excluding food and energy.
2. The goal inflation series excluding energy, as proposed by Clark (2001).
3. The median measure of the goal series as proposed by Bryan and Cecchetti (1994).[11]
4. An exponentially smoothed version of the goal series, using the weighting scheme proposed by Cogley (2002).
5. An exponentially smoothed version of the goal series excluding food and energy.
6. An exponentially smoothed version of the goal series excluding energy.
7. An exponentially smoothed version of the median measure of the goal series.

With regard to the measures cited in 4)-7) above, Cogley's (2002) exponentially smoothed measure is given by:

$$\tilde{\pi}_t = g_0 \sum_j (1-g_0)^j \pi_{t-j} \quad , \quad 0 < g_0 < 1 \qquad (1)$$

where π denotes the relevant inflation measure. Equation (1) defines the core measure as a one-sided geometric distributed lag of current and past inflation. While there is some flexibility in the choice of the gain parameter g_0, we will follow Cogley and set $g_0 = 0.125$.

Clark (2001) and Cogley (2002) have approached the issues of constructing and evaluating core measures of CPI inflation using somewhat similar criteria to ours. Clark's findings indicate that a superior core measure excludes energy prices, while Cogley argues in favor of a measure constructed by exponentially smoothing aggregate inflation. Our innovations are that we apply these criteria to different inflation goal variables (the PCE index and the methodologically consistent CPI, as compared to their work with the standard published CPI), and that we consider out-of-sample as well as in-sample forecasting performance. Smith (2004) also examines the within-sample and out-of-sample forecasting performance of candidate core measures for the methodologically consistent CPI and PCE index. She concludes that the median measures provide better forecasting performance than measures excluding food and energy. Our

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[10] The methodologically consistent CPI is available monthly from the Bureau of Labor Statistics under the name "CPI-URX," and is often referred to as the "research series." We use the more cumbersome title to emphasize its advantages in statistical analysis. Stewart and Reed (1999) describe the index.
[11] Steven Reed of the Bureau of Labor Statistics provided detailed price and expenditure weight data used to construct the methodologically consistent median CPI, and also supplied us with that index excluding energy.

work encompasses a wider number of potential core measures than Smith's, a longer sample period, and a different forecast modeling strategy.[12]

IV. Empirical Framework

The criteria we use to evaluate the core inflation measures differ in terms of complexity. While the comparison of average growth rates for the aggregate and core measures of inflation is relatively straightforward, this is not the case for tracking movements in trend inflation or forecasting future inflation. Consequently, we now provide additional details on variable construction, metrics, model specifications and testing procedures that are used in our analysis.

Tracking Trend Inflation

The issue of how well a core measure tracks the underlying trend in inflation requires additional assumptions about the way to measure trend inflation and the metric to gauge the deviation between the series. To construct the trend measure of inflation, we apply the Baxter-King (1999) band-pass filter to the data.[13] The band-pass filter essentially returns a component that eliminates all periods less than 8 years (32 quarters). Following Clark (2001), we use a measure of volatility to determine if a core inflation measure provides an accurate read of trend inflation. Specifically, we compute the Root Mean Squared Error (RMSE) of the difference between trend inflation and core inflation:

$$RMSE^{CORE} = \sqrt{\sum_t (\pi_t^{TREND} - \pi_t^{CORE})^2 / T} \quad , \quad t = 1,\ldots,T. \tag{2}$$

Model Specification and Testing Procedures

Our final set of criteria relates to the ability of the candidate core inflation measures to account for movements in aggregate inflation both within-sample and out-of-sample. It should be noted that the use of forecasting performance as a metric to evaluate core inflation measures is not universally accepted. This reluctance appears to reflect a number of concerns. One concern stems from the belief that observed movements in aggregate inflation often reflect idiosyncratic, non-monetary forces, so that Central Banks should just restrict their attention to the underlying trend in inflation. Whatever merits such an argument

[12] In contrast to the number of studies focusing on various core measures of CPI inflation, the analysis of core measures of PCE inflation seems to be more limited. Aside from Smith, an example of the latter includes Dolmas (2005).

[13] Dolmas (2005) also uses the Baxter-King band-pass filter to construct an estimate of trend inflation, while Bryan and Cecchetti (1994) and Clark (2001) use a centered moving average.

may have in a conceptual model of a monetary economy, the existence of a weak connection between a measure of aggregate inflation and its underlying trend as indicated by a core proxy makes it hard to imagine that the core variable would be of much public policy interest. Another concern relates to the basic difficulty of forecasting inflation. Forecast accuracy based on the current behavior of a core measure is quite likely to vary over time. Relationships that appear to satisfactorily predict inflation in one year will often deteriorate the next [Cecchetti, Chu, and Steindel (2000)].[14] While this concern is understandable, one can still use forecasting ability as a metric to rank core inflation variables.

The following specification serves as the benchmark model for our analysis of the within-sample prediction performance and the out-of-sample forecast performance of the core inflation measures:

$$\pi_{t+h} - \pi_t = \alpha_h + \beta_h(\pi_t - \pi_t^{CORE}) + \varepsilon_{t+h} \tag{3}$$

where $\pi_{t+h} = (400) * \ln(P_{t+h} / P_{t+h-1})$ is the *h*-quarter-ahead rate of inflation reported at an annual rate, $\pi_t = (400) * \ln(P_t / P_{t-1})$ is the current quarterly inflation rate reported at an annual rate, $\pi_t^{CORE} = 400 * \ln(P_t^{CORE} / P_{t-1}^{CORE})$ denotes one of the indicators of core inflation measured at an annual rate, and ε_{t+h} is a mean-zero random disturbance term.

The regression model in (3) has been used in studies such as Clark (2001), Hogan, Johnson and Laflèche (2001), Cutler (2001) and Cogley (2002).[15] An attractive feature of the model is that it is easy to interpret. In particular, it relates the change in inflation over the next *h* quarters to the contemporaneous gap between actual inflation and core inflation. That is, the current "core deviation" (i.e., transient movement in inflation) is used to predict how much aggregate inflation will change over the next *h* quarters. The specification of the model accords with the intuition that if a core measure is identifying current price changes that are expected to die out, then the core deviation by definition should also be providing a measure of an anticipated reversal in inflation.

While the formulation of the model in (3) is admittedly simple, Clark (2001) and others argue it is consistent with the beliefs of some policymakers and commentators who take movements in core inflation,

[14] We will assess the relevance of this argument through the application of structural break tests as well as an examination of the forecast performance of the core measures over various sub-periods.

by themselves, as signals of future changes in inflation. Moreover, the specification of the dependent and independent variables in terms of differences in inflation rates effectively ensures that the individual series are stationary, thereby circumventing any complications arising from the presence of unit roots.[16]

Another attractive feature of the model is that we can draw upon the ideal of a successful measure of core inflation to obtain restrictions on the parameters in equation (3). In particular, if one adopts the Bryan-Cecchetti (1994) definition of core inflation as "the component of price changes that is expected to persist over medium-run horizons of several years", then this would imply:

$$\pi_t^{CORE} = E[\pi_{t+h} \mid I_t] \tag{4}$$

where E denotes the expectations operator and I_t is an information set that includes information on price changes through time period *t*.[17] From equation (3), the Bryan-Cecchetti definition will hold under the joint restriction $\alpha_h = 0$ and $\beta_h = -1$. Not surprisingly, this restriction is analogous to testing expectations data for the property of unbiasedness. The value of β_h is of particular interest because it indicates whether the core deviation is correctly measuring the magnitude of the transient movements in inflation. Specifically, a value of β_h > (<) unity in absolute value indicates that the measured core deviation understates (overstates) the subsequent changes in inflation, and thus understates (overstates) the magnitude of current transients.

For the within-sample analysis, we undertake estimation of equation (3) using all available observations over a sample period and allowing the values of *h* to range from 1 to 12 quarters. Whenever *h*>1, there will be overlapping observations due to the forecast horizon exceeding the sampling interval of the data. Consequently, we use the Newey-West (1987) covariance matrix estimator to account for autocorrelation (and possible conditional heteroskedasticity) of the regression residuals.

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[15] Hogan, Johnson and Laflèche (2001) analyze Canadian data. Smith (2004) estimates models broadly comparable to equation (3), but her specification includes lagged values of actual inflation and core inflation as additional regressors.

[16] During the sample periods considered in this study, U.S. price inflation displays a very high degree of persistence. In particular, it is standard in the literature to model the series as an $I(1)$ process.

[17] For the moment, we can think of I_t as a subset of a larger information set Ω_t, with the latter including all information available through time *t*. The information set I_t is merely intended to represent the data

In the case of the out-of-sample analysis, we generate the forecasts through recursive estimation of equation (3). Specifically, we use data through quarter *t+h* to estimate the model relating the change in the inflation rate between quarter *t+h* and quarter *t* to the core deviation in quarter *t*. While data on the core deviation for quarters *t+1* through *t+h* are not used in the estimation process, these observations are nevertheless available. Consequently, the estimated model can be iterated forward by *h* quarters to produce an *h*-quarter-ahead forecast of inflation. We then move the sample forward by one quarter and repeat the exercise. For each measure of core inflation and horizon, the pseudo out-of-sample forecasting procedure will generate a single series of forecast errors.[18] We can then compute the RMSE of forecasts to compare the performance of the measures of core inflation.[19]

We explore two other issues that bear upon the within-sample and the out-of-sample evaluation of the core inflation measures. First, the discussion up to this point has considered the core measures in isolation. However, we can augment the empirical framework to include other variables that may contain additional predictive content for future movements in inflation. In particular, we can extend equation (3) such that:

$$\pi_{t+h} - \pi_t = \alpha_h + \beta_h(\pi_t - \pi_t^{CORE}) + \gamma_h X_t + \varepsilon_{t+h} \quad (5)$$

where X_t is a macroeconomic variable that is taken as an indicator of economic slack in the economy.[20] While there is a large set of possible candidates, we restrict ourselves to a measure of the unemployment rate, capacity utilization, and the output gap.[21] In order to adhere to the principle of parsimony, we only experiment with the macroeconomic variables on an individual basis so that γ_h is restricted to be a scalar.

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used to construct 'traditional' core measures of inflation. As such, it would also include expenditure weights on the various components needed to compute the median measures.

[18] We use the term 'pseudo' to acknowledge the fact that the analysis does not use real-time data sets.

[19] In another study examining core measures of the methodologically consistent CPI, Marques, Neves and Sarmento (2003) do not use RMSE to evaluate forecast performance. Instead, they argue that the deviation between aggregate inflation and a measure of core inflation should be correlated with future movements in aggregate inflation but uncorrelated with future movements in the core measure itself.

[20] We could have augmented X_t to include other types of variables such as financial indicators, oil prices, and various types of monetary aggregates. However, we selected the aforementioned variables based on the previous results of Cogley (2002) as well as to keep the analysis manageable.

[21] The unemployment rate is for prime age males (ages 25-54) to control for demographic changes. Following Cogley (2002), the output gap measure is constructed as $100*[y_t - \tilde{y}_t]$, where y_t is the log of real GDP and $\tilde{y}_t$ is an estimate of the trend from applying the exponential smoother in (1).

However, we consider both the level and changes in the macroeconomic variables to account for the possibility of rate-of-change effects.

A second issue concerns stability of the models in (3) and (5). Considerable debate has focused on whether there has been a recent breakdown in inflation forecast models, with the dating typically associated with the middle of the 1990s. To investigate the issue of structural change, we use the predictive tests developed by Ghysels, Guay and Hall (1998).[22] This testing procedure is particularly attractive because it does not require the researcher to specify the break point a priori, but rather allows for an endogenous determination of the break point. Moreover, we can test for instability of the parameters jointly as well as on an individual basis. However, it is necessary to exclude a fraction of the sample at each end from consideration, so that the set of possible break points lie within an interior range. Our testing procedure is based on a 5% trimming of the sample.

V. Empirical Results

The data on aggregate PCE inflation and the candidate core measures start in 1959:Q2. For the methodologically consistent CPI, the observations on aggregate inflation and the candidate core measures start in 1978:Q1.[23] To provide a basis of comparison as well as to determine the robustness of the results, we will also undertake analysis of PCE inflation starting in 1978:Q1. Because the observations on the median CPI series and the CPI ex energy series end in 2004:Q4, all of the analyses will end there to maintain consistency.

Chart 2 plots the growth of the PCE index against the candidate core measures over the period 1959-2004. Chart 3 plots the growth of the PCE index against the candidate core measures over the period 1978-2004, while Chart 4 provides the corresponding plots for the methodologically consistent CPI over the period 1978-2004. While the truncated sample period will not affect the values of actual PCE inflation or the measures excluding energy, excluding food and energy, and its median, it will alter the exponentially smoothed series.[24]

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[22] We use the Lagrange multiplier version of the testing procedure.

[23] Quarterly values of the price indexes are averages of the relevant monthly figures, except for the growth rate of the CPI ex energy series for 1978:Q1 which was calculated as the growth of the index from December 1977 to March 1978.

[24] Our intention is to treat the PCE index in an identical manner to the CPI index over the truncated sample period. While the measures of economic slack such as the unemployment rate and capacity utilization will also be unaffected by the change in sample period, this will not be true for our measure of the output gap.

Transparency of Design, Similarity of Means, and Coherence to Trend Inflation

All of our candidate core measures appear to be "transparent" in the sense that they are related to the corresponding measures of aggregate inflation in a relatively straightforward, reproducible fashion.[25] Table 1 addresses the next two criteria for a core measure—ability to match the mean of aggregate inflation and to track trend inflation. The table provides information on the PCE index for the post-1959 period, and for the PCE index and the methodologically consistent CPI for the post-1978 period.

The first criterion is similarity of means. For the PCE index during the full period, all of the candidate core measures have means quite near to that of aggregate PCE inflation itself. The situation is somewhat different for both the PCE and CPI measures during the post-1978 period. For both price indexes, the means of the measure excluding food and energy and the measure excluding energy are quite close to that of their respective goal inflation series. However, the median measures have averages somewhat higher, as do the various exponentially smoothed series (though the difference between the exponentially smoothed CPI and the headline series is fairly small). It is likely that the general process of disinflation characterizing much of the last quarter-century accounts for some of these differences. The exponentially smoothed series are weighted sums of current and past inflation rates. If inflation is generally trending downward, there should be a tendency for the exponentially smoothed measure of inflation to be a bit higher than current inflation. Furthermore, if inflation is declining, there may also be a tendency for the outliers in the cross-sectional distribution of price change to be skewed toward negative or low readings, and thereby contributing to the median price change running a bit higher than the average price change.

The second criterion is the proximity of the candidate core measure to the current underlying trend in goal inflation. Chart 5 depicts the trend estimates, where we drop 2 years of data from the beginning and end of the filtered series because they are relatively poorly estimated. Turning back to Table 1, the RMSEs of the exponentially smoothed measures tend to track the trend more closely than the ex-food and energy, ex-energy, and median measures. Looking more closely, the exponentially smoothed version of the

[25] Admittedly, the "methodologically consistent" CPI has not received a great deal of prominence, and that the construction of the median measures and exponential smoothing involves a bit of effort. Because the current expenditure weights of PCE components may be read right off of the corresponding current-dollar consumption data it is a straightforward matter to construct the median PCE series.

headline PCE lies closest to the trend (by a narrow margin) during the full period. In the case of the post-1978 period, the exponentially smoothed median series are clearly the closest series.

These simple descriptive criteria show no clearly superior core measures. For the PCE data over the longer post-1959 period, the exponentially smoothed aggregate series had a mean very close to that of the goal series as well as the smallest deviation from trend inflation. It should be noted, however, that the performance of the exponentially smoothed ex-energy measure was almost identical. For the PCE series after 1978, the exponentially smoothed median measure was closest to trend inflation, although its mean deviated the furthest from that of the goal series. A comparable statement may be made about the CPI (except that the exponentially smoothed CPI ex energy had a mean even further from that of the actual CPI than did the exponentially smoothed median). In all instances the "standard" ex-food and energy core measures had comparable means to the goals, but a weaker connection to the trends than some of the other candidates. The median measures did not have a comparable mean to the goal measures in the post-1978 period and also were relatively distant from the trends compared to other candidates.

Within-sample Evaluation

We now examine the results from estimating equation (3) across the various sample periods, forecast horizons and core measures. Because of the large number of regressions and to save space, we do not report estimates of individual parameters and standard errors. Instead, the subsequent discussion is intended to provide a summary of the main findings.

Three results are notable. First, the $\overline{R}^2$ of the regression for each core measure of PCE inflation is typically lower over the full sample (Chart 6) than over the truncated sample (Chart 7). Thus, inflation appears to be more predictable during the latter half of the post-1960 period. When we restrict our attention to the post-1978 period, the explanatory power of each core measure for CPI inflation (Chart 8) is almost always higher than that for PCE inflation. With regard to the fit of the regressions for CPI inflation, the improvement relative to the PCE as well as the absolute magnitude is quite impressive. This is particularly true for the median and its exponentially smoothed version which are able to explain approximately 50 percent of the total variation in CPI inflation at horizons exceeding 8 quarters (2 years). On the other hand, it is interesting to note that the conventional measure excluding food and energy as well as the exponentially smoothed aggregate measure favored by Cogley (2002) tend to have the lowest explanatory content for CPI inflation.

Second, there is a marked increase in the explanatory content of the core measures as the forecast horizon increases. This result corroborates the previous findings of Hogan, Johnson and Laflèche (2001) and Cogley (2002) and is consistent with the intended design of a core measure to identify transients in the data. Not surprisingly, one would expect a greater effectiveness at filtering transients to translate directly into an improved ability to explain subsequent reversals in inflation. As Charts 6-8 demonstrate, however, there is considerable variation across the core measures in terms of their ability to remove transients from the data. It is also interesting to note that that the predictability for PCE inflation peaks at around 8 quarters over the full sample period, whereas it tends to rise steadily across the horizons for PCE and CPI inflation over the truncated sample period.

Last, the tests for 'unbiasedness' of the core measures reported in Table 2 differ markedly across the longer and shorter samples. The tests for unbiasedness were only conducted at the 12 quarter horizon to allow sufficient time for the identified transients to dissipate. While we fail to reject the property of unbiasedness over the longer sample period, we strongly reject unbiasedness for every core measure of inflation over the shorter sample period.[26] It is interesting to note that the source of the rejection does not stem from the slope coefficient, as most of the core measures satisfy the restriction of $\beta_{12} = -1$. Rather, the rejection is principally due to the intercept displaying a large and negative value. This result is not particularly surprising in light of the behavior of inflation over the post-1980 period. Specifically, it would appear that the core measures are effectively removing the transient noise around trend inflation, but are unable to account for the sustained decline in trend inflation over this sample period.[27]

With regard to the behavior of β_h, we find that most of the point estimates tend to approach and settle near -1 somewhere around h =8 quarters. However, there are some series that seem to either overestimate or underestimate the magnitude of the current transients in the data even when the horizon is extended out to 12 quarters (3 years). As shown in table 2, the ex energy measure understates the inflation

[26] The test statistic is distributed asymptotically as $F(2, 169)$ and $F(2, 94)$, respectively, over the longer and shorter samples. It should be noted that we would reject unbiasedness for the exponentially smoothed versions of the ex food and energy measure and median at a 10% significance level over the longer sample.

reversal $(\beta_{12} < -1)$ for the PCE index over the post-1978 period, while the median does the same for both price indexes over the post-1978 period. On the other hand, the exponentially smoothed versions of the ex food and energy measure and median measure overstate $(\beta_{12} > -1)$ the inflation reversal for the PCE over the full sample period.

As previously discussed, there is no reason to confine our attention to measures of core inflation when explaining subsequent movements in aggregate inflation. Consequently, we now consider the results from estimating equation (5) in which we combine the core measures with macroeconomic variables that are conventionally viewed as indicators of slack in the economy.[28] Because of the even larger number of estimated regressions involved in this part of the analysis, we again refrain from reporting estimates of the individual parameters and their standard errors. As before, we instead elect to provide a summary of the main findings.

These results suggest four main conclusions:

First, the evidence is now somewhat mixed concerning the predictability of inflation during the post-1978 period. While the (adjusted) within-sample fit for each core measure of PCE inflation remains much higher at a 12-quarter horizon over the shorter sample, the $\overline{R}^2$ of the regression for each core PCE measure now displays a greater similarity across sample periods. On the other hand, the addition of the macroeconomic variables does not appear to have impacted the relative predictability of CPI and PCE inflation over the shorter sample period. As before, the same combination of a core inflation measure and macroeconomic variable typically produces a higher $\overline{R}^2$ for the CPI inflation regressions across the various horizons.

Second, while the addition of macroeconomic variables can improve the predictability of aggregate inflation, their contribution can vary considerably across the core measures. The top and bottom panels of Chart 9 depict the (adjusted) goodness-of-fit measures for both the univariate regressions and bivariate regressions for the median CPI and exponentially smoothed CPI ex food and energy, respectively,

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[27] This contrasts with the longer sample where the sustained decline in inflation is preceded by a sustained rise in inflation.
[28] The issue of data availability also affects our analysis using capacity utilization over the post-1959 and post-1978 periods. Specifically, we use capacity utilization measured at the industrial level over the shorter

over the post-1978 period. As shown in the upper panel, the macroeconomic variables offer very little improvement in the fit of the regression over the various horizons.[29] On the other hand, the bottom panel shows a marked improvement in the fit of the regression when we include capacity utilization, the output gap, or the unemployment rate as a second explanatory variable.

Third, the predictive power of the core measures in combination with the macroeconomic variables was almost always higher when the macroeconomic variables entered the regression as a level rather than as a change. We interpret this finding as indicating the absence of "rate-of-change' effects. Within the candidate list of macroeconomic variables, the level of the unemployment rate typically resulted in the largest improvement in the fit of the regression equation. The bottom panel of Chart 9 is very representative of these findings.

Last, the highest $\overline{R}^2$ for the PCE inflation regressions (over both sample periods) and CPI inflation regressions involved the use of exponential smoothing and the level of a macroeconomic variable. However, exponential smoothing did not universally offer a marked improvement in terms of explanatory content relative to the other candidate core measures such as ex food and energy, ex energy or the median. This finding contrasts sharply with Cogley (2002) and likely reflects our use of the methodologically consistent CPI series as well as a difference in sample periods.

Out-of-sample Forecast Evaluation

We select three starting dates for our out-of-sample forecasts for PCE inflation over the longer sample period, and two starting dates for PCE deflator and CPI inflation over the shorter sample period. Specifically, all three forecast exercises include 1990:Q1 and 1995:Q1 as starting dates, with 1980:Q1 serving as an additional starting date for PCE inflation over the longer sample period. That is, the first 1-quarter out-of-sample forecast for the longer sample corresponds to 1980:Q1.[30] Similarly, the first 4-quarter out-of-sample forecast for the longer sample corresponds to 1980:Q4. As with the within-sample analysis, the out-of-sample forecast analyses all end in 2004:Q4.

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sample. Because the series is not available before 1967, we use capacity utilization of the manufacturing sector over the longer sample

[29] Admittedly, this statement may require some qualification due to the fairly impressive fit of the univariate regression on its own.

[30] As previously discussed, this forecast is based on model estimation for the 1-quarter-ahead change in the inflation rate up through 1979:Q4 using data on the regressors for 1979:Q3 and earlier. The forecast is then

We initially consider univariate forecasts based on the regression model in equation (3). Table 3 reports the RMSE statistics, in annual percentage terms, for PCE inflation over the longer sample for the post-1980, post-1990, and post-1995 forecast periods. Table 4 reports the RMSE statistics, in annual percentage terms, for PCE and CPI inflation over the shorter sample for the post-1990 and post-1995 periods. We restrict the analysis to horizons *h*=1, 4, 8 and 12 quarters to keep the discussion manageable, with the lowest RMSE at each horizon for the various out-of sample forecast periods highlighted in boldface type.

Taken together, the evidence indicates that the forecast performance of the core measures, in both relative as well as absolute terms, can vary considerably over the choices of sample period and aggregate price index. The performance also varies across forecast horizons, although the differences are more noticeable and emerge more clearly over the medium-run of several years. For PCE inflation over the longer sample, Table 3 shows Clark's (2001) ex-energy measure and Bryan and Cecchetti's (1994) median measure generally produce more accurate forecasts than the other candidate series over the post-1980 period. However, a closer examination of the results indicates that good overall performance can mask poor forecasting ability over other episodes. For example, while the ex-energy measure is also the most successful in forecasting over the post-1990 and post-1995 periods, the median measure fares quite poorly. Consequently, much of the overall forecasting success of the median measure stems from the 1980-1990 sub-period. With regard to the use of exponential smoothing, the evidence is somewhat mixed on the extent of the forecasting improvement that it can offer. While there are instances in which exponentially smoothing an individual series leads to an improvement in RMSE, a look at the RMSEs for the ex food and energy, ex energy and median measures over the post-1980 period demonstrates how this procedure can also deliver worse RMSEs on the order of 15 -25%.

When we turn our attention to PCE inflation over the shorter sample period, we observe from the top panel of Table 4 that the median and exponentially smoothed median outperform the other candidate series. In particular, the relative forecast accuracy in some cases is quite impressive with RMSEs that can be lower than alternatives by as much as 40%. As before, the median and exponentially smoothed median begin to distinguish themselves as the forecast horizons extend out to 8-12 quarters (2-3 years). Compared

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constructed by iterating the model forward by one quarter and using the available observations on the to their performance using the longer sample, the forecast accuracy of most of the core measures at 8 and 12 quarters is quite similar over the post-1990 period. For the post-1995 period, however, the RMSEs are generally noticeably higher.

In the case of CPI inflation, the exponentially smoothed median generally delivers the best RMSEs. On the other hand, and in contrast to our reported results for PCE inflation over the longer sample, the ex energy measure as well as its exponentially smoothed version perform quite poorly at the longer forecast horizons. This finding also contrasts with Clark's reported evidence and again likely reflects differences in sample periods as well as in our use of the methodologically consistent series. Restricting attention to the shorter sample period, it is also of interest to note that the RMSEs for CPI inflation are typically larger than those for PCE inflation for each candidate core inflation series at each horizon.

With regard to the inclusion of macroeconomic variables in the out-of-sample forecasts, we again provide a summary of the main findings to keep the discussion manageable. For the most part, the measures producing the most accurate univariate forecasts tended to see their performance carry over to the bivariate forecasts. For example, the ex-energy measure generally maintained its better forecasting record for PCE inflation over the longer sample period. Similarly, the median and its exponentially smoothed version continued to provide more accurate forecasts on average than the other core measures of inflation over the shorter sample.

There are, however, several other interesting findings that emerge from an examination of the bivariate out-of-sample forecasts. Table 5 and Table 6 report the combination of core measures and macroeconomic variables that generate the lowest RMSE for the same sample periods and forecast horizons previously considered in Table 3 and Table 4, respectively. As shown, the results from the longer sample demonstrate the importance and benefits that can arise from the application of exponential smoothing techniques. There is also much more compelling evidence in support of rate-of-change effects. Specifically, the lowest RMSE is achieved with a macroeconomic variable expressed as a change in 3 out of 12 cases for PCE inflation over the longer sample period, and in 4 out of 8 cases for PCE inflation and 5 out of 8 cases for CPI inflation over the shorter sample period.

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regressors for 1979:Q4.

When compare the results from Tables 3-4 to those reported in Tables 5-6, there are instances in which the inclusion of macroeconomic variables can lead to improvements in relative forecast accuracy that are economically large. This is particularly evident for PCE inflation over the shorter sample where the exponentially smoothed aggregate measure along with the unemployment rate can produce lower RMSE statistics on the order of 30% and 60% compared to the univariate forecasts in Table 4. When the comparisons across the univariate and bivariate forecasts are made on the basis of lowest RMSE, then the improvements in relative forecast accuracy are admittedly much more modest. Of course, there is no reason to presume that the addition of the macroeconomic variables will necessarily improve out-of-sample forecast performance. The top panel of Chart 10 shows where the inclusion of the macroeconomic variables essentially results in no change in forecast accuracy, while the bottom panel provides an example where forecast performance actually worsens through the inclusion of the macroeconomic variables.

Parameter Stability

Throughout the analysis, we have maintained the assumption of a stable relationship between the goal inflation series and the core measures of inflation (as well as macroeconomic variables) over the post-1959 and post-1978 periods. This is evident in the within-sample analysis by the estimation of a single parameter vector for the models and in the out-of-sample analysis by the use of recursive estimation rather than a rolling window to generate forecasts. However, there are reasons why this assumption may require closer scrutiny. For example, some commentators have claimed that a wide range of inflation forecasting models experienced a breakdown during the middle 1990s. In addition, some of the goodness-of-fit and RMSE measures reported for PCE inflation across the longer and shorter samples would appear to hint at the possibility of parameter instability.

These considerations motivate our use of predictive tests developed by Ghysels, Guay and Hall (1998) to explore the issue of structural change. One can think of the test procedure as essentially looking over an interior range of the data for purposes of identifying the possible break date. The analysis considers both the univariate model in equation (3) and the bivariate model in equation (5), and also tests the constancy of all the parameters of the model as well as constancy of the individual parameters.[31] The joint tests of parameter stability impose a common break date across the parameters. Because the disparity in the performance of the core measures, either on an individual basis or in combination with the macroeconomic variables, is more notable at longer horizons, we restrict our attention to horizons of *h*=8 and 12 quarters.[32] As before, we offer a summary due to the large number of tests performed.

Over the longer sample, the parameters of the univariate model for PCE inflation appear stable. When we examine the bivariate model, the results generally support the claim that the parameters are stable. As shown in Chart 11, what little evidence of instability appears to be associated with the output gap variable at a horizon of *h*=12 quarters.

For the post-1978 period, the test statistics for PCE inflation again provide little evidence of parameter instability for the univariate model. For the bivariate model, however, there is now evidence of instability across two dimensions. With regard to the macroeconomic variables, the upper panel of Chart 12 depicts some evidence of shifts in the coefficient on the change in the output gap variable as well as shifts in the coefficient on the change in the unemployment rate. In addition, Chart 13 now indicates instability in the effect of the core deviation term associated with the ex energy measure on future values of inflation.

For CPI inflation, however, the results speak to a much greater concern about parameter instability in terms of incidence and statistical significance. In contrast to the estimated models for PCE inflation, the instability is much more concentrated in the coefficients on the core deviation term than the macroeconomic variables. Consequently, the test statistics indicate instability in both the univariate and bivariate models. Moreover, Chart 14 provides evidence of a breakdown in the relationship between aggregate inflation and core measures based on exponential smoothing of aggregate inflation, median inflation as well as the conventional and exponentially smoothed version of the ex food and energy series.

Another attractive feature of the structural break tests is that we can associate the test statistics with historical dates. Interestingly, there is a close correspondence between the structural break dates for PCE and CPI inflation over the short sample period, with the dates coinciding with the episode of the Volcker disinflation. For the significant test statistics in Charts 12 and 13, the dates all correspond to 1980:Q1. For the significant test statistics in Chart 14, 1979:Q1 was identified as the break date for the

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[31] Because of the overlapping nature of the data, we again employ the Newey-West (1987) covariance matrix estimator in the construction of the test stastics.

[32] Nevertheless, it should be noted that there is considerable evidence of parameter instability for PCE and CPI inflation at horizons of *h*=1 and 4 quarters over the shorter sample. The instability is evident regardless

exponentially smoothed CPI, as well as the CPI ex food and energy and its exponentially smoothed version. For the median CPI, the selected date is 1981:Q1. Because the Volcker disinflation is largely viewed as changing/improving the Federal Reserve's credibility towards establishing a lower inflation goal, one interpretation of the results is that it is detecting a combination of subsequent changes in the persistence of aggregate inflation and the degree of pass-through in an economy.

Taken together, the findings document some evidence of instability in the in the structures of the underlying estimating models. We would suggest, however, that some caveats to this conclusion are in order. For example, our results are silent on the issue of the quantitative significance of the instability in the parameters. Consequently, we cannot provide any insight at the moment about how much of an effect the shifts may have on the forecasts produced by either the the univariate or bivariate models. In addition, the conflicting evidence for PCE inflation over the post-1959 and post-1978 periods could reflect sensitivity of the test procedure to different sample sizes or indicate additional structural breaks that are present in the pre-1978 data. We feel that both of these issues warrant further exploration, especially with the attention that some of these core measures have drawn based upon their cited predictive content and forecasting capability.

VI. Conclusion

Many Central Banks highlight measures of "core" consumer price inflation in the course of policy formulation and communication. It should be recognized that the choice to stabilize consumer inflation is by itself something of a second-best solution to a more overriding goal of stabilizing the growth in an aggregate (general) price index. Moreover, stabilization of a truncated "core" price measure is even further removed from longer-run goals and is at best an intermediate target of policy. Like all proposed intermediate targets, "core" price measures should be judged on their usefulness to attain final goals.

Viewing stabilization of either PCE or CPI inflation as plausible goals for U.S. monetary policy, we evaluate a wide variety of candidate "core" inflation measures. Just about all of the measures demonstrate the ability to track the means and current trends of goal inflation. A number, particularly the median measure and its exponentially smoothed transformation, display good explanatory power in within-

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of whether we examine the univariate or bivariate models, or consider the parameters individually or jointly.

sample exercises for subsequent movements in overall inflation two or three years ahead, with or without controlling for simple measures of economic slack.

Unfortunately, the promising results weaken when we critically examine out-of sample forecasting performance and the structural stability of the models. We continue to find that the two median measures do a good job of forecasting PCE inflation out-of-sample since 1990 or 1995 when the regression models use data starting in 1978; their performance is far less impressive if the estimation period is longer. However, no core measure does an outstanding job forecasting CPI inflation. As is the case for the in-sample analysis, forecasting performance is not systematically improved or worsened using controls for economic slack.

Not surprisingly, the somewhat erratic out-of-sample results are accompanied by evidence of some structural instability in the forecasting equations. As an overall conclusion, our criteria does not allow us to identify a clear "best" or "worst" measure of either core PCE or core CPI inflation. Perhaps more fundamentally, we find no strong evidence to suggest that a selected core measure will be able to retain its relative usefulness as a tool for to forecast inflation for any given period, even when supplemented by measures of slack in the economy. Consequently, it would appear that policy would be best served by recognizing that core measures differ in the quality and nature of the insights they can provide about the dynamics of inflation and to draw from this varied information for guidance.

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Table 1
Average Inflation Rates and Volatilities Around Trend

Inflation Measure	1959-2004 Mean (Percent)	1961-2002 RMSE($\pi^{CORE} - \pi^{TREND}$) (Percent)
PCE	3.69	---
PCE ex food & energy	3.60	1.03
PCE ex energy	3.65	1.02
Median PCE	3.77	1.00
ES PCE	3.65	0.78
ES PCE ex food & energy	3.60	0.97
ES PCE ex energy	3.62	0.79
ES Median PCE	3.74	0.95

Note: ES denotes exponentially smoothed series

Inflation Measure	1978-2004 Mean (Percent)	1980-2002 RMSE($\pi^{CORE} - \pi^{TREND}$) (Percent)
PCE	3.61	---
PCE ex food & energy	3.58	0.68
PCE ex energy	3.57	0.67
Median PCE	3.89	0.70
ES PCE	3.91	0.55
ES PCE ex food & energy	3.90	0.62
ES PCE ex energy	3.91	0.53
ES Median PCE	4.12	0.39

Note: ES denotes exponentially smoothed series

Inflation Measure	1978-2004 Mean (Percent)	1980-2002 RMSE($\pi^{CORE} - \pi^{TREND}$) (Percent)
CPI	3.80	---
CPI ex food & energy	3.86	0.66
CPI ex energy	3.80	0.75
Median CPI	4.03	0.83
ES CPI	3.90	0.56
ES CPI ex food & energy	3.98	0.81
ES CPI ex energy	4.13	0.58
ES Median CPI	4.32	0.45

Note: ES denotes exponentially smoothed series

Table 2
Unbiasedness Test

1959-2004

Inflation Measure	α_{12}^{a}	β_{12}^{b}	$H_0: \alpha_{12} = 0 \text{ and } \beta_{12} = -1$
PCE ex food & energy	0.111 (0.187)	-1.059 (0.183)	0.218 *p*-value = 0.804
PCE ex energy	0.069 (0.189)	-1.491 (0.275)	1.640 *p*-value = 0.197
Median PCE	-0.008 (0.189)	-1.090 (0.201)	0.102 *p*-value = 0.903
ES PCE	0.074 (0.185)	-0.816 (0.132)	1.043 *p*-value = 0.354
ES PCE ex food & energy	0.098 (0.180)	-0.745* (0.107)	3.025 *p*-value = 0.051
ES PCE ex energy	0.097 (0.180)	-0.850 (0.120)	0.943 *p*-value = 0.391
ES Median PCE	0.034 (0.183)	-0.725* (0.113)	2.921 *p*-value = 0.056

Note: Standard errors using Newey-West (1987) covariance matrix estimator reported in parentheses. ES denotes exponentially smoothed series.

[a] $H_0: \alpha_{12} = 0$

[b] $H_0: \beta_{12} = -1$

* Significant at the 5 percent level
** Significant at the 1 percent level

1978-2004

Inflation Measure	α_{12}^{a}	β_{12}^{b}	$H_0: \alpha_{12} = 0 \text{ and } \beta_{12} = -1$
PCE ex food & energy	-0.918** (0.195)	-1.146 (0.194)	11.163 *p*-value = 0.0
PCE ex energy	-0.876** (0.190)	-1.482* (0.229)	12.772 *p*-value = 0.0
Median PCE	-1.263** (0.188)	-1.431* (0.191)	22.505 *p*-value = 0.0
ES PCE	-1.198** (0.204)	-0.893 (0.155)	19.967 *p*-value = 0.0
ES PCE ex food & energy	-1.214** (0.184)	-0.899 (0.116)	24.828 *p*-value = 0.0
ES PCE ex energy	-1.233** (0.189)	-0.966 (0.131)	23.312 *p*-value = 0.0
ES Median PCE	-1.394** (0.181)	-1.025 (0.118)	32.686 *p*-value = 0.0

Note: Standard errors using Newey-West (1987) covariance matrix estimator reported in parentheses. ES denotes exponentially smoothed series.

[a] $H_0: \alpha_{12} = 0$

[b] $H_0: \beta_{12} = -1$

*Significant at the 5 percent level
** Significant at the 1 percent level

Table 2 (continued)

1978-2004

Inflation Measure	α_{12}^{a}	β_{12}^{b}	$H_0: \alpha_{12} = 0$ *and* $\beta_{12} = -1$
CPI ex food & energy	-0.973** (0.236)	-1.024 (0.160)	8.521 *p*-value = 0.0
CPI ex energy	-0.906** (0.217)	-1.231 (0.153)	9.567 *p*-value = 0.0
Median CPI	-1.161** (0.198)	-1.332* (0.133)	18.198 *p*-value = 0.0
ES CPI	-0.936** (0.234)	-0.885 (0.136)	8.634 *p*-value = 0.0
ES CPI ex food & energy	-1.024** (0.218)	-0.804 (0.100)	14.105 *p*-value = 0.0
ES CPI ex energy	-1.276** (0.211)	-1.093 (0.120)	18.497 *p*-value = 0.0
ES Median CPI	-1.437** (0.207)	-1.179 (0.120)	24.155 *p*-value = 0.0

Note: Standard errors using Newey-West (1987) covariance matrix estimator reported in parentheses. ES denotes exponentially smoothed series.

[a] $H_0: \alpha_{12} = 0$

[b] $H_0: \beta_{12} = -1$

*Significant at the 5 percent level
** Significant at the 1 percent level

Table 3
Forecasting Performance of Alternative Measures of Core Inflation
RMSE of Univariate Forecasts

1959-2004

PCE Deflator	Core Measure	Post-1980 Sample				Post-1990 Sample				Post-1995 Sample			
		h=1	*h*=4	*h*=8	*h*=12	*h*=1	*h*=4	*h*=8	*h*=12	*h*=1	*h*=4	*h*=8	*h*=12
	Ex F&E	1.228	1.552	2.210	2.707	1.024	1.214	**1.304**	1.438	1.005	1.120	1.170	**0.948**
	Ex E	1.187	**1.454**	**2.077**	**2.549**	**0.973**	**1.111**	1.306	**1.408**	**0.946**	**1.035**	1.140	0.997
	Median	**1.167**	1.514	2.192	2.677	0.986	1.212	1.537	1.798	0.989	1.130	1.365	1.422
	ES Total	1.205	1.678	2.769	3.336	0.994	1.163	1.305	1.476	0.967	1.066	1.132	1.019
	ES Ex F&E	1.208	1.623	2.601	3.138	1.003	1.170	1.355	1.568	0.977	1.056	1.133	1.064
	ES Ex E	1.197	1.646	2.692	3.237	0.987	1.145	1.312	1.519	0.961	1.038	**1.096**	1.043
	ES Median	1.203	1.641	2.625	3.137	1.001	1.180	1.416	1.622	0.976	1.066	1.204	1.144

Note: Lowest RMSE in boldface. ES denotes exponentially smoothed series.

Table 4
Forecasting Performance of Alternative Measures of Core Inflation
RMSE of Univariate Forecasts

1978-2004

PCE Deflator	Core Measure	Post-1990 Sample *h*=1	*h*=4	*h*=8	*h*=12	Post-1995 Sample *h*=1	*h*=4	*h*=8	*h*=12
	Ex F&E	1.000	1.186	1.283	1.502	0.987	1.160	1.440	1.743
	Ex E	**0.958**	**1.106**	1.256	1.458	**0.933**	1.101	1.355	1.590
	Median	**0.958**	1.108	1.127	1.284	0.981	1.081	**1.015**	**1.131**
	ES Total	0.972	1.170	1.214	1.452	0.953	1.157	1.421	1.758
	ES Ex F&E	0.985	1.152	1.212	1.489	0.968	1.148	1.434	1.851
	ES Ex E	0.964	1.124	1.180	1.476	0.948	1.128	1.399	1.816
	ES Median	**0.958**	1.111	**1.010**	**1.095**	0.932	**1.079**	1.137	1.304

Note: ES denotes exponentially smoothes series.

1978-2004

CPI	Core Measure	Post-1990 Sample *h*=1	*h*=4	*h*=8	*h*=12	Post-1995 Sample *h*=1	*h*=4	*h*=8	*h*=12
	Ex F&E	1.314	1.523	1.480	1.703	1.235	1.483	1.591	1.885
	Ex E	1.295	1.432	1.555	1.825	1.197	1.382	1.574	1.867
	Median	**1.233**	1.383	1.477	1.868	1.267	1.491	1.467	**1.658**
	ES Total	1.355	1.586	1.455	**1.506**	1.249	1.518	1.607	1.752
	ES Ex F&E	1.373	1.565	1.422	1.540	1.266	1.507	1.582	1.833
	ES Ex E	1.292	1.413	1.394	1.768	1.207	1.420	1.626	2.092
	ES Median	1.249	**1.306**	**1.167**	1.559	**1.164**	**1.285**	**1.313**	1.698

Note: ES denotes exponentially smoothes series.

Table 5
Forecasting Performance of Alternative Measures of Core Inflation
RMSE of Bivariate Forecasts

1959-2004

PCE Deflator				
Post-1980 Sample	Horizon	Core Measure	Macro Variable	Lowest RMSE
	1	ES Ex E	Unemployment Rate	1.115
	4	ES Ex F&E	Unemployment Rate	1.275
	8	ES Ex F&E	Unemployment Rate	1.824
	12	Ex E	Output Gap	2.467
Post-1990 Sample	Horizon	Core Measure	Macro Variable	Lowest RMSE
	1	ES Ex E	Unemployment Rate	0.941
	4	Ex E	Unemployment Rate	1.111
	8	ES Ex E	Output Gap	1.116
	12	Ex F&E	Output Gap	1.266
Post-1995 Sample	Horizon	Core Measure	Macro Variable	Lowest RMSE
	1	Ex E	Output Gap	0.938
	4	Ex E	Δ(Output Gap)	1.046
	8	Ex E	Δ(Capacity Utilization)	1.099
	12	Ex F&E	Output Gap	0.961

Note: ES denotes exponentially smoothes series.

Table 6
Forecasting Performance of Alternative Measures of Core Inflation
RMSE of Bivariate Forecasts

1978-2004

PCE Deflator				
Post-1990 Sample	Horizon	Core Measure	Macro Variable	Lowest RMSE
	1	ES Median	Output Gap	0.936
	4	Median	Δ(Unemployment Rate)	1.094
	8	ES Median	Δ(Unemployment Rate)	0.984
	12	ES Total	Unemployment Rate	1.042
Post-1995 Sample	Horizon	Core Measure	Macro Variable	Lowest RMSE
	1	ES Median	Output Gap	0.921
	4	Median	Δ(Output Gap)	1.075
	8	Median	Δ(Capacity Utilization)	0.940
	12	ES Total	Unemployment Rate	1.008

Note: ES denotes exponentially smoothes series.

1978-2004

CPI				
Post-1990 Sample	Horizon	Core Measure	Macro Variable	Lowest RMSE
	1	Median	Δ(Capacity Utilization)	1.219
	4	ES Median	Δ(Unemployment Rate)	1.296
	8	ES Median	Δ(Unemployment Rate)	1.120
	12	ES Ex E	Unemployment Rate	1.486
Post-1995 Sample	Horizon	Core Measure	Macro Variable	Lowest RMSE
	1	ES Median	Output Gap	1.138
	4	ES Median	Δ(Output Gap)	1.280
	8	ES Median	Output Gap	1.252
	12	ES Ex E	Unemployment Rate	1.312

Note: ES denotes exponentially smoothes series.

Chart 1
CPI Inflation: 1978 - 2004

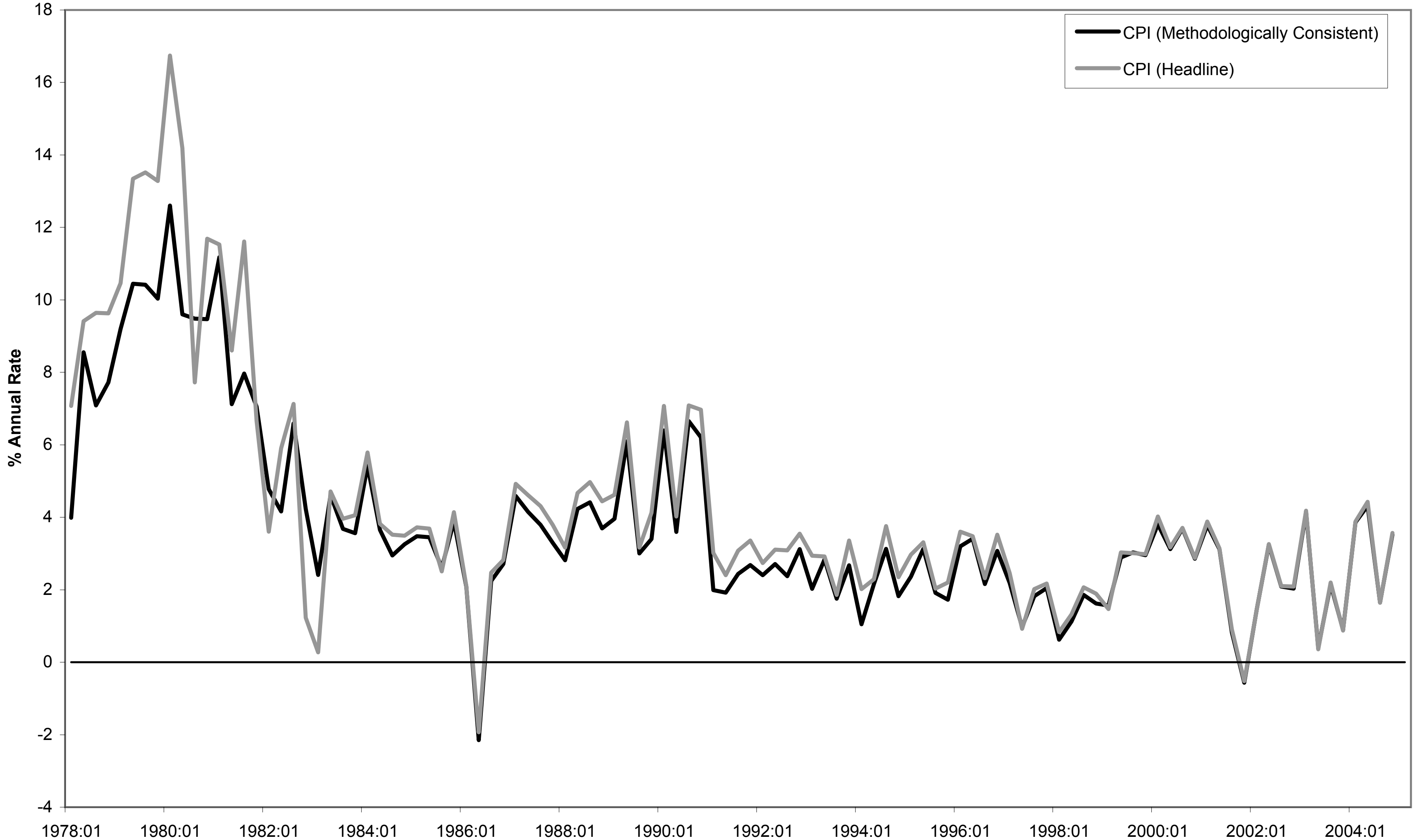
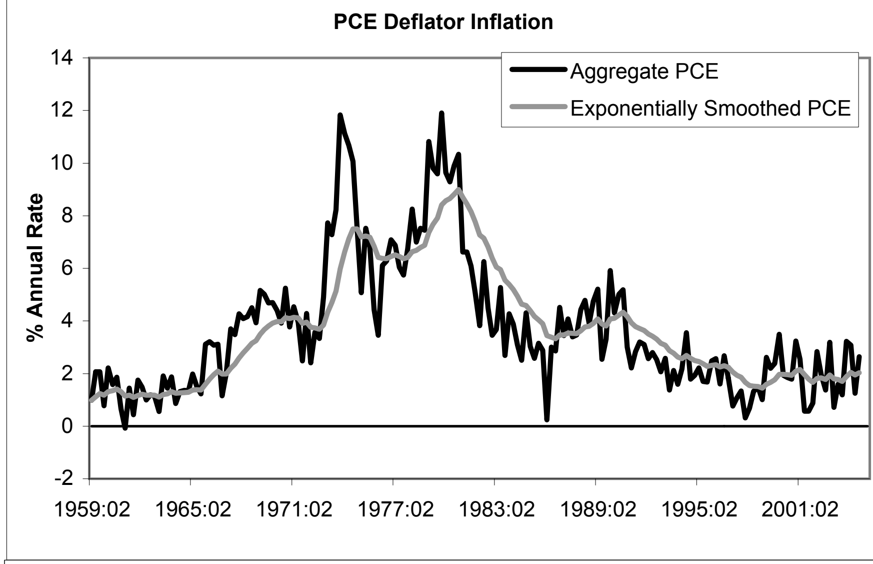
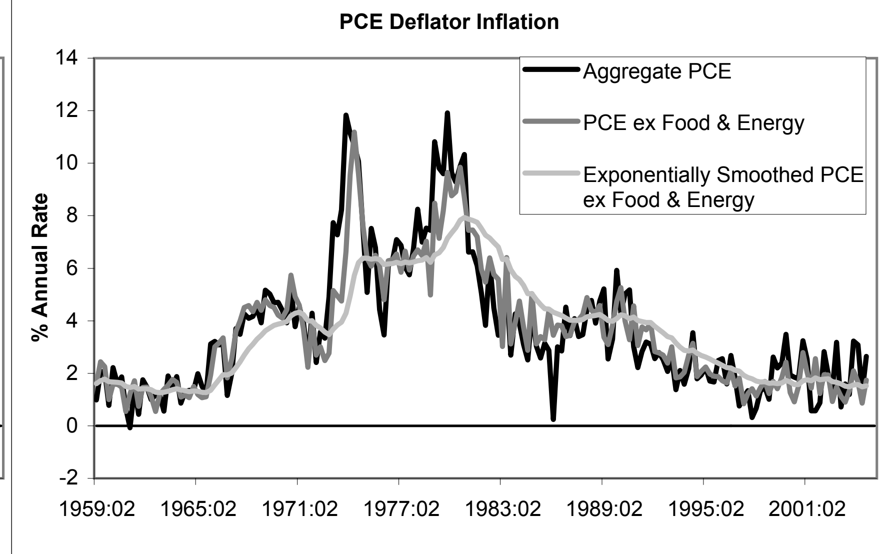
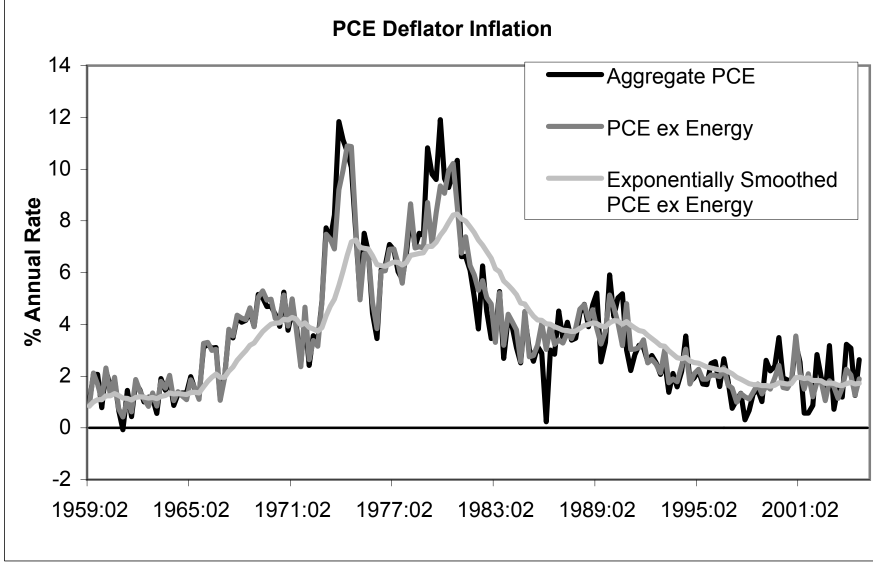


Chart 2
PCE Deflator Inflation and Core Measures: 1959 - 2004







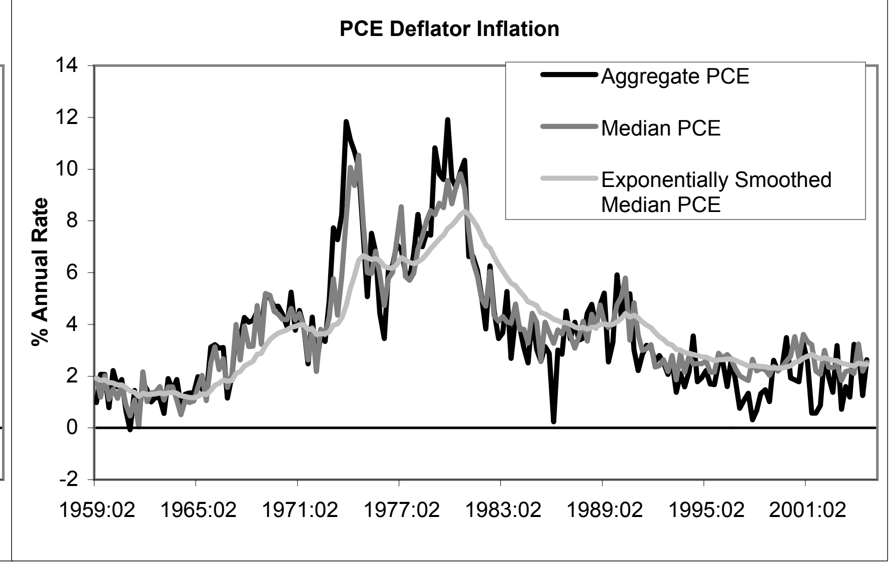


Chart 3
PCE Deflator Inflation and Core Measures: 1978 - 2004

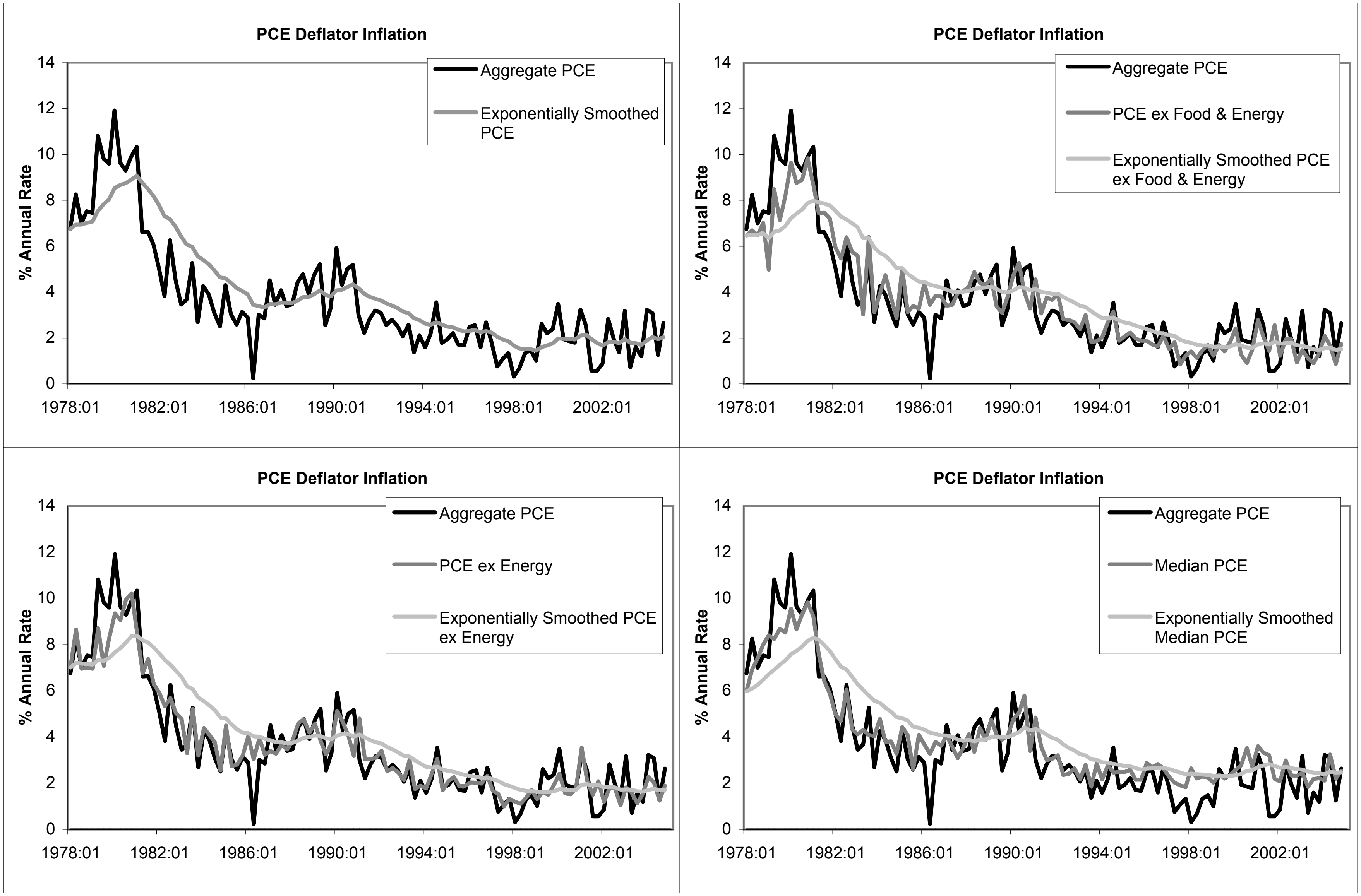


Chart 4
CPI Inflation and Core Measures: 1978 - 2004

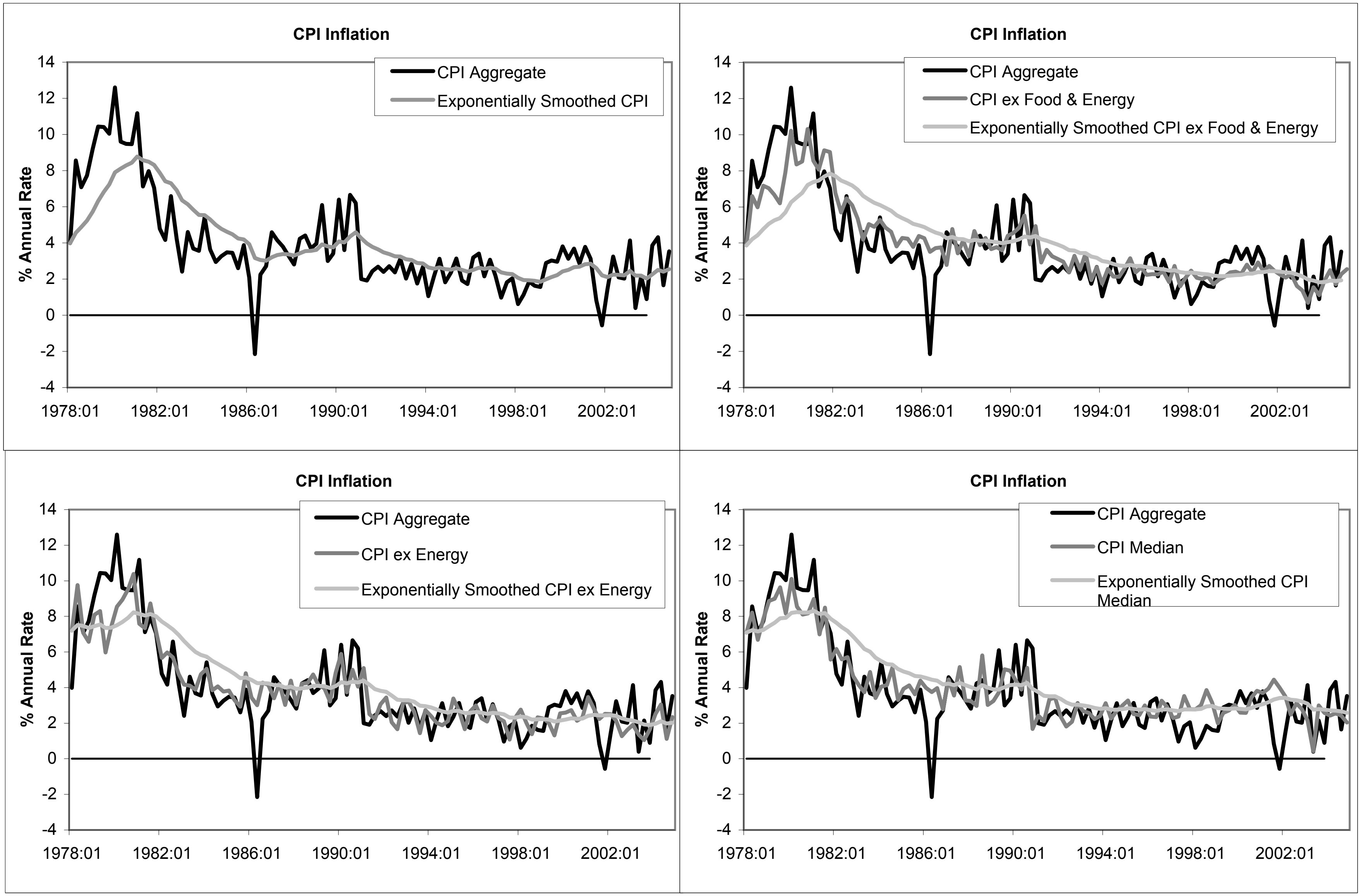


Chart 5
Aggregate Inflation and Estimated Trend Inflation

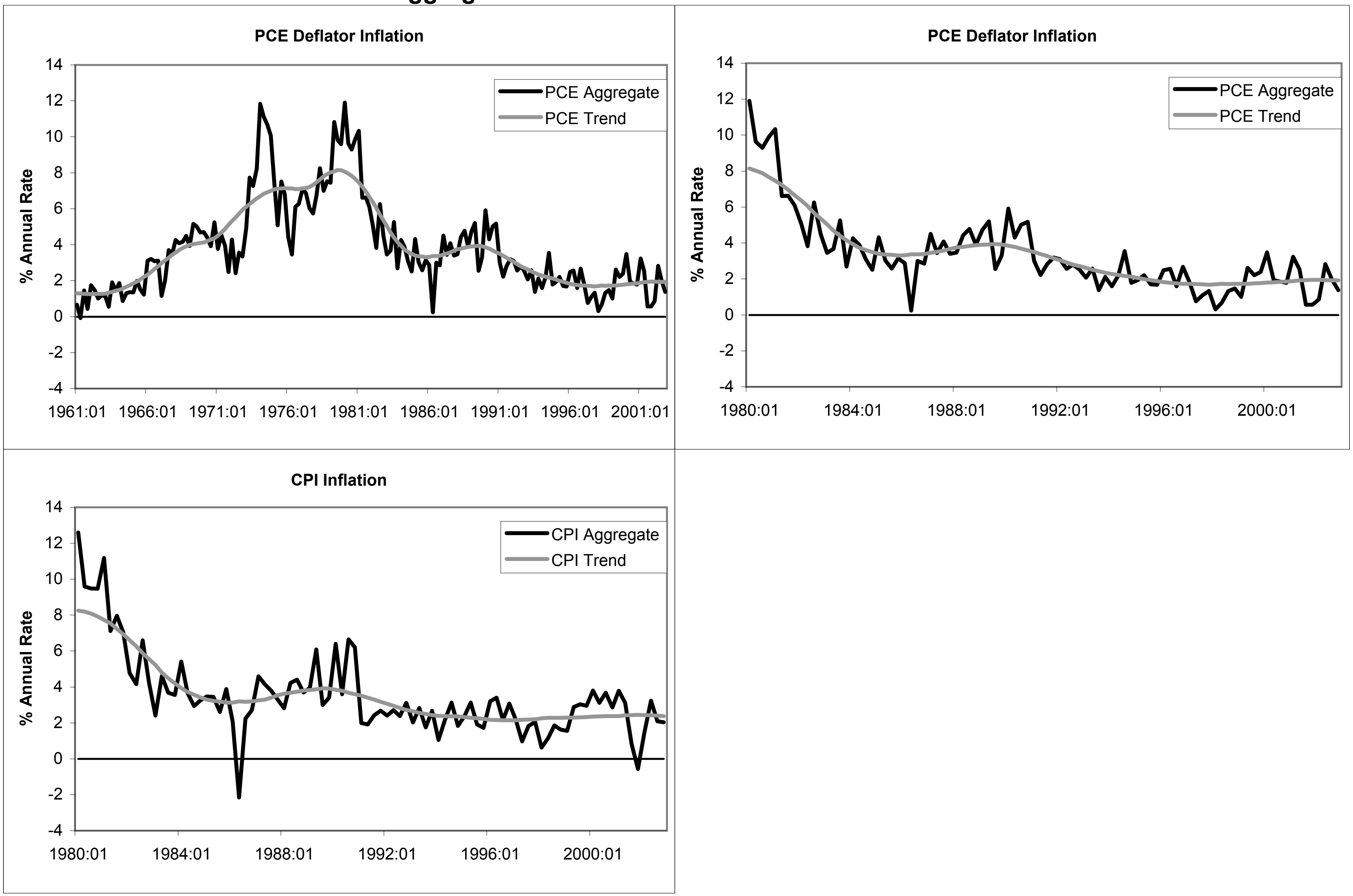
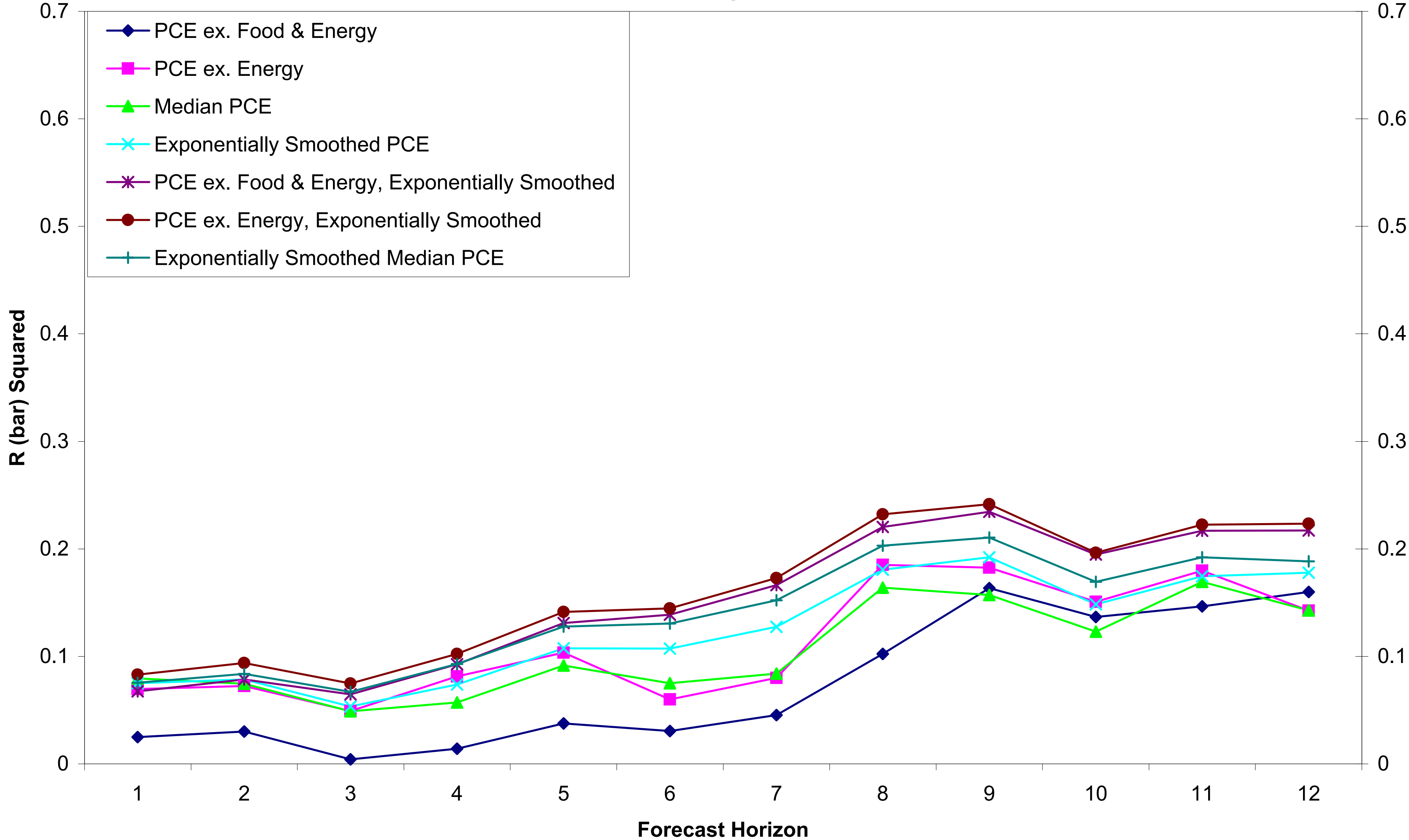


Chart 6
PCE Deflator Inflation: 1959 - 2004
Within-Sample Fit



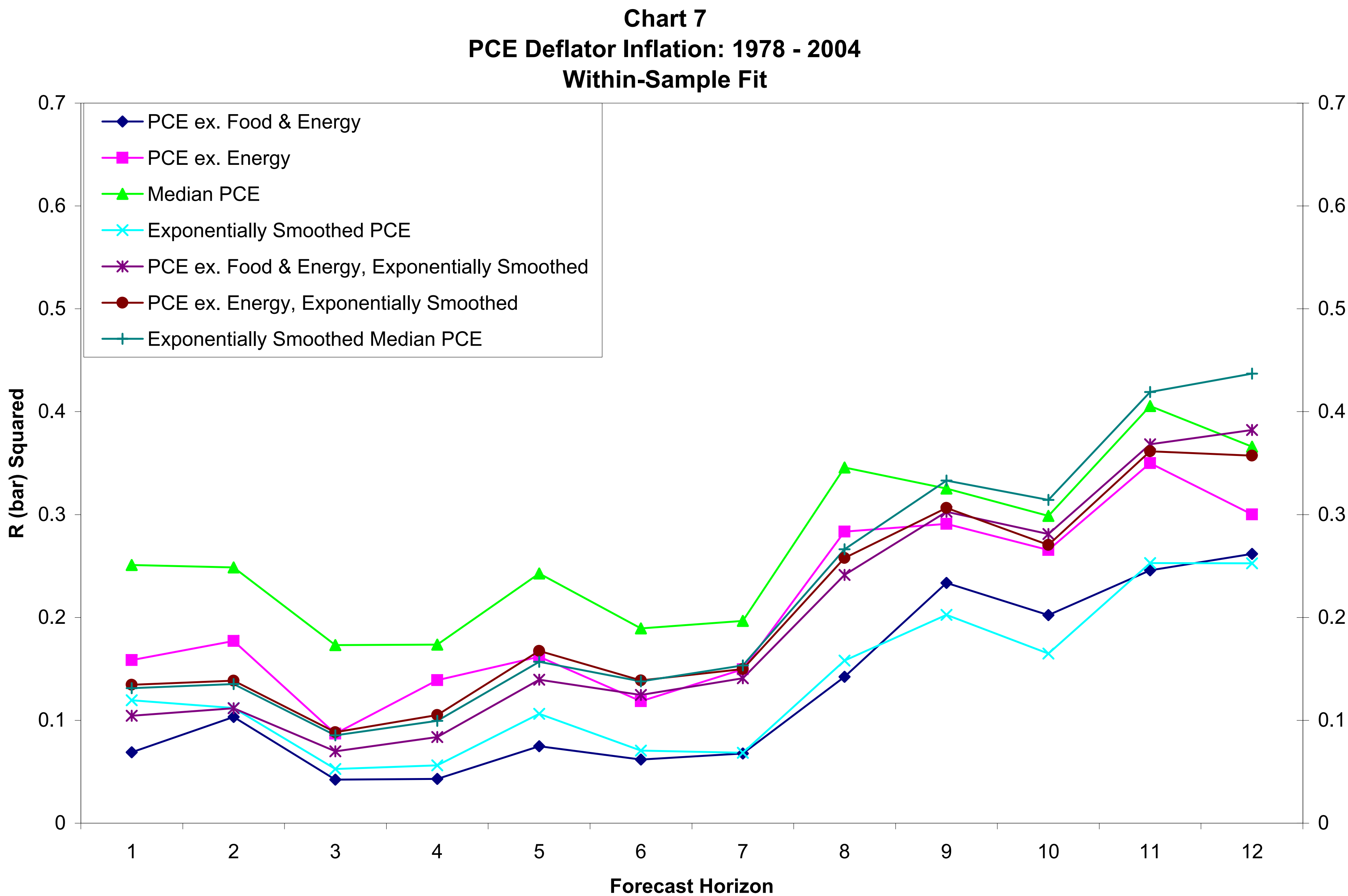


Chart 7
PCE Deflator Inflation: 1978 - 2004
Within-Sample Fit
PCE ex. Food & Energy
PCE ex. Energy
Median PCE
Exponentially Smoothed PCE
PCE ex. Food & Energy, Exponentially Smoothed
PCE ex. Energy, Exponentially Smoothed
Exponentially Smoothed Median PCE
R (bar) Squared
Forecast Horizon
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
1
2
3
4
5
6
7
8
9
10
11
12

Chart 8
CPI Inflation: 1978 - 2004
Within-Sample Fit

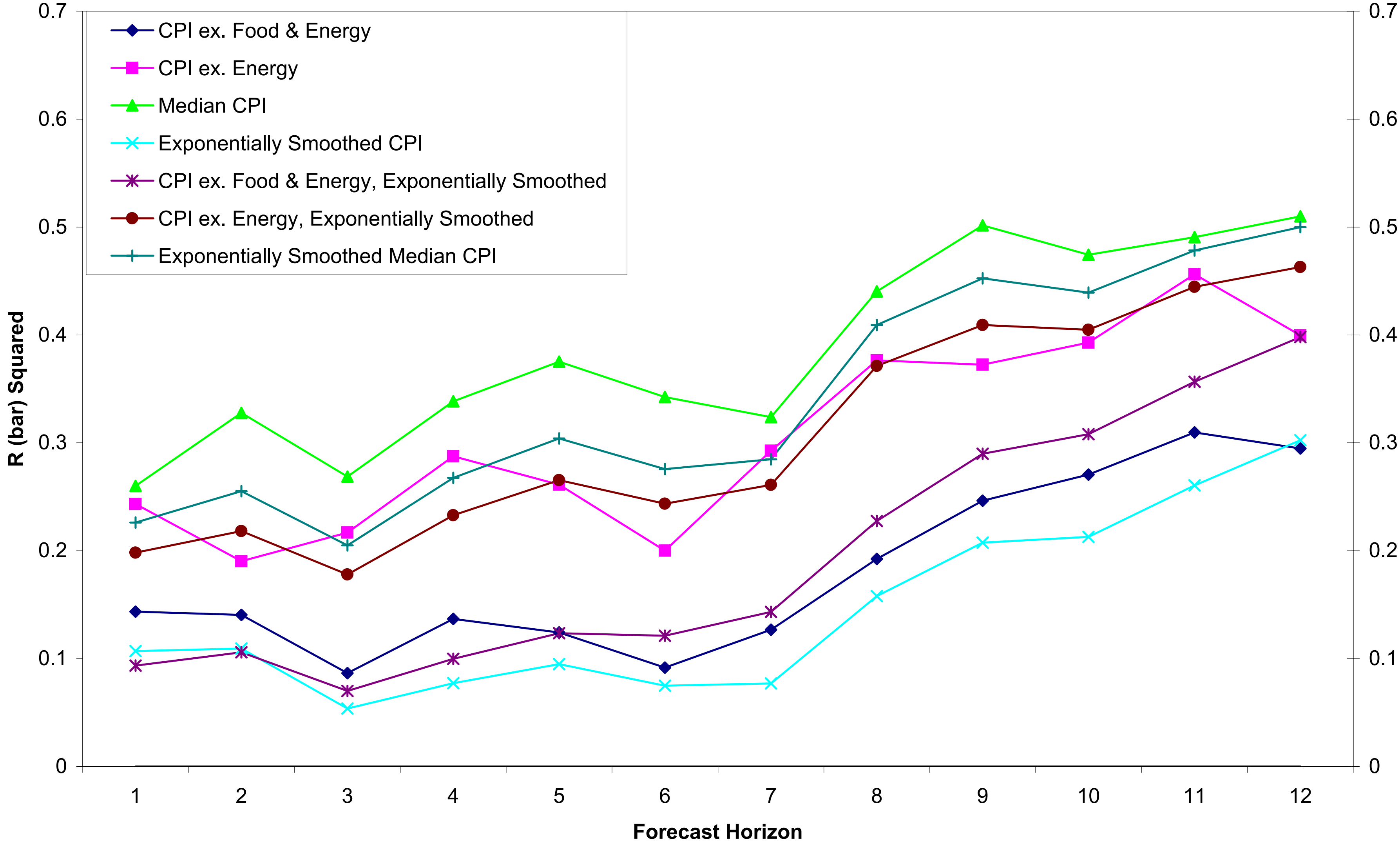
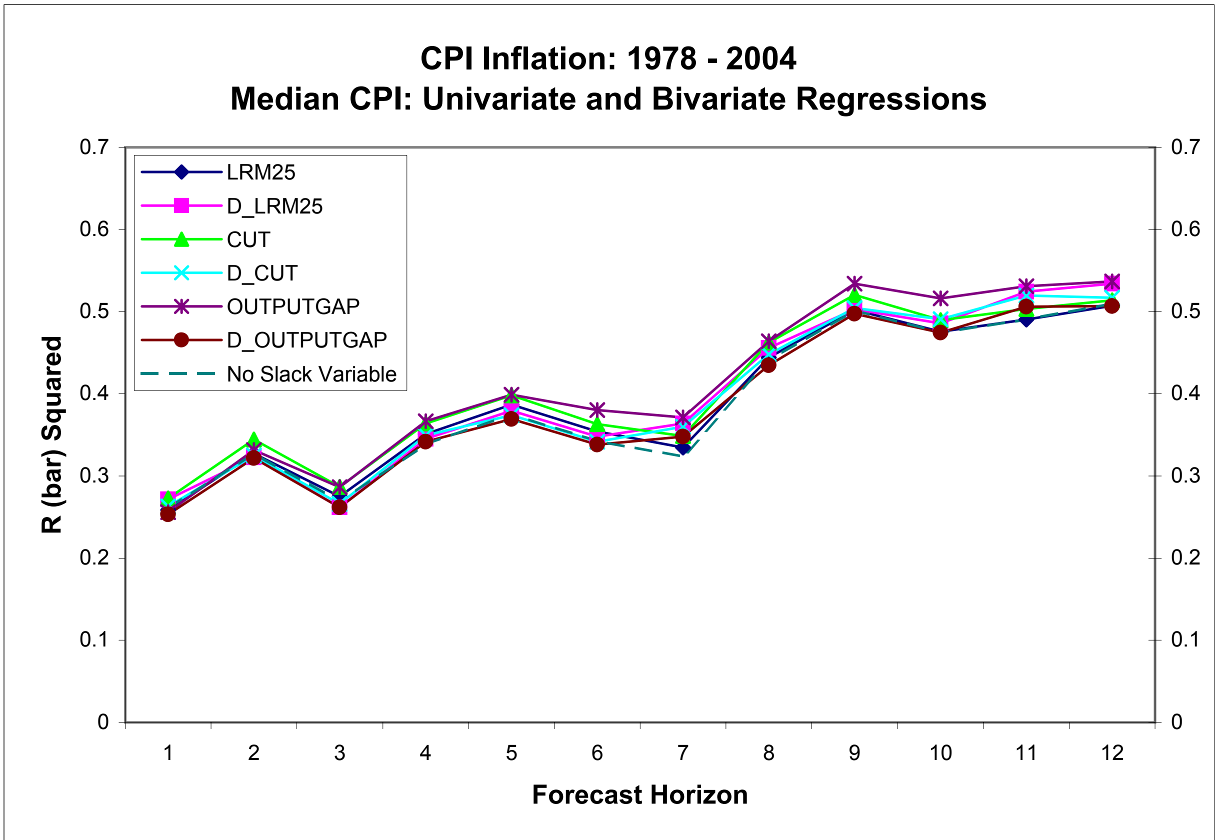
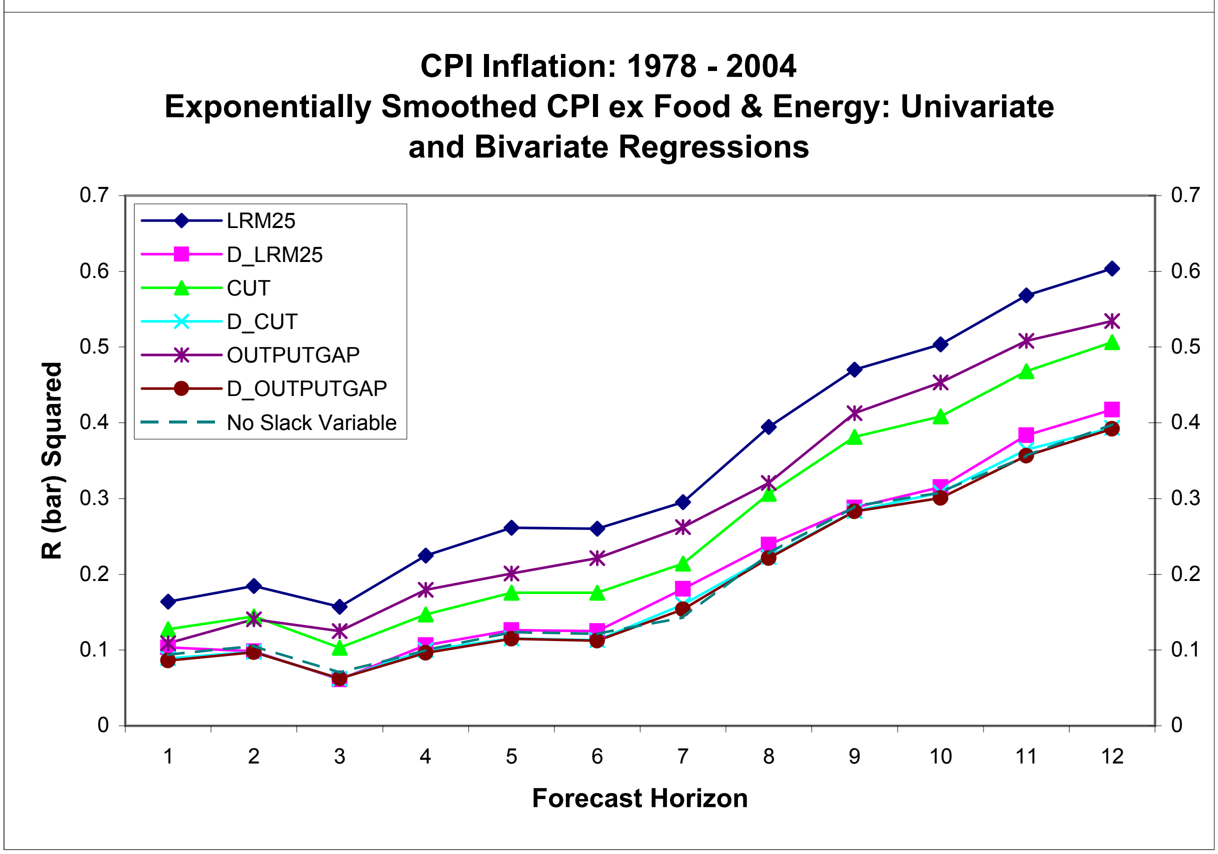


Chart 9

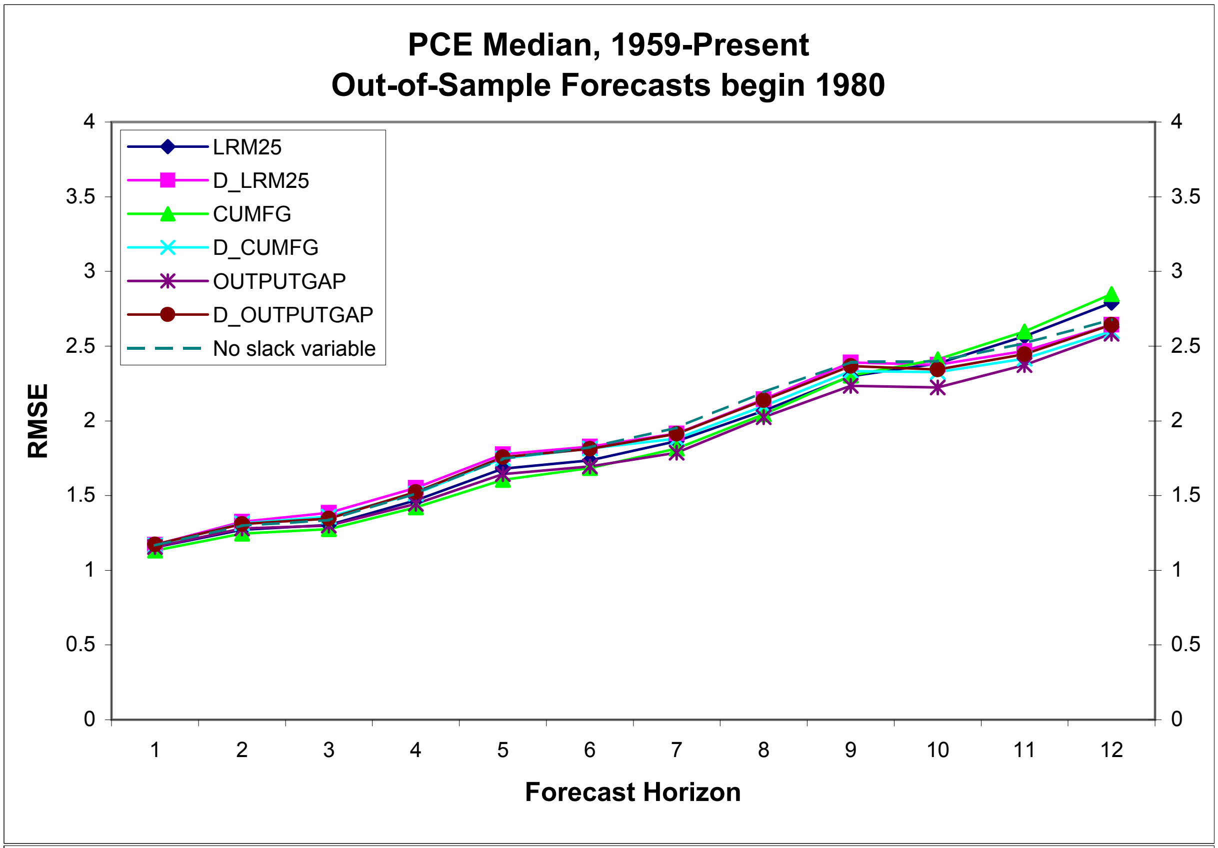


CPI Inflation: 1978 - 2004
Median CPI: Univariate and Bivariate Regressions
R (bar) Squared
Forecast Horizon
LRM25
D_LRM25
CUT
D_CUT
OUTPUTGAP
D_OUTPUTGAP
No Slack Variable
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
1
2
3
4
5
6
7
8
9
10
11
12

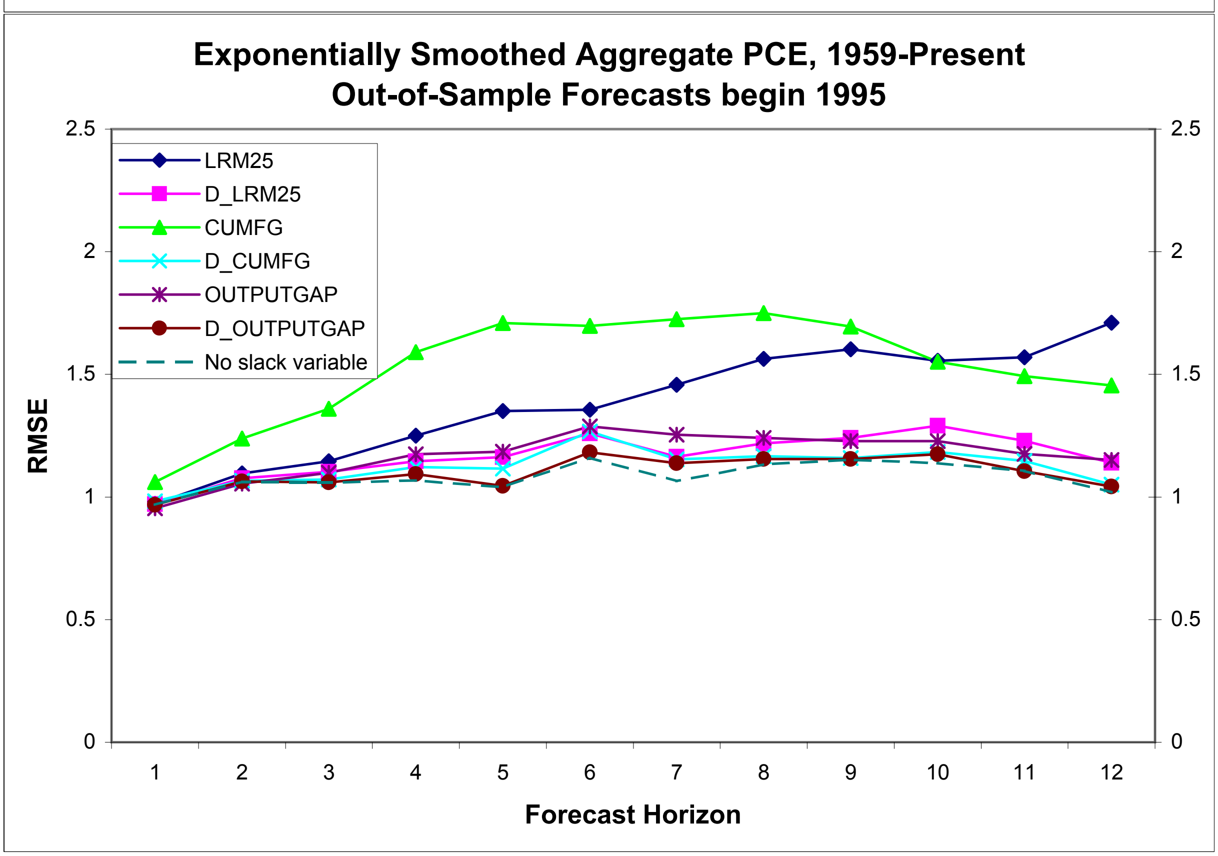


CPI Inflation: 1978 - 2004
Exponentially Smoothed CPI ex Food & Energy: Univariate and Bivariate Regressions
R (bar) Squared
Forecast Horizon
LRM25
D_LRM25
CUT
D_CUT
OUTPUTGAP
D_OUTPUTGAP
No Slack Variable
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
1
2
3
4
5
6
7
8
9
10
11
12

Chart 10



PCE Median, 1959-Present
Out-of-Sample Forecasts begin 1980
RMSE
Forecast Horizon
LRM25
D_LRM25
CUMFG
D_CUMFG
OUTPUTGAP
D_OUTPUTGAP
No slack variable
0
0.5
1
1.5
2
2.5
3
3.5
4
1
2
3
4
5
6
7
8
9
10
11
12



Exponentially Smoothed Aggregate PCE, 1959-Present
Out-of-Sample Forecasts begin 1995
RMSE
Forecast Horizon
LRM25
D_LRM25
CUMFG
D_CUMFG
OUTPUTGAP
D_OUTPUTGAP
No slack variable
0
0.5
1
1.5
2
2.5
1
2
3
4
5
6
7
8
9
10
11
12

Chart 11
Supremum Statistic for Coefficient on Macroeconomic Variable, 12-quarter Horizon
PCE 1959-Present

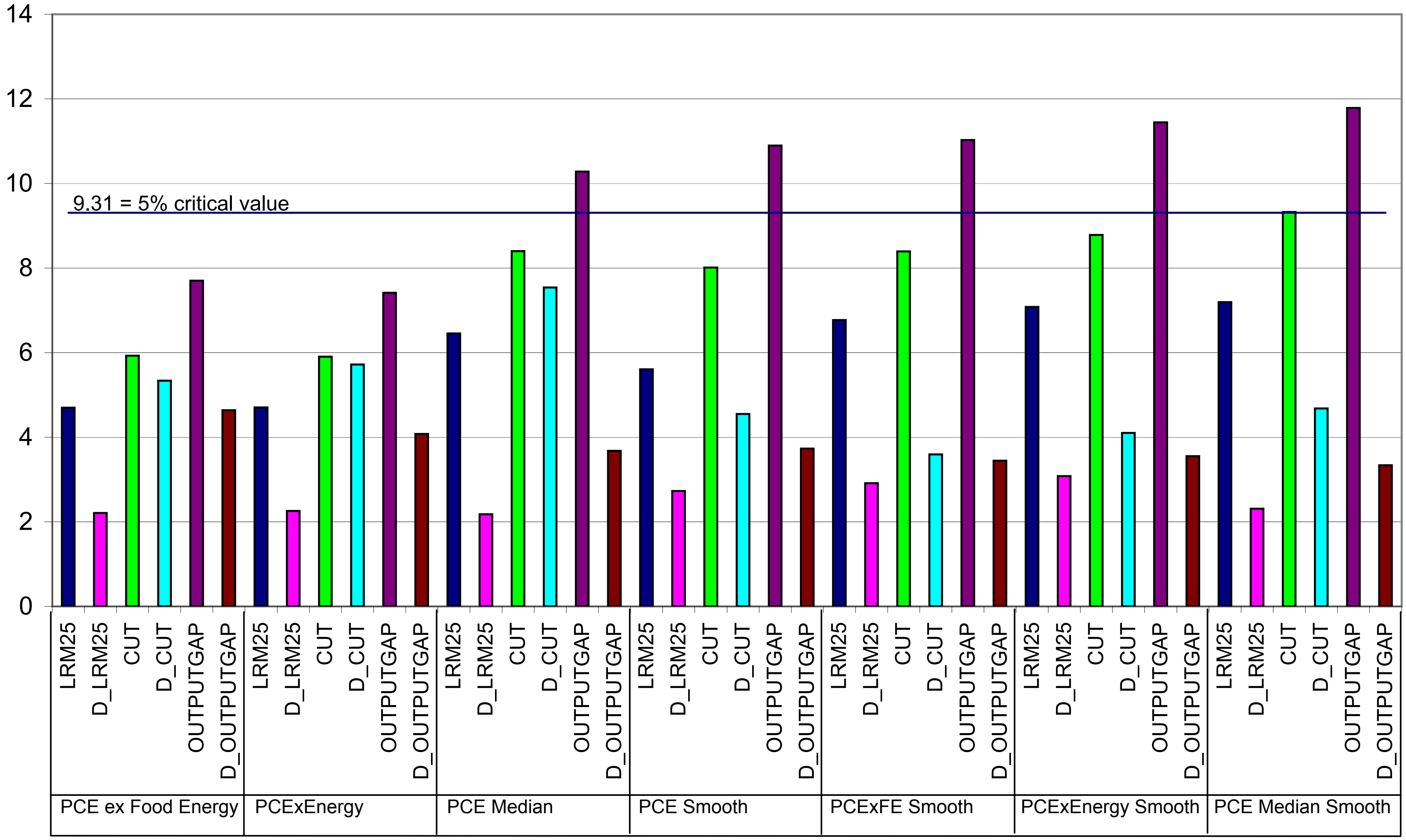


Chart 12
Supremum Statistic for Coefficient on Macroeconomic Variable, 12-quarter Horizon
PCE 1978-Present

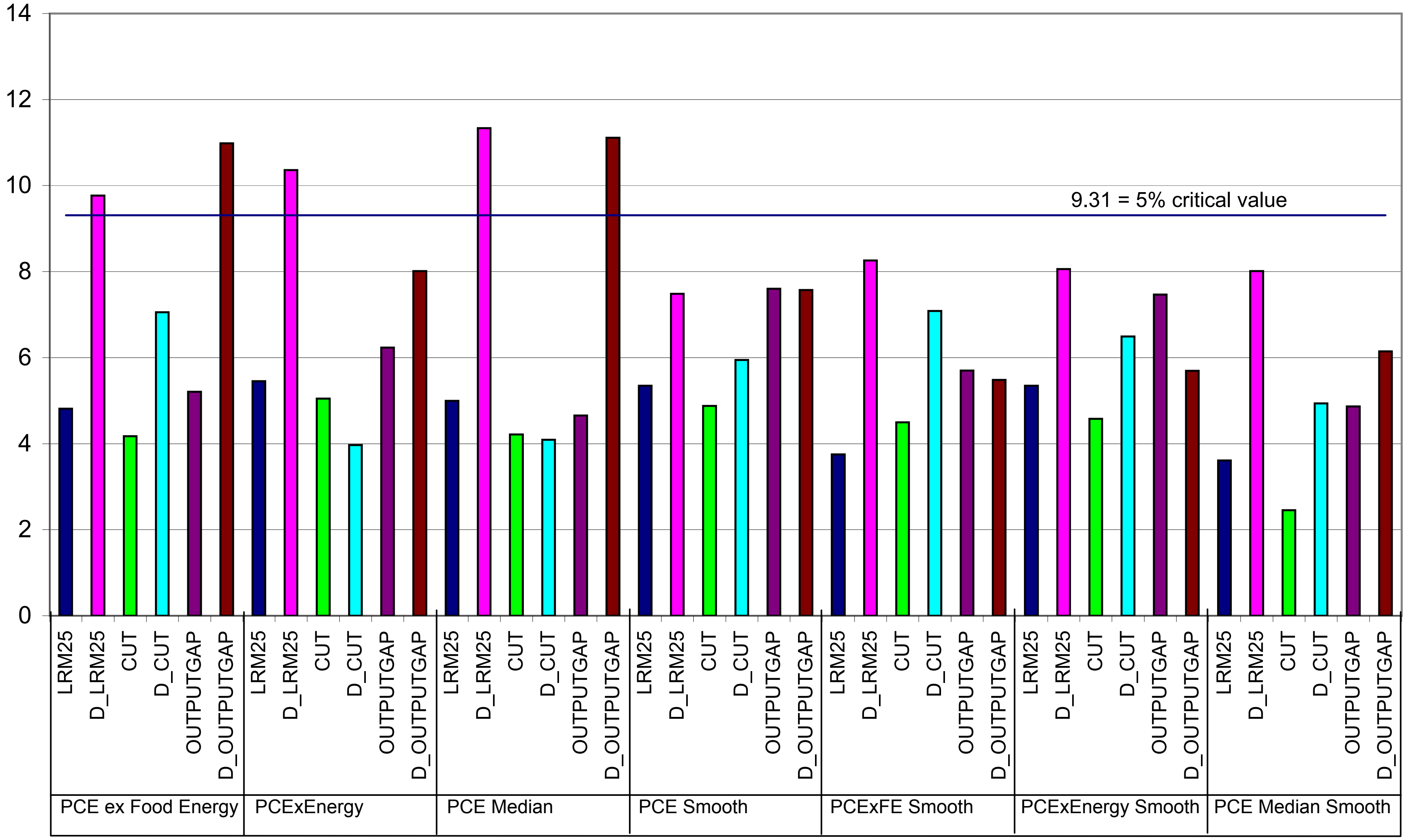


Chart 13
Supremum Statistic for Coefficient on Core Deviation, 12-quarter Horizon
PCE 1978-Present

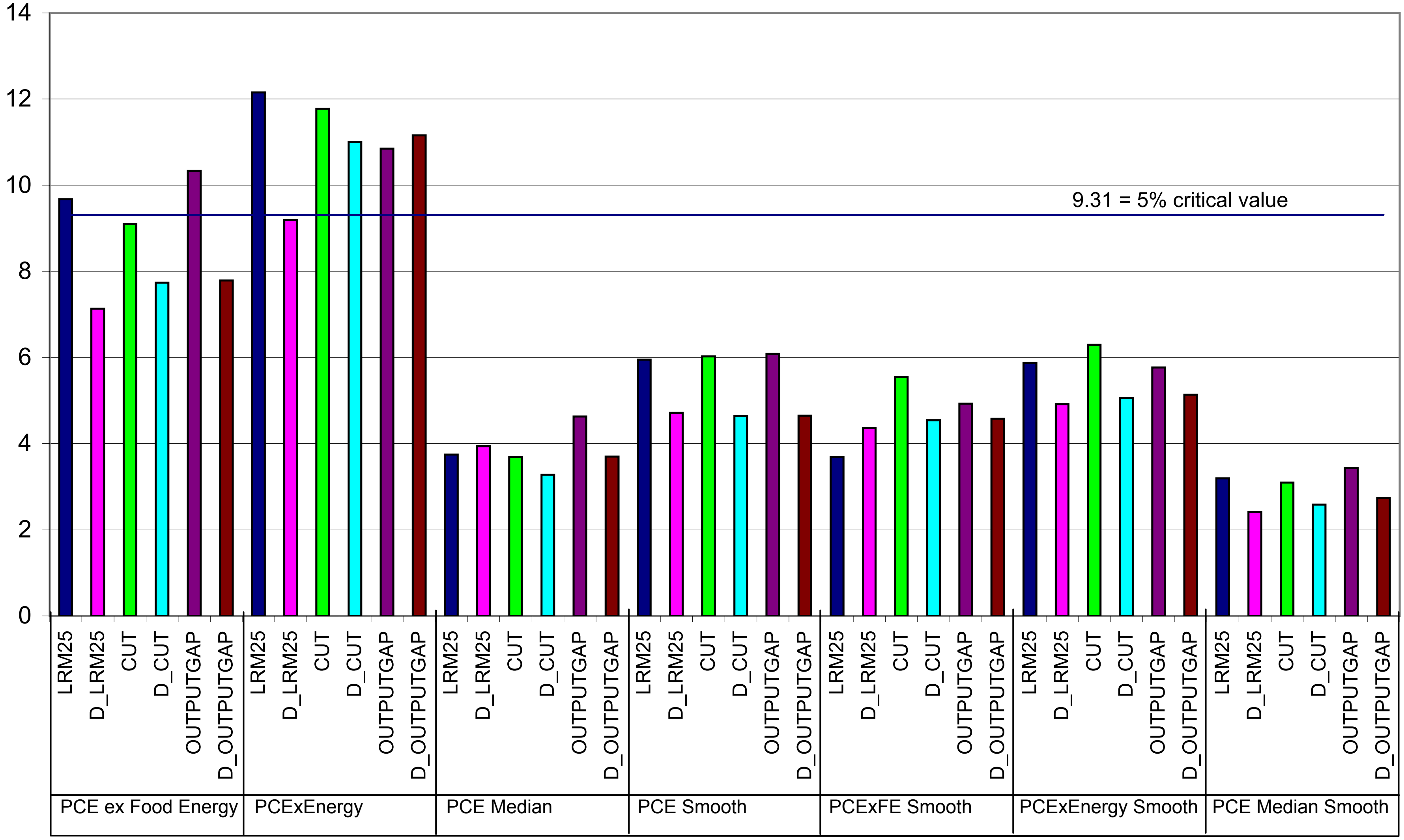


Chart 14
Supremum Statistic for Coefficient on Core Deviation, 8-quarter Horizon
CPI 1978-Present