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# Weighted Median Inflation: Is This Core Inflation?

This paper investigates core inflation defined as the best predictor of inflation. I compare forecasts obtained using the mean, weighted median, trimmed mean, and less food and energy inflation rates for the consumer price index and the personal consumption expenditure deflator for the current U.S. monetary policy regime. Another issue addressed is that of the systematic bias that exists due to the differences in means of these measures. I test whether correcting for this bias can lead to better inflation forecasts. This paper finds that adjusting for bias improves forecasting and that the weighted median is a better forecaster than the alternative measures and thus is a good measure of core inflation.

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What is core inflation? Core inflation, in general, is the underlying or persistent part of inflation, and there is long-standing interest in measuring it. Eckstein (1981) introduced a measure of core inflation as the "trend increase in the cost of the factors of production" (p. 7). Today, the most common measure of core inflation popularized by both policy makers and academics is the consumer price index less food and energy. In the last few years, there has been renewed interest in the definition and measurement of core inflation due to the work of Bryan and Cecchetti (1994) and Bryan, Cecchetti, and Wiggins (1997). These papers propose limited-influence estimators such as the weighted median and trimmed means as measures of core inflation.

The debate about which measure is best is muddied by the lack of a precise definition of core inflation.[1] Many discussions of core inflation do not define it.

1. See Alvarez and Llano Matea (1999), Apel and Jansson (1999), Cockerell (1999), and Johnson (1999) for further discussion.

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Bryan and Cecchetti (1994) define core inflation as the measure most correlated with money growth, and Bryan, Cecchetti, and Wiggins (1997) define it as the measure most correlated with a smoothed trend inflation rate. My definition of core inflation is complementary to their definitions; I define core inflation as the best forecaster of inflation. This definition captures a common intuition of core inflation: core inflation should be a good indicator of the future movements of inflation. Blinder (1982, 1997) suggests this definition of core inflation as well.

My analysis in this paper is for the current monetary policy regime, which started in the early 1980s, in the U.S. I examine several possible candidates, including limited-influence estimators (e.g., the weighted median and trimmed mean), less food and energy inflation and lagged inflation to determine which is the best predictor of future inflation. Although Bryan and Cecchetti (1994) perform a brief forecasting exercise using the consumer price index, this paper provides a more detailed analysis and includes forecasting of the personal consumption expenditure deflator. This paper focuses on unconditional models and also corrects for the systematic difference in means that exists between the candidate variables and the forecasted variable. Additionally, I examine several different time-series models that impose different inflation dynamics. Finally, both in-sample and out-of-sample estimation is performed.

The results support the simple conclusion that the weighted median is the best measure of core inflation. Indeed, the weighted median dominates its competitors at predicting future inflation in various models. Also, adding an additional inflation variable does not improve the forecasts beyond using the weighted median alone. The weighted median is an informative measure of core inflation.

The rest of this paper is organized as follows. I examine unconditional models testing different specifications in Section 1. Section 2 examines out-of-sample forecasts, and Section 3 concludes.

## 1. IN-SAMPLE PREDICTION

I examine what is the best forecaster of the 12-month ahead inflation rate for both the consumer price index and the personal consumption expenditure deflator. For the consumer price index, I test whether the mean inflation rate (CPI), the weighted median inflation rate (CPIMED), the trimmed mean inflation rate (CPITM),[2] or the less food and energy inflation rate (CPIX) is the best measure of core inflation or, analogously, performs best when forecasting the 12-month ahead inflation rate.[3] For predicting the 12-month ahead personal consumption expenditure deflator inflation

2. I use a 9% trim from each tail since this is the optimal trim found by Bryan, Cecchetti, and Wiggins (1997).

3. I use the research series for the CPI and CPIX. Both are seasonally adjusted and are obtained from Ken Stewart at the Bureau of Labor Statistics (BLS). There have been important methodological changes to the computation of the all-items consumer price index-urban (CPI-U) over many years. These changes do not make the post- and pre-January 1998 CPI-U comparable. The BLS has computed a research series that recomputed the pre-January 1998 index using these new methods. For further discussion, see Stewart and Reed (1999).

rate, I test whether the mean inflation rate (PCE), the weighted median inflation rate (PCEMED), or the less food and energy inflation rate (PCEX) is core inflation.[4] Not only do I examine these variables individually but I also consider combinations as candidates for core inflation.

I forecast both the consumer price index and the personal expenditure consumption deflator, which report the inflation rate in the economy. These two inflation rates generally follow the same trend, yet they can be substantially different at a given point. The consumer price index is the most well-known and widely reported measure of inflation. The personal consumption expenditure deflator differs from the consumer price index and is often considered more useful for monetary policy decisions. The main difference is the fixed weights of the consumer price index versus the chain weighting used to compute the personal consumption expenditure deflator. Additionally, the consumer price index is not revised, whereas the personal consumption expenditure deflator may be revised.

The 12-month ahead inflation rate is based on the all-items research consumer price index or the personal consumption expenditure deflator and is defined as $\pi_{t,t+12} = \ln(P_{t+12}/P_t)$, where $P$ is the monthly price index. The CPI and CPIX, and the PCE and PCEX are defined as $(12/k)\ln(P_t/P_{t-k})$, where $P$ is the monthly price index for each series and $k$ is the number of months. For example, the annualized one-month inflation rate for the research consumer price index is $\pi_{t-1,t} = 12\ln(P_t/P_{t-1})$. I also use the previous 12-month inflation rates. For the CPIMED, CPITM, and PCEMED, I follow the work of Bryan and Cecchetti (1994) and Bryan, Cecchetti, and Wiggins (1997).[5] I use the following formula to compute the weighted trimmed mean and median, and I use the relative importance weights for the consumer price index[6] and the shares of each component at every month for the personal consumption expenditure deflator[7] to order the component price changes in order to find the trimmed mean or weighted median.[8]

$$\bar{\pi}_\alpha = \frac{1}{N-2m}\sum_{i=m}^{N-m}\pi^i_{t-k,t} \tag{1}$$

$$\pi^i_{t-k,t} = \ln\left(\frac{P^i_t}{P^i_{t-k}}\right),\ m = N\alpha\ ,$$

4. The personal consumption expenditure deflator and components are available at the website of the Bureau of Economic Analysis. The list of components used to compute the weighted median is available from the author upon request. I do not consider the trimmed mean for the personal consumption expenditure deflator because the optimal trim is unknown. Finding the optimal trim is a paper unto itself and is not the focus of this paper.

5. The raw component data for the consumer price index are available on request from the Federal Reserve Bank of Cleveland.

6. The relative importance weights (RI) are available in December of each year. To obtain the monthly relative importance weights for the following 11 months, I use the same formula as that used by the Federal Reserve Bank in Cleveland. The formula is $\mathrm{RI}^i_{t+1} = \mathrm{RI}^i_t\left(\frac{1+\pi^i_t}{1+\pi_t}\right)$, where $i$ denotes the component of the CPI. The relative importance weights are reset every December to equal the relative importance weights reported by the BLS. The calculated relative importance weights are also available on request from the Federal Reserve Bank of Cleveland.

7. The expenditure shares are calculated by the author. The share for each component at every month is calculated as the nominal spending on each component in that month divided by total nominal spending in that month.

8. For a discussion of the trimmed mean, see Poirier (1995), p. 255.

where $m$ is the largest integer less than or equal to $N\alpha$, and $i$ indicates the component; $k = 1$ and 12; $\alpha = 0.09$ for the trimmed mean, and $\alpha = 0.50$ for the weighted median; $N = 36$ or 41 for the CPI, and $N = 52$ for the PCE.

My interest is in determining what the best predictor of inflation is in this current monetary regime; I am holding the regime constant for this analysis. I start in 1982 and use monthly data from 1982:1 to 2000:12 for the consumer price index and 1982:1 to 2000:6 for the personal consumption expenditure deflator.

For each inflation series, I assume a unit root structure and a co-integrating relationship between the 12-month ahead inflation rate and the candidate measures. I impose a co-integrating relationship of $\pi_{t,t+12} - x_{t-y,t} \sim I(0)$, where $\pi$ is 12-month ahead inflation rate for the consumer price index or the personal consumption expenditure deflator, and $x$ is the CPI, CPIMED, CPITM, or CPIX or the PCE, PCEMED, and PCEX, respectively, and $y$ is 1 or 12. The unit root and co-integration assumptions are consistent with the findings of Freeman (1998) and Stock and Watson (1999), and these assumptions assure that these inflation rates do not diverge from each other in the long run.

During the sample period, the mean of the dependent variable and the means of the candidate measures are not equal. This difference in means suggests that there is a systematic bias, meaning that one inflation rate on average will be higher or lower than another. This differential needs to be accounted for; if it is not corrected, then the candidate measure with its mean closest to that of the dependent variable will have an advantage in estimation under the unit root and co-integration structure.[9,10]

The first set of regressions I perform considers the predictive power of each of the candidate measures in forecasting its headline measure. A natural starting point is to ask whether last year's mean, weighted median, trimmed mean, or less food and energy inflation rate can predict next year's headline inflation. In these regressions, I find that a limited-influence estimator may be a good predictor of future inflation. The idea that the less food and energy inflation rate is a good measure of core inflation is diminished since it performs poorly for both the prediction of the consumer price index and the personal consumption expenditure deflator. This result is confirmed by both the non-bias-adjusted and bias-adjusted results.

I have examined the predictive power of only one variable, and there might be some benefit from considering more than one variable. I perform regressions where predicted inflation is the weighted sum of two inflation variables and compare these results with the single variable regressions from above. These regressions demonstrate the relative contribution of each variable. Both the CPIMED and CPITM contribute to predicting future inflation in conjunction with either the CPI or the

9. I correct this systematic bias by equaling the means of the independent variables to the mean of the dependent variable. In each period, the variables are corrected by $x_t = x_t^* + \text{bias}$, where $x_t^*$ is the actual, original inflation rate of the independent variables. In the initial regressions, I examine the results both with and without the bias adjustment. The results support the same general conclusions; therefore, in the remainder of the paper, I present the results using the bias-adjusted inflation measures.

10. Additionally, the question arises whether the bias between the means is predictable. If it is not, then even if the median beats the other measures, it does not necessarily indicate that the median is a better forecaster. This issue is addressed through the use of out-of-sample forecasts.

CPIX. The results are stronger for the personal consumption expenditure deflator. The PCEMED alone is a good predictor of future inflation. All these results suggest that the median may be useful in forecasting.[11]

I now examine more general models. I examine three other models: a distributed lag model, an exponential decay model, and a benchmark univariate time-series (ARMA) model. For the benchmark model, I find the best-fitting ARMA model using the monthly inflation data. This model is slightly different from the forecasting models discussed below. The models below use the 12-month ahead inflation rate as the dependent variable. There is no straightforward way to estimate this ARMA model using the 12-month ahead inflation rates because problems arise due to the overlapping nature of the data. Therefore, I construct a forecast of the 12-month ahead inflation rate from the best-fitting monthly ARMA model, which is an ARMA(2,8) for the consumer price index and an ARMA(6,4) for the personal consumption expenditure deflator. I estimate the ARMA in first differences in order to impose the unit root structure.[12]

The next model is an unrestricted distributed lag model where there are 24 monthly lags of the independent variable. This model restricts the sum of the coefficients to equal 1 but places no other restriction on the coefficient weights. This regression still uses the 12-month ahead inflation rate as the dependent variable. The regression equation is

$$\pi_{t,t+12} = (1 - \beta(1))x_{t-1,t} + \beta(L)Lx_{t-1,t} + \varepsilon_{t+12}\,, \tag{2}$$

where $\pi$ is the 12-month ahead consumer price index or the personal consumption expenditure deflator inflation rates, and $x$ is the CPI, CPIMED, CPITM, or CPIX or the PCE, PCEMED, and PCEX, respectively, and the lag polynomial $\beta(L)$ is of order 23 and is estimated by ordinary least squares. The standard errors for the regression are computed using the Newey–West procedure.[13] The use of the distributed lag model allows the past two years of inflation to have an effect on the next year's inflation, which is consistent with current economic thinking. This equation does not explicitly model the structure or the way in which past inflation influences future inflation, and the data are left to choose which past lags are important and which are not.

The final model is an exponential decay model. The theoretical exponential decay model is

$$\pi_{t,t+12} = x_{t-1,t} + \beta x_{t-2,t-1} + \beta^2 x_{t-3,t-2} + \ldots + \varepsilon_{t+12}\,, \tag{3}$$

where $\pi$ is the consumer price index or the personal consumption expenditure deflator inflation rates, and $x$ is the CPI, CPIMED, CPITM, or CPIX or the PCE, PCEMED, and PCEX, respectively. This equation has an infinite lag structure;

11. Complete regression results are available from the author upon request.

12. Complete details are available from the author upon request.

13. I use Newey–West (1987) corrected standard errors with lags equal to int(4($T$/100)^(2/9)) on all my regressions due to the overlapping structure of the data. **(Q1)**

however, for empirical reasons, I chose 24 monthly lags.[14] I rewrite Equation (3) to impose the lag truncation and to require that the coefficients on the lagged terms sum up to 1, and I estimate using nonlinear least squares. Here, the standard errors on the decay parameters are also corrected with the Newey–West procedure. The exponential decay model places an explicit structure on the lags of the candidate measures. The model places higher weights on the more recent months and lower weights on months that are further in the past. This model uses the general intuition that to predict future inflation, the most recent months are the most important.

Recall that I am only examining the bias-corrected results. Tables 1A and 1B present the results comparing the two models for each variable. Comparing the Akaike information criterion (AIC) or the Schwarz criterion (SC) (since I have models with different numbers of estimated parameters) for each variable, the exponential decay model is a better predictor of future inflation than the distributed lag model.[15]

TABLE 1

Comparison of In-Sample Models

| Model | AIC | SC |
|---|---|---|
| A. Consumer Price Index Inflation Rate | | |
| ARMA(2,8) | 3.10 | 3.11 |
| CPI | | |
| Exponential decay | 3.12 | 3.13 |
| Distributed lag | 3.24 | 3.59 |
| CPIMED | | |
| Exponential decay | 2.81 | 2.82 |
| Distributed lag | 2.89 | 3.24 |
| CPITM | | |
| Exponential decay | 3.78 | 3.79 |
| Distributed lag | 3.66 | 4.00 |
| CPIX | | |
| Exponential decay | 3.11 | 3.13 |
| Distributed lag | 3.17 | 3.52 |
| B. Personal Consumption Expenditure Deflator Inflation Rate | | |
| ARMA(6,4) | 2.66 | 2.68 |
| PCE | | |
| Exponential decay | 2.58 | 2.60 |
| Distributed lag | 2.62 | 2.97 |
| PCEMED | | |
| Exponential decay | 2.19 | 2.21 |
| Distributed lag | 2.29 | 2.65 |
| PCEX | | |
| Exponential decay | 2.63 | 2.64 |
| Distributed lag | 2.68 | 3.03 |
| C. Bivariate Exponential Decay Models | | |
| CPI and CPIMED | 2.79 | 2.84 |
| PCE and PCEMED | 2.21 | 2.26 |

14. I tested shorter (12 months) and longer (36 months) lag structures. At 12 months, many of the coefficient estimates were not close to zero, and at 36 months, the last 12 coefficients were basically zero.

15. For a model with $k$ parameters and sample $T$, the AIC is $1 + \ln(2\pi) + \ln(\tilde{\varepsilon}'\tilde{\varepsilon}/T) + 2k/T$ and the SC is $1 + \ln(2\pi) + \ln(\tilde{\varepsilon}'\tilde{\varepsilon}/T) + \ln(T)/T$. The AIC and SC are only suggestive because they assume that the error process is serially uncorrelated.

The results demonstrate that the weighted median is very good at predicting the future inflation rate. The AIC for the CPIMED under the exponential decay model is on average 15% lower than the AIC of the other measures. For the PCEMED, the AIC is on average 16% better. Additionally, the exponential decay model even performs better than the benchmark ARMA model for both the consumer price index and the personal consumption expenditure deflator. Since the exponential decay model appears to be informative in predicting inflation, I want to examine whether combining two inflation variables improves the prediction of future inflation.[16]

In Table 1C, the results for two bivariate regressions are shown. Comparing these bivariate regressions with the regressions using only the weighted median, one can see that the weighted median predicts future inflation well and may not be improved upon by adding in the additional measure.

## 2. FORECASTING: OUT-OF-SAMPLE PREDICTION

An additional issue that needs to be addressed is whether the median can forecast well in an out-of-sample exercise. This issue is important for considering whether these measures are useful in the monetary policy decision-making process. The out-of-sample forecasts test the models under more realistic conditions. In-sample prediction can give information about how the economy reacted in the past; however, what I want to know is whether these models including bias adjustment are a sensible way of making future predictions about inflation.

I forecast at three time horizons, 12, 18, and 24 months; these are the time horizons over which monetary policy makers are interested in knowing the path of inflation. I only test the exponential decay model since that model performed best in the earlier results. I forecast future inflation using the bias-adjusted candidate measures. I find the bias in the early part of the sample, 1982:1 to 1989:12, and create new values for the variables for the entire sample.[17] I use the data from 1982:1 to 1989:12 to set the coefficient estimates that are used in the forecasting model. I perform simple static forecasts for the period 1990:1 to the end of the sample for both the consumer price index and the personal consumption expenditure deflator.

The results for the unconditional out-of-sample forecasts are very similar to the in-sample prediction results. In Table 2, the root mean square error (RMSE) is reported for each variable. As before, the weighted median is best (i.e., minimizes the RMSE). Examining the 18-month ahead forecasts, the RMSE of the CPIMED model is the smallest and is 21.05% lower than the RMSE of the CPIX model, 27.04% lower than the RMSE of the CPITM model, and 23.29% lower than the RMSE of the CPI model. The RMSE of the PCEMED model is 29.62% lower than the RMSE

16. Complete regression results are available from the author upon request.

17. By finding the bias for the early part of the sample and adjusting the data, I test implicitly whether the bias is predictable. If the bias is unpredictable, then adjusting the data should not lead to better forecasts as it does.

TABLE 2

OUT-OF-SAMPLE FORECASTING RESULTS FOR THE 12-, 18-, AND 24-MONTH FORECAST HORIZONS **(Q2)**

| Variables | RMSE | | |
|---|---|---|---|
| | 12 months | 18 months | 24 months |
| A. Consumer Price Index[a] | | | |
| CPI | 0.9656 | 1.0177 | 1.0482 |
| CPIMED | 0.8197 | 0.7807 | 0.7477 |
| CPITM | 1.0508 | 1.0700 | 1.0856 |
| CPIX | 1.0138 | 0.9888 | 0.9879 |
| B. Personal Consumption Expenditure Deflator[b] | | | |
| PCE | 0.7723 | 0.8055 | 0.8653 |
| PCEMED | 0.6156 | 0.5880 | 0.5697 |
| PCEX | 0.8604 | 0.8355 | 0.8289 |

NOTES: [a]The samples used for the three forecast horizons are 1990:1 to 2000:12, 1990:1 to 2000:6, and 1990:1 to 1999:12, respectively. [b]The samples used for the three forecast horizons are 1990:1 to 2000:6, 1990:1 to 1999:12, and 1990:1 to 1999:6, respectively.

of the PCEX, and 27.00% lower than the RMSE of the PCE.[18] To better understand the differences in RMSEs, I graph the actual versus forecasted inflation rates in Figures 1 and 2. From these graphs, it appears that the forecast based on the weighted median tracks the actual 18-month ahead inflation rate well for both measures. For example, when actual inflation falls in the early 1990s, the median is the first inflation variable to pick up on the new trend of lower inflation. Additionally, the median does not fall dramatically in 1997 and predicts the upturn in inflation in 1998. The graphs of the 12-month ahead inflation forecasts and the 24-month ahead inflation forecasts are similar to those of the 18-month ahead forecasts for both the consumer price index and the personal consumption expenditure deflator. Overall, the graphs demonstrate the superior forecasting ability of the weighted median.

The out-of-sample forecasting has shown that the weighted median is a robust indicator of future inflation when forecasting either the consumer price index or the personal consumption expenditure deflator. Additionally, this forecasting exercise adds credibility to the idea that the systematic biases between the inflation measures should be taken into account when forecasting inflation.

## 3. CONCLUSIONS

The concept of core inflation has often been used over the past 20 years and has generally been measured by the less food and energy inflation rate. Recently, due to the work of Bryan and Cecchetti (1994) and Bryan, Cecchetti, and Wiggins (1997), another measure, the weighted median, has been suggested as a possible improved measure of core inflation. Much of the debate about core inflation has centered on there not being a clear definition; therefore, I define core inflation as the best forecaster of inflation, and by using this definition, I confirm that the weighted median does have merit as core inflation.

18. The percentage improvement in RMSE is similar over the other time horizons.

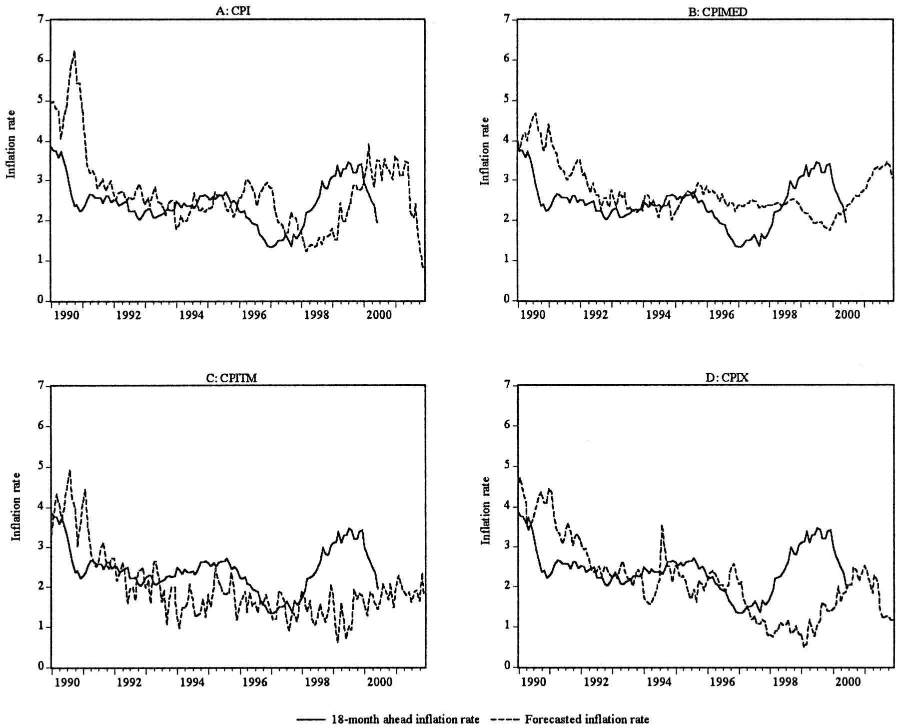


FIG. 1. Comparison of CPI Forecasts

In particular, I find that, for the current monetary policy regime in the U.S., using the weighted median to forecast future inflation is superior. The weighted median outperforms the other measures in several models. This paper adds credibility to the idea that large relative price changes, no matter which sector they come from, should be excluded from the measure of underlying or core inflation. Overall, the weighted median provides a useful measure to understand the movement of underlying inflation in the economy and a more accurate measure of inflationary pressures.

This paper has examined only the most recent period, and its goal has been to find the best forecaster within this regime. With the appointment of Volcker and the consequent recession, the nature of monetary policy changed. When discussing these results, the degree of monetary accommodation and the degree of "persistence" in supply shocks is held constant. The pre-1982 period is a different regime, and a different measure might be core inflation or the best forecaster. An extension of this paper would be to examine different regimes across time and across countries and establish whether the results are the same.

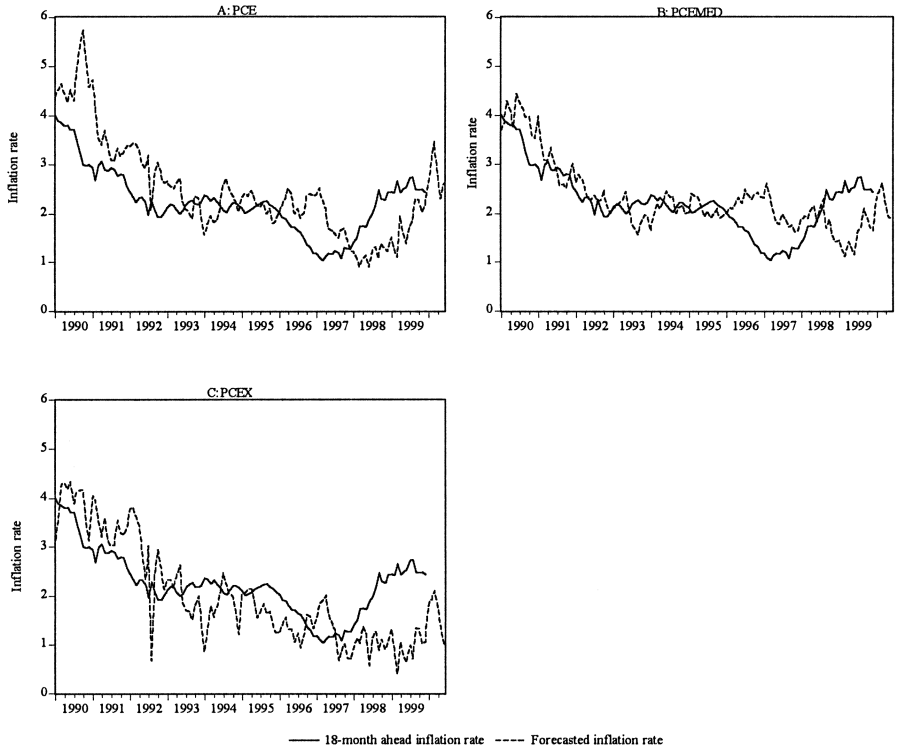


FIG. 2. Comparison of PCE Forecasts

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