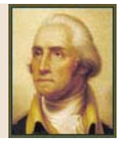
Research Program on Forecasting



Forecast Errors Before and After the Great Moderation

Edward N. Gamber
Department of Economics
Lafayette College
Easton, PA 18042
(610)-330-5310
gambere@lafayette.edu

Julie K. Smith
Department of Economics
Lafayette College
Easton, PA 18042
(610)-330-5310
smithjk@lafayette.edu

Matthew Weiss
Brooklyn Law School
Brooklyn, New York, 11202
Matthewweiss@gmail.com

Updated
March 20, 2009

RPF Working Paper No. 2008-001
http://www.gwu.edu/~forcpgm/2008-001.pdf

RESEARCH PROGRAM ON FORECASTING
Center of Economic Research
Department of Economics
The George Washington University
Washington, DC 20052
http://www.gwu.edu/~forcpgm

Forecast Errors Before and After the Great Moderation

By

Edward N. Gamber
Department of Economics
Lafayette College
Easton, PA 18042
(610)-330-5310
gambere@lafayette.edu

Julie K. Smith
Department of Economics
Lafayette College
Easton, PA 18042
(610)-330-5310
smithjk@lafayette.edu

Matthew Weiss
Brooklyn Law School
Brooklyn, New York, 11202
Matthewweiss@gmail.com

March 20, 2009

We thank Pao-Lin Tien, Fred Joutz, Tara Sinclair, Herman Stekler and John Duca for helpful comments and suggestions. We thank Eduardo Diaz for research assistance. All remaining errors are solely the responsibility of the authors.

Forecaster Errors Before and After the Great Moderation

(Abstract)

This paper investigates the change in private-sector and Federal Reserve forecasts before and after the Great Moderation. We view the Great Moderation as a natural experiment. Using forecasts produced by the Survey of Professional Forecasters and the Federal Reserve (Greenbook forecasts) we investigate four questions: 1) How large was the decline in forecast errors? 2) Did forecast accuracy improve relative to the decline in volatility of growth and inflation? 3) Did forecasters respond to the Great Moderation? 4) What are the potential benefits to monetary policymakers of smaller forecast errors? We find that the absolute median error as well as the cross-sectional volatility of forecast errors decreased significantly. Forecasters appeared to have narrowed the dispersion of their forecasts in response to the Great Moderation. Forecast accuracy did not improve relative to the reduction in the volatility of the economy. To the extent that the Fed is forward-looking when it sets its federal funds rate target, improvements in forecast accuracy imply substantial improvements in the Fed's ability to reach its optimum federal funds rate target.

1. Introduction

Since the mid-1980s the U.S. economy has experienced a Great Moderation. Both GDP growth and inflation volatility have declined significantly. Figures 1 and 2 show real GDP growth and inflation over the past 60 years. Margaret M. McConnell and Gabriel Perez-Quiros (2000) found that the most likely break point for GDP volatility is the first quarter of 1984. James A. Kahn, McConnell and Perez-Quiros (2002) find a break in inflation volatility at about that same time although the relative smoothness of inflation post-1984 is not unprecedented (inflation was relatively smooth in the 1950s as well). The standard deviation of annualized GDP growth from 1947 through 1983 was nearly 5%. From 1984 through 2008 the standard deviation of annualized real GDP growth was 2.2%. Similarly, the standard deviation of inflation (annualized growth of the GDP deflator) from 1947 through 1983 was 3.3%. From 1984 through 2008 the standard deviation of inflation has been 1.05%.

The decline in GDP and inflation volatility provides a natural experiment to investigate how forecasts of growth and inflation respond to changes in the underlying distributions of those variables. We address the following questions. 1) How large was the decline in forecast errors? 2) Did forecast accuracy improve relative to the decline in volatility of growth and inflation? 3) Did forecasters respond to the Great Moderation? 4) What are the potential benefits to monetary policymakers of smaller forecast errors? We investigate these questions by looking at changes in forecast accuracy for the Survey of Professional Forecasters (SPF) and the Federal Reserve (FR)[1].

1. The forecasts we use in this study are the Greenbook forecasts which are prepared by the staff of the Board of Governors and are therefore sometimes referred to as the staff forecasts to differentiate them from the forecasts presented by the members of the FOMC. See Gavin and Mandal (2001) for a comparison of private sector and FOMC forecasts.

We find that the absolute value of forecast errors for both the Survey of Professional Forecasters and the Federal Reserve fell significantly after the Great Moderation. At most forecast horizons the decline was 50% or more. We also find that the dispersion of forecasts in the Survey of Professional Forecasters dropped significantly after the Great Moderation. We argue that the drop in dispersion indicates that forecasters did in fact respond to the Great Moderation by changing their forecasts. The decline in the dispersion of forecasts was roughly coincident with the onset of the Great Moderation. Finally, we find that the improvement in forecasting implies that the Fed is likely to be 3 percentage points closer to its perfect-foresight federal funds target based on the Taylor rule.

In section 2 we review the literature on the Great Moderation. Section 3 describes the data. Section 4 presents evidence on the improvement in forecast performance after the Great Moderation. Section 5 looks at the change in forecast performance relative to the reduction in the volatility of GDP growth and inflation. Section 6 presents a model of forecaster behavior, which shows that in order to detect a change in forecaster behavior, one must look at the change in the cross-sectional dispersion of forecasts. Section 7 presents the results from the endogenous break point tests. Section 8 discusses the possible benefits of smaller forecast errors for monetary policy and section 9 concludes.

2. Literature Investigating the Sources of the Great Moderation

The Great Moderation in both growth and inflation are clearly evident from Figures 1 and 2. But the causes of the Great Moderation are still debated. In general, researchers classify causes of the Great Moderation into three categories: good luck, improved policy and structural change. By “good luck” researchers mean smaller shocks to the economy. Improved policy generally refers to improved monetary policy. Structural change means that the propagation mechanism which translates shocks into business cycle fluctuations has changed in a way that leads to smaller fluctuations.

McConnell and Perez-Quiros (MPQ) and more recently Davis and Kahn (2008) attribute the decline in GDP volatility to structural change. They show that the decline in GDP volatility was due mainly to a decline in the volatility of durable goods output, which resulted from improved inventory management. Kim, Nelson and Piger (2003) find that the Great Moderation was more broadly based than durable goods output suggesting that policy could have played an important role in the Great Moderation. Stock and Watson (2002) investigate several sources of the Great Moderation. They find that improved policy accounted for 20-30% of the moderation in GDP. Identifiable good luck accounts for another 20-30% of the moderation and unidentifiable good luck accounts for the rest (40-60%).

Another issue discussed in the literature is whether the moderation was due to a change in the propagation mechanism or the size of shocks feeding into an unchanging propagation mechanism. Recent work by Gali and Gambetti (2009) and Ramey and Vine (2006) suggests that the propagation mechanism did change. In contrast, Stock and Watson (2002), Justiniano and Pimiceri (2006) and Arias et al. (2006) find that the propagation mechanism has remained stable but the shocks got smaller starting in the early to mid 1980s.

3. Data

We use three sources of data to measure the decline in forecast errors that occurred with the onset of the Great Moderation. The first source is the Survey of Professional Forecasters (SPF)[2], the second source is the Federal Reserve's Greenbook forecasts which are released with a 5-year lag and the third is a set of forecasts produced by a sequence of ARMA models which serve as our benchmark forecasts. The sample of forecasts from the Survey of Professional Forecasters covers the period 1968.4 through 2008.4. The sample of forecasts from the Greenbooks covers the sample 1965.11 through 2002.12. The Greenbook forecasts are prepared for each FOMC meeting (12 meetings per year prior to the early 1980s and 8 meetings per year since that time). For the forecast error comparisons we use the common sample period of 1968.11 through 2002.12.

Our variables of interest are quarterly real output growth and quarterly inflation. We investigate the change in forecast accuracy for horizons 1 through 4 quarters ahead. Although the unit of analysis is the same in all three datasets, that is, quarterly forecasts, the frequency at which we observe those forecasts does differ across the three datasets. The SPF forecasts are quarterly, the ARMA forecasts are monthly and the Greenbook forecasts are produced only during months in which there are FOMC meetings.

Our forecast errors are computed using the real-time measures of real output growth and inflation (see Croushore and Stark, 2001). Our real-time measures are the first final revisions published by the Bureau of Economic Analysis at the end of the third

[2] The SPF was previously called the ASA-NBER survey of forecasters from 1968 to 1990. The Federal Reserve Bank of Philadelphia took over the survey in 1990. See Croushore and Stark (2001) for a complete description of the SPF.

month following the end of each quarter[3]. We define the forecast errors as the difference between the real time actual observation and the forecast of that observation. Real output growth is measured as the annualized growth of real GNP before 1992 and real GDP afterwards. Inflation is the annualized growth of the GNP deflator prior to 1992, the GDP deflator between 1992 and 1996 and the GDP chain-weighted price index after 1996. These changes in measures of real growth and inflation match the changes in the variables that the Federal Reserve and SPF were forecasting.

4. Forecast Errors Before and After the Great Moderation

We begin by looking at the absolute value of the median forecast error from the SPF before and after the onset of the Great Moderation. According to MPQ, the Great Moderation began in the first quarter of 1984. We measure the average of the median error before and after the Great Moderation by estimating the following regression:

$$|error_t| = \alpha_1 D_{1t} + \alpha_2 D_{2t} + \varepsilon_t \qquad (1)$$

where,

$D_{1t} = 1$ for t $\leq$ 1983:4

0 for t > 1983:4

$D_{2t} = 0$ for t $\leq$ 1983:4

1 for t > 1983:4

Table 1 shows the results for the absolute value of the median SPF errors for forecast horizons 1-4. We obtained similar results for the absolute value of the mean but chose to focus on the median because the Jarque-Bera test strongly rejected normality in

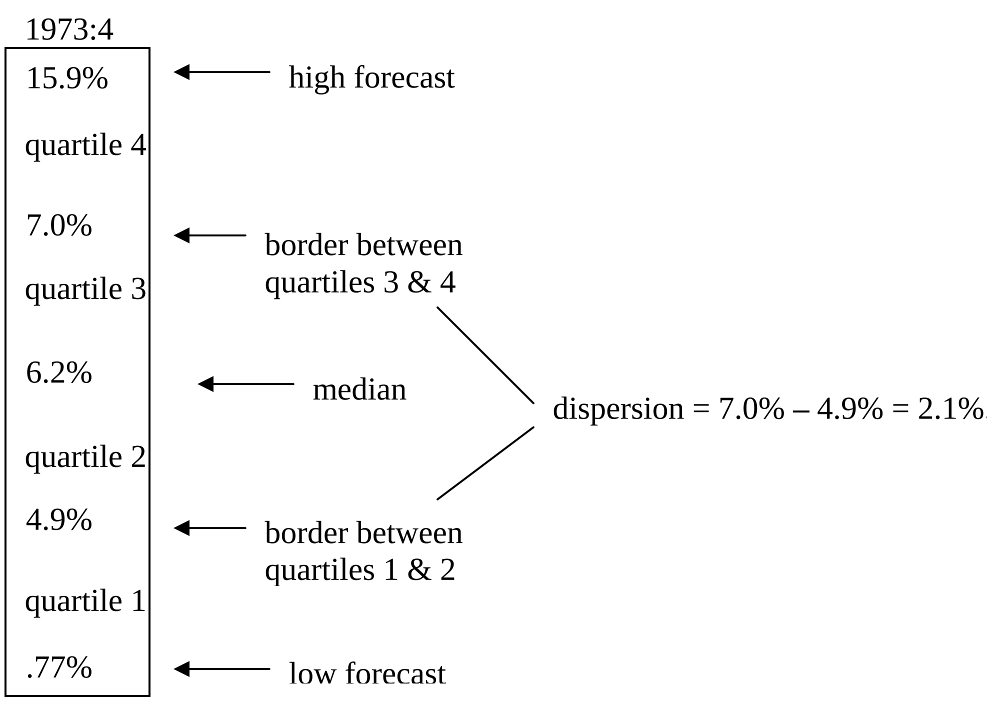
3. These real-time measures are also referred to as the 90-day measures.

the cross-sectional distribution of the SPF data. The results in Table 1 show that the absolute value of the median forecast error dropped by half in most cases (by more than half in some cases) and the decrease was statistically significant in all cases. The reduction in forecast errors is about the same across all 4 horizons.

Table 2 shows the results for the absolute value of the forecast error for horizons 1 to 4 for the Federal Reserve Greenbook forecasts. The values for the average forecast errors of the Fed are similar to the values for the average (and median) forecast errors for the SPF. In addition, like the SPF, the Fed's forecast errors dropped significantly with the onset of the Great Moderation, in many cases by half or more. And, like the SPF, the Fed's forecast performance, by this measure, improved almost equally at all forecast horizons.

Our benchmark forecast model is a recursively estimated ARMA model. We identified and estimated a separate ARMA model for each real-time monthly data set starting in 1968.11 and continuing through 2002.12. The specification for each model is based on the minimum SIC statistic. Table 3 shows the results for the absolute value of the ARMA forecast errors. The ARMA errors are uniformly larger than both the Fed errors and the SPF's errors before the onset of the Great Moderation. The percentage decline in the size of the errors ranges from 55% to 60%, only slight larger than the percentage declines in the SPF and Fed errors. A particularly large drop occurred at the 1-quarter horizon for real output growth. Prior to 1983 the ARMA forecast error for 1-quarter head growth was almost 4% and after 1984.1 that error dropped 58% which is 12 percentage points larger than the drop in SPF errors and 14 percentage points larger than the drop in Fed errors. After the Great Moderation the sizes of the ARMA forecast errors are nearly identical to the SPF and Fed errors. Figure 3 summarizes the information contained in Tables 1 through 3.

An advantage of the SPF dataset is that it can provide information on changes in the cross-sectional dispersion of forecasts over time. Table 4 shows the results of estimating equation (1) by replacing the absolute error as the dependent variable with a measure of the cross-sectional dispersion of forecasts at each point in time. We chose to measure the cross-sectional dispersion by taking the difference between the upper third quartile and lower first quartile of the forecast errors in each quarter. Again, we chose this measure instead of the standard deviation of forecasts errors because the forecast errors are not normally distributed.   The diagram below illustrates our calculation for the 1-quarter ahead forecasts of inflation for 1973:4. We first ordered the forecasts from high to low and divided the forecasts into quartiles. We then subtracted the forecast at the border between the 3^{rd} and 4^{th} quartile from the forecast at the border between the 1^{st} and 2nd quartile to compute the dispersion of forecasts for that quarter. For 1973:4, the dispersion measure was 7.0% – 4.9% = 2.1%.



The results in Table 4 indicate that the dispersion of forecast errors for growth decreased significantly at all forecast horizons with the onset of the Great Moderation. The dispersion of inflation forecasts dropped at horizons 1 and 4, but the decline at horizon 2 is not significant and the decline at horizon 3 is only marginally significant. In percentage terms, the drop in the dispersion of growth forecasts across forecast horizons are nearly identical (45-50%). For inflation, the decline in dispersion is mixed: the 1 and 4 quarter horizon dispersion dropped by 23%. The dispersion of inflation forecast errors declined by 15% at the 2-quarter ahead horizon and 16% at the 3-quarter ahead horizon. Figures 5 and 6 summarize the results contained in Table 4.

5. Has Forecast Performance Improved Relative to the Change in Forecastability?

Although professional and Fed forecasts declined in absolute value and volatility after the Great Moderation, the economy was, in some sense, easier to forecast because both growth and inflation were less volatile. An interesting question, therefore, is whether forecast errors fell relative to the change in the degree of difficulty, or forecastability of the economy.

With respect to inflation, Atkeson and Ohanian (2001) and Stock and Watson (2007) found that most of the decline in volatility after 1984 was due to a drop in the volatility of the predictable part of inflation. Thus, overall forecast errors should have declined after 1984, but forecast errors normalized for the reduction in volatility should not have declined and may have in fact increased.

Campbell (2007) decomposes the volatility of real output growth into a predictable part and an unpredictable part. He uses the SPF to measure the predictable part arguing that the SPF represents a reasonable benchmark for the "forecastability" of the economy. Previous researchers had used fixed-weight autoregressive time series models to produce benchmark forecasts. The SPF has two advantages over those models: SPF forecasts are based on real-time data and they are much more data-rich compared to univariate models.

However, using the SPF as a benchmark for the forecastability of the economy ignores the microeconomics of forecasting. The Great Moderation reduced the cost of producing a given-sized forecast error. In the face of this reduction in cost, forecasters face an income and a substitution effect, which may or may not result in them "choosing" to reduce their overall forecast error. By equating the size of the SPF error with the change in forecastability, Campbell implicitly assumed that there is no substitution effect.

Because of these microeconomic considerations, we choose to measure the forecastability of the economy using our benchmark ARMA forecasts. Our ARMA models have the advantage that they are based on statistical criterion (lowest SIC) and therefore not subject to the income and substitution effects described above[4]. The forecast error for the ARMA benchmark forecast error for horizon *h* at time *t* is denoted $ARMA\ error_t^h$

4. We examined ARMA models from ARMA(0,0) to ARMA (8,8) when selecting a specification for each time period.

To investigate whether forecast errors fell relative to the reduction in the volatility of growth and inflation we constructed an h-step ahead normalized forecast error

$$NE_t^h = \frac{\left|error_t^h\right|}{\sum_{i=-2}^{2} \frac{|ARMA\ error_{t-i}^h|}{5}} \qquad (2)$$

where $\sum_{i=-2}^{2} \frac{|ARMA\ error_{t-i}^h|}{5}$ is a centered 4-month moving average of the *h*-step ahead ARMA forecast error. The numerator of equation (2) contains the *h*-step ahead forecast error for either the SPF or the Greenbook. Thus, the normalized error controls for the degree of difficulty in forecasting (the forecastability) as defined by the ARMA model.

Tables 5 and 6 show the results from estimating equation (1) replacing the dependent variable with the normalized error, NE_t for the SPF and the Fed respectively. The results of both tables suggest that forecasting did not improve relative to the reduction in the volatility of the economy. In most cases the normalized error, NE_t increased slightly (but not significantly). In those few cases where NE_t fell, the reduction was insignificant as well. Figures 7 and 8 summarize the results in Tables 5 and 6.

6. A Model of Forecaster Behavior

The drop in the volatility of the economy after the Great Moderation would result in smaller errors, even if forecasters continued to use the same model. Therefore, it is not possible to detect a change in forecaster behavior by looking at the absolute median error of the SPF or the absolute error of the Fed. To illustrate this point, suppose the economy follows a simple MA(1) process:

$$y_t = \beta\varepsilon_{t-1} + \varepsilon_t \qquad \varepsilon_t \sim WN(0, \sigma^2) \qquad (3)$$

where y_t is real output growth (or inflation). Suppose pre-Great Moderation, $\beta = \beta^{pre}$ and post-Great Moderation, $\beta = \beta^{post}$. Further, assume the variance of the shock is $\sigma^{2,pre}$ before the Great Moderation and $\sigma^{2,post}$ afterward.

If forecasters know the true model of the economy leading up to the Great Moderation (they know β^{pre}) and they continue to use that model immediately after the Great Moderation. Their 1-step ahead forecast error will therefore be:

$$y_{t+1} - \hat{y}_{t+1} = (\beta^{pre} - \beta^{post})\varepsilon_t + \varepsilon_{t+1}$$

If the propagation mechanism remains unchanged $(\beta^{pre} = \beta^{post})$ as in Stock and Watson (2002), Justiniano and Pimiceri (2006) and Arias et al. (2006), then it is clear that the absolute size of the error will fall even if forecasters do not change their model since the absolute size of ε_{t+1} declined after the Great Moderation. Therefore, if we assume that the Great Moderation was due to only a decline in the size of the shock, then we are unable to detect a change in forecaster behavior by looking at the absolute size of the error.

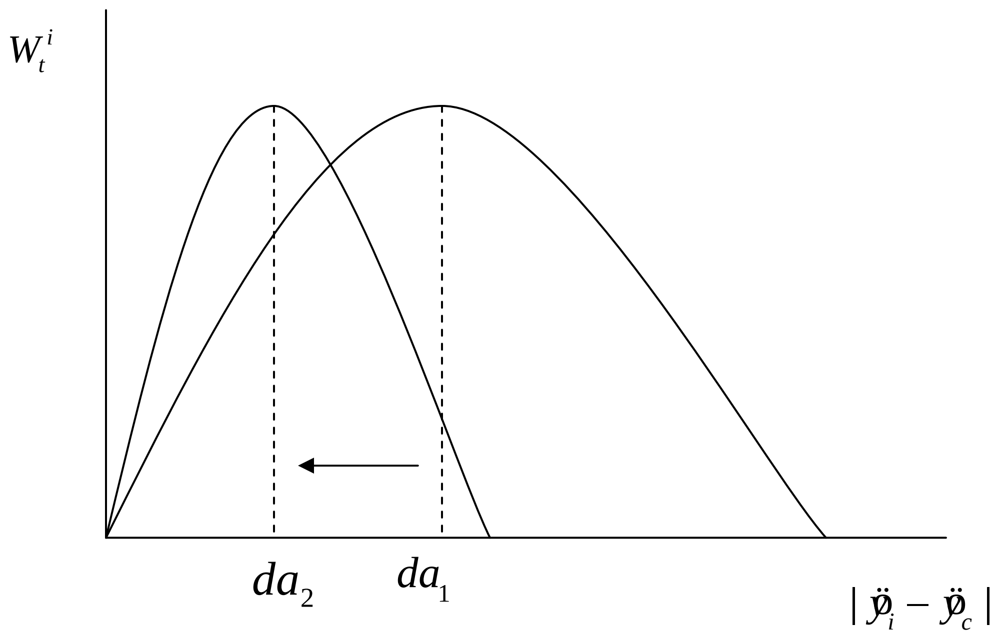
So how can we then detect a change in forecaster behavior in response to the Great Moderation? Lamont (2002) proposes a model based on Scharfstein and Stein (1990) that explains why forecasts will differ among forecasters at any point in time. By modifying the Lamont model we are able to explain how data on the cross-sectional distribution of forecast errors can be used to detect a change in forecaster behavior in response to the Great Moderation.

Lamont (2002) suggests that a forecaster's wage is a function of the absolute value of the forecast error and the distance between his individual forecast and the consensus forecast. This second argument is meant to capture the benefit that a forecaster will receive by distinguishing his or her forecast from the consensus forecast. In Lamont's model:

$$W_t^i = f(|\varepsilon_t|, |\ddot{p}_i - \ddot{p}_c|) \quad (6)$$

where $f_1' \leq 0$ and where $|\ddot{p}_c|$ is the consensus forecast (which could be either the mean or median forecast). If $f_2' > 0,$ then forecasters will "scatter" meaning that there will be a distribution of forecasts at each point in time.

The Lamont model explains why forecasts might differ at each point in time. We extend that model to provide a possible explanation for why forecasters in our sample may have responded to a decrease in the volatility of the economy as measured by σ^2. We hypothesize that an individual forecaster's wage is increasing in the distance from the consensus up to a point. Beyond that point, an individual forecaster's wage is decreasing in the distance from the consensus. If $f_2' > 0$ throughout, a forecaster would maximize his wage by publishing a forecast of infinity. Obviously there is some point at which a forecast goes from being "different" to being "absurd." We call this point "*da*" and hypothesize that $da = g(\sigma^2), \quad g' > 0$. For a constant forecast error, the relationship between an individual forecaster's wage and the distance of his forecast from the consensus is increasing to a point (*da*) and then decreasing after that point as depicted below.



With the onset of the Great Moderation, the relationship between W_t^i and $|\ddot{y}_i - \ddot{y}_c|$ shifted to the left and therefore the boundary between “different” and “absurd” shifted left as well: $da_2 = g(\sigma^{2,post}) < da_1 = g(\sigma^{2,pre})$ Lamont’s theory, along with the reasonable assumption that the *da* depends on σ^2, provides an explanation for why the cross-sectional distribution of forecasts shrank following the onset of the Great Moderation.

The results reported in Table 4 and Figures 5 and 6 show the drop in the dispersion of forecast errors after the onset of the Great Moderation. These results are consistent with the model presented in this section (especially the growth forecast errors) and they provide evidence that forecasters did in fact respond to the Great Moderation.

7. Endogenous Break Point Tests

The results presented in Tables 1-6 assume that the Great Moderation started in the first quarter of 1984. However, it is certainly possible that response of forecasters to the break in volatility does not correspond to the actual break in volatility. In this section we present results from an endogenous break point test to determine the timing of forecasters' response to the Great Moderation.

The analysis in Section 6 suggests that in order to detect a change in forecaster behavior we must look at the timing of the decrease in the cross-sectional dispersion of forecast errors. Table 7 reports the results of searching endogenously for the break point in the interquartile dispersion series. We estimated equation (1) with the interquartile dispersion as the dependent variable over each sample split beginning in 1975:3 (to allow enough degrees of freedom) and ending with 2002:12. Table 7 reports the date at which the split most likely occurred based on the likelihood ratio statistic[5].

The decline in the dispersion of output growth forecasting errors appears to have occurred in the early 1980s (except for the 2-quarter-ahead horizon for real output growth). Similarly, the dispersion of inflation forecast errors decline in the early-to-mid-1980s. Thus, it appears that forecasters adjusted their forecasts almost contemporaneously with the Great Moderation. These results are consistent with the rational expectations hypothesis.

[5] The p-values are computed using Hansen's (2000) "fixed regressor bootstrap" procedure.

8. The Benefits for Monetary Policy Making

There are several ways in which a reduction in the size of forecast errors benefits the economy as a whole. Improved inventory management and improved cost projections are two examples. In the public sector, the reduction in forecast errors could translate into improved policymaking. In this section, we look specifically at the benefits of the reduction in the size of forecast errors in the context of monetary policy. Following Sinclair et al. (2009), we measure the improvement in monetary policy by computing the policy forecast error. The policy forecast error is the difference between the federal funds interest rate target that the Fed would set under perfect foresight and the federal funds interest rate target it would set if it based its target on a forward-looking Taylor rule. Thus, this calculation begins with the assumption that the Fed (implicitly) follows the Taylor rule:

$$i_t^{T,e} = r* + \pi_{t+h}^e + 0.5(\pi_{t+h}^e - \pi*) + 0.5(y_{t+h}^e - y*) \qquad (7)$$

where $i^{T,e}$ is the target federal fund rate based on expected inflation and output growth, $r*$ is the target real interest rate, $\pi*$ is the target inflation rate and $y*$ is the (log of) potential output. Monetary policy is forward-looking: π_{t+h}^e and y_{t+h}^e are the h-step ahead expectations or forecasts of inflation and output growth[6]. Orphanides (2001) argues that the relevant horizon for the Fed is 4 quarters, thus we set h =4 for our analysis.

The Fed's optimal federal funds rate, i_t^T is

$$i_t^T = r* + \pi_{t+4}^A + 0.5(\pi_{t+4}^A - \pi*) + 0.5(y_{t+4}^A - y*), \qquad (8)$$

6. See Sinclair et al. (2009) for why it is appropriate to use output growth rather than the (log of) real output.

where π_{t+4}^{A} and y_{t+4}^{A} are the actual (real time) values of inflation and output growth. As long as the Fed's forecasts are unbiased, $i_t^T = i_t^{T,e}$ on average. Period by period, however, i_t^T will differ from $i_t^{T,e}$ because of errors in forecasting. Sinclair et al. call this the policy forecast error, PFE_t

$$PFE_t = i_t^T - i_t^{T,e} = 1.5\left(\pi_{t+4}^{A} - \pi_{t+4}^{e}\right) + 0.5\left(y_{t+4}^{A} - y_{t+4}^{e}\right) \qquad (9)$$

Although the policy forecast error will be zero on average, it is informative to look at the absolute value of this error to get a sense of how far away from the optimal federal funds rate the Fed would be if it followed the Taylor rule *meeting by meeting*. Using the coefficients from Table 2 we can compute the average absolute *PFE*, pre and post 1984:1:

$|PFE_t|$= 1.5(1.88) + .5(3.08) = 4.36 prior to 1984:1

$|PFE_t|$= 1.5(0.75) + .5(1.68) = 1.40 after to 1984:1

The difference, 2.96, represents the reduction in the absolute value of the PFE as a result of the Great Moderation. Thus, one direct measurable benefit of the reduction in forecast errors associated with Great Moderation is that the Fed, on average, is nearly three percentage points closer to the optimal federal funds rate.

There is considerable evidence that the federal funds rate is more persistent than described by the standard Taylor rule (equation (7)). Some researchers (Clarida, Gali, Gertler (2000)) have argued that the source of persistence is the Fed smoothing interest rates by gradually moving to the optimal interest rate rather than setting the target federal funds rate equal to the (expected) optimal federal funds rate period by period. The reason that the Fed might move gradually to the optimal rate is because of both forecast uncertainty and data uncertainty. If the Fed realizes that it has made an error forecasting growth or inflation, or if data are revised, it is easier to undo or reverse the federal funds rate change if it has only partly adjusted toward the (now erroneous) optimum. In other words, the absolute value of the PFE's calculated above likely overstates the actual errors that the Fed experienced because the Fed's approach of gradually moving to the optimum means that they probably never fully got to the optimum before they realize that they mis-forecasted growth or inflation. But to the extent that the Fed is smoothing its interest rate changes to mitigate the effects of forecast uncertainty, the reduction in forecast uncertainty associated with the Great Moderation implies that the Fed can move toward the perfect-foresight federal funds target rate more quickly than they could prior to the mid-1980s.

9. Summary and Conclusion

U.S. growth and inflation volatility dropped significantly in the mid-1980s. The empirical evidence presented in this paper shows that forecast errors dropped in absolute size, but forecast errors normalized for the size of economic fluctuation remained roughly unchanged. The cross-sectional dispersion of forecasts fell in conjunction with the Great Moderation, which is consistent with a change in forecaster behavior in response to the Great Moderation. By our calculation, the reduction in forecast errors makes it easier for the Fed to conduct monetary policy by either allowing the Fed to achieve a target federal funds rate that is closer to the perfect-foresight target rate or by reducing the Fed's need to gradually move towards the optimal target.

Figure 1

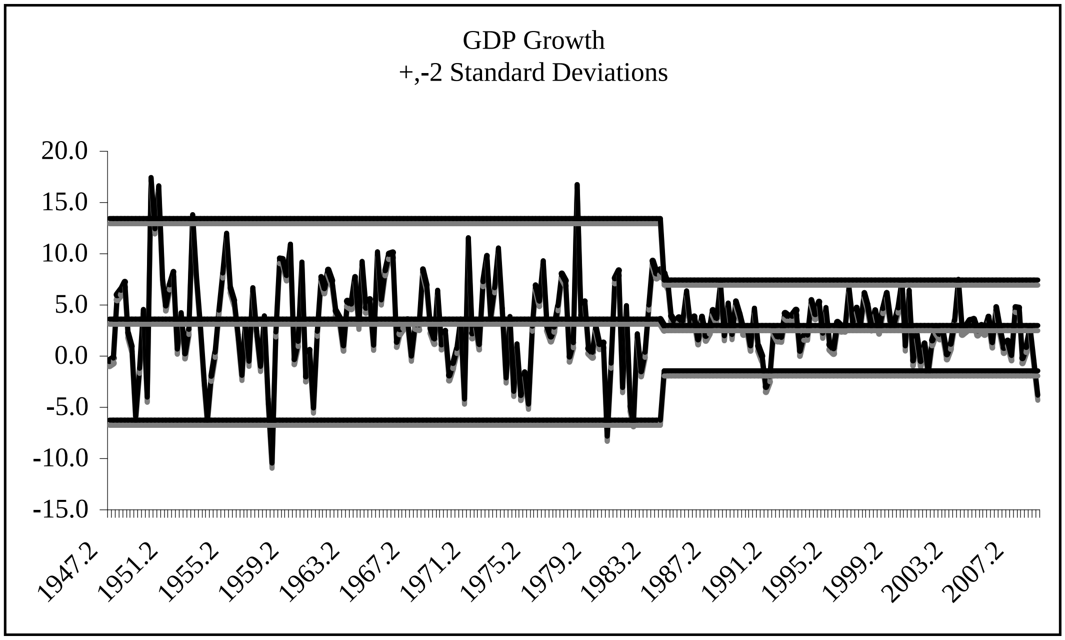


Figure 2

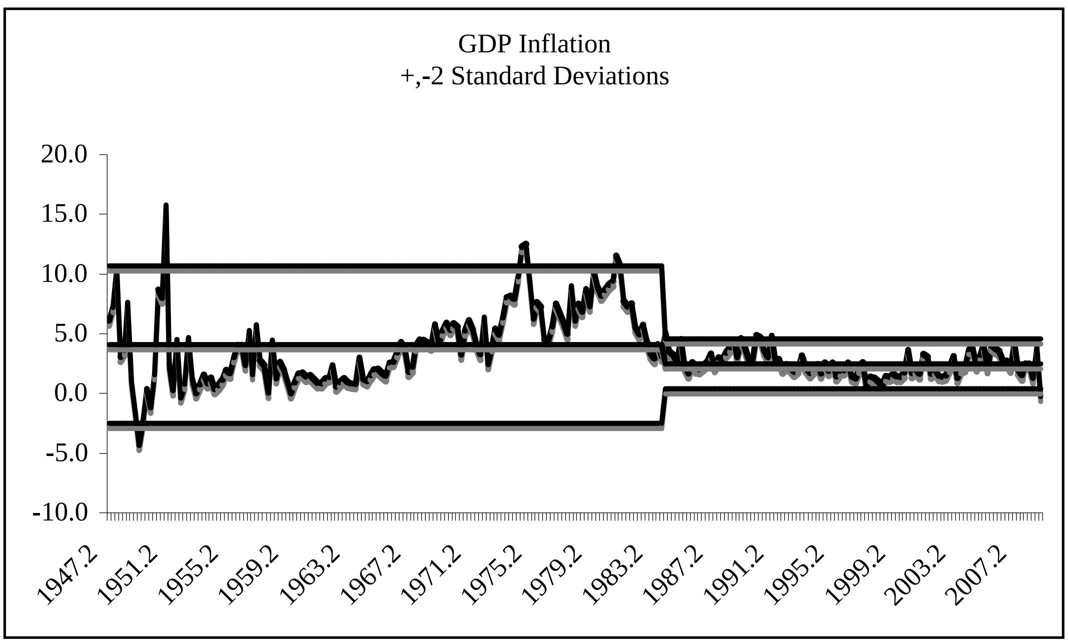


Figure 3

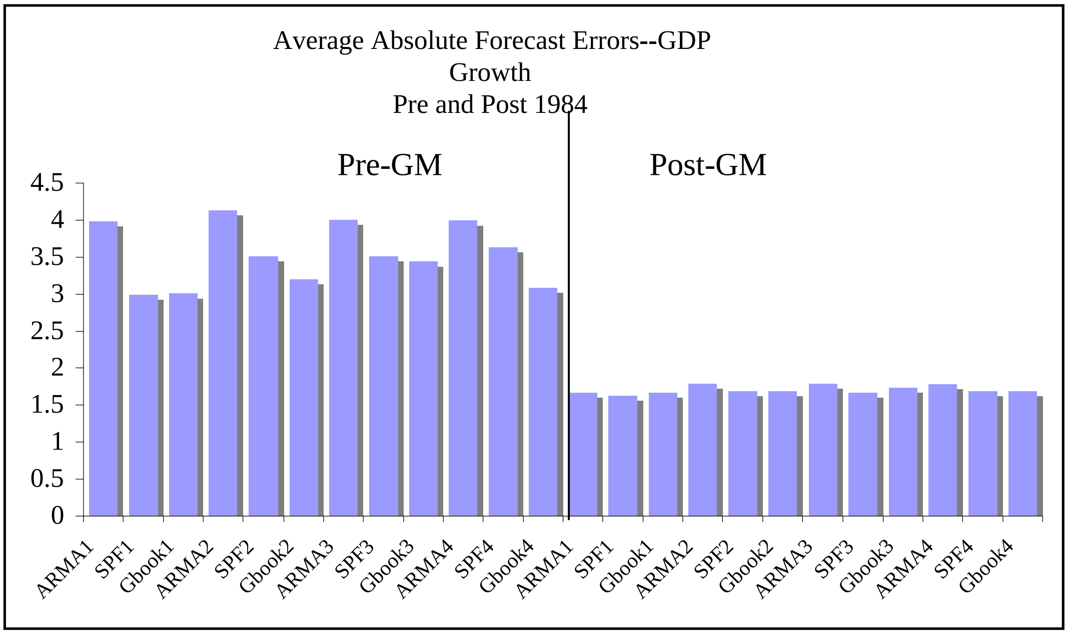


Figure 4

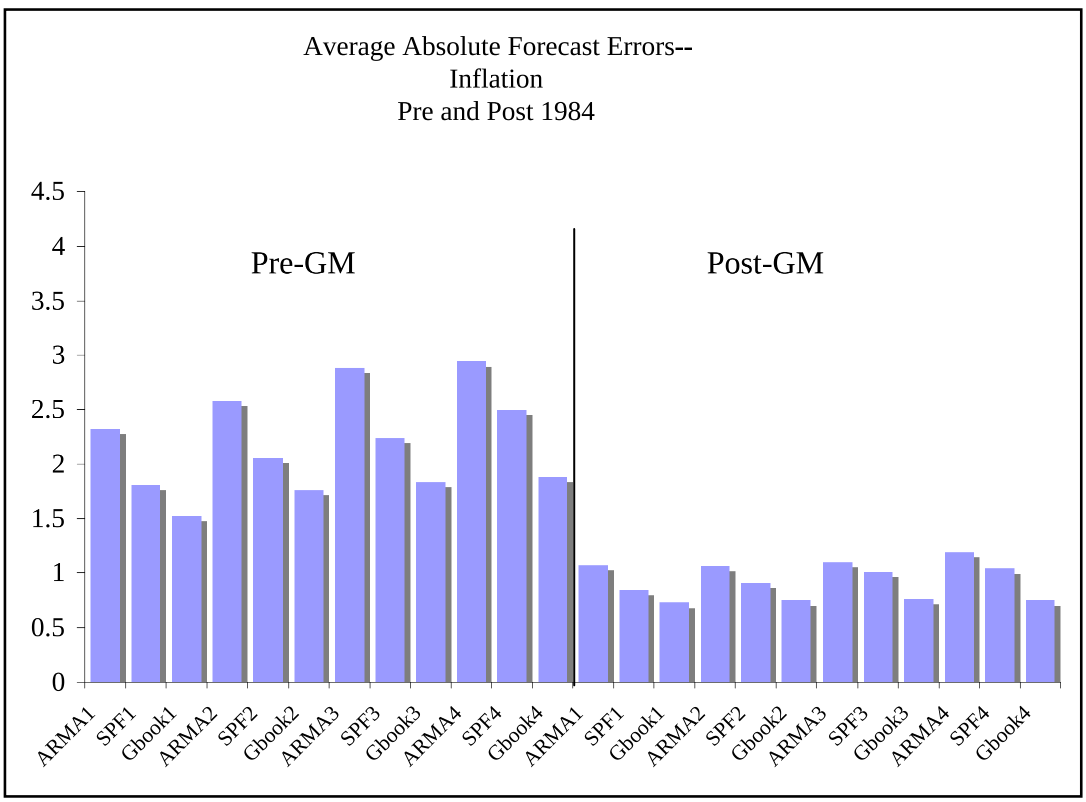


Figure 5

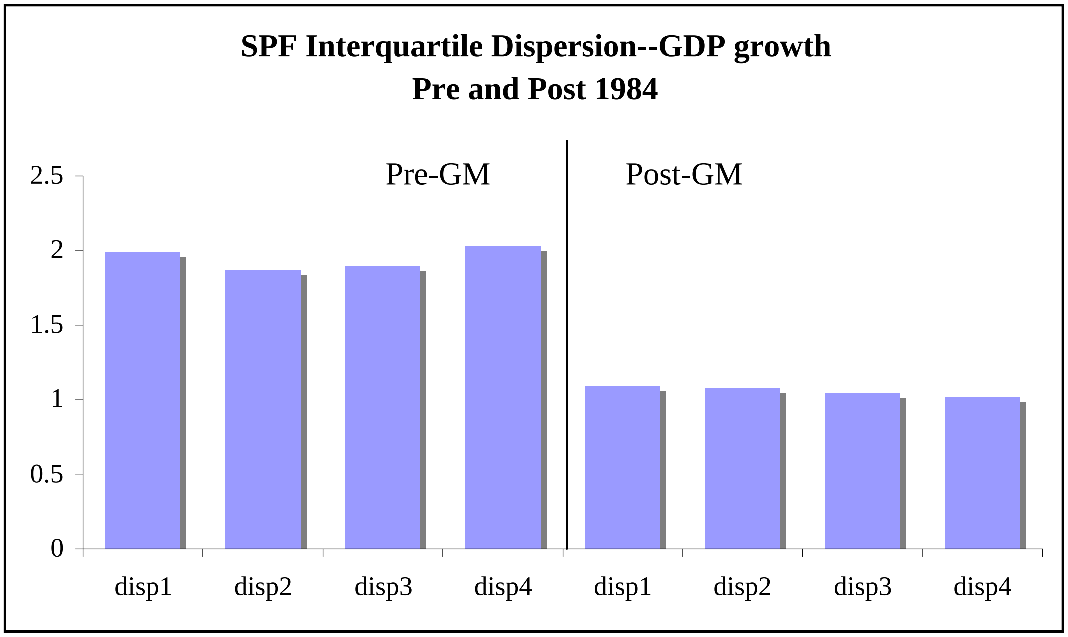


Figure 6

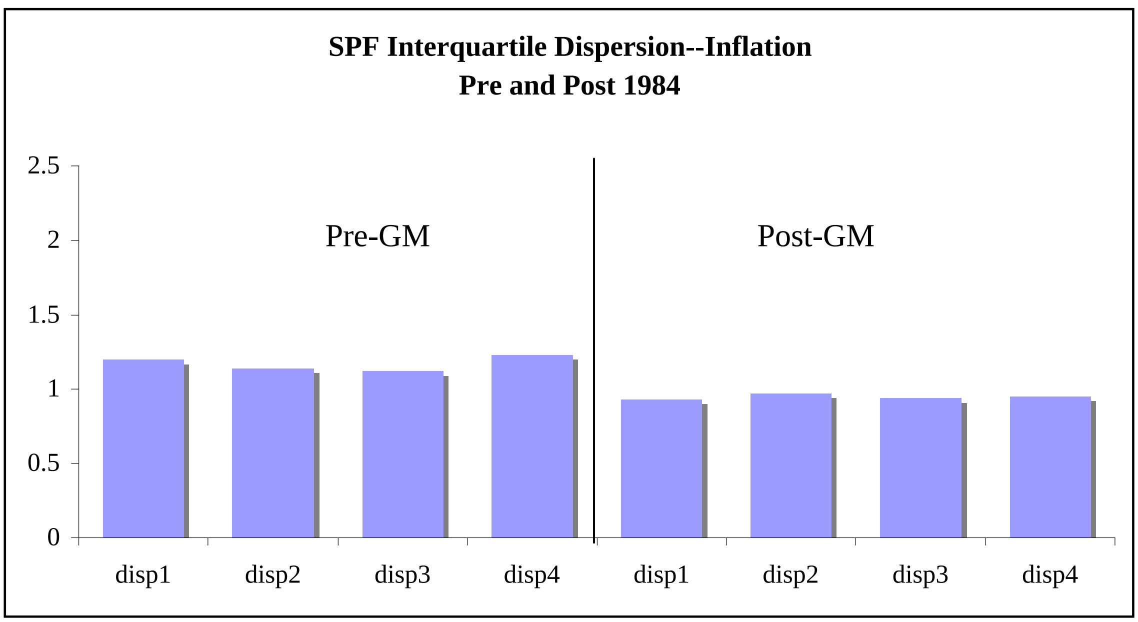


Figure 7

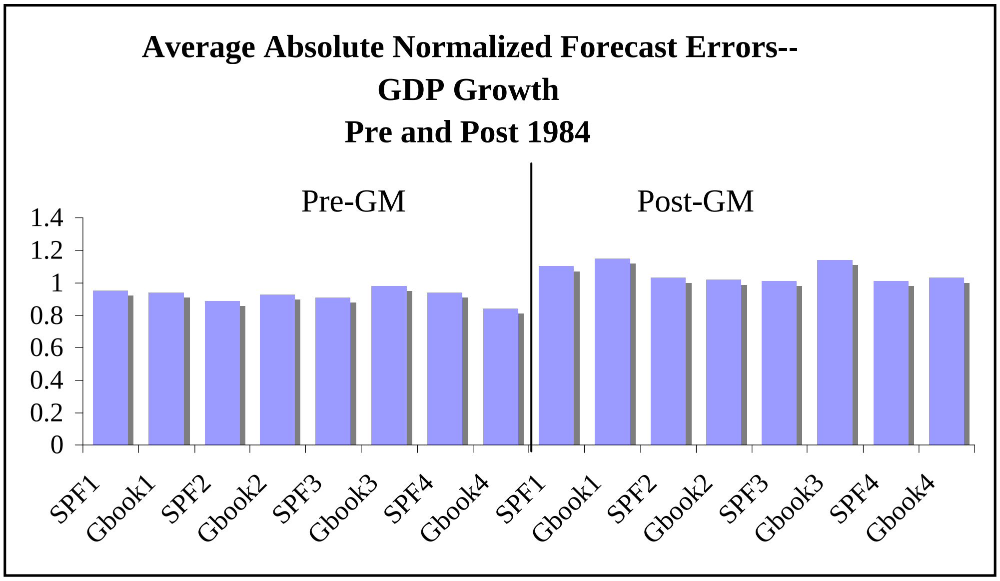


Figure 8

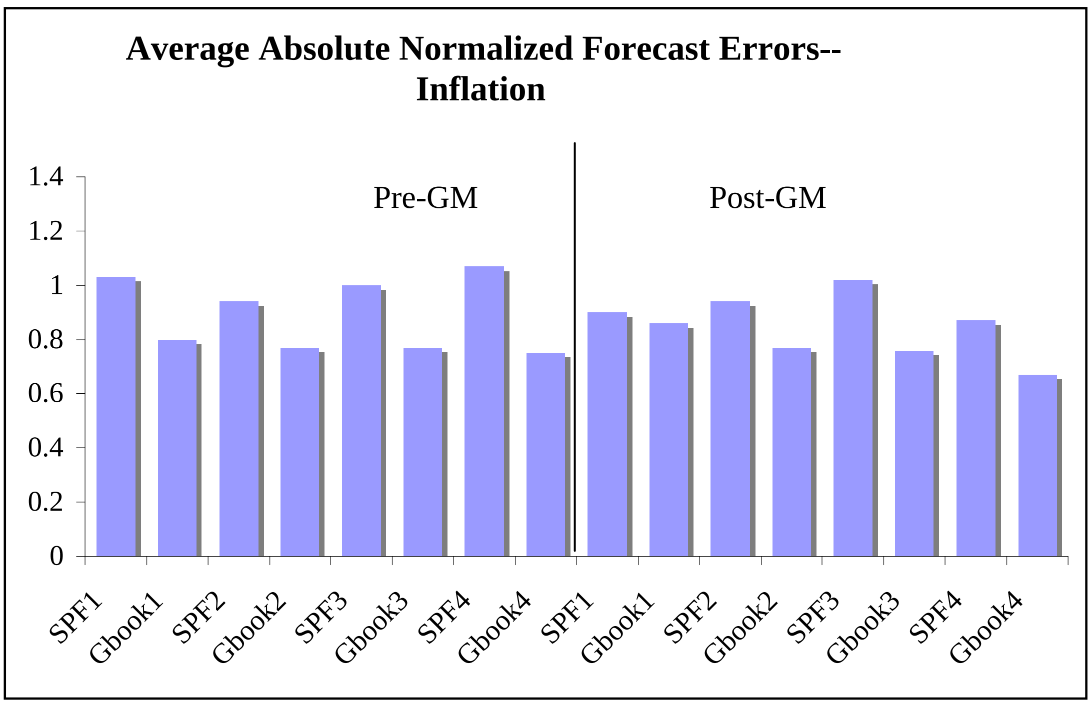


Table 1
Pre and Post 1984:1 Absolute Median Forecast Errors
Survey of Professional Forecasters

Forecast Error for	α_1	α_2	α_1-α_2
y_{t+1}	2.99** (.35)	1.62** (.13)	1.37** (.37)
y_{t+2}	3.51** (.40)	1.68** (.13)	1.82** (.42)
y_{t+3}	3.51** (.43)	1.67** (.16)	1.83** (.45)
y_{t+4}	3.63** (.45)	1.68** (.15)	1.95** (.48)
π_{t+1}	1.81** (.19)	.84** (.07)	.96** (.20)
π_{t+2}	2.06** (.24)	.91** (.08)	1.15** (.26)
π_{t+3}	2.24** (.28)	1.01** (.09)	1.23** (.29)
π_{t+4}	2.50** (.33)	1.04** (.09)	1.46** (.34)

Notes:
Newey-West standard errors are in parentheses below the coefficient estimates
** indicates significant at the 0.01 level

Table 2
Pre and Post 1984:1 Absolute Forecast Errors
Federal Reserve Greenbook Forecasts

Forecast Error for	α_1	α_2	α_1-α_2
y_{t+1}	3.01** (.35)	1.67** (.12)	1.33** (.36)
y_{t+2}	3.20** (.38)	1.68** (.15)	1.51** (.41)
y_{t+3}	3.44** (.46)	1.74** (.15)	1.70** (.49)
y_{t+4}	3.08** (.37)	1.68** (.16)	1.40** (.41)
π_{t+1}	1.52** (.19)	.73** (.06)	.80** (.20)
π_{t+2}	1.76** (.25)	.75** (.06)	1.02** (.26)
π_{t+3}	1.83** (.29)	.76** (.06)	1.07** (.30)
π_{t+4}	1.88** (.33)	.75** (.07)	1.13** (.34)

Notes:
Newey-West standard errors are in parentheses below the coefficient estimates
** indicates significant at the 0.01 level
* indicates significant at the 0.05 level

Table 3
Pre and Post 1984:1 Absolute Forecast Errors
ARMA models

Forecast Error for	α_1	α_2	α_1-α_2
y_{t+1}	3.98** (.46)	1.67** (.15)	2.31** (.49)
y_{t+2}	4.13** (.41)	1.79** (.15)	2.33** (.44)
y_{t+3}	4.00** (.47)	1.79** (.16)	2.20** (.50)
y_{t+4}	3.99** (.43)	1.78** (.15)	2.21** (.46)
π_{t+1}	2.32** (.27)	1.07** (.09)	1.32** (.28)
π_{t+2}	2.58** (.28)	1.06** (.08)	1.52** (.29)
π_{t+3}	2.88** (.31)	1.10** (.07)	1.78** (.32)
π_{t+4}	2.94** (.33)	1.19** (.08)	1.75** (.34)

Notes:
Newey-West standard errors are in parentheses below the coefficient estimates
** indicates significant at the 0.01 level

Table 4
Pre and Post 1984:1 Interquartile Dispersion
Survey of Professional Forecasters

Forecast Error for	α_1	α_2	α_1-α_2
y_{t+1}	1.99** (.10)	1.09** (.05)	.91** (.11)
y_{t+2}	1.87** (.08)	1.08** (.06)	.79** (.09)
y_{t+3}	1.90** (.08)	1.04** (.05)	.87** (.09)
y_{t+4}	2.03** (.08)	1.02** (.05)	1.01** (.09)
π_{t+1}	1.20** (.08)	.93** (.04)	.27** (.09)
π_{t+2}	1.14** (.10)	.97** (.04)	.17 (.11)
π_{t+3}	1.12** (.09)	.94** (.04)	.18† (.10)
π_{t+4}	1.23** (.08)	.95** (.04)	.28** (.09)

Notes:
Newey-West standard errors are in parentheses below the coefficient estimates
** indicates significant at the 0.01 level
† indicates significance at the .10 level

Table 5
Pre and Post 1984:1 Absolute Normalized Forecast Errors
Survey of Professional Forecasters

Forecast Error for	α_1	α_2	α_1-α_2
y_{t+1}	.95** (.14)	1.10** (.09)	-.14 (.17)
y_{t+2}	.89** (.07)	1.03** (.08)	-.14 (.11)
y_{t+3}	.91** (.07)	1.01** (.10)	-.10 (.11)
y_{t+4}	.94** (.08)	1.01** (.09)	-.08 (.12)
π_{t+1}	1.03** (.13)	.90** (.07)	.13 (.14)
π_{t+2}	.94** (.10)	.94** (.08)	-.001 (.13)
π_{t+3}	1.00** (.15)	1.02** (.10)	-.02 (.18)
π_{t+4}	1.07** (.16)	.87** (.07)	.20 (.17)

Notes:
Newey-West standard errors are in parentheses below the coefficient estimates
** indicates significant at the 0.01 level

Table 6
Pre and Post 1984:1 Absolute Normalized Forecast Errors
Federal Reserve Greenbook Forecasts

Forecast Error for	α_1	α_2	α_1-α_2
y_{t+1}	.94** (.11)	1.15** (.09)	-.20 (.15)
y_{t+2}	.93** (.12)	1.02** (.09)	-.08 (.15)
y_{t+3}	.98** (.09)	1.14** (.12)	-.16 (.15)
y_{t+4}	.84** (.07)	1.03** (.09)	-.19 (.12)
π_{t+1}	.80** (.07)	.86** (.07)	-.06 (.10)
π_{t+2}	.77** (.08)	.77** (.05)	.008 (.09)
π_{t+3}	.77** (.11)	.76** (.06)	.01 (.13)
π_{t+4}	.75** (.11)	.67** (.05)	.08 (.12)

Notes:
Newey-West standard errors are in parentheses below the coefficient estimates
** indicates significant at the 0.01 level

Table 7
Endogenous Breakpoint Test
Interquartile Dispersion
Survey of Professional Forecasters

Dispersion of Forecast Error for	Break Date	p-value
y_{t+1}	1983.2	.000
y_{t+2}	1990.11	.000
y_{t+3}	1983.8	.000
y_{t+4}	1981.11	.000
π_{t+1}	1982.8	.000
π_{t+2}	1982.8	.000
π_{t+3}	1985.11	.000
π_{t+4}	1986.5	.000

Notes: the p-values were computed by the "fixed-regressor bootstrap method" described in Hansen (2000).

References

Alcala, F. and I. Sancho, "Output Composition and the U.S. Output Volatility Decline," Universidad de Murcia Working Paper, February 2003.

Atkeson, Andrew and Lee E. Ohanian, 2001. "Are Phillips Curves Useful for Forecasting Inflation?" *Federal Reserve Bank of Minneapolis Quarterly Review*, **25** (2001), 2-11.

Arias, A., G. Hansen and L. Ohanian, "Why Have Business Cycle Fluctuations Become Less Volatile?" National Bureau of Economic Research Working Paper 12079, 2006.

Campbell, Sean D., "Macroeconomic Volatility, Predictability and Uncertainty in the Great Moderation: Evidence from the Survey of Professional Forecasters," *Journal of Business and Economic Statistics*, v. 25, n. 2, April 2007, pp. 191-200.

Clarida, R., J. Gali and M. Gertler, "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory" *Quarterly Journal of Economics*, vol. 115, February 2000, pp. 147-80.

Croushore, Dean and Tom Stark, A Real-Time Dataset for Macroeconomists, *Journal of Econometrics*, vol. 105, November 2001, pp. 111-130.

Davis, Steven J. and James A. Kahn, "Interpreting the Great Moderation: Changes in the Volatility of Economic Activity at the Macro and Micro Levels," Federal Reserve Bank of New York, Staff Report # 334, July 2008.

Gali, Jordi and Luca Gambetti, " *American Economic Journal of Macroeconomics*," vol. 1, no. 1, January 2009, pp. 26-57.

Gavin, William T., and Rachel J. Mandal, 2001. "Forecasting Inflation and Growth: Do Private Forecasts Match Those of Policymakers?" *Review*, Federal Reserve Bank of St. Louis, May/June (2001) 11-19.

Hansen, Bruce, "Testing For Structural Change In Conditional Models," *Journal of Econometrics*, vol. 97, 2000, pp. 93-115.

Herrera, A. and Pesavento, E. "The Decline in U.S. Output Volatility: Structural Changes and Inventory Investment," Michigan State University Working Paper, August 2004.

Irvine, O. and S. Shuh, "Inventory Investment and Output Volatility," Federal Reserve Bank of Boston Working Paper Series, paper no. 02-6 (2002).

Justiniano, A. and G. Primiceri, “The Time Varying Volatility of Macroeconomic Fluctuations,” National Bureau of Economic Research Working Paper, 12022, 2006.

Kahn, J., M. McConnell and G. Perez-Quiros, “On the Causes of Increased Stability of the U.S. Economy,” Federal Reserve Bank of New York *Economic Policy Review*, May 2002, pp. 183-202.

Keane, Michael and D. Runkle, “Testing Rationality of Price Forecasts: New Evidence from Panel Data,” *American Economic Review*, vol. 80, no. 4, 1990, pp. 714-735.

Kim, C., C. Nelson, and J. Piger, “The Less Volatile U.S. Economy: A Bayesian Investigation of Timing, Breadth, and Potential Explanations, Federal Reserve Bank of St. Louis Working Paper, March 2003.

Lamont, Owen, “Macroeconomic Forecasts and Microeconomic Forecasters,” *Journal of Economic Behavior and Organization*, July 2002.

McConnell, M. and G. Perez-Quiros, “Output Fluctuations in the United States: What Has Changed Since the Early 1980s?” *American Economic Review*, Vol. 90, No. 5, 2000, pp. 1464-1476.

Moreno, A. “Reaching Inflation Stability,” Columbia University Working Paper, October 21, 2002.

Orphanides, Athanasios, “Monetary Policy Rules Based on Real-Time Data,” *American Economic Review*, vol. 91, no. 4, September 2001, pp. 961-84.

Ramey, V. and D. Vine, “Declining Volatility in the US Automobile Industry,” *American Economic Review*, 2006, vol. 95, no. 5, pp. 1876-89.

Romer, C. and D. Romer, “Federal Reserve Information and the Behavior of Interest Rates,” *American Economic Review*, vol. 90, no. 3, June 2000, pp. 429-57.

Scharfstein, David and Jeremy Stein, “Herd Behavior and Investment,” *American Economic Review*, vol. 80, 1990, pp. 464-79.

Sinclair, T. , E. Gamber, H. Stekler and E. Reid, “Multivariate Forecast Errors and the Taylor Rule,”

Stock, J. and M. Watson, “Has the Business Cycle Changed and Why?” NBER Working Paper 9127, September 2002.

____________________, “Why Has U.S. Inflation Become Harder to Forecast?” *Journal of Money, Credit and Banking*, **39** (2007).

Zarnowitz, V. and L. Lambros, "Consensus and Uncertainty in Economic Prediction," *Journal of Political Economy*, vol. 95, no. 3, June 1987, pp. 591-621.