Macroeconomic Dynamics, **20**, 2016, 791–818. Printed in the United States of America.
doi:10.1017/S1365100514000625

USING FORECASTS TO UNCOVER THE LOSS FUNCTION OF FEDERAL OPEN MARKET COMMITTEE MEMBERS

CHRISTIAN PIERDZIOCH
Helmut-Schmidt-University

JAN-CHRISTOPH RÜLKE
EBS—Universität für Wirtschaft und Recht

PETER TILLMANN
Justus-Liebig-University Giessen

We revisit the sources of the bias in Federal Reserve forecasts and assess whether a precautionary motive can explain the forecast bias. In contrast to the existing literature, we use forecasts submitted by individual Federal Open Market Committee (FOMC) members to uncover members' implicit loss function. Our key finding is that the loss function of FOMC members is asymmetric: FOMC members incur a higher loss when they underpredict (overpredict) inflation and unemployment (nominal and real growth) as compared to their making an overprediction (underprediction) of similar size. We also find that an asymmetric loss function, in some cases, weakens evidence against forecast rationality, though results depend on the variable being projected and the subgroup of FOMC members being studied. Furthermore, we add to the recent controversy on the relative quality of FOMC forecasts compared to staff forecasts. Our results suggest that differences in predictive ability could indeed stem from differences in preferences.

Keywords: Federal Open Market Committee, Forecasting, Asymmetric Loss Function, Monetary Policy

1. INTRODUCTION

One of the key stylized facts in monetary economics is that monetary policy affects macroeconomic variables with a sizable time lag. It is therefore important for monetary policy makers to gauge the most likely paths of nominal and real variables. At most central banks, the staff prepares a wide range of forecasts prior to policy

We are grateful to two anonymous referees, an associate editor, David Laidler, Matthias Neuenkirch, Athanasios Orphanides, Maik Wolters, participants at the Seventeenth Spring Meeting of Young Economists, the Scottish Economic Society Conference 2012, the First Workshop on Empirical Monetary Economics 2013, and seminar participants at the University of Dortmund, the Deutsche Bundesbank, and the Viessmann Research Centre for helpful comments and suggestions. Address correspondence to: Jan-Christophe Rülke, Department of Management and Economics, EBS—Business School, Rheingaustrasse 1, D-65375 Oestrich-Winkel, Germany; e-mail: jan-christoph.ruelke@ebs.edu.

 1365-1005/16

decisions. In the case of the Federal Reserve, these staff forecasts are collected in the Greenbook made available to each member of the Federal Open Market Committee (FOMC). However, a peculiar characteristic of the policy making process in the United States is that FOMC members themselves regularly formulate forecasts. Interest rate decisions, thus, are guided by economic projections from at least two different sources.

Whereas the interest-rate-setting behavior of the FOMC receives enormous attention in the literature, knowledge of the FOMC's forecasting behavior is limited. This is an important deficit, because Orphanides and Wieland (2008) and Wieland and Wolters (2013) show that the FOMC's own projections are more important for explaining interest rate decisions than observed macroeconomic outcomes. Until recently, an analysis of FOMC forecasts was difficult because individual forecasts are not publicly available. Instead, the Fed publishes only the range of forecasts, not the individual forecasts. A new data set put together by Romer (2010), however, contains individual forecasts for the period 1992 to 2000.

We use the Romer (2010) data set to study the loss function of individual FOMC members using the approach developed by Elliott et al. (2005).[1] This approach backs out the parameters of a forecaster's loss function based on historical forecast errors. The approach, thereby, renders it possible to take the finding into account that FOMC forecasts exhibiting systematic forecast errors do not necessarily imply a departure from rationality. Rather, the forecasts could be consistent with rational forecasters minimizing a nonstandard, asymmetric loss function. Our analysis allows us to assess whether any systematic forecast errors are departures from forecast rationality or can be explained by a precautionary motive arising because forecasters have an asymmetric loss function. Our key finding lends support to the view that the loss function of FOMC members is asymmetric: FOMC members seem to incur a higher loss when they underpredict inflation and unemployment than for an overprediction of similar size. For real and nominal growth, FOMC members seem to incur a higher loss when the forecast exceeds actual growth than when it undershoots the realized growth rate. This result also holds in small samples and for subgroups of members, i.e., voting members or Federal Reserve governors. An important difference between our research and studies on asymmetric monetary policy or nonstandard objective functions is that we shed light on asymmetric losses based on the track record of forecast errors. Hence, the loss function we study is the loss function forecasters optimize when submitting a macroeconomic projection.

Our empirical investigation is similar to Capistrán's (2008) study. The crucial difference, however, is that he uncovers the loss function of the Federal Reserve staff based on inflation forecasts from the Greenbook. He finds that since the Volcker disinflation, an underprediction of inflation has been approximately four times as costly as an overprediction. We, in contrast, are able to use forecasts submitted by individual FOMC members. An important advantage is that this data set allows us to examine differences in the shape of the loss function between different subgroups of members, such as voting and nonvoting members, experts and nonexperts.

In another recent paper, Caunedo et al. (2013) investigate the loss function based on Greenbook forecasts jointly for different macroeconomic variables. They find that the forecasts can be rationalized under asymmetric loss, whereas the degree of asymmetry depends on the phase of the business cycle. In doing so, they offer an explanation of the monetary policy change in the late 1970s, which can be attributed to a combination of different preferences over expansions and recessions and less frequent recessions during that time period.

Our findings also add to the recent controversy on the quality of FOMC forecasts compared to staff forecasts. Romer and Romer (2008) show that FOMC forecasts add little information above and beyond Greenbook forecasts. Ellison and Sargent (2012) assume that the FOMC's forecasts describe worst-case scenarios used to make monetary policy robust with respect to misspecifications of the staff's model. Based on this assumption and a simple model, they replicate the findings of Romer and Romer (2008). Our findings suggest that the staff's loss function and the one driving FOMC members' forecasts might differ with respect to their degree of asymmetry.[2]

We also find that an asymmetric loss function does not reconcile forecasting performance with rationality in several cases. The results of the rationality tests, however, depend on the variable being projected and the subgroup of FOMC members that forms forecasts (governors, voting members, nonvoting members). On balance, our results imply that the bias of FOMC forecasts must stem at least in part from another factor yet to be explained. Interestingly, however, forecast rationality under an asymmetric loss function is rejected less frequently in the group of governors and voting FOMC members than in the sample comprising all FOMC members. This is consistent with evidence on strategic behavior of nonvoting members recently provided by Rülke and Tillmann (2011) and Tillmann (2011a, 2011b).

Our contribution also adds to three other strands of the literature. First, our findings are relevant to recent attempts to study monetary policy preferences based on individual voting information from monetary policy committees.[3] Belden (1989), Havrilesky and Gildea (1991), Chappell et al. (2005), Meade (2005), Zhang and Semmler (2005), Gerlach-Kristen (2008, 2009), Riboni and Ruge-Murcia (2008), and Besley et al. (2008) use data on the voting behavior of members of either the FOMC or the Bank of England's Monetary Policy Committee to uncover policy preferences. Ruge-Murcia (2003) analyzes whether central bankers' preferences are asymmetric around an inflation target and reports asymmetric preference parameters for Canada, Sweden, and the United Kingdom. Here, we complement this line of research by providing evidence on the shape of the loss function governing FOMC members' economic projections.

Second, researchers try to infer the degree of asymmetry of the central banks' objective function from estimated interest rate rules. Surico (2007) estimates a reaction function for the Fed derived from Nobay and Peel's (2003) potentially asymmetric linex-loss function. He finds that before 1979 the Fed weighted positive and negative deviations of the inflation rate from the target differently. After 1979, however, preferences appear symmetric. Rather than specifying a particular loss function, Kilian and Manganelli (2008) present and estimate a risk management model of the Fed weighing upside and downside risks to policy objectives.

Third, we shed light on the sources of the forecast bias in Federal Reserve forecasts. Studies by Gavin (2003), Gavin and Mandal (2003), and Gavin and Pande (2008) examine the accuracy of the FOMC's published forecast range. In contrast, we examine the bias of individual forecasts, based on a flexible functional form of the forecasters' loss function.

The remainder of the paper is organized as follows. Section 2 introduces the data set. Section 3 presents the methodology used to uncover the functional form of the FOMC's loss function. The results are discussed in Section 4. Section 5 presents an extensive set of robustness tests. Some tentative conclusions are drawn in Section 6.

2. THE DATA SET

We use the data set compiled and disseminated by Romer (2010). It contains individual forecasts for real growth, nominal growth, inflation, and the unemployment rate. During these years, the Fed published the monetary policy report to Congress following its February and July meetings. The FOMC individual forecasts are made only twice a year and the published version of the forecasts can differ from the forecasts that members had originally submitted before the FOMC meetings. Subsequently, the range as well as the median forecast is published. For our analysis we use individual forecasts of FOMC members, which are available for the time period 1992–2000.[4] As part of the preparation of this report, every FOMC member submits his or her own forecasts, after intensive briefing by the Board staff. The published report contains the range of forecasts but does not report member-specific forecasts. Romer (2010), however, managed to obtain those individual forecasts from the Federal Reserve and put together a data set. Because of the publication lag of more than ten years, the data set, at the time of writing of this paper, ended in 2000. The data set contains forecasts from board members as well as the twelve voting and nonvoting regional Federal Reserve Bank presidents. It does not, however, contain forecasts from the chair, because he does not submit his forecasts to the FOMC meetings.

In the July report, the FOMC prepares forecasts of the inflation rate, the annual growth rate of real and nominal GDP, and the unemployment rate in the fourth quarters of the current and the next calendar year. These forecasts are referred to as two-quarters-ahead and six-quarters-ahead forecasts, respectively. The February report contains forecasts of the same variables for the fourth quarter of the current calendar year. These forecasts are referred to as four-quarters-ahead forecasts.

Because policy makers may form their forecasts with respect to the "true" state of the economy, we contrast the forecasts with revised data on actual realizations.[5]

TABLE 1. Summary statistics of the forecast errors

Variable	h	Full sample	Voting members	Governors	Greenbook
Real growth rate	2	.68$^{*,+}$	.69$^{*,+}$	.69$^{*,+}$	1.19$^{*,+}$
	4	.99$^{*,+}$	1.02$^{*,+}$	1.01$^{*,+}$	1.11$^{*,+}$
	6	.75$^{*,+}$	.72$^{*,+}$	.85$^{*,+}$	.73^{+}
Nominal growth rate	2	.39$^{*,+}$	.37$^{*,+}$	.40$^{*,+}$	—
	4	.71$^{*,+}$	.77$^{*,+}$	.76$^{*,+}$	—
	6	.40$^{*,+}$	.34	.48	—
Inflation rate	2	−.10$^{*,+}$	−.11^{+}	−.05	.43$^{*,+}$
	4	.00	−.01	.02	.47$^{*,+}$
	6	−.17$^{*,+}$	−.23	−.12	.54$^{*,+}$
Unemployment rate	2	−.17$^{*,+}$	−.15$^{*,+}$	−.22$^{*,+}$	—
	4	−.24$^{*,+}$	−.24$^{*,+}$	−.25$^{*,+}$	—
	6	−.18$^{*,+}$	−.18$^{*,+}$	−.24$^{*,+}$	—

Notes: The table reports the unconditional mean of the forecast errors, defined as $s_t - f_t$. * indicates whether the unconditional bias is significantly different from zero at the 1% level. + indicates whether the null hypothesis of the Wilcoxon rank sum test (H_0: forecast errors are symmetrically distributed) can be rejected at the 1% level.

All forecasts are assumed to be conditional on every member's own judgment of the "appropriate policy" path over the forecast horizon. In total, we have available 457 forecasts for each macroeconomic variable. Although the data have a time-series as well as a cross-sectional dimension, we pool the data when estimating the loss function. To account for group-specific characteristics, we analyze various subsamples of the data.

A potential drawback in any empirical analysis of the individual FOMC forecasts is that the sample period covers the Great Moderation. One peculiar characteristic of this period is that the FOMC mostly overpredicted the inflation rate and underpredicted the real growth rate. Hence, the data encompass an expansion phase in which the Federal Reserve and other forecasters gradually learned that the underlying mean of output growth rates was higher than expected. To examine the time-series and cross-sectional dimensions of the data, Figure 1 plots the forecasts for the three different time horizons (two-, four-, and six-quarters-ahead forecasts as triangles, dots, and squares, respectively) and the realized values (solid line).

The vertical distances between the forecasts and the solid line can be interpreted as the forecast errors. Two observations stand out. First, cross-sectional heterogeneity of forecasts is a characteristic feature of the data. For instance, in February 1994 the real growth (inflation) forecasts vary across FOMC members between 2.5 (2.3) and 3.8 (4.0) percent. Second, there appears to be a sufficient degree of variation over time to justify our approach, based on the historical series of forecast errors. In fact, there are many periods of under- and overprediction of all four variables.[6]

Table 1 summarizes the unconditional forecast errors for the full sample period as well as for voting members and governors separately. FOMC members on

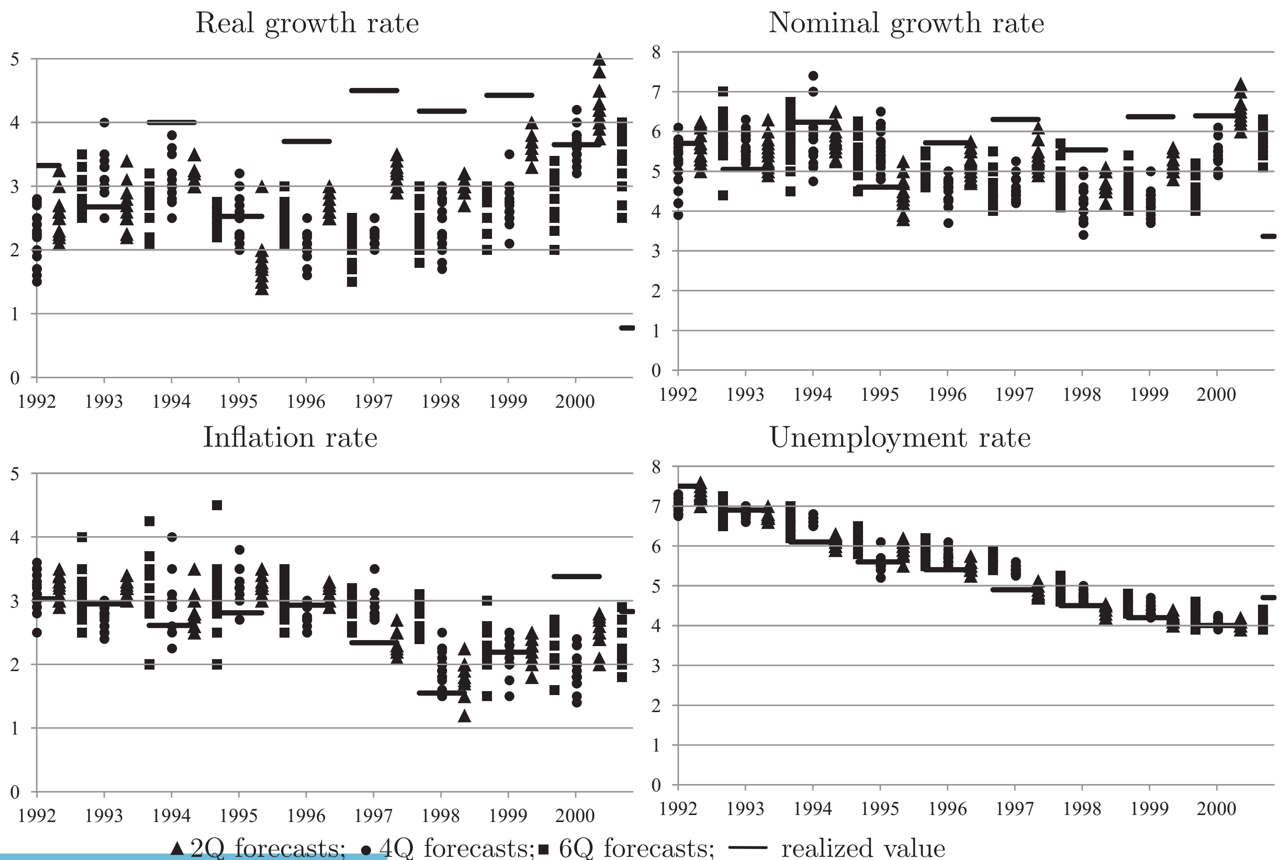

FIGURE 1. Individual FOMC forecasts. The figure shows the forecasts of the FOMC and the realized value based on revised data for the two-, four-, and six-quarters-ahead forecast as triangles, dots, and squares, respectively. The data on the realized values are taken from the IMF's database.

average underprojected the real and nominal growth rates, whereas they overprojected the unemployment rate. In addition, FOMC members on average overprojected the inflation rate in their July meetings (h = 2 and 6), whereas this is only the case for the voting members and the governors to a much lesser extent. In most cases (except for the inflation rate), the forecast errors are asymmetrically distributed, as indicated by the rejection of the null hypothesis of the Wilcoxon rank sum test.

3. MODELING AN ASYMMETRIC LOSS FUNCTION

A traditional Mincer–Zarnowitz test of forecast unbiasedness is a joint test of the symmetry of the loss function and the efficient use of information. The finding of biased forecasts could, in principle, result from a violation of either the assumption of symmetry or the assumption of informational efficiency. In our empirical study, we employ the approach developed by Elliott et al. (2005) to study the shape of the FOMC members' loss function. The idea is to search for the shape of the loss function of a forecaster that would be most consistent with the forecaster's past forecast errors.[7]

The approach rests on the assumption that the loss function, $\mathcal{L}$, of a forecaster can be described in the general functional form

$$\mathcal{L} = [\alpha + (1 - 2\alpha) I(s_{t+h} - f_{t+h} < 0)] |s_{t+h} - f_{t+h}|^p, \tag{1}$$

where f_{t+h} reflects the forecast submitted by an individual FOMC member in period t for a variable to be realized h periods in the future. This realization is denoted as s_{t+h}. Thus, the forecast error is $s_{t+h} - f_{t+h}$. The expression $I(s_{t+h} - f_{t+h} < 0)$ reflects an indicator function. The parameter p governs the general functional form of the loss function, where a lin–lin loss function obtains for $p = 1$, and a quad–quad loss function results if one sets $p = 2$. The parameter $\alpha \in (0, 1)$ governs the degree of asymmetry of the loss function and is our primary parameter of interest. A symmetric loss function results in the case $\alpha = 0.5$. For $\alpha > 0.5$, underpredicting a variable causes a higher loss than overpredicting. For $\alpha < 0.5$, overpredicting is more costly than underpredicting. For $\alpha = 0.5$ and $p = 2$, the loss a forecaster incurs increases in the squared forecast error. For $\alpha = 0.5$ and $p = 1$, the loss increases in the absolute forecast error.

Elliott et al. (2005) show that, for a given parameter p, the asymmetry parameter, α, can be estimated consistently by a generalized method of moments (GMM) approach, which gives the estimator

$$\hat{\alpha} = \frac{\gamma_1' \hat{S}^{-1} \gamma_2}{\gamma_1' \hat{S}^{-1} \gamma_1}, \tag{2}$$

where we define

$$\gamma_1 = \frac{1}{T} \sum_{t=\tau}^{T+\tau-h} v_t |s_{t+h} - f_{t+h}|^{p-1} \tag{3}$$

and

$$\gamma_2 = \frac{1}{T} \sum_{t=\tau}^{T+\tau-h} v_t I(s_{t+h} - f_{t+h} < 0)|s_{t+h} - f_{t+h}|^{p-1}, \tag{4}$$

and the vector of instruments, v_t, is used to estimate a weighting matrix given by

$$\hat{S} = \frac{1}{T} \sum_{t=\tau}^{T+\tau-h} v_t v_t' (I(s_{t+h} - f_{t+h} < 0) - \hat{\alpha})^2 |s_{t+h} - f_{t+h}|^{2p-2}. \tag{5}$$

The number of forecasts, starting in period $\tau + h$, is given by T. With the weighting matrix depending on $\hat{\alpha}$, estimation is done iteratively.

The instruments used are a constant (Model 1), a constant and the lagged actual value (Model 2), and a constant and the lagged Federal Funds rate (Model 3). The lagged instruments (Models 2 and 3) are realized values for period $t - 1$, which are available to the FOMC when it submits the forecast in period t. In addition, we used the lagged realized value based on real time data. The results, which are available upon request, are qualitatively similar and support our baseline results.

Testing whether $\hat{\alpha}$ differs from α_0 is done using the z-test $\sqrt{T}(\hat{\alpha} - \alpha_0) \rightarrow \mathcal{N}(0, (\hat{h}'\hat{S}^{-1}\hat{h})^{-1})$, where $\hat{h} = \frac{1}{T} \sum_{t=\tau}^{T+\tau-h} v_t |s_{t+h} - f_{t+h}|^{p-1}$. Elliott et al. (2005) prove that testing for rationality of forecasts, conditional on a loss function of lin–lin or quad–quad type, can be achieved by computing

$$J(\hat{\alpha}) = \frac{1}{T} \left(x'\hat{S}^{-1}x\right) \sim \chi^2_{d-1}, \tag{6}$$

where $x = \sum_{t=\tau}^{T+\tau-h} v_t [I(s_{t+h} - f_{t+h} < 0) - \hat{\alpha}] |s_{t+h} - f_{t+h}|^{p-1}$ and $d > 1$ denotes the number of instruments. For a symmetric loss function, we have $J(0.5) \sim \chi^2_d$. The statistic $J(0.5)$ answers the question of whether forecasters under the maintained assumption of a symmetric loss function form rational forecasts. For a lin–lin or quad–quad loss function, the test $J(\hat{\alpha})$ answers the question of whether forecasters form rational forecasts, given an estimated asymmetric loss function.

4. UNCOVERING THE LOSS FUNCTION AS IMPLIED BY FOMC FORECASTS

In this section we present our main results and several robustness tests and, based on the recent literature on FOMC forecasting, put them into perspective.

4.1. The Estimated Loss Function

Table 2 summarizes the estimates of the asymmetry parameter for a lin–lin loss function and for a quad–quad loss function, based on the full sample of data.[8] The general picture emerging is that there are indeed deviations from a symmetric loss function.[9] However, there are also important differences across the forecast variables. FOMC members appear to perceive a higher loss when underestimating

TABLE 2. Estimating the asymmetry parameter (all members)

Variable	h	$\hat{\alpha}_{\text{model1}}$	se	z-test	$\hat{\alpha}_{\text{model2}}$	se	z-test	$\hat{\alpha}_{\text{model3}}$	se	z-test
Panel A: lin–lin loss function										
Real growth rate	2	0.145	0.029	−12.45	0.028	0.013	−35.41	0.144	0.028	−12.50
	4	0.203	0.033	−9.15	0.130	0.027	−13.64	0.117	0.026	−14.71
	6	0.257	0.035	−6.87	0.217	0.033	−8.48	0.256	0.035	−6.90
Nominal growth rate	2	0.243	0.035	−7.37	0.232	0.034	−7.83	0.194	0.032	−9.55
	4	0.281	0.036	−6.03	0.269	0.036	−6.46	0.162	0.030	−11.35
	6	0.355	0.039	−3.73	0.328	0.038	−4.53	0.334	0.038	−4.34
Inflation rate	2	0.730	0.036	6.40	0.730	0.036	6.40	0.766	0.034	7.74
	4	0.562	0.040	1.55	0.562	0.040	1.55	0.562	0.040	1.56
	6	0.665	0.038	4.30	0.713	0.037	5.80	0.685	0.038	4.91
Unemployment rate	2	0.546	0.040	1.14	0.618	0.039	2.98	0.555	0.040	1.37
	4	0.745	0.035	6.96	0.753	0.035	7.27	0.798	0.032	9.20
	6	0.671	0.038	4.49	0.682	0.038	5.02	0.960	0.016	28.82
Panel B: quad–quad loss function										
Real growth rate	2	0.091	0.022	−18.50	0.011	0.007	−74.64	0.092	0.022	−18.51
	4	0.075	0.016	−25.92	0.058	0.015	−30.37	0.020	0.007	−68.54
	6	0.235	0.044	−6.02	0.201	0.035	−8.53	0.211	0.041	−7.08
Nominal growth rate	2	0.169	0.032	−10.31	0.164	0.031	−10.72	0.092	0.023	−17.65
	4	0.186	0.031	−10.05	0.129	0.025	−14.88	0.072	0.022	−19.58
	6	0.344	0.045	−3.48	0.352	0.044	−3.39	0.352	0.045	−3.31
Inflation rate	2	0.653	0.056	2.75	0.899	0.027	14.64	0.984	0.014	33.99
	4	0.509	0.056	0.16	0.639	0.050	2.78	0.529	0.055	0.52
	6	0.646	0.048	3.07	0.839	0.031	10.83	0.711	0.044	4.79
Unemployment rate	2	0.848	0.028	12.20	0.951	0.015	29.67	0.861	0.027	13.54
	4	0.913	0.021	20.11	0.964	0.013	36.07	0.947	0.016	27.25
	6	0.737	0.041	5.81	0.836	0.030	11.17	1.000	0.010	48.68

Notes: se = standard error. The instruments used are a constant (Model 1), a constant and the lagged actual value (Model 2), and a constant and the lagged Federal Funds rate (Model 3). The null hypothesis of the z-test is that $\alpha = 0.5$. $h = 2, 4$, and 6 refers to the forecast horizons of two, four, and six months.

the inflation rate and the unemployment rate. For both variables, $\hat{\alpha}$ is significantly larger than 0.5. Thus, an FOMC member forecasting the inflation rate to be too low relative to the eventual realization experiences a larger loss than a fellow member forecasting the inflation rate to be too high. For the nominal and real growth rate, the opposite is true [see also Patton and Timmermann (2007)]. In these cases, overpredicting is more costly than underpredicting. These findings are robust with respect to the different specifications of the loss function as well as across different sets of instruments.

4.2. Forecast Rationality

To study forecast rationality conditional on the loss function given in equation (1), Table 3 reports the J-test results of forecast rationality. The results for the lin–lin (quad-quad) loss function imply that under a symmetric loss function, only in 2 (1) out of 24 cases can rationality not be rejected at a 1% significance level. Under a flexible loss function, forecast rationality cannot be rejected in 9 (7) cases.

TABLE 3. Testing for forecast rationality (all members)

Variable	h	J(0.5)	p-value	$J(\hat{\alpha}_{\text{model2}})$	p-value	J(0.5)	p-value	$J(\hat{\alpha}_{\text{model3}})$	p-value
				Panel A: lin–lin loss function					
Real growth rate	2	82.83	0.000	18.82	0.000	76.80	0.000	0.15	0.702
	4	57.26	0.000	15.08	0.000	74.50	0.000	17.06	0.000
	6	54.79	0.000	10.70	0.001	36.16	0.000	0.21	0.645
Nominal growth rate	2	42.41	0.000	3.24	0.072	53.23	0.000	12.32	0.000
	4	32.29	0.000	4.13	0.042	65.25	0.000	26.95	0.000
	6	29.25	0.000	12.17	0.000	23.07	0.000	9.80	0.002
Inflation rate	2	32.24	0.000	0.00	0.981	37.24	0.000	10.19	0.001
	4	2.37	0.307	0.01	0.941	2.76	0.252	0.38	0.536
	6	39.06	0.000	17.26	0.000	22.29	0.000	8.46	0.004
Unemployment rate	2	48.28	0.000	46.24	0.000	13.06	0.001	12.45	0.000
	4	38.75	0.000	2.49	0.115	49.19	0.000	13.66	0.000
	6	24.10	0.000	4.45	0.034	45.36	0.000	46.63	0.000
				Panel B: quad–quad loss function					
Real growth rate	2	89.20	0.000	13.79	0.000	86.24	0.000	0.14	0.709
	4	80.29	0.000	7.21	0.007	79.90	0.000	15.04	0.000
	6	33.45	0.000	1.57	0.211	33.57	0.000	1.84	0.175
Nominal growth rate	2	48.57	0.000	0.70	0.403	55.36	0.000	12.13	0.000
	4	50.63	0.000	10.13	0.001	69.10	0.000	26.52	0.000
	6	11.33	0.003	0.63	0.426	20.16	0.000	13.87	0.000
Inflation rate	2	37.96	0.000	15.01	0.000	23.68	0.000	20.06	0.000
	4	17.55	0.000	12.50	0.000	2.70	0.260	2.58	0.109
	6	57.03	0.000	22.39	0.000	17.09	0.000	11.92	0.001
Unemployment rate	2	37.52	0.000	24.31	0.000	39.69	0.000	2.74	0.098
	4	77.05	0.000	10.81	0.001	74.00	0.000	8.41	0.004
	6	45.16	0.000	11.46	0.000	39.49	0.000	33.26	0.000

Notes: $J(0.5)$ denotes the J-test for a symmetric loss function. $J(\hat{\alpha})$ denotes the J-test for a lin–lin and quad–quad loss function, respectively. The instruments used are a constant and the lagged actual value (Model 2) and a constant and the lagged Federal Funds rate (Model 3).

Hence, under a flexible loss function, FOMC forecasts tend to be somewhat less in conflict with rationality.

Still, considerations other than asymmetries might play a role in the forecasting process. In fact, one could think of several reasons for which forecasters' loss functions might deviate from the standard functional form that we study in this paper. Members might use their forecasts to influence monetary policy decisions according to their preferences. Previous research based on the same data set is consistent with that view. Tillmann (2011a) finds that hawkish nonvoters overpredict inflation whereas dovish nonvoters systematically underpredict inflation. In a similar vein, McCracken (2010) argues that hawkish members have an incentive to forecast high inflation in order to support the need for tighter monetary policy. Rülke and Tillmann (2011) provide evidence consistent with the view that nonvoting members "anti-herd," i.e., they intentionally scatter their inflation forecasts away from the forecast consensus. It is thus warranted to study subsets of FOMC members.

TABLE 4. Estimating the asymmetry parameter (voting members)

Variable	h	$\hat{\alpha}_{\text{model1}}$	se	z-test	$\hat{\alpha}_{\text{model2}}$	se	z-test	$\hat{\alpha}_{\text{model3}}$	se	z-test
					Panel A: lin–lin loss function					
Real growth rate	2	0.132	0.047	−7.91	0.016	0.017	−27.92	0.129	0.046	−8.06
	4	0.173	0.052	−6.23	0.110	0.043	−9.02	0.106	0.043	−9.24
	6	0.283	0.062	−3.51	0.237	0.058	−4.50	0.283	0.062	−3.51
Nominal growth rate	2	0.264	0.061	−3.89	0.219	0.057	−4.95	0.214	0.056	−5.07
	4	0.231	0.058	−4.61	0.054	0.031	−14.18	0.111	0.044	−8.93
	6	0.340	0.065	−2.47	0.309	0.063	−3.02	0.326	0.064	−2.70
Inflation rate	2	0.755	0.059	4.31	0.767	0.058	4.59	0.783	0.057	4.99
	4	0.596	0.068	1.41	0.600	0.068	1.48	0.597	0.068	1.42
	6	0.660	0.065	2.47	0.756	0.059	4.34	0.676	0.064	2.73
Unemployment rate	2	0.528	0.069	0.41	0.600	0.067	1.49	0.535	0.069	0.51
	4	0.769	0.058	4.61	0.800	0.055	5.41	0.846	0.050	6.89
	6	0.717	0.062	3.51	0.739	0.060	3.97	0.963	0.026	17.82
					Panel B: quad–quad loss function					
Real growth rate	2	0.094	0.039	−10.50	0.003	0.003	−183.91	0.055	0.027	−16.63
	4	0.069	0.026	−16.46	0.059	0.025	−17.96	0.018	0.010	−48.14
	6	0.243	0.074	−3.46	0.221	0.063	−4.46	0.230	0.070	−3.86
Nominal growth rate	2	0.183	0.055	−5.82	0.171	0.053	−6.26	0.129	0.048	−7.75
	4	0.153	0.050	−6.94	0.062	0.030	−14.40	0.053	0.033	−13.60
	6	0.362	0.078	−1.78	0.371	0.077	−1.68	0.373	0.078	−1.63
Inflation rate	2	0.673	0.085	2.04	0.896	0.046	8.54	0.919	0.045	9.36
	4	0.512	0.091	0.13	0.715	0.076	2.82	0.531	0.088	0.36
	6	0.684	0.078	2.35	0.897	0.043	9.23	0.738	0.073	3.26
Unemployment rate	2	0.809	0.055	5.59	0.948	0.026	17.08	0.847	0.048	7.25
	4	0.926	0.036	11.97	0.993	0.014	36.03	0.964	0.027	17.26
	6	0.747	0.067	3.66	0.853	0.050	7.11	1.000	0.012	32.08

Notes: se = standard error. The instruments used are a constant (Model 1), a constant and the lagged actual value (Model 2), and a constant and the lagged Federal Funds rate (Model 3). The null hypothesis of the z-test is that $\alpha = 0.5$. $h = 2, 4$, and 6 refers to the forecast horizons of two, four, and six months.

4.3. Subsets of FOMC Members

A key characteristic of the policy making process in the United States is that the voting right on the FOMC rotates across the regional Federal Reserve Bank presidents, whereas the Federal Reserve Governors are always allowed to vote.[10] All members, however, submit forecasts. Tables 4 and 5 report the results for voters only, which leaves 299 observations for each macroeconomic variable. Our general result remains unchanged; i.e., for the inflation rate and the unemployment rate, FOMC members perceive a higher loss when underpredicting the inflation rate compared to an overprediction. For real and nominal growth forecasts, FOMC members incur a higher loss when overpredicting real economic activity. Interestingly, the results in Table 5 indicate that the hypothesis of forecast rationality can be rejected in fewer cases than for the full sample. Under a lin–lin (quad–quad) loss function, forecast rationality cannot be rejected in 19 (18) cases at a 1% significance level. Hence, evidence against forecast rationality under an asymmetric loss function is weaker for voters than for the full sample.[11]

TABLE 5. Testing for forecast rationality (voting members)

Variable	h	$J(0.5)$	p-value	$J(\hat{\alpha}_{\text{model2}})$	p-value	$J(0.5)$	p-value	$J(\hat{\alpha}_{\text{model3}})$	p-value
Panel A: lin–lin loss function									
Real growth rate	2	30.81	0.000	6.35	0.012	28.77	0.000	0.22	0.642
	4	23.03	0.000	4.23	0.040	27.26	0.000	4.43	0.035
	6	18.52	0.000	4.63	0.031	9.98	0.007	0.00	0.971
Nominal growth rate	2	14.82	0.001	4.27	0.039	16.71	0.000	4.62	0.032
	4	18.48	0.000	10.29	0.001	25.48	0.000	8.01	0.005
	6	11.74	0.003	4.31	0.038	7.53	0.023	2.09	0.148
Inflation rate	2	14.62	0.001	1.20	0.274	14.92	0.001	2.63	0.105
	4	2.84	0.241	1.06	0.304	2.05	0.359	0.12	0.729
	6	17.56	0.000	9.89	0.002	7.14	0.028	2.31	0.129
Unemployment rate	2	19.64	0.000	19.02	0.000	5.20	0.074	5.23	0.022
	4	16.98	0.000	2.66	0.103	21.06	0.000	5.74	0.017
	6	12.61	0.002	2.49	0.115	17.28	0.000	14.08	0.000
Panel B: quad–quad loss function									
Real growth rate	2	30.07	0.000	5.31	0.021	29.68	0.000	2.00	0.157
	4	28.71	0.000	1.71	0.191	28.40	0.000	4.88	0.027
	6	10.75	0.005	0.31	0.579	11.04	0.004	0.26	0.610
Nominal growth rate	2	16.86	0.000	0.76	0.384	17.56	0.000	4.77	0.029
	4	21.47	0.000	5.28	0.022	24.51	0.000	6.85	0.009
	6	3.28	0.194	0.52	0.471	8.81	0.012	6.91	0.009
Inflation rate	2	13.90	0.001	6.19	0.013	9.29	0.010	7.00	0.008
	4	9.02	0.011	6.64	0.010	0.60	0.742	0.48	0.487
	6	22.07	0.000	8.05	0.005	7.75	0.021	3.04	0.081
Unemployment rate	2	13.60	0.001	10.41	0.001	12.83	0.002	2.98	0.084
	4	28.85	0.000	4.09	0.043	27.22	0.000	2.68	0.102
	6	17.51	0.000	4.83	0.028	14.41	0.000	11.64	0.001

Notes: $J(0.5)$ denotes the J-test for a symmetric loss function. $J(\hat{\alpha})$ denotes the J-test for a lin–lin and quad–quad loss function, respectively. The instruments used are a constant and the lagged actual value (Model 2) and a constant and the lagged Federal Funds rate (Model 3).

As a robustness test, we use only the 133 forecasts submitted by the Federal Reserve governors based at the Federal Reserve Board. Tables 6 and 7 again report strong evidence of an asymmetric loss function. The general picture that emerges, however, is that evidence against rationality is weaker under an asymmetric loss function for governors than for all members.

Because the numbers of observations for the voting members is relatively small, we also study the forecasts of the nonvoters.[12] The results corroborate the results shown in Tables 3, 5, and 7. Evidence against the rationality of forecasts is stronger for nonvoters than for governors with respect to forecasts of the inflation rate and the unemployment rate. Forecasts of nonvoters thus appear to be a source of deviations from forecast rationality detected for forecasts of the inflation rate and the unemployment rate reported in Table 3.

The heterogeneity among the FOMC members might trace back to differences in preferences and expertise. Hansen et al. (2012) use voting data from the Bank of England to show that different individual assessments of the economy strongly influence votes after controlling for individual policy preferences. They estimate

TABLE 6. Estimating the asymmetry parameter (Federal Reserve governors)

Variable	h	$\hat{\alpha}_{\text{model1}}$	se	z-test	$\hat{\alpha}_{\text{model2}}$	se	z-test	$\hat{\alpha}_{\text{model3}}$	se	z-test
Panel A: lin–lin loss function										
Real growth rate	2	0.159	0.055	−6.18	0.047	0.032	−14.29	0.139	0.052	−6.94
	4	0.244	0.064	−3.99	0.170	0.056	−5.90	0.139	0.052	−6.99
	6	0.273	0.067	−3.39	0.226	0.063	−4.34	0.272	0.067	−3.40
Nominal growth rate	2	0.273	0.067	−3.39	0.224	0.063	−4.39	0.211	0.062	−4.70
	4	0.289	0.068	−3.13	0.142	0.052	−6.88	0.135	0.051	−7.16
	6	0.341	0.071	−2.23	0.312	0.070	−2.69	0.317	0.070	−2.60
Inflation rate	2	0.636	0.073	1.88	0.638	0.072	1.90	0.652	0.072	2.12
	4	0.600	0.073	1.37	0.601	0.073	1.39	0.604	0.073	1.43
	6	0.682	0.070	2.59	0.692	0.070	2.76	0.689	0.070	2.70
Unemployment rate	2	0.682	0.070	2.59	0.803	0.060	5.07	0.703	0.069	2.95
	4	0.756	0.064	3.99	0.820	0.057	5.60	0.851	0.053	6.59
	6	0.705	0.069	2.97	0.711	0.068	3.09	0.966	0.027	17.00
Panel B: quad–quad loss function										
Real growth rate	2	0.110	0.046	−8.40	0.022	0.018	−26.85	0.104	0.046	−8.62
	4	0.090	0.035	−11.74	0.076	0.032	−13.16	0.020	0.013	−36.59
	6	0.203	0.078	−3.81	0.147	0.052	−6.76	0.166	0.068	−4.92
Nominal growth rate	2	0.201	0.064	−4.66	0.176	0.060	−5.41	0.093	0.042	−9.69
	4	0.194	0.058	−5.27	0.093	0.038	−10.77	0.066	0.041	−10.70
	6	0.312	0.080	−2.34	0.317	0.078	−2.34	0.314	0.080	−2.32
Inflation rate	2	0.600	0.114	0.88	0.839	0.068	4.96	0.853	0.062	4.99
	4	0.467	0.103	−0.32	0.501	0.097	0.01	0.467	0.100	−0.33
	6	0.620	0.095	1.26	0.772	0.071	3.83	0.710	0.084	2.49
Unemployment rate	2	0.907	0.039	10.45	0.966	0.023	20.42	0.907	0.039	10.51
	4	0.911	0.035	11.69	0.989	0.010	48.74	0.971	0.018	25.77
	6	0.799	0.062	4.82	0.844	0.052	6.68	1.000	0.013	38.19

Notes: se = standard error. The instruments used are a constant (Model 1), a constant and the lagged actual value (Model 2), and a constant and the lagged Federal Funds rate (Model 3). The null hypothesis of the z-test is that $\alpha = 0.5$. $h = 2$, 4, and 6 refers to the forecast horizon of two, four, and six months.

that internal members form more precise assessments than externals and are also more hawkish, though preference differences are very small if members vote strategically.

As a further exercise, we thus form a group of "experts" and a group of "nonexperts." To differentiate between the two groups, we study whether FOMC members made forecasts more (less) accurate than the average forecast. Technically, we calculate in every period of time the absolute forecast error for each FOMC member and compare the absolute forecast error with the mean absolute forecast error for each FOMC meeting, implying a time-varying classification of expertise. We compute the classification of expertise for the four different variables separately. Experts (nonexperts) are those FOMC members who made better (worse) forecasts than the average forecast. Tables 8 and 9 show the estimates of the asymmetry parameter for experts and nonexperts. The main message is that the asymmetry parameter, $\hat{\alpha}$, for the nominal and real growth rate (inflation rate and unemployment rate) tends to be significantly lower (higher) than 0.5, indicating that both experts and nonexperts perceive a higher loss when overestimating (underestimating) the

TABLE 7. Testing for forecast rationality (Federal Reserve governors)

Variable	h	$J(0.5)$	p-value	$J(\hat{\alpha}_{\text{model2}})$	p-value	$J(0.5)$	p-value	$J(\hat{\alpha}_{\text{model3}})$	p-value
				Panel A: lin–lin loss function					
Real growth rate	2	22.15	0.000	5.46	0.019	21.32	0.000	1.25	0.264
	4	13.04	0.001	5.09	0.024	20.67	0.000	6.56	0.010
	6	15.16	0.001	3.73	0.054	9.13	0.010	0.05	0.818
Nominal growth rate	2	11.98	0.003	3.89	0.049	14.37	0.001	4.69	0.030
	4	11.58	0.003	9.23	0.002	22.73	0.000	9.48	0.002
	6	8.78	0.012	3.36	0.067	7.39	0.025	2.84	0.092
Inflation rate	2	3.51	0.173	0.20	0.656	5.04	0.080	2.31	0.129
	4	2.04	0.360	0.24	0.626	2.73	0.256	0.85	0.356
	6	7.40	0.025	1.16	0.281	6.38	0.041	0.80	0.372
Unemployment rate	2	14.94	0.001	8.82	0.003	7.58	0.023	2.33	0.127
	4	14.59	0.001	4.56	0.033	18.56	0.000	6.09	0.014
	6	8.08	0.018	0.68	0.408	14.27	0.000	12.34	0.000
				Panel B: quad–quad loss function					
Real growth rate	2	24.56	0.000	3.99	0.046	23.28	0.000	0.78	0.378
	4	21.91	0.000	1.51	0.219	22.94	0.000	5.05	0.025
	6	12.29	0.002	0.86	0.353	12.03	0.002	0.84	0.360
Nominal growth rate	2	13.87	0.001	1.34	0.248	17.46	0.000	4.76	0.029
	4	14.49	0.001	5.49	0.019	23.10	0.000	9.60	0.002
	6	4.72	0.095	0.07	0.790	7.08	0.029	4.37	0.037
Inflation rate	2	7.85	0.020	3.59	0.058	6.80	0.033	5.68	0.017
	4	0.59	0.745	0.59	0.443	0.10	0.950	0.00	1.000
	6	12.42	0.002	4.35	0.037	4.29	0.117	3.25	0.072
Unemployment rate	2	14.94	0.001	4.39	0.036	15.45	0.000	0.00	0.944
	4	22.59	0.000	5.65	0.017	22.87	0.000	4.27	0.039
	6	14.30	0.001	1.74	0.190	14.60	0.001	9.66	0.002

Notes: $J(0.5)$ denotes the J-test for a symmetric loss function. $J(\hat{\alpha})$ denotes the J-test for a lin–lin and quad–quad loss function, respectively. The instruments used are a constant and the lagged actual value (Model 2) and a constant and the lagged Federal Funds rate (Model 3).

actual value. In sum, the results for experts and nonexperts support our baseline results. Tables 10 and 11 show the results of the rationality test for experts and nonexperts. Again, the results show that, with few exceptions, there is not much difference between the two groups.

Figure 2 plots the implications of our empirical findings for the shape of the FOMC's loss function, where we assume for illustrative purposes that the loss function is of the quad–quad form and the forecast horizon is $h = 4$ (four quarters ahead, Model 1). The solid dark line represents the results for all members, the solid gray line represents the results for voting members, and the dashed line represents the results for governors. The figure shows that, as far as inflation and unemployment figures are concerned, the loss for an underprediction is larger than the loss for an overprediction of similar size. Put differently, the FOMC members incur the same loss when overpredicting the unemployment rate by 4 percentage points or underpredicting by 2 percentage points. For nominal and real growth forecasts, in contrast, the FOMC members experience the same loss of an underprediction of the growth rate by 4 percentage points and an overprediction of about 2 percentage points.

TABLE 8. Estimating the asymmetry parameter (experts)

Variable	h	$\hat{\alpha}_{\text{model1}}$	se	z-test	$\hat{\alpha}_{\text{model2}}$	se	z-test	$\hat{\alpha}_{\text{model3}}$	se	z-test
Panel A: lin–lin loss function										
Real growth rate	2	0.184	0.045	−7.102	0.033	0.020	−22.90	0.184	0.045	−7.103
	4	0.221	0.047	−5.907	0.121	0.037	−10.17	0.141	0.040	−9.057
	6	0.247	0.050	−5.024	0.169	0.044	−7.530	0.242	0.050	−5.143
Nominal growth rate	2	0.216	0.048	−5.930	0.199	0.046	−6.487	0.177	0.044	−7.295
	4	0.307	0.053	−3.631	0.301	0.053	−3.752	0.207	0.047	−6.252
	6	0.427	0.060	−1.226	0.418	0.060	−1.371	0.419	0.060	−1.361
Inflation rate	2	0.680	0.053	3.397	0.701	0.052	3.873	0.690	0.052	3.618
	4	0.562	0.053	1.175	0.562	0.053	1.186	0.562	0.053	1.186
	6	0.641	0.054	2.596	0.681	0.053	3.432	0.660	0.054	2.978
Unemployment rate	2	0.422	0.054	−1.445	0.230	0.046	−5.834	0.407	0.054	−1.716
	4	0.667	0.051	3.298	0.670	0.050	3.363	0.702	0.049	4.110
	6	0.663	0.053	3.074	0.668	0.053	3.182	0.970	0.019	24.77
Panel B: quad–quad loss function										
Real growth rate	2	0.103	0.031	−13.03	0.008	0.006	−81.81	0.103	0.030	−13.32
	4	0.061	0.018	−24.67	0.041	0.015	−31.10	0.015	0.006	−77.26
	6	0.184	0.059	−5.350	0.198	0.051	−5.930	0.136	0.049	−7.438
Nominal growth rate	2	0.097	0.029	−13.77	0.097	0.029	−13.77	0.043	0.017	−27.13
	4	0.169	0.040	−8.268	0.136	0.034	−10.70	0.065	0.027	−16.23
	6	0.460	0.076	−0.530	0.436	0.070	−0.912	0.558	0.068	0.850
Inflation rate	2	0.645	0.083	1.739	0.763	0.056	4.686	0.904	0.046	8.722
	4	0.528	0.079	0.351	0.709	0.061	3.455	0.582	0.074	1.112
	6	0.581	0.073	1.111	0.802	0.051	5.968	0.671	0.067	2.532
Unemployment rate	2	0.854	0.040	8.846	0.948	0.023	19.75	0.859	0.039	9.233
	4	0.915	0.024	17.39	0.988	0.009	56.16	0.946	0.019	24.10
	6	0.766	0.054	4.920	0.845	0.040	8.673	1.013	0.008	64.67

Notes: The instruments used are a constant (Model 1), a constant and the lagged actual value (Model 2), and a constant and the lagged Federal Funds rate (Model 3). The null hypothesis of the z-test is that $\alpha = 0.5$.

4.4. A Comparison with Greenbook Forecasts

We now compare the loss function estimated on FOMC forecasts with a loss function estimated on Greenbook forecasts, i.e., the Fed's staff forecasts. To this end, we use only those Greenbook forecasts with forecast horizons of two, four, and six quarters, and we stick to the sample period from 1992 to 2000. Figure 3 shows the Greenbook forecasts for the real growth rate (left panel) and the inflation rate (right panel). Interestingly, in contrast to the FOMC forecasts, the Fed's staff has not overprojected the inflation rate during this time period. This supports Romer and Romer (2008), who show that the FOMC forecasts are systematically different from the Greenbook forecasts. Table 1 reports the summary statistics of the Greenbook forecasts and shows that in contrast to the FOMC, the Fed's staff has underprojected the inflation rate during the time period under consideration.

The estimation results (Table 12) show that for the real growth rate the staff's loss function resembles that of the FOMC. However, the asymmetry parameter, $\hat{\alpha}$, for the inflation rate is smaller, indicating substantial differences between the FOMC's and the staff's preferences with respect to forecasting the inflation rate.

TABLE 9. Estimating the asymmetry parameter (nonexperts)

Variable	h	$\hat{\alpha}_{\text{model1}}$	se	z-test	$\hat{\alpha}_{\text{model2}}$	se	z-test	$\hat{\alpha}_{\text{model3}}$	se	z-test
					Panel A: lin–lin loss function					
Real growth rate	2	0.105	0.035	−11.21	0.022	0.017	−28.11	0.103	0.035	−11.42
	4	0.184	0.045	−7.102	0.136	0.039	−9.255	0.093	0.033	−12.22
	6	0.266	0.050	−4.712	0.249	0.049	−5.158	0.266	0.050	−4.714
Nominal	2	0.269	0.050	−4.595	0.261	0.050	−4.804	0.211	0.046	−6.258
	4	0.256	0.049	−4.927	0.203	0.046	−6.538	0.111	0.036	−10.96
	6	0.298	0.050	−4.057	0.247	0.047	−5.382	0.266	0.048	−4.856
Inflation rate	2	0.784	0.048	5.930	0.900	0.035	11.46	0.993	0.010	50.19
	4	0.563	0.062	1.008	0.564	0.062	1.036	0.563	0.062	1.009
	6	0.689	0.054	3.516	0.746	0.051	4.857	0.721	0.052	4.245
Unemployment rate	2	0.696	0.055	3.532	0.815	0.047	6.723	0.725	0.054	4.184
	4	0.849	0.044	7.896	0.890	0.039	10.12	0.911	0.035	11.76
	6	0.694	0.054	3.582	0.719	0.053	4.124	0.940	0.028	15.69
					Panel B: quad–quad loss function					
Real growth rate	2	0.084	0.030	−13.71	0.013	0.010	−48.93	0.085	0.030	−13.71
	4	0.084	0.024	−17.21	0.071	0.023	−19.04	0.024	0.011	−43.84
	6	0.263	0.059	−3.990	0.194	0.046	−6.660	0.248	0.057	−4.444
Nominal growth rate	2	0.198	0.043	−6.989	0.190	0.042	−7.370	0.116	0.033	−11.82
	4	0.195	0.043	−7.168	0.125	0.033	−11.35	0.075	0.031	−13.86
	6	0.290	0.054	−3.907	0.298	0.053	−3.792	0.279	0.054	−4.123
Inflation rate	2	0.657	0.071	2.210	0.958	0.028	16.47	1.007	0.010	53.37
	4	0.498	0.075	−0.030	0.613	0.070	1.618	0.503	0.075	0.045
	6	0.676	0.060	2.917	0.853	0.038	9.201	0.734	0.056	4.147
Unemployment rate	2	0.845	0.038	9.200	0.957	0.019	23.48	0.862	0.035	10.40
	4	0.913	0.029	14.01	0.952	0.021	21.82	0.948	0.023	19.23
	6	0.723	0.055	4.054	0.828	0.042	7.887	1.003	0.018	28.20

Notes: The instruments used are a constant (Model 1), a constant and the lagged actual value (Model 2), and a constant and the lagged Federal Funds rate (Model 3). The null hypothesis of the z-test is that $\alpha = 0.5$.

This also highlights that the staff's loss function during the sample period from 1992 to 2000 is not representative of the staff's loss function over the entire post-Volcker era studied by Capistrán (2008). His point estimates of $\hat{\alpha}$ range between 0.8 and 0.9 for the full post-Volcker period.[13]

In sum, for both real growth and inflation forecasts, an overprediction is more costly than an underprediction.[14] Forecast rationality under an estimated asymmetric loss function cannot be rejected in the majority of cases. Still, we note that the estimated asymmetric loss function only depends on forecast errors. Patton and Timmermann (2007), who also study output forecasts derived from the Greenbook, suggest that the loss function may depend not only on forecast errors, but also on realized values.

5. ROBUSTNESS

5.1. Simulation Experiment

To assess the robustness of our results, to account for a potential small sample problem, and to account for the potential effect of the Great Moderation on our

TABLE 10. Testing for forecast rationality (experts)

Variable	h	$J(0.5)$	p-value	$J(\hat{\alpha}_{\text{model2}})$	p-value	$J(0.5)$	p-value	$J(\hat{\alpha}_{\text{model3}})$	p-value
Panel A: lin–lin loss function									
Real growth rate	2	35.33	0.000	12.32	0.000	30.32	0.000	0.00	0.959
	4	26.41	0.000	10.10	0.002	34.57	0.000	8.56	0.003
	6	34.01	0.000	8.52	0.004	19.11	0.000	0.63	0.428
Nominal growth rate	2	25.07	0.000	2.12	0.145	28.46	0.000	4.53	0.033
	4	12.10	0.002	1.03	0.311	28.00	0.000	12.73	0.000
	6	5.57	0.062	3.52	0.061	4.80	0.091	3.29	0.070
Inflation rate	2	15.15	0.001	4.14	0.042	11.48	0.003	2.07	0.150
	4	1.77	0.414	0.39	0.530	1.79	0.408	0.42	0.516
	6	16.86	0.000	8.63	0.003	9.75	0.008	4.57	0.033
Unemployment rate	2	34.88	0.000	29.45	0.000	8.93	0.012	6.38	0.012
	4	10.42	0.006	0.75	0.387	16.51	0.000	7.54	0.006
	6	9.78	0.008	1.21	0.271	26.00	0.000	26.18	0.000
Panel B: quad–quad loss function									
Real growth rate	2	39.89	0.000	10.08	0.002	38.25	0.000	0.00	0.987
	4	39.00	0.000	6.18	0.013	37.47	0.000	9.24	0.002
	6	18.91	0.000	0.23	0.632	21.36	0.000	1.91	0.167
Nominal growth rate	2	28.40	0.000	0.01	0.908	28.24	0.000	6.05	0.014
	4	24.70	0.000	2.97	0.085	34.65	0.000	14.53	0.000
	6	1.42	0.493	0.65	0.420	10.03	0.007	9.75	0.002
Inflation rate	2	13.79	0.001	2.67	0.102	11.81	0.003	7.48	0.006
	4	13.46	0.001	6.24	0.013	2.76	0.252	2.01	0.156
	6	27.26	0.000	11.54	0.001	8.93	0.012	7.10	0.008
Unemployment rate	2	15.48	0.000	12.51	0.000	16.54	0.000	0.40	0.528
	4	41.00	0.000	12.27	0.001	40.05	0.000	5.64	0.018
	6	24.18	0.000	4.26	0.039	23.81	0.000	15.75	0.000

Notes: $J(0.5)$ denotes the J-test for a symmetric loss function. $J(\hat{\alpha})$ denotes the J-test for a lin–lin and quad–quad loss function, respectively. The instruments used are a constant and the lagged actual value (Model 2) and a constant and the lagged Federal Funds rate (Model 3).

results, we set up the following simulation experiment: We randomly draw 100 times out of the 457 FOMC forecasts a sample with $n = 100$ observations, where we make sure that the forecast horizon is the same for all observations. We then compute for every random sample the asymmetry parameter. Figure 4 shows the resulting 100 estimates of the asymmetry parameter, where every dot represents one estimate of the asymmetry parameter and the forecast horizon is $h = 2$ in Panel A and $h = 4$ in Panel B. The estimates for the real/nominal growth rate (inflation rate/unemployment rate) are displayed on the vertical/horizontal axis.

Estimates of the asymmetry parameter for the real growth rate forecasts are smaller than 0.5. Estimates for the nominal growth rate forecasts are also smaller than 0.5, but the estimated asymmetry parameter and the dispersion of the estimates are larger than in the case of the real growth rate forecasts. As for the unemployment rate, the simulation results confirm that the estimated asymmetry parameter tends to be larger than 0.5. For the inflation rate, the estimated asymmetry parameter is also larger than 0.5 in the majority of cases.

TABLE 11. Testing for forecast rationality (nonexperts)

Variable	h	$J(0.5)$	p-value	$J(\hat{\alpha}_{\text{model2}})$	p-value	$J(0.5)$	p-value	$J(\hat{\alpha}_{\text{model3}})$	p-value
				Panel A: lin–lin loss function					
Real growth rate	2	48.95	0.000	6.59	0.010	47.46	0.000	0.26	0.612
	4	31.22	0.000	5.03	0.025	40.15	0.000	8.52	0.004
	6	21.96	0.000	2.64	0.104	17.34	0.000	0.02	0.891
Nominal growth rate	2	17.77	0.000	1.33	0.249	25.31	0.000	7.87	0.005
	4	21.28	0.000	7.07	0.008	38.41	0.000	14.60	0.000
	6	26.79	0.000	8.43	0.004	20.09	0.000	5.69	0.017
Inflation rate	2	29.77	0.000	10.74	0.001	27.54	0.000	15.69	0.000
	4	1.80	0.407	0.85	0.357	1.03	0.597	0.03	0.865
	6	22.53	0.000	8.53	0.004	13.49	0.001	5.36	0.021
Unemployment rate	2	22.36	0.000	13.04	0.000	13.92	0.001	4.49	0.034
	4	33.46	0.000	3.51	0.061	36.52	0.000	5.04	0.025
	6	15.28	0.001	3.97	0.046	20.28	0.000	20.08	0.000
				Panel B: quad–quad loss function					
Real growth rate	2	51.20	0.000	5.88	0.015	49.98	0.000	0.17	0.678
	4	43.24	0.000	2.82	0.093	43.74	0.000	8.28	0.004
	6	18.61	0.000	2.94	0.086	15.41	0.001	0.61	0.437
Nominal growth rate	2	26.38	0.000	0.75	0.387	31.59	0.000	8.62	0.003
	4	28.61	0.000	7.22	0.007	38.90	0.000	16.32	0.000
	6	14.41	0.001	2.02	0.155	16.84	0.000	7.46	0.006
Inflation rate	2	27.45	0.000	11.59	0.001	15.28	0.001	13.04	0.000
	4	8.70	0.013	6.91	0.009	0.88	0.645	0.88	0.348
	6	34.27	0.000	11.76	0.001	10.75	0.005	6.56	0.010
Unemployment rate	2	22.96	0.000	15.55	0.000	24.20	0.000	2.38	0.123
	4	40.66	0.000	3.83	0.050	39.61	0.000	4.18	0.041
	6	24.10	0.000	7.59	0.006	18.49	0.000	20.38	0.000

Notes: $J(0.5)$ denotes the J-test for a symmetric loss function. $J(\hat{\alpha})$ denotes the J-test for a lin–lin and quad–quad loss function, respectively. The instruments used are a constant and the lagged actual value (Model 2) and a constant and the lagged Federal Funds rate (Model 3).

TABLE 12. Loss function of Greenbook forecasts

Variable	h	$\hat{\alpha}_{\text{model1}}$	se	z-test	$\hat{\alpha}_{\text{model2}}$	se	z-test	$J(0.5)$	p-value	$J(\alpha_{\text{model2}})$	p-value
					Panel A: lin–lin loss function						
Real growth rate	2	0.222	0.069	−4.01	0.060	0.040	−11.11	13.35	0.001	6.63	0.010
	4	0.194	0.066	−4.63	0.193	0.066	−4.67	13.51	0.001	0.09	0.760
	6	0.232	0.069	−4.01	0.178	0.064	−5.04	11.60	0.003	2.46	0.117
Inflation rate	2	0.195	0.066	−4.63	0.155	0.060	−5.73	14.29	0.001	2.07	0.151
	4	0.139	0.058	−6.27	0.104	0.051	−7.80	19.37	0.000	1.60	0.206
	6	0.222	0.069	−4.01	0.222	0.069	−4.01	11.11	0.004	0.01	0.943
					Panel B: quad–quad loss function						
Real growth rate	2	0.051	0.022	−20.70	0.011	0.008	−64.17	19.72	0.000	4.76	0.029
	4	0.038	0.018	−25.78	0.037	0.018	−26.35	18.65	0.000	0.11	0.736
	6	0.261	0.095	−2.51	0.246	0.095	−2.69	5.84	0.054	1.22	0.269
Inflation	2	0.040	0.019	−23.66	0.040	0.019	−23.71	17.98	0.000	0.00	0.958
	4	0.063	0.036	−12.27	0.063	0.036	−12.28	16.57	0.000	0.00	0.947
	6	0.176	0.066	−4.90	0.149	0.057	−6.12	12.87	0.002	0.69	0.406

Notes: The table reports the estimates of the loss function based on Greenbook forecasts. The instruments used are a constant (Model 1), a constant and the lagged actual value (Model 2). The null hypothesis of the z-test is that $\alpha = 0.5$.

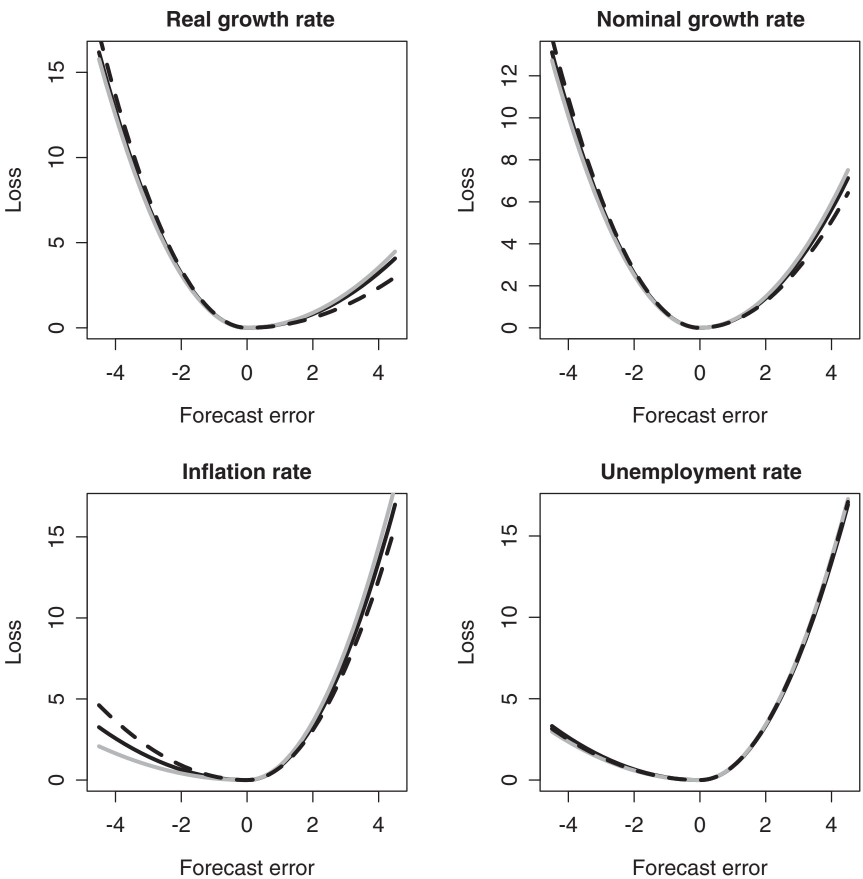

FIGURE 2. Quad–quad loss function as implied by FOMC forecasts (quad–quad function, $h = 6$). The shape of the loss function is governed by the estimated asymmetry parameter, $\hat{\alpha}$, under Model 2. Solid dark line = all FOMC members. Solid gray line = voting members. Dashed line = governors.

Figure 5 shows the p-values of the corresponding rationality tests. In line with the results summarized in Table 3, the tests strongly reject rationality in the case of real growth rate forecasts, irrespective of the assumed shape of the loss function. For the nominal growth rate forecasts, an asymmetric loss function yields weaker evidence against forecast rationality, but the p-values show a large variation. Simulation results for the inflation rate show that an asymmetric loss function performs better than a symmetric loss function with respect to the rationality of forecasts for $h = 2$, but the picture is less clear for $h = 4$. Finally, simulation results for the unemployment rate forecasts provide weaker evidence against rational forecasts under an asymmetric than under a symmetric loss function for $h = 4$, but the majority of simulation runs yields significant J tests.

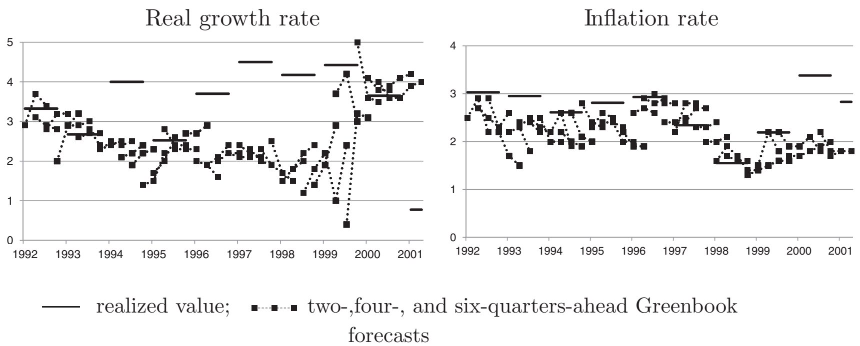

FIGURE 3. Greenbook forecasts. The figure shows the two-, four-, and six-quarters-ahead real growth and inflation rate forecasts published in the Greenbook as well as the actual values. The data on the realized values are taken from the IMF's database.

5.2. Recursive Estimates

The sample period covers the 1990s, over which the U.S. economy grew strongly without accompanying inflationary pressure. Observers at that time frequently argued that the underlying output–inflation trade-off underwent a structural break.[15] If there was indeed a structural break that went unnoticed by forecasters, the resulting forecast errors would have been systematically biased, and hence the hypothesis underlying the test for rationality would be violated.

If rejection of forecast rationality merely reflects forecaster learning in the case of a structural break, it should not be possible to reject forecast rationality before a potential structural break. After a structural break, in contrast, the p-values of the J-tests should indicate significance of the test results. To evaluate the potential caveat that a structural break in the data-generating process distorts the results of our rationality tests, we estimate the model for an initial sample period covering data up to 1995 and then sequentially add an additional year of observations in every recursion. The recursive estimates are based on a lin–lin loss function (all members, Model 2) and yield series of estimated asymmetry parameters, $\hat{\alpha}$, as well as p-values for the J-test. These series are depicted in Figure 6 for two forecast horizons.[16] For inflation and real growth forecasts, the estimated degree of asymmetry remains remarkably stable over the sample period. Although forecasts for unemployment exhibit some degree of variation in the estimated $\hat{\alpha}$, this variation never invalidates our basic conclusion. In fact, the series of estimated coefficients never crosses the 0.5 line from above. The asymmetry underlying nominal growth forecasts changes direction for $h = 4$, but this does not come as a surprise, as these forecasts reflect the joint properties of the real growth and inflation forecasts, making these forecasts prone to statistical artifacts. Figure 7 shows the p-values of the recursively estimated J-tests. With the exception of a short-lived peak in the p-value for inflation rate

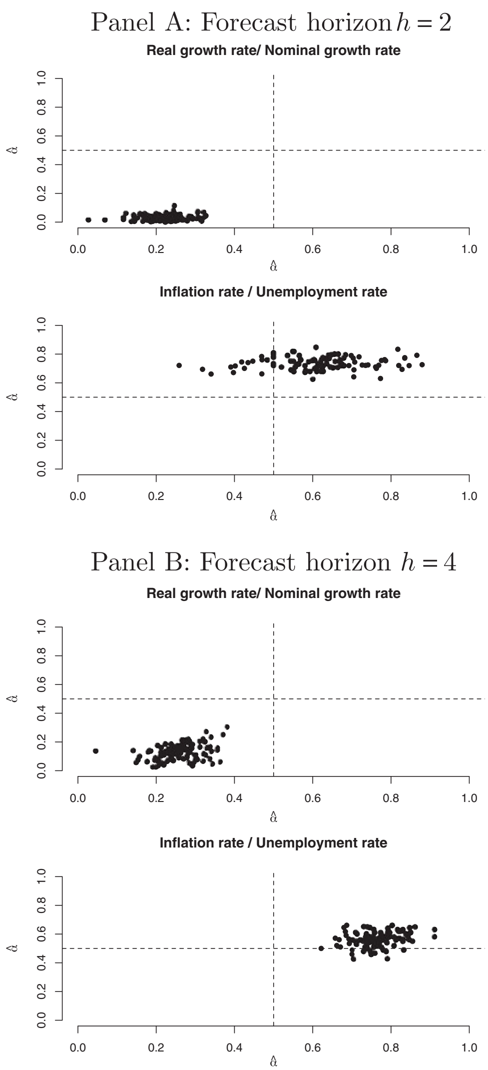

FIGURE 4. Simulation results: asymmetry parameter, $\hat{\alpha}$ (Model 2), estimated on simulated data. Every dot represents the results of one out of 100 simulations, where every simulation features $n = 100$ random observations drawn from the FOMC forecasts. The forecast horizon is $h = 2$ in Panel A and $h = 4$ in Panel B. The loss function is of the lin–lin form. The estimates for the real/nominal growth rate (inflation rate/unemployment rate) are displayed on the vertical/horizontal axis. The dashed horizontal and vertical lines represent the cases of a symmetric loss function ($\alpha = 0.5$). The estimates for the actual data (Table 2) are 0.028 (0.232) for the real (nominal) growth rate and 0.730 (0.618) for the inflation rate (unemployment rate) and $h = 2$. For $h = 4$, the estimates for the actual data are 0.130 (0.269) for the real (nominal) growth rate and 0.562 (0.682) for the inflation rate (unemployment rate).

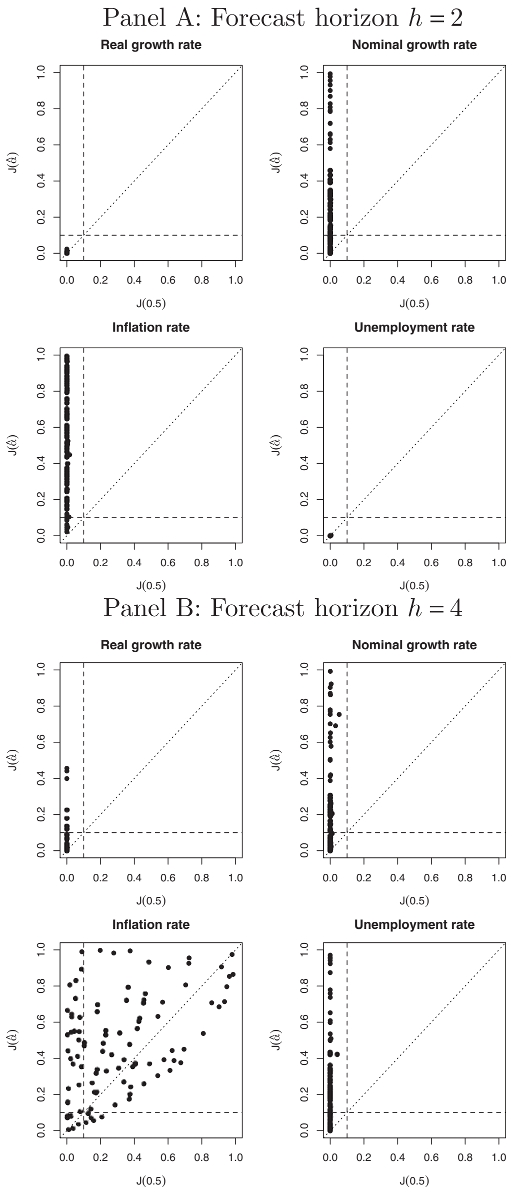

FIGURE 5. Simulation results: rationality tests—the p-values of the J-tests under an assumed symmetric, $J(0.5)$, and an estimated asymmetric, $J(\hat{\alpha})$, loss function. Every dot represents the results of one out of 100 simulations, where every simulation features $n = 100$ random observations drawn from the FOMC forecasts. The forecast horizon is $h = 2$ in Panel A and $h = 4$ in Panel B. The loss function is of the lin–lin form. The dashed horizontal and vertical lines represent the 10% significance lines. The dashed lines with slope equal to unity help to compare the relative magnitude of the p-values.

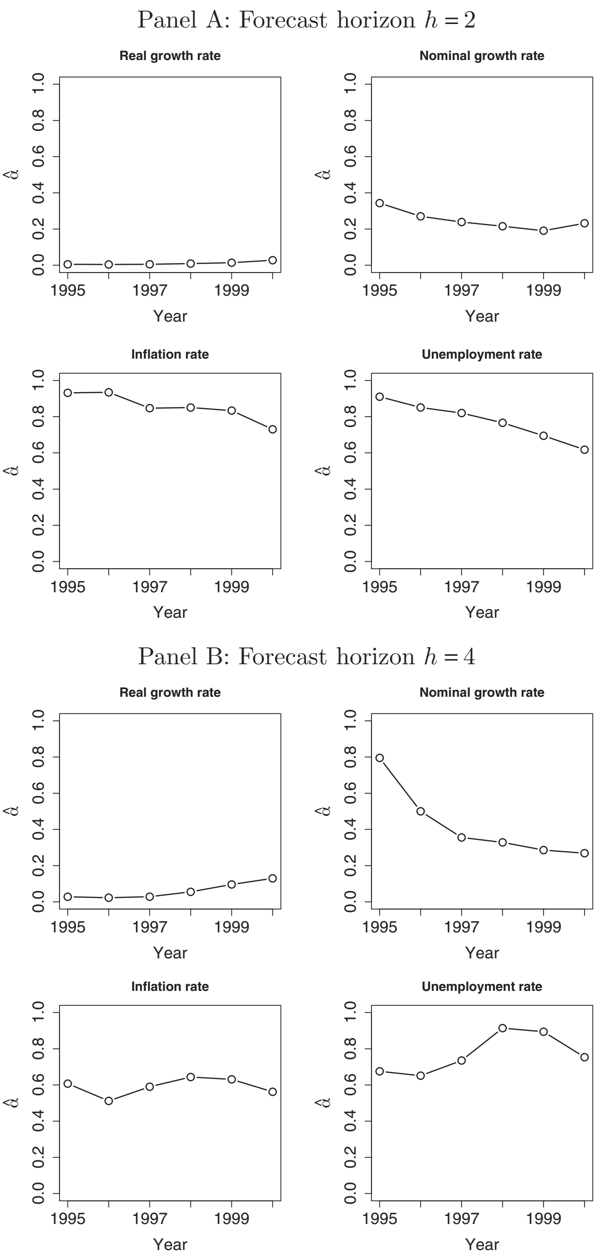

FIGURE 6. Recursive estimates: asymmetry parameter—the recursively estimated asymmetry parameter, $\hat{\alpha}$. Every dot represents one estimate based on Model 2. The recursive estimation starts in 1995, and one year of data is added in every recursion. Estimates are based on a lin–lin loss function (all members).

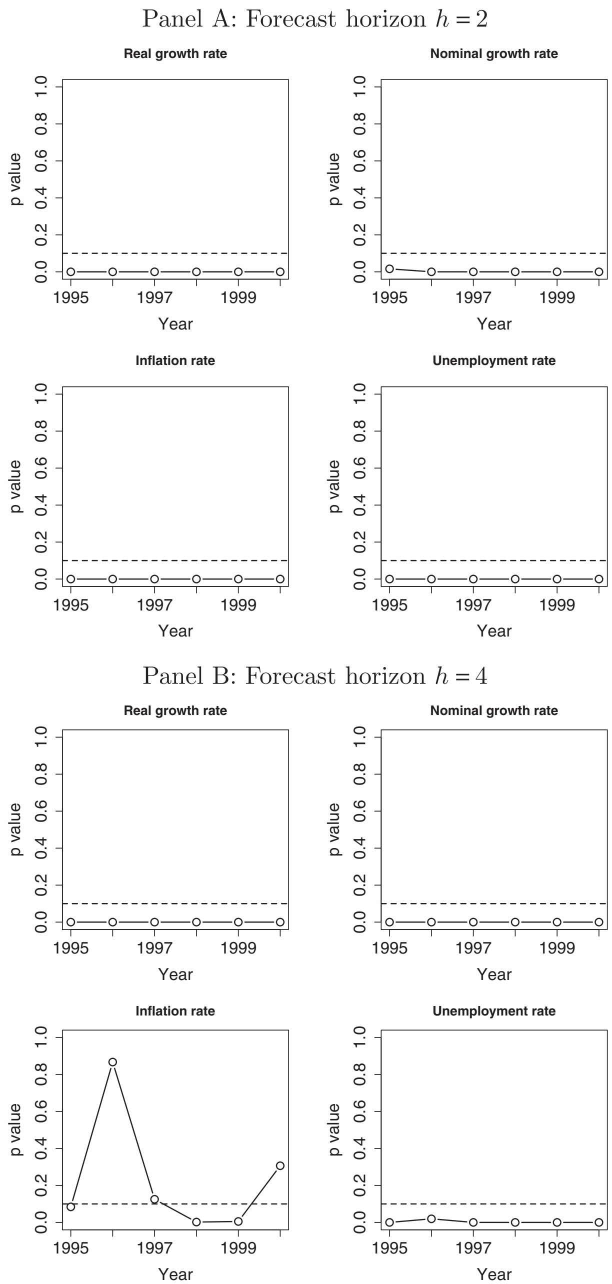

FIGURE 7. Recursive estimates: rationality tests—the recursively computed $J(\hat{\alpha})$ tests. Every dot represents the p-value for Model 2. The recursive estimation starts in 1995, and one year of data is added in every recursion. Estimates are based on a lin–lin loss function (all members).

forecasts ($h = 4$), all p-values remain fairly stable during the second half of the 1990s.[17]

In sum, the recursive estimates corroborate the robustness of our earlier findings. None of our core results appears to be affected by structural breaks in the data series. In fact, the results are consistent with the view that the FOMC forecasters were aware of the breaks in mean inflation and unemployment.

6. CONCLUDING REMARKS

We have studied the loss function of FOMC members as implied by individual forecasts for key macroeconomic variables. The results clearly suggest that the loss function is asymmetric. Apparently, FOMC members experience a higher loss when overpredicting the nominal and real growth rate compared to underpredicting them. In contrast, FOMC members perceive a higher loss when underestimating the inflation rate and the unemployment rate. We also have reported evidence that forecast rationality under an asymmetric loss can be rejected less frequently than under a symmetric loss function; we find interesting differences in this respect between governors and voting members and nonvoting members. Results of a simulation experiment and recursive estimates help to build confidence in our results.

Like any study using Romer's (2010) data set of individual FOMC forecasts, our sample period is limited to the period of the so-called Great Moderation. Hence, a question is whether the asymmetry of the FOMC is related to this particular period. Capistran (2008) finds evidence in favor of an asymmetric loss function based on the time period 1966–1998, which indicates that the asymmetry of the FOMC loss function is not a phenomenon of a specific period.

It is also important to reiterate that rejecting forecast rationality does not necessarily imply that forecasters in fact make irrational forecasts. The results in this paper suggest that conditional on a specific functional form of the forecasters' loss function, which features asymmetries, the forecasts do not support, in some cases, the hypothesis of forecast rationality. One interpretation of this result is that forecasters indeed deliver forecasts that are not consistent with forecast rationality. Another interpretation, though, is that forecasters' loss function is more general than assumed under the null hypothesis of the J-test used in this study. Further work is needed to broaden the class of admissible loss functions, probably taking strategic motives of FOMC members into account.

Another implication that needs to be addressed is the impact of an asymmetric loss function of FOMC forecasters on monetary policy decisions. If members fear underpredicting inflation, they may follow a precautionary motive when adjusting interest rates. Recently, Branch (2013) linked biased forecasts based on an asymmetric loss function to a nowcast-based policy rule. This is certainly a promising field for future empirical research.

NOTES

1. Pierdzioch et al. (2012) apply this methodology to study forecasts published by the Bank of Canada.

2. Bhattacharjee and Gelain (2011) analyze the FOMC's forecast performance in a Bayesian setting and investigate which information in the Greenbook and the regional Fed forecasts contribute to model uncertainty. They provide an explanation for the poor forecast performance based on concerns for robust policies under model misspecification.

3. A survey of recent studies on policymaking in monetary policy committees is provided by Blinder (2009).

4. In 2007, the frequency of forecasts was increased and the coverage was broadened.

5. The data are taken from the IMF's database (codes): real growth rate (USEBQGDP%), nominal growth rate (USOF%GPN), inflation rate (USCPIYY%R), unemployment rate (USUN%TOTR). Following the argument that FOMC members might target the first release of data, we also contrasted the forecasts with real-time data. The results are qualitatively similar and are available upon request. One notable difference is that the loss function for forecasts of the nominal growth rate appears to be symmetric rather than asymmetric when real-time data are used.

6. This data set has been used by Rülke and Tillmann (2011) and Tillmann (2011a) to examine the degree of strategic behavior of FOMC members in the forecasting process. An in-depth analysis of other aspects of the forecasting behavior of FOMC members based on individual forecast data is provided by Banterghansa and McCracken (2009).

7. The approach of Elliott et al. (2005) is further generalized in Patton and Timmermann (2007) to the case of unknown loss.

8. We coded all estimations and simulations using the free software R Release 2.15.0 [R Development Core Team (2012)].

9. We also accounted for the fact that the variables are not independent from each other. Tillmann (2010a, 2010b) reports that the FOMC forecasts are consistent with Okun's law and the Phillips curve, indicating that the FOMC forecasts reflect, e.g., the inflation–output tradeoff. Accordingly, we estimated the loss function for each variable using the forecast errors of the other variables as instruments. The results, which are not reported here in order to save journal space, corroborate our baseline results.

10. The president of the New York Fed does not participate in the rotation scheme. From the remaining 11 regional Federal Reserve Banks, four presidents are entitled to vote in a given year.

11. The results corroborate the notion of strategic forecasting discussed before insofar as forecast rationality under the stipulated asymmetric loss function is more pronounced (as far as the inflation rate and the unemployment rate are concerned) for governors and in the group of voting FOMC members compared to the sample comprising all FOMC members.

12. To economize on journal space, results for nonvoters are not reported but are available upon request from the authors.

13. It should be noted, however, that the loss function studied by Capistrán (2008) depends on the wedge between the actual inflation rate and the inflation target, whereas our loss function depends on the forecast error.

14. Wang and Lee (2014) also investigate the forecasts of the Fed's staff as published in the Greenbook and those of professional forecasters. They show that the Greenbook inflation forecasts are based on an asymmetric loss function and the asymmetry in the real growth forecasts is more pronounced when the last revised vintage data rather than real-time vintage are used.

15. The FOMC deliberations reflected this debate. Meade and Thornton (2012) document that FOMC members increasingly referred to concepts such as "potential output," "Phillips curve," and "NAIRU" toward the second half of the 1990s. Tillmann (2010b) uses Romer's (2010) data set to show that the Phillips curve trade-off reflected in individual FOMC forecasts changed in the mid-1990s.

16. Using Greenbook and SPF forecasts, Wang and Lee (2014) show that the degree and direction of asymmetry in the loss function are time-varying.

17. The interpretation of the peak in the p-value for the inflation rate should not be stretched too far, as it does not show up when we use a quad–quad loss function. In all other respects, the results for the quad–quad loss function (and for Model 3) are similar to the results reported in Figures 6 and 7. Results are not reported but are available upon request.

REFERENCES

Banternghansa, Chanont and Michael W. McCracken (2009) Forecast Disagreement among FOMC Members. Working paper 2009-059A, Federal Reserve Bank of St. Louis.

Belden, Susan (1989) Policy preferences of FOMC members as revealed by dissenting votes. *Journal of Money, Credit and Banking* 21, 432–441.

Besley, Timothy, Neil Meade, and Paolo Surico (2008) Insiders versus outsiders in monetary policy-making. *American Economic Review: Papers and Proceedings* 98, 218–223.

Bhattacharjee, Arnab and Paolo Gelain (2011) Monetary Policy under Model Uncertainty: A Bayesian Analysis of FOMC Forecasts. Working paper, University of Dundee.

Blinder, Alan S. (2009) Making monetary policy by committee. *International Finance* 12, 171–194.

Branch, William A. (2013) Nowcasting and the Taylor Rule. Working paper, University of California, Irvine.

Capistrán, Carlos (2008) Bias in Federal Reserve inflation forecasts: Is the Federal Reserve irrational or just cautious? *Journal of Monetary Economics* 55, 1415–1427.

Caunedo, Julieta, Riccardo DiCecio, Ivana Komunjer, and Michael T. Owyang (2013) Federal Reserve Forecasts: Asymmetry and State-Dependence. Working paper 2013-012A, Federal Reserve Bank of St. Louis.

Chappell, Henry W., Rob R. McGregor, and Todd Vermilyea (2005) *Committee Decisions in Monetary Policy: Evidence from Historical Records of the Federal Open Market Committee*. Cambridge, MA: MIT Press.

Elliott, Graham, Ivana Komunjer, and Alan Timmermann (2005) Estimation and testing of forecast rationality under flexible loss. *Review of Economic Studies* 72, 1107–1125.

Ellison, Martin and Thomas Sargent (2012) A defence of the FOMC. *International Economic Review* 53, 1047–1065.

Gavin, William T. (2003) FOMC forecasts: Is all the information in the central tendency? *Federal Reserve Bank of St. Louis Review* May/June 2003, 27–46.

Gavin, William T. and Rachel J. Mandal (2003) Evaluating FOMC forecasts. *International Journal of Forecasting* 19, 655–667.

Gavin, William T. and Geetanjali Pande (2008) FOMC consensus forecasts. *Federal Reserve Bank of St. Louis Review* May/June 2008, 149–163.

Gerlach-Kristen, Petra (2008) The role of the chairman in setting monetary policy: Individualistic vs. autocratically collegial MPCs. *International Journal of Central Banking* 4, 119–143.

Gerlach-Kristen, Petra (2009) Outsiders at the Bank of England's MPC. *Journal of Money, Credit and Banking* 41, 1099–1115.

Hansen, Stephen, Michael McMahon, and Carlos Velasco Rivera (2012) How Experts Decide: Preferences or Private Assessments on a Monetary Policy Committee? Working paper, Universitat Pompeu Fabra.

Havrilesky, Thomas, and John A. Gildea (1991) The policy preferences of FOMC members as revealed by dissenting votes—A comment. *Journal of Money, Credit and Banking* 23, 130–138.

Kilian, Lutz and Simone Manganelli (2008) The central banker as a risk manager: Estimating the Federal Reserve's preferences under Greenspan. *Journal of Money, Credit and Banking* 40, 1103–1129.

McCracken, Michael W. (2010) Using FOMC Forecasts to Forecast the Economy. Economic synopses, no. 5, Federal Reserve Bank of St. Louis.

Meade, Ellen E. (2005) The FOMC: Preferences, voting, and consensus. *Federal Reserve Bank of St. Louis Review* 87, 93-101.

Meade, Ellen E. and Daniel L. Thornton (2012) The Phillips curve and US monetary policy: What the FOMC transcripts tell us. *Oxford Economic Papers* 64, 197–216.

Nobay, A. Robert and David Peel (2003) Optimal discretionary monetary policy in a model of asymmetric central bank preferences. *Economic Journal* 113, 657–665.

Orphanides, Athanasios and Volker Wieland (2008) Economic projections and rules of thumb for monetary policy. *Federal Reserve Bank of St. Louis Review,* 307–324.

Patton, Andrew J. and Allan Timmermann (2007) Testing forecast optimality under unknown loss. *Journal of the American Statistical Association* 102, 1172–1184.

Pierdzioch, Christian, Rülke, Jan-Christoph, and Georg Stadtmann (2012) On the loss function of the Bank of Canada: A note. *Economics Letters* 115, 155–159.

R Development Core Team (2012) *R: A Language and Environment for Statistical Computing.* Vienna: R Foundation for Statistical Computing. Available at http://www.R-project.org.

Riboni, Alessandro and Francisco J. Ruge-Murcia (2008) Preference heterogeneity in monetary policy committees. *International Journal of Central Banking* 4, 213–233.

Romer, Christina and David H. Romer (2008) The FOMC versus the staff: Where can monetary policymakers add value? *American Economic Review: Papers and Proceedings* 98, 230–235.

Romer, David H. (2010) A new data set on monetary policy: The economic forecasts of individual members of the FOMC. *Journal of Money, Credit and Banking* 42, 951–957.

Ruge-Murcia, Francisco J. (2003) Inflation targeting under asymmetric preferences. *Journal of Money, Credit and Banking* 35, 763–785.

Rülke, Jan-Christoph and Peter Tillmann (2011) Do FOMC members herd? *Economics Letters* 113, 176–179.

Surico, Paolo (2007) The Fed's monetary policy rule and U.S. inflation: The case of asymmetric preferences. *Journal of Economic Dynamics and Control* 31, 305–324.

Tillmann, Peter (2010a) Do FOMC members believe in Okun's Law? *Economics Bulletin* 30, 2398–2404.

Tillmann, Peter (2010b) The Fed's perceived Phillips curve: Evidence from individual FOMC forecasts. *Journal of Macroeconomics* 32, 1008–1013.

Tillmann, Peter (2011a) Strategic forecasting on the FOMC. *European Journal of Political Economy* 27, 547–553.

Tillmann, Peter (2011b) Parameter uncertainty and non-linear monetary policy rules. *Macroeconomics Dynamics* 15, 184–200.

Wang, Yiyao and Tae-Hwy Lee (2014) Asymmetric loss in the Greenbook and the Survey of Professional Forecasters. *International Journal of Forecasting* 30(2), 235–245.

Wieland, Volker and Maik H. Wolters (2013) Forecasting and policy making. In G. Elliott and A. Timmermann (eds.), *Handbook of Economic Forecasting,* vol. 2, pp. 239–325. Amsterdam: Elsevier.

Zhang, Wenlang and Willi Semmler (2005) Monetary policy rules under uncertainty: Empirical evidence, adaptive learning and robust control. *Macroeconomic Dynamics* 9(5), 651–681.