Finding SPF Percentiles Closest to Greenbook

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February 5, 2015

Abstract

To find forecasts that are closest to Greenbook forecast from the Survey of Professional Forecasters, this paper looks for SPF cross-sectional percentile forecasts that are not encompassed by Greenbook forecast under Greenbook's loss preference, which exhibits time-varying asymmetry. To evaluate SPF percentile forecasts under Greenbook's loss function, we introduce the forecast encompassing test for the asymmetric least square regression of conditional expectiles. From the analysis of the U.S. quarterly real output and inflation forecasts over the past four decades, we find that almost all SPF percentiles are encompassed by Greenbook forecast in full data period. However there is evidence in sub-periods that many SPF percentiles are not encompassed by Greenbook. Among those not-encompassed SPF percentiles, the best SPF percentile closest to Greenbook for real output growth forecast is near the median, while the best SPF percentile for inflation forecast is far below the median in the left tail of the SPF cross-sectional distribution.

Key Words: Greenbook, Survey of Professional Forecasters, estimation of flexible loss function, SPF cross-sectional distribution, SPF percentiles, encompassing test, asymmetric least squares.

JEL Classification: C53, E37, E27

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1 Introduction

A key issue in economic decision-making is the accurate prediction of future economy. Among many U.S. forecasting projects the Greenbook (GB) project of the Federal Reserve Board is known for better forecast performance than others. Romer and Romer (2000) find that Greenbook inflation forecast outperforms several other inflation forecasts made by private sectors. In their later research (Romer and Romer 2008), the Romers also show that Greenbook forecast dominates the Federal Open Market Committee (FOMC) forecast in predicting inflation and unemployment rate. Furthermore, Greenbook forecast is closely related to monetary policy. The common perception is that Greenbook has advantage in information regarding Fed's policy intention and will be used in policy-making process (Sims 2002, Faust and Wright 2009). This makes Greenbook useful for economic decision-making since it may reveal the future path of monetary policy.

However, Greenbook is released with a five year lag, which prevents private sectors from taking advantage of it. It is therefore desirable to have an alternative forecast that best proxies Greenbook forecast. In this paper we try to find the best proxies for Greenbook from the cross-sectional percentiles of the Survey of Professional Forecasters (SPF). The SPF forecasts are made by forecasters that largely come from the business/finance world. Zarnowitz and Braun (1993) find that SPF forecast significantly outperforms many econometric and time series forecasting models. Different from many forecast projects that report only one point forecast each time, the SPF contains a survey of multiple forecasts at each time. The cross-sectional distribution among different SPF forecasters provides a large set of alternative forecasts from which a good Greenbook substitute may be found.

In the literature, Romer and Romer (2000) are the first who compare the performance of Greenbook forecast and SPF forecasts. They find that Greenbook inflation forecast strictly dominates SPF's median inflation forecast, which has been further examined in depth by Rossi and Sekhposyan (2014). Romer and Romer (2000) use only the median of SPF forecasts while ignoring other percentiles. In fact, the median of SPF forecasts has been widely used to represent the whole cross-sectional distribution of the SPF forecasts, but it is not clear whether the median is superior to other percentiles of the cross-sectional distribution of the SPF forecasts. Besides, the Romers' comparison is based on the mean squared error (MSE) loss that is symmetric. However, Capistran

(2008) finds that the loss function of Greenbook is significantly asymmetric over certain periods. In these regards, our paper extends the Romers' (2000) study in two aspects, by comparing Greenbook with all SPF percentiles and by allowing potential asymmetry in the criterion (loss) function for the comparison.

The goal of this paper is to search for the SPF percentiles that are *close* to Greenbook in forecasting real output growth and inflation. We measure the distance (how close is close) from the encompassing statistic between a SPF percentile and Greenbook. We formulate the encompassing statistic (see e.g., Harvey, Leybourne and Newbold 1998) based on the asymmetric least squares (ALS) regression (Newey and Powell 1987) in terms of Greenbook's loss function with its asymmetric extent estimated. We estimate the asymmetric quadratic loss for Greenbook by the GMM of Elliott, Komunjer and Timmermann (2005, EKT) and then we look for the best SPF percentile that is least encompassed by Greenbook forecast under the estimated Greenbook's loss function.

From the analysis of the U.S. quarterly real output and inflation forecasts over the past four decades, we find that almost all SPF percentiles are encompassed by Greenbook forecast in full data period especially for inflation forecast. This result shows that Greenbook forecast has information advantage against almost all percentiles of SPF forecast, especially in forecasting inflation. However there is evidence in sub-periods that many SPF percentiles are not encompassed by Greenbook. Among the SPF percentiles that are not encompassed by Greenbook, the best SPF percentile is found near the median (or above the median in recent years) for real output growth forecast, but it is in the lower percentiles far below the median for inflation forecast. It indicates that common practice of using the SPF median can be misleading for inflation forecast and better SPF percentiles can be found from using the procedure proposed in this paper.

The paper is organized as follows. Section 2 presents the estimation of the Greenbook's loss function. Section 3 presents the encompassing results of comparing SPF percentiles with Greenbook under the estimated Greenbook's loss function. Section 4 concludes. Section 5 explains how we estimate the encompassing statistic and its asymptotic standard error from the asymmetric least regression under the estimated Greenbook's loss function.

2 Estimating Greenbook's Loss Function Asymmetry

Greenbook forecast is prepared by the Federal Reserve Board (FRB) before each FOMC meeting. There are typically two forecasts per quarter, one made in the first month of each quarter and the other made in the last month of each quarter, but we choose the former to be our Greenbook forecast in evaluation of the SPFs.[1] We use annualized quarter-over-quarter growth rates of both real GNP/GDP forecast (real output forecast) and GNP/GDP deflator forecast (inflation forecast).[2] Both one-quarter-ahead ($h = 1$) forecast and one-year-ahead ($h = 4$) forecast are included to check whether forecast horizon affects our results. One-quarter-ahead forecasts are available for the period $1968Q4-2006Q4$, and one-year-ahead forecasts are available for the period $1974Q4-2006Q4$. These sample periods will be referred to as "the full data period". In this paper, real-time data is used as realized value for those variables of interest, because it contains fewer re-benchmarking and definitional changes compared to the revised data which uses the latest vintage (Croushore and Stark 2001).

In this section, we estimate Greenbook's loss function asymmetry. Subsection 2.1 briefly introduces the EKT methodology for estimation. Subsection 2.2 presents the estimation results of Greenbook's loss function asymmetry.

2.1 The EKT Methodology

Assume that the h-step-ahead Greenbook forecast f_t for y_{t+h} is conditional on the information set $\mathcal{F}_t$ at time t and adopts the following loss function

$$L\left(f_t;\alpha\right) = \left[\alpha + (1-2\alpha)\cdot 1(e_t < 0)\right]\cdot |e_t|^p, \tag{1}$$

where $e_t = y_{t+h} - f_t$, $1(\cdot)$ is the indicator function and $\alpha \in (0, 1)$. p determines the shape of the loss function and is fixed at $p = 2$ throughout our analysis.[3]

We adopt the EKT method to estimate α of Greenbook's loss function. For a given (unknown) parameter α, we also assume the Greenbook forecast $f_t = \theta' W_t$ is linear in $W_t \in \mathcal{F}_t$ with $\theta \in \Theta \subset \mathbb{R}^k$

[1] SPF forecast is made during the second month of each quarter. Therefore, last-month Greenbook forecast is not a proper benchmark for SPF forecast, since it may have SPF forecast in their information set.

[2] The forecasts were for growth of GNP and GNP price index before 1992 and for GDP and GDP price index afterwards.

[3] As noted in Section 3.2 we considered both $p = 1, 2$. As the results are similar we focus on $p = 2$ for presentation. Regression with the loss function (1) with $p = 2$ is the expectile regression of Newey and Powell (1987). When $p = 1$, the regression is quantile regression of Koenker and Bassett (1978).

satisfying

$$\min_{\theta} E\left(L(f_t;\alpha)\right). \tag{2}$$

The first order condition is

$$E\left(W_t \cdot \left[1\left(e_t < 0\right) - \alpha\right] \cdot |e_t|\right) = 0, \tag{3}$$

and the second order condition can be verified (EKT, p. 1121).

Under proper assumptions, $\theta(\alpha)$ is a one-to-one mapping from $(0,1)$ to the parameter space Θ. This one-to-one relation enables us to back out the parameter α from f_t. However, W_t, the information set of the producer (the FRB) of Greenbook is not available to us (a user of the Greenbook). So we use an m-vector instrument V_t to estimate the scalar α. Results presented in this paper are computed using the instruments $V_t = (1, y_{t-1})'$ of a constant and the lagged realized value with $m = 2$. The estimation results with various other choices of the instrument were similar.

The orthogonality conditions with the instruments can be written as

$$A(f_t;\alpha) := E\left(V_t \cdot \left[1\left(e_t < 0\right) - \alpha\right] \cdot |e_t|\right) = 0. \tag{4}$$

Let α_0 be the unique minimum of the weighted quadratic distance

$$\alpha_0 := \arg\min_{\alpha} Q(f_t;\alpha) = A(f_t;\alpha)' \cdot S^{-1} \cdot A(f_t;\alpha), \tag{5}$$

where S is a positive definite $m \times m$ weight matrix. Let $B\left(f_t\right) := E\left(V_t \cdot |e_t|\right)$ and $C\left(f_t\right) := E\left(V_t \cdot 1\left(e_t < 0\right) \cdot |e_t|\right)$. Notice that $A(f_t;\alpha) = C\left(f_t\right) - \alpha B\left(f_t\right)$. Hence, $Q\left(f_t;\alpha\right)$ is a quadratic equation in α. Taking the first derivative of $Q(f_t;\alpha)$ with respect to α, we obtain α_0 as

$$\alpha_0 = \frac{B\left(f_t\right)' S^{-1} C\left(f_t\right)}{B\left(f_t\right)' S^{-1} B\left(f_t\right)}. \tag{6}$$

Given the forecast vector $\mathbf{f} := \left(f_1 \ \dots \ f_T\right)'$, α_0 is consistently estimated by $\hat{\alpha}_T\left(\mathbf{f}\right)$,

$$\hat{\alpha}_T\left(\mathbf{f}\right) = \frac{\hat{B}_T'\left(\mathbf{f}\right) \hat{S}_T^{-1}\left(\mathbf{f};\alpha\right) \hat{C}_T\left(\mathbf{f}\right)}{\hat{B}_T'\left(\mathbf{f}\right) \hat{S}_T^{-1}\left(\mathbf{f};\alpha\right) \hat{B}_T\left(\mathbf{f}\right)}, \tag{7}$$

where $\hat{B}_T\left(\mathbf{f}\right) := \frac{1}{T}\sum_{t=1}^{T} V_t \cdot |e_t|$ and $\hat{C}_T\left(\mathbf{f}\right) := \frac{1}{T}\sum_{t=1}^{T} V_t \cdot 1\left(e_t < 0\right) \cdot |e_t|$. The estimation of S uses Newey and West's (1987) method.[4] EKT (2005) show that this estimator is consistent and

[4] The Newey and West estimator of S is $\hat{S}_T\left(\mathbf{f};\alpha\right) = T^{-1}\sum_{j=-4}^{4} \omega_{|j|} \sum_{t=|j|}^{T} a\left(f_t;\alpha\right) a'\left(f_{t-|j|};\alpha\right)$, where $a\left(f_t;\alpha\right) := V_t \cdot \left[1\left(e_t < 0\right) - \alpha\right] \cdot |e_t|$ and $\omega_{|j|} = 1 - \frac{|j|}{5}$. Because the computation of $\hat{S}_T(\mathbf{f};\alpha)$ depends on α, we use iteration starting from $\hat{S}_T(\mathbf{f};\alpha) = I_m$ to compute the initial estimate $\hat{\alpha}_{T,1}\left(\mathbf{f}\right)$, then plug it into $\hat{S}_T(\mathbf{f};\hat{\alpha}_{T,1}\left(\mathbf{f}\right))$ to get a more efficient weighting matrix $\hat{S}_T^{-1}(\mathbf{f};\hat{\alpha}_{T,1}\left(\mathbf{f}\right))$, and use $\hat{S}_T^{-1}(\mathbf{f};\hat{\alpha}_{T,1}\left(\mathbf{f}\right))$ to compute a new estimate $\hat{\alpha}_{T,2}\left(\mathbf{f}\right)$. These steps are repeated until convergence.

asymptotic normal, conditional on the observed forecast vector $\mathbf{f}$,

$$\sqrt{T}\ \hat{G}_T^{-1/2}\left(\mathbf{f};\alpha\right)\ \left(\hat{\alpha}_T\left(\mathbf{f}\right)-\alpha_0\right)\Big|\ \mathbf{f}\quad\overset{d}{\to}N\left(0,1\right),\tag{8}$$

where $\hat{G}_T\left(\mathbf{f};\alpha\right):=\left[\hat{B}_T'\left(\mathbf{f}\right)\hat{S}_T^{-1}\left(\mathbf{f};\alpha\right)\hat{B}_T\left(\mathbf{f}\right)\right]^{-1}$.

Moreover, when more number of instruments are used than the number of parameter to estimate, i.e., $m>1$, the over-identification test can be served as a diagnostic check for the adequacy of the estimated asymmetry conditional on the observed forecast series $\mathbf{f}$. This is to test whether the estimated asymmetry $\hat{\alpha}_T\left(\mathbf{f}\right)$ satisfies the moment condition in (4) by the following statistic

$$J_T\left(\mathbf{f};\hat{\alpha}_T\left(\mathbf{f}\right)\right):=T\times\hat{A}_T(\mathbf{f};\hat{\alpha}_T\left(\mathbf{f}\right))'\ \hat{S}_T^{-1}(\mathbf{f};\hat{\alpha}_T\left(\mathbf{f}\right))\ \hat{A}_T(\mathbf{f};\hat{\alpha}_T\left(\mathbf{f}\right)),\tag{9}$$

where $\hat{A}_T\left(\mathbf{f};\hat{\alpha}_T\left(\mathbf{f}\right)\right):=\hat{C}_T\left(\mathbf{f}\right)-\hat{\alpha}_T\left(\mathbf{f}\right)\hat{B}_T\left(\mathbf{f}\right)$. Under the null hypothesis $H_0: A(f_t;\alpha_0)=0$, the statistic $J_T\left(\mathbf{f};\hat{\alpha}_T\left(\mathbf{f}\right)\right)$ follows the asymptotic χ^2 distribution with $(m-1)$ degrees of freedom.

Additionally, with a fixed value α_1, the following statistic

$$J_T\left(\mathbf{f};\alpha_1\right)=T\times\hat{A}_T(\mathbf{f};\alpha_1)'\ \hat{S}_T^{-1}\left(\mathbf{f};\alpha_1\right)\ \hat{A}_T(\mathbf{f};\alpha_1)\tag{10}$$

serves as a diagnostic check for the adequacy of the loss function with $\alpha=\alpha_1$ conditional on the observed forecast series $\mathbf{f}$. Under the null hypothesis $H_0: A(f_t;\alpha_1)=0$, the statistic $J_T\left(\mathbf{f};\alpha_1\right)$ follows the asymptotic χ^2 distribution with m degrees of freedom.

2.2 Empirical Results: Estimation of Greenbook Loss Function

Let $\mathbf{f}^{GB}:=\left(f_1^{GB}\ \ldots\ f_T^{GB}\right)'$ be the vector of Greenbook forecasts. Plugging $\mathbf{f}^{GB}$ into equations (7), (8), (9), and (10), we estimate the Greenbook's loss function asymmetry $\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)$, its asymptotic standard error $T^{-1/2}\ \hat{G}_T^{1/2}\left(\mathbf{f}^{GB};\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)\right)$, the diagnostic statistic $J_T\left(\mathbf{f}^{GB};\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)\right)$ for the adequacy of the estimated loss function for Greenbook forecast, and the diagnostic statistic $J_T\left(\mathbf{f}^{GB};\alpha_1=0.5\right)$ for the adequacy of the symmetric loss function for Greenbook forecast. Table 1 summarizes the estimation and test results in the full data period and three sub-periods: Before-1982, 1982-2000, and After-2000.[5]

Table 1 About Here

[5] This way of splitting the data is according to Capistran and Timmermann's (2009) finding that "the shift in the sign of the bias observed for a substantial portion of forecasters around 1982", and an apparent shift in the direction of Greenbook's loss asymmetry in both real output growth and inflation forecasts after 2000.

In full data period, for both real output growth forecast and inflation forecast, and for both short horizon forecast and long horizon forecast, the symmetric loss function seems to be adequate for Greenbook, because the point estimates of $\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)$ are not significantly different from 0.5 according to their asymptotic standard errors reported in Column 3 of Table 1. This result is consistent with the diagnostic statistics $J_T\left(\mathbf{f}^{GB};0.5\right)$ and their asymptotic p-values reported in Column 5 are all too large to reject the adequacy of the symmetric loss for Greenbook.

However, for the three sub-periods, most estimates of the loss function parameter are significantly different from 0.5. In the sub-periods before 1982 and after 2000, the estimated loss function parameters are significantly larger than 0.5 for real output forecast, but are significantly lower than 0.5 for inflation forecast, especially for the long horizon $h = 4$. In the sub-period 1982-2000, the estimated loss function parameter are significantly smaller than 0.5 for real output growth forecast, but are significantly higher than 0.5 for inflation forecast. These significant asymmetry results for the three sub-periods are consistent with the diagnostic test results in Column 5.

The results in Column 4 supports the adequacy of the estimated loss function for Greenbook, with all p-values but one larger than 0.05. It is useful to note that the p-value of $J_T\left(\mathbf{f}^{GB};\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)\right)$ are uniformly larger than that of $J_T\left(\mathbf{f}^{GB};0.5\right)$, indicating that the estimated loss function may be more adequate for Greenbook than fixing $\alpha = 0.5$, even for the full data period. Furthermore, the asymmetry exhibits a time-varying nature as discussed from Column 3. Therefore, in the next section, in finding SPF percentiles closest to Greenbook, we will use the estimated loss function rather than using the loss function with $\alpha = 0.5$ even for the full data period.

3 Comparing SPF Percentiles in Greenbook's Loss Function

The goal of this paper is to search for SPF's cross-sectional percentiles that are closest to the Greenbook, in the sense that they are not encompassed by Greenbook in terms of Greenbook's estimated loss function. If we make economic decision based on Greenbook forecast, we would be benefited from the FRB's monetary policy since Greenbook is used in policy making. In reality Greenbook is available with a five year lag and thus we wish to see if there exists a SPF percentile that is similar to Greenbook. While the SPF-median has been widely used, it may not be among the group of SPF percentiles that are closest to Greenbook.

We consider the SPF as a reasonable collection of forecasts alternative to Greenbook. One may wonder why we choose the SPF as a collection of alternative forecasts to Greenbook. Another possibility can be the FOMC forecasts published in Monetary Policy Report of the FRB. The FOMC forecasts from this report have been compared to Greenbook forecasts and SPF forecasts by Gavin and Pande (2008) and Romer and Romer (2008). The upside is that the FOMC forecasts are constructed after actually seeing the Greenbook numbers and hence there is a reason to expect that the FOMC forecasts can be good alternative forecasts to Greenbook because Greenbook will become available with 5 year lag. However, a downside is that the FOMC forecasts have been available only twice a year until very recently. Both Greenbook and SPF are available in quarterly frequency. Gavin and Pande (2008) compare the relative forecast accuracy of the FOMC and SPF forecasts for output growth and inflation and find the differences are negligible.

3.1 SPF Percentiles

Survey of Professional Forecasters is the oldest quarterly survey forecast in the United States. Unlike other forecast projects, the SPF contains a survey of different forecasts at each time. In order to evaluate forecast performance of different component forecasts in the SPF, we define the ith percentile of SPF forecasts in a cross-sectional distribution of SPF forecasts at time t $(t = 1, 2, ..., T)$. Let n_t be the number of forecasts in the SPF at time t. The n_t cross-sectional SPF forecasts at time t are ordered from the smallest to the largest, and the ith percentile, $f_t^{SPF(i)}$, $i \in [0, 100]$, are computed. The time series vector $\mathbf{f}^{SPF(i)} := \left(f_1^{SPF(i)} \ \ldots \ f_T^{SPF(i)} \right)'$ is the ith percentile forecast series (denoted $SPF(i)$). Our goal is to find out a set of $\{i\}$ such that $\mathbf{f}^{SPF(i)}$ is not encompassed by Greenbook forecast $\mathbf{f}^{GB}$ in terms of the loss function $L(\cdot; \alpha)$ in (1) with $\alpha = \hat{\alpha}_T \left(\mathbf{f}^{GB}\right)$ from Table 1.

We use the SPF forecast data in the same way as we do with Greenbook forecast in the beginning of Section 2. We use the annualized SPF forecasts for quarter-over-quarter growth rate of real GNP/GDP and GNP/GDP deflator. Both one-quarter-ahead $(h = 1)$ and one-year-ahead $(h = 4)$ forecasts are used, and the data periods for both horizons are the same as those in Greenbook forecast.

3.2 Encompassing Test for Comparing SPF Percentiles in Greenbook's Loss

To examine which SPF-percentile is least encompassed by Greenbook, consider a combined forecast (CF)

$$f_t^{CF(i)} := \left(1 - \lambda^{(i)}\right) f_t^{GB} + \lambda^{(i)} f_t^{SPF(i)}. \tag{11}$$

The combined forecast contains $SPF(i)$ with the weight $\lambda^{(i)}$ which may be either positive or negative. If $\lambda^{(i)} = 0$, $SPF(i)$ is encompassed by Greenbook forecast. If $\lambda^{(i)} < 0$, $SPF(i)$ should go "short" in forming a portfolio of the two forecasts, in which case the combined forecast can still be better than Greenbook forecast with shorting $SPF(i)$ with a negative weight and thus $SPF(i)$ is dominated by Greenbook forecast. If $\lambda^{(i)} > 0$, $SPF(i)$ has some contribution to the combined forecast that is improved over Greenbook and thus $SPF(i)$ is not encompassed by Greenbook forecast. Our goal in this paper is to find SPF percentiles closest to Greenbook. We measure the closeness using $\lambda^{(i)}$. The larger $\lambda^{(i)}$ is, the closer $SPF(i)$ is to Greenbook. We look for $SPF(i)$ least encompassed by Greenbook, that is $SPF(i)$ with the largest value of $\lambda^{(i)} > 0$. Hence, we test the null hypothesis $H_0 : \lambda^{(i)} = 0$ against the one-sided alternative $H_1 : \lambda^{(i)} > 0$.

Define the forecast errors $e_t^{GB} := y_{t+h} - f_t^{GB}$, $e_t^{SPF(i)} := y_{t+h} - f_t^{SPF(i)}$, and $e_t^{CF(i)} := y_{t+h} - f_t^{CF(i)}$. The equation (11) can be rewritten with forecast errors as

$$e_t^{GB} = \lambda^{(i)} \left(e_t^{GB} - e_t^{SPF(i)}\right) + e_t^{CF(i)}. \tag{12}$$

The combination weight $\lambda^{(i)}$ is estimated from

$$\lambda^{(i)} = \arg\min_{\lambda^{(i)}} E\left[L\left(f_t^{CF(i)}; \hat{\alpha}_T\left(\mathbf{f}^{GB}\right)\right)\right]$$

where

$$L\left(f_t^{CF(i)}; \hat{\alpha}_T\left(\mathbf{f}^{GB}\right)\right) = \left[\hat{\alpha}_T\left(\mathbf{f}^{GB}\right) + \left(1 - 2\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)\right) \cdot 1\left(e_t^{CF(i)} < 0\right)\right] \cdot \left|e_t^{CF(i)}\right|^p . \tag{13}$$ [6]

Note that we evaluate $SPF(i)$ relative to Greenbook under Greenbook's loss function using estimated loss parameter $\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)$. Thus $\lambda^{(i)}$ depends on $\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)$, and $\lambda^{(i)}\left(\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)\right)$ is preferred notation to $\lambda^{(i)}$. With this in mind, a short notation $\lambda^{(i)}$ is used below for brevity.

[6] The loss function (13) with $p = 2$ gives the expectile regression. While the encompassing literature uses the symmetric squared forecast error loss, we use the asymmetric squared error loss. To the best of our knowledge this is new in the forecast encompassing literature. The expectile regression with $\alpha = 0.5$ gives the encompassing result of the existing literature for the conditional mean regression.

Under the null hypothesis $H_0 : \lambda^{(i)} = 0$, f_t^{GB} encompasses $f_t^{SPF(i)}$. It means that, under Greenbook's loss function, Greenbook forecast is superior to $SPF(i)$ forecast, in the sense that if we have both of them at hand the best forecast combination is just the Greenbook forecast. If the null hypothesis is rejected in favor of the one-sided alternative $H_1 : \lambda^{(i)} > 0$, $SPF(i)$ can contribute to the forecast combination. Appendix shows how we estimate $\hat{\lambda}_T^{(i)} := \hat{\lambda}_T^{(i)}\left(\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)\right)$ and its consistent asymptotic standard error $\mathrm{se}\left(\hat{\lambda}_T^{(i)}\right)$ by applying the method of asymmetric least squares expectile regression. The 5% asymptotic critical value to test the null hypothesis $H_0 : \lambda^{(i)} = 0$ against the one-sided alternative $H_1 : \lambda^{(i)} > 0$ is then computed by $C_T^{(i)} = 1.645\times\ \mathrm{se}\left(\hat{\lambda}_T^{(i)}\right)$ for $i = 1, ..., 100$. If $\hat{\lambda}_T^{(i)} > C_T^{(i)}$ for each percentile $i = 1, ..., 100$, the null hypothesis that $SPF(i)$ is encompassed by Greenbook $\left(H_0 : \lambda^{(i)} = 0\right)$ is rejected at 5% level in favor of the alternative hypothesis that $SPF(i)$ is not encompassed by Greenbook $\left(H_1 : \lambda^{(i)} > 0\right)$.

3.3 Empirical Results: Finding SPF Percentiles Closest to Greenbook

In our empirical results (Figures 1-4) we present $\hat{\lambda}_T^{(i)}$ (solid black line) and $C_T^{(i)}$ (dashed red line). Our goal is to find the SPF percentile closest to Greenbook with the largest value of $\hat{\lambda}_T^{(i)}$. Figure 1 summarizes the encompassing results for the full date period and Figures 2, 3, 4 for the three sub-periods (Before 1982, 1982-2000, After 2000) respectively.

Figures 1-4 About Here

For the **full data period** in Figure 1, we find the following.

1. For real output growth forecast for both horizons $h = 1, 4$, while most SPF percentiles are encompassed by Greenbook, we find that the best SPF percentile, the percentile i with the largest estimated value of $\lambda^{(i)}$, is near the median as seen from Figure 1(a,b). The best SPF percentiles are found near the median (54th for $h = 1$ and 41st for $h = 4$). They have very large positive values of $\hat{\lambda}_T^{(i)}$ significantly ($h = 1$) and nearly significantly ($h = 4$).

2. For inflation forecast, all SPF percentiles are encompassed by Greenbook for both $h = 1, 4$. This can be read from Figure 1(c,d) as $\hat{\lambda}_T^{(i)}$ are near zero and $\hat{\lambda}_T^{(i)} < C_T^{(i)}$ for all i. This finding confirms Romer and Romer (2000) who discovered Greenbook's information advantage over private sectors in forecasting inflation. The best SPF percentiles for inflation forecast are far

away from the median and the point estimates $\hat{\lambda}_T^{(i)}$ for inflation forecast are much smaller and virtually zero.

3. Greenbook's dominance over the SPF-percentiles is much more significant in inflation forecast than in real output growth forecast. Most SPF percentiles have the positive $\hat{\lambda}_T^{(i)}$ for real output growth, but have virtually zero weight for inflation.

For the sub-period **Before-1982** in Figure 2, the encompassing results are more significant. We find the following.

1. For real output growth forecast for both $h = 1, 4$, about an half of SPF percentiles below around the SPF-median are encompassed by Greenbook: $\hat{\lambda}_T^{(i)} < C_T^{(i)}$ for $i < 56$ in $h = 1$ (Figure 2a), and $\hat{\lambda}_T^{(i)} < C_T^{(i)}$ for $i < 39$ in $h = 4$ (Figure 2b). The remaining SPF percentiles above the SPF-median are not encompassed by Greenbook. The best SPF percentiles with the largest value of $\hat{\lambda}^{(i)}$ are found near the median (Figure 2(a,b)) with significantly positive values of $\hat{\lambda}_T^{(i)}$.

2. For inflation forecast for $h = 1$, all SPF percentiles are encompassed by Greenbook (Figure 2(c)) with $\hat{\lambda}_T^{(i)}$ near zero and insignificant $\left(\hat{\lambda}_T^{(i)} < C_T^{(i)}\right)$ for all i. This confirms Romer and Romer (2000) again. However, for inflation forecast for $h = 4$, SPF percentiles in the left tail are not encompassed by Greenbook $\left(\hat{\lambda}_T^{(i)} > C_T^{(i)} \text{ for } i < 35\right)$ and the best SPF percentile is below the 20th percentile.

3. There are many SPF percentiles that are not encompassed by Greenbook. The best SPF percentiles are found near the SPF-median for real output growth ($h = 1, 4$) but they are far below the SPF-median for inflation ($h = 4$). Greenbook's dominance over the SPF-percentiles is significant only in inflation forecast with $h = 1$ (Figure 2c).

For the sub-period **1982-2000** in Figure 3, we find the following.

1. For real output growth forecast for both $h = 1, 4$, the best SPF percentiles with the largest $\hat{\lambda}_T^{(i)}$ are near the median (Figure 3(a,b)). They have very large positive values of $\hat{\lambda}_T^{(i)}$ significantly ($h = 1$) or nearly significantly ($h = 4$).

2. For inflation forecast, all SPF percentiles are encompassed by Greenbook for both $h = 1, 4$. This can be seen from Figure 3(c,d) as $\hat{\lambda}_T^{(i)}$ are near zero and $\hat{\lambda}_T^{(i)} < C_T^{(i)}$ for all i. This also confirms Romer and Romer (2000) with $\hat{\lambda}_T^{(i)}$ small near zero.

3. Greenbook's dominance over the SPF-percentiles is more significant in inflation forecast than in real output growth forecast. For real output growth, there are many SPF percentiles that are not encompassed by Greenbook. The best SPF percentiles are found near the SPF-median for real output growth. For inflation forecasts, all SPF percentiles are encompassed by Greenbook.

For the sub-period **After-2000** in Figure 4, we note that the sample size is small as it is only for 6 years for $2001Q1 - 2006Q4$. Nevertheless the encompassing results are clear.

1. For real output growth forecast for $h = 1$, lower and middle SPF percentiles are encompassed by Greenbook with $\hat{\lambda}_T^{(i)} < C_T^{(i)}$ while many upper SPF percentiles are not encompassed by Greenbook with $\hat{\lambda}_T^{(i)} > C_T^{(i)}$. The best SPF percentile with the largest value of $\hat{\lambda}^{(i)}$ is above the median as seen from Figure 4(a,b). There are many large positive values of $\hat{\lambda}_T^{(i)}$ (significantly larger than zero) over a wide range of SPF percentiles for $h = 4$.

2. For inflation forecast many lower SPF percentiles are not encompassed by Greenbook as seen from Figure 4(c,d). For $h = 1$, $\hat{\lambda}_T^{(i)}$ are above zero for almost all percentiles i, and even significantly larger than zero $\left(\hat{\lambda}_T^{(i)} > C_T^{(i)}\right)$ for many lower percentiles i in the left tail. For $h = 4$, many SPF percentiles in the left tail are not encompassed by Greenbook and the best SPF percentile is found near the 13th percentile. This may show that the findings of Romer and Romer (2000) have got weakened in this recent period.

3. Greenbook's dominance over the SPF-percentiles has become weaker. There are many SPF percentiles that are not encompassed by Greenbook for both real output growth and inflation for both $h = 1, 4$. The best SPF percentiles are found above the SPF-median for real output growth ($h = 1, 4$) but they are far below the SPF-median for inflation ($h = 1, 4$).

To summarize, Greenbook's dominance over SPF-percentiles is more significant in inflation forecast than in real output growth forecast. It implies that Greenbook forecasters' information advantage over the SPF participants is more significant in forecasting inflation than in forecasting real output growth. Also, Greenbook's dominance over SPF-percentiles is more significant in the full data period as Greenbook encompasses the SPF percentiles in full data period. However, evidence in sub-periods indicates that these have changed over time as noted by Rossi and Sekhposyan (2014), and many SPF percentiles are not encompassed by Greenbook in more recent period. The encompassing results for the three sub-periods in Figures 2, 3, 4 are more significant than for the full data period in Figure 1. While most SPF percentiles are encompassed by Greenbook, there are many SPF percentiles not encompassed by Greenbook, in forecasting real output growth in all three sub-periods and in forecasting inflation in Before-1982 and especially After-2000. Among all SPF percentiles not encompassed by Greenbook, the best SPF percentile is near or above the median for real output growth forecast. But it is in the lower percentiles for inflation forecast for the sub-period Before-1982 (Figure 2d) and the sub-period After-2000 (Figure 4(c,d)). In all three sub-periods Greenbook's encompassing SPF-percentiles is much more significant in inflation forecast than in real output growth forecast. This result is in line with previous literature as well as with the result in full data period. However, while the weights of all SPF percentiles in forecasting inflation are around zero in the full date period, some lower percentiles in the sub-period After-2000 (Figure 4(c,d)) are not encompassed by Greenbook in forecasting inflation. This indicates that inflation forecasts of lower SPF percentiles provide useful information in addition to the Greenbook after 2000.

4 Conclusions

Greenbook forecasts are used by the policy makers but they are not made available publicly until five years later. We ask a question how SPF may be used as an alternative forecast until Greenbook forecast becomes available public. This question prompted us to consider the cross-sectional percentiles of the SPF survey. Because there are frequent replacements in the membership of the SPF forecasters due to entries and exits, the SPF does not produce balanced panel data of forecasts. Therefore, instead of following a panel of the individual forecasters, we examine the cross-sectional SPF-percentiles and look for which parts of the SPF cross-sectional distribution can be good (or bad) substitutes for Greenbook forecast, so that the users of the SPF can have the forecasts that are closest to the Greenbook forecasts of the policy makers. For that matter, we test which SPF-percentiles are not encompassed by the Greenbook forecast. The encompassing test is conducted under the estimated Greenbook's loss function (asymmetric squared error) so that each SPF percentile is evaluated relative to Greenbook forecast. This leads us to introduce the forecast encompassing test for the asymmetric least squares regression.

According to our encompassing test results, the common practice of using the SPF-median could be misleading, especially in forecasting inflation. The best SPF percentiles for inflation forecast that are not encompassed by Greenbook are far left from the median in the low tail percentiles of the SPF cross-sectional distribution. Hence, the SPF-median would over-predict inflation relative to Greenbook.

5 Appendix

The appendix explains how we compute $\hat{\lambda}_T^{(i)}$ and $\mathrm{se}\left(\hat{\lambda}_T^{(i)}\right)$. Consider the linear expectile regression

$$y_t = x_t'\beta\left(\alpha\right) + u_t\left(\alpha\right), \tag{14}$$

where y_t is a scalar dependent variable and x_t is a $k \times 1$ vector. The $k \times 1$ parameter $\beta\left(\alpha\right)$, the asymmetric least squares (ALS) estimator, minimizes the loss function in (13) with $p = 2$

$$E\ \left|\alpha - 1(u_t\left(\alpha\right) < 0)\right| \cdot u_t^2\left(\alpha\right) := E\ w_t\left(\alpha\right) \cdot u_t^2\left(\alpha\right), \tag{15}$$

with $w_t(\alpha) = \left|\alpha - 1(u_t(\alpha) < 0)\right|$, by solving the following equation iteratively

$$\hat{\beta}_T(\alpha) = \left\{\sum_{t=1}^{T}\left|\alpha - 1\left(y_t < x_t'\hat{\beta}_T\left(\alpha\right)\right)\right| \cdot x_t x_t'\right\}^{-1} \sum_{t=1}^{T}\left|\alpha - 1\left(y_t < x_t'\hat{\beta}_T\left(\alpha\right)\right)\right| \cdot x_t y_t. \tag{16}$$

Newey and Powell (1987, pp. 827-828) show the asymptotic normality of $\hat{\beta}_T(\alpha)$ and its consistent covariance matrix estimator. That is, for the simple case when $k = 1$ as in our model in (12),

$$\sqrt{T}\ \hat{D}_T^{-1/2}\left(\alpha\right)\ \left(\hat{\beta}_T(\alpha) - \beta(\alpha)\right) \xrightarrow{d} N\left(0, 1\right) \tag{17}$$

where $\hat{D}_T\left(\alpha\right) = \hat{W}_T^{-2}\left(\alpha\right)\hat{V}_T\left(\alpha\right)$, $\hat{W}_T\left(\alpha\right) = \frac{1}{T}\sum_{t=1}^{T}\hat{w}_t(\alpha)x_t^2$, $\hat{V}_T\left(\alpha\right) = \frac{1}{T}\sum_{t=1}^{T}\hat{w}_t^2(\alpha)\hat{u}_t^2(\alpha)x_t^2$, $\hat{u}_t(\alpha) = y_t - x_t'\hat{\beta}(\alpha)$, and $\hat{w}_t(\alpha) = \left|\alpha - 1(\hat{u}_t(\alpha) < 0)\right|$.

In our notation, $\alpha = \hat{\alpha}_T\left(\mathbf{f}^{GB}\right), \beta\left(\alpha\right) = \lambda^{(i)}$, $k = 1$, $y_t = e_t^{GB}$, and $x_t = \left(e_t^{GB} - e_t^{SPF(i)}\right)$. The ALS estimator $\hat{\lambda}_T^{(i)} := \hat{\lambda}_T^{(i)}\left(\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)\right)$ is computed iteratively from

$$\begin{aligned}\hat{\lambda}_T^{(i)} &= \left[\sum_{t=1}^{T}\left|\hat{\alpha}_T\left(\mathbf{f}^{GB}\right) - 1\left\{e_t^{GB} < \hat{\lambda}_T^{(i)}\left(e_t^{GB} - e_t^{SPF(i)}\right)\right\}\right| \cdot \left(e_t^{GB} - e_t^{SPF(i)}\right)^2\right]^{-1} \\ &\quad \times \left[\sum_{t=1}^{T}\left|\hat{\alpha}_T\left(\mathbf{f}^{GB}\right) - 1\left\{e_t^{GB} < \hat{\lambda}_T^{(i)}\left(e_t^{GB} - e_t^{SPF(i)}\right)\right\}\right| \cdot \left(e_t^{GB} - e_t^{SPF(i)}\right) e_t^{GB}\right].\end{aligned} \tag{18}$$

The asymptotic standard error of $\hat{\lambda}_T^{(i)}$ is $\text{se}\left(\hat{\lambda}_T^{(i)}\left(\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)\right)\right) = T^{-1/2}\ \hat{D}_T^{1/2}\left(\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)\right).$

References

Capistran, Carlos (2008). "Bias in Federal Reserve Inflation Forecasts: Is the Federal Reserve Irrational or Just Cautious?" *Journal of Monetary Economics* 55(8), 1415-1427.

Capistran, Carlos and Allan Timmermann (2009). "Disagreement and Biases in Inflation Expectations." *Journal of Money, Credit and Banking* 41(2-3), 365-396.

Croushore, Dean and Tom Stark (2001). "A Real-Time Data Set for Macroeconomists." *Journal of Econometrics* 105(1), 111-130.

Elliott, Graham, Ivana Komunjer and Allan Timmermann (2005). "Estimation and Testing of Forecast Rationality under Flexible Loss." *Review of Economic Studies* 72(4), 1107-1125.

Faust, Jon and Jonathan H. Wright (2009). "Comparing Greenbook and Reduced Form Forecasts Using a Large Real Time Dataset." *Journal of Business and Economic Statistics* 27(4), 468-479.

Gavin, William T. and Geetanjali Pande (2008). "FOMC Consensus Forecasts", *Federal Reserve Bank of St. Louis Review* 90(3), 149-164.

Harvey, David S., Stephen J. Leybourne and Paul Newbold (1998). "Tests for Forecast Encompassing." *Journal of Business and Economic Statistics* 16(2), 254-259.

Koenker, Roger and Gilbert Bassett Jr. (1978). "Regression Quantiles." *Econometrica* 46(1), 33-50.

Newey, Whitney K. and James L. Powell (1987). "Asymmetric Least Squares Estimation and Testing." *Econometrica* 55(4), 819-847.

Newey, Whitney K. and Kenneth D. West (1987). "A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix." *Econometrica* 55(3), 703-708.

Romer, Christina D. and David H. Romer (2000). "Federal Reserve Information and the Behavior of Interest Rates." *American Economic Review* 90(3), 429-457.

Romer, Christina D. and David H. Romer (2008). "The FOMC versus the Staff: Where Can Monetary Policymakers Add Value?" *American Economic Review* 98(2), 230-235.

Rossi, Barbara and Tatevik Sekhposyan (2014). "Forecast Rationality Tests in the Presence of Instabilities, with Applications to Federal Reserve and Survey Forecasts." University of Pompeu Fabra and Texas A&M University.

Sims, Christopher A. (2002). "The Role of Models and Probabilities in the Monetary Policy Process." *Brookings Papers on Economic Activity* 2002(2), 1-62.

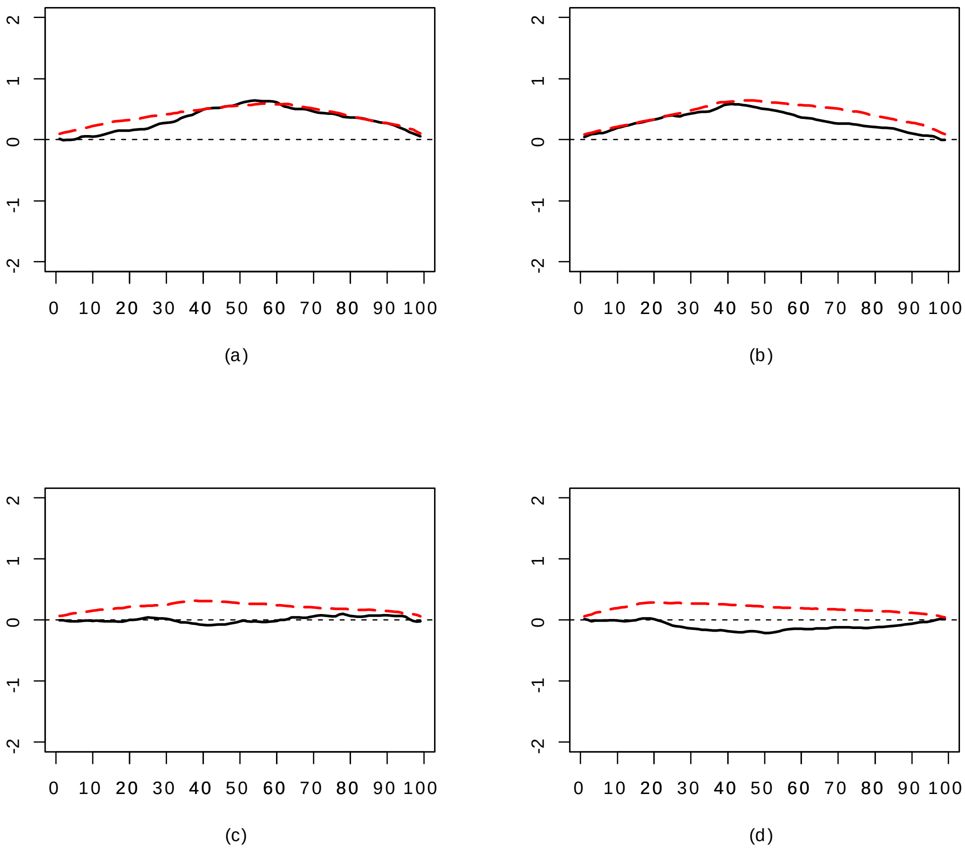
Zarnowitz, Victor and Phillip Braun (1993). "Twenty-Two Years of the NBER-ASA Quarterly Economic Outlook Surveys: Aspects and Comparisons of Forecasting Performance," *Business Cycles, Indicators and Forecasting*, pp. 11-94. University of Chicago Press.

Table 1. Estimation of Greenbook Loss Function and Diagnostics

	y_{t+h}	$\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)$	$J_T\left(\mathbf{f}^{GB};\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)\right)$	$J_T\left(\mathbf{f}^{GB};0.5\right)$
Full data period	real output growth, $h=1$	.586 [.064]	0.527 (.468)	2.370 (.306)
	real output growth, $h=4$	.579 [.074]	0.006 (.940)	1.163 (.559)
	inflation, $h=1$	.529 [.077]	0.006 (.938)	0.143 (.931)
	inflation, $h=4$	.603 [.093]	0.004 (.949)	1.226 (.542)
Before-1982	real output growth, $h=1$	.732 [.085]	1.452 (.228)	8.848 (.012)
	real output growth, $h=4$	.861 [.103]	4.228 (.004)	16.546 (.000)
	inflation, $h=1$	.407 [.123]	1.267 (.260)	1.841 (.398)
	inflation, $h=4$	.156 [.109]	1.648 (.199)	11.672 (.003)
1982-2000	real output growth, $h=1$	.351 [.090]	1.208 (.272)	3.974 (.137)
	real output growth, $h=4$	.371 [.100]	0.867 (.352)	2.544 (.280)
	inflation, $h=1$	.780 [.057]	0.209 (.648)	24.622 (.000)
	inflation, $h=4$	.884 [.047]	0.864 (.353)	66.381 (.000)
After-2000	real output growth, $h=1$	.856 [.066]	1.771 (.192)	30.624 (.000)
	real output growth, $h=4$	.778 [.078]	0.255 (.614)	13.160 (.001)
	inflation, $h=1$	.139 [.121]	0.607 (.436)	9.472 (.009)
	inflation, $h=4$	.111 [.066]	1.395 (.238)	36.409 (.000)

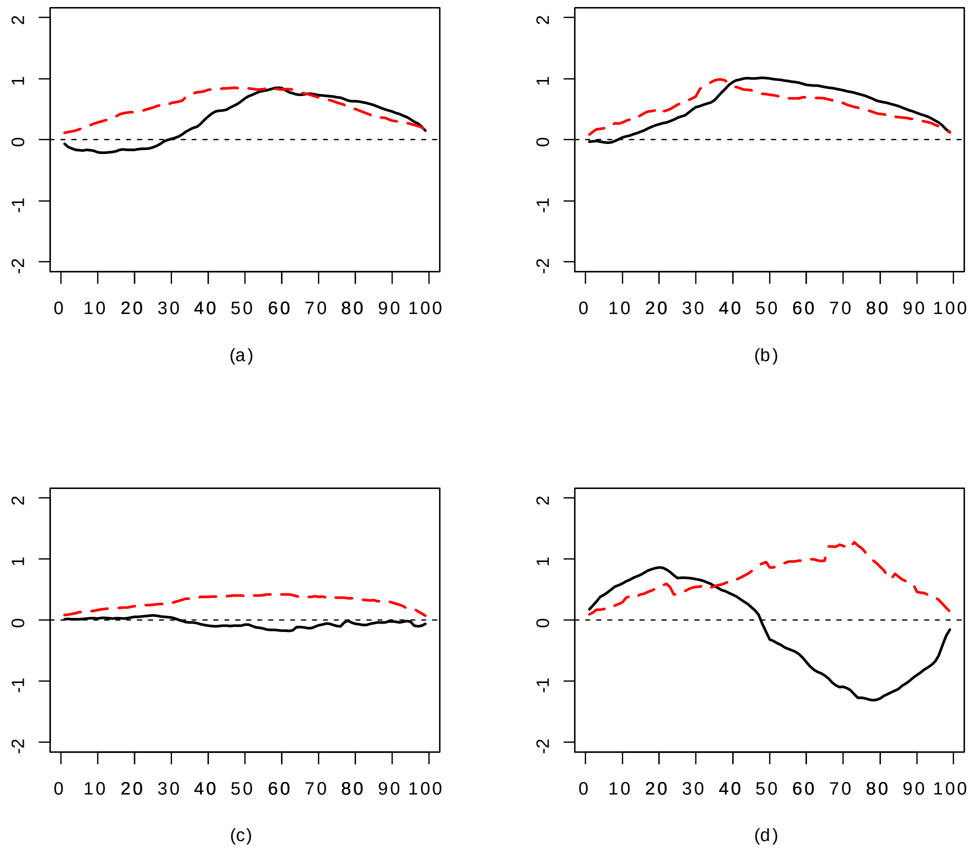
Notes: Column 3 reports the estimates $\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)$ and their asymptotic standard errors [in square brackets] for Greenbook forecast $\mathbf{f}^{GB}$. Column 4 reports the over-identifying test statistics that check for adequacy of the estimated α values with the asymptotic p-values of the test statistics (in parentheses). Column 5 reports the test statistics for adequacy of the symmetric loss with $\alpha = 0.5$ values with the asymptotic p-values of the test statistics (in parentheses). The full data period and three sets of sub-period data are used as indicated in Column 1.

Figure 1. Forecast Encompassing Test: Full Data Period



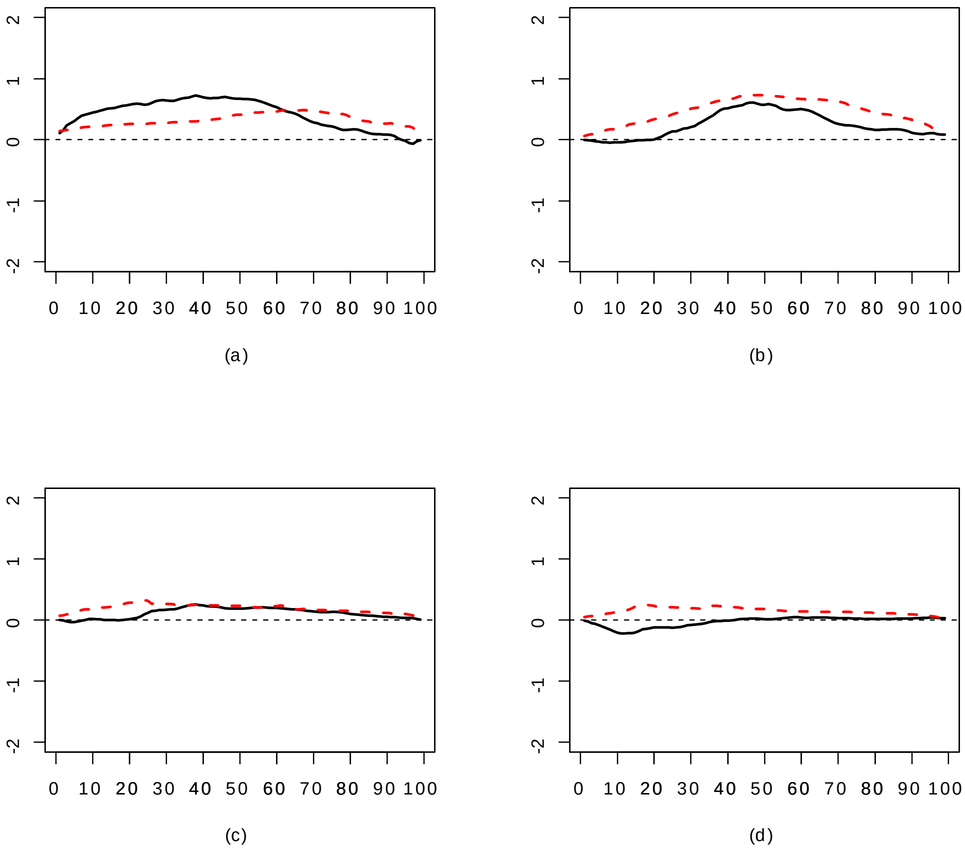
Notes: The solid black line is the estimates of $\hat{\lambda}_T^{(i)}\left(\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)\right)$ for different $SPF(i)$. The abscissa represents the ith SPF-percentile. The dashed red line is the 5% asymptotic critical values $1.645{\times}\mathrm{se}\left(\hat{\lambda}_T^{(i)}\left(\hat{\alpha}_T\left(\mathbf{f}^{GB}\right)\right)\right)$, and the dotted line is for $H_0 : \lambda^{(i)} = 0$. Panel (a) is for real output growth forecast with $h = 1$, Panel (b) is for real output growth forecast with $h = 4$, Panel (c) is for inflation forecast with $h = 1$, and Panel (d) is for inflation forecast with $h = 4$.

Figure 2. Forecast Encompassing Test: Before-1982



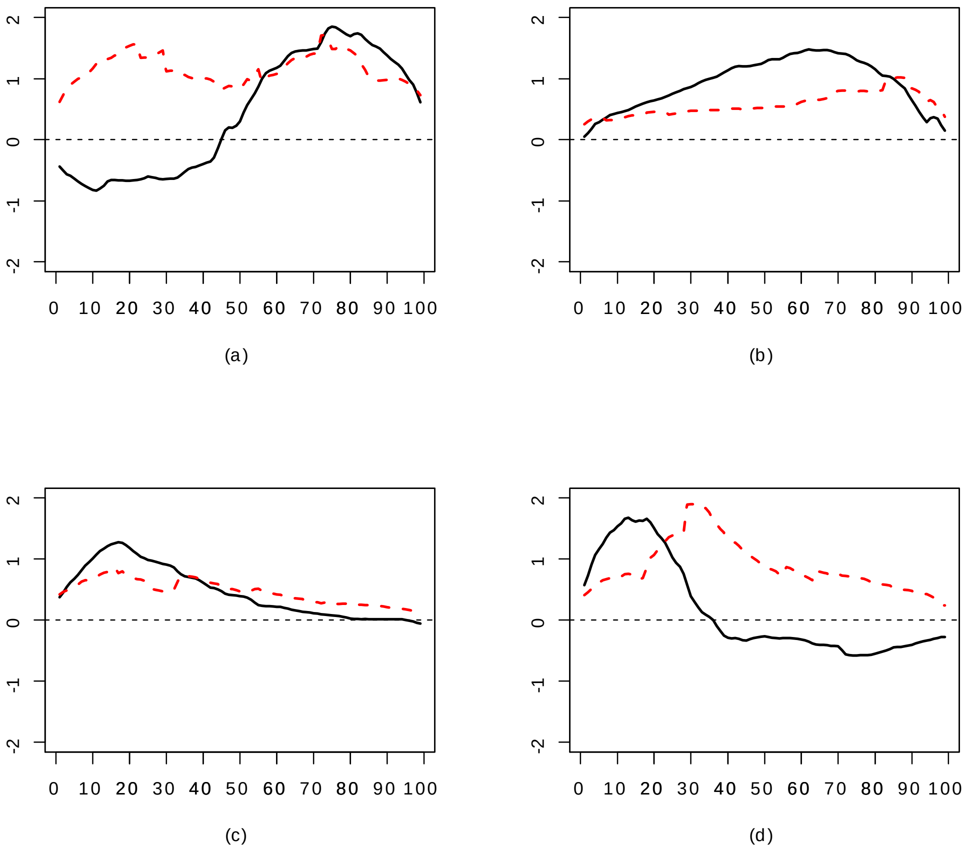
Notes: See Figure 1.

Figure 3. Forecast Encompassing Test: 1982-2000



Notes: See Figure 1.

Figure 4. Forecast Encompassing Test: After-2000



Notes: See Figure 1.