

# Macroeconomic Uncertainty Indices Based on Nowcast and Forecast Error Distributions

By BARBARA ROSSI AND TATEVIK SEKHPOSYAN\*

\* Rossi: ICREA-University of Pompeu Fabra, Barcelona GSE and CREI, c/Ramon Trias Fargas 25/27, Barcelona 08005, Spain (e-mail: [barbara.rossi@upf.edu](mailto:barbara.rossi@upf.edu)). Sekhposyan: Texas A&M University, 4228 TAMU, College Station, TX 77843, United States (email: [tsekhposyan@tamu.edu](mailto:tsekhposyan@tamu.edu)). Acknowledgments. We thank C. Scotti for sharing the uncertainty index proposed in her paper, S. Vahey and participants of seminars at CREI, the University of Warwick, ASSA, CEF, CFE, Advances in Applied Macro-Finance and Forecasting conferences for comments. This research is supported by the Spanish Ministry of Economy and Competitiveness (Grant ECO2012-33247).

The Great Recession of 2007:IV-2009:II sparked great interest in understanding uncertainty and its effects on the macroeconomy. This paper introduces a new approach to measure uncertainty. We start from the same premise as in Jurado et al. (2014), that is: “What matters for economic decision making is whether the economy has become more or less predictable; that is, less or more uncertain.” However, as opposed to Jurado et al. (2014), the uncertainty index we propose relies on the unconditional likelihood of the observed outcome. More specifically, our proposed index is the percentile in the historical distribution of forecast errors associated with the realized forecast error. For example, if, according to the unconditional

distribution of forecast errors, a forecast error of 2% is in the 99-th percentile and the realized forecast error is indeed 2%, then we conclude that there is substantial uncertainty.

The measure we propose is a complementary and possibly more general measure of uncertainty based on assessing the likelihood of a realization. The attractive feature of our approach is that it summarizes the information in the ex-ante probabilistic forecast as well as in the ex-post realization. In addition, as it is a distribution-based measure of uncertainty, it distinguishes between periods of high and low uncertainty measured by probabilities as opposed to arbitrary thresholds. Finally, our measure also has the advantage of providing information on whether the uncertainty is upside or downside.

Our measure of uncertainty relies on the model used to forecast the economy. We focus on the Survey of Professional Forecasters’ (SPF) forecasts since they are regarded to be well performing benchmarks (Faust and Wright, 2013).<sup>1</sup>

<sup>1</sup> Online Appendix shows that our results are robust to using model-based, namely equal weighted combination forecasts.

Clearly, the choice of the representative macroeconomic variable used in our proposed index is very important. In particular, since our goal is to propose an index that measures uncertainty of the state of the economy, we focus on macroeconomic variables that are representative of the business cycle, such as Gross Domestic Product (GDP).<sup>2</sup>

Our contribution differs from those in the literature for several reasons. First, some of the existing measures (e.g. Bloom, 2009) identify uncertainty as the unconditional volatility of certain series (e.g. the stock market returns). As discussed in Jurado et al. (2014), this approach cannot distinguish between expected and unexpected movements; we focus, instead, on the uncertainty relative to the predicted outcome. Second, other existing measures (e.g. Jurado et al., 2014) focus on the variance of the forecast errors; our measure is a complementary and more general way to describe uncertainty. In fact, we measure the unconditional probability of observing the realized value. The two measures are different, for example, in situations where the ex-ante predictive uncertainty, measured by certain deciles of forecast error distribution, changes, yet the variance of the forecast error remains

the same. In addition, measuring uncertainty by the variance of the forecast errors implies that positive and negative outcomes are symmetric and of the same importance; our measure, instead, allows for asymmetry. Finally, our measure is based on the realized forecast error distribution, thus it provides a measure that summarizes uncertainty in the data as well as uncertainty associated with parameter estimation (for model-based forecasts).

Our work is also related to other recent contributions. Baker et al. (2013) propose to measure economic policy uncertainty using a news-based policy uncertainty index and other “fundamental” measures of policy uncertainty and dispersion. Scotti (2013) uses surprises from Bloomberg forecasts to construct measures of economic uncertainty. We, instead, measure how likely we were to observe the actual forecast error relative to the ex-ante unconditional forecast error distribution. Furthermore, we distinguish between upside and downside uncertainty, which might affect the macroeconomy in different ways. Segal et al. (2014) also propose to distinguish between positive and negative uncertainty, but focus on realized volatility in high frequency data environment.

<sup>2</sup> Our methodology could also be applied to construct indices based on forecasts of the unobserved state of the economy, although we do

not investigate this in our empirical analysis. In addition, we can also construct variable-specific uncertainty indices as discussed in the online Appendix.

## I. Macroeconomic Uncertainty Index

The macroeconomic uncertainty index we propose is based on comparing the realized forecast error of a macroeconomic variable of interest with the historical forecast error distribution of that variable. If the realization is in the tails of the distribution, we conclude that the realization was very difficult to predict from all the available (past and present) information and the macroeconomic environment is very uncertain.

We focus on a variable of interest that is informative on the state of the business cycle. In particular, we focus on real GDP following Stock and Watson (1999, p. 15), who note that: “although the business cycle technically is defined by co-movements across many sectors and series, (...) the cyclical component of real GDP is a useful proxy for the overall business cycle.” We extract the cyclical component by first differencing. Thus, our main macroeconomic uncertainty index uses real GDP growth - although one can construct other variable-specific indices.

Let the  $h$ -step-ahead forecast error for the scalar variable  $y_{t+h}$  be denoted by  $e_{t+h} = y_{t+h} - E_t(y_{t+h})$ , for  $t = R, \dots, T$ . Let  $p(e)$  denote the forecast error distribution; this could be either the unconditional density of forecast errors (which results in an ex-post measure of

uncertainty) or the density of forecast errors up to a certain point in time (which results in a real-time measure of uncertainty). Forecast errors can be obtained using forecasts from parametric models or surveys.

Our proposed index is based on the cumulative density of forecast errors evaluated at the actual realized forecast error,  $e_{t+h}$ :  $U_{t+h} = \int_{-\infty}^{e_{t+h}} p(e)de$ . By construction,  $U_{t+h}$  is between zero and one. A large value of the index (close to one, say) indicates that the realized value was very different from the expected value. In particular, a realized value much higher than the expected value measures a positive “shock.” Conversely, a very small value of the index (close to zero, say) indicates that the realized value was much smaller than its expected value, i.e. a negative, unexpected “shock.” Note that uncertainty is measured by the forecast error realization relative to its ex-ante probability. To convey information about the asymmetry in uncertainty, we propose to construct both “positive” and “negative” uncertainty indices over time:

$$(1) U_{t+h}^+ = \frac{1}{2} + \max\left\{U_{t+h} - \frac{1}{2}, 0\right\}$$

$$(2) U_{t+h}^- = \frac{1}{2} + \max\left\{\frac{1}{2} - U_{t+h}, 0\right\}$$

Thus,  $U_{t+h}^+$  measures uncertainty arising from news or outcomes that are unexpectedly positive (e.g. higher GDP than expected) and  $U_{t+h}^-$  measures uncertainty associated with

news or outcomes that are unexpectedly negative (e.g. lower GDP than expected). We refer to  $U_{t+h}^+$  as a measure of upside uncertainty, and to  $U_{t+h}^-$  as a measure of downside uncertainty. By construction,  $U_{t+h}^+$  and  $U_{t+h}^-$  are between one-half and one. We define an overall uncertainty index as:

$$(3) \quad U_{t+h}^* = \frac{1}{2} + \left| U_{t+h} - \frac{1}{2} \right|.$$

To understand our index, consider Figure 1. The upper panel plots the unconditional probability distribution function (pdf) of the forecast errors (dotted line with circles) in real output growth forecasts from 1968:IV-2014:I. In addition, we plot the forecast errors associated with two recent episodes of interest. The darker (blue) vertical bar on the left identifies the forecast error associated with current quarter real GDP growth forecast in 2008:III, the quarter of Lehman's bankruptcy. The lighter vertical bar on the right (in green) depicts the forecast error in 2009:III, the first quarter after the trough of the Great Recession. The middle panel plots the cumulative distribution function (cdf) corresponding to the pdf in the upper panel, that is  $U_{t+h}$ . The figure suggests that the ex-ante probability of observing the forecast error realized in 2008:III was 0.07, while it was 0.69 for the forecast error realized in 2009:III. The deviation of these probabilities from the average occurrence (0.50) is larger in 2008:III than in 2009:III.

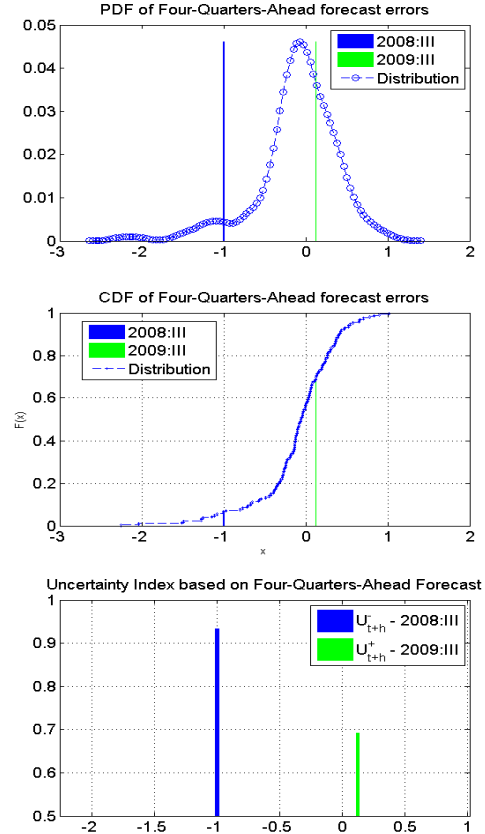


FIGURE 1. UNCERTAINTY EXAMPLE

*Note:* The figures depict the empirical pdf and cdf distributions of SPF forecast errors of real GDP growth as well as the realized forecast errors in the quarter of Lehman bankruptcy (2008:III) and in the first quarter after the Great Recession (2009:III).

Thus, our indices  $U_{t+h}^+$  and  $U_{t+h}^-$  assign a higher uncertainty to 2008:III as shown in the bottom panel. We can quantify the difference in the uncertainty levels with probabilities: the realization in 2008:III had 24% less chance of occurring than that in 2009:III. Thus, we associate 2008:III with downside uncertainty and 2009:III with upside uncertainty.

Figure 2 plots our estimated uncertainty index, together with its 90<sup>th</sup> percentile value. The index is based on GDP forecasts from the SPF by the Philadelphia Fed and the “Advance” release of the GDP. We focus on

the quarterly growth rate of the four-quarter-moving average real GNP/GDP for the current quarter,  $h = 0$ , as well as four quarters ahead,  $h = 4$ . We assume the forecasters know the past realized values from the Real-time dataset (Croushore and Stark, 2001), a fair assumption according to the SPF documentation.<sup>3</sup>

The two upper panels in Figure 2 plot our downside ( $U_{t+h}^-$ ) and upside uncertainty ( $U_{t+h}^+$ ) indices together with NBER recessions dates (shaded areas). It is clear that our measure of downside uncertainty coincides with, and in many occasions leads, the NBER recession dates. The uncertainty measure based on four-quarter-ahead forecasts is less noisy and contains more precise information about the recessions relative to the ones based on the nowcasts. Interestingly, our measure also picks up several episodes of upside uncertainty, notably in the late 1990s, a period associated with under-estimation of productivity growth. The two bottom panels in Figure 2 plot our uncertainty measure in real-time. The real-time measure updates the forecast error distribution each quarter from 1985:I onwards. As shown, the real-time measure of uncertainty is less volatile and the upside and downside uncertainty episodes are more sharply defined.

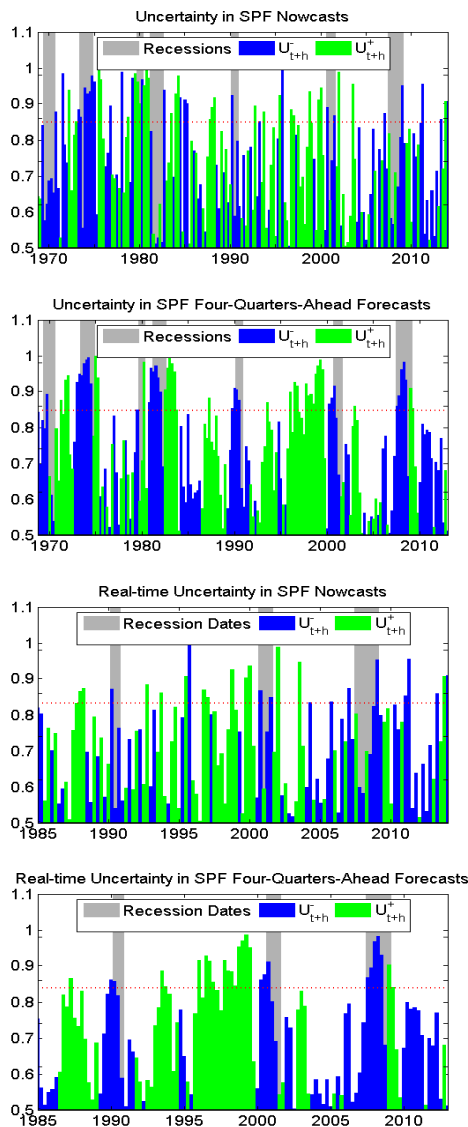


FIGURE 2. UNCERTAINTY INDICES

Note: The figures depict the uncertainty measures obtained from SPF output growth nowcast and four-quarter-ahead forecast error densities.

## II. A Comparison with Existing Measures

We compare our SPF-based macroeconomic uncertainty index associated with four-quarter-ahead GDP growth forecasts

<sup>3</sup> The SPF respondents also provide probabilistic density forecasts of current and following year output growth. Unreported robustness exercises show that uncertainty measures from these densities are

similar, yet less noisy and more clearly leading the cycle. These measures, however, have the drawback of mixing multi-horizon forecasts.

with several indices proposed in the literature, including: VXO as in Bloom (2009); Baker et al.'s (2013) policy uncertainty index, “BBD”; Jurado et al.'s (2014) macroeconomic uncertainty index, “JLN”; and Scotti's (2013) macroeconomic surprise based uncertainty index, “Scotti.” We make the measures comparable by picking index values for the dates (months) closest to the SPF survey’s deadline dates. We further standardize the indices to express them in the same units.

In the common sample period our overall uncertainty index,  $U_{t+h}^*$ , is more closely correlated with VXO than the other measures (corr = 0.29). When we split the measure to account for upside and downside uncertainty, we find that the downside measure is more correlated with “JLN” (corr = 0.37), while the upside measure is more correlated with “VXO” (corr = 0.19) and closely linked, yet negatively correlated, with “JLN” (corr = -0.23).

### III. Uncertainty and the Macroeconomy

In order to assess the macroeconomic impact of uncertainty, we estimate a recursively ordered six-variable Vector Autoregression (VAR) that includes the (log)

of GDP, the (log) of employment, the Federal Funds rate, the (log) of stock prices and the uncertainty index (we consider several indices, one-at-a-time), in addition to a deterministic trend and a constant.<sup>4</sup> We report mean impulse responses to one standard deviation increase in uncertainty as well as the 90% bootstrapped coverage areas based on 2000 simulations.

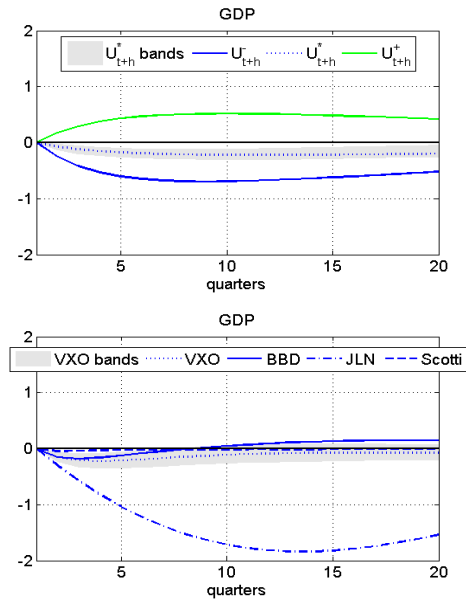


FIGURE 3. IMPACT OF UNCERTAINTY ON GDP

*Note:* The figures depict impulse responses of GDP to various uncertainty shocks measured by various indices.

Figure 3 shows the impact of various uncertainty measures on output. Our overall uncertainty measure,  $U_{t+h}^*$ , only marginally affects output, yet its effects are persistent. Quantitatively these results are similar to the VXO, “BBD” and “Scotti” indices. However,

<sup>4</sup> The VAR specification is the same as in Baker et al.'s (2013), although ours is at a quarterly frequency, and accordingly we use GDP instead of real industrial production. We order the variables as in the benchmark specification of Jurado et al. (2014), i.e. from slow to fast

moving. Our results are robust to using the industrial production index and alternative ordering assumptions of Baker et al. (2013). The lag order is one, selected by the Bayesian Information Criterion. For each uncertainty index the VAR is estimated over a period for which there is available data.

when we distinguish between downside and upside uncertainty, we find that downside measure,  $U_{t+h}^-$ , has a larger effect on output than the overall index. The upside uncertainty index,  $U_{t+h}^+$ , also has significant effects. They are similar in magnitude and opposite in sign to the downside index. The “JLN” index estimates much larger effects on GDP. Furthermore, the responses are statistically different from those based on the VXO and other measures.

#### IV. Conclusions

This paper proposes new measures of macroeconomic uncertainty. Our proposed indices quantify how unexpected the mistakes in predicting relevant macroeconomic outcomes are relative to their historic distributions. Moreover, they characterize uncertainty in terms of probabilities. For the following reasons, our measures differ from those in the literature. First, they distinguish between upside and downside uncertainty. Second, they uncover that the late 1990s are characterized by upside uncertainty. Third, we find that the upside uncertainty has significant macroeconomic effects, which remains to be explained theoretically. Our framework can be extended to construct joint measures of uncertainty for groups of variables. This could be useful if, for instance, the Federal Reserve

aimed to quantify the overall uncertainty in the labor market.

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