Understanding the Sources of Macroeconomic Uncertainty

Barbara Rossi, Tatevik Sekhposyan, Matthieu Soupre

ICREA - UPF    Texas A&M University    UPF

European Central Bank

June 4, 2016
Objective of the Paper

• Recent economic events (great recession, unconventional monetary policy, fiscal cliff, etc.) sparked great interest in understanding uncertainty and its macroeconomic impact.

  • Stock and Watson (2012) suggests the liquidity-risk and uncertainty shocks to be the most important contributor to the decline in the U.S. GDP during the Great Recession
  • 2/3 of the recession’s decline in GDP and employment

• There has been increased emphasis in trying to characterize uncertainty, which is inherently unobserved.

• There are many measures of uncertainty
  • ex-ante, ex-post, disagreement, mean-squared forecast errors, forecast error distributions, etc.

• Our paper proposes to reconcile the various measures.
The Measure of Uncertainty Matters

FIGURE 3. IMPACT OF UNCERTAINTY ON GDP

Note: The figure depicts impulse responses of GDP to uncertainty shocks measured by various indices.
The Measure of Uncertainty Matters
Summary of Various Measures

- Based on some observables
  - realized volatility, implied volatility (VIX, VXO, Bloom, 2009), Baker, Bloom & Davis (2015) index

- Measures of ex-ante uncertainty or perceived uncertainty
  - typically based on surveys
  - disagreement as a special case

- Ex-post measures of uncertainty
  - based on forecast errors
  - Has the notion that “What matters for economic decision making is whether the economy has become more or less predictable; that is, less or more uncertain.”
Our Contribution

- We propose a **predictive distribution-based** uncertainty measure.

- We can further decompose this measure to
  - measures of **aggregate uncertainty** and **disagreement**
  - measures of bias (**Knightian**) and realized variance (**risk**)
  - measures of **ex-ante** and **ex-post** uncertainty

- We provide evidence of differential macroeconomic impact.

- Provide simulation experiments documenting the evolution of the channels of the various measures of uncertainty.
Risk versus Knightian Uncertainty

- **Risk** - uncertainty stemming from the fact that a realization of the state of nature is not known in advance even if all possible states of nature and their likelihoods could be reasonably contemplated.
  - various measures of volatility

- **Knightian Uncertainty** - uncertainty stemming from the fact that it is not possible to assign correct probabilities to future outcomes or agree on the probabilities.
  - depends on the realization or the disagreement among forecasted probabilities
Understanding the Sources of Macroeconomic Uncertainty

Uncertainty Index based on Density Forecasts

- At a particular point in time you have
  1. the density forecast
  2. realization
Uncertainty Index based on Density Forecasts

Work with a binary variable and cdf instead. Let

- $x_{t+h}(r) = 1\{y_{t+h} < r\}$
- $p_{s,t+h|t}(r) = P(x_{t+h}(r) = 1|\Omega_{s,t})$

For a given threshold $r$, $s$-th forecaster’s uncertainty is:

$$u_{s,t+h|t}(r) = E\left[\left(x_{t+h}(r) - p_{s,t+h|t}(r)\right)^2 | \mathcal{S}_{t-R}\right].$$

Has the spirit of a forecast error for a particular quantile.
The Uncertainty Index

- The measure of uncertainty is defined as the average of the individual uncertainty measure across forecasters:

\[
\begin{align*}
    u_{t+h|t}(r) &= \frac{1}{N} \sum_{s=1}^{N} u_{s,t+h|t}(r) \\
    &= \frac{1}{N} \sum_{s=1}^{N} \mathbb{E} \left[ (x_{t+h}(r) - p_{s,t+h|t}(r))^2 \bigg| \mathcal{F}_{t-R} \right]
\end{align*}
\]

- Similar to Lahiri & Sheng (2010), Zarnowitz & Lambros (1987) for a particular point in a distribution

- Uncertainty

\[
    U_{t+h|t} = \int_{-\infty}^{+\infty} u_{t+h|t}(r) \, dr
\]
Decomposition I: Aggregate Uncertainty & Disagreement

\[ u_{t+h|t}(r) = \frac{1}{N} \sum_{s=1}^{N} E_t \left[ (x_{t+h}(r) - p_{t+h|t} + p_{t+h|t} - p_{s,t+h|t}(r))^2 \right] \]

\[ = E_t \left( x_{t+h}(r) - p_{t+h|t}(r) \right)^2 \]

\[ + \frac{1}{N} \sum_{s=1}^{N} E_t \left[ (p_{t+h|t}(r) - p_{s,t+h|t}(r))^2 \right] \]

\[ = u^A_{t+h|t}(r) + d_{t+h|t}(r), \]

\[ U_{t+h|t} = \int_{-\infty}^{\infty} u^A_{t+h|t}(r) \, dr + \int_{-\infty}^{\infty} d_{t+h|t}(r) \, dr \]

\[ \underbrace{U_{t+h|t}}_{\text{“Uncertainty”}} = \underbrace{U^A_{t+h|t}}_{\text{“Aggregate Uncertainty”}} + \underbrace{D_{t+h|t}}_{\text{“Disagreement”}} \]
Decomposition II: Aggregate Uncertainty as Risk and Knightian Uncertainty

\[ u_{t+h}^A (r) = \left( \left[ E (p_{t+h|t} (r) | \mathcal{S}_{t-R}^t) - E (x_{t+h} (r) | \mathcal{S}_{t-R}^t) \right]^2 \right) + V (x_{t+h} (r) | \mathcal{S}_{t-R}^t) + V (p_{t+h|t} (r) | \mathcal{S}_{t-R}^t) - 2 \text{Cov} (x_{t+h} (r) , p_{t+h|t} (r) | \mathcal{S}_{t-R}^t) , \]

\[ U_{t+h|t}^A \approx B_{t+h|t} + V_{t+h|t} + \text{Vol}_{t+h|t} \]

“Mean-Bias” “Dispersion” “(Realized) Risk”

Putting things together

\[ U_{t+h|t} \approx \text{Vol}_{t+h|t} + B_{t+h|t} + D_{t+h|t} \]

“(Realized) Risk” “Knightian Uncertainty”
Decomposition III: Aggregate Uncertainty as Ex-Ante and Ex-Post Uncertainty

- Let $\hat{y}_{t+h|t} \sim N(\mu_{t+h|t}, \sigma^2_{t+h|t})$.
- This is the density forecast.

\[ U^A_{t+h|t} = E|Y - y_{t+h}| - 0.5E|Y - Y'| = \]
\[
\left[ 2\sigma_{t+h|t} \phi \left( \frac{y_{t+h} - \mu_{t+h|t}}{\sigma_{t+h|t}} \right) + (y_{t+h} - \mu_{t+h|t}) \left( 2\Phi \left( \frac{y_{t+h} - \mu_{t+h|t}}{\sigma_{t+h|t}} \right) \right) \right]
\]

- "Ex-Post"

\[-\sigma_{t+h} / \sqrt{\pi}\]

- "Ex-Ante"
Recap

We propose

- to look at total uncertainty as an average squared **distributional** forecast error
- still has the notion that the **unpredictable elements** constitute to uncertainty

We can distinguish between

- aggregate uncertainty and disagreement
- realized risk and Knightian uncertainty
- ex-ante and ex-post uncertainty
Empirical Implementation

- Density forecasts from the Survey of Professional Forecasters provided by the Philadelphia Fed
  - assign a probability value over pre-defined intervals for a variety of variables
  - forecasts are for the current year and next year year-over-year growth rates

- Use Dovern et al. (2012) re-weighting scheme to get 4-step-ahead forecasts:

  \[
  \hat{f}_{t+4|t}^{FH} = \frac{k}{4} \hat{f}_{t+k|t}^{FE} + \frac{4-k}{4} \hat{f}_{t+k+4|t}^{FE}.
  \]

- 4-quarter-ahead growth of “Advance” release in real time

- Empirical counterparts with 4-quarter-moving averages
Data

- Predictive quantiles of SPF
Data

- Predictive quantiles of SPF
Data

- Predictive quantiles of SPF versus the realizations
The role of disagreement is very small
Disagreement lags the aggregate measure
Results: Decompositions II and III

Knightian vs. Realized Risk

- Ex-ante volatility larger than the realized volatility
- Ex-ante volatility is smoother than the realized one
- Knightian uncertainty and ex-post are more important for the aggregate uncertainty
Resolution of Uncertainty over Time

![Uncertainty](image1)

![Aggregate Uncertainty](image2)

![Disagreement](image3)
Resolution of Uncertainty over Time

- $U_{t+h|t}$
- $V_{t+h|t}$
- $B_{t+h|t}$
- $\text{Vol}_{t+h|t}$
- $\text{Cov}_{t+h|t}$
Results: Decomposition I for Inflation

Uncertainty, Aggregate Uncertainty and Disagreement

- Uncertainty
- $U^A_{t+h|t}$
- Disagreement
Results: Decompositions II and III for Inflation

Knightian vs. Risk

Ex-Ante vs Ex-Post Decomposition

- Ex-ante volatility larger than the realized volatility
- Ex-ante volatility is smoother than the realized one
- Bias and ex post are more important for the aggregate uncertainty, though the latter more for dynamics
Comparison with some Existing Measures

- Jurado et al. (2015) similar to ex-post
- Baker et al. (2015) similar to ex-ante
- Roughly similar patterns
Macroeconomic Impact

- Based on (the log of) real GDP, (the log of) employment, the Federal Funds rate, (the log of) stock prices and uncertainty indices + const

- Uncertainty indices are standardized

- Identification according to recursive ordering

- Lag length is selected via BIC

- Robust to an 11 variable specification
Decomposition I

- Insignificant response to disagreement
• Insignificant response to realized risk
• Effects of dispersion are expansionary
• Effects of ex-ante uncertainty are insignificant
Glancing through a lens of a model

- Model and parameter values inspired by Ilut and Schneider (2014)

- Data is generated by
\[ Z_{t+1} = \rho_z Z_t + \mu_t^* + u_{t+1} \]

- \( \mu_t^* \) ambiguous component, \( \mu_t^* \sim iidN(0, \sigma_z - \sigma_u) \)
  \[ \rightarrow \] lack confidence to assign probabilities to all relevant events

- \( u_{t+1} \) random component (capturing risk), \( u_{t}^* \sim iidN(0, \sigma_u) \)
  \[ \rightarrow \] can assign probabilities to all relevant events

- Agents get noisy signals about \( \mu_t^* \)
  \[ \rightarrow \] conflicting news reports, disagreement among experts, poor information, etc.
Glancing through a lens of a model

- Data is generated by
  \[ Z_{t+1} = \rho_z Z_t + \mu_t^* + u_{t+1} \]

- Agents get noisy signals about \( \mu_t^* \)

- Their beliefs set is \( \mu_t \in [-a_t, -a_t + 2|a_t|] \)

- They choose \( \mu_t^{**} = \min[-a_t, -a_t + 2|a_t|] \), worst case scenario

- While the agents get signals according to
  \[ a_{t+1} - \bar{a} = \rho_a (a_t - \bar{a}) + \sigma_a \epsilon^a_{t+1}. \]

- \( \bar{a} = n\sigma_z \) and \( \sigma_a = \sigma_n \sigma_z \) for \( n \in (0, 1) \)
Glancing through a lens of a model

General notions about the model:

- Ambiguity is about the mean.

- It yields a perceived law of motion that is misspecified in the mean.

- The shocks to risk ($\sigma_u$) not only affect the second moment dynamics, but can propagate through the mean.
  $\rightarrow$ It affects the width of the confidence set.

- Different than the news shocks since the signal does not need to be validated by a realization.
Glancing through a lens of a model

- Baseline Parameter Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho_z$</td>
<td>0.625</td>
<td>estimated</td>
</tr>
<tr>
<td>$\rho_a$</td>
<td>0.887</td>
<td>IS mode</td>
</tr>
<tr>
<td>$n$</td>
<td>0.995</td>
<td>IS mode</td>
</tr>
<tr>
<td>$\sigma_u$</td>
<td>0.780</td>
<td>estimate</td>
</tr>
<tr>
<td>$\sigma_\mu$</td>
<td>0.500</td>
<td>arbitrary</td>
</tr>
<tr>
<td>$\sigma_n$</td>
<td>0.134</td>
<td>IS mode</td>
</tr>
</tbody>
</table>

- Simulate for 254 periods, with a burn in of 100.

- Scenarios
  1. changing level of ambiguity - change in the quality of the mean signal
  2. changing level of risk - implies change in the ambiguity mean and variance
  3. changing risk in a model with no ambiguity
Simulation Results

1. Changing the Level of Ambiguity

\[ n = 0.2 \quad n = 0.8 \]
Simulation Results

2. Changing the Level of Risk

\[ \sigma_u = 0.3 \quad \sigma_u = 1 \]
Simulation Results

3. Changing the Level of Risk, no Ambiguity

\[ \sigma_u = 0.3 \]

\[ \sigma_u = 1 \]
Scenario 4: Increasing Cross-Sectional Dispersion in Ambiguity

\[ \sigma_{n,L} = 0.5 \]

\[ \sigma_{n,L} = 1 \]

Uncertainty, Aggregate Uncertainty and Disagreement

Knightian Uncertainty/Realized Risk

Ex-Ante vs. Ex-Post Decomposition
Conclusions

- Propose a way to reconcile various measures of uncertainty.

- They differ with their business cycle dynamics, as well as macroeconomic impact.

- One can reconcile the dynamics of the various measures of uncertainty with a model with ambiguity.