Understanding the Sources of Macroeconomic Uncertainty

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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

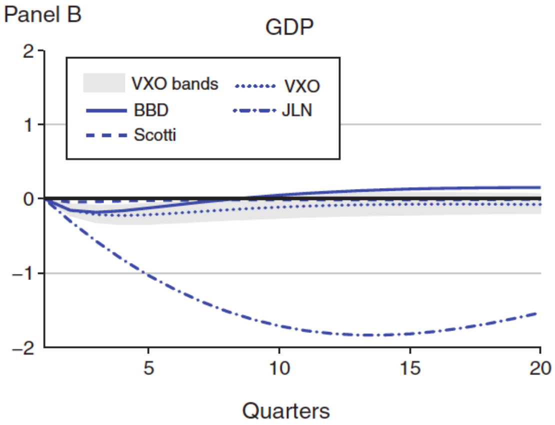
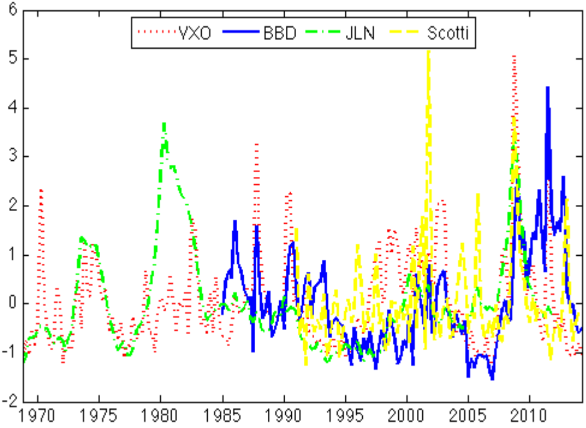


FIGURE 3. IMPACT OF UNCERTAINTY ON GDP

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
  - Clements (2015), Leduc & Liu (2015), D'Amico & Orphanides (2014), Patton & Timmermann (2010), etc.
- 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."
  - Jurado, Ludvigson & Ng (2015), Rossi & Sekhposyan (2015), Scotti (2013), etc.

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

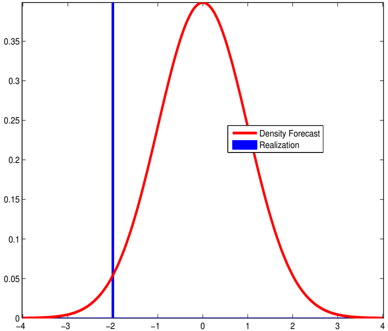
- Risk - uncertainty stemming from the fact that a realization of the state of nature is not known in advance even if all possible states of nature and their likelihoods could be reasonably contemplated.
  - various measures of volatility

- 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

Uncertainty Index based on Density Forecasts

- At a particular point in time you have

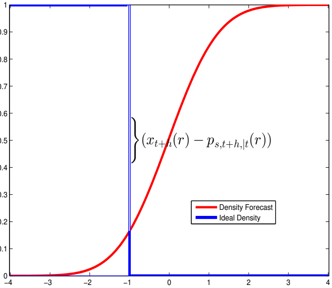
  [1.] the density forecast [2.] realization



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:

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

- Has the sprit 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:

$$\begin{aligned} u_{t+h|t}(r) &= \frac{1}{N}\sum_{s=1}^{N} u_{s,t+h|t}(r) \\ &= \frac{1}{N}\sum_{s=1}^{N} E\left[\left(x_{t+h}(r) - p_{s,t+h|t}(r)\right)^2 |\Im_{t-R}^{t}\right] \end{aligned}$$

- 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

$$\begin{aligned} u_{t+h|t}(r) &= \frac{1}{N}\sum_{s=1}^{N} E_t\left[\left(x_{t+h}(r) - p_{t+h|t} + p_{t+h|t} - p_{s,t+h|t}(r)\right)^2\right] \\ &= E_t\left(x_{t+h}(r) - p_{t+h|t}(r)\right)^2 \\ &+ \frac{1}{N}\sum_{s=1}^{N} E_t\left[\left(p_{t+h|t}(r) - p_{s,t+h|t}(r)\right)^2\right] \\ &= u^A_{t+h|t}(r) + d_{t+h|t}(r), \end{aligned}$$

$$\begin{aligned} U_{t+h|t} &= \int_{-\infty}^{\infty} u^A_{t+h|t}(r)\,dr + \int_{-\infty}^{\infty} d_{t+h|t}(r)\,dr \\ \underbrace{\phantom{U_{t+h|t}}}_{\text{“Uncertainty”}} &= \underbrace{U^A_{t+h|t}}_{\text{“Aggregate Uncertainty”}} + \underbrace{D_{t+h|t}}_{\text{“Disagreement”}} \end{aligned}$$

Decomposition II: Aggregate Uncertainty as Risk and Knightian Uncertainty

$$\begin{aligned} u^{A}_{t+h}(r) &= \left(\left[E\left(p_{t+h|t}(r) \,|\Im^{t}_{t-R} \right) - E\left(x_{t+h}(r) \,|\Im^{t}_{t-R} \right) \right]^{2} \right) \\ &+ V\left(x_{t+h}(r) \,|\Im^{t}_{t-R} \right) + V(p_{t+h|t}(r) \,|\Im^{t}_{t-R}) \\ &- 2Cov(x_{t+h}(r), p_{t+h|t}(r) \,|\Im^{t}_{t-R}), \end{aligned}$$

$$U^{A}_{t+h|t} \approx \underbrace{B_{t+h|t}}_{\text{“Mean-Bias”}} + \underbrace{V_{t+h|t}}_{\text{“Dispersion”}} + \underbrace{Vol_{t+h|t}}_{\text{“(Realized) Risk”}}$$

Putting things together

$$U_{t+h|t} \approx \underbrace{Vol_{t+h|t}}_{\text{“(Realized) Risk”}} + \underbrace{B_{t+h|t} + D_{t+h|t}}_{\text{“Knightian Uncertainty”}}$$

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.

$$U^A_{t+h|t} = E|Y - y_{t+h}| - 0.5E|Y - Y'| =$$

$$\underbrace{\left[2\sigma_{t+h|t}\phi\left(\frac{y_{t+h}-\mu_{t+h|t}}{\sigma_{t+h|t}}\right) + \left(y_{t+h}-\mu_{t+h|t}\right)\left(2\Phi\left(\frac{y_{t+h}-\mu_{t+h|t}}{\sigma_{t+h|t}}\right)\right.\right.}_{\text{"Ex-Post"}}$$

$$-\underbrace{\sigma_{t+h}/\sqrt{\pi}}_{\text{"Ex-Ante"}}$$

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
  - $\rightarrow$ assign a probability value over pre-defined intervals for a variety of variables
  - $\rightarrow$ 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:

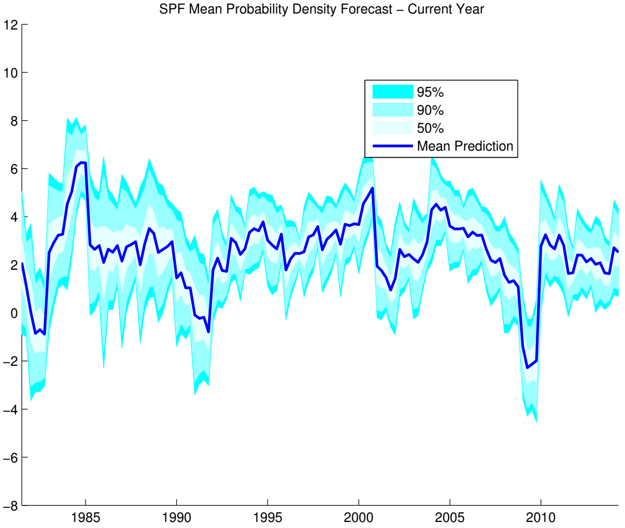
$$\widehat{f}^{FH}_{t+4|t} = \frac{k}{4}\widehat{f}^{FE}_{t+k|t} + \frac{4-k}{4}\widehat{f}^{FE}_{t+k+4|t}.$$

- 4-quarter-ahead growth of "Advance" release in real time

- Empirical counterparts with 4-quarter-moving averages

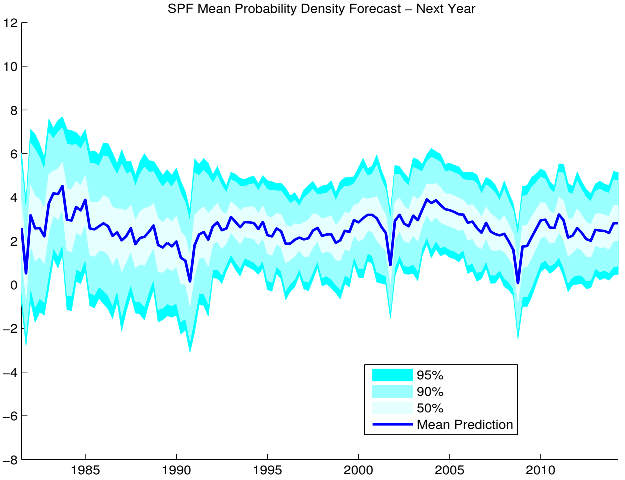
Data

- Predictive quantiles of SPF



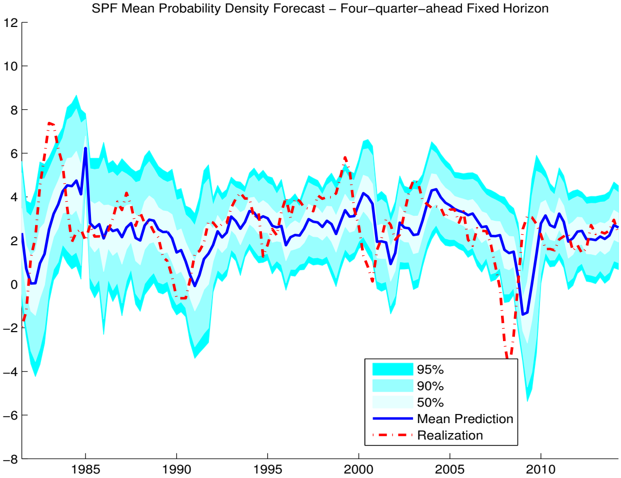
Data

- Predictive quantiles of SPF

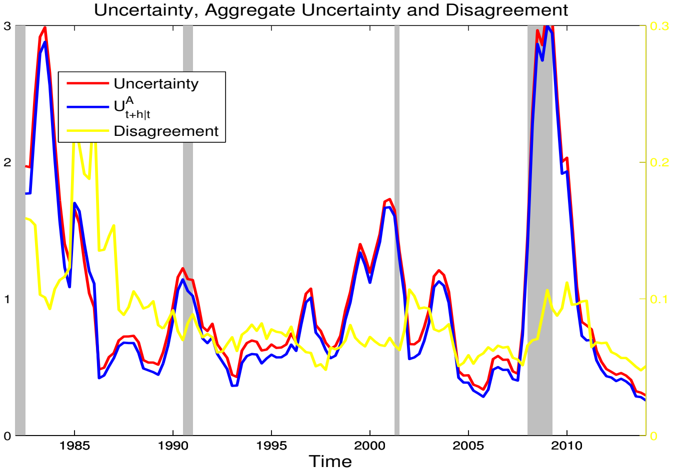


Data

- Predictive quantiles of SPF versus the realizations



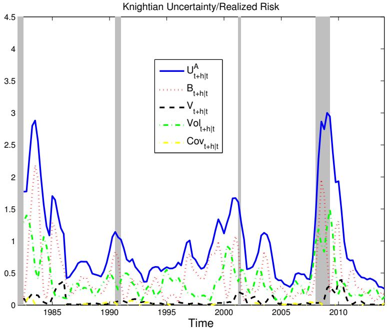
Results: Decomposition I



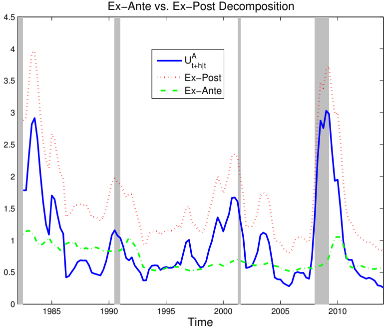
- The role of disagreement is very small
- Disagreement lags the aggregate measure

Results: Decompositions II and III

Knightian vs. Realized Risk

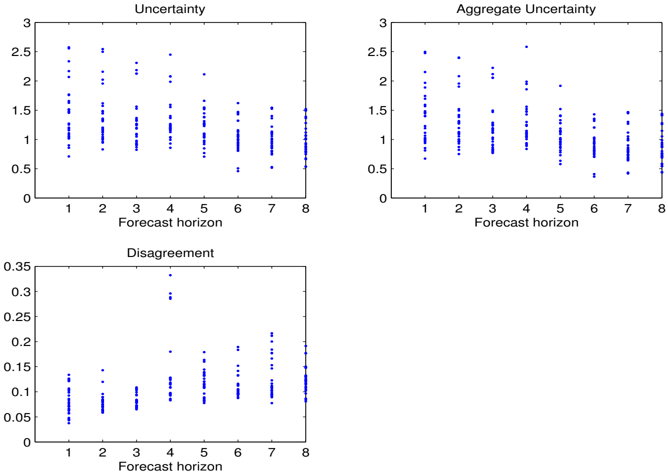


Ex-Ante vs Ex-Post

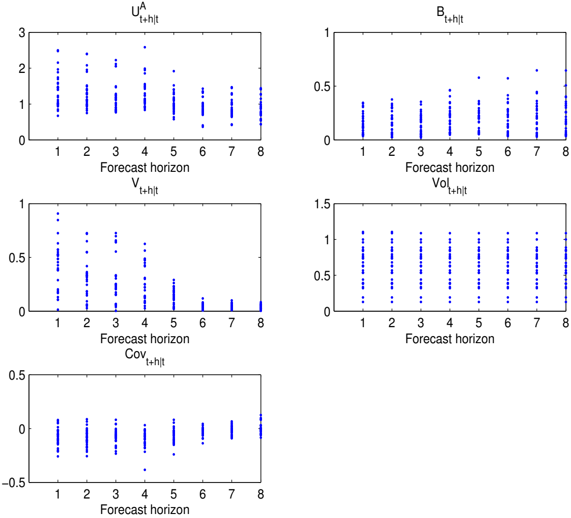


- Ex-ante volatility larger than the realized volatility
- Ex-ante volatility is smoother than the realized one
- Knightian uncertainty and ex-post are more important for the aggregate uncertainty

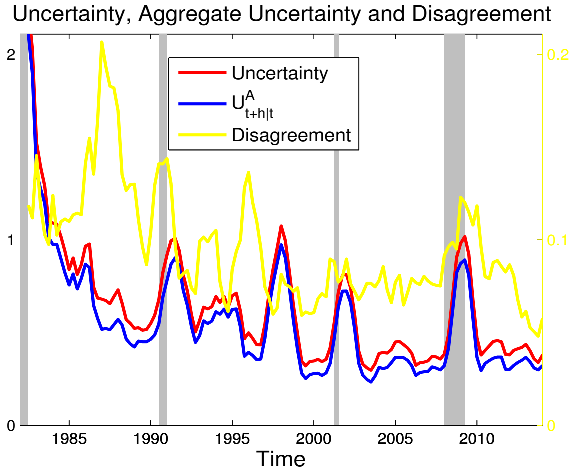
Resolution of Uncertainty over Time



Resolution of Uncertainty over Time

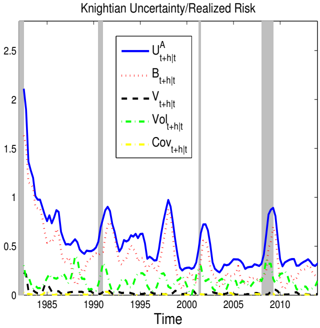


Results: Decomposition I for Inflation

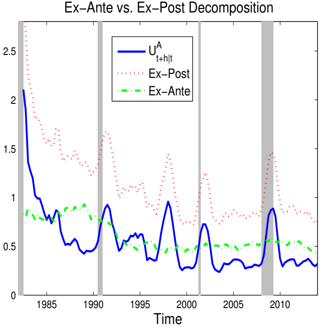


Results: Decompositions II and III for Inflation

Knightian vs. Risk

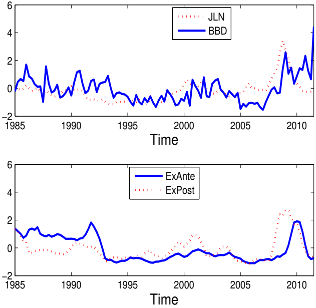


Ex-Ante vs Ex-Post



- 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

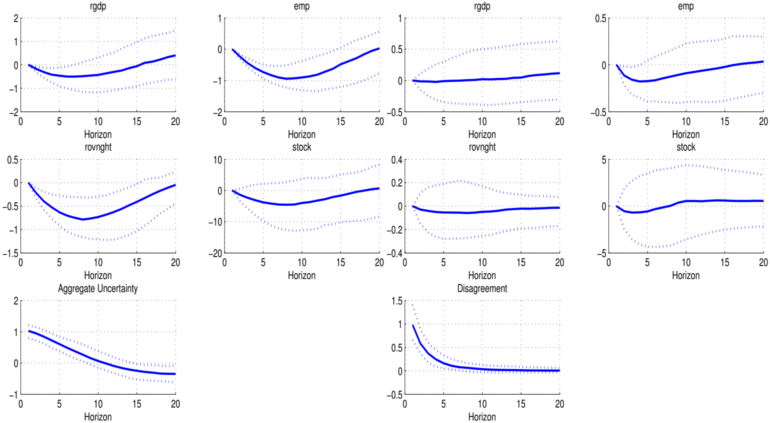


- Jurado et al. (2015) similar to ex-post
- Baker et al. (2015) similar to ex-ante
- Roughly similar patterns

Macroeconomic Impact

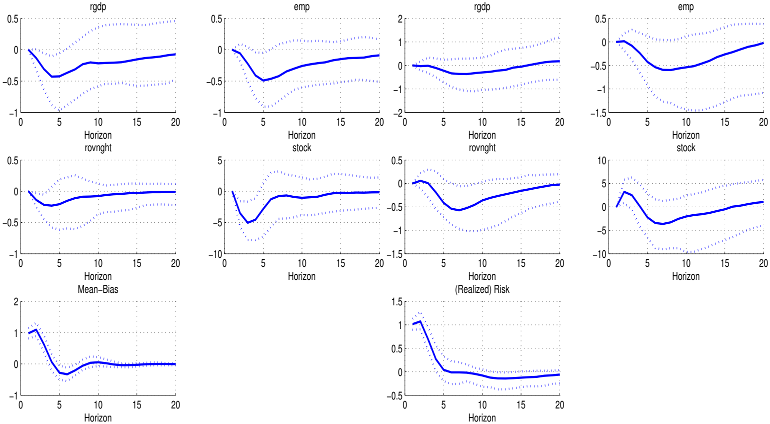
- Based on (the log of) real GDP, (the log of) employment, the Federal Funds rate, (the log of) stock prices and uncertainty indices + const
- Uncertainty indices are standardized
- Identification according to recursive ordering
- Lag length is selected via BIC
- Robust to an 11 variable specification

Decomposition I



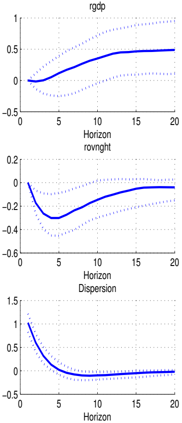
- Insignificant response to disagreement

Decomposition II



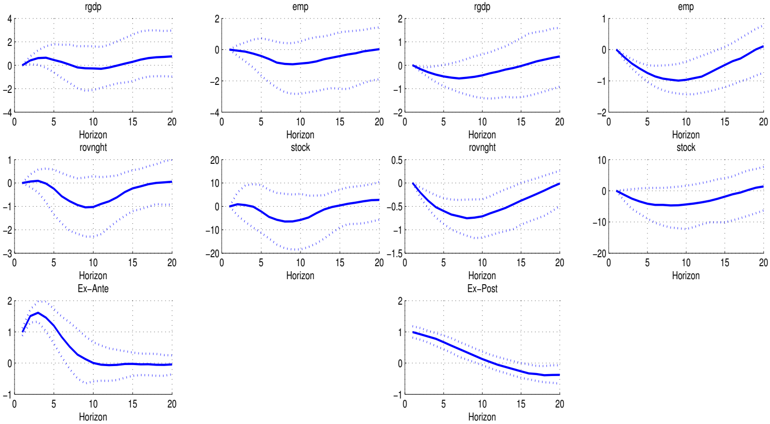
- Insignificant response to realized risk

Decomposition II



- Effects of dispersion are expansionary

Decomposition III



- 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

$$Z_{t+1} = \rho_z Z_t + \mu_t^* + u_{t+1}$$

- μ_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 μ_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 μ_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

$$a_{t+1} - \bar{a} = \rho_a(a_t - \bar{a}) + \sigma_a \epsilon_{t+1}^a.$$

- $\bar{a} = n\sigma_z$ 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 (σ_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

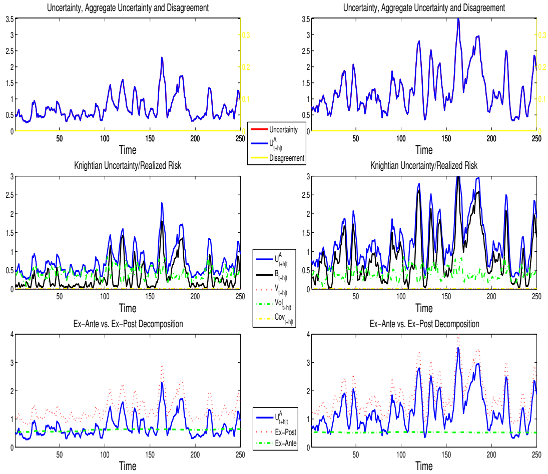
ρ_z	0.625	estimated
ρ_a	0.887	IS mode
n	0.995	IS mode
σ_u	0.780	estimate
σ_μ	0.500	arbitrary
σ_n	0.134	IS mode

- 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

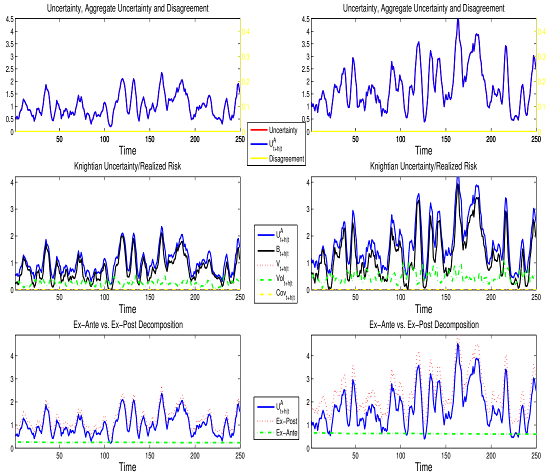
$n = 0.2$ $\qquad$ $n = 0.8$



Simulation Results

2. Changing the Level of Risk

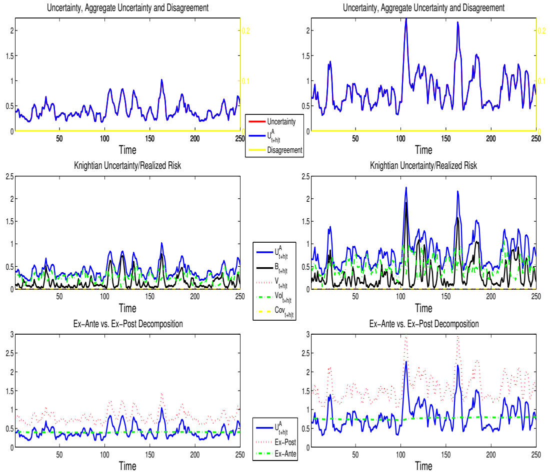
$\sigma_u = 0.3$ $\sigma_u = 1$



Simulation Results

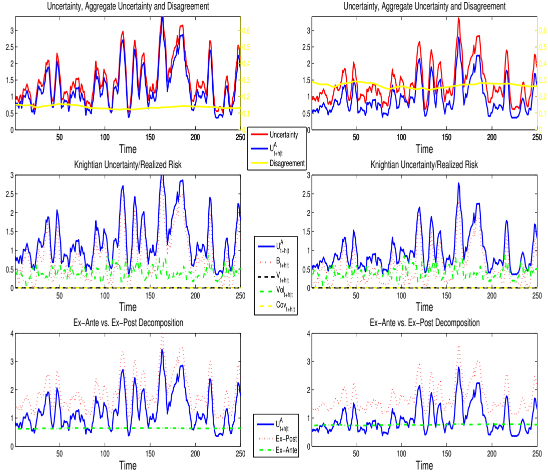
3. Changing the Level of Risk, no Ambiguity

$\sigma_u = 0.3$ $\sigma_u = 1$



Scenario 4: Increasing Cross-Sectional Dispersion in Ambiguity

$\sigma_{n,I} = 0.5$ $\sigma_{n,I} = 1$



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.