Assessing Policy-Relevant Uncertainty and Risks

Francesca Loria
Federal Reserve Board

Bilateral Assistance and Capacity Building for Central Banks
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Roadmap

1. Forms of Uncertainty and Risks
   - A Taxonomy of Uncertainty and Risks
   - Measurement of Uncertainty
2. Assessing Uncertainty and the Balance of Risks around the Outlook
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   - Judgment and Scenario Analysis
   - Econometric Assessments
3. Snapshots from the Frontier of Outlook-at-Risk Models
   - Testing Growth Vulnerabilities and Macro-Financial Linkages
   - Inflation at Risk
   - Assessing Macroeconomic Tail Risk
   - Understanding Growth-at-Risk: A Markov-Switching Approach
   - Beyond Point Forecasts: Econometric Analysis of Macroeconomic Risk

Accounting for Uncertainty and Risks in Monetary Policy

Bauer, Berge, Fiori, Loria and Zhong (2025)

A Summary

- Paper was background for FOMC discussion of the **Federal Reserve's 2025 review of its monetary policy strategy, tools, and communications**.
- Discusses how **risks and uncertainty that are relevant for monetary policy** are measured, assessed and communicated.
- Provides a **taxonomy of policy-relevant uncertainty** and reviews **tools for assessing and quantifying uncertainty and the balance of risks**.
- Major central banks rely on *qualitative* tools to communicate uncertainty, while *quantitative* approaches remain emerging with no consensus on best practices.
- Communication of uncertainty and balance of risks not covered today.

Forms of Uncertainty and Risks

Definitions

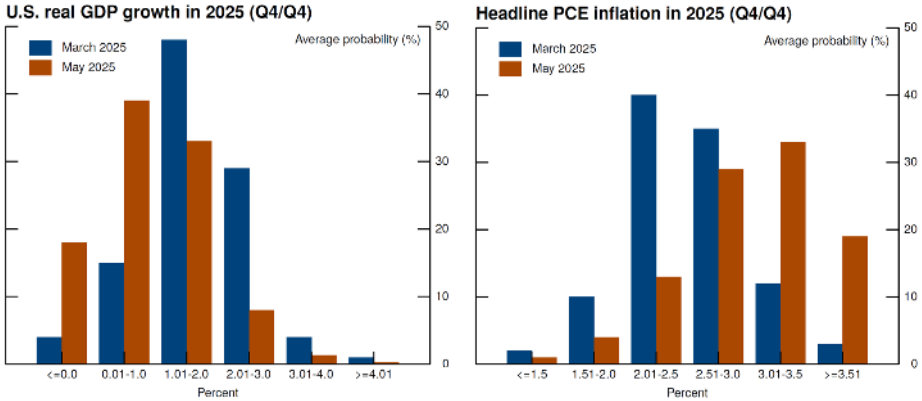
- Uncertainty and risks are relevant for monetary policy because they may **affect the ability of central banks to achieve their statutory objectives**.

- There are many usages and definitions of the terms "uncertainty' and "risk" in policy discussions and in the economics literature.

- "***Higher uncertainty/risk***" = greater dispersion of possible future outcomes, either because confidence intervals around a central forecast are wider, or because tail risks are higher.

- "***Balance of risks***" = direction in which outcomes are considered to be more likely, whether to the upside or to the downside.

Probabilistic Forecasts in the Survey of Market Expectations



Note: Average probabilities of Q4/Q4 real GDP growth (left panel) and PCE inflation (right panel) falling into different intervals from the New York Fed Survey of Market Expectations.

Source: Survey of Market Expectations, Federal Reserve Bank of New York.

A Taxonomy of Uncertainty and Risks

A Useful Framework

- Uncertainty results from a multitude of factors.
- We provide a taxonomy of uncertainty and risks.
- We use the **three broad categories proposed by Bernanke (2007)**:
  1. Uncertainty about the *state* of the economy
  2. Uncertainty about the *structure* of the economy
  3. Uncertainty about *expectations*

Uncertainty about the State of the Economy

- **Economic indicators**: Incomplete, prone to mismeasurement and revision, usually released with a delay, and insufficient during black swan events.
- **Policy-relevant guideposts** (u^*, π^*, etc.): Inference is demanding, especially in real time.
- **Economic shocks** (supply, demand, etc.): Unobserved, and their nature, size and persistence are hard to pin down, thus requiring considerable judgment.

Uncertainty about the Structure of the Economy

- **Model uncertainty**
  - Which model best describes the economy?
  - New or large shocks may necessitate considerable modifications to models.
- **Parameter uncertainty**
  - Model parameters are not perfectly known, but have profound consequences.
  - E.g., responsiveness of inflation to resource slack — the Phillips curve slope.
- **Transmission of monetary policy**
  - Imperfect knowledge about underlying mechanisms and structural parameters.
  - Estimates of timing and magnitude of monetary policy effects vary widely.
  - Monetary transmission may vary over time and with business cycle state.
- **Structural changes**
  - Arise from a multitude of factors (e.g., demographic and technological change).
  - Can alter policy-relevant objects (e.g., r^*).
  - Macro-financial linkages also prone to change (e.g., during financial stress).

Uncertainty about Expectations

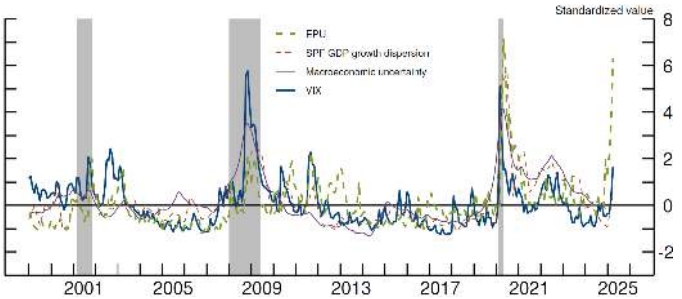
- **Expectations formation**
  - Standard macroeconomic models typically assume rational expectations and inflation expectations that are anchored in the longer run.
  - But alternative assumptions (e.g., learning and backward-looking expectations) may have implications for strength and lags of monetary policy transmission.
- **Measures of public expectations**
  - Survey-based measures: noisy and tend to differ across respondent type.
  - Market-based measures suffer from "hall of mirrors" problem in uncertain times.
- **Policy reaction function**
  - Public's understanding about the policy reaction function influences the transmission of monetary policy.
  - While policymakers can provide information about its reaction function, the public's perception can vary over time (e.g., through learning from CB).

Measurement of Uncertainty

An Overview

Similarly to Cascaldi-Garcia *et al.* (2023), we divide commonly used empirical measures of uncertainty into four categories:

1. Financial market-based
2. Survey-based
3. Text-based
4. Statistical measures



Sources: Economic Policy Uncertainty Index for United States via FRED; Survey of Professional Forecasters, Federal Reserve Bank of Philadelphia; Sydney Ludvigson's website; Chicago Board Options Exchange VIX data via Bloomberg.

Financial Market-Based Measures

- Measures of uncertainty based on financial markets are **derived from prices of financial assets, including futures, options, and other derivatives**.
- Many indicators also capture shifts in the balance of risks towards adverse outcomes (e.g, the VIX rises disproportionately during financial stress).
- **Key advantage**: Available at a very high frequency, forward looking over specific periods of time, and **reflect risk as priced by markets**.
- **Key limitation**: Measures typically include risk and liquidity premiums, complicating their interpretation.

Survey-Based Measures

- **Rely on survey responses about current or future economic outcomes** from businesses, households, and professional forecasters.
- Many surveys attempt to directly measure uncertainty and the balance of risks by asking respondents to provide probability distributions for future outcomes.
- Can also be used to measure uncertainty by quantifying forecast disagreement, but mixed evidence on its usefulness as uncertainty proxy.
- **Key advantage**: Directly measure beliefs about the economy from **firms, households, forecasters, or market participants**.
- **Disadvantages**: Typically low(er) frequency, and respondents often lack strong incentives—unlike market measures tied to financial outcomes.

Textual Analysis Based Measures

- Quantify uncertainty **based on the frequency of newspaper articles** or other documents that discuss it.
- Text-based indexes **reflect the public's perception** of uncertainty and the balance of risks about specific policies and economic events.
- **Key advantage**: **Timeliness and specificity about sources of uncertainty** that are hard to measure using traditional data.
- **Disadvantages**: Lack of probabilistic and quantitative interpretations, and the potential sensitivity to changes in text sources (e.g. media coverage habits).

Statistical Models

- Quantify uncertainty as the **time-varying volatility of the forecast errors across many economic and financial indicators**.
- **Key advantage**: Resulting measure of uncertainty is **grounded in econometric theory and leverages a large amount of data**.
- **However**, these measures depend on modeling choices that may be imperfect and may not easily address new risks or abrupt shifts in uncertainty.
- As we will discuss later, statistical models are **also used to quantify changes in the balance of risks around the outlook**.

Summary

- **Many different empirical measures are available** as direct or indirect proxies of policy-relevant uncertainties (see overview in Table 1 of the paper).
- Each measure has its own advantages and disadvantages.
- **Monitoring a suite of measures can help identify salient risks and uncertainty**, despite significant degree of comovement across many indicators.

Assessing Uncertainty and the Balance of Risks around the Outlook

An Overview

- Accounting for the balance of risks around a forecast is especially critical when policymakers must consider policy tradeoffs in the face of adverse outcomes.
- When risks are not balanced, the mean outlook—computed by weighting outcomes by their probabilities—will differ from modal, or most likely, outlook.
- As discussed in Garga et al. (2025), this mean–mode differential has an important bearing on policy considerations.

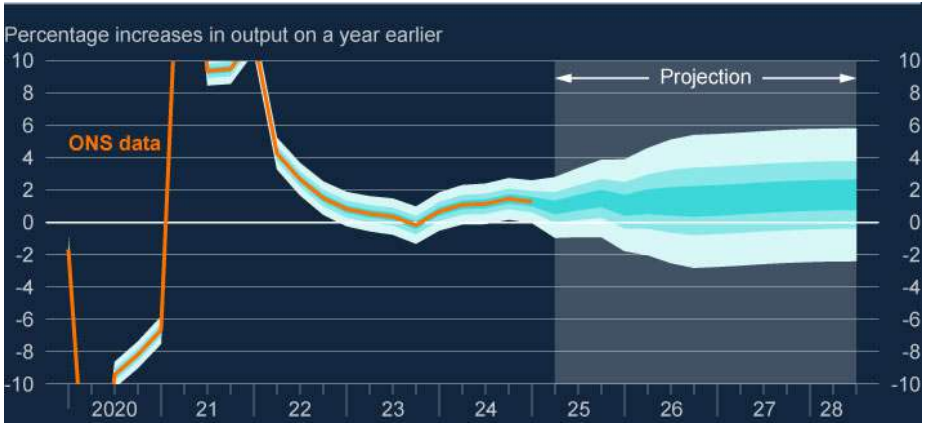
Fan Charts

Fan Charts

- Plot confidence bands based on historical forecast errors around the forecast.
- Confidence bands are typically assumed to be symmetric, but asymmetry can be incorporated through judgment or if historical data suggests so.
- Forecast errors have the advantage of encapsulating previously realized uncertainty and risks, no matter the source, but their use has drawbacks.
  - Size of a typical forecast error is sensitive to time span included in the sample.
  - Historical experience may be of limited value during heigtened uncertainty.
  - In contrast, the use of some of the forward-looking indicators, with judgment or econometric models, may allow to identify risks that are most relevant.

Bank of England – August 2025 Monetary Policy Report

GDP Growth Projection Based on Market Interest Rate Expectations,
Other Policy Measures as Announced



Judgment and Scenario Analysis

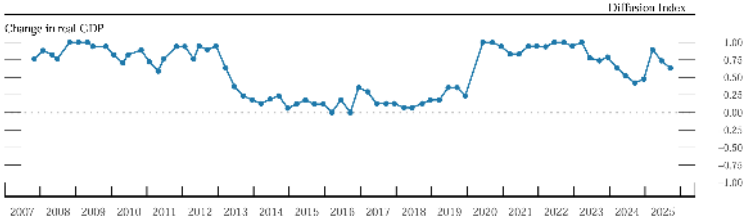
Judgment

- **Policymakers and forecasters may also use judgment to assess uncertainty and the balance of risks.**

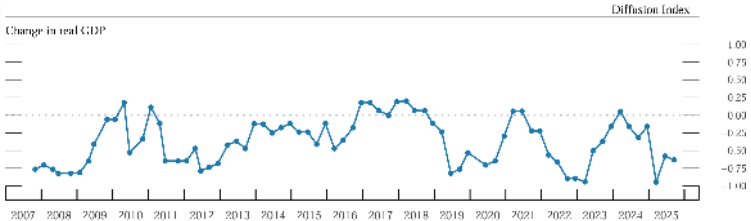
- The **SEP**, for example, provides the **FOMC participants' qualitative assessment of uncertainty and the balance of risks**.
  - Associated with the outlook for output, the unemployment rate, and inflation.
  - Uncertainty is assessed by counting participants who see it as lower, similar, or higher than the past 20 years.
  - Participants judge whether risks are tilted down, balanced, or tilted up.
  - Evolution of uncertainty and risk balance shown via diffusion indexes over time.

Survey of Economic Projections – September 2025

Participants' **Uncertainty** Assessments



Participants' **Risk** Assessments



Scenario Analysis

Compares forecasts produced under different assumptions.

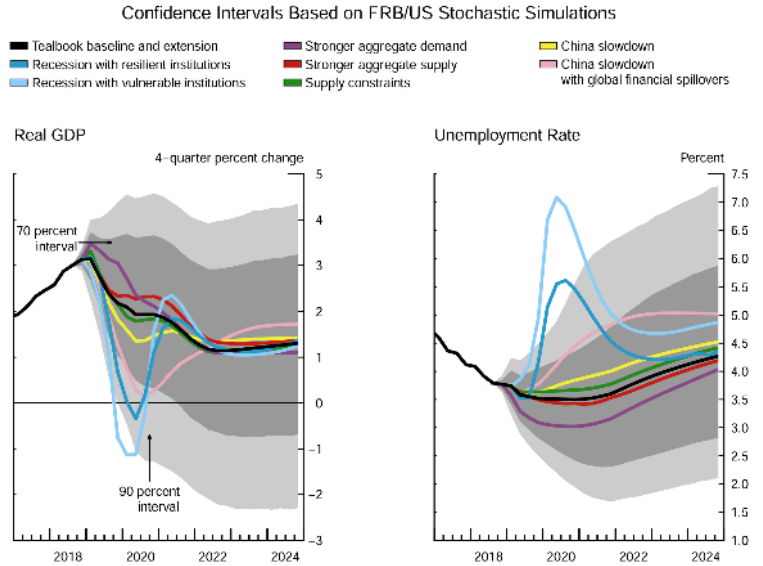
- **Flexible**: Can address various forms of risk and uncertainty in taxonomy.
- First step is the subjective identification of salient risks to the outlook.
- Their implications can be qualitatively described, or quantified in a model.
  - When risks stem from uncertainty around the structure of the economy, scenarios can explore alternative model calibrations.
  - Can be used to compare simulations under different monetary policy rules.
- **Requires several consequential choices**, including the choice of relevant risks, the economic model, and the methodology.

Scenario Analysis in the Tealbook

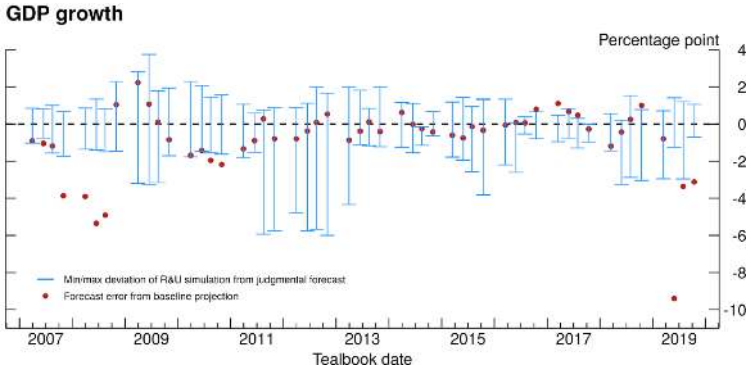
In each Tealbook, the FED Board staff produces several alternative scenarios that explore the implications of events that deviate from baseline assumptions.

- Scenarios may reflect assumptions that are plausible but not incorporated in the modal forecast.
- Or, scenarios may explore risks that are unlikely to materialize but could have large economic effects and be significant for monetary policy.

Alternative Scenarios in January 2019 Tealbook



How Large Are the Risks from the Alternative Scenarios Presented in the Tealbook?



Note: The blue whisker bars show the range of outcomes for four-quarter-ahead real GDP growth, from the alternative simulations in the R&U section of the Tealbook, in deviations from the baseline projection. The red dots show the forecast error—defined as actual less forecast—from the baseline Tealbook forecast. The chart is produced using the second Tealbook from each quarter. Sample period is March 2007–December 2019.

Source: Tealbook (formerly Greenbook) Data Set, Federal Reserve Bank of Philadelphia; staff calculations.

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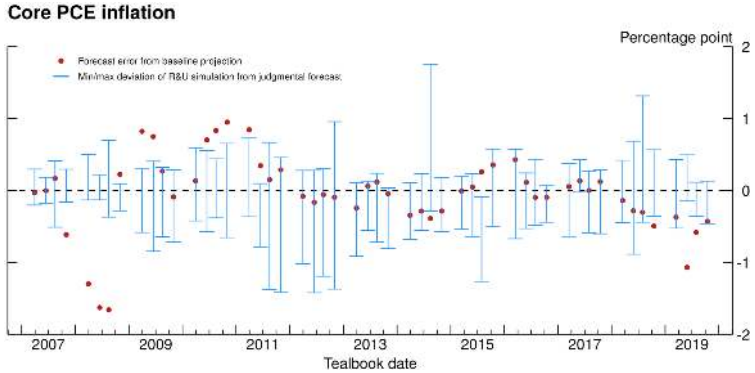

Note: The blue whisker bars show the range of outcomes for four-quarter-ahead core PCE inflation, from the alternative simulations in the R&U section of the Tealbook, in deviations from the baseline projection. The red dots show the forecast error—defined as actual less forecast—from the baseline Tealbook forecast. The chart is produced using the second Tealbook from each quarter. Sample period is March 2007–December 2019.

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Econometric Assessments

Econometric Assessments I

Growing literature uses econometric models to assess uncertainty and risk balance.

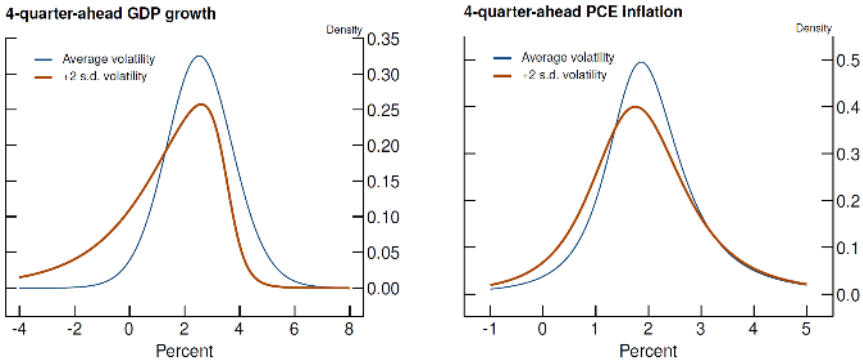
- **Forecast-error based**: Measures predictability of economic variables using volatility of forecast errors across many series to proxy uncertainty.

  Examples: Jurado, Ludvigson and Ng (2015), Ludvigson, Ma and Ng (2021), Londono, Ma and Wilson (2024)

- **Outlook at risk**: Links economic or financial indicators to the full distribution of future outcomes, highlighting periods of high uncertainty or skewed risk.

  Examples: Adrian, Boyarchenko and Giannone (2019), Kiley (2022), Lenza, Moutachaker and Paredes (2023), López-Salido and Loria (2024) Ajello, Favara, Marchal and Szoke (2024), Caldara, Scotti and Zhong (2023), Caldara, Cascaldi-Garcia, Cuba-Borda and Loria (Forthcoming), Bekaert, Engstrom and Ermolov (2025)

Dual Mandate Based on an Outlook-at-Risk Model



Note: Distribution of four-quarter-ahead GDP growth (left panel) and PCE price inflation (right panel) predicted using the Financial Conditions Impulse on Growth (FCI-G) and realized volatility from the S&P 500 index. The blue distribution is the predicted density given financial conditions and realized volatility at their mean values. The red distribution is the density assuming average financial conditions, but with realized volatility at two times its standard deviation. Sample period is 1990:Q1—2024:Q4.

Source: FCI-G index data, Federal Reserve Board (Ajello, Cavallo, Favara, Peterman, Schindler and Sinha, 2023); S&P 500 index data via Bloomberg; staff calculations using the methodology of Adrian, Boyarchenko and Giannone (2019).

Econometric Assessments II

- **Judgment and statistics**:
  - Incorporates expert judgment into statistical models to create conditional forecasts and scenarios, combining scenario analysis with econometric rigor.
  - Useful for tilting projections toward specific risks or highlighting periods when risks are are not sufficiently accounted for within a given set of scenarios.

  Examples: Cogley, Morozov and Sargent (2005), Antolin-Diaz, Petrella and Rubio-Ramirez (2021)

- **Model simulation**: Uses repeated shocks in macroeconomic models to generate uncertainty bands showing possible paths of the economy.

- **A Synthesis:** Adrian, Giannone, Luciani and West (2025) review key pillars of central bank risk analysis—(large) macro models, scenarios, and statistical tools—and propose a framework to integrate them.

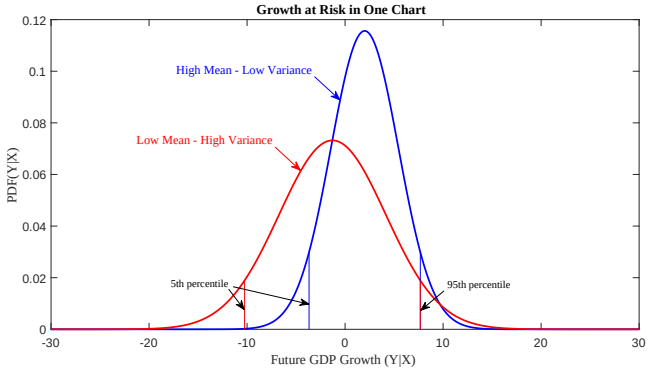
Summary

- Assessing uncertainty and balancing risks with models is challenging.
- Model choice and input variables are based on historical patterns, which can misrepresent emerging risks.
- Tails of predictive distributions shift only after shocks appear in the data, making these measures slower to respond.
- Variables used in econometric methods differ in specific risks they measure.

Snapshots from the Frontier of Outlook-at-Risk Models

Outlook-at-Risk Models

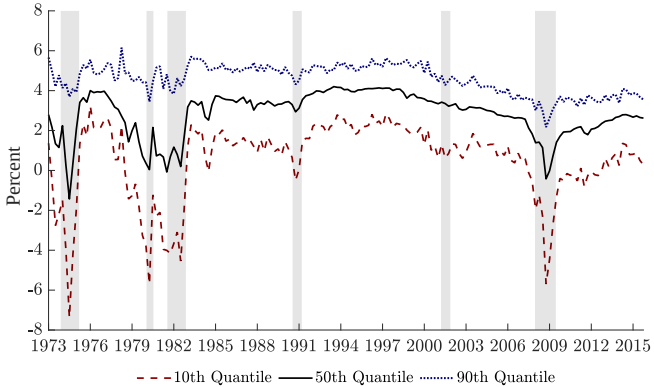
- Characterize the **distribution** of macro variables **given** economic indicators.
- **Goal:** Measure uncertainty and risks around forecast.
- **Key result of growth-at-risk literature**: (Conditional) mean and volatility of GDP growth are negatively correlated.



Example: "Vulnerable Growth"

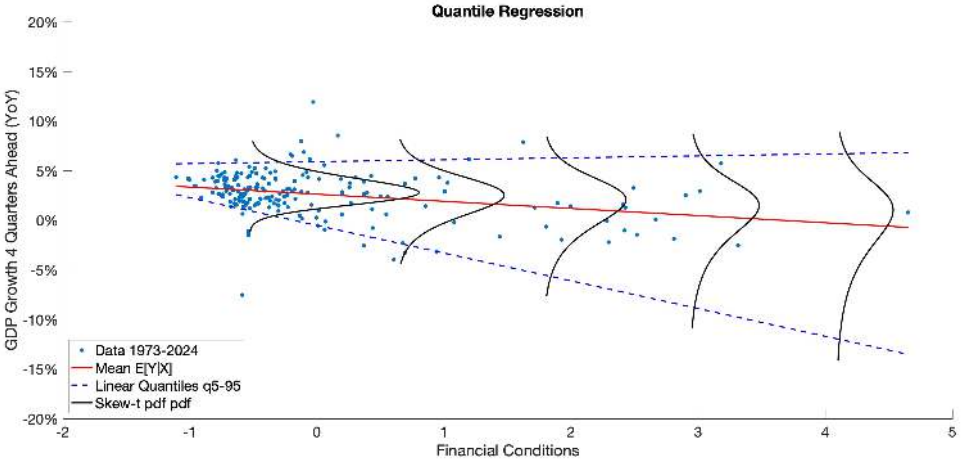
Adrian, Boyarchenko and Giannone (2019)

Quantile Regression: $\widehat{\mathcal{Q}}_\tau(\bar{\Delta} y_{t+1,t+4}|x_t) = \hat{\alpha}_\tau + \hat{\beta}_\tau nfci_t + \hat{\gamma}_\tau y_t$



Predictive Four-Quarters-Ahead Real GDP Growth (YoY) Quantiles

Why? Macro-Financial Linkages are Asymmetric



One-Year-Ahead GPD Growth and Financial Conditions, Adrian et al. (2019)

Testing Growth Vulnerabilities and Macro-Financial Linkages

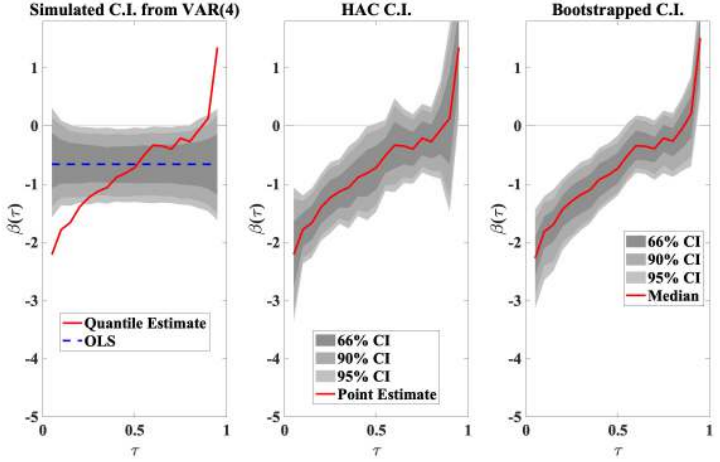
Furno, Giannone, Iania, Loria and Schulz (Forthcoming)

Motivation

- Growth-at-risk very influential, replicated across space and methodologies.
- Some papers have criticized it as non robust.
- In particular, the literature has considered the following questions
  1. Macro-financial linkages: **Do financial conditions help predict risk?**
  2. Non-linearities: **Are risks asymmetric?**

We reassess them using newly developed robust inference methods for quantile regression with time series data, which is not a simple problem.

Macro-Financial Linkages Strong in Lower Tail of Growth



$$\mathcal{Q}_\tau(\bar{\Delta} y_{t+1,t+4}|x_t) = \hat{\alpha}_\tau + \hat{\beta}_\tau nfci_t + \hat{\gamma}_\tau y_t$$

Inflation at Risk

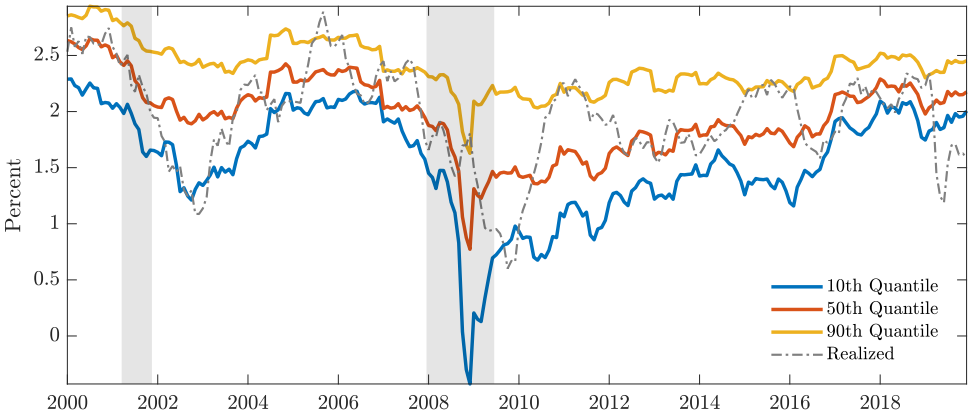
López-Salido and Loria (2024)

Inflation at Risk

- **Methodology:** We use quantile regressions with theory-based inflation drivers to study the inflation outlook in the US, euro area, and OECD panel.

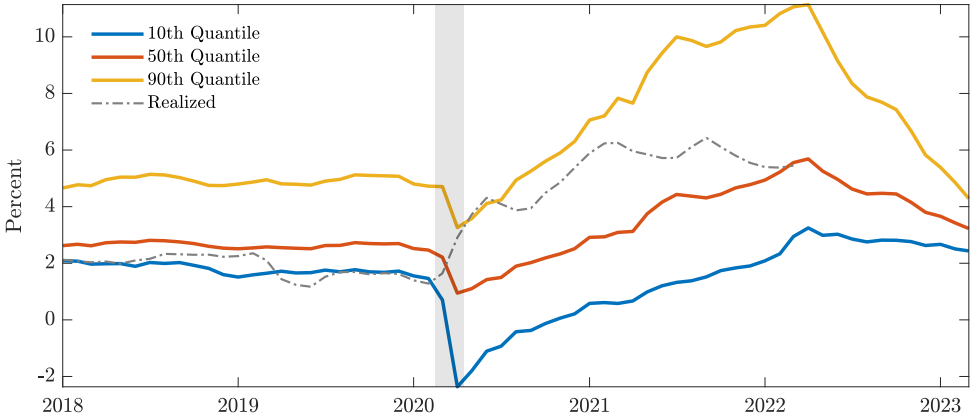
- **Main Findings:**
  - The results reveal significant **asymmetries in the inflation outlook**—even during periods of low and stable inflation.
  - **Financial conditions also have a nonlinear impact** on the predictive distribution of inflation—not just on GDP growth.
  - The **importance of inflation drivers has evolved over time**.

Downside Risks from Tight Financial Conditions during GFC



One-Year-Ahead Core CPI US Inflation Quantiles

Pandemic-Era Stimulus and Supply Constraints Sustained Upside Risks



One-Year-Ahead Core CPI US Inflation Quantiles

Assessing Macroeconomic Tail Risk

Loria, Matthes and Zhang (2019)

What We Do and What We Find

- **Starting Point:** "Growth-at-Risk" shows that downside risks to future growth are large and asymmetric.

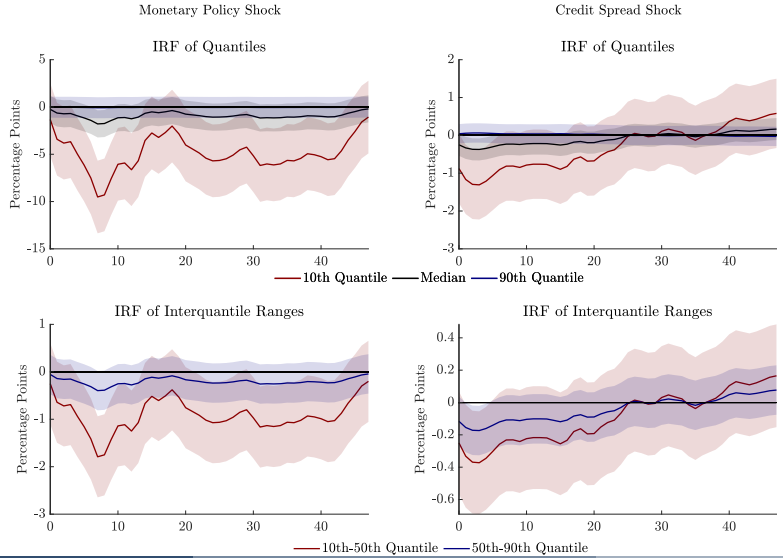
- **Key Question:** Are these asymmetries shock-specific or shocks affect GDP in an asymmetric manner in general?

- **Methodology:** Combine *quantile regression* and *local projections* to estimate the effects of structural shocks on the growth outlook.

$$q_{\tau,t+s} = \delta^s_\tau + \theta^s_\tau \; shock_t + \Psi(L)^s_\tau \; controls_t + u^s_{\tau,t+s}, \quad s = \{0, \ldots, S\}$$

- **Main Findings:**
  - Financial, monetary policy, oil price, and uncertainty shocks all have *disproportionate effects* on the left tail (10th percentile) relative to the median.
  - Responses indicate a common transmission mechanism.

Asymmetry in Growth Outlook not Driven by Specific Shock



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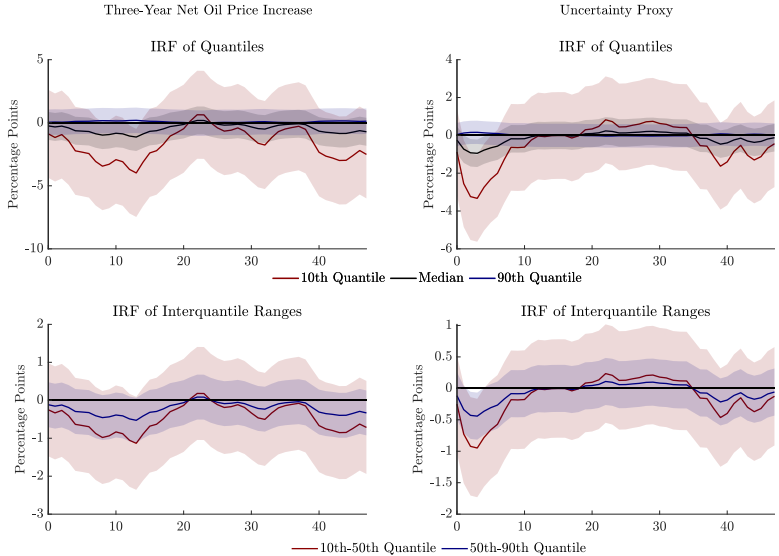

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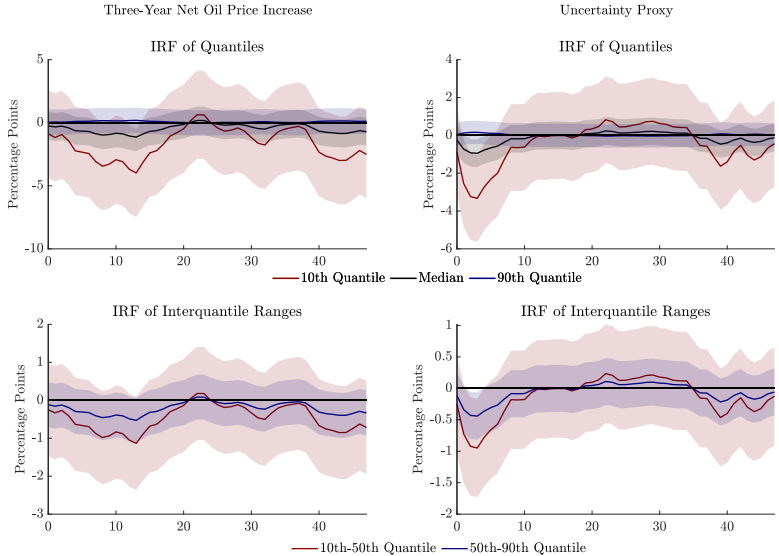


Understanding Growth-at-Risk: A Markov-Switching Approach

Caldara, Cascaldi-Garcia, Cuba-Borda and Loria (Forthcoming)

Many Open Questions Left

1. **How do we interpret macroeconomic risk?**
2. What are the channels driving macroeconomic risk?
3. What are the implications of different (monetary) policy strategies for macroeconomic risk?
4. ...

Answering these questions requires a coherent *structural* framework.

The Paper in a Nutshell

We show that **Markov-switching VAR models** provide a joint framework to measure risks and study how shocks affect the balance of risk.

- Detect **asymmetries in future outcome distributions** of key macro series, as commonly found in the academic literature (e.g., *growth-at-risk*).

- Uncover **asymmetric effect of shocks on the economy** (can construct IRFs of marginal and joint densities, etc.).

Mechanics

- We estimate the following **Markov-switching VAR:**

$$\mathbf{y}_t = \mathbf{C}(s_t) + \mathbf{B}_1(s_t)\mathbf{y}_{t-1} + \ldots + \mathbf{B}_p(s_t)\mathbf{y}_{t-p} + \mathbf{u}_t$$

$\mathbf{y}_t$: industrial production (in deviation from trend), financial factor

$\mathbf{u}_t \sim \mathcal{MVN}(0, \Omega(s_t))$: regime-dependent volatility

$\mathbf{C}(s_t)$, $\mathbf{B}_i(s_t)$: switching intercept and lag matrices

- **Transition probabilities:** Depend on economic and financial conditions.

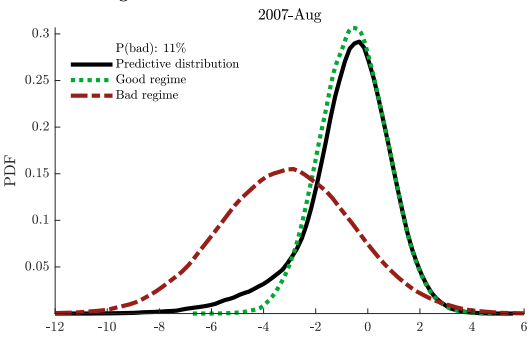
- **Predictive distributions:** Constructed by simulating the model while allowing for regime changes throughout the forecast horizon.

Macroeconomic and Financial Risks During Global Financial Crisis

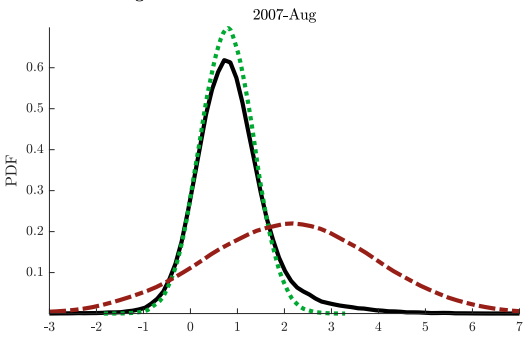
"Financial market conditions have deteriorated, and tighter credit conditions and increased uncertainty have the potential to restrain economic growth going forward. In these circumstances, although recent data suggest that the economy has continued to expand at a moderate pace, the Federal Open Market Committee judges that the downside risks to growth have increased appreciably."

August 17, 2007 FOMC statement

Avg. Industrial Production Over Next 12 Months



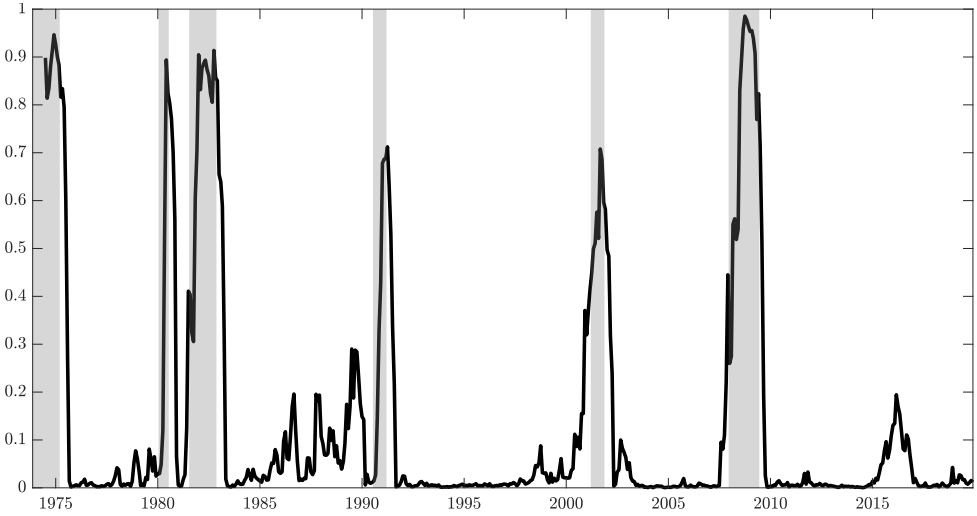
Avg. Financial Factor Over Next 12 Months



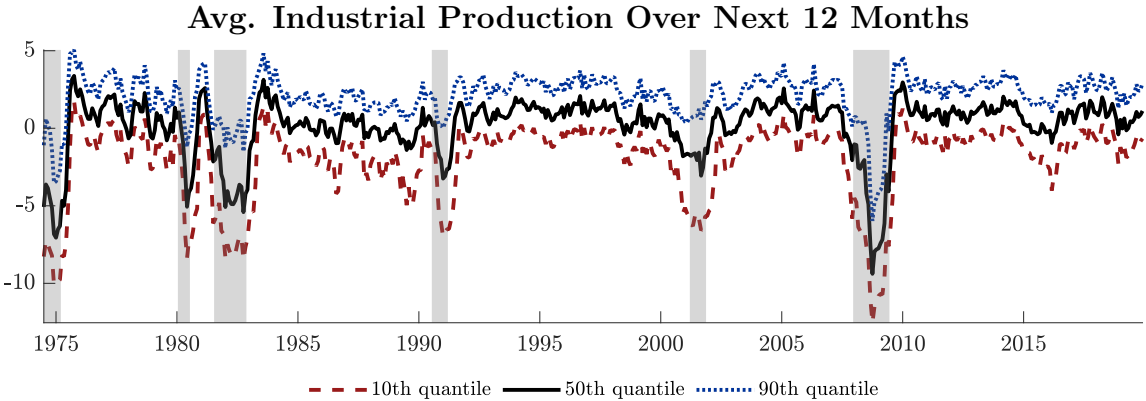
Intuitive Interpretation of Macroeconomic Risk

- At any point in time (at least two) states of the world can occur with a certain probability. This generates a distribution of predicted future macro outcomes.
- Regime uncertainty AND distinct dynamics across regimes generate risk.
- **Implication:** First order shocks can affect higher-order moments.
- **Why:** Shocks affect both model *dynamics* and regime *transitions* ("risk").

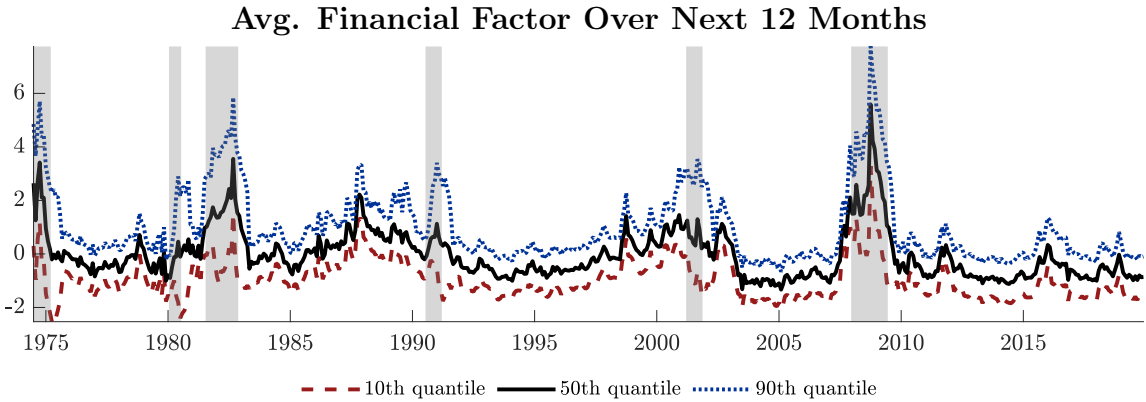
Bad Regime Probability Closely Tracks NBER Recessions



Downside Risks to Macroeconomic Activity Intensify around Recessions

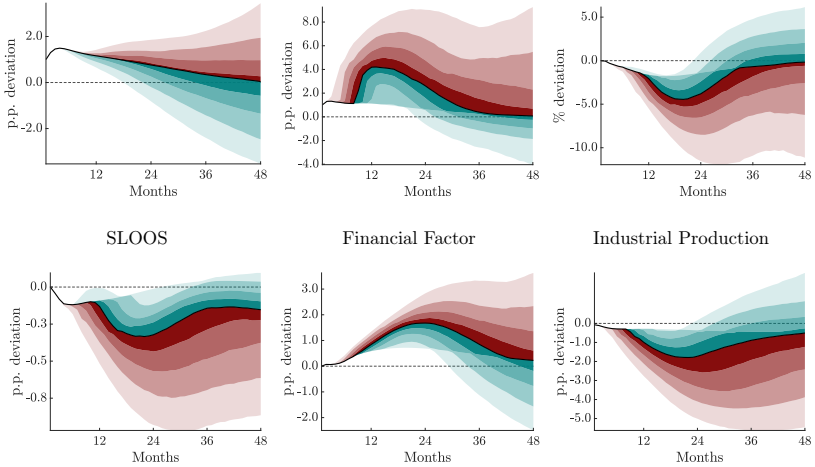


Upside Risks to Financial Conditions Intensify around Recessions



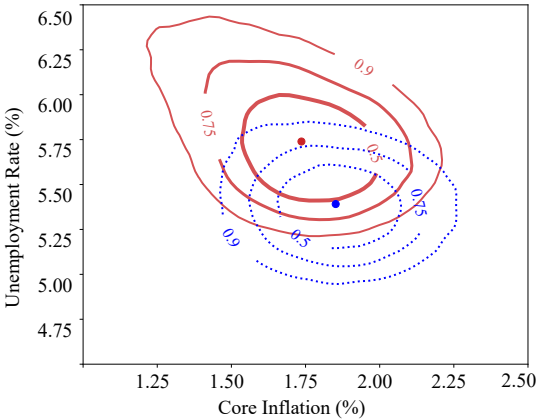
Shocks Have an Asymmetric Effect on the Economy

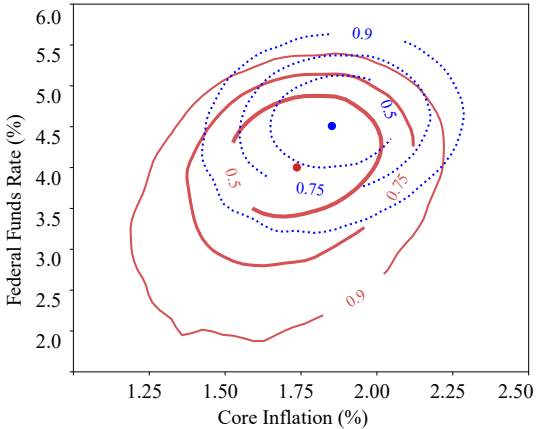
Responses to tighter lending conditions in August 2007



... and on its Balance of Risks

One-year-ahead joint distributions as of Aug-2007.
Baseline (blue) vs. conditional on a tightening shock to bank lending standards (red).





Summary

- **Looking beyond point forecasts, reveals rich tail dynamics**.
  - Substantial asymmetries in growth and inflation outlook.
  - Financial conditions are key predictors of macroeconomic risk and macro-financial linkages are particularly strong in left tail.
  - Asymmetry does not appear to be driven by a specific shock.
- **Markov-switching models offer a unified framework to study risk**.
  - Provide intuitive interpretation of macroeconomic risk and insight into the channels generating risk.
  - Can both quantify risk and assess the causal impact of structural shocks on the balance of risk.

Beyond Point Forecasts: Econometric Analysis of Macroeconomic Risk

Adrian, Boyarchenko, Furno, Giannone, Iania, Lenza, Loria, Fernandes and Sola (Forthcoming)

A Book on Macroeconomic Risk

Part I – Fundamentals

1. Macroeconomic Risk
2. Growth-at-Risk
3. Density-Based Risk Measures
4. Forecast Evaluation

Part II – Extensions

1. Markov-Switching Models
2. Large-Scale Forecasting
3. Policy and Academic Implications

Resources

- Replication Packages
- Additional Material (Slides)

Conclusion

Key Takeaways

- Monitoring uncertainty and risks is **essential** for monetary policy.
- Policymakers use a **variety of measures** to assess risks.
- Extracting clear signals is **complex and requires judgment**.
- Effective risk monitoring requires a **comprehensive toolkit** combining macroeconomic and statistical methods.
- A **wide range of techniques exists and continues to be developed** to quantify uncertainty and evaluate the balance of risks.
- Many research avenues remain to be explored, including the analysis of global and sectoral linkages, and the theoretical modeling of macroeconomic risk.

References I

Adrian, T., Boyarchenko, N., Furno, F., Giannone, D., Iania, L., Lenza, M., Loria, F., Fernandes, C. M. and Sola, S. (Forthcoming). Monitoring and Forecasting Macro Risk.

—, — and Giannone, D. (2019). Vulnerable Growth. *American Economic Review*, **109** (4), 1263–1289.

—, Giannone, D., Luciani, M. and West, M. (2025). *Scenario Synthesis and Macroeconomic Risk*. Tech. Rep. 2025-36, Board of Governors of the Federal Reserve System.

Ajello, A., Cavallo, M., Favara, G., Peterman, W., Schindler, J. W. and Sinha, N. R. (2023). A New Index to Measure U.S. Financial Conditions. `https://www.federalreserve.gov/econres/notes/feds-notes/a-new-index-to-measure-us-financial-conditions-20230630.html`, accessed: 2025-08-22.

—, Favara, G., Marchal, G. and Szoke, B. (2024). Financial Conditions and Risks to the Economic Outlook. `https://www.federalreserve.gov/econres/notes/feds-notes/financial-conditions-and-risks-to-the-economic-outlook-20240920.html`, accessed: 2025-08-22.

References II

Antolin-Diaz, J., Petrella, I. and Rubio-Ramirez, J. F. (2021). Structural Scenario Analysis with SVARs. *Journal of Monetary Economics*, **117**, 798–815.

Bekaert, G., Engstrom, E. and Ermolov, A. (2025). Uncertainty and the Economy: The Evolving Distributions of Aggregate Supply and Demand Shocks. *American Economic Journal: Macroeconomics*, forthcoming.

Bernanke, B. S. (2007). Monetary Policy under Uncertainty. RePEc handle: RePEc:fip:fedgsq:327.

Caldara, D., Cascaldi-Garcia, D., Cuba-Borda, P. and Loria, F. (Forthcoming). Understanding Growth-at-Risk: A Markov-Switching Approach.

—, Scotti, C. and Zhong, M. (2023). Macroeconomic and Financial Risks: A Tale of Mean and Volatility. Paper presented at the 12th ECB Conference on Forecasting Techniques, European Central Bank, Frankfurt, June 12.

Cascaldi-Garcia, D., Sarisoy, C., Londono, J. M., Sun, B., Datta, D. D., Ferreira, T., Grishchenko, O., Jahan-Parvar, M. R., Loria, F., Ma, S., Rodriguez, M., Zer, I. and Rogers, J. (2023). What Is Certain about Uncertainty? *Journal of Economic Literature*, **61** (2), 624–654.

References III

Cogley, T., Morozov, S. and Sargent, T. J. (2005). Bayesian Fan Charts for U.K. Inflation: Forecasting and Sources of Uncertainty in an Evolving Monetary System. *Journal of Economic Dynamics and Control*, **29** (11), 1893–1925.

Furno, F., Giannone, D., Iania, L., Loria, F. and Schulz, C. (Forthcoming). Testing Growth Vulnerabilities and Macro-Financial Linkages.

Jurado, K., Ludvigson, S. C. and Ng, S. (2015). Measuring Uncertainty. *American Economic Review*, **105** (3), 1177–1216.

Kiley, M. T. (2022). Unemployment Risk. *Journal of Money, Credit and Banking*, **54** (5), 1407–1424.

Lenza, M., Moutachaker, I. and Paredes, J. (2023). Forecasting Euro Area Inflation with Machine Learning Models. *European Central Bank Research Bulletin*.

Londono, J. M., Ma, S. and Wilson, B. A. (2024). The Global Transmission of Real Economic Uncertainty. *Journal of Money, Credit and Banking*, **56** (3), 1–31.

References IV

Loria, F., Matthes, C. and Zhang, D. (2019). *Assessing Macroeconomic Tail Risk*. Finance and Economics Discussion Series 2019-026, Board of Governors of the Federal Reserve System (U.S.).

Ludvigson, S. C., Ma, S. and Ng, S. (2021). Uncertainty and Business Cycles: Exogenous Impulse or Endogenous Response? *American Economic Journal: Macroeconomics*, **13** (4), 369–410.

López-Salido, D. and Loria, F. (2024). Inflation at Risk. *Journal of Monetary Economics*, **145**.