Text Shocks and Monetary Surprises:
Text Analysis of FOMC Statements with Machine Learning

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† *The views presented here are those of the author and not of the Federal Reserve System.*

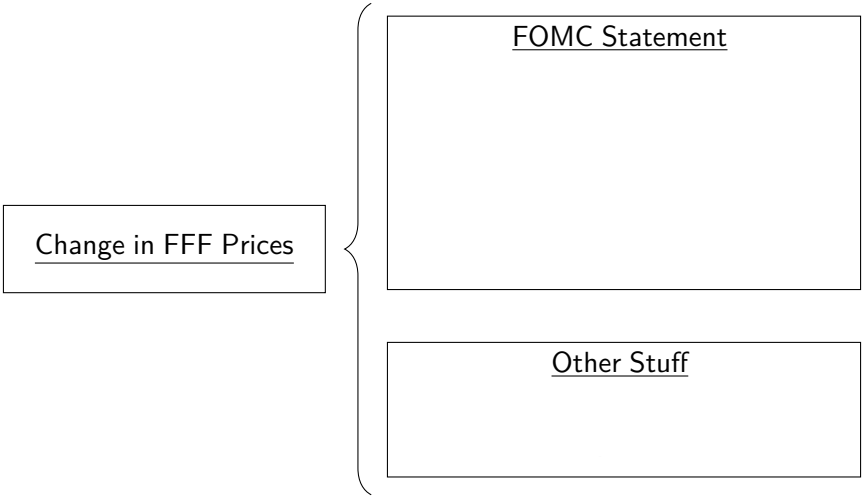
Motivation

- Federal Open Market Committee (FOMC) releases a statement after meetings
- Monetary shocks are unanticipated changes in monetary policy
  - Used to infer the casual effect on the economy
- Recent periods at the zero lower bound $\rightarrow$ less variation in conventional policy
- High frequency changes in fed funds futures (FFF),
  - Captures changes in expectations of target rate
  - Noisy measure of monetary *and* forward guidance shocks

Challenge in Using FFF Prices as Monetary Shock

Ex.

FFF prices respond to more than just monetary policy and forward guidance



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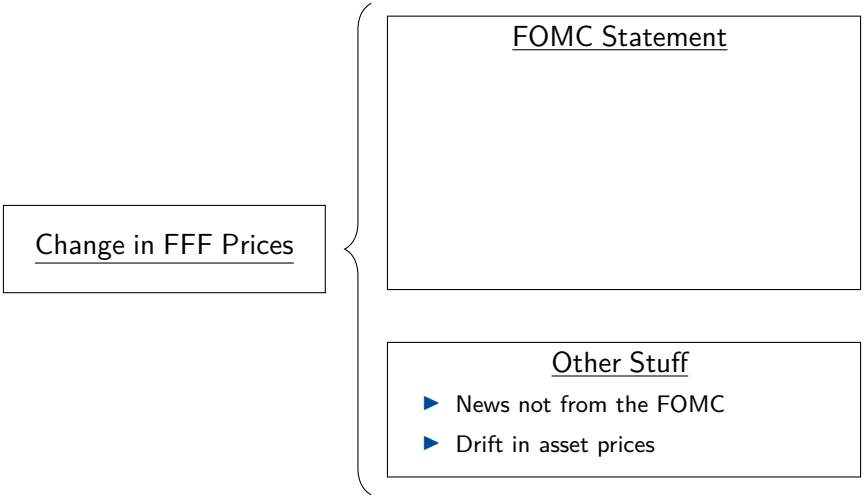

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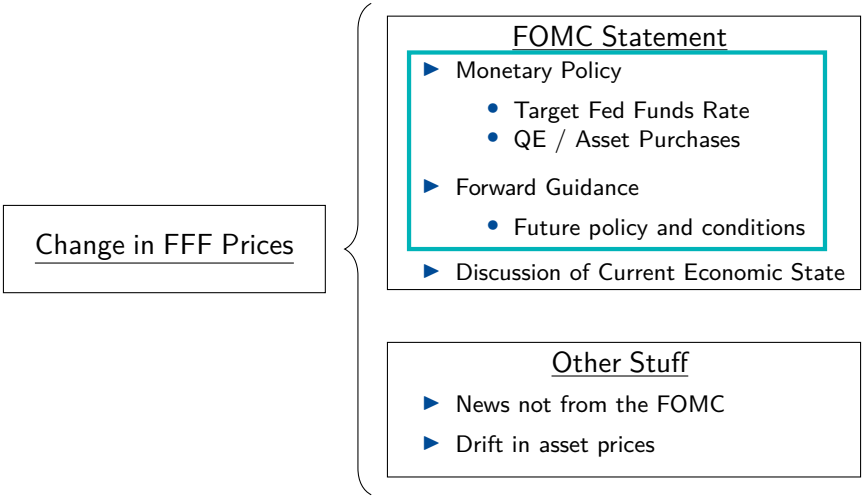


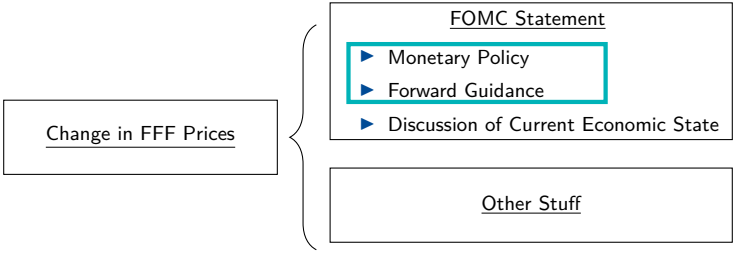
Research Questions

How can we:

1. Predict the change in FFF prices from the FOMC statement text?
2. Isolate price changes from monetary policy and forward guidance language?
3. Use this relationship to understand monetary policy effects?

This Paper

1. Apply a text-analysis neural network from computer science literature
   - Predict change in FFFs prices coming from words in FOMC statements
2. Create a new monetary shock series, Text Shocks
   - Use alternative statements from meeting materials, 2005-2014
   - Alternatives share non-policy information $\rightarrow$ create meeting-information fixed effect
   - Isolate price changes from monetary policy and forward guidance



Preview of Results

- Compare Text Shock with other FFF-based monetary shocks for 2005-2014

1. Estimate response of daily changes in interest rates:
   - All have similar effect on nominal rates
   - Text shock double effect real rates compared to other series
2. Estimate impulse responses using local projection approach:
   - ↑ text shock → significant ↓ output growth, inflation, ↑ excess bond premium
   - ↑ FFF-based shocks → small ↑ output growth, inflation, ↓ excess bond premium

Literature

Handlan(2020)

Monetary Policy Shocks

- Bu, Rogers and Wu (2019); Campbell, Evans, Fisher and Justiniano (2012); Christiano, Eichenbaum and Evans (1999); Cieslak and Schrimpf (2019); Gertler and Karadi (2015); Gurkaynak, Sack and Swanson (2004); Nakamura and Steinsson (2018); Ramey (2016); Romer and Romer (2004)
- **Contribution**: a new shock series based on variation in statement text

Literature

Monetary Policy Shocks

- Bu et al. (2019); Campbell et al. (2012); Christiano et al. (1999); Cieslak and Schrimpf (2019); Gertler and Karadi (2015); Gurkaynak et al. (2004); Nakamura and Steinsson (2018); Ramey (2016); Romer and Romer (2004)
- **Contribution**: a new shock series based on variation in statement text

Text Analysis in Economics

- **Text Analysis in Economics:** Gentzkow et al. (2019)
- **Market Response to Fed's Words:** Doh et al. (2020); Handlan (2020); Hansen and McMahon (2016); Husted et al. (2017); Lunsford (2020)
- **Fed Objectives from Fed's Words:** Cieslak and Vissing-Jorgensen (2020); Hansen et al. (2018); Shapiro and Wilson (2019)
- **Contribution**: use text-analysis neural network, find larger effect on real economy

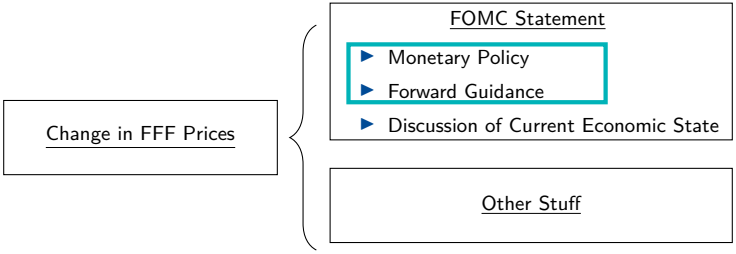
Presentation Outline

Overview of Creating Text Shocks

To isolate shift in FFF prices that come from monetary policy and forward guidance:

Step 1: Text-analysis neural network to predict price changes from FOMC statement text

Step 2: Use alt. statements to remove price changes from non-policy text



Text-Analysis Neural Network: Inputs and Outputs

- **Input**: FOMC statement text from scheduled FOMC meetings
  - 165 statements from May 1999 - Oct 2019
- **Output**: $\Delta E_t[r]$, change in federal funds rate (FFR) expectations for meeting t
  - FFF prices from 10-min before to 20-min after release statement t
  - Transform FFF prices to FFR expectations: $\Delta E_t[r_t]$, $\Delta E_t[r_{t+1}]$
  - Condense to 1-dimension as 1st principal component: $\Delta E_t[r]$
- **Goal**: estimate function from **input** to **output** variables
  - Nonparametric regression approximated by many linear & nonlinear data combos

Text Prep Example FFF→ $\Delta E[r]$ Correlation PCA Interpret $\Delta E_t[r]$

Text-Analysis Neural Network: Approach

- Yang et al. (2020) neural network trained to predict missing words
  - Ex: Gmail predicts next word using written words

    Great to hear from... $\Longrightarrow$ Great to hear from *you*
  - Trained on large collection of general English text
  - Produces a vector that jointly represents language of text input, think PCA
- Transfer Learning: adjust the algorithm to predict numerical output variable
  - Their parameters to produce vector representation of document
  - Add new parameters to then map to output variable
  - This approach decreases training sample requirements

NN Training Overview XLNet Info Input Visual

Text-Analysis Neural Network: Training and Evaluation

- Split data into training (132) and testing (33) samples
  - Condition on: change federal funds rate, Fed chair, and pre/post 2007
- Train neural network parameters to fit training data
- Evaluate the neural network $\rightarrow$ prediction for testing (out-of-sample) data
  - Correlation between output variable and prediction
    - In-Sample $\rightarrow$ 0.8
    - Out-of-Sample $\rightarrow$ 0.2

Scatter Plot

  - Robustness: cross validation (LOOCV) and back-translation synthetic data

Text-Analysis Neural Network: Advantages and Intuition

- Outperforms using Δ Target FFR for predicting $\Delta E[r]$ Target FFR
- Neural network predicts Example
  - Differences between statements that match narrative approach
  - More intricate representation of text than word-count approach

Presentation Outline

Step 2: Control for Fed Information Effect

- "Fed Information Effect": FFF price changes from Fed's analysis of current state
- Use alternative statements from FOMC meeting materials, 2005-2014
- Create a meeting-information fixed effect $\rightarrow$ Fed Information Effect

Alternative A
- Monetary Policy Alt A
- Forward Guidance Alt A
- **Current Economic Analysis**

Alternative B
- Monetary Policy Alt B
- Forward Guidance Alt B
- **Current Economic Analysis**

Alternative C
- Monetary Policy Alt C
- Forward Guidance Alt C
- **Current Economic Analysis**

Alts Over Time

"Fed Information Effect" Measure (2005-2014)

Measure "Fed Information Effect" $\rightarrow$ FFF price changes common across alternatives:

1. Feed each alternative into the trained neural network
2. Predict $\Delta E_t[r]$ for each alternative $a \in A \rightarrow \widehat{\Delta E_t[r]}_a$
3. Average the counterfactual changes in expectations

$$\sum_{a \in A} \frac{1}{A} \widehat{\Delta E_t[r]}_a$$

Creating the Cleaned Text Shocks (2005-2014)

- For every meeting t,

$$\textbf{Cleaned Text Shock}_t = \underbrace{\widehat{\Delta E_t[r]}_{text}}_{\text{Step 1}} - \underbrace{\sum_{a \in A} \frac{1}{A} \widehat{\Delta E_t[r]}_a}_{\text{Step 2}}$$

- Shock interpretation:
  - Unanticipated changes to monetary policy and forward guidance
  - Controlling for the Fed Information Effect

Graph Validation: Forward Guidance

Presentation Outline

Compare with Other Shock Measures

Summary Stats Graph NS & $\Delta E[r]_{FFF}$ Back-This Paper

- Compare results for different shock series:
  1. Gertler and Karadi (2015) shock $\rightarrow$ Δ 1-Y Treasury instrumented with Δ FF4
  2. Nakamura and Steinsson (2018) shock $\rightarrow$ 1st principal component of Δ FFF, Δ ED
  3. $\Delta E[r]_{FFF}$ $\rightarrow$ 1st principal component of $\Delta E_t[r_t]$,$\Delta E_t[r_{t+1}]$
  4. $\widehat{\Delta E[r]}_{text}$ $\rightarrow$ Text shock
  5. $\widehat{\Delta E[r]}_{clean}$ $\rightarrow$ Cleaned text shock
- Units are same across shocks

1 bp increase in shock $\rightarrow$ 1 bp increase in 1-year Treasury yield

Nominal and Real Interest Rates

- Consider *nominal* and *real* interest rates, n, for maturity $i \in \{1, 2, 3, 5, 10\}$:
  1. ΔTY^i = Daily change in i-year Treasury yields
  2. $\Delta TIPS^i$ = Daily change in i-year Treasury Inflation-Protected Securities
- Specification:

$$\Delta Yield^{n,i} = \beta_0^{n,i,k} + \beta_1^{n,i,k} \; shock^k + \varepsilon^{n,i,k}$$

  - Shock $k \in \{$GK Shock, NS Shock, $\Delta E[r]_{FFF}$, $\widehat{\Delta E[r]}_{text}$, $\widehat{\Delta E[r]}_{clean}\}$

Nominal and Real Interest Rates

- Cleaned text shocks indicates monetary policy has
  - Similar effect on *nominal* interest rates Plot
  - Double effect on *real* interest rates Plot

  relative to other FFF shocks (GK Shock, NS Shock, $\Delta E[r]_{FFF}$, $\widehat{\Delta E[r]}_{text}$)
- Controlling for Fed information effect in FFF shocks is *quantitatively* important

Presentation Outline

Data and Local Projection Method

- Monthly variables from FRED (Y): Sum Stats
  - Log industrial production
  - Log CPI
  - 1-year Treasury Yield
  - Excess bond premium (EBP) (Gilchrist and Zakrajsek, 2012)
- Convert shock series to monthly frequency (no meeting $\Rightarrow$ zero shock) Sum Stats
  - $\widehat{\Delta E[r]}_{clean}$, GK Shock (FF4), $\Delta E[r]_{FFF}$, $\widehat{\Delta E[r]}_{text}$
- Local projection method (Jordà, 2005)

$$Y_{i,t+h} = \theta^k_{i,h}\ shock^k_t + \text{control variables} + \xi^k_{t+h}$$

Impulse Responses

- 100 basis point ↑ monetary shock : ↓ output and inflation, ↑ EBP for:
  - $\widehat{\Delta E[r]}_{clean}$, Plot
- 100 basis point ↑ monetary shock : ↑ output and inflation, ↓ EBP for:
  - GK shock (FF4), Plot
  - $\Delta E[r]_{FFF}$, Plot
  - $\Delta E[r]_{text}$, Plot
- Controlling for Fed information effect in FFF shocks is *qualitatively* important

Conclusion

- FOMC statement text provide variation beyond changes to FFR target
- New *monetary policy text shock* series from 2005-2014
  - Comes from variation in the text
  - Controls for the "Fed Information Effect"
  - Captures forward guidance effect
- Cleaned text shock has larger impact on real interest rates
- Increase text shock $\rightarrow$ decreases output and inflation (contractionary shock)
- Next, more analysis of Fed announcements to study monetary transmission

Sequential Similarity | Variance Draft $\widehat{\Delta E[r]}$ | Variance Sentence $\widehat{\Delta E[r]}$

Thank You!

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References I

Bu, C., Rogers, J., Wu, W., 2019. A Unified Measure of Fed Monetary Policy Shocks. Finance and Economics Discussion Series URL: https://www.federalreserve.gov/econres/feds/a-unified-measure-of-fed-monetary-policy-shocks.htm, doi:https://doi.org/10.17016/FEDS.2019.043r1.

Campbell, J., Evans, C.L., Fisher, J., Justiniano, A., 2012. Macroeconomic Effects of Federal Reserve Forward Guidance. Brookings Papers on Economic Activity 43, 1–80. URL: https://econpapers.repec.org/article/binbpeajo/v_3a43_3ay_3a2012_3ai_3a2012-01_3ap_3a1-80.htm.

Christiano, L.J., Eichenbaum, M., Evans, C.L., 1999. Chapter 2 Monetary policy shocks: What have we learned and to what end?, in: Handbook of Macroeconomics. Elsevier. volume 1, pp. 65–148. URL: https://linkinghub.elsevier.com/retrieve/pii/S1574004899010058, doi:10.1016/S1574-0048(99)01005-8.

Cieslak, A., Schrimpf, A., 2019. Non-monetary news in central bank communication. Journal of International Economics 118, 293–315. URL: http://www.sciencedirect.com/science/article/pii/S002219961830268X, doi:10.1016/j.jinteco.2019.01.012.

Cieslak, A., Vissing-Jorgensen, A., 2020. The Economics of the Fed Put. Working Paper 26894. National Bureau of Economic Research. URL: http://www.nber.org/papers/w26894, doi:10.3386/w26894.

Doh, T., Song, D., Yang, S.K., 2020. Deciphering Federal Reserve Communication via Text Analysis of Alternative FOMC Statements. The Federal Reserve Bank of Kansas City Research Working Papers URL: https://www.kansascityfed.org/publications/research/rwp/articles/2020/deciphering-federal-reserve-communication-via-text-analysis, doi:10.18651/RWP2020-14.

Gentzkow, M., Kelly, B., Taddy, M., 2019. Text as Data. Journal of Economic Literature 57, 535–574. URL: https://pubs.aeaweb.org/doi/10.1257/jel.20181020, doi:10.1257/jel.20181020.

Gertler, M., Karadi, P., 2015. Monetary Policy Surprises, Credit Costs, and Economic Activity. American Economic Journal: Macroeconomics 7, 44–76. URL: http://pubs.aeaweb.org/doi/10.1257/mac.20130329, doi:10.1257/mac.20130329.

Gilchrist, S., Zakrajsek, E., 2012. Credit Spreads and Business Cycle Fluctuations. American Economic Review 102, 1692–1720. URL: https://pubs.aeaweb.org/doi/10.1257/aer.102.4.1692, doi:10.1257/aer.102.4.1692.

GÃŒrkaynak, R.S., Sack, B., Wright, J.H., 2006. The U.S. Treasury Yield Curve: 1961 to the Present , 42.

Gurkaynak, R.S., Sack, B., Swanson, E., 2004. Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements. Finance and Economic Discussion Series , 43.

References II

Handlan, A., 2020. Fedspeak matters: Fomc Statements and Monetary Policy Expectations. Working Paper URL: https://sites.google.com/umn.edu/amy-handlan/research.

Hansen, S., McMahon, M., 2016. Shocking language: Understanding the macroeconomic effects of central bank communication. Journal of International Economics 99, S114–S133. URL: http://www.sciencedirect.com/science/article/pii/S0022199615001828, doi:10.1016/j.jinteco.2015.12.008.

Hansen, S., McMahon, M., Prat, A., 2018. Transparency and Deliberation Within the FOMC: A Computational Linguistics Approach. The Quarterly Journal of Economics 133, 801–870. URL: https://academic.oup.com/qje/article/133/2/801/4582916, doi:10.1093/qje/qjx045.

Husted, L., Rogers, J., Sun, B., 2017. Monetary Policy Uncertainty. International Finance Discussion Paper 2017, 1–56. URL: https://www.federalreserve.gov/econres/ifdp/files/ifdp1215.pdf, doi:10.17016/IFDP.2017.1215.

Jordà, O., 2005. Estimation and Inference of Impulse Responses by Local Projections. The American Economic Review 95, 161–182. URL: http://www.jstor.org/stable/4132675.

Lunsford, K.G., 2020. Policy Language and Information Effects in the Early Days of Federal Reserve Forward Guidance. American Economic Review 110, 2899–2934. URL: https://www.aeaweb.org/articles?id=10.1257/aer.20181721, doi:10.1257/aer.20181721.

Nakamura, E., Steinsson, J., 2018. High-Frequency Identification of Monetary Non-Neutrality: The Information Effect. The Quarterly Journal of Economics 133, 1283–1330. URL: https://academic.oup.com/qje/article/133/3/1283/4828341, doi:10.1093/qje/qjy004.

Ramey, V.A., 2016. Chapter 2 - Macroeconomic Shocks and Their Propagation, in: Taylor, J.B., Uhlig, H. (Eds.), Handbook of Macroeconomics. Elsevier. volume 2, pp. 71–162. URL: http://www.sciencedirect.com/science/article/pii/S1574004816000045, doi:10.1016/bs.hesmac.2016.03.003.

Romer, C.D., Romer, D.H., 2004. A New Measure of Monetary Shocks: Derivation and Implications. American Economic Review 94, 43.

Shapiro, A.H., Wilson, D.J., 2019. Taking the Fed at its Word: A New Approach to Estimating Central Bank Objectives Using Text Analysis. Federal Reserve Bank of San Francisco, Working Paper Series , 01–74URL: http://www.frbsf.org/economic-research/publications/working-papers/2019/02, doi:10.24148/wp2019-02.

Yang, Z., Dai, Z., Yang, Y., Carbonell, J., Salakhutdinov, R., Le, Q.V., 2020. XLNet: Generalized Autoregressive Pretraining for Language Understanding. Working Paper URL: http://arxiv.org/abs/1906.08237. arXiv: 1906.08237.

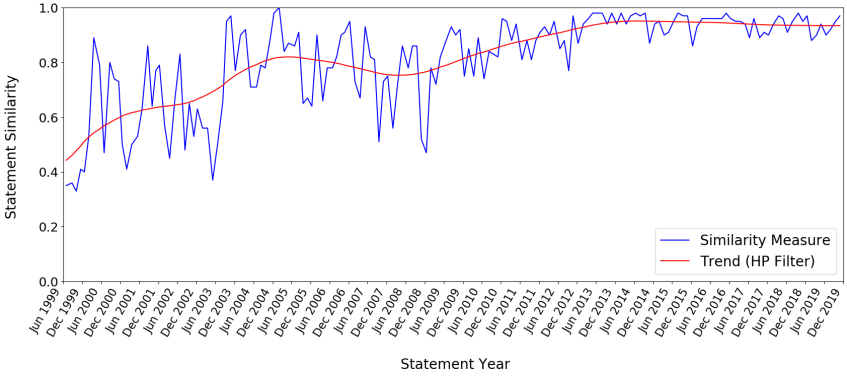
FedSpeak Matters (Handlan, 2020)

Back

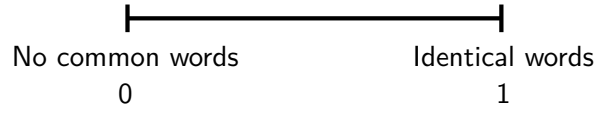
- Produce a sequential-statement similarity measure
- Similarity measure captures magnitude, not direction of word changes
- Key Findings:
  1. FOMC statements have become more similar over time
  2. Decrease in sequential similarity correlated with increase FFF changes
  3. Impact from Bernanke's statements $>$ Yellen's statements $>$ Greenspan's statements

FOMC Statement Similarity with Previous Statement

Back-lit review Back-conclusion



Document similarity takes values between 0 and 1:



Main Regression

Back

$$|\Delta \mathbb{E}_i[r_j]| = \beta_0 + \beta_1 S_i^1 + \beta_2 |\Delta r_i| + \beta_3 \left(S_i^1 \times |\Delta r_i| \right) + \epsilon_i$$

	$\lvert\Delta\mathbb{E}[r_0]\rvert$	$\lvert\Delta\mathbb{E}[r_1]\rvert$	$\lvert\Delta\mathbb{E}[r_2]\rvert$	$\lvert\Delta\mathbb{E}[r_3]\rvert$
S^1	-0.074***	-0.043***	-0.067***	-0.061***
	(0.014)	(0.012)	(0.014)	(0.019)
$\lvert\Delta r\rvert$	0.047	0.038	0.049	0.023
	(0.031)	(0.029)	(0.033)	(0.037)
$S^1 \times \lvert\Delta r\rvert$	-0.042	-0.070	-0.007	-0.193
	(0.094)	(0.098)	(0.102)	(0.136)
Intercept	-0.004*	0.003	0.002	0.006***
	(0.002)	(0.002)	(0.002)	(0.002)
N	164	164	164	154
R^2	0.43	0.42	0.37	0.44

Notes: HAC standard errors in parentheses. * is significance at the 10% level, ** is significance at the 5% level, and *** is significance at the 1% level.

Example FOMC Statement (Sept 2006) by Sentence

Back-Intro Back-Data

1. The Federal Open Market Committee decided today to keep its target for the federal funds rate at 5-1/4 percent.
2. The moderation in economic growth appears to be continuing, partly reflecting a cooling of the housing market.
3. Readings on core inflation have been elevated, and the high levels of resource utilization and of the prices of energy and other commodities have the potential to sustain inflation pressures.
4. However, inflation pressures seem likely to moderate over time, reflecting reduced impetus from energy prices, contained inflation expectations, and the cumulative effects of monetary policy actions and other factors restraining aggregate demand.
5. Nonetheless, the Committee judges that some inflation risks remain.
6. The extent and timing of any additional firming that may be needed to address these risks will depend on the evolution of the outlook for both inflation and economic growth, as implied by incoming information.

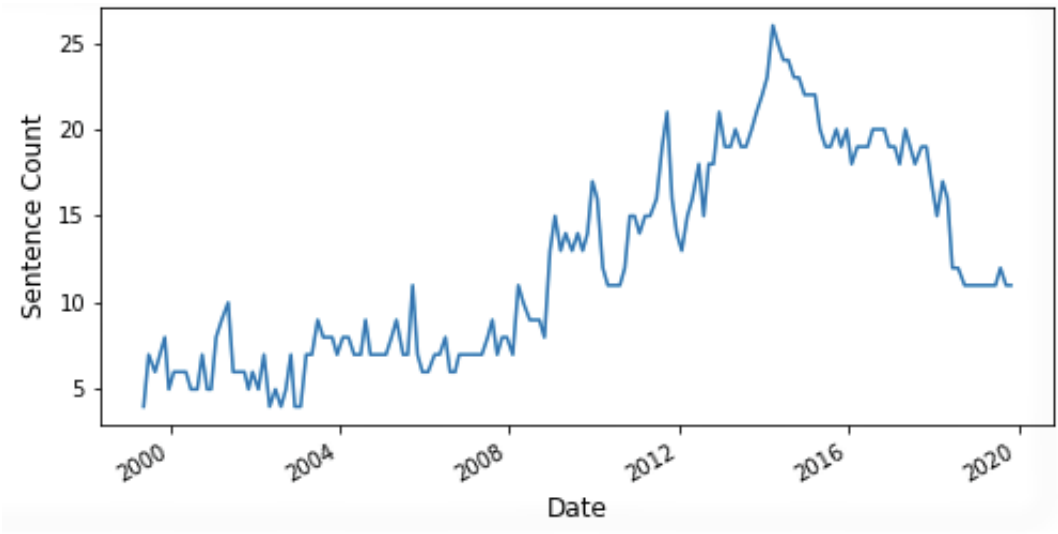
Clean FOMC Statement Text

Back

- Remove:
  - Remove hyperlinks and urls from statement's webpage
  - Remove FOMC member voting record from end of statement
  - Remove list of regional banks whose requests were approved
  - Remove release timestamp (ie, "For immediate release")
- Change:
  - Standardize text coding as UTF-8 (ie, change length of "-")
  - Collapse spacing between words to one space
  - Replace end of sentences with '<sep>'
  - Add document identifier '<cls>'

FOMC Statement Length

Back



Fed Funds Futures to Expectations

Back

- FFF settlement price is the average federal funds rate over expiration month.
- Trading price before FOMC meeting in expiration month:

$$fff_t^1 = 100 - \left(\frac{d}{m} \; r_{t-1} + \frac{m-d}{m} \; \mathbb{E}_t[r_t] \right)$$

  day of meeting=d, days in month=m, ffr before r_{t-1} and after r_t meeting

- Change in *fff* represent expectations
  - Unexpected change in FFR

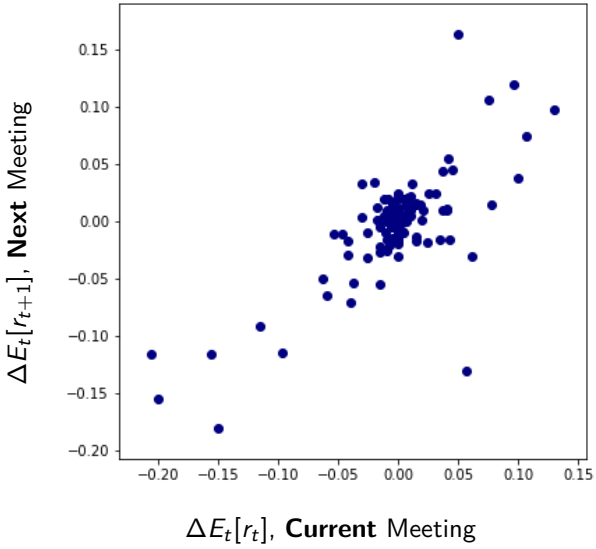
$$\mathbb{E}_{t+\Delta}[r_t] - \mathbb{E}_t[r_t] = \frac{m}{m-d} \left(fff_t^1 - fff_{t+\Delta}^1 \right)$$

  - Shift in FFR expectations for next meeting in $(n-1)$ months

$$\mathbb{E}_{t+\Delta}[r_{t+1}] - \mathbb{E}_t[r_{t+1}] = \frac{m_2}{m_2 - d_2} \left(fff_t^n - fff_{t+\Delta}^n - \frac{d_2}{m_2} \left(\mathbb{E}_{t+\Delta}[r_t] - \mathbb{E}_t[r_t] \right) \right)$$

Correlation of Changes in Fed Funds Rate Expectations

Back



Principal Component Analysis (PCA)

Back

- PCA method to reduce data's dimension without sacrificing variation
- Ex: dataset with two variables x^1, x^2 and N observations
- First principal component data projection:

$$\underbrace{PC1}_{Nx1} = \underbrace{X}_{Nx2} \cdot \underbrace{V}_{2x1}$$

  where V is eigenvector of X's covariance matrix with highest eigenvalue
- Largest eigenvalue represents the maximum common variability of the data
- The corresponding eigenvector, while arbitrarily scaled, then is the direction that captures that variation

FFR Expectations Representation

Back

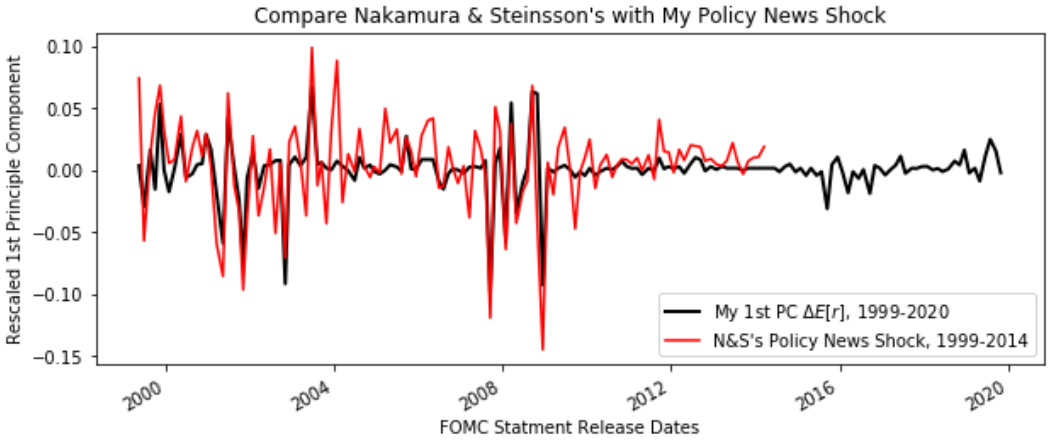
- FOMC meetings occur between 1-3 months apart
- Keep track of meeting dates to know which FFF to use
- $\Delta E_t[r_t]$ and $\Delta E_t[r_{t+1}]$ calculated with fff^1 through fff^4
- No $\Delta E_t[r_{t+2}]$ and $\Delta E_t[r_{t+3}]$ due to low liquidity of fff^5 and fff^6
- FFR expectations represented as the first PC of $\Delta E_t[r_t]$ and $\Delta E_t[r_{t+1}]$

Interpret the 1st Principal Component $\Delta E_t[r]$ Back-Data Intro

- A 100 basis point $\uparrow$ in 1st principal component $\Delta E_t[r]$
  - 180 basis point $\uparrow$ in $\Delta E_t[r_t]$
  - 168 basis point $\uparrow$ in $\Delta E_t[r_{t+1}]$
  - 100 basis point $\uparrow$ in 1-year Treasury yield
- Follow Nakamura and Steinsson (2018) to scale $\Delta E_t[r]$ to 1-year treasury

Comparison with NS Shock

Back - Data Intro Back - Shock Measures



Note: Nakamura and Steinsson (2018) use $\Delta E_t[r_t]$, $\Delta E_t[r_{t+1}]$, *and* Eurodollar futures

Neural Network Training

Back

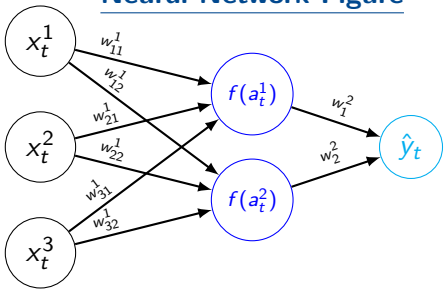
- Train the neural network $\rightarrow$ fitting network to training data Network Example
  1. Fix network structure (nodes and layers) UAT&Layers
  2. Iteratively update parameters to $\downarrow$ prediction error for training data Updating
  3. Evaluate the neural network $\rightarrow$ prediction out-of-sample (testing) Overfitting
  4. Poor out-of-sample performance, go back to step 1

Example of a Small Neural Network Setup

Back

- Data: 4 variables x^1, x^2, x^3, y
- Goal: Predict y from $X \equiv x^1, x^2, x^3$
- Example: 2 layers, 2 "hidden" nodes
- From X_t to $\hat{y}_t$ for observation $t \in T$:
  - Linearly combine $x_t^1, x_t^2, x_t^3 \rightarrow a_t^j$
  - f is a non-linear function
  - $\hat{y}_t$ is predicted output
- Training prediction error $\rightarrow$ update w
- Testing prediction error $\rightarrow$ update network structure

Neural Network Figure



Neural Network Matrix Algebra

$$\begin{bmatrix} x_t^1 & x_t^2 & x_t^3 \end{bmatrix} \begin{bmatrix} w_{11}^1 & w_{12}^1 \\ w_{21}^1 & w_{22}^1 \\ w_{31}^1 & w_{32}^1 \end{bmatrix} = \begin{bmatrix} a_t^1 & a_t^2 \end{bmatrix}$$

$$\begin{bmatrix} f(a_t^1) & f(a_t^2) \end{bmatrix} \begin{bmatrix} w_1^2 \\ w_2^2 \end{bmatrix} = \hat{y}_t$$

Update Weights

Back

- Error function: $C = \sum_{t \in T} \frac{1}{T} (\hat{y}_t - y_t)^2$
- $\frac{\partial C}{\partial w_{i,j}^{\ell}}$ for all weights $w_{i,j}^{\ell}$ is known from f and network structure
- Iteratively change weights to minimize error (ie, gradient descent)

Overfitting

Back

- To address overfitting concerns:
  - Evaluate on out-of-sample/testing data (ie $Corr(\hat{y}_t, y_t)$ for $t \notin T$)
  - Limit training $\rightarrow$ parameter updating or number of iterations
  - Increase variety of training data
  - Change neural network structure (nodes/layers)

Universal Approximation vs Many Layers

Back

- Universal Approximation Theorem
  - Neural network, with at least 1 hidden layer, can approximate any function
  - No sufficiency and nothing about training
- More layers

  $\rightarrow$ Fewer parameters for same underlying function

  $\rightarrow$ Fewer training iterations and data requirements

Text Analysis NN Input and Output

Back

- Each FOMC statement is matched with $\Delta E_t[r]$ calculated from FFF prices
- Input X_t is a matrix : columns are words in order, rows are the 768x1 word-vectors

Statement Text	Dec 12, 2006: "The Federal Open Market Committee decided today to keep its target for the federal funds rate at $5\frac{1}{4}$ percent..."
Input Matrix	768 rows (word features) ↓ 256 columns (text length) → $\begin{bmatrix} \underbrace{x_t^1}_{The} & \underbrace{x_t^2}_{Federal} & \underbrace{x_t^3}_{Open} & \underbrace{x_t^4}_{Market} & \underbrace{x_t^5}_{Committee} & \underbrace{x_t^6}_{decided} & \dots & \underbrace{x_t^{256}}_{.} \end{bmatrix}$

- Output y_t is $\Delta E_t[r]$, 1st principal component of FFR expectation changes
- Update parameters to minimize $\sum_{t \in T} \frac{1}{T}(\widehat{\Delta E_t[r]} - \Delta E_t[r])^2$

XLNet (Yang et al., 2020) 1/3

Back

- Use text analysis, 12-layer neural network from Yang et al. (2020)
  - State-of-the-art on tasks: translation, question & answer, classification/regression
  - Transfer learning: "pretrained" parameters to reduce training requirements
  - Use their structure, pretrained weights, numerical word representations
- Text is a sequence of numerical vectors that represent words and the overall document
- Trained to predict randomly-masked words in sentence given observed words

XLNet (Yang et al., 2020) 2/3

Back

- Starts with 32000 words with embeddings of 768 dimensions
  - Words of similar meaning will have more similar vectors but without context
  - Vectors clustered according to co-occurrence
- 12 layers and 110 million network parameters
- Training data: BookCorpus(11,038 books), English Wikipedia (6 mil. articles), Giga5 (9.9 mil. news articles), ClueWeb12 (733 mil. webpages), Common Crawl (1K+ TB text from webpages)

XLNet Transfer Learning 3/3

Back

- Yang et al. (2020) initially train to predict missing words from text
- Neural network parameters from Yang et al. (2020) already "understand" English
- Yang et al. (2020): using trained parameters as initial parameters for new task

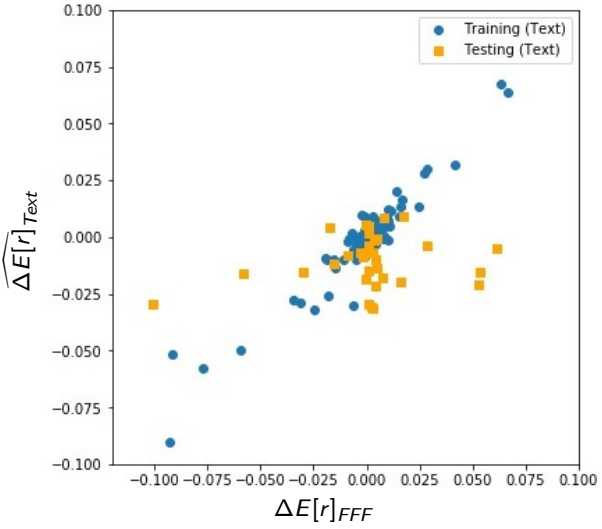
  $\Longrightarrow$ higher accuracy, lower data requirements for new task

- Update weights to predict $\Delta E[r]$, a "label", from FOMC statement text

Evaluation

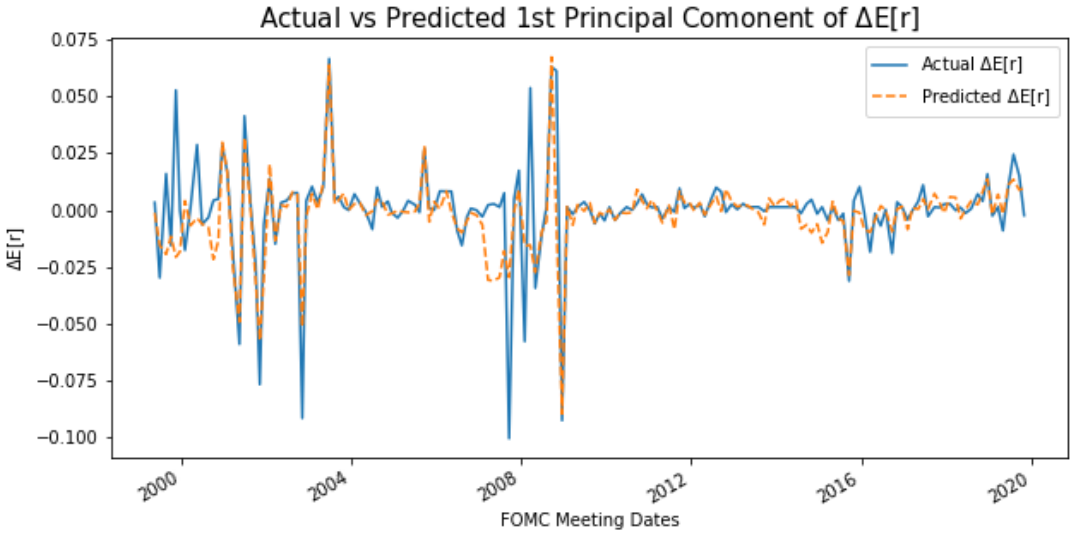
Back Over Time

- Compare output variable, $\Delta E[r]$, and network prediction, $\widehat{\Delta E[r]}$, for $t \in \textit{Testing}$
- Testing, Pearson correlation $= 0.2$
- Whole sample correlation $= 0.72$



Actual and Predicted $\Delta E_t[r]$ Over Time

Back



Statement Text vs. Changes in Target Federal Funds Rate

Back TFFR Graph

- On *training* sample:

$$\Delta E_t[r]_{FFF} = \beta_0 + \beta_1 \Delta \textit{Target FFR}$$

- $\hat{\beta}_1 = 0.05$ to calculate $\widehat{\Delta E_t[r]}_{target}$ for *testing* sample
- Out-of-Sample prediction comparison:

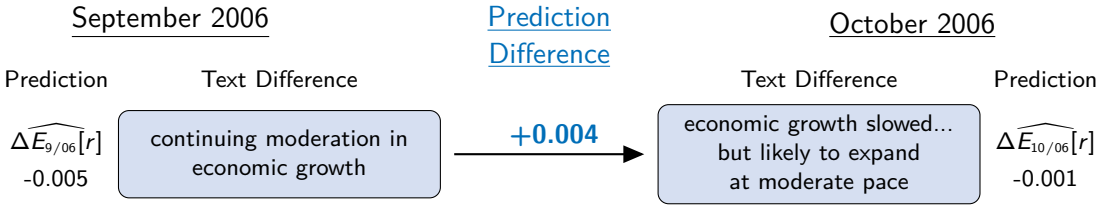
Comparison Visual

	FOMC Statement Text	Δ Target FFR
Corr($\widehat{\Delta E[r]}$,$\Delta E[r]$)	0.2	0.1
R^2	0.04	0.01
N	33	33

Regression Together

Difference in Prediction for Different Text

- Two statements with few differences $\rightarrow$ compare neural network prediction
- Increase in $\widehat{E_t[r]} \rightarrow$ increase expectation path of FFR
- Neural network picks up long-term word dependencies



Difference in Prediction for Different Text

Back Row 1 Row 2 Row 3 Full Text 1

Left Examples		Prediction Difference	Right Examples	
Prediction	Key Text		Key Text	Prediction
$\widehat{\Delta E_{9/06}[r]}$ -0.005	continuing moderation in economic growth	+0.004	economic growth slowed... but likely to expand at moderate pace	$\widehat{\Delta E_{10/06}[r]}$ -0.001
$\widehat{\Delta E_{12/16}[r]}$ 0.002	unemployment declined... inflation moved up, but remains low... raise target FFR	-0.011	unemployment remains low... inflation remains low... maintain target FFR	$\widehat{\Delta E_{2/17}[r]}$ -0.009
$\widehat{\Delta E_{5/19}[r]}$ -0.002	economic activity rose... household spending slowed... inflation remained low	+0.013	economic activity is rising... household spending picked up...inflation declined but uncertain about outlook	$\widehat{\Delta E_{6/19}[r]}$ 0.011

Examples of Predicted $\Delta E_t[r]$ (1)

- Sept. 2006 FOMC Statement
  - $\Delta E_t[r] = -0.003$
  - $\widehat{\Delta E_t[r]} = -0.005$
  - $\Delta TargetFFR = 0$
- ... percent. **The moderation in economic growth appears to be continuing, partly reflecting a cooling of the housing market**. Readings on...

- Oct. 2006 FOMC Statement
  - $\Delta E_t[r] = 0.001$
  - $\widehat{\Delta E_t[r]} = -0.001$
  - $\Delta TargetFFR = 0$
- ... percent. **Economic growth has slowed over the course of the year, partly reflecting a cooling of the housing market. Going forward, the economy seems likely to expand at a moderate pace.** Readings on...

Examples of Predicted $\Delta E_t[r]$ (2)

Back

- Dec 2016 FOMC Statement
  - $\Delta E_t[r] = 0.0014$
  - $\widehat{\Delta E_t[r]} = 0.0015$
  - $\Delta TargetFFR = 0.25$
- ... economic activity **has been expanding** at a moderate pace since mid-year...the unemployment rate **has declined**. Household spending **has been rising moderately**... Inflation has increased **since earlier this year** but is still below the Committee's 2 percent longer-run objective, **partly reflecting earlier declines in energy prices and in prices of non-energy imports. Market-based measures of inflation compensation have moved up considerably but still are low... Inflation is expected to rise to 2 percent over the medium term as the transitory effects of past declines in energy and import prices dissipate and the labor market strengthens further.** ... the Committee decided to **raise** the target range for the federal funds rate ...

- Feb 2017 FOMC Statement
  - $\Delta E_t[r] = -0.004$
  - $\widehat{\Delta E_t[r]} = -0.009$
  - $\Delta TargetFFR = 0$
- ... economic activity **has continued to expand** at a moderate pace...the unemployment rate **stayed near its recent low.** Household spending **has continued to rise moderately** ... **Measures of consumer and business sentiment have improved of late.** Inflation increased **in recent quarters** but is still below the Committee's 2 percent longer-run objective. **Market-based measures of inflation compensation remain low**... **and inflation will rise to 2 percent over the medium term.**.... the Committee decided to **maintain** the target range for the federal funds rate ...

Examples of Predicted $\Delta E_t[r]$ (3)

Back

- May 2019 FOMC Statement
  - $\Delta E_t[r] = -0.009$
  - $\widehat{\Delta E_t[r]} = -0.002$
  - $\Delta TargetFFR = 0$
- ... economic activity **rose** at a solid rate ... **Growth of household spending and business fixed investment slowed in the first quarter** ...On balance, market-based measures of **inflation compensation have remained low** in recent months .... In light of **global economic and financial developments** and muted inflation pressures, **the Committee will be patient as it determines what future adjustments to the target range for the federal funds rate may be appropriate to support these outcomes** ...

- June 2019 FOMC Statement
  - $\Delta E_t[r] = 0.0112$
  - $\widehat{\Delta E_t[r]} = 0.0113$
  - $\Delta TargetFFR = 0$
- ... economic activity **is rising** at a moderate rate ...**Although growth of household spending appears to have picked up from earlier in the year, indicators of business fixed investment have been soft** ...Market-based measures of **inflation compensation have declined** ...but **uncertainties** about this outlook have increased. In light of these **uncertainties** and muted inflation pressures, **the Committee will closely monitor the implications of incoming information for the economic outlook and will act as appropriate to sustain the expansion, with a strong labor market and inflation near its symmetric 2 percent objective** ...

Whole Sept 2006/Oct 2006 Statement

Row 1 Back

Sept 2006 FOMC Statement:

The Federal Open Market Committee decided today to keep its target for the federal funds rate at 5-1/4 percent. **The moderation in economic growth appears to be continuing, partly reflecting a cooling of the housing market.** Readings on core inflation have been elevated, and the high levels of resource utilization and of the prices of energy and other commodities have the potential to sustain inflation pressures. However, inflation pressures seem likely to moderate over time, reflecting reduced impetus from energy prices, contained inflation expectations, and the cumulative effects of monetary policy actions and other factors restraining aggregate demand. Nonetheless, the Committee judges that some inflation risks remain. The extent and timing of any additional firming that may be needed to address these risks will depend on the evolution of the outlook for both inflation and economic growth, as implied by incoming information.

Oct 2006 FOMC Statement:

The Federal Open Market Committee decided today to keep its target for the federal funds rate at 5-1/4 percent. **Economic growth has slowed over the course of the year, partly reflecting a cooling of the housing market. Going forward, the economy seems likely to expand at a moderate pace.** Readings on core inflation have been elevated, and the high level of resource utilization has the potential to sustain inflation pressures. However, inflation pressures seem likely to moderate over time, reflecting reduced impetus from energy prices, contained inflation expectations, and the cumulative effects of monetary policy actions and other factors restraining aggregate demand. Nonetheless, the Committee judges that some inflation risks remain. The extent and timing of any additional firming that may be needed to address these risks will depend on the evolution of the outlook for both inflation and economic growth, as implied by incoming information.

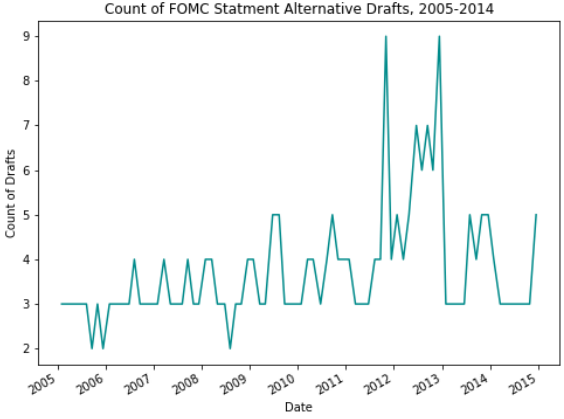
Expectations with Target Rate and Text Shock

Back

	$\Delta E_t[r_t]$	$\Delta E_t[r_{t+1}]$	$\Delta E_t[r_{t+2}]$	$\Delta E_t[r_{t+3}]$
Δ *Target FFR*	0.06***	0.07***	0.08***	0.16***
	(0.02)	(0.01)	(0.01)	(0.02)
N	165	165	163	82
R^2	0.07	0.13	0.16	0.34
Adj. R^2	0.07	0.12	0.15	0.33
Δ *Target FFR*	0.00	0.03**	0.04***	0.10***
	(0.01)	(0.01)	(0.01)	(0.02)
$\widehat{\Delta E[r]}_{text}$	1.69***	1.46***	1.37***	1.26***
	(0.15)	(0.15)	(0.16)	(0.23)
N	165	165	163	82
R^2	0.47	0.46	0.42	0.52
Adj. R^2	0.47	0.45	0.41	0.51

Alternative Statements from Meeting Materials

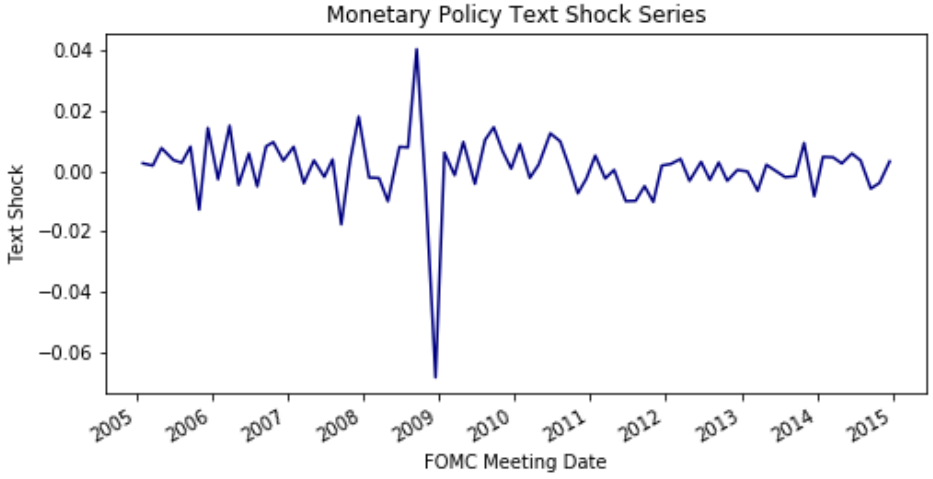
Examples Back-Cleaned Text Shock



- Alternative statements are in FOMC meeting materials
- Meeting materials released on a 5 year lag
- Alternative statements from 2005-2014
- Count new wording is as a different alternative

Cleaned Text Shocks (2005-2014)

Back



Cleaned Text Shocks Capture Forward Guidance Effect

Back

- Current expectations of the target rate $h \in \{0, 1, 2, 3\}$ meetings from now
- Compare regression specifications for different horizon h and shock k

$$\Delta E_t[r_{t+h}] = \beta^{h,k} shock_t^k + \eta_t^{h,k}$$

where shock k is:

  - Cleaned Text Shocks, Text Shock, or 1st principal component of FFF

- Only for Cleaned Text Shocks do:
  - Coefficients increase as FFF maturity increases Coef Plot
  - R^2 increases as FFF maturity increases R^2 Plot

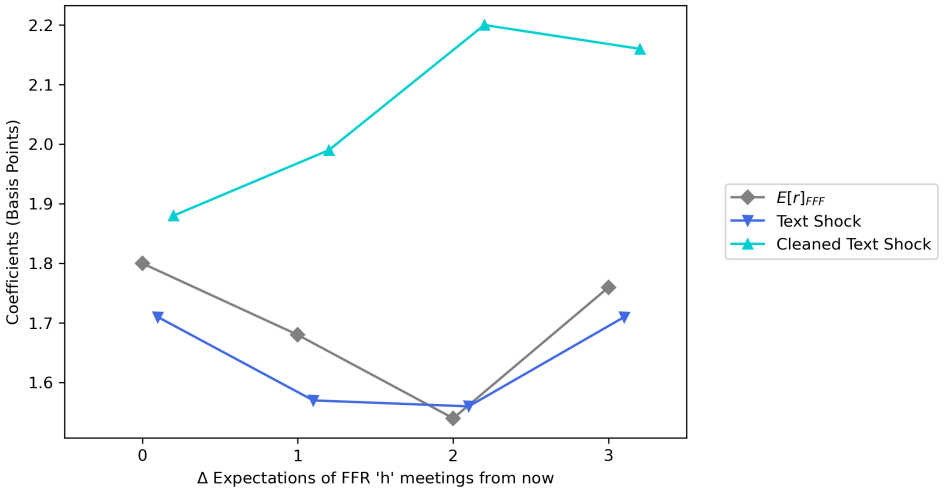
Expectations with Target Rate and Cleaned Text Shock

Back

	$\Delta E_t[r_t]$	$\Delta E_t[r_{t+1}]$	$\Delta E_t[r_{t+2}]$	$\Delta E_t[r_{t+3}]$
Δ *Target FFR*	0.06***	0.07***	0.08***	0.16***
	(0.02)	(0.01)	(0.01)	(0.02)
N	165	165	163	82
R^2	0.07	0.13	0.16	0.34
Adj. R^2	0.07	0.12	0.15	0.33
Δ *Target FFR*	0.02	0.00	0.03	0.11***
	(0.02)	(0.02)	(0.02)	(0.03)
$\widehat{\Delta E[r]}_{clean}$	1.75***	1.97***	1.92***	1.32***
	(0.35)	(0.38)	(0.38)	(0.42)
N	80	80	80	43
R^2	0.33	0.31	0.38	0.57
Adj. R^2	0.31	0.29	0.36	0.55

Forward Guidance: Coefficients Over Expectations Horizons

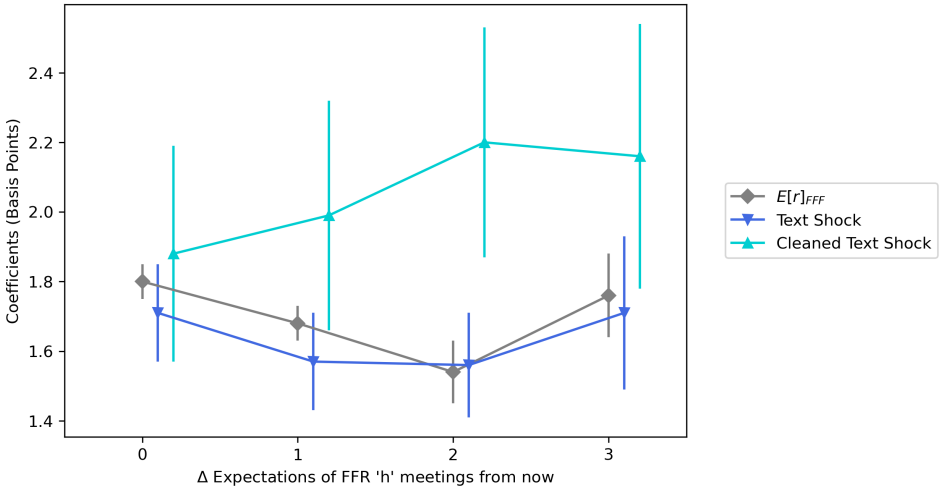
Back



Reg tables Graph with Bands

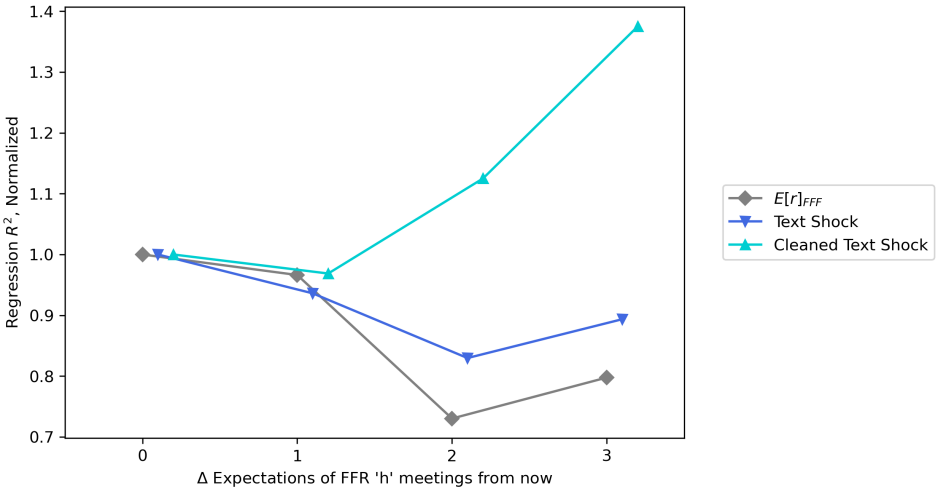
Forward Guidance: Coefficients with Confidence Intervals

Back



Forward Guidance: R^2 Over Expectations Horizons

Back



Reg tables

Forward Guidance capture by Text Shocks Regression Table

Back

	$\Delta E_t[r_t]$	$\Delta E_t[r_{t+1}]$	$\Delta E_t[r_{t+2}]$	$\Delta E_t[r_{t+3}]$
Cleaned Text Shock$_t$	1.88***	1.99***	2.20***	2.16***
	(0.31)	(0.33)	(0.33)	(0.38)
N	80	80	80	43
R^2	0.32	0.31	0.36	0.44
Adj. R^2	0.32	0.30	0.35	0.42

Note: $E_r[r_{t+h}]$ represents expectations at meeting t about FFR h meeting(s) away. Intercepts for regression are zero.

Reg with Target FFR Others: $\Delta E_t[r]$ & Unclean Shock

Forward Guidance Table Comparison

Back

	$\Delta E_t[r_t]$	$\Delta E_t[r_{t+1}]$	$\Delta E_t[r_{t+2}]$	$\Delta E_t[r_{t+3}]$
Intercept	-0.00**	-0.00*	-0.00	-0.01*
	(0.00)	(0.00)	(0.00)	(0.00)
$\Delta E[r]_{FFF}$	1.80***	1.68***	1.54***	1.76***
	(0.05)	(0.05)	(0.09)	(0.12)
N	165	165	163	82
R^2	0.89	0.86	0.65	0.71
Adj. R^2	0.89	0.86	0.65	0.71

Intercept	0.00	0.00	0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
$\widehat{\Delta E[r]}_{text}$	1.71***	1.57***	1.56***	1.71***
	(0.14)	(0.14)	(0.15)	(0.22)
N	165	165	163	82
R^2	0.47	0.44	0.39	0.42
Adj. R^2	0.47	0.44	0.38	0.41

Summary Statistics of Monetary Shock Series (2005-2014)

Back

	$\Delta E[r]_{FFF}$	$\widehat{\Delta E[r]}_{text}$	$\widehat{\Delta E[r]}_{clean}$	NS Shock	$\Delta FF4$	$\Delta TY1(\Delta FF4)$
count	80	80	80	74	80	80
mean	-0.0000	-0.0027	0.0011	0.0039	-0.0018	-0.0042
std	0.0215	0.0158	0.0113	0.0321	0.0395	0.0294
min	-0.1009	-0.0900	-0.0685	-0.1452	-0.19	-0.1441
median	0.0013	-0.0007	0.0022	0.0076	0	-0.0029
max	0.0631	0.0675	0.0406	0.0679	0.115	0.0825

Summary Statistics of Treasury Yields

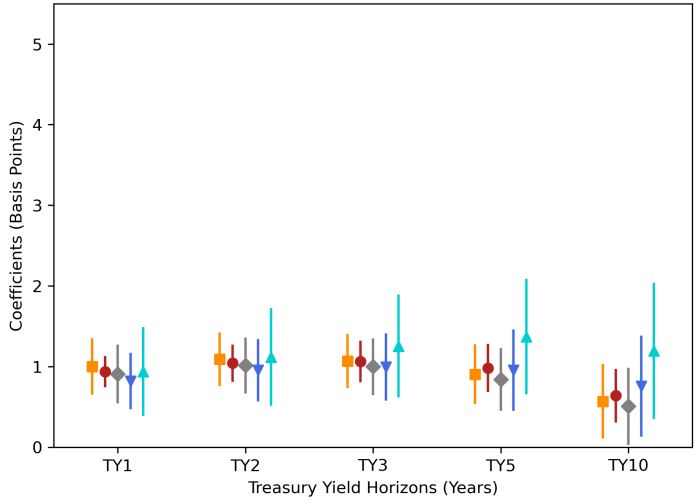
	$\Delta\ TY_1$	$\Delta\ TY_2$	$\Delta\ TY_3$	$\Delta\ TY_5$	$\Delta\ TY_{10}$
count	80	80	80	80	80
mean	-0.0009	0.0018	0.0025	0.0012	0.0004
std	0.0544	0.0661	0.0772	0.0918	0.0923
min	-0.2045	-0.2641	-0.3477	-0.4708	-0.5189
25%	-0.0198	-0.027	-0.0314	-0.0385	-0.0356
50%	0.0019	-0.0008	0.0009	0.008	0.0135
75%	0.0189	0.0322	0.0469	0.0444	0.0569
max	0.2023	0.2296	0.2263	0.1844	0.2019

Summary Statistics of TIPS Yields

	Δ $TIPS_2$	Δ $TIPS_3$	Δ $TIPS_5$	Δ $TIPS_{10}$
count	80	80	80	80
mean	-0.0072	-0.0081	-0.0074	-0.0047
std	0.1183	0.1141	0.1094	0.0963
min	-0.5215	-0.5499	-0.5818	-0.5705
25%	-0.0467	-0.0476	-0.0509	-0.0353
50%	-0.0024	0.0032	0.009	0.0072
75%	0.0484	0.0522	0.0451	0.0463
max	0.3637	0.2998	0.2187	0.1569

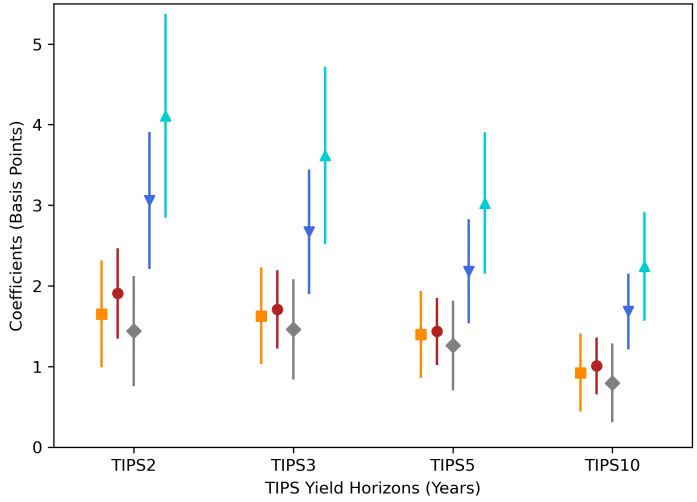
Treasury Yields, Nominal Interest Rates

Back Table



TIPS yields, Real Interest Rates

Back Table



Treasury Yields, Nominal Interest Rates

Back to Graph

	ΔTY_1	ΔTY_2	ΔTY_3	ΔTY_5	ΔTY_{10}
GK Shock	-	0.81***	0.79***	0.67**	0.42
	-	(0.25)	(0.25)	(0.27)	(0.34)
NS Shock	0.94***	1.04***	1.06***	0.98***	0.64*
	(0.19)	(0.23)	(0.26)	(0.30)	(0.33)
$\Delta E[r]_{FFF}$	0.91**	1.01***	1.00***	0.84**	0.51
	(0.36)	(0.35)	(0.35)	(0.39)	(0.48)
$\widehat{\Delta E[r]}_{text}$	0.82**	0.96**	1.00**	0.96*	0.76
	(0.35)	(0.39)	(0.42)	(0.51)	(0.63)
$\widehat{\Delta E[r]}_{clean}$	0.94*	1.12*	1.25**	1.37*	1.20
	(0.55)	(0.61)	(0.64)	(0.72)	(0.85)

Note: Each row and column come from different specification. HAC standard errors in parentheses.

* sig. at 10% level, ** sig. at 5% level, and *** sig. at 1% level.

Δ Target Rate

TIPS yields, Real Interest Rates

Back to Graph

	$\Delta TIPS_2$	$\Delta TIPS_3$	$\Delta TIPS_5$	$\Delta TIPS_{10}$
GK Shock	1.23**	1.21***	1.04***	0.69*
	(0.49)	(0.45)	(0.40)	(0.36)
NS Shock	1.91***	1.71***	1.44***	1.01***
	(0.56)	(0.49)	(0.42)	(0.35)
$\Delta E[r]_{FFF}$	1.44**	1.46**	1.26**	0.80
	(0.68)	(0.62)	(0.55)	(0.49)
$\widehat{\Delta E[r]}_{text}$	3.06***	2.67***	2.18***	1.68***
	(0.85)	(0.77)	(0.65)	(0.47)
$\widehat{\Delta E[r]}_{cleaned}$	4.11***	3.62***	3.03***	2.24***
	(1.26)	(1.10)	(0.88)	(0.67)

Note: Each row and column come from different specification. Standard errors in parentheses.

* sig. at 10% level, ** sig. at 5% level, and *** sig. at 1% level.

Δ Target Rate

Target Federal Funds Rate

	ΔTY_1	ΔTY_2	ΔTY_3	ΔTY_5	ΔTY_{10}
Δ *Target FFR*	0.04**	0.02	0.01	0.00	-0.00
	(0.02)	(0.03)	(0.04)	(0.03)	(0.03)

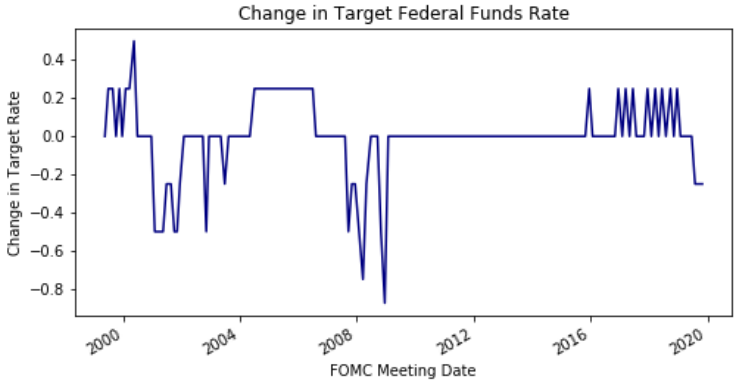
	$\Delta TIPS_2$	$\Delta TIPS_3$	$\Delta TIPS_5$	$\Delta TIPS_{10}$
Δ *Target FFR*	0.12**	0.10*	0.04	0.03
	(0.05)	(0.05)	(0.03)	(0.03)

* sig. at 10% level, ** sig. at 5% level, and *** sig. at 1% level.

TY TIPS

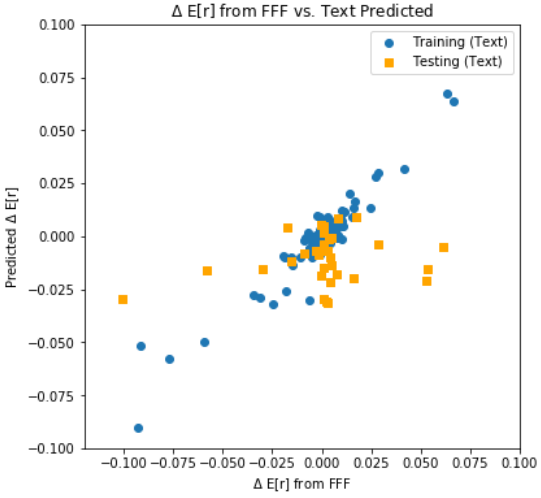
Changes in Target Federal Funds Rate

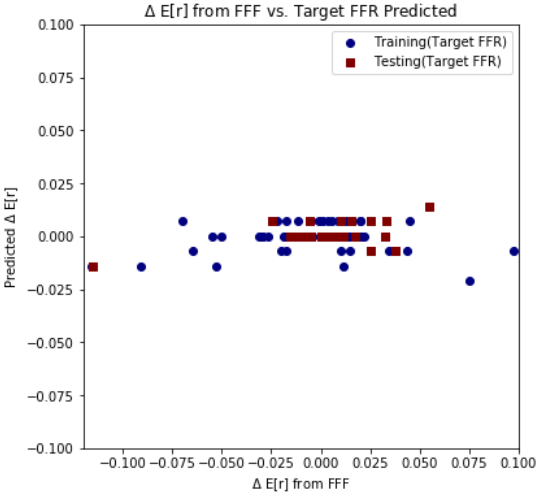
Back



Graphical Comparison

Back





Dovish Alternative (Alt A)

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Oct 2006, Dovish Alternative, NN predicted change in FFR expectations = .25

The Federal Open Market Committee decided today to keep its target for the federal funds rate at 5 1/4 percent. Economic growth appears to have slowed further in the third quarter, partly reflecting a cooling of the housing market. Although there is a risk that the slowdown in economic growth may become more pronounced, the economy seems likely to expand at a moderate pace. Readings on core inflation have been elevated, and the high level of resource utilization has the potential to sustain inflation pressures. However, inflation pressures seem likely to moderate over time, reflecting reduced impetus from energy prices, contained inflation expectations, and the cumulative effects of monetary policy actions and other factors restraining aggregate demand. In these circumstances, future policy adjustments will depend on the evolution of the outlook for both inflation and economic growth, as implied by incoming information.

Hawkish Alternative (Alt C)

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Nov 2010, Hawkish Alternative, NN predicted change in FFR expectations = .36

Information received since the Federal Open Market Committee met in September indicates that the economic recovery is proceeding. Household income and spending are increasing , and business spending on equipment and software is rising. The contraction in bank lending has slowed. The Committee anticipates a gradual return to higher levels of resource utilization in a context of price stability. The Committee decided to maintain the target range for the federal funds rate at 0 to 1/4 percent and anticipates that economic conditions are likely to warrant low levels for the federal funds rate for some time. For the time being, the Committee also will maintain its existing policy of reinvesting principal payments from its securities holdings. The Committee will continue to monitor the economic outlook and financial developments and anticipates that it will gradually begin to remove policy accommodation at the appropriate time to promote maximum employment and price stability.

Describe VAR Data

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	log IP	log CPI	EBP	TY_1
count	120	120	120	120
mean	4.60	5.39	0.04	1.64
std	0.05	0.05	0.85	1.88
min	4.47	5.29	-0.92	0.09
25%	4.57	5.35	-0.40	0.20
50%	4.61	5.40	-0.22	0.42
75%	4.63	5.44	-0.01	3.41
max	4.67	5.48	3.47	5.20

Note: All logs are natural logarithms. Industrial production (IP) and Consumer Price Index (CPI) are sourced from FRED. The Excess Bond Premium (EBP) is from Gilchrist and Zakrajsek (2012) and here is in percentage points. The 1 year Treasury Yield (TY_1) is from GÃŒrkaynak, Sack and Wright (2006).

Converting Shock Series to Monthly Frequency

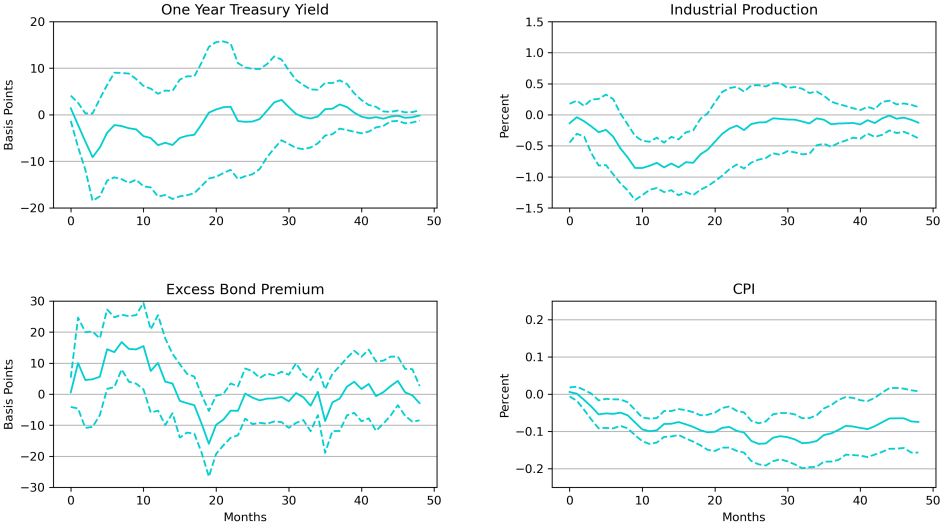
Back

- Shock values in months without FOMC meetings are set equal to zero
- Gertler and Karadi (2015) use 30 day rolling mean of shocks to convert to monthly, but use 3-month-ahead FFF (FF4) to create comparable series

	Text Shock	Cleaned Text Shock	PC1 FFF	GK FF4	GK rolling average
count	120	120	120	120	90
mean	-0.0018	0.0007	-0.0000	-0.0012	-0.005371
std	0.0129	0.0092	0.0175	0.0322	0.032843
min	-0.09	-0.0685	-0.1009	-0.1900	-0.206291
25%	-0.0016	-0.0014	0	0	-0.0048
50%	0	0	0	0	0
75%	0.0008	0.0036	0.0013	0	0.0037
max	0.0675	0.0406	0.0631	0.1150	0.0561

Responses to Cleaned Text Shock

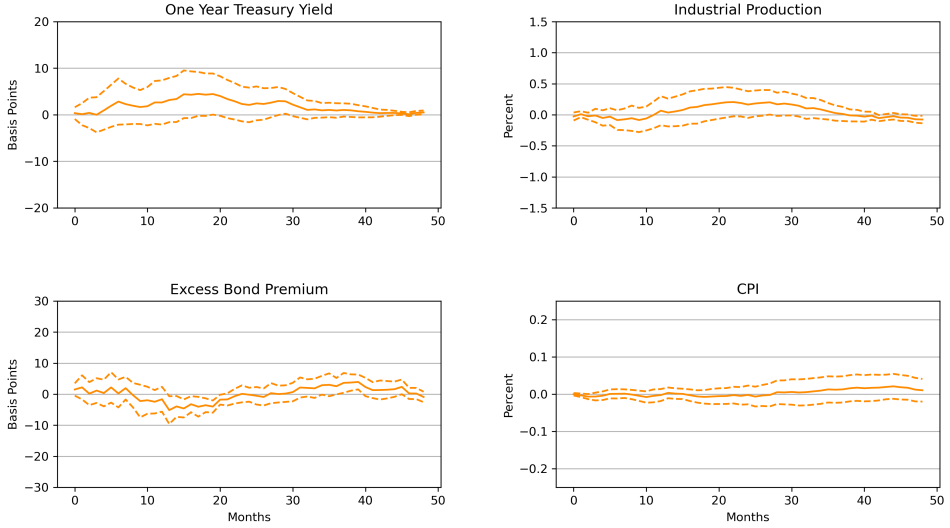
Back



Note: 90% confidence bands from HAC standard errors. Above are responses to a 100 basis point increase in the shock.

Responses to GK Shock (FF4)

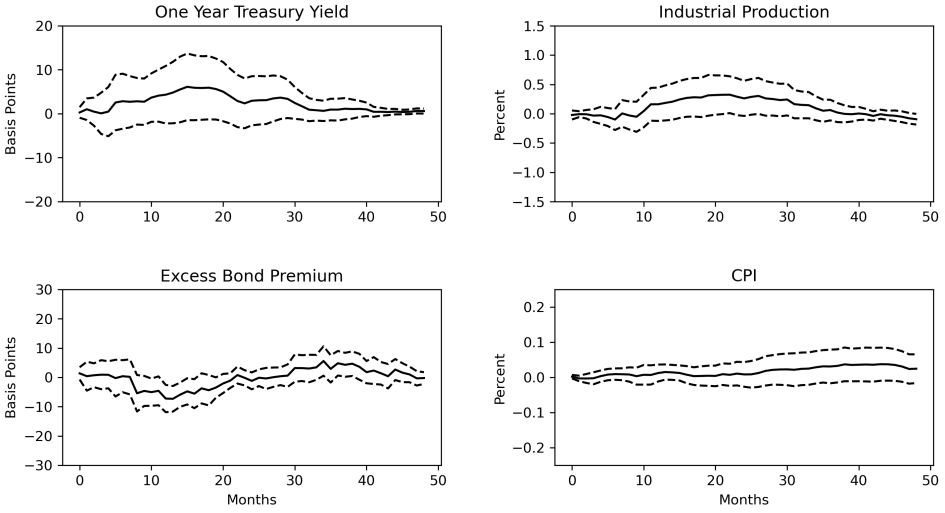
Back GK Rolling Avg.



Note: 90% confidence bands from HAC standard errors. Above are responses to a 100 basis point increase in the shock.

Responses to GK Shock (FF4, rolling average)

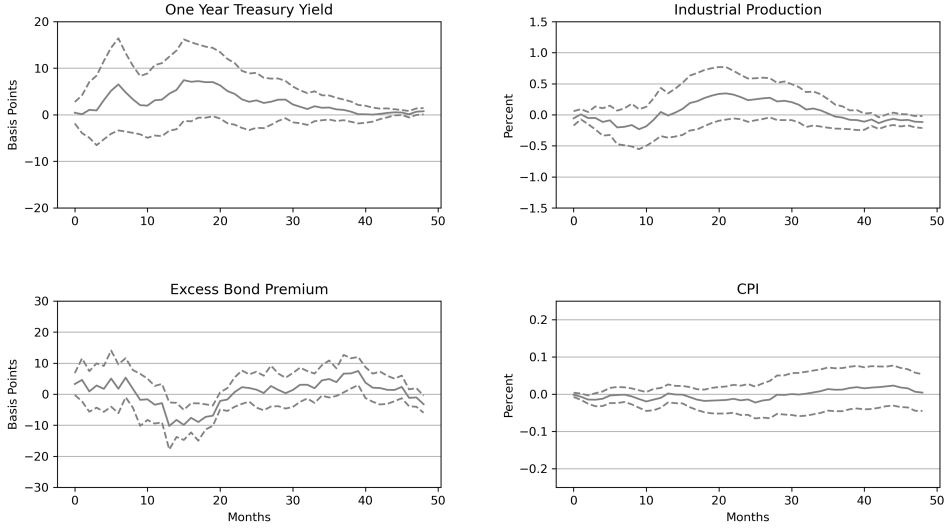
Back



Note: 90% confidence bands from HAC standard errors. Above are responses to a 100 basis point increase in the shock.

Responses to Shock to First PC of FFF Price Changes

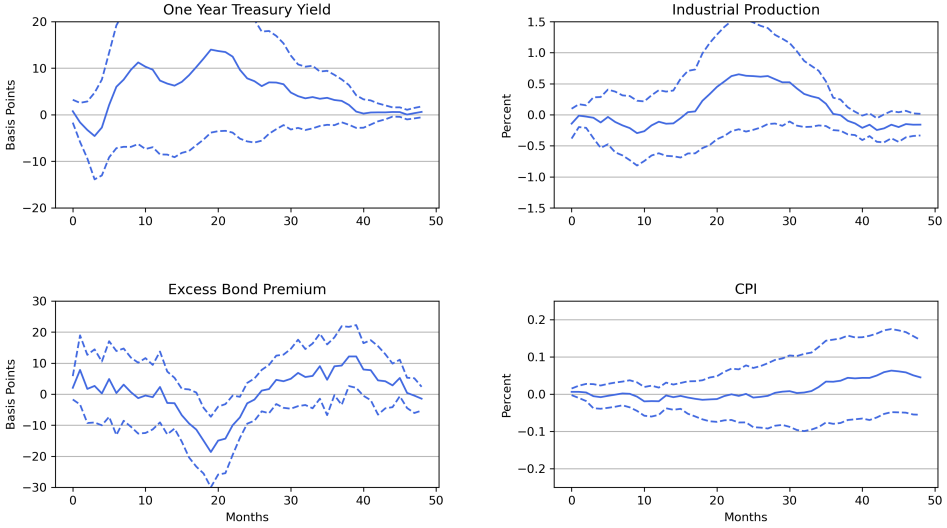
Back



Note: 90% confidence bands from HAC standard errors. Above are responses to a 100 basis point increase in the shock.

Responses to Text Shock

Back



Note: 90% confidence bands from HAC standard errors. Above are responses to a 100 basis point increase in the shock.

Variance of $\widehat{\Delta E[r]}$ Over Alternative-Statement Drafts

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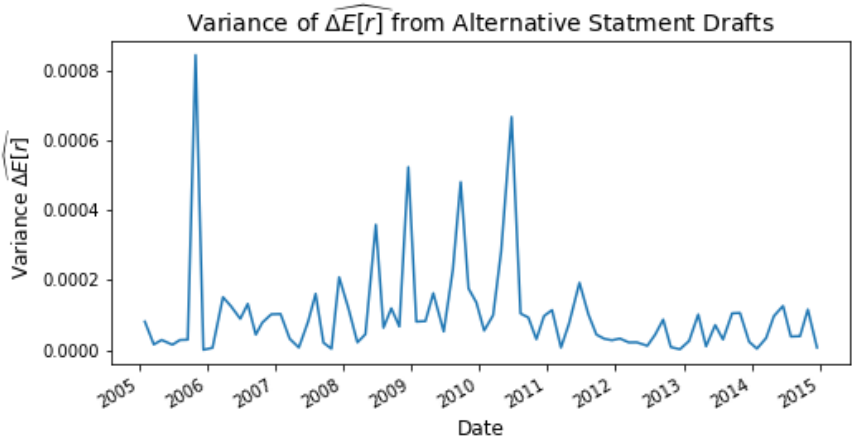

Compare with HRS(2019) Monetary Policy Uncertainty

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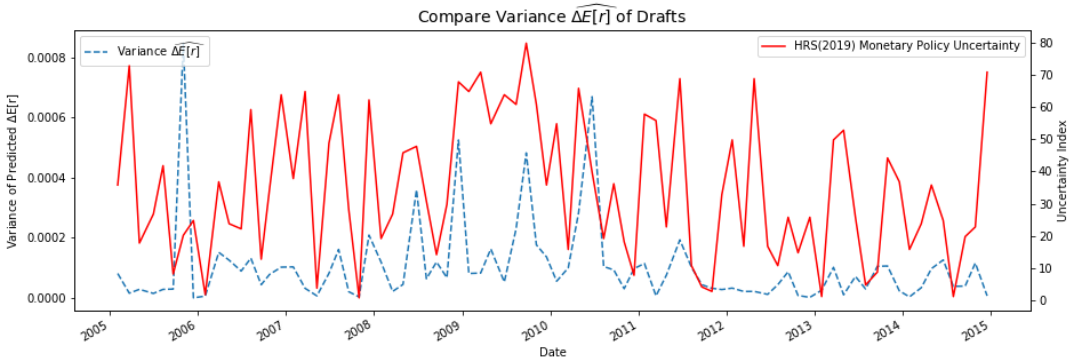

- HRS(2019) Monetary Policy Uncertainty calculated from newspapers

Variance of $\widehat{\Delta E[r]_t}$ Over Sentences

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