Deciphering Fedspeak: The Information Content of FOMC Meetings

Narasimhan Jegadeesh

Di Wu*

December 16, 2015

ABSTRACT

We present a new approach to quantify the economic and policy content of Federal Reserve communications by dissecting the Federal Open Market Committee (FOMC) meeting minutes into distinct economic topics, and simultaneously extract the tone and uncertainty level of each topic. We use market reaction to objectively assess the relative informativeness of each topic, and we find significant incremental informational value from the topic contents, despite that the minutes are released several weeks after the original meetings. Furthermore, we find evidence consistent of the Fed possessing superior information, which is then transmitted to the market through the language of the minutes.

*Narasimhan Jegadeesh is the Dean's Distinguished Professor at the Goizueta Business School, Emory University, and NBER, ph: 404-727-4821, email: Jegadeesh@emory.edu. Di (Andrew) Wu is a Ph.D. Candidate of Finance at The Wharton School, University of Pennsylvania, ph: 215-898-2543, email: wudi1@wharton.upenn.edu. We would like to thank Itay Goldestin, Jeremy Siegel, Rob Stambaugh, Paul Tetlock, Paula Tkac, Amir Yaron, and seminar participants at the Federal Reserve Bank of Atlanta and the Wharton School for helpful comments and suggestions.

1. Introduction

Monetary policies implemented by the Federal Reserve have profound effects on the global economy. Numerous papers in the economics and finance literature examine the determinants and effects of such policies using *quantitative* "Fed proxies" such as the federal funds target rate or the reserve requirement. In addition to these hard data, the Fed routinely releases large amounts of *qualitative* information, such as meeting minutes, transcripts, and speeches, in an effort to foster effective communication with the public and achieve greater operational transparency. While a voluminous literature examines market reactions to quantitative information such as rate changes, very few papers explore the informativeness of these "soft" data conveyed in the language of Fed communications. Do they have incremental information value? How does the market react to these data? Can they be used as alternative predictors of economic and policy outcomes?

Our paper fills the void by presenting an innovative, topic-based approach to determine the informativeness of FOMC meeting minutes, which are detailed summaries of everything discussed during the preceding meeting. Because such discussions encompass a wide range of topics, the proportions of which vary widely from meeting to meeting, we use an automated algorithm based on Bayesian learning to objectively and robustly classify each individual paragraph in the minutes into four distinct economic themes that intuitively correspond to specific Fed mandates and tasks: *Growth*, *Inflation*, *Financial markets*, and *Policy*. We then simultaneously extract contents–the tone and uncertainty level–from the texts of each minutes, and by topic. Compared to a manual approach such as Romer and Romer (1989), our objective approach minimizes any potential researcher-induced bias, thereby allowing us to accurately gauge the specific context of each discussion and, for each meeting minutes, obtain a granular measure of topic mix that human readers cannot accurately identify. To further remove any subjectivity, we assess the informativeness of each topic based on financial market's reactions to the release of the minutes.

We find several new results with our approach. First, we demonstrate that the texts of FOMC minutes contain incremental information not incorporated in either rate announcements or the more timely meeting statements, despite the fact that the minutes are released several weeks after the meetings. Lucca and Moench (2015) find strong evidence that policy announcements on the day of the FOMC meeting is associated with significantly higher stock market volatilities both on and prior to the meeting days. We show that, several weeks after the meeting dates, the release of the minutes is also correlated with a similar degree of volatility spike in both equity and debt markets.

Our next set of tests examine the granular source of this additional informativeness from individual topics. We first demonstrate that, when treated as a single unit, each document as a whole does not yield informative results: neither whole-document tone nor uncertainty is significantly related to market reaction. However, the market do find the discussion on individual topics informative, and assign different informational value to different topics. The market finds traditional “dual mandate" themes, such as *Inflation*, most informative. Interestingly, the market also reacts strongly to the content of the relatively new topic of *Financial markets*, reflecting the Fed’s increasingly important role of maintaining systemic stability, particularly during and after the recent financial crisis. Furthermore, we find that the *Policy* topic is not only deemed informative by the market, but its discussion is also orthogonal to existing economic conditions, indicating that the FOMC members do not necessarily follow fixed guidelines such as the Taylor rule when setting the monetary policy. Our topic-content Scores also hold significant predictive power for real economic activities, which we explore in a related research.

The results above suggest that the Fed possesses superior information than other market participants. Our next tests examine whether such superior information is transmitted to the market through “soft channels” conveyed by language of the minutes. We show that the price jumps at the release of the minutes do not revert, and market volatility is greatly reduced after

the release of the minutes. This is consistent with information transmission into the market at the time of the minutes' release.

Our paper contributes to the literature on three fronts. First, our paper is the first in finance to use a topic-based textual analysis approach on the FOMC minutes, and our approach provides collection of intuitive indicators on multiple facets of the economy and monetary policy, which are also orthogonal from existing economic variables. Alternative text-based economic indicators also exist, such as Baker, Bloom, and Davis (2015), which is based on counting the frequency of uncertainty-related words in news reports. By contrast, our policy indicators are derived directly from the language of policy makers themselves. Unlike news reports, each FOMC minutes is likely to be painstakingly scrutinized by the market, and the usage of every word from the minutes thus matters. This is evidenced by the significant market reaction to our measures. As such, our economic and policy indicators are likely to contain more policy-relevant information and less noise.

Second, our paper furthers the burgeoning literature of financial textual analysis by being the first to employ a paragraph-level information retrieval system that moves beyond the traditional word-based approach employed in current literature such as Tetlock (2007), Hanley and Hoberg (2010), Loughran and McDonald (2011), and Jegadeesh and Wu (2013). This paper is the first in finance to employ on FOMC minutes the Latent Dirichlet Allocation (LDA) model of automated topic retrieval, which has been successfully employed to characterize topics of a wide variety of document sources, from journal articles in Nature to patient-discharge reports.[1] Compared to word-based alternative approaches such as Singular Value Decomposition used by Boukus and Rosenberg (2006), Bayesian methods that explicitly account for the distribution of both topics and words such as the LDA are ideally suited to our collection of FOMC minutes for the following reasons: first, the topic mix and content of FOMC minutes are sufficiently varied, which leads to both robust and intuitively appealing classification results that are on

[1] For a list of LDA applications and an evaluation of their effectiveness, see Blei, Ng, and Jordan (2003).

par with or exceeds manual classification by researchers.[2] Second, compared to manual approaches, our approach is entirely objective, relying only on the structure of the provided texts, and does not require subjective input from researchers. Third, many paragraphs in the FOMC minutes exhibit several topics without a dominant topic. In this case researchers would have difficulty manually identifying the proportion of each topic, while our algorithm outputs the proportion directly, enabling us to compute a unified topic-content score for each minutes.

Furthermore, we provide a model-free alternative of time-varying monetary policy. Structural models such as Ang, Boivin, Dong, and Loo-Kung (2002), Campbell, Pflueger, and Viceira (2015) and Sims and Zha (2006) usually posit the existence of latent policy "regimes" beyond the observable data, and estimate such regimes in a structural VAR setting. However, the specific mechanism from which policies are generated depends on the underlying model supplied by the researcher, which can be subjective. By contrast, our approach directly outputs the economic and policy contents from the texts of FOMC minutes. Our Policy Score series can be interacted with any identifiable economic variables, thereby explicitly generating "latent" states such as policy *tone*, *aggressiveness*, or *uncertainty*, etc. Therefore, our text-based measure nicely complements the interest-rate-based structural models by providing additional rich data moments.

The rest of the paper is organized as follows. Section 2 describes our sample and data sources. Section 3 introduces our automated, topic-based content analysis methodology. Section 4 reports the results of our empirical tests and explores the sources of predictive power of our measures. Section 6 concludes.

[2]We manually select 50 paragraphs and employ 10 research assistants to classify them manually into our topic collection and to identify the topic mixture. On average the algorithm agrees with human researchers in 46 out of 50 cases. See Section 3.2 for details.

2. Data

2.1. Introduction of FOMC meetings and minutes

This subsection provides a brief overview of the logistic details of FOMC meetings and the release of the meeting minutes. From the early 1980s, the FOMC holds eight regularly scheduled meetings per year, during which members discuss the economic outlook and formulate monetary policy. Any policy change decided at the meeting is immediately implemented through open market operations. Prior to 1994, no public announcement about policy was made and the market inferred any policy change through the size and direction of the open market operations on the next day. Starting from January 1994, specific policy changes were made public in a short *meeting statement* released immediately after the meeting.

Moreover, during each meeting, detailed records of the discussions are kept, then summarized in the form of *meeting minutes*, which are released to the public after a delay.[3] The minutes contain no new information received between the meeting date and the release date, and instead serve as an overview of the members' internal discussions on their economic outlook, as well as a nuanced explanation of the rationale for any policy change.

The meeting minutes follow a highly structured writing style. They are routinely consisted of four major sections. The first section outlines the administrative detail of the meeting and reviews previous open market operations. The second section provides the staff's review and outlook of the economic and financial situation, prepared in advance of the meeting. The next two sections provide the bulk of the economic content: the third section details the FOMC members' discussion of the current economic and financial situation, as well as their own economic outlook and projections. The last section is mostly related to policy and discusses the rationale for current policy and outlook for future policies. We remove the first section prior to

[3]The delay ranges between three and eight weeks. The Fed implemented a series of accelerated release schedule during the 1990s and 2000s, which shortened the lag from eight (before 2004) from three weeks (after 2004). From 1997 onward, the minutes are released at 2:00pm Eastern Standard Time.

processing the documents since it is unlikely to contain any economically meaningful content.

2.2. The FOMC minutes sample

We download all FOMC meeting minutes between the February 1991 and June 2015 meetings from FOMC's web site. Some minutes in earlier periods are only available in scanned PDF format, and we and obtain all textual data from these PDF documents using a text extraction engine.[4] We also record the date of the meeting, and the date and earliest time of the release of each minutes by examining the timestamp of the released file. Our sample consists of 196 meeting minutes (thereafter referred to as Minutes).

For each Minutes, we develop a textual parsing algorithm to simultaneously achieve the following: 1) remove the introductory section of the Minutes that lists participant names and administrative matters, and remove the section on specific open market operations (e.g. amount of securities purchased); 2) break the document into individual paragraphs; 3) record the specific section where each paragraph is located (e.g. Staff Economic Discussion or Members' Discussion), and, 5) obtain paragraph length in the number of words. This procedure produces 28,676 unique sentences and 5,644 paragraphs. The average sentence length is 29 words.

2.3. Market reaction data

In many of our tests, we use high-frequency trading data from both equity and bond markets in order to measure market reactions to the contents of the minutes as broadly as possible. For the equity market, our main instrument is the tick-by-tick trading data from the SPDR exchange-traded fund by State Street to proxy for the overall level of stock market response. The SPDR, launched in 1993, follows the S&P 500 index with negligible tracking error. Trading volume has increased dramatically since 2000, making SPDR one of the most liquid stocks. Since volume prior to 2000 is low, we restrict our sample period from 2000 to 2015. As an additional robustness check, we also use proprietary data on the S&P E-Mini futures contracts

[4]Minutes downloaded in PDF at http://www.federalreserve.gov/monetarypolicy/fomccalendars.htm

from the Chicago Mercantile Exchange (CME), which offers similar liquidity levels post-2000. Our results are similar using both instruments.

For the bond markets, we use high-frequency electronic trading data for the Eurodollar futures contracts obtained from the CME. To construct the trading history, we use the “front month" contract, which is the one with expiration date closest to the trading date. Electronic trading was sporadic prior to 2003, and as a result, for Eurodollar futures, we can only construct a reliable trading history for a shorter sample period from 2003 to 2014.

Next, we construct our event window around the time when the meeting minutes are released. We then calculate return volatility during the event window. After 1997, the official release time for the meeting minutes is 2:00pm Eastern Standard Time. However, it is possible that some minutes are released early or late. As such, for each release day, we use an automated algorithm to simultaneously search the FOMC's official web site, Bloomberg, Dow Jones Newswires, and Thomson Reuters, and comparing the time on the FOMC timestamp with that of the first news story of the same day on the Minutes' release. We record the release time as the the earliest time that the minutes (or news about the minutes) are reported among the these sources. The actual release time ranges between 1:59pm and 2:06pm. Therefore, we construct our event window as the 15-minute window between 2:00pm and 2:15pm each day. Our result is robust to alternative event window specifications. The results are also similar using windows ranging from 20 minutes to two hours.[5]

We then calculate event-window return and, following convention, raw return volatility for the equity market is computed as the squared event-window return and that for the Eurodollar market is computed as the absolute value of yield changes. Specifically, for each minutes t in our sample,

$$R_t^{SPY} = \frac{P_{t,2:15pm}^{SPY} - P_{t,2:00pm}^{SPY}}{P_{t,2:00pm}^{SPY}} \tag{1a}$$

[5]We have used windows starting as early as 1:50pm to as late as 2:05pm. We also used window lengths from 20 minutes to 2 hours, in 10-minute increments. The results are similar thoughout most window lengths.

$$R_t^{ED} = \frac{Y_{t,2:15pm}^{ED} - Y_{t,2:00pm}^{ED}}{Y_{t,2:00pm}^{ED}} \tag{1b}$$

$$V_t^{SPY} = \left(R_t^{SPY}\right)^2 = \left(\frac{P_{t,2:15pm}^{SPY} - P_{t,2:00pm}^{SPY}}{P_{t,2:00pm}^{SPY}}\right)^2 \tag{1c}$$

$$V_t^{ED} = \left|R_t^{ED}\right| = \left|\frac{Y_{t,2:15pm}^{ED} - Y_{t,2:00pm}^{ED}}{Y_{t,2:00pm}^{ED}}\right| \tag{1d}$$

Because we use a very short, 15-minute window in constructing the market volatility measure, confounding effects from other macroeconomic variables are negligible, as the minutes are released predominantly on Wednesdays and (before 2004) Thursdays, and no other significant economic indicators are released on these afternoons.[6] To further ensure that any volatility change during our short event window is solely a contemporaneous response to the minutes' release, rather than a delayed response to other macroeconomic events, we separate the event window volatility into an expected and unexpected part. Specifically, we compute the unexpected volatility on the release day as the difference between the raw volatility and the average event window volatility, computed per Equations (1c) and (1d), in the past k trading days:

$$UV_{t,k} = V_t - \sum_{j=1}^{k} \frac{V_{t-j}}{k} \tag{2}$$

In general we set k between 5 and 30 trading days. Most results in our Tables are reported using $k = 20$ days. The results are little changed when k is set to other lengths. We therefore omit the k-subscript and instead use the notation in UV_t subsequent discussions.

[6] See http://www.bloomberg.com/markets/economic-calendar for a schedule of important economic news. Usually no other significant news are scheduled to release on Wednesdays. On Thursdays most other indicators are released on the morning prior to market open.

3. Methodology

Because each Minutes is a summary of everything that is discussed during the preceding meeting, it is a mixture of a wide range of topics. This is demonstrated by several excerpts from the minutes that we present in Appendix A: while one paragraph discusses the latest developments on inflation, another paragraph might provide outlook on financial markets. Another paragraph might discuss both. Several complications arise from these multi-faceted texts: First, which discussions are informative and which are not? Second, many words have different connotations under different contexts. For example, *increase* is considered a positive word in the economic growth context, but has negative connotations in the inflation context. How do we separate these contexts? Third, the proportion and content of discussions on each topic are likely to vary from meeting to meeting. How should one accurately measure these proportions?

These are our motivation for using a topic-based approach that isolates the content of each topic prior to content extraction. This approach allows us to address the above concerns simultaneously by 1) on the paragraph level, accurately gauging the context of each paragraph, and 2) on the document level, obtaining a granular measure of time-varying content proportions that human readers cannot accurately identify. Overall, our approach adds another dimension that enhances traditional content analysis. This section describes our methodology to separate the FOMC minutes into individual topics and extract the content from each topic.

3.1. The Latent Dirichlet Allocation (LDA) algorithm

We first classify each Minutes into distinct topics with the Latent Dirichlet Allocation (LDA) algorithm first developed by Blei et al. (2003), which belongs to a broader class of probabilistic topic models that use hierarchical Bayesian analysis to uncover the underlying semantic structure of textual documents. The common intuition behind such topic models can be summarized by two statistical distributions, which constitute the latent data generating process: The base unit of our analysis is a paragraph. Each paragraph is sufficiently summarized as a distribution

over a collection of topics, each of which is, in turn, a distribution over the collection of English words used in the sample texts. For example, a paragraph that discusses inflation should be represented by a distribution that places a high weight on a topic that places high weights on words such as *prices, CPI, inflation*, etc. By contrast, a topic that places high weights on *foreign trade* and *imports* should receive a low weight in this paragraph distribution.

However, the two distributions are unobservable from the point of the researcher. The advantage of probabilistic topic models is that, using Bayesian techniques, such models efficiently infer the hidden distributional properties from the observable data (i.e. the collection of documents). LDA represents one particular parameterization of the model: We assume that these two latent distributions belong to the Dirichlet family. Then, armed with this functional form and the observed words in each paragraph, we compute the posterior (i.e. empirical) paragraph and topic distributions using the standard Bayes Theorem. These empirical distributions are the main outputs of the model. The only inputs in LDA are the document texts and the number of topics. As such, compared to a manual classification approach, researcher-induced subjectivity and bias are minimized.

We illustrate our approach with a simple example. Suppose that the full set of revelant FOMC vocabulary consists of only $V = 4$ words (ignore common words such as *we*, *the*, etc): {*employment*, *layoff*, *imports*, *trade*}. We are given $D = 3$ paragraphs:

1. *Employment situation is good and layoff has declined.*
2. *Imports have increased and the outlook for trade is good.*
3. *Imports look good, and employment situation is also good.*

A human reader would intuitively recognize that the first paragraph is about employment and the second is about foreign trade. The third paragraph is a mixture of both. Suppose we fit the LDA model with $N = 2$ topics. If the model performs satisfactorily, then first, the posterior topic distributions should clearly and intuitively identify the topics and thus be something

similar to:

- $\hat{\beta}_1 \equiv \{\hat{P}_{topic1}(employment), \hat{P}_{topic1}(layoff), \hat{P}_{topic1}(imports), \hat{P}_{topic1}(trade)\}$
  $= \{0.55, 0.43, 0.01, 0.01\}$
- $\hat{\beta}_2 \equiv \{\hat{P}_{topic2}(employment), \hat{P}_{topic2}(layoff), \hat{P}_{topic2}(imports), \hat{P}_{topic2}(trade)\}$
  $= \{0.01, 0.01, 0.60, 0.48\}$

Next, the posterior topic mixture in each paragraph should correspond to the human reader's intuition:

- $\hat{\theta}_1 \equiv \{\hat{P}_{paragraph1}(Topic1), \hat{P}_{paragraph1}(Topic2)\} = \{0.99, 0.01\}$
- $\hat{\theta}_2 \equiv \{\hat{P}_{paragraph2}(Topic1), \hat{P}_{paragraph2}(Topic2)\} = \{0.01, 0.99\}$
- $\hat{\theta}_3 \equiv \{\hat{P}_{paragraph3}(Topic1), \hat{P}_{paragraph3}(Topic2)\} = \{0.51, 0.49\}$

We proceed with our LDA classification of the FOMC minutes simply by generalizing this example to our sample of $D = 5,644$ unique paragraphs. This set of paragraphs becomes our document collection and our input to the LDA algorithm. Stop words, such as *a, the*, etc., are removed prior to processing. This results in a collection of $V = 61,432$ words.

Next, we hypothesize that there are $N = 8$ unique topics in the document. Our results are robust to alternative specifications from $N = 5$ to $N = 10$.[7] This is the only manual step in the entire process. Here, each of the N topics represents a distribution over the V words in the FOMC vocabulary, and each paragraph is a mixture of the N topics. We assume that the observable data, i.e. words in each document, is generated from a probabilistic data generating process parameterized as follows:

1. Each of paragraph $d = 1, \ldots, D$ contains a mixture of N topics. Let the proportion of topic n in paragraph d be $\theta_{d,n}$ and let the vector $\theta_d = [\theta_{d,1}, \ldots, \theta_{d,N}]'$ represent the true topic

[7] Because each FOMC minutes contains at least four sections, it is likely that $N \geq 5$. When the number of topics increase, some topics become redundant. However, the algorithm results in a similar number of major topics after grouping similar topics as discussed below.

mixture of paragraph d. For each d, we assume that this mixture follows an order-N Dirichlet distribution over the N topics, governed by the latent, parameter vector μ of size N:

$$\theta_d \sim Dirichlet_N(\mu)$$

2. Given paragraph d's topic mixture θ_d, let the assignment of each word i in document d into topics be $Z_{d,i}$, where $Z_{d,i} \in \{1, \ldots, N\}$. We assume that this assignment follows the multinomial distribution governed by the document-specific topic vector θ_d described in the previous step:

$$Z_{d,i}|\theta_d \sim Multinomial(\theta_d) \tag{3}$$

Suppose there are I_d unique words in document d. Let the vector Z_d denote the collection of the topic assignment of all words within d, i.e. $Z_d = \{Z_{d,i}\}_{i=1}^{I_d}$

3. The N topic distributions (applied universally to all paragraphs) are in the collection $\beta = \{\beta_1, \ldots, \beta_N\}$. Each topic β_n also follows an order-V Dirichlet distribution over the V words, governed by the latent scalar parameter ϕ:

$$\beta_n \sim Dirichlet_V(\phi) \tag{4}$$

4. For each word i in document d, there are V choices to choose from based on our FOMC vocabulary. Conditional on the chosen topic for word i in Step 2 above (i.e. a draw from Distribution (3)), and on the structure of the topic distribution from Step 3 (i.e. a draw from Distribution (4)), we assume that actual choice of the word, $W_{d,i}$, follows a multinomial distribution governed by the resulting word-topic assignment $\beta_{Z_{d,i}}$:

$$W_{d,i}|\left(\{\beta_n\}_{n=1}^{N}, Z_{d,i}\right) \sim Multinomial(\beta_{Z_{d,i}})$$

Similarly, let the W_d denote the collection of the vocabulary choice of all words within document d: $W_d = \{W_{d,i}\}_{i=1}^{I_d}$

The above four distributions constitute the latent data generating process that results in

our observable document collection $\{W_d\}_{d=1}^D$. Recall that they are not directly observable to the researcher. Instead, the only observable data is the occurrence of the actual words i in each document d, i.e. W_d. We can then write the overall data generating process as the joint distribution of latent variables $\{\beta_n\}_{n=1}^N, \{\theta_d\}_{d=1}^D, \{Z_d\}_{d=1}^D$ and the observable variable $\{W_d\}_{d=1}^D$:

$$\begin{aligned} & P\left(\{\beta_n\}_{n=1}^N, \{\theta_d\}_{d=1}^D, \{Z_d\}_{d=1}^D, \{W_d\}_{d=1}^D\right) \\ & = \prod_{n=1}^N P(\beta_n) \prod_{d=1}^D P(\theta_d) \left[\prod_{i=1}^{I_d} P(Z_{d,i}|\theta_d) P\left(W_{d,i}|\{\beta_n\}_{n=1}^N, Z_{d,i}\right) \right] \end{aligned}$$

where $P(\cdot)$ are the respective (Dirichlet or multinomial) density functions specified above.

Now that we observe our FOMC document collection $\{W_d\}_{d=1}^D$, we can compute the posterior distribution of the document-topic structure given the observed documents using Bayes' Rule:

$$P\left(\{\beta_n\}_{n=1}^N, \{\theta_d\}_{d=1}^D, \{Z_d\}_{d=1}^D | \{W_d\}_{d=1}^D\right) = \frac{P\left(\{\beta_n\}_{n=1}^N, \{\theta_d\}_{d=1}^D, \{Z_d\}_{d=1}^D, \{W_d\}_{d=1}^D\right)}{P\left(\{W_d\}_{d=1}^D\right)}. \quad (5)$$

Similar to other Bayesian inference methods, the numerator in Equation (5) and can be easily computed. The denominator is by construction a double integral and therefore cannot be feasibly computed. However, it can be efficiently approximated using a Gibbs sampler. We use a customized Gibbs sampler for fast implementation and defer the technical aspects of the Bayesian inference to the Online Appendix.

3.2. Results from the LDA inference

Once the posterior probabilities are computed, we compute the posterior expectations of two key latent variables, which represent the main output from the LDA algorithm:

1. Posterior vocabulary distribution for each topic: $\{\hat{\beta}_1, \ldots, \hat{\beta}_N\}$
2. Posterior topic mixture for each paragraph in our collection: $\{\hat{\theta}_1, \ldots, \hat{\theta}_D\}$

The first set of output from our LDA procedure identifies the topics. For each topic k, $\hat{\beta}_k = [\hat{\beta}_{k,1}, \ldots, \hat{\beta}_{k,V}]'$, and each entry $\hat{\beta}_{k,j}$ represents the *probability that the word j characterizes*

topic k. Our FOMC document collection has $V = 61,432$ unique terms. As a result, each $\hat{\beta}_k$ contains 61,432 entries, the majority of which receives a weight close to zero. Table 1 reports the top 20 words for each topic. This table demonstrates that the topics are clearly identified by the LDA, as the top words from each classified topic are mostly distinct and identify their respective topics with little ambiguity. For example, the first topic consists of keywords such as *policy*, *stance*, etc., indicating that this topic is about monetary policy, and addresses the plan, performance, and outlook of monetary policies. The second topic consists of keywords such as *inflation*, *energy*, etc., suggesting that this topic is about inflation. In fact, the rest of the topics can be similarly identified by the top keyword from their respective classification, as 3) market, 4) employment, 5) economic growth, 6) foreign trade, 7) consumption, and 8) production and investment.[8]

The second set of output is the collection of paragraph-level topic mixture vectors, $\{\hat{\theta}_1, \ldots, \hat{\theta}_D\}$. From this collection, each paragraph d has one mixture, $\hat{\theta}_d = [\hat{\theta}_{d,1}, \ldots, \hat{\theta}_{d,N}]'$. Because there are 8 topics, each vector $\hat{\theta}_d$ has 8 entries, where each $\hat{\theta}_{d,n}$ corresponds to the *proportion* of paragraph d that is devoted to topic n. The 8 entries sum up to one for each paragraph. We plot the time series of the proportion of each topic in Figure 1. The shaded areas in Figure 1 corresponds to NBER-designated recession periods.

Interestingly, Figure 1 shows significant time variation in the proportion of the FOMC minutes devoted to each topic. For example, from 1992 onward, a progressively smaller proportion of the minutes has been devoted to the *growth* topic, which went from the predominant topic in the minutes to a much less prominent portion. At the same time, this decrease has been offset by increases in the proportions of the other topics, particularly those on *policy*, *inflation* and *market*. This finding likely reflects the dynamic roles and responsibilities of the Fed over time: on one hand, it has been increasingly transparent and forthcoming about its policy outlook and

[8]Because topics 4 to 8 are individual components of economic growth, for ease of interpretation by human readers in some of our cross-validations, and as an additional robustness check, we group them into one *economic growth* topic. This results in 4 major topics: *policy*, *inflation*, *growth*, and *market*. The results for tests using this grouping can be found in the Appendix.

expectations. On the other hand, it is increasingly taking up a regulatory role in maintaining the stability of the financial markets, such as negotiating the rescue of systematically important banks and the subsequent TARP initiatives (the proportion of the *market* topic tripled during the recent financial crisis). Overall, this table demonstrates that the FOMC minutes are not uniformly-written documents that always address one particular issue, but a compendium of discussions on various issues, whose proportion change continuously over time. This highlights the importance and usefulness of our topic-based approach.

Finally, as an additional robustness check, we randomly select 50 paragraphs from each of the two groups that satisfy the following properties:

1. Paragraphs classified as containing $\geq 99\%$ of a single topic.
2. Paragraphs classified as containing a mixture of two, three and four topics (each topic having a proportion of at least $\geq 10\%$).[9]

A selection of the texts are presented verbatim in Appendix A. We then ask a team of 10 human readers, mostly undergraduate students at the University of Pennsylvania, to identify the topic mixtures of these 100 paragraphs, without revealing the LDA classification result. For paragraghs that are identified by the LDA as containing only a single topic, human readers and the LDA agree in 49 of the 50 paragraphs (e.g. they both identify a paragraph into the *policy* topic). For multiple-topic paragraphs, human readers agree with the LDA in 46 of the 50 paragraphs about the number and type of the topic. However, they often have difficulties pinning down the exact proportions of each topic, especially when the number of topics is higher than three. For example, many readers identify the last paragraph (4 topics) of Appendix A as containing 25% of each topic, whereas the LDA offers a more granular topic proportion mix that is potentially more accurate. This test demonstrates two advantages of our automated topic classification approach. First, it offers an accurate topic classification that is consistent with common intuition. Second, for each document, it offers a granular, time-varying topic mixture

[9]This is done according to our grouping procedure discussed in the previous footnote.

that is more accurate than manual reading, thereby potentially minimizing researcher-induced bias.

3.3. Extraction of contents

Having obtained the estimate of topic proportions, we now proceed to extract the contents for each paragraph-topic combination, using a bag-of-words approach similar to Tetlock (2007) and Jegadeesh and Wu (2013). Specifically, for each paragraph, we simultaneously extract the tone and uncertainty of each topic by tabulating the frequency of keywords in the respective tone and uncertainty lexicons. The Tone content consists of the frequency of positive words (*positive tone*), negative words (*negative tone*), and the difference in frequency between positive and negative tonal words (*net tone*) in a comprehensive tonal lexicon that merges the Harvard IV-4 Psychosociological Dictionary[10] and the financial tonal lists developed by Loughran and McDonald (2011). The *uncertainty* content is the frequency of keywords in the "uncertain words" lexicon developed by Loughran and McDonald (2011).[11]

Since each paragraph is a mixture of 8 topics, the topic contents can be summarized in 8 paragraph-level content *Scores*. Specifically, for meeting t, paragraph d, topics $n = 1, \ldots, 8$, and content $c \in \{\text{positive tone}, \text{negative tone}, \text{net tone}, \text{uncertainty}\}$:

$$Score^{t}_{d,n,c} = \hat{\theta}^{t}_{d,n} F^{t}_{d,c}$$

where $\hat{\theta}^{t}_{d,n}$ is the topic-n proportion estimate for paragraph d from LDA, and $F^{t}_{d,c}$ is the number of occurrences of content words from the respective tonal or uncertainty lexicons in paragraph d. In addition, we isolate a list of tonal words that are associated with quantity increases and decreases.[12] We reverse the connotation for these words when they are used in the *inflation* topic. For example, *gain* is considered as a positive word by both lexicons. However, it should be treated as a negative word when used in the *inflation* context, because a *gain* in inflation

[10] Available at http://www.wjh.harvard.edu/~inquirer/homecat.htm.
[11] Available at http://www3.nd.edu/~mcdonald/Word_Lists.html.
[12] Available at http://fnce.wharton.upenn.edu/profile/1661/.

is considered negative by the Fed and thus increases the likelihood of tightening actions. In general, a higher Tone Score indicates a more positive/easing or less negative/tightening tone, and a higher uncertainty Score reflects a higher degree of uncertainty in the paragraph.

Next, similar to Jegadeesh and Wu (2013), we aggregate the Scores to the document level as the sum of individual paragraph scores, weighted by the inverse of paragraph length in number of words:

$$Score^t_{n,c} = \sum_{d=1}^{D_t} Score^t_{d,n,c} \left(\frac{1}{T^t_d} \right), \tag{6}$$

where T^t_d is the total number of words in paragraph d, and D_t is the total number of paragraphs in Document t. The term $\left(\frac{1}{T^t_d} \right)$ reflects the intuitive notion that the strength of the topic tone is negatively related to overall paragraph length. Longer paragraphs are more difficult to read and process, and are therefore downweighted.

Figure 2 plots the 10-period moving average of the document-level Net Tone and Uncertainty Scores of each of the 8 topics over time. For ease of comparison, the Scores are standardized to a mean of zero and standard deviation of one. Similar to the proportions in Figure 1, this figure demonstrate the large difference between the topic *contents* over time. Specifically, Panels 2(a) and 2(b) display the Tone Scores for topics 1-4 and 5-8, respectively. While most Tone Scores seem to be procyclical, some are much more so than the others. For example, most economic growth related topic Scores are procyclical, becoming more positive during boom periods and turning sharply negative during recessions. This is probably not surprising because FOMC members' discussions on this topic is likely based on their review and outlook of the underlying economic conditions, which are likely to be quite persistent. On the other hand, the Score for the *policy* topic seems to lead economic cycles, as it usually turns half way into the cycle before other series changes direction. This suggests that, particularly during bad economic times, the Fed seems to convey its future (easing) policy direction via more positive policy-related languages before actually taking the easing actions. This finding

further suggests that the discussions on some topics are probably more informative than others. Our topic-based approach therefore can highlight the informative topics and construct content indices that are deemed important by the market, and therefore useful for predicting future economic conditions and policies. The rest of our paper is focused on assessing this ability.

Panels 2(c) and 2(d) plots the Uncertainty Scores for the corresponding topics. These figures demonstrate a similarly high degree of variance in the Fed's use of uncertain languages, both over time and across topics. A case in point is during and after the recent financial crisis: the uncertainty level for the financial market topic spikes during the crisis and the ensuing economic recession, while most growth-related topics have seen uncertainty levels peak just as the economy was coming out of the trough. As conditions get better from 2011 onwards, uncertainty for these topics declined. Precisely around the same period, as the Fed prepares to exit the quantitative easing programs, uncertainty level for policy has spiked. This is consistent with the large volume of media reports that although the Fed is more confident about the economy, it is exceedingly cautious about the pace of future tightening. These observation suggests that the Uncertainty Scores can be used in conjunction of the Tone Scores to create powerful predictive indices. In this paper we focus on the market reaction to the Tone Scores, and leave the Uncertainty Scores and its associated predictive analysis to a companion paper.

4. Empirical tests and results

This section discusses our empirical tests and reviews the test results. We first assess the informativeness of the minutes as a whole, and then measure the relative informativeness of each individual topic and of its content using market reaction. We then relate our topic-specific content Scores to macroeconomic variables and explore the determinants of the scores. In addition, because a short textual statement is also released immediately after each meeting, we compare the informativeness of these statements with the minutes. Finally, we discuss some possible economic mechanism behind our results and explore the source of informativeness

from the minutes by analyzing whether the price reactions to the minutes are permanent.

4.1. Market Data

We examine the relation between the content of FOMC minutes and changes in aggregate stock market and interest rates to assess the information content of FOMC minutes. We use transaction prices of SPY to measure intraday market returns.[13] We obtain SPY transaction price data from NYSE's intraday Trade and Quote (TAQ) database. We use 3-month LIBOR rate implied by the nearest maturity Eurodollar futures contract as the interest rate measure.[14] We obtain transaction prices of Eurodollar futures from Chicago Mercantile Exchange.

4.2. Informativeness of FOMC minutes as a whole

We first examine whether the Minutes move the market i.e. whether market volatility increases following its release. Specifically, we examine whether the volatility during the release window is larger on release days than on non-release days using the following regression specifications:

$$V_t = a + bL_t + e_t \tag{7a}$$

$$V_t = \alpha + \beta L_t + \sum_{k=1}^{20} \gamma_k V_{t-k} + \epsilon_t \tag{7b}$$

where V_t is the 15-minute event window market volatility (on both release and non-release days) computed per Equation (1c). Within this short window, confounding effects from other macroeconomic variables are negligible, as no other important economic data is likely announced during this window.[15] L_t is a dummy variable that equals to one if a Minutes is released at date t. Each regression uses between 4,343 and 4,363 days of observation.

In addition, we use daily volatilities, V_{t-k}, $k = 1, \ldots, K$, in the days prior to the release

[13] SPY is a an actively traded ETF that tracks the S&P 500 index.

[14] Implied 3-month LIBOR=100-Eurodollar futures price.

[15] We confirm this by referring to the Bloomberg Economic Calendar of important economic indicator announcements and find no other significant announcements during this window.

day to address concerns about potentially biased interest rate expectations and control for any mean reversion induced by the minutes' release. Specifically, suppose a Minutes is completely uninformative, but the market expectation about the content of the minutes can be erroneously distorted between the meeting date and the release date, e.g. by interim speeches from other Fed officials. Therefore, when the Minutes is released, the market corrects its wrong expectation, thereby registering a higher than normal volatility. This produces a positive bias on the coefficient estimates of b in Regression (7a). However, because interim changes in expectation are also associated with changes in market volatility, we can use the daily volatility of the k-days between the meeting date and the release date to control for the effect of changing expectations. The estimate for β therefore measures the true level of informativeness of the minutes, conditional on all prior expectations.

We fit Regression (7b) above using K=0, 5, 10, and 20 trading days. The Minutes are released at 2:00 pm and hence we use the 15-minute window from 2:00 pm to 2:15 pm as the event window. To facilitate interpretation, we scale all regression coefficients by the unconditional mean of V_t across all observations. The coefficient estimates $\hat{b}$ and $\hat{\beta}$ can thus be interpreted as the *incremental* volatility introduced by the release of the minutes as a percentage of the average volatility in the event window across both release and non-release days.

Table 3 reports the coefficient estimates. The estimate for the release dummy, L_t, is significantly positive for all specifications, and it ranges from .5919 to .6130 for SPY. These estimates indicate that the volatility on the when the minutes are released is about 60% bigger than that during the same time on other days. The inclusion of lagged volatility as control variables increases regression R^2 since it accounts for time-variation in volatility, but it in does not materially affect the slope coefficients.

Table 3 also reports the results for volatility of LIBOR. The slope coefficients for LIBOR are between .2283 and .3054. Therefore, the proportional increase in LIBOR volatility is about half

that for SPY, indicating that the minutes have a relatively larger impact on the stock market.[16]

The result is surprising. Both Fleming and Piazzesi (2005) and Lucca and Moench (2015) find that on the actual FOMC meeting days, market volatilities are significantly higher. By contrast, the minutes are released several weeks after the original meetings, and intuitively, every action discussed by the minutes should already be public knowledge by then. Our finding that market volatility is also significantly higher on release days thus indicates that the minutes' *language* itself does contain additional, "soft" information not incorporated in the quantitative policy announcements such as interest rates, nor are they sufficiently conveyed by other post-meeting communications such as speeches and interviews of Fed officials. Recent macroeconomics literature such as Sims and Zha (2006) has used structural models to identify policy changes from observed interest rate data. Our findings indicate that the Minutes contain information beyond the rates data and therefore can be utilized to enhance monetary policy models without additional filtering. We examine the possible economic mechanisms in more detail in Section 4.6.

Next, we examine the informativeness of the overall document without dividing it into topics. This analysis sets a benchmark to judge the incremental information that can be divined through topic level analysis. We compute the Tone Scores for the entire document level relate them to unexpected market volatilities in the following regression:

$$UV_t = \alpha + \beta_c Score_c^t + \epsilon_t \tag{8}$$

where UV_t is the unexpected volatility around the event window on release date t, computed per Equation (2). $c \in \{\text{net tone}, \text{positive tone}, \text{negative tone}\}$ are the document-level net, positive, and negative tone Scores, computed per Equation (6) while setting all $\hat{\theta}$'s equal to one.

[16] Lucca and Moench (2015) demonstrate large excess returns in equities in anticipation of ammouncements after FOMC meetings. As an additional robustness check, we also extend the release window to 20 minutes from 1:55pm to 2:15pm to account for any pre-release leakage of information, or anticipation of such information. The results within the 20-minute window, shown in Panel B of the same table, are similar to that within the 15-minute window.

Each regression uses 138 observations corresponding to the minutes' release dates. These regressions explore the relation between the overall document tone and market reaction. If, for example, a more positive overall tone is more informative, then we would expect a positive correlation between tone and volatility, i.e. a positive estimate for β_{net}.

Table 4 reports the regression estimates. None of the coefficient estimates for the document-level content Scores are statistically different from zero, with t-statistics ranging between -1.69 and 0.32. This suggests that, on the document level, the market does not perceive the tone Scores as useful, as neither more positive nor more negative tone Scores are associated with higher market volatility. This suggests that when the entire document is viewed as a single unit the document tone is not related to changes in volatility. It is, however, possible that some topics are informative than others and the informative topics may not be evident when all topics are simultaneously considered. Therefore, our next set fore set of tests examine the informativeness of individual topics.

4.3. Relative informativeness of individual FOMC topics

Although the tone of the entire document is not informative, it is possible that some of the individual topics may be informative while some are not. For example, our discussions with industry practitioners reveal that they consistently find the discussion on inflation to be more informative than that on economic growth. Our next set of tests evaluates the informativeness of individual topics.

We examine the relation between unexpected volatility the proportion of each topic, and we also assess the informativeness of each topic's contents using Tone Scores. We specify the following relations between topic proportion, content Scores, and event window return volatility for each $c \in \{\text{positive tone}, \text{negative tone}, \text{net tone}\}$:

$$UV_t = a + \sum_{n=1}^{8} b_n \hat{\theta}_{n,t} + rX_t + e_t \tag{9a}$$

$$UV_t = \alpha + \sum_{n=1}^{8} \beta_n Score_{c,n}^t + \gamma X_t + \epsilon_t \tag{9b}$$

where UV_t is the unexpected volatility around the event window on release date t, computed per Equation (2), and X_t is the vector of macro controls variables that include:

- $IntRate$: the latest daily closing yield of 10-year Treasury notes obtained from the Department of Treasury.
- $UnEmp$: latest monthly rate of unemployment obtained from the Bureau of Labor Statistics.
- $Recession$: a dummy variable which equal to one if meeting date t falls within a NBER-designated recession period.

In order to explore market reactions as broadly as possible, we fit each regression with volatility data computed from both equity (SPY) and debt/interest rate (Eurodollar) markets. Each regression uses 138 daily observations from 2000 to 2015. In this setting, an estimate of b_n or $\beta_{c,n}$ that is statistically different from zero indicates informativeness of a topic, or its content Score: a significantly positive $\hat{\beta}$ suggests that the market respond more to a more positive topic tone while a significantly negative $\hat{\beta}$ suggests that the market find more information in a more negative topic tone. Similarly, a significantly positive $\hat{b}$ for topic n indicates that the market finds the discussion of this topic informative, when it is discussed more, regardless of the tone.

Table 5 displays the coefficient estimates from the proportion Regression (9a). The *growth* topic is omitted from the regression to prevent multicolinearity. All independent variables in the regressions are standardized to mean zero and unit standard deviation. First, relative to the *growth* topic, the coefficient estimates for *policy*, *inflation*, and *employment* proportions are all statistically significant and positive. This is consistent with the findings in Table 3 that the minutes do contain additional information. The findings in this table identify the granular source of this information: the market focuses it attention on the languages on monetary

policy, inflation, and employment situations, and do not pay particular attention to growth-related discussions. As the discussion on these key topics becomes more detailed (thus higher proportions), more information is transcribed in the texts, and the market responds more.

Columns (5) through (8) present the slope coefficients of Regression (9a) where the dependent variable is directional change in SPY or LIBOR. The slope coefficient for SPY is significantly positive and for LIBOR is significantly negative for tone on policy. A larger proportion of policy oriented discussion seems to be correlated with the Fed easing interest rates, which in turn results in lower rates and higher stock market. The proportion of other topics are not related to directional changes in SPY or LIBOR.

The left four columns of Tables 6 to 8 report the coefficient estimates for the tone Scores in Regression (9b). These tables suggest that, in addition to topic proportions, the market also views the tones of different topics differently and assigns different informational value to them. First, the coefficient estimates for inflation topic's Net tone Score is significantly negative, indicating a more negative or less positive tone is associated with a higher magnitude of market reaction. This is further confirmed by the positive estimate in Table 7, which shows that more negative language in inflation discussions is indeed associated with higher unexpected volatilities. Moreover, the estimate for positive inflation tone is not significant, further suggesting that market participants are particularly looking out for negative discussions on inflation. A similar pattern can be found for the policy and unemployment topics. For the policy topic in particular, the estimates using Eurodollar volatilities are more significant than using SPY volatilities. This indicates that the short-term debt markets are more sensitive to the discussions on monetary policy than the equity market. Broadly speaking, these results are consistent with the notion that the market reacts stronger to unanticipated tightening actions (indicated by more negative discussions) than an easing policy stance.

Our next set of tests explore the directional impact of our topic Scores. Here we examine whether, for example, a more negative discussion on inflation moves the market up or down.

After all, such discussion could indicate bad current conditions, but at the same time signal future easing actions. If the market is forward looking, then its response would not be uniform. As such, the informativeness of the topics is reflected by not only by market volatility, but also from the relation between the Scores and raw, directional returns during the event window. We therefore fit the following regression:

$$R_t = \alpha + \sum_{n=1}^{8} \beta_n Score^t_{\text{net tone},n} + \gamma X_t + \epsilon_t, \tag{10}$$

where R_t is the 15-minute event-window equity and interest rate market returns constructed according to Equations (1a) and (1b) and X_t is the vector of controls used in the previous regression. This regression explores the micro relation between the topic tones and directional returns. If the market indeed thinks that a particular tone for a particular topic is good/bad news, then it should respond accordingly, resulting in a positive/negative estimate for β.

The right four columns of Tables 5 and 6 report the coefficient estimates for the topic proportion and Net Tone Scores, respectively. First, surprisingly from Table 6, the estimates for the financial market topic is significantly negative: The equity market in particular actually interprets a more positive tone of market discussion as bad news, assigning a 0.1% lower with a one-standard-deviation change in the tone. This suggests that perhaps a need to prop up the economy is more positive in tone but the market views it as a negative signal. More significantly, the estimates for the policy and inflation topics are significantly positive for both SPY and Eurodollar markets (for the Eurodollar market, a negative coefficient indicates positive price movement): market return is on average between 0.09% and 0.13% higher during the 15-minute window with a one-standard-deviation increase in the scores. Thus, for discussions on monetary policy and inflation, the markets do view more positive tones as good news.

Finally, note that separately using equity and debt market data in directional regressions allows us to interpret the exact meanings of "positive" and "negative" in FOMC languages. The logic is as follows: while tightening actions might not have as pronounced an impact on equity

markets, they impact the credit markets more directly, because increases in interest rates (or rate expectations) is directly translated to higher yields. From Table 6, the coefficients for SPY and Eurodollars are indeed opposite in most cases: a more negative policy tone, for example, is associated with positive yield changes and negative stock market returns. This finding suggests that our topic-content Scores capture the degree of policy "tightness": a more positive tone is interpreted as a move toward easing, while a more negative tone means policy tightening.

4.4. Determinants of topic proportion and tone

How "orthogonal" are our granular, text-based measures from existing economic indicators? After all, the Fed is likely to take into account current economic conditions when formulating monetary policies. In addition, a whole section of the Minutes is devoted to reviewing current economic conditions and providing an outlook for future conditions. Many theoretical and structural frameworks of monetary policy making, for example the Taylor rule, also stiputates that monetary policy, usually proxied by the nominal interest rate, is related to changes in economic variables such as output, inflation and unemployment. Does the Taylor rule matter when the FOMC members are in the meeting room? This subsection specifically examines the relation between the proportion and content Scores of each topic and current economic conditions. From our discussion in Section 3.3, we expect the tone of several growth-related topics to be procyclical and follow the traditional Taylor rule, while some other, more "forward-looking" topics might not be the case. For example, as the FOMC members have much latitude in their policy discussions, the effect of macro variables on the Policy Score is likely to be ambiguous: if the Fed correctly anticipates economic cycles and changes policy before the cycle changes, then we might not see a significant relation between policy proportion/content and contemporaneous macro variables. The Policy Score is therefore likely to be the most orthogonal among the topics.

We examine the determinants of the topic proportion and content Scores via the following

regressions:

$$\hat{\theta}_{n,t} = a + bIntRate_t + rUnEmp_t + dRecession_t + e_t \tag{11a}$$

$$Score_n^t = \alpha + \beta IntRate_t + \gamma UnEmp_t + \delta Recession_t + \epsilon_t \tag{11b}$$

where $Score_n^t$ is the Net Tone Content Score for topic n and Minutes t, computed per Eq. (6). $\hat{\theta}_{n,t}$ is the topic-n proportion in Minutes t estimated using Eq. (5). We fit the regression using all 176 minutes Documents from 1991 to 2015.

Table 9 presents the coefficient estimates for the proportion regressions. The proportion of most growth-related topics are positively related to interest rates and negatively related to unemployment. The opposite relations can be found for the *inflation* and *market* topics. This suggests that during bad times, the Fed is more concerned about inflation (or deflation) and the health of the financial markets, than for economic growth and sub-topics like foreign trade. Table 10 reports the coefficient estimates for the Tone Score regressions. And here again, the tone of most *growth*-related topics are procyclical. Interestingly, the tone of the *policy* topic is not significantly related to existing economic conditions: none of the coefficient estimates are statistically significant. This again highlights the fact that the policy discussions during the meetings probably incorporate factors beyond current economic conditions, and therefore, the *policy* topic can serve as a leading indicator of the economy, which is corroborated by Fig. 1, where its Score usually “flips" half way into the economic cycle. We explore the predictive power of the topic Scores in a companion paper.

4.5. Relative informativeness of Statements vs. Minutes

Another useful test in illustrating the efficacy of our granular information extraction approach is comparing the minutes-based Scores with the information contained in the languages of meeting *statements*, which are very short documents (usually one paragraph) released immediately after each meeting. These statements outline the policy decision made during the meeting and (for later years) very succinctly discuss the rationale for such decisions. As such, the languages

of the statements can also potentially contain incremental information not conveyed by the hard numbers. Because of their very short length, the statements are not suitable for topic-based analyses. We therefore compute the content Scores for these statements as a whole, then compare those with our more granular Scores from the minutes and examine whether the granular Scores contain yet another layer of incremental information in addition to those contained in the statements.

Panel A of Table 14 assesses the incremental informativeness of statement languages using market reactions on the day of the meeting, and on the day of the corresponding minutes' release. Not surprisingly, the tone of the statements is significantly related to market reaction on the meeting day, even after controlling for any interest rate changes made during the meeting. This is not the case on the minutes' release days, as the statement tone is not statistically significant for either raw or unexpected volatility regressions.

To see this more clearly, we relate the informativeness of the statement languages to that of the minutes' individual topics in a predictive setting. If statements are as informative as the granular minutes-based Scores, then their tone should be able to predict the topic tone scores from the corresponding Minutes released for the same meeting. We therefore modify Regression (11b) as follows:

$$Score_n^t = \alpha + bScore_{\text{statement}} + \beta IntRate_t + \gamma UnEmp_t + \delta Recession_t + \epsilon_t, \qquad (12)$$

where $Score_{\text{statement}}$ is the overall Net Tone Score for the statement released at the same meeting.

Panel B of Table 14 presents the coefficient estimates. With the exception of the inflation topic, the coefficients for statement Tone Score are not statistically significant in all topics. This indicates that, although informative on their own, the statement tones are not enough to predict the tone of individual minutes topic Scores, and the more granular scores contain information not captured by the languages of the statements.

4.6. Discussion: Are these real information?

This section explores the reason why the minutes are informative. On the surface, this seems puzzling: the minutes are released a long time after the meetings, why would they contain any incremental information at all? However, there is an important distinction: the staff economists at the Fed and the FOMC members have access to a wide variety of confidential economic data, such as detailed records of interbank lending, that are not observable to other researchers. It is likely, therefore, that their information set is superior to that of other market participants. Due to the confidential nature of the data, they cannot disclose any quantitative facts in the minutes. However, it possible that such “inside" information influences the tone and uncertainty level of the minutes’ language.

We can jointly test the above hypothesis and whether such “soft" information is transmitted to the market by observing the market reactions to the minutes: if there is new information about the future economy *and* the information is transmitted to the market through the minutes, then the effect on prices should be permanent rather than temporary, and the price “jump" on the minutes release day that we document in the last section should be persistent and not revert quickly. In other words, because temporary price changes would be followed by price changes in the other direction, if market volatility declines after the minutes’ release windows, this would suggest that some real information that would have flowed to the market after the release windows indeed is revealed to the market during the release windows.

Figure 3 plots the average minute-by-minute return volatility in 15-minute bins for both release and non-release days. First, we confirm the same pattern found in the treasury market: market volatility spikes dramatically to about 1.6 times the normal levels on days where FOMC minutes are released. More importantly, volatility quickly declines after the minutes are released to about 20% lower than non-release days. As a result, the initial price jump at the release do not on average revert back, and prices on average stay at the new levels. This permanent “shift" in prices indicates that the overall level of uncertainty in the market is lower after

the release of the minutes, and supports our hypothesis that information is indeed transmitted from the Fed to the markets through the text of the minutes, and in a permanent fashion.

5. Alternative Specifications and Robustness Checks

Because our granular, topic-based textual content scores are derived using new methodology, we conduct a series of robustness checks to ensure that the economic inferences that we, and future researchers, can draw from our methods are valid and broadly applicable, and are not subject to the variations in test specifications and peculiarities of the text samples. This section outlines some concerns that one might raise about using our LDA approach to classify the FOMC minutes, and the results of our additional tests to address these concerns.

5.1. Shifts in textual sample over time

One might worry that over time, the writing style of the minutes might dramatically change, thus making our approach more prone to capturing style changes rather than variations in actual information. One particular example from our discussion with Fed personnel is that, after 2011, the minutes became much longer and more detailed in many topics. In addition, around the same time, the Fed began to release the actual economic forecasts by individual FOMC members at 4 out of the 8 meetings every year. This setting allows us to test the robustness of our methodology across different periods with different writing styles and potentially different overall informativeness. We first separate our sample into two halves, before and after (including) 2011. We then examine whether the overall informativeness has changed by separately plotting the average volatility around release days, for both samples, in the top panel of Figure 3.

This graph demonstrate that post-2011, the market reaction to the minutes' release is stronger, with the average volatility about 200% higher than normal. While this suggests that the market does pay increased attention to the minutes, Table 13, replicating Regression (9b)

for the two subsamples, shows no change in the *relative* informativeness of individual minutes topics captured by our granular Tone Scores: both the magnitude and the statistical significance of the estimates are similar across subsamples. This result suggests that our methodology is stable even when the overall level of informativeness can change with the writing style of the minutes.

In addition, we further separate the post-2011 sample into two subsample of release days according to whether the preceding meetings are accompanied by the release of Summary of Economic Projection (SEP) materials. After the April 2011 meeting, the FOMC begins to release participants' three-year and long-run projections of three economic indicators and target fed funds rate, based on their "individual assessments of appropriate monetary policy". These projections are released immediately after four of eight meetings annually. If the language of the minutes contain similar information to the projections, then for meetings with SEP releases, the market reaction to the subsequent release of the minutes would be more muted. The bottom panel of Figure 3 plots the daily volatility levels on release days with and without SEP releases. The figure shows that volatility levels are similar on both types of days, indicating that releasing individual forecasts does not decrease the relative informativeness of the minutes, and that the information contained in the minutes' languages is deemed by the market to be orthogonal to the SEP data.

5.2. Alternative lexicons and tone measures

One might also worry that, as our topic classification becomes more granular, the results are more sensitive to small changes in the tone measures that are purely attributable to the construction of the tonal scores. To address this issue, we conduct two tests where we intentionally magnify and reduce such differences. First, we modify Regressions (9b) and (10), using the change of the topic Net Tone Scores, rather than the Scores themselves, as the independent

variable:

$$UV_t = \alpha + \sum_{n=1}^{8} \beta_n \left(Score_{c,n}^{t} - Score_{c,n}^{t-1} \right) + \gamma X_t + \epsilon_t \tag{13a}$$

$$R_t = \alpha + \sum_{n=1}^{8} \beta_n \left(Score_{c,n}^{t} - Score_{c,n}^{t-1} \right) + \gamma X_t + \epsilon_t. \tag{13b}$$

This setting potentially introduces more noise into the analysis, as the differences in tone *between* meetings can be affected by both actual information and mechanically by the construction of our Scores. Beside serving as a robustness check, this specification also serves to examine whether the *change* in tone is related to volatility in the markets. Similarly, we artificially dampen such differences by inserting the absolute value of tones as the regressors in the above specification:

$$UV_t = \alpha + \sum_{n=1}^{8} \beta_n \left| Score_{c,n}^{t} \right| + \gamma X_t + \epsilon_t \tag{14a}$$

$$R_t = \alpha + \sum_{n=1}^{8} \beta_n \left| Score_{c,n}^{t} \right| + \gamma X_t + \epsilon_t. \tag{14b}$$

Beside serving as a robustness check, this specification also serves to examine whether the *volatility* in tone is related to volatility in the markets. Table 12 presents the coefficient estimates for regressions with tone differences and Table 11 presents results using the absolute value of tones. For tone changes, the results are very similar in signs and slightly larger in magnitudes. This is consistent with the intuitive notion that large changes in tones attracts more attention than smaller changes. Similarly, Table 11 shows that the coefficients for the volatility of key tone Scores from Table 6 are significantly positive, again intuitively confirming that higher variations in tone are indeed associated with more market reaction. Furthermore, the fact that the results are qualitatively unchanged from those in Table 6 indicates that our method is not subject to mechanical noises introduced by the construction of tone Scores.

Another concern is that, although we use the Loughran and McDonald (2011) tonal lexicons as part of our main lexicon, there might still be ambiguity in the *interpretation* of the tone of

some words classified as positive or negative by the lexicons. To address this issue, we first recompute the Net Tone Score for each topic using a unified, weighted lexicon also used by Jegadeesh and Wu (2013). This dictionary is constructed by merging the Harvard and LM lexicons (both positive and negative words), but instead of assigning any tonal connotations, each word is weighted objectively according to the market reaction to the 10-K filings in which a word is used. In this sense, a word associated with negative market returns is classified as a negative word. We then replicate Regressions (9b) and (10) using this new Net Tone Score and present the results in Table 15. Again, the results are very close to the original specification. This suggests that our approach is robust to alternative choices of lexicons.

6. Conclusion

We present a novel approach in financial content analysis to determine the informativeness of FOMC meeting minutes. This automated approach is based on the Latent Dirichlet Allocation (LDA) algorithm, which enables us to dissect minutes into distinct topics and simultaneously extract the tone and uncertainty level of each topic. In an event study setting, we use market reaction to assess the relative informativeness of each topic and find a significant relation between topic contents and market volatility. Furthermore, we find evidence consistent of the Fed possessing superior information, which is transmitted to the market through the text of the minutes.

Our measures of economic and policy outlook/uncertainty are both model-independent and robust, and can be readily applied to structural macroeconomic models, as well as reduced-form predictive models where policy uncertainty serves as an input. We are currently exploring several of such these issues.

References

Ang, A., Boivin, J., Dong, S., Loo-Kung, R., 2002. Monetary policy shifts and the term structure. Review of Economic Studies 78, 429–457.

Baker, S. R., Bloom, N., Davis, S. J., 2015. Measuring economic policy uncertainty. NBER Working Paper No. 21633.

Blei, D. M., Ng, A. Y., Jordan, M. I., 2003. Latent dirichlet allocation. the Journal of machine Learning research 3, 993–1022.

Boukus, E., Rosenberg, J. V., 2006. The information content of FOMC minutes. Working paper, Federal Reserve Bank of New York, New York, NY.

Campbell, J. Y., Pflueger, C., Viceira, L. M., 2015. Monetary policy drivers of bond and equity risks. Working paper, Harvard University, Cambridge, MA.

Fleming, M. J., Piazzesi, M., 2005. Monetary policy tick-by-tick. Working paper, University of Chicago, Chicago, IL.

Hanley, K. W., Hoberg, G., 2010. The information content of IPO prospectuses. Review of Financial Studies 23, 2821–2864.

Jegadeesh, N., Wu, D., 2013. Word power: A new approach for content analysis. Journal of Financial Economics 110, 712–729.

Loughran, T., McDonald, B., 2011. When is a liability not a liability? Textual analysis, dictionaries, and 10-Ks. Journal of Finance 66, 35–65.

Lucca, D. O., Moench, E., 2015. The pre-fomc announcement drift. Journal of Finance 70, 329–371.

Romer, C. D., Romer, D. H., 1989. Does monetary policy matter? a new test in the spirit of friedman and schwartz. In: *NBER Macroeconomics Annual 1989, Volume 4*, MIT Press, pp. 121–184.

Sims, C. A., Zha, T., 2006. Were there regime switches in U.S. monetary policy? American Economic Review 96, 54–81.

Tetlock, P. C., 2007. Giving content to investor sentiment: The role of media in the stock market. Journal of Finance 62, 1139–1168.

Appendix A Select FOMC Paragraphs with LDA Classification Results

Part 1. Single Topic Examples

Example 1. (99% growth mandate, other topics negligible)

With regard to developments and prospects in key sectors of the economy, members noted that despite further survey indications of eroding consumer confidence, consumer expenditures had strengthened in recent months after a pause earlier in the year. The pickup had featured rising sales of motor vehicles, and while the latter had slipped recently, a number of special factors such as shortages of popular models at the end of the model year and the effects of flooding in some parts of the Midwest suggested the need to withhold judgment on any downward shift in the underlying demand for motor vehicles. Tourism was reported to have strengthened considerably in many areas this summer, though there were major exceptions. As had been true for an extended period, consumer attitudes continued to be inhibited by concerns about employment opportunities, especially given further reductions in defense spending, the ongoing restructuring and related downsizing of many business operations, and the continuing efforts by business firms to limit the number of their permanent employees in order to hold down the rising costs of health care and other nonwage worker benefits. Members noted, however, that the growth in employment thus far this year, while tending to involve many low paying jobs, had greatly exceeded the rate of expansion in 1992. In the view of at least some members, appreciable further growth was likely as business firms found it increasingly difficult in an expanding economy to meet growing demands through outsourcing, temporary workers, and overtime work. Some members also noted that the newly legislated taxes on higher incomes would tend to curtail some consumer spending. The timing of that effect was uncertain; tax liabilities had already risen, but some payments on the added tax liabilities were not due until April of 1994 and 1995.

Example 2. Inflation Mandate (99% inflation mandate, other topics negligible)

The core consumer price index advanced at a faster rate in the first quarter than it had in the fourth quarter, reflecting the pass-through of higher energy prices and a leveling off of goods prices after sizable declines last year. The higher goods price inflation owed, in part, to the recent run-up in the prices of non-oil imports, energy, and other commodities. The price index for core personal consumption expenditures also rose at a faster rate in the first quarter than it had late last year. Despite the rise in inflation this year, however, the cumulative increase in the overall consumer price index for the year ending in March was somewhat less than the advance for the twelve months ending in March 2003. In the year ending in March, the increase in the price index for total personal consumption expenditures was similar to that of a year earlier. Survey measures of near-term inflation expectations edged up somewhat in March and April, but measures of longer-term expectations decreased. With regard to labor costs, average hourly earnings of production or nonsupervisory workers on private nonfarm payrolls rose notably less for the twelve months ending in March than they had in the year-earlier period. The overall increase in the employment cost index for private industry for the twelve months ending in March was about the same as that for the twelve-month period ending a year earlier, as wages and salaries decelerated and benefits accelerated.

Example 3. Financial Market Mandate (99% market mandate, other topics negligible)

Participants noted that financial markets were volatile over the intermeeting period, as investors responded to news on the European fiscal situation and the negotiations regarding the debt ceiling in the United States. However, the broad declines in stock prices and interest rates over the intermeeting period were seen as mostly reflecting the incoming data pointing to a weaker outlook for growth both in the United States and globally as well as a reduced willingness of investors to bear risk in light of the greater uncertainty about the outlook. While conditions in funding markets had tightened, it was noted that the condition of U.S. banks had strengthened in recent quarters and that the credit quality of both businesses and households had continued to improve.

Example 4. Policy Mandate (99% policy mandate, other topics negligible)

Participants discussed a number of policy tools that the Committee might employ if it decided to provide additional monetary accommodation to support a stronger economic recovery in a context of price stability. One of the policy options discussed was an extension of the period over which the Committee expected to maintain its target range for the federal funds rate at 0 to 1/4 percent. It was noted that such an extension might be particularly effective if done in conjunction with a statement indicating that a highly accommodative stance of monetary policy was likely to be maintained even as the recovery progressed. Given the uncertainty attending the economic outlook, a few participants questioned whether the conditionality of the forward guidance was sufficiently clear, and they suggested that the Committee should consider replacing the calendar date with guidance that was linked more directly to the economic factors that the Committee would consider in deciding to raise its target for the federal funds rate, or omit the forward guidance language entirely.

Part 2. Multiple Topic Examples

Example 5. (56% growth, 43% inflation)

The information reviewed at this meeting suggested that economic activity had weakened further in the opening months of the year. Production cutbacks were evident in a wide range of industries, and private payrolls had fallen markedly, especially in the goods producing sector. On the positive side, consumer confidence had rebounded sharply since the cease-fire in the Persian Gulf, retail sales and housing starts had strengthened recently, and exports had continued to expand. Broad measures of prices had slowed or contracted in January and February, but excluding energy and food prices, increases in those measures were higher than in previous months. Wage increases had moderated over the past several months.

Example 6. (83% financial market, 17% policy)

Committee members and Board members agreed that, with few exceptions, the functioning of most financial markets, including interbank markets, no longer showed significant impairment. Accordingly they agreed that the statement to be released following the meeting would indicate that the Federal Reserve would be closing the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility, the Commercial Paper Funding Facility, the Primary Dealer Credit Facility, and the Term Securities Lending Facility on February 1, 2010. Committee members also agreed to announce that temporary liquidity swap arrangements between the Federal Reserve and other central banks would expire on February 1. In addition, the statement would say that amounts available through the Term Auction Facility would be scaled back further, with $50 billion of 28-day credit to be offered on February 8 and 25 billion of 28-day credit to be offered at the final auction of March 8. The statement also would note that the anticipated expiration dates for the Term Asset-Backed Securities Loan Facility remained June 30, 2010, for loans backed by new-issue commercial mortgage-backed securities, and March 31, 2010, for loans backed by all other types of collateral. Members emphasized that they were prepared to modify these plans if necessary to support financial stability and economic growth.

Example 7. (34% growth, 31% financial market, 35% policy)

Open market operations during the intermeeting period continued to be directed toward maintaining the existing degree of pressure on reserve positions. The federal funds rate rose briefly in response to year-end pressures, but it otherwise tended to remain close to the 5-1/4 percent level expected with an unchanged policy stance. Other short-term interest rates generally were unchanged to slightly higher over the intermeeting period. Rates on intermediate- and long-term securities edged higher on balance in reaction to incoming data on economic activity that were on the firm side of market expectations; the increases in such rates appeared to be tempered, however, by favorable market reactions to new data on wages and prices. The generally positive news on economic growth and inflation along with favorable reports on earnings appeared to reinforce the optimism of equity market investors, and major indexes of stock prices increased markedly further over

the intermeeting period.

Example 8. (39% growth, 13% inflation, 20% financial market, 26% policy)

In their discussion of the economic situation and outlook, FOMC meeting participants indicated that the worsening financial situation, the slowdown in growth abroad, and incoming information on economic activity had led them to mark down significantly their outlook for growth. While economic activity had evidently already been slowing over the summer, the turmoil in recent weeks had apparently resulted in tighter financial conditions and greater uncertainty among businesses and households about economic prospects, further limiting their ability and willingness to make significant spending commitments. Recent measures of business and consumer sentiment had fallen to historical lows. Participants generally expected the economy to contract moderately in the second half of 2008 and the first half of 2009, and agreed that the downside risks to growth had increased. While some expected an improving financial situation to contribute to a recovery in growth by mid-2009, others judged that the period of economic weakness could persist for some time. Several participants indicated that they expected some fiscal stimulus in coming quarters, but they were uncertain about the extent and duration of the resulting support to economic activity. Participants agreed that in coming quarters inflation was likely to move down to levels consistent with price stability, reflecting the recent declines in the prices of energy and other commodities, the appreciation of the dollar, and the expected widening of margins of resource slack. Indeed, some saw a risk that over time inflation could fall below levels consistent with the Federal Reserve's dual objectives of price stability and maximum employment.

Figure 1: **FOMC Topic Proportions Over Time**

This figure plots the proportion of each topic identified by the LDA algorithm for each of the 196 FOMC minutes released between 1990 and 2015. The raw inputs for this figure are the 5,644 paragraph-level topic mixture vectors, $\{\hat{\theta}_1, \ldots, \hat{\theta}_{5644}\}$. Each vector $\hat{\theta}_d$ has 8 entries, where each $\hat{\theta}_{d,n}$ corresponds to the *proportion* of paragraph d that is devoted to topic n. The 8 entries sum up to one for each paragraph. The document-level proportion are paragraph-level proportions weighted by paragraph length. The shaded areas correspond to NBER-designated recession periods.

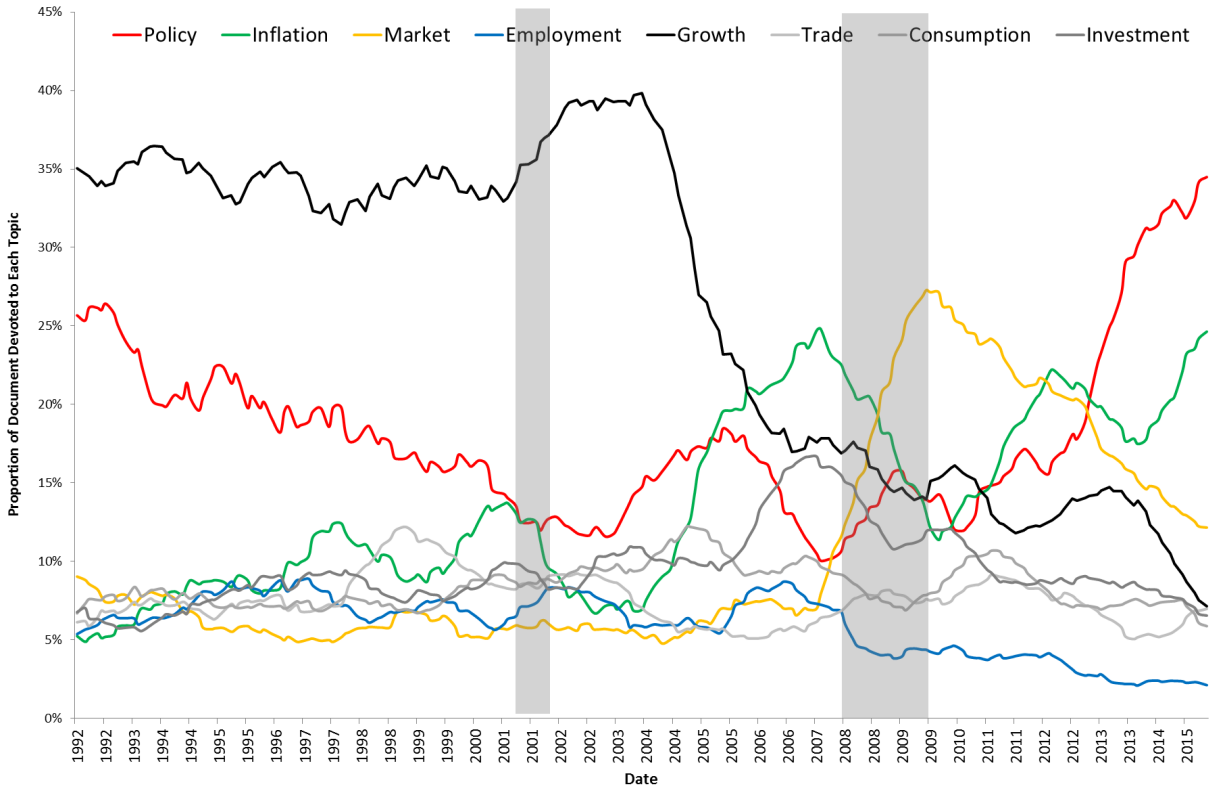
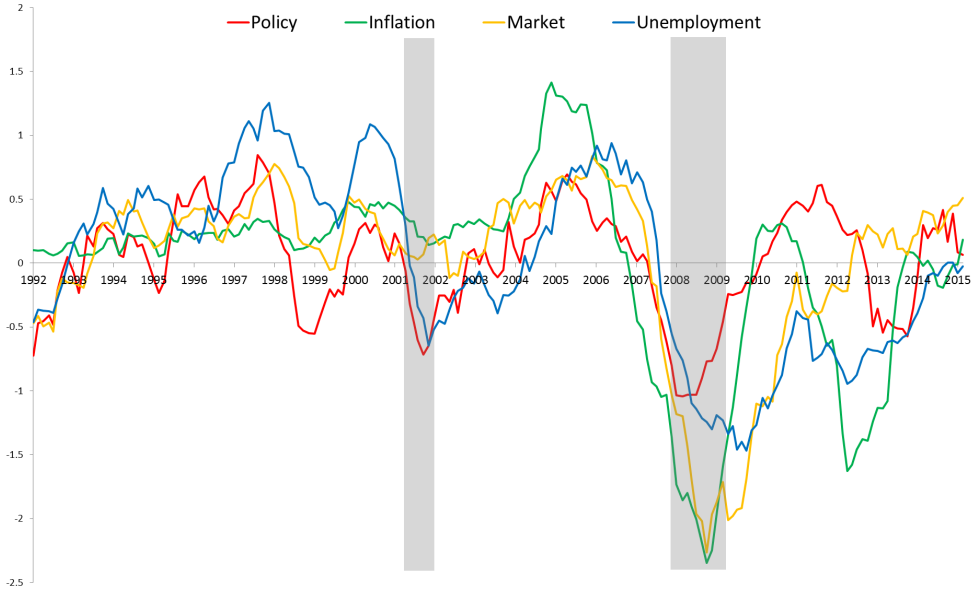
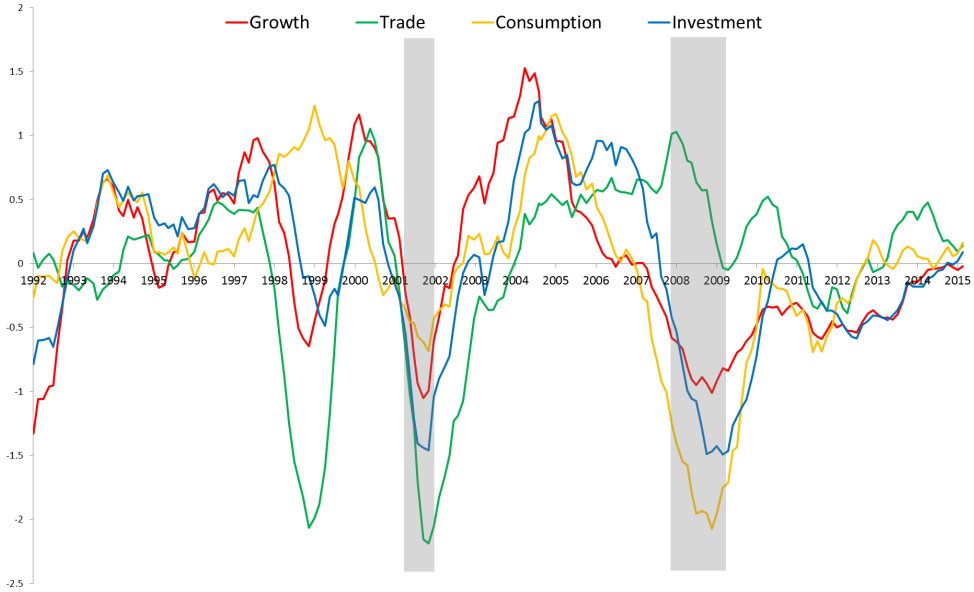


Figure 2: **FOMC Topic Content Scores Over Time**

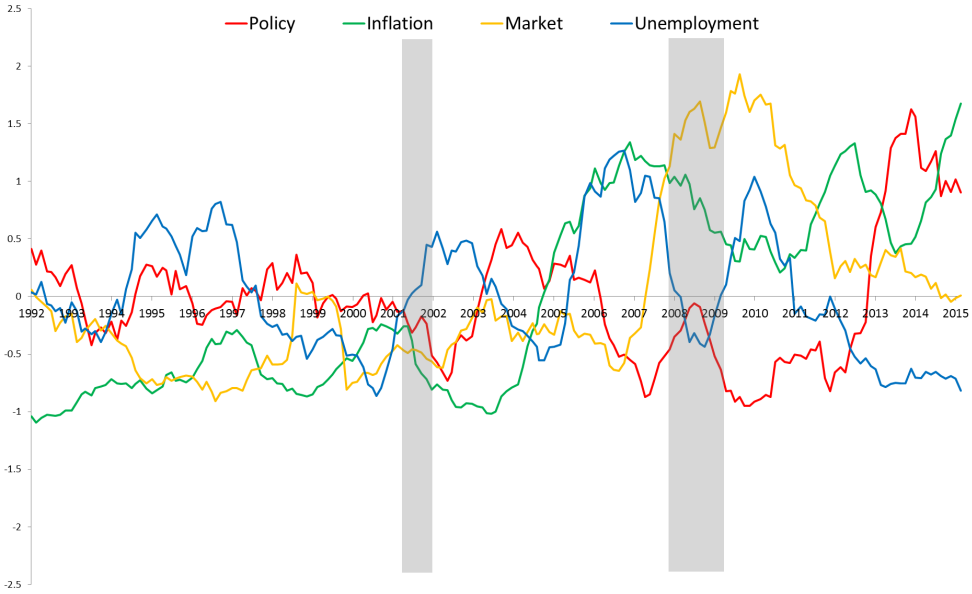
This figure plots the Net Tone and Uncertainty Scores of each topic identified by the LDA algorithm for each of the 196 FOMC minutes released between 1990 and 2015. The raw inputs for this figure are the 5,644 paragraph-level topic mixture vectors, $\{\hat{\theta}_1, \ldots, \hat{\theta}_{5644}\}$. Each vector $\hat{\theta}_d$ has 8 entries, where each $\hat{\theta}_{d,n}$ corresponds to the *proportion* of paragraph d that is devoted to topic n. These proportions are used to compute document-level Net Tone and Uncertainty Scores according to Equation (6) of the text. The shaded areas correspond to NBER-designated recession periods.



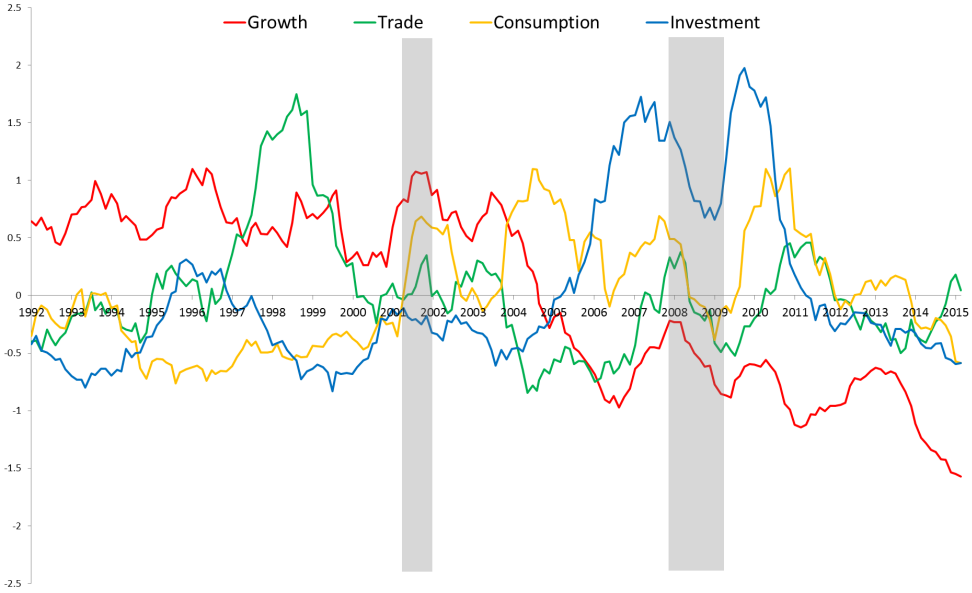
(a) Topic Net Tone Scores Over Time, Topics 1 to 4



(b) Topic Net Tone Scores Over Time, Topics 5 to 8



(c) Topic Uncertainty Scores Over Time, Topics 1 to 4



(d) Topic Uncertainty Scores Over Time, Topics 5 to 8

Figure 3: **Market reaction to the release of FOMC minutes**

This figure plots the daily average of 15-minute raw SPY return volatility, in various subsamples, from $t-3$ to $t+2$ days around the minutes release days t. The volatilities are computed according to Eq. (1c) of the text. The top panel shows the ratio of volatility on release days over that on non release days, for the full sample between 2000 and 2015, and two subsamples of 2000-2011 and 2011-2015, respectively. The bottom panel plots compares the raw volatility levels in the post-2011 subsample, between meetings with and without the release of Summary of Economic Projections (SEP) data.

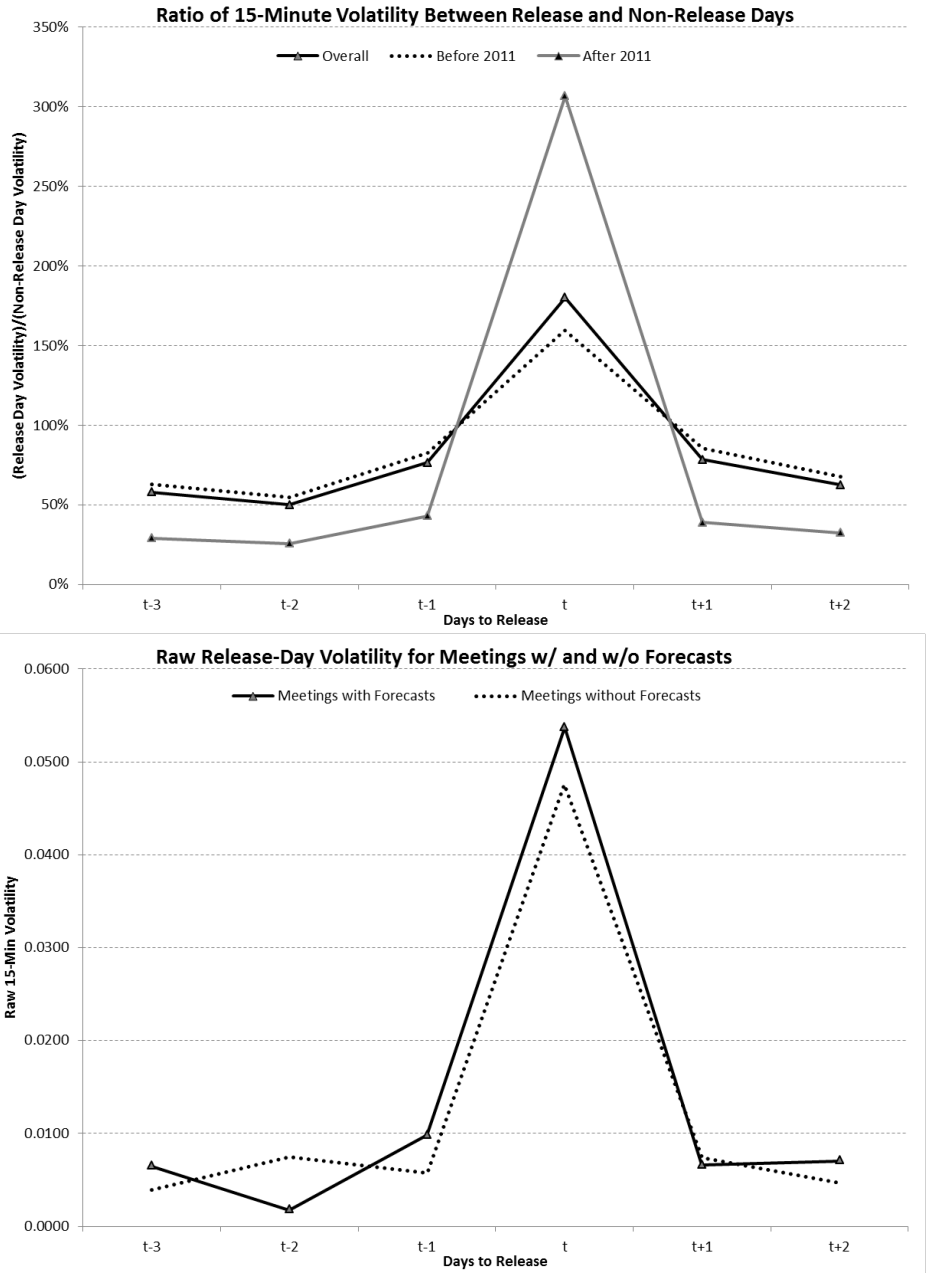


Figure 4: **Temporary vs. permanent reaction to the release of FOMC minutes**

This figure plots the ratio of average return volatility in 15-minute bins between release and non-release days. Return volatility is calculated as the standard deviation of minute-by-minute returns in each 15-minute bins according to Eq. (1c) of the text. The sample period is 2000-2015.

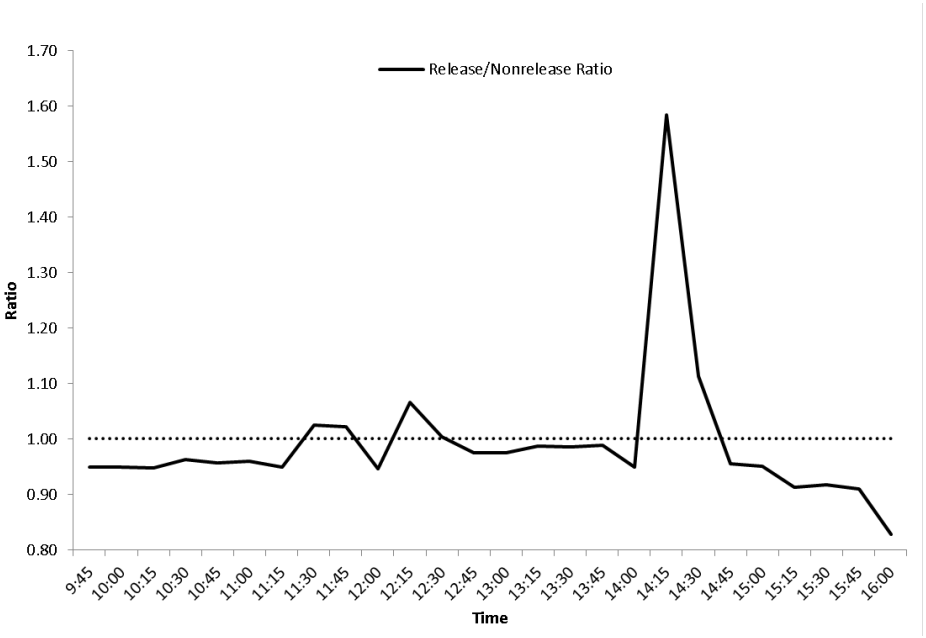


Table 1: **Distribution of Top LDA Topic Keywords**

This table reports the top 20 words for each topic identified by the LDA procedure. Each column in this table represents a topic $k = 1, \ldots, 8$, and the weights are estimates of $\hat{\beta}_{k,j}$ and represent the *probability that the word j characterizes topic k*. The distributional assumptions for the LDA model are outlined in Section 3 of the text. The estimation uses 5,644 paragraphs from FOMC meeting minutes released between 1990 and 2015.

Topic 1		Topic 2		Topic 3		Topic 4	
Weight	Word	Weight	Word	Weight	Word	Weight	Word
0.0445	policy	0.0788	inflation	0.0240	market	0.0335	labor
0.0216	monetary	0.0265	energy	0.0206	credit	0.0295	employment
0.0188	funds	0.0255	consumer	0.0172	yields	0.0250	job
0.0143	reserve	0.0226	labor	0.0146	financial	0.0247	workers
0.0133	risks	0.0212	core	0.0144	liquidity	0.0231	payroll
0.0113	financial	0.0178	expectations	0.0142	loans	0.0157	manufacturing
0.0104	agreed	0.0119	compensation	0.0141	securities	0.0151	hiring
0.0100	directive	0.0111	pce	0.0126	debt	0.0147	nonfarm
0.0086	guidance	0.0108	food	0.0123	spreads	0.0138	private
0.0080	purchases	0.0103	unemployment	0.0112	equity	0.0116	unemployment
0.0074	target	0.0099	real	0.0109	corporate	0.0108	inflation
0.0071	stability	0.0090	costs	0.0107	funds	0.0104	hourly
0.0071	easing	0.0089	index	0.0106	commercial	0.0103	services
0.0068	consistent	0.0085	commodity	0.0098	bank	0.0101	earnings
0.0065	stance	0.0082	oil	0.0086	nonfinancial	0.0099	food
0.0063	expectations	0.0072	slack	0.0078	investors	0.0095	costs
0.0057	tightening	0.0069	producer	0.0077	institutions	0.0091	force
0.0056	asset	0.0067	reflecting	0.0075	lending	0.0087	output
0.0054	action	0.0065	subdued	0.0072	issuance	0.0085	utilization
0.0052	view	0.0065	headline	0.0071	bonds	0.0085	construction

Topic 5		Topic 6		Topic 7		Topic 8	
Weight	Word	Weight	Word	Weight	Word	Weight	Word
0.0208	economy	0.0340	foreign	0.0448	consumer	0.0447	production
0.0169	business	0.0315	exports	0.0381	sales	0.0369	manufacturing
0.0129	economic	0.0289	u.s	0.0335	housing	0.0354	inventories
0.0111	demand	0.0268	dollar	0.0168	homes	0.0275	output
0.0087	productivity	0.0223	imports	0.0165	mortgage	0.0266	motor
0.0076	investment	0.0219	economies	0.0164	starts	0.0223	investment
0.0072	pressure	0.0166	countries	0.0145	construction	0.0201	industrial
0.0068	firms	0.0152	trade	0.0138	income	0.0160	sales
0.0063	financial	0.0140	major	0.0135	household	0.0149	equipment
0.0058	fiscal	0.0128	currencies	0.0134	gains	0.0143	vehicles
0.0057	prospects	0.0125	industrial	0.0131	expenditures	0.0141	business
0.0056	capital	0.0118	deficit	0.0105	single-family	0.0136	stocks
0.0055	confidence	0.0117	united	0.0101	retail	0.0118	wholesale
0.0055	strength	0.0112	japan	0.0098	motor	0.0118	capacity
0.0054	sectors	0.0098	exchange	0.0097	personal	0.0112	utilization
0.0053	potential	0.0097	euro	0.0091	purchases	0.0097	ratio
0.0051	favorable	0.0088	emerging	0.0078	vehicles	0.0090	industries
0.0050	costs	0.0084	sovereign	0.0077	existing	0.0087	retail
0.0049	anecdotal	0.0080	abroad	0.0076	residential	0.0074	accumulation
0.0049	stimulus	0.0072	european	0.0073	sentiment	0.0072	factory

Table 2: **Distribution of Estimated Weights Among Top Topic Keywords**

This table reports the sum of weights for the top 10 words, as well as sums of 10-word bins up to word 50, and the sums of words 51-100 and 101-200. Each column in this table represents a topic $k = 1, \ldots, 8$, and the weights are estimates of $\hat{\beta}_{k,j}$ and represent the *probability that the word j characterizes topic k*. The distributional assumptions for the LDA model are outlined in Section 3 of the text. The estimation uses 5,644 paragraphs from FOMC meeting minutes released between 1990 and 2015.

Top Words	Sum of Weights							
	(1) Policy	(2) Inflation	(3) Market	(4) Employment	(5) Growth	(6) Trade	(7) Consumption	(8) Investment
Top 10	**16.26%**	**22.74%**	**13.70%**	**17.67%**	**11.00%**	**21.72%**	**20.74%**	**24.86%**
11-20	7.20%	8.66%	8.75%	9.33%	5.90%	10.74%	9.71%	10.09%
21-30	4.95%	5.88%	5.78%	7.33%	4.44%	6.35%	6.32%	6.26%
31-40	3.66%	4.66%	4.60%	5.53%	3.91%	5.12%	4.87%	4.71%
Top 50	**35.34%**	**45.56%**	**36.52%**	**44.31%**	**28.65%**	**48.45%**	**45.64%**	**49.70%**
51-100	12.55%	14.19%	12.57%	15.40%	12.68%	14.99%	12.55%	13.00%
Top 100	**47.89%**	**59.75%**	**49.10%**	**59.71%**	**41.33%**	**63.44%**	**58.19%**	**62.70%**
101-200	14.53%	15.93%	14.50%	14.72%	15.34%	13.90%	14.15%	14.13%

Table 3: **Market Reaction to the Release of FOMC Minutes**

This table reports the coefficient estimates for Regression (7b), fitted using the release-day dummy, as well as lagged volatilities using K=0, 5, 10, and 20 trading days. The equity market regression uses transaction prices of SPY to measure intraday market returns. The Eurodollar market regression uses 3-month LIBOR rate implied by the nearest maturity Eurodollar futures contract as the interest rate measure. The top panel reports results using 15-minute event window market volatility and the bottom panel reports results using 20-minute window. Each regression uses between 4,343 and 4,363 days of observation.

Panel A. 15-Minutes Volatility

Equity Market	Number of Lags in Control			
	(None)	(5)	(10)	(20)
Release Dummy	0.5919***	0.6081***	0.6130***	0.6032***
	(6.32)	(6.99)	(7.13)	(7.02)
No. Obs	4363	4358	4353	4343
adj. R-sq	0.011	0.149	0.17	0.182
Eurodollar Market	Number of Lags in Control			
	(None)	(5)	(10)	(20)
Release Dummy	0.3054*	0.2283	0.2665*	0.2638*
	(2.02)	(1.74)	(2.01)	(1.98)
No. Obs	2627	2622	2617	2607
adj. R-sq	0.004	0.124	0.136	0.151

Panel B. 20-Minutes Volatility

Equity Market	Number of Lags in Control			
	(None)	(5)	(10)	(20)
Release Dummy	0.4965***	0.5174***	0.5418***	0.5084***
	(5.17)	(5.77)	(6.14)	(5.76)
No. Obs	4363	4358	4353	4343
adj. R-sq	0.009	0.134	0.161	0.173
Eurodollar Market	Number of Lags in Control			
	(None)	(5)	(10)	(20)
Release Dummy	0.3324*	0.2495	0.2962*	0.3019*
	(2.20)	(1.84)	(2.25)	(2.19)
No. Obs	2627	2622	2617	2607
adj. R-sq	0.001	0.125	0.137	0.146

Table 4: **Market Reaction to the Overall Content of FOMC Minutes**

This table reports the coefficient estimates for Regression (8). The dependent variable is the 15-minute unexpected volatility computed as the raw volatility minus the 20-day moving average, according to Equation 2 in the text. The independent variables are document-level tone scores computed according to Equation (6) without multiplying any topic proportions. The top panel reports the results using scores computed using the merged lexicon of Harvard-IV-4 and Loughran and McDonald (2011) lexicons and the bottom panel reports results using the LM lexicons only. Control variables are defined in Section 4.3 of the text. The estimates use 138 FOMC minutes released between 2000 and 2015.

Panel A. Unexpected Volatility; Merged Lexicon

	Net Tone (1)	Pos Tone (2)	Neg Tone (3)
Document Tone	-0.0159	-0.0086	0.0031
	(-1.69)	(-1.44)	(0.32)
Interest Rate	-0.007	-0.0085	-0.0074
	(-0.82)	(-1.32)	(-0.86)
Unemployment	-0.0062	-0.0081	-0.0067
	(-1.03)	(-1.79)	(-1.10)
Recession	-0.0486	-0.0072	-0.0286
	(-1.75)	(-0.41)	(-0.97)
N	138	138	138
R-sq	0.008	0.011	-0.012

Panel B. Unexpected Volatility; LM Lexicon

	Net Tone (1)	Pos Tone (2)	Neg Tone (3)
Document Tone	-0.012	-0.0057	0.0046
	(-1.29)	(-0.84)	(0.52)
Interest Rate	-0.006	-0.0074	-0.0074
	(-0.69)	(-1.09)	(-0.86)
Unemployment	-0.0074	-0.0083	-0.0071
	(-1.22)	(-1.83)	(-1.16)
Recession	-0.0445	-0.01	-0.0313
	(-1.55)	(-0.54)	(-1.10)
N	138	138	138
R-sq	-0.001	0.001	0.011

Table 5: **FOMC Topic Proportion and Market Reaction**

Columns (1) to (4) of this table report the coefficient estimates for Regression (9a). The dependent variable is the 15-minute unexpected volatility computed as the raw volatility minus the 20-day moving average, according to Equation 2 in the text. Columns (5) to (8) of this table report the coefficient estimates where the dependent variable is directional change in SPY or LIBOR. The equity market regression uses transaction prices of SPY to measure intraday market returns. The Eurodollar market regression uses 3-month LIBOR rate implied by the nearest maturity Eurodollar futures contract as the interest rate measure. The independent variables are document-level proportions for each topic. Control variables are defined in Section 4.3 of the text. The estimates use 138 FOMC minutes released between 2000 and 2015.

	Unexpected Volatility				Directional Price Change			
	Equity Market (SPY)		Debt Market (Eurodollar)		Equity Market (SPY)		Debt Market (Eurodollar)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Policy	0.0222*	0.0256*	0.3613**	0.0256*	0.0450	0.066727*	-0.2219**	-0.1789**
	(2.16)	(2.55)	(2.62)	(2.27)	(1.56)	(2.14)	(-2.60)	(-2.58)
Inflation	0.0212*	0.0235*	0.1629	0.1938*	-0.0150	0.0059	-0.1470	-0.1361
	(2.05)	(2.30)	(1.83)	(2.00)	(-0.64)	(0.22)	(-0.72)	(-0.55)
Market	0.0045	-0.0144	0.0775	0.0146	0.0255	-0.0131	0.1878	0.1052
	(0.37)	(-0.74)	(0.11)	(0.29)	(1.13)	(-0.38)	(1.47)	(1.16)
Employment	0.0170**	0.0168**	0.2611*	0.3008**	0.0249	0.0204	-0.2915	-0.2034
	(2.70)	(2.66)	(2.35)	(2.64)	(1.29)	(1.01)	(-1.84)	(-1.61)
Trade	-0.0022	0.0017	0.0948	0.1313	-0.0178	-0.0135	0.1719	0.0125
	(-0.42)	(0.32)	(1.26)	(1.37)	(-0.89)	(-0.65)	(0.26)	(0.12)
Consumption	-0.0004	0.0048	0.1076	0.0702	0.0007	0.0114	0.0356	0.0532
	(-0.08)	(0.82)	(0.53)	(0.57)	(0.03)	(0.52)	(1.10)	(1.18)
Investment	0.0294*	0.0306*	-0.0090	0.0007	0.0383	0.0331	-0.0111	-0.0089
	(1.98)	(2.27)	(-0.25)	(0.02)	(1.29)	(1.11)	(-0.72)	(-0.43)
Control Variables								
Interest Rate		-0.0004		0.1633		0.0107		0.1218
		(-0.04)		(1.16)		(0.49)		(0.88)
Unemployment		0.0237		0.1509		0.0197		-0.1086
		(1.63)		(1.61)		(1.70)		(-0.53)
Recession		0.0152		0.3124		-0.1261		-0.0044
		(0.75)		(1.07)		(-1.22)		(-0.10)
N	138	138	88	88	138	138	88	88
adj. R-sq	0.073	0.075	0.060	0.068	0.000	0.013	0.015	0.011

Table 6: **FOMC Topic Net Tone Score and Market Reaction**

Columns (1) to (4) of this table report the coefficient estimates for Regression (9b). The dependent variable is the 15-minute unexpected volatility computed as the raw volatility minus the 20-day moving average, according to Equation 2 in the text. Columns (5) to (8) of this table report the coefficient estimates where the dependent variable is directional change in SPY or LIBOR. The equity market regression uses transaction prices of SPY to measure intraday market returns and volatilities. The Eurodollar market regression uses 3-month LIBOR rate and volatilities implied by the nearest maturity Eurodollar futures contract. The independent variables are document-level Net Tone scores for each of the 8 LDA-identified topics, computed according to Equation (6). Control variables are defined in Section 4.3 of the text. The estimates use 138 FOMC minutes released between 2000 and 2015.

	Unexpected Volatility				Directional Price Change			
	Equity Market (SPY)		Debt Market (Eurodollar)		Equity Market (SPY)		Debt Market (Eurodollar)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Policy	-0.0014	-0.0137	-0.3448**	-0.3512*	0.0609*	0.0670**	-0.4146**	-0.4412*
	(-0.20)	(-1.48)	(-2.58)	(-2.23)	(2.44)	(2.70)	(-2.62)	(-2.38)
Inflation	-0.0180*	-0.0187**	-0.3719***	-0.3723***	0.0443**	0.0445*	-0.4740**	-0.4839**
	(-2.34)	(-2.77)	(-3.11)	(-3.25)	(2.76)	(2.49)	(-2.58)	(-2.67)
Market	-0.0047	-0.0024	0.0656	0.1001	-0.0560**	-0.0556**	0.1018	0.0693
	(-0.69)	(-0.32)	(0.20)	(0.30)	(-2.73)	(-2.65)	(0.74)	(0.62)
Employment	-0.0155*	-0.0154*	-0.1731*	-0.2087	0.0433	0.0601*	-0.0994	-0.2330
	(-2.46)	(-2.33)	(-2.04)	(-1.86)	(1.91)	(2.36)	(-1.87)	(-1.59)
Economy	0.0279	0.0350*	0.1753	0.1386	0.0025	-0.0143	-0.1439	-0.1171
	(1.88)	(2.26)	(1.54)	(1.49)	(0.14)	(-0.82)	(-0.65)	(-1.37)
Trade	-0.0075	-0.0096	-0.4511	-0.0797	0.0030	0.0050	0.0097	0.0126
	(-0.84)	(-1.05)	(-0.12)	(-0.04)	(0.16)	(0.03)	(0.38)	(0.35)
Consumption	0.0157*	0.0144*	0.1695	0.0878	-0.0364	-0.0539*	0.3381	0.1917
	(2.00)	(2.02)	(1.43)	(1.19)	(-1.38)	(-2.03)	(0.72)	(0.52)
Investment	-0.0131	-0.0136	0.0901	-0.0478	-0.0595*	-0.0698**	-0.0015	-0.0123
	(-1.35)	(-1.34)	(0.07)	(-0.82)	(-2.55)	(-3.00)	(-0.81)	(-0.86)
Control Variables								
Interest Rate		-0.0002		0.1683		0.0195		0.1200
		(-0.98)		(0.64)		(1.07)		(0.52)
Unemployment		0.0221		0.0474		0.0169		-0.1477
		(1.69)		(1.25)		(1.05)		(-0.21)
Recession		0.0173		-0.0735		-0.1170		-0.0093
		(1.70)		(-0.14)		(-1.84)		(-0.36)
N	138	138	88	88	138	138	88	88
adj. R-sq	0.069	0.077	0.084	0.080	0.015	0.025	0.012	0.009

Table 7: **Negative Topic Tones and and Market Volatility**

This table reports the coefficient estimates for Regression (9b), where the independent variable is the Negative Tone Scores for each of the 8 LDA-identified topics computed according to Equation (6) of the text. The dependent variable is the 15-minute unexpected volatility computed as the raw volatility minus the 20-day moving average, according to Equation 2 in the text. The equity market regression uses transaction prices of SPY to measure intraday market volatilities. The Eurodollar market regression uses 3-month LIBOR rate volatilities implied by the nearest maturity Eurodollar futures contract. The estimates use 138 FOMC minutes released between 2000 and 2015.

	Markets			
	Equity (SPY)		Debt (Eurodollar)	
	(1)	(2)	(3)	(4)
Policy	0.0189*	0.0151	0.2517**	0.2508**
	(2.28)	(1.91)	(2.43)	(2.47)
Inflation	0.0162*	0.0206**	-0.1538**	-0.1832*
	(2.53)	(2.95)	(-2.50)	(-2.18)
Market	-0.0154	-0.0187*	-0.1917*	-0.2021*
	(-1.63)	(-2.05)	(-2.15)	(-2.12)
Employment	0.0158*	0.0168*	0.0324	0.1297
	(2.10)	(2.27)	(1.32)	(0.81)
Economy	-0.0089	-0.0037	0.2994***	0.3318***
	(-1.46)	(-0.56)	(3.22)	(3.39)
Trade	-0.0016	-0.0024	0.1172	0.0453
	(-0.31)	(-0.47)	(0.80)	(0.71)
Consumption	0.0015	-0.0025	-0.1826	-0.0333
	(0.26)	(-0.46)	(-0.07)	(-0.22)
Investment	-0.0023	-0.0015	-0.0647	-0.1021
	(-0.44)	(-0.29)	(-1.35)	(-1.45)
Control Variables				
Interest Rate		-0.0007		0.2293
		(-0.17)		(1.04)
Unemployment		0.0181*		0.0837
		(2.46)		(1.16)
Recession		0.0142		0.0002
		(0.59)		(0.01)
N	138	138	88	88
adj. R-sq	0.054	0.069	0.128	0.142

Table 8: **Positive Topic Tones and and Market Volatility**

This table reports the coefficient estimates for Regression (9b), where the independent variable is the Positive Tone Scores for each of the 8 LDA-identified topics computed according to Equation (6) of the text. The dependent variable is the 15-minute unexpected volatility computed as the raw volatility minus the 20-day moving average, according to Equation 2 in the text. The equity market regression uses transaction prices of SPY to measure intraday market volatilities. The Eurodollar market regression uses 3-month LIBOR rate volatilities implied by the nearest maturity Eurodollar futures contract. The estimates use 138 FOMC minutes released between 2000 and 2015.

	Markets			
	Equity (SPY)		Debt (Eurodollar)	
	(1)	(2)	(3)	(4)
Policy	-0.0156*	-0.0131*	-0.0012	-0.0253
	(-2.16)	(-2.13)	(-0.02)	(-0.37)
Inflation	0.0005	0.0009	-0.0678	-0.0942
	(0.07)	(0.12)	(-0.88)	(-1.13)
Market	-0.0277*	-0.0341*	-0.1553*	-0.1556*
	(-2.55)	(-2.53)	(-2.18)	(-2.11)
Employment	0.0021	0.0039	0.1740	0.1246
	(0.31)	(0.67)	(1.74)	(1.80)
Economy	-0.0293***	-0.0227**	0.1322*	0.1807*
	(-3.71)	(-2.75)	(2.06)	(2.14)
Trade	-0.0029	-0.0028	0.1007*	0.0852
	(-0.59)	(-0.59)	(2.03)	(1.79)
Consumption	0.0036	0.001	-0.0045	0.0120
	(0.53)	(0.13)	(-0.28)	(0.13)
Investment	0.007	0.0066	-0.0244	-0.0469
	(1.01)	(0.96)	(-0.52)	(-0.14)
Control Variables				
Interest Rate		-0.0005		0.1619
		(-0.21)		(1.12)
Unemployment		0.0147		0.0800
		(1.38)		(1.16)
Recession		0.0118		0.1192
		(0.51)		(0.42)
N	138	138	88	88
adj. R-sq	0.050	0.051	0.073	0.064

Table 9: **Topic Proportion and Macroeconomic Variables**

This table reports the coefficient estimates for Regression (11a). The independent variables are document-level proportions for each topic. The independent variables are related to macroeconomic conditions and defined in Section 4.3 of the text. These variables are also used as controls in other regressions. The estimates use 196 FOMC minutes released between 1990 and 2015.

	Topics							
	(1) Policy	(2) Inflation	(3) Market	(4) Employment	(5) Growth	(6) Trade	(7) Consumption	(8) Investment
Interest Rate	0.0487	-0.432***	-0.221***	-0.107*	0.409***	0.00231	-0.164***	0.244***
	(1.06)	(-13.12)	(-8.96)	(-2.47)	(13.46)	(0.05)	(-3.71)	(6.38)
Unemployment	0.0690	-0.0425	0.345***	-0.156***	-0.0799*	-0.0694	-0.179***	-0.158***
	(1.42)	(-1.22)	(13.23)	(-3.38)	(-2.48)	(-1.42)	(-3.81)	(-3.90)
Recession Dummy	-0.446	-0.0926	0.974***	-0.913***	-0.102	0.227	0.153	-0.138
	(-1.85)	(-0.54)	(7.56)	(-4.00)	(-0.64)	(0.94)	(0.66)	(-0.69)
N	196	196	196	196	196	196	196	196
adj. R-sq	0.015	0.493	0.717	0.114	0.568	0.001	0.085	0.315

Table 10: **Topic Tone Scores and Macroeconomic Variables**

This table reports the coefficient estimates for Regression (11b). The independent variables are Net, Positive, and Negative Tone Scores for each of the 8 LDA-identified topics computed according to Equation (6) of the text. The independent variables are related to macroeconomic conditions and defined in Section 4.3 of the text. These variables are also used as controls in other regressions. The estimates use 196 FOMC minutes released between 1990 and 2015.

Panel A: Net Tone

	Topic							
	Policy	Inflation	Market	Employment	Economy	Trade	Consumption	Investment
Interest Rate	0.0036	0.1160**	-0.0129	0.1334***	-0.0029	0.0030	0.0475	0.0536
	(0.08)	(2.78)	(-0.31)	(3.66)	(-0.07)	(0.06)	(1.16)	(1.35)
Unemployment	0.0308	-0.0481	-0.1683***	-0.2332***	-0.1398**	0.0294	-0.0759	-0.0965*
	(0.65)	(-1.09)	(-3.81)	(-6.03)	(-3.15)	(0.60)	(-1.76)	(-2.30)
Recession	-0.9529***	-1.2035***	-1.2021***	-1.1137***	-1.2576***	-0.4359	-1.4928***	-1.5910***
	(-4.07)	(-5.50)	(-5.50)	(-5.83)	(-5.73)	(-1.80)	(-6.99)	(-7.67)
N	196	196	196	196	196	196	196	196
adj. R-sq	0.067	0.185	0.187	0.378	0.180	0.003	0.222	0.266

Panel B: Positive Tone

	Topic							
	Policy	Inflation	Market	Employment	Economy	Trade	Consumption	Investment
Interest Rate	0.0127	-0.3390***	-0.1157**	0.1125**	0.2913***	-0.0408	-0.0035	0.1746***
	(0.28)	(-8.58)	(-2.93)	(2.70)	(7.71)	(-0.89)	(-0.08)	(4.37)
Unemployment	0.1252**	-0.0944*	0.1964***	-0.1530***	-0.0916*	-0.0679	-0.1328**	-0.1758***
	(2.60)	(-2.26)	(4.70)	(-3.46)	(-2.29)	(-1.40)	(-2.81)	(-4.16)
Recession	-0.4292	-0.0616	0.9733***	-0.7880***	-0.3288	0.4367	-0.6714**	-0.5139*
	(-1.81)	(-0.30)	(4.71)	(-3.61)	(-1.66)	(1.81)	(-2.88)	(-2.46)
N	196	196	196	196	196	196	196	196
adj. R-sq	0.037	0.271	0.274	0.187	0.333	0.013	0.072	0.256

Panel C: Negative Tone

	Topic							
	Policy	Inflation	Market	Employment	Economy	Trade	Consumption	Investment
Interest Rate	0.0064	-0.3109***	-0.0469	-0.0553	0.3267***	-0.0269	-0.0645	0.1029*
	(0.14)	(-8.51)	(-1.28)	(-1.27)	(8.55)	(-0.59)	(-1.51)	(2.54)
Unemployment	0.0667	-0.0159	0.2367***	0.1509**	0.0349	-0.0685	-0.0252	-0.0481
	(1.37)	(-0.41)	(6.09)	(3.27)	(0.86)	(-1.42)	(-0.56)	(-1.12)
Recession	0.4631	1.0189***	1.4762***	0.6496**	0.8651***	0.6803**	1.3034***	1.5669***
	(1.93)	(5.33)	(7.68)	(2.85)	(4.32)	(2.86)	(5.84)	(7.40)
N	196	196	196	196	196	196	196	196
adj. R-sq	0.015	0.377	0.371	0.114	0.318	0.036	0.153	0.236

Table 11: **Volatility Reaction to the Magnitude of Tones**

This table reports the coefficient estimates for Regression (14a). The dependent variable is the 15-minute unexpected volatility computed as the raw volatility minus the 20-day moving average, according to Equation 2 in the text. The independent variables are the absolute values of document-level Net Tone scores for each of the 8 LDA-identified topics computed according to Equation (6). Control variables are defined in Section 4.3 of the text. The estimates use 138 FOMC minutes released between 2000 and 2015.

	Models	
	(1)	(2)
Policy	0.0192*	0.0155*
	(2.60)	(2.19)
Inflation	0.0133*	0.0160*
	(2.01)	(2.00)
Market	0.0153*	0.0173*
	(2.00)	(2.02)
Employment	0.0115*	0.0138*
	(2.06)	(2.19)
Economy	0.0018	0.0035
	(0.32)	(0.50)
Trade	-0.0018	0.0025
	(-0.33)	(0.51)
Consumption	0.0103	0.0049
	(1.70)	(0.68)
Investment	0.009	0.0143
	(1.25)	(1.96)
Control Variables		
Interest Rate		-0.0010
		(-0.17)
Unemployment		0.0156
		(1.77)
Recession		0.0157
		(1.34)
N	138	138
adj. R-sq	0.068	0.070

Table 12: **Market Reaction to Tone Changes**

Columns (1) and (2) of this table report the coefficient estimates for Regression (13a). The dependent variable is the 15-minute unexpected volatility computed as the raw volatility minus the 20-day moving average, according to Equation 2 in the text. Columns (3) and (4) of this table report the coefficient estimates where the dependent variable is directional change in SPY. The independent variables are the changes in document-level Net Tone scores for each of the 8 LDA-identified topics computed according to Equation (6). Control variables are defined in Section 4.3 of the text. The estimates use 138 FOMC minutes released between 2000 and 2015.

	Unexpected Volatility		Directional Price Change	
	(1)	(2)	(3)	(4)
Policy	0.0244***	0.0274***	0.0756***	0.0723***
	(5.12)	(5.21)	(5.04)	(5.22)
Inflation	-0.0094	-0.0187*	0.0579*	0.0547*
	(-1.10)	(-2.15)	(2.23)	(2.25)
Market	-0.0144*	-0.0098*	-0.0738	-0.0726*
	(-2.16)	(-2.44)	(-1.95)	(-2.05)
Employment	0.0093	0.0151	0.0403*	0.0483*
	(0.47)	(0.71)	(2.09)	(2.01)
Economy	0.0013	0.0018	0.0032	0.0026
	(1.09)	(1.30)	(0.57)	(0.43)
Trade	-0.0021	-0.0028	-0.0075	-0.0052
	(-0.24)	(-0.29)	(-0.57)	(-1.22)
Consumption	0.0024	0.0006	0.0042	-0.0006
	(0.84)	(0.17)	(0.02)	(-0.12)
Investment	-0.0009	0.0001	0.0014	0.0023
	(-0.64)	(0.09)	(0.22)	(0.24)
Control Variables				
Interest Rate		-0.0025		
		(-0.60)		(1.02)
Unemployment		0.0115		0.0119
		(1.41)		(0.93)
Recession		0.0153		-0.1401
		(1.42)		(-1.78)
N	138	138	138	138
adj. R-sq	0.058	0.077	0.014	0.027

Table 13: **Market Reaction Pre- and Post-2011**

This table reproduces Table 6 for different subsamples. The equity market regression uses transaction prices of SPY to measure intraday market returns and volatilities. The Eurodollar market regression uses 3-month LIBOR rate and volatilities implied by the nearest maturity Eurodollar futures contract. The pre-2011 sample uses 101 FOMC minutes released between 2000 and 2011. The post-2011 sample uses 101 FOMC minutes released between 2011 and 2015. Control variables are defined in Section 4.3 of the text.

	Unexpected Volatility				Directional Price Change			
	Pre-2011		Post-2011		Pre-2011		Post-2011	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Policy	-0.0123	-0.0127	-0.0228	-0.0243	0.0523*	0.0649**	0.0637*	0.0711*
	(-1.15)	(-1.31)	(-1.82)	(-1.57)	(2.24)	(2.69)	(2.50)	(2.53)
Inflation	-0.0150	-0.0128*	-0.0261*	-0.0219*	0.0644*	0.0737*	0.0388	0.0203
	(-1.55)	(-2.37)	(-2.55)	(-2.47)	(2.14)	(2.32)	(1.78)	(1.72)
Market	-0.0096	-0.0043	-0.0056	-0.0050	-0.0631*	-0.0526*	-0.0464*	-0.0741**
	(-1.62)	(-1.09)	(-0.53)	(-0.37)	(-2.49)	(-1.99)	(-2.54)	(-3.65)
Employment	-0.0194*	-0.0120*	-0.0288*	-0.0279*	0.0416	0.0632*	0.0470**	0.0642*
	(-2.11)	(-2.22)	(-2.01)	(-2.42)	(1.61)	(2.20)	(2.77)	(2.65)
Economy	-0.0158	-0.0162	0.0313*	0.0297*	0.0198	0.0202	-0.0139	-0.0088
	(-1.96)	(-1.98)	(2.50)	(2.34)	(1.14)	(0.32)	(-1.03)	(-0.72)
Trade	-0.0094	-0.0089	0.0001	-0.0018	0.0165	0.0127	-0.0206	0.0028
	(-1.41)	(-1.31)	(0.01)	(-0.18)	(0.72)	(0.54)	(-0.85)	(0.12)
Consumption	0.0317**	0.0308**	0.0144	0.0153	-0.0178	-0.0500	-0.0315	-0.0442
	(3.25)	(3.01)	(1.14)	(1.14)	(-0.21)	(-0.13)	(-0.91)	(-0.24)
Investment	0.0047	0.0024	-0.0365*	-0.0351*	-0.0645*	-0.0770*	-0.0444*	-0.0628*
	(0.50)	(0.26)	(-2.34)	(-2.34)	(-2.23)	(-2.60)	(-2.05)	(-2.14)
Control Variables								
Interest Rate		-0.0022		0.0016		0.0071		0.1572*
		(-0.13)		(0.54)		(0.68)		(2.31)
Unemployment		0.0117		0.0114		0.0105		0.0155
		(1.62)		(0.17)		(0.58)		(0.72)
Recession		0.0179		N/A		-0.0463		N/A
		(0.71)		N/A		(-0.78)		N/A
N	101	101	37	37	101	101	37	37
adj. R-sq	0.043	0.040	0.140	0.089	0.015	0.018	0.127	0.172

Table 14: **Statements and Minutes**

Panel A of this table presents the coefficient estimates from Regression (9b), where the independent variable is the document-level Net Tone Scores from FOMC Statements, computed according to Equation (6) of the text. The Meeting Day subsample uses days when the FOMC meetings take place, and the Minutes Release Day subsample uses the days when the corresponding meeting minutes are released. Panel B of this table presents the regression estimates of the Minutes topic Net Tone Scores regressed on the document-level Net Tone Scores from FOMC statements. Control variables are defined in Section 4.3 of the text.

Panel A: Statement Tone and Volatility

	Raw Volatility				Unexpected Volatility			
	Meeting Day		Minutes Release Day		Meeting Day		Minutes Release Day	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Statement Net Tone	0.0612*	0.0610*	0.0117	0.0031	-0.0416*	-0.0403*	0.0123	0.0096
	(2.40)	(2.49)	(0.60)	(0.15)	(-2.03)	(-2.12)	(1.54)	(1.25)
Interest Rate		0.0257		0.0228		-0.0093		-0.0009
		(0.83)		(0.81)		(-0.96)		(-0.96)
Unemployment		0.0103		0.0187		0.0106*		0.0177*
		(1.02)		(1.82)		(2.08)		(2.05)
Recession		-0.0616		-0.0700		0.0169		0.0032
		(-0.12)		(-1.15)		(0.37)		(0.11)
N	132	132	130	130	132	132	130	130
adj. R-sq	0.032	0.020	-0.005	0.002	0.027	0.041	0.017	0.036

Panel B: Predictability of Minutes' Contents Using Statements

	Dependent Variable=Net Tone Score of Each Minutes Topic							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Policy	Inflation	Market	Employment	Economy	Trade	Consumption	Investment
Statement Tone	0.1021	0.2070*	-0.0640	-0.0213	0.0699	-0.0805	0.0102	-0.1342
	(1.87)	(2.20)	(-0.63)	(-0.27)	(0.89)	(-0.93)	(0.15)	(-1.44)
Interest Rate	-0.0623*	0.3682***	-0.0005	0.1325*	-0.1364	0.0071	0.0454	0.0169
	(-2.14)	(4.64)	(-0.01)	(2.44)	(-0.89)	(0.62)	(0.91)	(0.30)
Unemployment	-0.0511	0.0199	-0.1350***	-0.2093***	-0.0269*	0.0700	-0.0717	0.0097
	(-0.92)	(0.33)	(-5.97)	(-4.31)	(-2.13)	(1.04)	(-1.51)	(0.16)
Recession	-0.3741**	-0.8616***	0.9646**	-0.6085**	-1.0868***	-0.5187	-1.5546***	-1.5732***
	(-3.07)	(-4.12)	(2.92)	(-3.06)	(-4.59)	(-1.74)	(-7.83)	(-6.79)
N	142	142	142	142	142	142	142	142
adj. R-sq	0.093	0.269	0.183	0.394	0.150	0.007	0.269	0.240

Table 15: **Market Reaction to Tone Computed Using Market-Weighted Lexicons**

This table reproduces Table 6 for different Net Tone Score measures. The independent variables are document-level Net Tone scores for each of the 8 LDA-identified topics, computed according to Equation (6), using the market-weighted lexicon developed by Jegadeesh and Wu (2013). Control variables are defined in Section 4.3 of the text. The estimates use 138 FOMC minutes released between 2000 and 2015.

	Unexpected Volatility		Directional Price Change	
	(1)	(2)	(3)	(4)
Policy	-0.003	-0.0073*	0.0531	0.05439*
	(-0.99)	(-2.11)	(1.92)	(2.10)
Inflation	-0.0097*	-0.0135*	0.0061	0.0133
	(-2.05)	(-2.54)	(0.29)	(0.60)
Market	-0.0045	-0.0127	-0.0399*	-0.0474**
	(-0.98)	(-1.96)	(-2.13)	(-2.94)
Employment	-0.0027	-0.0019	0.0303	0.0597*
	(-0.52)	(-0.36)	(1.72)	(2.12)
Economy	0.0149**	0.0188**	0.0828**	0.0754**
	(2.77)	(3.13)	(3.16)	(3.10)
Trade	-0.0183	-0.0142	0.0461	0.0519
	(-1.57)	(-1.26)	(1.35)	(1.45)
Consumption	-0.0191*	-0.0240**	-0.0199	-0.0086
	(-2.58)	(-2.94)	(-0.79)	(-0.33)
Investment	0.0316***	0.0343***	-0.0707*	-0.0709*
	(3.48)	(3.92)	(-2.25)	(-2.25)
Control Variables				
Interest Rate		-0.0013		0.0191
		(-0.70)		(1.40)
Unemployment		0.0134**		0.0252
		(2.11)		(0.65)
Recession		0.0153		-0.1241
		(0.60)		(-0.90)
N	138	138	138	138
adj. R-sq	0.067	0.077	0.027	0.033