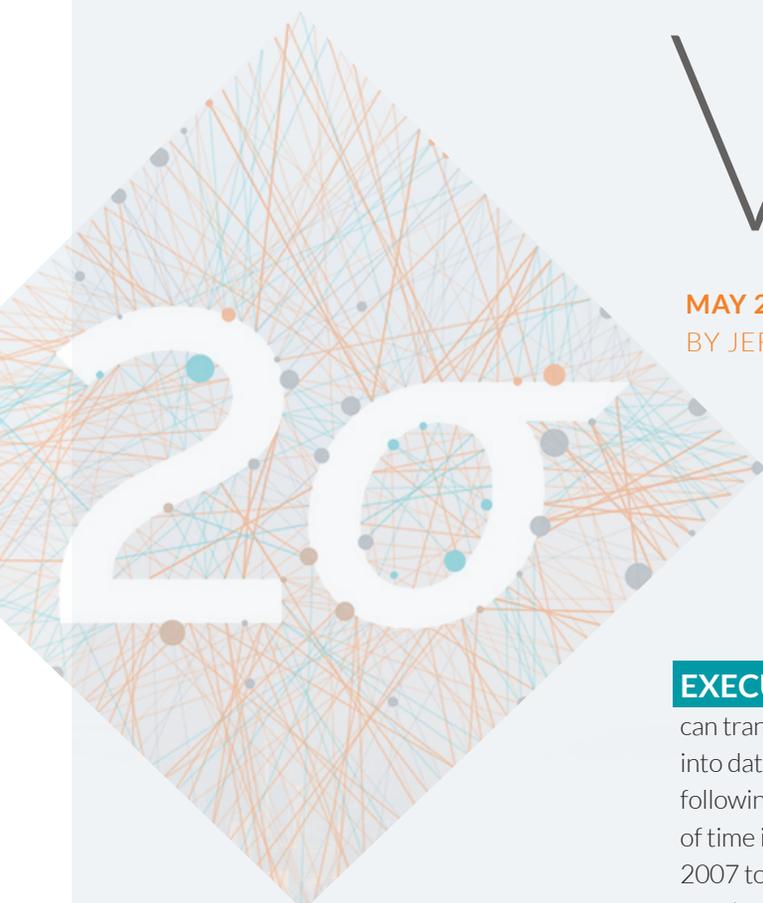




Street View

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EXECUTIVE SUMMARY

Natural language processing techniques can translate Federal Open Market Committee (FOMC) meeting minutes into data. The results appear both intuitive and informative. For example, following the 2007-2009 financial crisis, the Fed increased the amount of time it devoted to discussing financial markets from 10 percent in 2007 to nearly 40 percent in late 2008. At more recent meetings, the Fed spent approximately equal time (~20 percent) discussing inflation, growth, financial markets, and policy. Topics like employment and trade have commanded only five percent of the Fed's mindshare of late. Knowing what concerns the Fed might help allocators sharpen their focus on the long-term issues that matter for both monetary policy and the broader economy.

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In Shakespeare's *Hamlet*, chief counselor to the king Lord Polonius asked the protagonist what he was reading. Hamlet accurately, if imprecisely, replied, "words, words, words." Counselors to asset allocators might ask the same thing of so-called "Fed watchers," who dutifully interpret the US Federal Reserve's Federal Open Market Committee's (FOMC) meeting minutes. The FOMC publishes these minutes three weeks after each of its eight scheduled annual meetings, likely to help asset allocators and others understand the slightly delayed but more detailed views held by the Fed's monetary policy decision makers.

Historically, interpretations of those minutes required art, so Fed watchers pontificated and critiqued. Now natural language processing techniques can translate those minutes into relatively objective data. The results appear both intuitive and informative. For example, during the 2007-2009 financial crisis, the Fed increased the amount of time it devoted to discussing financial markets from 10 percent in 2007 to nearly 40 percent during late 2008. At more recent meetings, the Fed spent approximately equal time (~20 percent) discussing inflation, growth, financial markets, and policy. Topics like employment and trade have commanded less than five percent of the Fed's mindshare during 2016. Knowing what matters concern the Fed might help allocators sharpen their focus on the long-term issues that matter for both monetary policy and the broader economy.

THE FOMC'S MEETING MINUTES LEND THEMSELVES WELL TO NATURAL LANGUAGE PROCESSING

Analyses based on natural language processing (NLP) techniques usually require two main ingredients – a large number of texts worth analyzing and consistency across those texts. The FOMC's meeting minutes offer both ingredients. Since 1993, the FOMC has published meeting minutes eight times per year using a relatively consistent structure.

Natural language processing (NLP) techniques can consistently and objectively identify and calculate time-variation in topics discussed in these FOMC minutes at a granular level. Blei, Ng, and Jordan (2003) describe one such technique – Latent Dirichlet Allocation (LDA). LDA algorithms try to classify the text into "unobserved topics" or groups, and then map each word of a text into those unobserved topics. Principal component analyses (PCA) of empirical data might offer a clarifying analogy, in that both LDA and PCA ignore any specific context or pre-conceived categories in order to statistically and unbiasedly identify relationships to reduce dimensionality or complexity. Similar to a PCA, a nearly infinite number of "unobserved topics" could perfectly describe a given text. For practical reasons, researchers

typically select only a manageable few. The technical appendix offers more details.

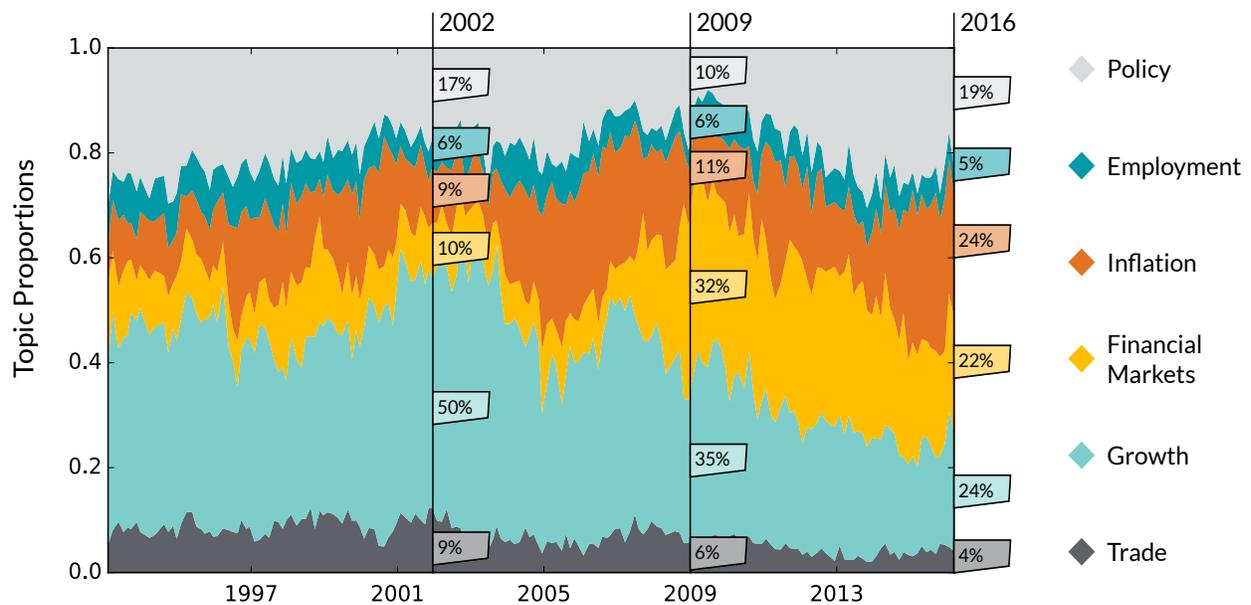
THREE TRENDS JUMP OUT OF THE NLP ANALYSIS OF THE FOMC'S MEETING MINUTES

The analysis highlights three trends in the FOMC meeting minutes (Figure 1). First, financial markets have captured and sustained a significant share of the FOMC's discussions since the 2007-2009 financial crisis, seemingly at the expense of growth. Prior to 2007, the Fed typically devoted less than 10 percent of FOMC meetings to discussing financial markets. A notable exception occurred from 1997 to 1999 during the rolling Asian, Latin American, and Russian financial crises. Those events reaffirmed the stereotype that the Fed offered a "Greenspan put," or an FOMC backstop to financial stress.

Beginning in mid-2007, stress in the financial markets again commanded the Fed's attention, and the market vernacular shifted from the "Greenspan put" to the "Bernanke put." At its peak in late 2008, the FOMC devoted nearly 37 percent of its meeting minutes to discussing financial markets, using words such as "securities," "credit," "dollar," "rates," and "mortgage." Since

FIGURE 1

FOMC Topic Proportions



Note: Author's Analysis. Chart shows the proportion of FOMC meeting minutes that cover specific topics (e.g., policy) based on an LDA analysis similar described by Blei et al. (2003) and similar to Jegadeesh and Wu (2015). Table reports the average proportion by topic for select years. Results may not total 100% due to rounding.

then, the share of the FOMC's attention has trended lower, though it has remained persistently above 20 percent during both the Bernanke and Yellen eras at the Fed. In contrast, the FOMC has reduced the relative fraction of its meetings dedicated to discussing growth. In 2002, for example, 50 percent of the FOMC minutes covered topics related to economic growth. That share has fallen by half in the minutes released so far during 2016 (January and March meetings).

Second, inflation has become an increasingly important topic since 2014. During the 2007-2009 financial crisis, the FOMC devoted only 15 percent of its meeting minutes to discussing inflation. Since mid-2014, that fraction increased to more than 20 percent and, during the past few meetings, close to 30 percent. The other element of the Fed's dual mandate, employment, has persistently commanded less attention (~5 percent).

Third, while inflation appears to have captured the greatest share of the FOMC's mind for the past few months, the FOMC seems relatively unfocused. For the first time in the data set, four topics individually command

more than 20 percent of the minutes: inflation, growth, policy, and financial markets. This might imply that these topics have become more interrelated today than in the past. It might also reflect a societal trend towards multitasking. Either way, the job of Fed watchers appears to have become more complex.

IMPLICATIONS

As one of the most informed and influential economic actors in the global economy, the FOMC's views matter. At its eight regularly scheduled meetings per year, the FOMC reviews economic and financial conditions, determines its stance of monetary policy, and assesses the risks to its long-run goals of price stability and sustainable economic growth. Since the FOMC consists of a time-varying group of twelve, not always like-minded individuals who communicate in relatively qualitative and imprecise terms, minutes from the meeting represent subjective views.

Market observers trying to glean insights from these meeting minutes once needed to rely on the subjective interpretation of so-called expert "Fed watchers" (e.g.,

Romer and Romer, 1989) or their own interpretation. Now, asset allocators can apply natural language processing techniques to extract insights from the FOMC's published meeting minutes, turning qualitative inputs into more easily analyzed, quantitative data. This paper's analysis focused on topic identification and relative weights within FOMC discussions, but that represents only one potential application. Numerous other potential applications exist. For example, one could use this data to evaluate the tone or sentiment of a meeting. With the advancement of NLP, market observers might enjoy the option of limiting the amount of subjectivity they need to layer on to understanding the subjective views of the FOMC. Paraphrasing Polonius, market observers might discern more method in the Fed's alleged madness.

BRIEF TECHNICAL APPENDIX

The mechanics of applying an LDA algorithm to FOMC minutes are straightforward. First, a custom text parser converts the raw text from the minutes into digestible input for the LDA algorithm. The parser drops the first section of the FOMC minutes describing previous open market operations, based on assumptions that those do not contain salient information. Next, the parser breaks each set of minutes into their constituent paragraphs. The parser removes "stop words" including pronouns, articles, prepositions, conjunctions, numbers, weeks,

months, and other commonly occurring non-topic specific words, such as "federal," "reserve" or "session."

The number of unobserved topics is an important input into the LDA algorithm. According to Blei (2012), interpretability offers a legitimate reason for choosing the appropriate number of groups in the algorithm, as opposed to standard model selection techniques in machine learning, such as out-of-sample prediction accuracy. After iterating over LDA models with the number of topics varying from five to 12, an eight-topic model seemed to offer the most interpretable output for FOMC minutes, at least based on the words associated with each topic. Since these eight topics appeared to overlap somewhat (e.g., Topic 2 included words like "securities," "credit," and "market," while Topic 4 included words like "financial," "market," and "equity"), Figure 1 aggregates these machine-selected topics into six more sensible groups: growth, inflation, financial markets, employment and trade.¹ The figure reports the fraction of FOMC meeting minutes that discusses each of those six groups.

¹ For more details on the approach or the results of the LDA algorithm, please reach out to the authors or your Two Sigma relationship manager.

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INTERESTING TECHNOLOGY-RELATED ARTICLES

Two Sigma views itself as a technology company that applies a rigorous, scientific method-based approach to investment management. Our technology is inspired by a diverse set of fields including artificial intelligence and distributed computing. Occasionally, we read articles in the popular press that describe applications of technology that we find interesting, thought-provoking, and relevant for people thinking about improving the investment management process. Below is a subset of the articles we read this month. Please do not view the inclusion of these articles as an endorsement by Two Sigma of their viewpoints or the companies discussed therein. Two Sigma welcomes discussions (and contributions) about these and other such technology-related articles.

“Moore’s Law Running Out of Room, Tech Looks for a Successor” by John Markoff, *New York Times*, May 4, 2016 (http://www.nytimes.com/2016/05/05/technology/moores-law-running-out-of-room-tech-looks-for-a-successor.html?ref=business&_r=1)

The physical limitations and quantum mechanics of atomic-sized components will likely limit the ability of scientists to further shrink silicon chips, implying that Moore’s Law will no longer predict the rate of traditional semiconductor innovation. Defined by Intel co-founder Gordon Moore, it is not so much a scientific law as an observation that the number of transistors that can fit on an integrated circuit has roughly doubled every two years. However, as that number nears its physical limit, scientists have expanded their search for new technologies to replace the ubiquitous silicon computer chip itself. Quantum computing is emerging as a way to apply quantum physics to increase computing speed and efficiency. Scientists are also experimenting with graphene, a single-atom-thick carbon compound, as an alternative to produce smaller, faster, and most importantly, less power-hungry transistors. The death of Moore’s Law, whenever it finally arrives, does not mean the end of steady improvements in computational power. In fact, it may even herald greater innovation.

“IBM’s Watson Helped Design Karolina Kurkova’s Light-Up Dress for the Met Gala” by , Liz Stinson, *Wired*, May 3, 2016 (<http://www.wired.com/2016/05/ibms-watson-helped-design-karolina-kurkovas-light-dress-met-gala/>)

Marrying brains and beauty, the fashion designer Marchesa partnered with IBM’s Watson to create the “Cognitive Dress” that debuted at the Met Gala on May 2. The designers embroidered 150 LED-connected flowers onto the dress to change color depending upon how Twitter followers reacted. Watson’s Tone Analyzer API used a “color psychology” algorithm and a collection of Marchesa runway dress images to map out a color palette signifying five different emotions. On the night of the gala, Watson categorized the tweets associated with the dress into joy, patience, excitement, encouragement, or curiosity and changed the flower colors accordingly.

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