

Latent semantic analysis of the FOMC statements

FOMC
statements

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Abstract

Purpose – The purpose of this paper is to analyze the content of the statements that are released by the Federal Open Market Committee (FOMC) after its meetings, identify the main textual associative patterns in the statements and examine their impact on the US treasury market.

Design/methodology/approach – Latent semantic analysis (LSA), a language processing technique that allows recognition of the textual associative patterns in documents, is applied to all the statements released by the FOMC between 2003 and 2014, so as to identify the main textual “themes” used by the Committee in its communication to the public. The importance of the main identified “themes” is tracked over time, before examining their (collective and individual) effect on treasury market yield volatility via time-series regression analysis.

Findings – We find that FOMC statements incorporate multiple, multifaceted and recurring textual themes, with six of them being able to characterize most of the communicated monetary policy in the authors’ sample period. The themes are statistically significant in explaining the variation in three-month, two-year, five-year and ten-year treasury yields, even after controlling for monetary policy uncertainty and the concurrent economic outlook.

Research limitations/implications – The main research implication of the authors’ study is that the LSA can successfully identify the most economically significant themes underlying the Fed’s communication, as the latter is expressed in monetary policy statements. The authors feel that the findings of the study would be strengthened if the analysis was repeated using intra-day (tick-by-tick or five-minute) data on treasury yields.

JEL classification – E5, F3, G1

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Social implications – The authors’ findings are consistent with the notion that the move to “increased transparency” by the Fed is important and meaningful for financial and capital markets, as suggested by the significant effect that the most important identified textual themes have on treasury yield volatility.

Originality/value – This paper makes a timely contribution to a fairly recent stream of research that combines specific textual and statistical techniques so as to conduct content analysis. To the best of their knowledge, the authors’ study is the first that applies the LSA to the statements released by the FOMC.

Keywords Content analysis, Monetary policy, Latent semantic analysis, Fed wording, FOMC statements, Treasury market

Paper type Research paper

1. Introduction

Content analysis, the method of studying the communication process and quantifying the content of documents in terms of intensity and direction of meaning has been the focus of several recent studies across different disciplines. From social sciences, media and politics (Young and Soroka, 2012; Magerman *et al.*, 2010) to economics, banking and finance (Zavodny and Ginther, 2005; Lucca and Trebbi, 2009; Loughran and McDonald, 2011, among others), researchers have used a large and heterogeneous set of manual or computer-based techniques to identify messages or even measure sentiment, in an effort to link the content/linguistic findings with subsequent actions or implications for the respective audience or markets.

The fact that not all economies have achieved a steady path of recovery after the great financial crisis has resulted in most major central banks adopting divergent policy stances and, thus, conducting monetary policy has become more complex. In that respect, the means of communication selected by central banks prove critical to provide transparency to the market regarding policy decisions and to set the expectations for the future direction of monetary policy [1]. With previous research establishing that monetary policy is critical for the economy (Christiano *et al.*, 2004; Eggertsson and Woodford, 2003, among others), many past studies focused on monetary policy and its implications on the markets (Cook and Hahn, 1987, Kohn and Sack, 2004, among others). More recently, a growing body of papers on content analysis has focused on the communication tools of central banks around the globe (Blinder *et al.*, 2008; Hendry and Madeley, 2010), with an emphasis on the US central bank (Gürkaynak *et al.*, 2005, Boukus and Rosenberg, 2006, among others). Undeniably, the implementation and the communication of the Fed policy are of great importance in the context of global financial stability, and this is deemed even more important at present, at a time when the global economy and financial markets have displayed increasing fragility.

As the US monetary policymaking body has changed its communication strategy radically over the past two decades (Lucca and Moench, 2015), much research is focused on inferring Fed policy from the communication methods used, as those choices themselves have become increasingly important aspects of monetary policy; Mayer (1999), Orphanides (2003), Chappell and McGregor (2004), Broadus (2004) and Reinhart and Sack (2005) are among the first who conduct narrative approaches on how to measure this issue. As the Fed uses its great range of communication tools to inform the public on monetary policy, this “commitment to transparency” (Mishkin, 2004) has spurred an increased focus on the exact wording the Fed is using (Yellen, 2012). This has led Gürkaynak *et al.* (2005) to support that central bank wording is the major driver of markets’ reaction, rather than the actual change in monetary policy and Blinder *et al.* (2008) argue that financial markets respond to multi-faceted qualitative information introduced through the several types of communication.

This paper examines the treasury market reaction to Fed monetary policy, as the latter is revealed to market participants through the Federal Open Market Committee (FOMC) statements that are released immediately after each policy meeting[2]. The FOMC statements are very closely watched by market participants and are widely cited by market analysts as the most important gauge of Fed policy (Lucca and Trebbi, 2009; Farka and Fleissig, 2011) and as the largest market-moving event (Rosa, 2013).

To analyze the wording used in the FOMC statements, we use a statistical method known as latent semantic analysis (LSA), a language processing technique for analyzing relationships between a set of documents and the terms they contain[3]. Unlike many notable past studies that use manual, subjective and judgmental text interpretation techniques (Cook and Hahn, 1987; Blinder *et al.*, 2008; Zavadny and Ginther, 2005; Farka and Fleissig, 2011), the LSA allows objective statistical extraction of text themes that are not specified a priori by the researcher and thus lack bias.

Using all the FOMC statements released from May 2003 to December 2014, we first testify that the LSA identifies six recurring textual themes, which can explain more than half of the variation of meanings communicated through the monetary policy announcements. We attempt an interpretation of the identified FOMC themes and establish that the extracted themes are indeed correlated with current and future economic conditions. We further establish – via regression analysis – that the treasury market reaction to the statements' release depends on these specific themes and that when combined with certain financial and macroeconomic indicators, FOMC policy meanings have a significant impact on the yield curve dynamics, predominantly on medium- to long-term maturities. Unlike Reinhart and Sack (2005) who suggest that market reaction across FOMC communications is fairly homogeneous, our findings suggest that the market reaction seems rather nuanced and is highly dependent on the policy stance depicted by each wording theme.

Our work in this paper follows a fairly recent stream of research (notably the work of Zavadny and Ginther, 2005; Boukus and Rosenberg, 2006 and Lucca and Trebbi, 2009) that combines specific textual and statistical techniques so as to conduct content analysis and measure the effects of certain policy communication on asset prices in financial markets. We contribute to this literature in a number of ways. First, the study examines the same type of policy information as in Gürkaynak *et al.* (2005) and Farka and Fleissig (2011) through a statistical, language-processing technique that allows identification of multiple, recurring and economically significant textual themes which are free of reader's judgment or bias by its construction. Moreover, the LSA method has not been used in the context of central banking communications before, with the notable exception of Boukus and Rosenberg (2006) whose study is the one closest in spirit to our work. Thus, our study complements the findings and extends the conclusions of Boukus and Rosenberg (2006) by examining via LSA the textual themes incorporated in the FOMC statements, which constitute the Fed's most important communication tool. Last but not least, as our period of study extends to the Financial Crisis and beyond, we are able to provide valuable insight on the main semantic themes that the Fed insisted on during this extensively researched period.

Overall, our analysis and findings suggest that the FOMC statements are highly comprehensive as a means of monetary policy communication and that they include meaningful content for the treasury market. Our empirical findings suggest that Fed policy communication, as designated through the FOMC statements, has been of much greater significance for the market since the financial crisis, and that Fed wording is simultaneously crucial and efficient in adjusting market expectations toward the policymakers' decisions and outlook for the future path of monetary policy, output growth and inflation. Ultimately, our analysis suggests that the increased Fed transparency is meaningful and markets appear

to respond to it, and as monetary policy communication methods further evolve and transparency goes farther, the impact on the treasury and other financial markets may become even greater in the future.

The rest of the study is organized as follows: Section 2 describes the LSA method that we use in quantifying the textual themes of the FOMC statements. Section 3 describes the data of the study. Section 4 presents the results of the LSA, identifies and describes the textual themes that are extracted from the FOMC statements and investigates their association with macroeconomic and financial market indicators. Section 5 investigates the treasury market reaction to FOMC statements releases. Finally, Section 6 concludes the study.

2. Applying latent semantic analysis

2.1 Introduction to the latent semantic analysis approach

The LSA method is a language processing technique that allows the recognition of relationships between a set of documents and the terms included in them[4]. More specifically, the LSA allows extraction of conceptual meanings from a body of text (our sample of FOMC statements), by detecting similarities and differences in word and phrase usage, both within each document (statement) and across all documents in the sample period. As an output, it produces what Boukus and Rosenberg (2006) refer to as “the major associative patterns in the data” or simply the underlying textual “themes” of the set of documents, by associating words and phrases by their frequency in appearing within and across documents.

2.2 Formation of the corpus and text preprocessing

Before performing LSA, we need to group all $d = 99$ documents (FOMC statements) that comprise our sample into one textual collection called the “corpus”. The $d = 99$ statements are described in detail in our data selection in Section 3.

The first step in performing LSA is to preprocess the corpus; preprocessing can be described as a routine that comprises of the following sequential steps:

- eliminate text formatting, including capitalization, pronunciation, symbols, digits or other special characters that might appear in the text;
- remove extremely common and “function-neutral words” that do not contribute to the informational value of the document (stop words); these words typically include pronouns, articles, prepositions, conjunctions, numbers, days, weeks, months and names;
- apply lemmatization to all remaining terms; lemmatization is the procedure by which all plurals are transformed into singular forms and past-tense verbs are replaced with their present-tense versions; and
- apply stemming to all the remaining terms. Stemming is the process of producing common etymological roots and then map them.

An example of how all the above steps of preprocessing are applied to the FOMC statements appears in Appendix B (available online, see Footnote 1).

It should be noted that all phrases and references to the decision-making process and voters of the FOMC have been removed from the “corpus[5]”. Moreover, the textual analysis in this paper is conducted using the QDA Miner® and WordStat® software of Provalis Research[6]. For the identification of stop words in preprocessing, we choose to modify the dictionary that is available (by default) in the software, by incorporating all necessary changes in the context of our FOMC application. In doing this, we follow the influential work

of Loughran and McDonald (2011), who provide a sentiment word list specifically attributed to accounting and finance topics[7].

Last but not least, it should be pointed that the stemming process is implemented by using the Porter (1980) stemming algorithm, which has proved successful in many applications under different contexts[8]. For future reference, we note here that the final corpus produced by preprocessing all our $d = 99$ FOMC statements comprises of 419 unique terms across *all documents*, with each preprocessed document $i = 1, 2, \dots, 99$ having t_i unique terms (with $t_i \leq 419$ by construction).

2.3 The latent semantic analysis algorithm

The application of the LSA technique in our context starts by using each preprocessed document $i = 1, 2, \dots, 99 = d$, to construct a $[t_i \times 1]$ *term-frequency vector*. Each element of the term-frequency vector is equal to the frequency rate of a term in the document, and it is calculated as the number of occurrences of that term (within the i doc) divided by the total number of terms t_i of the i statement. The intuition behind constructing the term-frequency vector is that the more often a term appears within a particular document, the more it contributes to the information content of that document and it characterizes its meaning (Grimaldi, 2011).

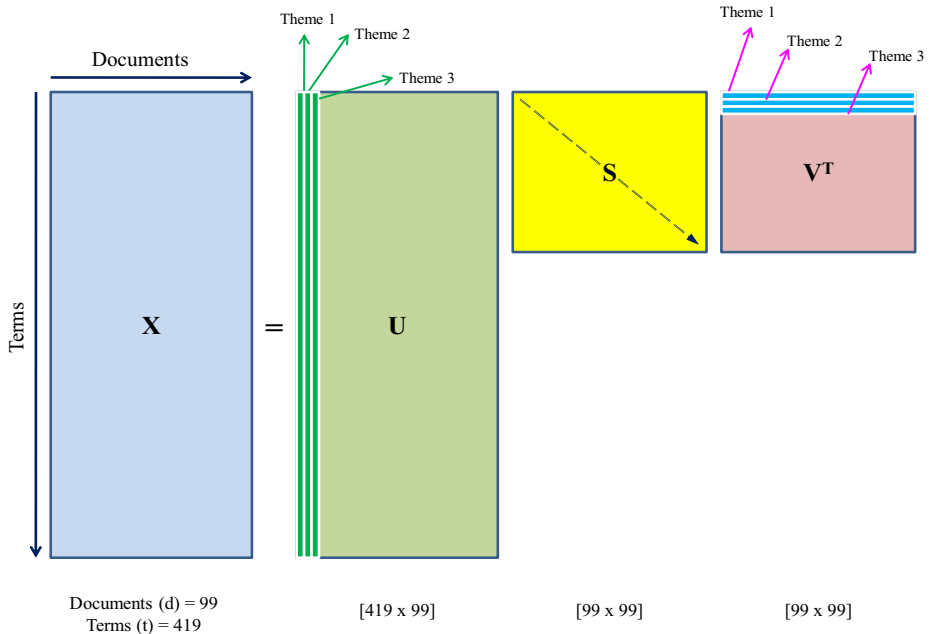
The next step is to merge the $d = 99$ term-frequency vectors, keeping any common terms only once, so as to form a $t \times d$ matrix, with $t = \max\{t_i, i = 1, \dots, d\}$ the number of unique terms across all statements. Recall that in our application, this matrix has $t = 419$ rows and $d = 99$ columns. The matrix rows represent unique terms that appear at least once in the entire processed corpus, while columns represent each document in the sample period. The elements of the matrix are the frequency rates of the unique terms in all the statements. The elements of each matrix row are then demeaned (by subtracting the corresponding row mean) to form the so-called *term-document matrix*, which we denote by \mathbf{X} . The term-document matrix is rectangular (more terms/rows than documents/columns) and generally sparse, as the unique terms do not appear in every document. Moreover, $\mathbf{X}\mathbf{X}^T$, the covariance matrix of (demeaned) term frequencies is singular.

In the final step of the method, the underlying textual “themes” of the statements are extracted using singular value decomposition (SVD) of the term-document matrix[9]. These themes are derived from the covariances between term frequencies across documents. SVD decomposes the term-document matrix \mathbf{X} into:

$$\mathbf{X}_{t \times d} = \mathbf{U}_{t \times d} \mathbf{S}_{d \times d} \mathbf{V}_{d \times d}^T \quad (1)$$

Given that \mathbf{X} is mean-centered, the columns of \mathbf{U} are equal to the eigenvectors of $\mathbf{X}\mathbf{X}^T$ and the columns of \mathbf{V} are the principal component values of \mathbf{X} . The \mathbf{S} matrix is diagonal, with its diagonal elements equal to the square roots of the eigenvalues of $\mathbf{X}^T \mathbf{X}$, in decreasing order.

The importance of the decomposition for the extraction of the textual themes and identification of their importance can be better appreciated with the help of Figure 1. The columns of \mathbf{U} (eigenvectors of $\mathbf{X}\mathbf{X}^T$) characterize the importance of each term in each theme, while the columns of \mathbf{V} (rows of \mathbf{V}^T) characterize the presence (contribution) of each textual theme in each document. The diagonal elements of \mathbf{S} represent the importance of each theme across the entire corpus in decreasing order, with the first (last) textual theme being the most (least) dominant concept in the variation of the FOMC statements. If documents in \mathbf{X} are in chronological order, as it is commonly the case, we can extract the time series of term scores via the product $\mathbf{U}\mathbf{S}$.



Notes: The figure illustrates the decomposition of the term-document matrix (X) into matrices U , S and V^T . The U matrix defines the contribution of each unique term to themes, the V matrix defines the contribution of each theme to documents and the S matrix is a diagonal matrix of singular values through which we can extrapolate the importance (the explanatory power) of each theme to the text corpus. The columns of U matrix marked in green characterize the importance of each term in the first three themes (Eigenvectors 1, 2 and 3). Similarly, the first three rows of V^T colored in red define the importance of Themes 1, 2 and 3 for each document, respectively. The graphical depiction of SVD of a matrix X is based on the relevant representations of Berry *et al.* (1995), Wall *et al.* (2003) and Boukus and Rosenberg (2006)

Figure 1.
SVD of the
term-document matrix
(X)

3. Data

3.1 The Federal Open Market Committee statements

In terms of history, since 1981, the FOMC convenes for eight regularly scheduled meetings per year, apart from any additional special meetings or telephone conferences that may be held upon extraordinary cases. Up until 1994, the Committee did not announce anything to the general public, with the first FOMC statement issued after a regular meeting of February 4, 1994. In the following years, up until mid-1999, the FOMC only issued statements when *changes to the funds rate* were decided, but in May 1999, the Committee initiated the statement release after each and every meeting.

Recent FOMC statements have reached a total of 900 words approximately (Figure A1 in the Appendix), which shows that central bank communication is of pivotal interest for policymakers, especially after the Financial Crisis of 2007 and its aftermath. There are many notable steps that the Fed has taken toward the evolution of their communication tools and strategy since 1994, with that point in time considered by many as the beginning of the

“forward guidance” scheme[10]. This evolution of communication has been greatly perceived through the increased transparency and forward policy guidance, with the latter being one of the most important examples of unconventional monetary policy.

Our analysis in this paper is based on all FOMC statements released over the period from May 2003 to December 2014, with our total sample comprising 99 statements. We have decided to restrict our sample period from mid-2003 and onward, given the recent suggestions (Rosa, 2011, 2013) that since mid-2003, the statements have indeed become more informative and their final form had been settled.

Panel A of Figure 2 summarizes the most common stop words that are identified and excluded from our statements’ corpus during preprocessing, such as *the, have, to, and, in, committee* and *be*. Panel B of Figure 2 lists some of the common stems and their associated terms from the FOMC statements; for instance, the terms *expect, expectance, expectancy, expectation, expectations, expected, expecting* and *expects* map to *expect*. Additionally, in Panel C of the table, we report the total and unique terms count at different stages of preprocessing. Before any filtering, each statement seems to have around 404 words on average, of which the unique terms stand to about 333. When filtering out the unnecessary parts of the statements (stop words among others) and after completing all the preprocessing steps, the unique terms are reduced to around 137 per statement, while across the full sample, unique terms come to a total of 419 words.

3.2 Financial and macroeconomic data

In terms of our empirical analysis, we collect data for several indicators that are considered as top gauges of financial and macroeconomic conditions and which are expected to be usual points of reference for the policymakers during FOMC discussions on monetary policy. Moreover, we collect a wide range of treasury market data so as to use them in terms of measuring and analyzing the financial market reaction to FOMC statement releases over our sample period.

More specifically, we collect data for twelve market indicators and eight macroeconomic indicators, with all the financial market variables measured on the day of the FOMC statement release and the macroeconomic variables measured using the final revised data that would have been available at the meeting. Among the financial indicators collected, we use the daily Fed Funds Futures settlement prices (from Bloomberg) for the two-month-ahead contract traded at the Chicago Board of Trade, to calculate the expected Fed Funds Rate (Krueger and Kuttner, 1996; Gürkaynak, 2005). We also collect data for the S&P 500 index, the foreign exchange value of the dollar, the price of crude oil (all of which are used as control variables in our empirical investigation), and we estimate the so-called “credit spread” and “term spread” indicators[11][12]. Furthermore, we use the three-month Eurodollar implied volatility and the volatility index (VIX) from the Chicago Board Options Exchange as measures of monetary policy uncertainty and financial markets’ stress, respectively[13].

As far as the macroeconomic indicators are concerned, we collect data for the GDP, GDP deflator, core personal consumption expenditure (PCE), core consumer price index (CPI), industrial production, unemployment rate, ISM manufacturing and non-manufacturing indices, as well as the University of Michigan consumer confidence index, which have been often highlighted from the policy-makers for their importance.

At the same time, we collect daily data for all the available series of “on-the-run” treasury yields from the Federal Reserve H.15 release and Bloomberg, to examine the treasury market reaction to FOMC statement releases over our sample period. As in Fleming and Piazzesi (2005) and Boukus and Rosenberg (2006), we use the absolute value of yield changes, constructed by using the high and low of the average bid and ask yields for each day, to identify the information shocks in the treasury market.

Panel A. Most frequent stop words		Panel B. Stemmer mapping		Panel C. Word counts during preprocessing			
Stop Word	Frequency	Original Word	Stem		Words		
the	11.83%	accommodation	accomod	total text sample	No. of terms	Mean	Std. Dev.
have	7.41%	accommodative			39,964	404	204
to	7.11%	addition	addition	stop word filtering	21,354	216	106
and	6.06%	additional		after stemming	17,328	175	86
committee	4.26%	announce	announce				
in	4.19%	announcement					
be	3.44%	begin	begin				
is	2.60%	beginning		total text sample	No. of terms	Mean	Std. Dev.
a	2.52%	business	busi		32,963	333	197
that	2.32%	business		stop word filtering	17,089	173	102
will	2.26%	businesses		after stemming	13,520	137	82
for	1.73%	continuation	contin				
fed	1.64%	continue					
at	1.51%	continuous					
with	1.29%	decline	declin				
as	1.19%	declined					
percent	1.05%	declines					
on	0.97%	declining					
term	0.88%	develop	develop				
over	0.84%	development					
		expect	expect				
		expectance					
		expectancy					
		expectation					
		expectations					
		expected					
		expecters					
		expecting					
		expects					
		foresee	forese				
		foreseeing					
		foresees					
		foreseeable					
		increase	increas				
		increases					
		increaseth					
		increasing					
		market	market				
		marketable					
		markets					
		proceed	proce				
		proceeds					
		proceeded	proceed				
		proceeders					
		proceeding					
		proceedings					
		policies	polici				
		policy					
		remain	remain				
		remained					
		remaining					
		remains					
		secure	secur				
		securely					
		securing					
		securities					
		security					
		support	support				
		supportable					
		supportance					
		supported					
		supporter					
		supporters					
		supporting					

The frequency reported is extracted by dividing the number of uses of the stop words by the total number of stop words in the corpus.

Notes: The Table reports summary statistics of FOMC statements for the sample period from May 2003 to December 2014. Panel A lists the twenty five most frequent stop words. Panel B exhibits some common words used in the statements with their stemmed form-root. Panel C reports the word count under various stages of document preprocessing, both for unedited and edited statements

Figure 2.
FOMC statements
data

Table I reports summary statistics for the treasury market data. An initial observation from Panel A is that although all treasury instruments exhibit a fair amount of average yield volatility on the FOMC statement release dates (ranging from 3.8387 basis points for the 12-month instrument, to 12.6582 basis points in the 5-year one), it seems that the longer-maturity yields exhibit a more pronounced volatility reaction, suggesting that it is the long-end of the yield curve that responds more to the information in the FOMC statements during our sample period[14]. Moreover, we observe that yield volatility is significantly greater on FOMC statement release dates than on any other day on average. Furthermore, days when the FOMC statements are released exhibit greater yield volatility when compared to the days the FOMC minutes are released, at least for the medium- to long-term end of the yield curve (maturities of one year and greater). This evidence, in line with Rosa (2011, 2013), provides preliminary confirmation that the FOMC statements contain information not yet incorporated in the markets.

4. Textual themes from the Federal Open Market Committee statements

4.1 Content analysis of the term-document matrix

In Table II, we present the 30 terms with the highest relative frequency for the entire sample period, as well as for three subintervals created as per Fed presidency term[15].

Over the entire sample period, we observe in Panel A of Table II that many significant terms such as *inflat*, *economy*, *price*, *growth* and *labor* that are closely related to the Fed's objectives are indeed included in the list with the most frequent terms across the board. It is also worth noting that there are some words with unusually high frequency in the total sample, such as *secure*, *purchase*, *pace* and *accommodate*, which are particularly common in the majority of the statements following the financial crisis and which clearly pinpoint the unprecedented unconventional policy measures adopted by the Fed.

Taking into account the evolution of the FOMC statements' structure over our sample period, we may uphold that the largest portion of the statement is focused on presenting the current economic conditions and how future expectations about the economy fit into the Fed's monetary policy plan. Among the key topics of interest are levels of inflation, labor market conditions, monetary policy accommodation (either in the form of low rates and/or large-scale asset purchases), housing market, consumer spending, output growth, industrial production and developments in financial markets.

4.2 Extracting and interpreting themes

Results from applying SVD to our term-document matrix are reported in Table III. Panel A of Table III summarizes the contribution of each characteristic theme to the "variability" of the text in our sample period. Based on the estimated matrix of eigenvalues (S), we determine the fraction of variance explained by each theme by dividing each eigenvalue by the sum of all eigenvalues (all diagonal elements in S).

The four textual themes with the highest importance (eigenvalue) in our sample period can account for half of the total variance (50 per cent) in the statements, with two additional themes (Themes 5 and 6) adding another 10.37 per cent to the explanatory power. The first 20 themes explain around 87 per cent of the total variance and when accounting for the first 50 themes this amount reaches almost 98 per cent.

In the remainder of the study, we focus on the first six textual themes that collectively account for over 60 per cent of the total text variance. This decision follows naturally from the "rule of thumb" that has been used in the factor and principal component analysis literature[16]. Panel B of Table IV reports summary statistics for the six most important textual themes in our sample period. All themes, except the sixth one, appear highly

Absolute value of yield change	No. of observations	Mean	<i>t</i> -test (1)	<i>t</i> -test (2)	SD	Skewness	Kurtosis
			On statement release dates—on minutes release dates < 0	On statement release dates—on all other dates < 0			
<i>Panel A. FOMC Statement release dates</i>							
1-month yield	99	7.6751		*	0.1788	7.2248	61.5091
3-month yield	99	5.8243		**	0.0994	4.1090	22.4355
6-month yield	99	4.8566		***	0.0653	2.8837	9.9487
12-month yield	54	3.8387	*	*	0.0611	3.3918	12.6384
2-year yield	99	9.5775	****	****	0.0783	1.8119	3.9427
3-year yield	88	9.8664	****	****	0.0634	1.6387	3.1970
5-year yield	99	12.6582	****	****	0.0895	2.1118	5.4662
7-year yield	47	12.6198	****	****	0.0958	3.1152	12.2042
10-year yield	99	11.6349	****	****	0.0820	2.7850	10.3592
20-year yield	49	11.1632	****	****	0.0772	2.8132	9.4629
30-year yield	99	10.1402	****	****	0.0646	2.5644	9.8839
<i>Panel B. FOMC Minutes release dates</i>							
Absolute value of yield change	No. of observations	Mean	SD	Skewness	Kurtosis		
1-month yield	94	5.3118	0.0751	3.4590	13.1609		
3-month yield	94	4.3869	0.0766	6.0440	43.9786		
6-month yield	94	3.8016	0.0581	4.5000	23.4902		
12-month yield	52	2.6331	0.0297	3.0100	12.0337		
2-year yield	94	7.1724	0.0485	1.3117	2.5288		
3-year yield	87	7.7798	0.0417	1.0949	1.5440		
5-year yield	94	9.5559	0.0482	1.6155	2.8820		
7-year yield	46	9.0804	0.0317	1.3334	2.1842		
10-year yield	94	9.0444	0.0427	1.6130	3.2719		
20-year yield	49	7.7580	0.0344	1.2265	1.2713		
30-year yield	94	8.1665	0.0389	1.0109	0.6416		
<i>Panel C. All other dates</i>							
1-month yield	2,717	5.2061	0.0907	7.4593	91.5001		
3-month yield	2,717	3.9699	0.0700	7.6667	89.9724		
6-month yield	2,717	3.3510	0.0480	6.2621	65.9813		
12-month yield	1,527	2.6819	0.0404	6.0329	57.3420		
2-year yield	2,717	6.3585	0.0539	2.4954	11.3783		
3-year yield	2,496	6.6422	0.0422	1.6862	4.6535		
5-year yield	2,717	8.6317	0.0507	1.8761	5.7234		
7-year yield	1,362	8.4326	0.0418	1.7075	5.7793		

Table I.
Treasury yield data

(continued)

Table I.

Absolute value of yield change	No. of observations	Mean	SD	Skewness	Kurtosis
10-year yield	2,717	8.4969	0.0442	1.7373	4.7908
20-year yield	1,437	7.6492	0.0382	1.9685	5.9821
30-year yield	2,717	7.9727	0.0408	1.9983	8.0964

Notes: The table reports summary statistics for the absolute value of treasury yield changes. Units are presented in decimal points. Yields are based on the closing bid yields as reported by Bloomberg database for all the available on-the-run treasury maturities, excluding all weekend days, public holidays and periods during which certain treasury instruments were not tradable at the market. The average absolute value of yield change reported in all panels is in basis points. Under *t*-test (1), we report one-sided *t*-tests under the null hypothesis that the mean absolute treasury yield change on the days the FOMC minutes are released exceeds the mean absolute treasury yield change on the days the FOMC statements are released. Under *t*-test (2), we report one-sided *t*-tests under the null hypothesis that the mean absolute treasury yield change on days with no FOMC releases exceeds the mean absolute treasury yield change on the days the FOMC statements are released. For both *t*-tests, asterisks ****, ***, ** and * indicate rejection of the null hypothesis at the 1, 2, 5 and 10% significance level, respectively

persistent over the whole sample period, with statistically significant (at the 1 per cent level) first-order autocorrelations. The sixth theme is not persistent as it seems to be significant only during the financial crisis of 2007.

The correlations between first-order autoregressive theme residuals and intermeeting changes in macroeconomic and financial indicators over the entire sample period are reported in Table IV. This is useful for detecting whether the FOMC statements are shaped based on information of current economic conditions and also explore whether FOMC statements express the policy makers' concerns over the future economic prospects. Panel A of Table IV summarizes the contemporaneous time-series correlation of the identified textual themes with macroeconomic and financial indicators. In Panel B of Table IV, the themes predictive power is assessed (by means of the correlation between the Themes' residuals and future values of financial and macroeconomic variables). Themes appear to exhibit a fair degree of correlation with leading indicator variables, mostly with financial market indicators and at a significantly lesser degree with economic variables. The most compelling findings are seen in Panel B with Theme 1 exhibiting the strongest signs of predictability toward leading financial and economic indicator variables. This seems to suggest that the continuous enhancement and effects of transparency and "forward guidance" language in the statements set clearly the stage for the policymakers' effort to better guide the public's understanding of the central bank's reaction function to future economic conditions and so as to reduce the resulting uncertainty about future path of policy.

Interpreting the extracted textual themes is an extremely challenging task that could be easily influenced by the researcher's subjectivity. However, we attempt to attach a meaning to each identified theme, based purely on their semantic orientation extracted through their constituent words and sentences, their prevalence over our sample period and the leading and contemporaneous correlations discussed above.

To accomplish this, we start by observing the importance of the most characteristic terms or phrases that are identified in each textual theme and the evolution and intensity, over time, of the six major identified themes in our sample period.

For the importance of the most characteristic terms or phrases that are identified in each textual theme, the loadings of the *U* matrix from our SVD allow one to measure the contribution and importance of each word or term to a particular theme. Figure 3 plots the loadings for the ten most important terms in our identified Themes 1-6. Panel A displays

Term	5/2003-12/2014: All FED Chairs		5/2003-1/2006 Chair: A. Greenspan		3/2006-1/2014 Chair: B. Bernanke		3/2014-12/2014 Chair: J. Yellen	
	Frequency (%)	Term	Frequency (%)	Term	Frequency (%)	Term	Frequency (%)	
<i>Panel A. No global weighting</i>								
INFLAT	3.99	INFLAT	4.28	INFLAT	3.79	INFLAT	4.73	
ECONOM	3.14	PRICE	3.34	ECONOM	3.45	LONG	3.36	
RATE	2.49	POLICI	3.09	RATE	2.62	MARKET	3.13	
MARKET	2.23	GROWTH	3.02	CONTINU	2.36	LABOR	2.98	
CONTINU	2.10	ECONOM	2.71	MARKET	2.22	CONDITION	2.13	
PRICE	1.88	ACCOMMOD	2.52	SECUR	1.99	EXPECT	2.13	
REMAIN	1.87	RATE	2.46	REMAIN	1.85	ECONOM	2.04	
SECUR	1.76	REMAIN	2.08	PRICE	1.81	EMPLOY	2.04	
POLICI	1.74	UNDERLI	2.02	EXPECT	1.56	SECUR	2.04	
LONG	1.72	ACTION	1.95	GROWTH	1.54	RATE	1.94	
EXPECT	1.69	EXPECT	1.89	LONG	1.52	POLICI	1.89	
GROWTH	1.54	STABIL	1.83	POLICI	1.49	PURCHAS	1.85	
CONDITION	1.41	RISK	1.76	FINANCI	1.37	REMAIN	1.80	
PACE	1.34	MONETARI	1.76	CONDITION	1.37	CURRENT	1.75	
STABIL	1.32	LOW	1.70	STABIL	1.32	CONSIST	1.61	
PURCHAS	1.24	INCREAS	1.58	PURCHAS	1.30	MAXIMUM	1.61	
LABOR	1.22	ACTIV	1.51	PACE	1.26	PACE	1.61	
FUND	1.21	EQUAL	1.51	LEVEL	1.21	CONTINU	1.56	
FINANCI	1.15	ATTAIN	1.45	FUND	1.19	IMPROV	1.52	
CONSIST	1.09	FUND	1.45	CONSIST	1.16	RANG	1.47	
LEVEL	1.07	TARGET	1.45	MORTGAG	1.11	ASSET	1.37	
MORTGAG	1.02	ROUGHLI	1.45	ANTICIP	1.03	MORTGAG	1.37	
ACCOMMOD	1.00	PRODUCT	1.45	LOW	1.01	MAINTAIN	1.33	
IMPROV	0.98	PACE	1.45	OUTLOOK	1.00	TARGET	1.28	
LOW	0.97	DOWNSID	1.32	MANDAT	0.98	ACCOMMOD	1.23	
SUPPORT	0.94	ONGO	1.32	INFORM	0.96	APPROPRI	1.23	
EMPLOY	0.92	PERCEIV	1.32	MODER	0.94	ASSESS	1.23	
MANDAT	0.90	UPSID	1.32	RECOVERI	0.91	INFORM	1.23	
OUTLOOK	0.89	SUPPORT	1.32	LABOR	0.88	MANDAT	1.23	
INFORM	0.89	ROBUST	1.26	HOUS	0.86	INDIC	1.18	
<i>Panel B. TF-IDF weights</i>								
SECUR	0.54	ACTION	0.36	PURCHAS	0.43	OCCUR	0.10	
PURCHAS	0.50	PACE	0.31	SECUR	0.43	LOW	0.09	
CONSIST	0.46	ENERGI	0.31	CONSIST	0.40	SUGGEST	0.08	
MANDAT	0.41	ELEV	0.26	ACCOMMOD	0.39	CHANG	0.08	
MORTGAG	0.39	EVID	0.25	MANDAT	0.38	ENERGI	0.08	
LONG	0.39	ADD	0.25	LONG	0.36	GUIDANC	0.08	
APPROPRI	0.33	STABIL	0.24	APPROPRI	0.34	DECLIN	0.07	
ACCOMMOD	0.32	BALANC	0.23	MORTGAG	0.34	ADD	0.07	
EMPLOY	0.31	CONSUM	0.23	FACIL	0.24	RESTRAIN	0.07	
MAXIMUM	0.30	FALL	0.23	EMPLOY	0.23	GROWTH	0.06	
ASSET	0.30	IMPORT	0.23	ASSET	0.23	ELEV	0.05	
ANTICIP	0.27	PRESS	0.23	UNEMPLOY	0.23	EVID	0.05	
RECOVERI	0.24	UNWELCOM	0.23	MAXIMUM	0.23	LIKELIHOOD	0.05	
LABOR	0.23	RISE	0.23	DUAL	0.22	PERFORM	0.05	
DUAL	0.23	FIRM	0.23	ANTICIP	0.22	POS	0.05	

Table II.
Most frequent terms used

(continued)

Table II.

5/2003-12/2014: All FED Chairs		5/2003-1/2006 Chair: A. Greenspan		3/2006-1/2014 Chair: B. Bernanke		3/2014-12/2014 Chair: J. Yellen	
Term	Frequency (%)	Term	Frequency (%)	Term	Frequency (%)	Term	Frequency (%)
CURRENT	0.22	SOLID	0.23	RECOVERI	0.21	RECENT	0.05
UNEMPLOY	0.22	SPEND	0.23	CREDIT	0.21	RECOGN	0.05
TREASURI	0.22	HURRICAN	0.22	LABOR	0.20	SHOW	0.05
ASSESS	0.22	CONDITION	0.22	TREASURI	0.20	ADVERS	0.05
PROGRESS	0.22	MUT	0.22	IMPROV	0.19	COMPENS	0.05
CREDIT	0.22	APPROPRI	0.22	GOAL	0.19	CONVERS	0.05
FINANCI	0.21	GRADUAL	0.22	MAINTAIN	0.18	GAIN	0.05
FACIL	0.20	JUDG	0.22	ACTIV	0.18	JOB	0.05
GOAL	0.20	IMPROV	0.22	CONTINU	0.18	MIX	0.05
RANG	0.20	NEED	0.22	MATUR	0.17	REBOUND	0.05
IMPROV	0.20	CORE	0.21	BALANC	0.17	REFLECT	0.05
CONDITION	0.20	FULFIL	0.21	DECLIN	0.17	SOLID	0.05
BALANC	0.19	LONG	0.21	PACE	0.17	SOONER	0.05
INDIC	0.19	EXCE	0.21	SUPPORT	0.17	STATE	0.05
LEVEL	0.19	EXPAND	0.21	COMMODO	0.16	SURVEI	0.05

Notes: This table shows the 30 most frequent unique terms that appear in the FOMC statements. In panel A, the term frequencies are the number of occurrences of each term divided by the total number of stemmed terms per document. In panel B, the aforementioned term frequencies are multiplied by the inverse document frequency (as per the TFIDF methodology)

the key words with the greatest meaningful contribution to the respective themes, and Panel B displays the words incorporating either the most positive or the most negative tone in each theme.

For the evolution and intensity, over time, of the six major identified themes, the first six rows of matrix V^T in our decomposition signify the prevalence, over time, of the six most significant textual themes. These are plotted in Figure 4. Combining the results and findings from the two aforementioned figures, i.e. the one depicting the key terms per theme with the other that exhibits the intensity of the Themes over time, can assist us in providing a detailed discussion of the six most important Themes derived from the FOMC Statements during our sample period.

Key terms for Theme 1 include *growth, inflat, risk, modern, action, energy, need, price, core* and *press* which highlight the Fed policy balancing between sustainable growth and price stability. Indeed, from Figure 4, we may observe that this theme remains strong for the period until the end of 2007, a period during which policymakers were concentrated in the confrontation of the persistently low inflation. Theme 1 fluctuates as the Fed adopts, initially, an aggressive path of successive rate hikes, but around 2007 policymakers begin to lower rates as the first signs of the economic slowdown emerge. Based on clustering results, *economy growth, price stable and inflat pres* play a major role in the determination of Theme 1. Overall, Theme 1 appears most closely tied to current and future economic conditions, remaining firm at times of low volatility in financial markets and as such, anticipating an environment of improving economic conditions.

Theme 2 is mostly associated with terms like *accommodate, price, policy, equal, underlie* and phrases such as *monetary policy, policy accommodate, economy* and *active*, which suggest that FOMC focus on the Fed Funds Rate as the main tool of conducting monetary policy. Based on Figure 4, we see that Theme 2 exhibits strength (mid-2003 to 2005) based on

Themes	Singular value	Eigenvalue	Variance explained (%)	Cumulative variance explained (%)		
<i>Panel A. Variance explained by themes</i>						
1	0.4310	0.1857	19.57	19.57		
2	0.3517	0.1237	13.03	32.60		
3	0.3179	0.1011	10.64	43.24		
4	0.2534	0.0642	6.76	50.00		
5	0.2289	0.0524	5.52	55.52		
6	0.2146	0.0460	4.85	60.37		
7	0.1873	0.0351	3.70	64.07		
8	0.1765	0.0311	3.28	67.35		
9	0.1637	0.0268	2.82	70.17		
10	0.1470	0.0216	2.28	72.45		
20	0.0952	0.0091	0.95	87.04		
50	0.0364	0.0013	0.14	97.98		
99	0.0000	0.0000	0.00	100.00		
Theme	No. of observations	Mean	SD	Skewness	Kurtosis	Autocorr.
<i>Panel B. Summary statistics for theme levels</i>						
1	99	0.00	0.10	0.22	-1.72	0.91****
2	99	0.00	0.10	-0.08	0.30	0.93****
3	99	0.00	0.10	-1.21	1.31	0.87****
4	99	0.00	0.10	-0.63	0.85	0.85****
5	99	0.00	0.10	-0.09	-0.42	0.88****
6	99	0.00	0.10	2.58	16.79	0.19*

Table III.
Estimation of FOMC
statements themes

Notes: Panel A summarizes the amount each theme contributes to the overall understanding of the text corpus based on the matrix of singular values (S). Panel B displays summary statistics for each of the first six themes as expressed by the V matrix, asterisks **** and * indicate statistical significance at the 1 and 10% level, respectively

the then prevailing economic sentiment which indicates a growing economy and thus revealing policymakers' view that using Fed Funds Rate to tighten policy was considered appropriate at that time. Theme 2 is negatively correlated with three-month treasury yields as its presence weakens during periods of economic expansion where short-term rates increase, while is also positively correlated with a widening term spread, thus envisaging contractionary policy coupled with tightening financial conditions.

Some of the key words for Theme 3 include *employ, inflat, polici, long, accommod, consist, pace, mandat, liquid, fund, financi* and *market* that point toward a policy inclination to focus particularly on the employment conditions which are considered crucial in terms of the monetary policy decision-making process. By further filtering the statements based on the clustering process, we locate phrases such as *labor market, maximum employment, asset purchases* and *promote maximum employment and price stability*, which also add to the thematic content stated above. In terms of time evolution, Theme 3 waves mostly to the upside until mid-2007, it then follows a negative trajectory from early 2008 until the end of 2009, rises again around the end of 2010 and remains consistently positive till our days. Based on the theme's correlation with financial and macro-variables, we are inclined to support that this theme portrays a stable economic environment (falling volatility in the markets) pointing to continuous recovery.

Indicator	Theme 1	Theme 2	Theme 3	Theme 4	Theme 5	Theme 6
<i>Panel A. Contemporaneous correlations with AR1 theme residuals</i>						
Financial market indicators						
Expected federal funds rate	0.00451	-0.00059	0.00548	-0.00100	-0.00475	0.00545***
Eurodollar 3m implied volatility	-0.00650	0.07618**	-0.04596*	0.00659	-0.03067	0.00285
CBOE VIX	0.01712	0.21881	-0.17496	-0.00051	-0.16319	-0.01512
3-month treasury yield	0.01595***	-0.02389***	0.01294***	0.01622***	0.01013*	-0.00029
2-year treasury yield	0.00255	0.00082	0.00693	0.00266	-0.00019	0.00327
5-year treasury yield	-0.00015	0.00771	0.00599	-0.00178	-0.00401	0.00066
10-year treasury yield	-0.00298	0.01105	0.00486	-0.00458	-0.00521	0.00004
Moody's seasoned Baa corporate bond yields	0.00136	0.01400	0.00249	0.00253	0.00033	-0.000241
Term spread	-0.01778**	0.03418***	-0.00801	-0.01880***	-0.01485**	0.00047
Credit spread	0.00307	0.00386	-0.00308	0.00748	0.00431	-0.00159
S&P 500	0.02269	-0.04249	0.11156***	-0.00994	0.04612	0.01531
NYMEX dollar index	-0.02550	0.03320	-0.01146	-0.01381	-0.02833	0.00197
US crude oil	0.13168	-0.09560	-0.00204	0.08853	0.02075	-0.02011
Macroeconomic indicators						
GDP growth	-0.10685	0.04400	-0.04378	-0.08884	-0.11192	0.05499*
GDP deflator	-0.00333	-0.01399	0.01345	-0.00621	0.02590	-0.00363
Core PCE MoM	0.00014	0.00287	-0.00216	0.00018	-0.00024	0.00078
Core PCE YoY	-0.00034	-0.00105	-0.00009	0.00255	-0.00012	0.00145
Core CPI MoM	0.00073	0.00196	0.00006	0.00015	0.00197	0.00005
Core CPI YoY	0.00111	-0.00137	0.00451	0.00606*	0.00220	0.00142
Industrial production	-0.01159	0.03018	0.01156	-0.00994	-0.02378	0.00122
Unemployment rate	-0.00187	-0.00231	-0.00573	-0.00169	0.00474	-0.00199
ISM manufacturing PMI composite index	0.02922	0.00352	-0.00003	-0.03639	0.02245	0.00117
ISM non-manufacturing PMI composite index	-0.01479	0.07134	0.01685	-0.04195	-0.02462	0.00523
Univ. of Michigan consumer confidence index	-0.13244*	0.07179	-0.02416	-0.10657*	-0.11341*	0.02225

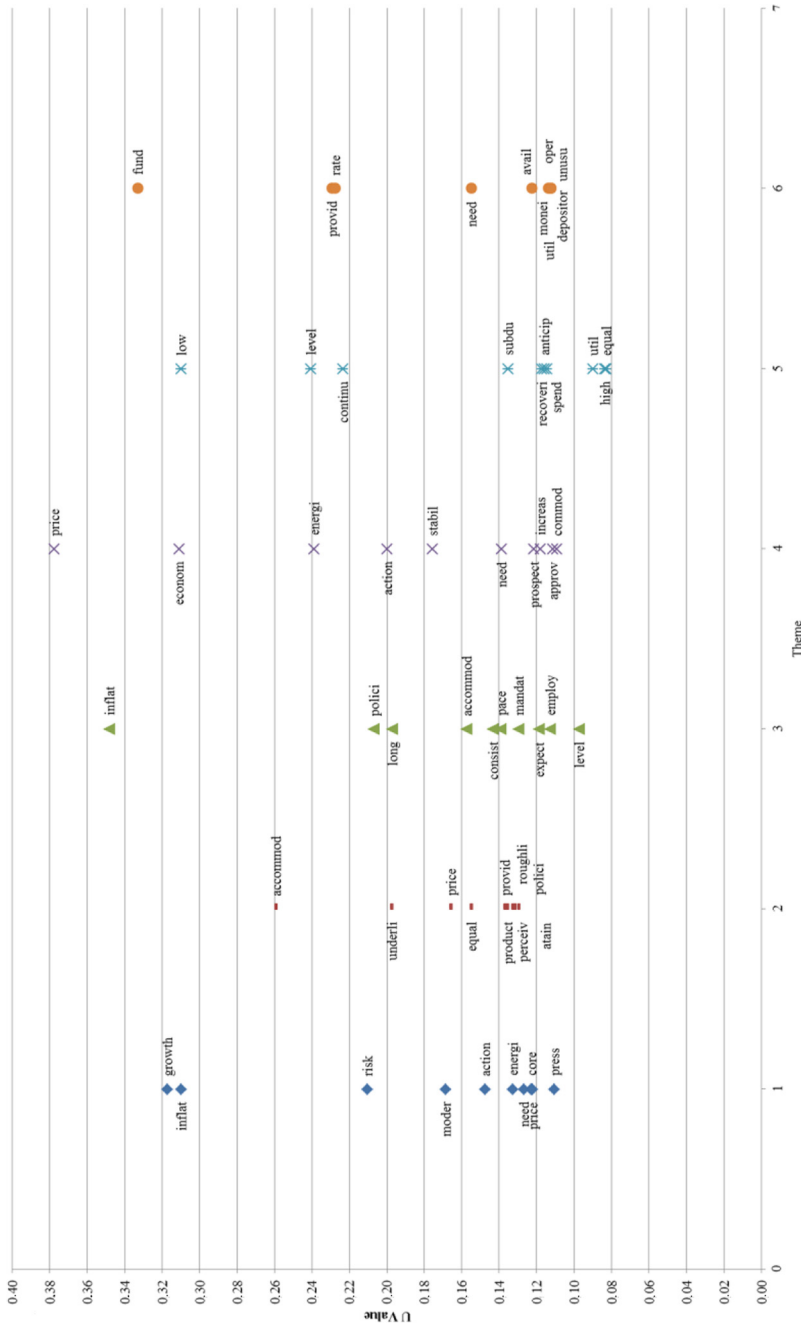
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Table IV.
Correlations of themes
with macroeconomic
and financial market
indicators

Table IV.

Indicator	Theme 1	Theme 2	Theme 3	Theme 4	Theme 5	Theme 6
<i>Panel B. Lead correlations with ARI theme residuals</i>						
Financial market indicators						
Expected federal funds rate	0.08096*	-0.08912*	-0.04966	-0.00467	-0.01395	0.03397*
Eurodollar 3m implied volatility	-0.14361*	0.04335	-0.01224	0.04473	0.12781*	0.01190
CBOE VIX	-0.62228***	0.43163	-0.38260**	0.04454	0.27128	-0.06102
3-month treasury yield	0.06903	-0.07750	-0.04320	-0.01922	-0.01886	0.03805**
2-year treasury yield	0.07920**	-0.07004	-0.04271	0.00173	-0.01011	0.03130*
5-year treasury yield	0.06876**	-0.04570	-0.03626	0.00277	0.00338	0.02289*
10-year treasury yield	0.05133**	-0.02540	-0.02709	0.00455	0.01100	0.01569
Moody's seasoned Baa corporate bond yields	-0.00372	0.00308	-0.03685**	0.00206	0.02620	0.00215
Term spread	-0.01975	0.05203	0.01569	0.02205	0.02970	-0.02270*
Credit spread	-0.05424***	0.02841	-0.00987	-0.00330	0.01570	-0.01375
S&P 500	0.07793	-0.19836	0.07369	-0.02915	-0.35062**	-0.10621
NYMEX dollar index	0.08428	0.01556	0.03085	-0.00989	0.02697	0.03910
US crude oil	-0.26317	-0.52408	-0.01304	0.34359	-0.17566	-0.16259
Macroeconomic indicators						
GDP growth	0.06442	0.07909	0.01470	0.03928	0.09759	-0.06407**
GDP deflator	0.01018	0.02526	-0.01165	0.02837**	-0.02050	-0.00022
Core PCE MoM	0.00055	-0.00300	0.00109	0.00124	0.00056	0.00083
Core PCE YoY	0.01912*	-0.02028*	-0.00349	0.00386	-0.00577	0.00689
Core CPI MoM	0.00059	-0.00286	0.00022	0.00174	-0.00191	0.00115
Core CPI YoY	0.00984	-0.02056	-0.00765	-0.00659	-0.01450	0.00331
Industrial production	0.00483	-0.03848*	0.00804	0.00155	0.00906	0.01249
Unemployment rate	-0.07078*	0.01863	0.03563	0.00955	0.04110	0.00374
ISM manufacturing PMI composite index	0.18543	-0.04294	0.12503	0.11450	-0.05508	0.05868
ISM non-manufacturing PMI composite index	0.18343**	-0.04151	0.09606	0.09868	-0.04403	0.04306
Univ. of Michigan consumer confidence index	0.28348**	0.10718	0.01937	0.01065	-0.11276	0.05415

Notes: The table reports correlation coefficients between first-order autoregressive theme residuals and intermeeting changes in macroeconomic and financial market indicators over the sample period. Panel A reports contemporaneous correlations to detect the relation between current economic conditions and themes expressed through the FOMC statements. Panel B reports the correlations of themes with the lead of the indicator variable, as a measure of the predictive content of the statements' forward guidance implications, asterisks ***, **, * and * indicate statistical significance at the 1, 2, 5 and 10% level, respectively

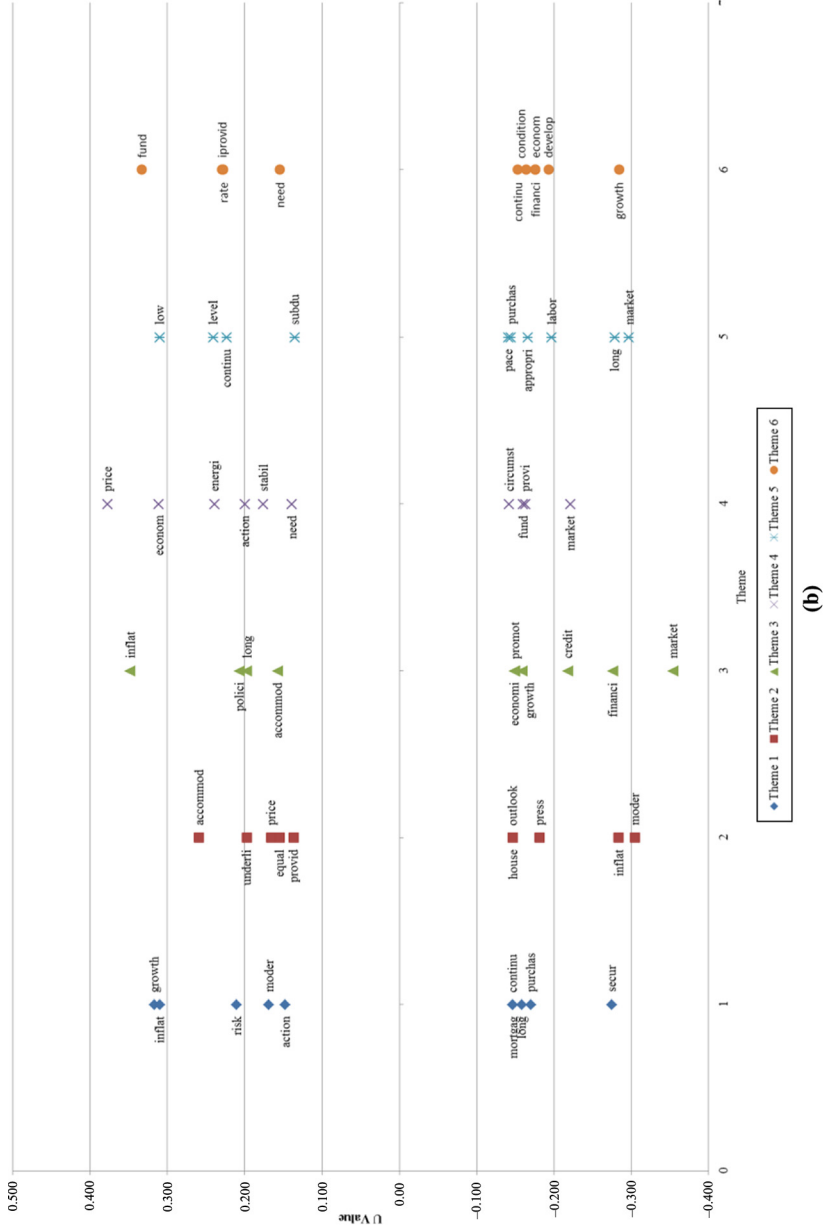


◆ Theme 1 - Theme 2 ▲ Theme 3 X Theme 4 X Theme 5 ● Theme 6

(a)

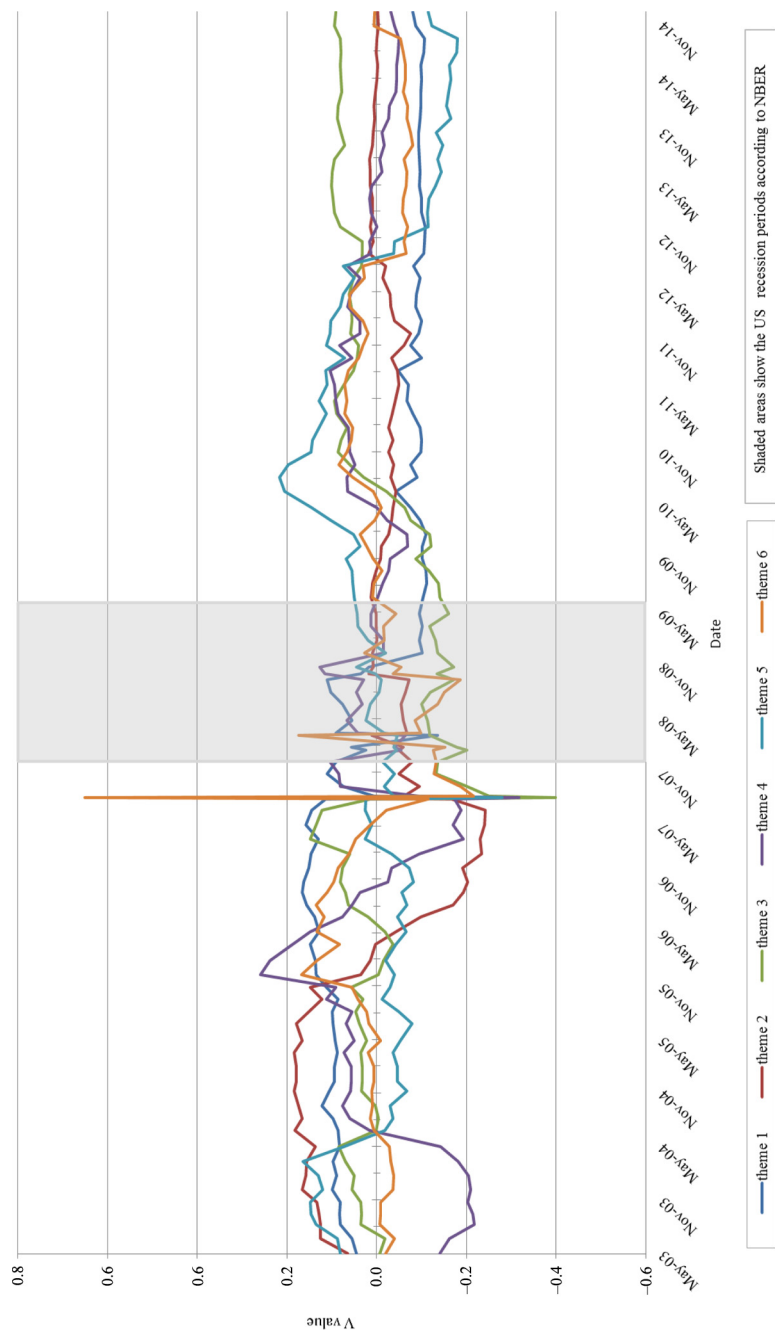
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Figure 3. Characteristic terms for Themes 1 through 6



Notes: The figure displays the ten most important terms, according to term contribution to themes (U matrix) for each of the first six themes. Panel A presents the most important terms by a sense of meaningful contribution to each theme, while Panel B shows the most characteristic terms per theme in a sense of weighting in a text meaning

Figure 3.



Notes: This figure graphs the time-series prevalence of Themes 1 to 6, based on the full sample of FOMC statements over the sample period

Figure 4.
Time-series of theme loadings

Theme 4 is mainly described from terms such as *price, econom, energi, stabil, commod, action* and phrases like *energi and commod, foster maximum use and price stabil and inflat pres*. All the above seem to highlight the policymakers' concerns about the continuously rising commodity and energy prices and their potential impact on economic growth. Theme 4 rises aggressively to "top up" at mid-2006 and then falls aggressively as well to "bottom out" at mid-2007; after that period, it seems to fluctuate around the zero level of interest, almost equally distributed between positive and negative values. According to the findings presented in Table IV, this theme generally seems to indicate tighter credit conditions, but it simultaneously points to rising inflation risks (both current and future).

Predominant terms for Theme 5 include words such as *low, level, continu, subdue, recoveri* and phrases such as *dual mandate, maximum employment and price stability*. Theme 5 is sustained at considerable positive levels in early 2003 before starting to retreat into slightly negative territory throughout the period of policy tightening from the Fed (2004-2006). It then rises gradually again, starting to show significant persistence particularly since the initiation of the Fed's quantitative easing programs and until late 2012. This scheme envisages Fed's commitment to maintain its accommodative policy bias to promote economic growth.

Finally, Theme 6 is mostly characterized from terms such as *fund, provid, rate, money, depositor, risk, monitor, financi, develop* which point toward excess policy concerns about particular situations and market events that give worrisome signals about the upcoming tight financial conditions and decelerating growth. This theme displays a wide wave pattern over time, overshooting or plummeting at very specific points in time; Theme 6 levels out around December 2005 (when hurricane Katrina inflicted serious damage to the US economy), skyrockets on August 2007 (evidence of a collapsing mortgage market and bankruptcies of construction companies and financial firms involved in the MBS market) and launches again "to the sky" on March 2008 (when some of the major Central Banks globally started intervening in the markets to prevent the collapse of the financial system). The theme's positive lead correlations with a declining term spread and collapsing economic conditions is excessively evident at times when extraordinary events or serious market developments – as the ones previously mentioned – pose significant risks to the economy.

It is worth stressing that one of the themes we identify in this study of the FOMC statements, Theme 6, is only pronounced at times of extraordinary events (hurricane Katrina at the end of 2005) or serious market developments that pose systemic risks to the economy (e.g. collapsing mortgage market in 2007), and is absent from the FOMC minutes' themes identified by Boukus and Rosenberg (2006), whose research motivated our work. Theme 6 is related to grave developments from extraordinary events that are specific to our sample period and the recent Financial Crisis of 2007-2009. It should be further noted that the five "Minutes themes" in Boukus and Rosenberg (2006) and the remaining five "Statements themes" we identify and discuss in this study are not directly comparable or "one-to-one", and this is not only due to the differences in the sample period of the two studies. The themes identified in the FOMC statements are very condensed and include multifaceted information of very high density, as policymakers try to improve communication more and more over time via an approximately single-paged statement they release to the markets, whereas minutes record all views and arguments in relation to each and every discussion item on the FOMC meeting agenda. This difference in the identified themes and their importance is partly highlighted by the differences in the explained cumulative corpus variance that is accomplished by the important statement themes (55.52-60.37 per cent by five or six themes in this study) and the important minutes themes (36.7 per cent in Boukus and Rosenberg, 2006), respectively. Given that FOMC statements are released right after the committee's

meetings and several days before the minutes become public information, it is only natural to ask whether the minutes still have incremental information, over and above the one contained in the immediately released statement. This is something we investigate further in the empirical section that follows.

5. The treasury market reaction to textual themes in FOMC statements

In this section, we examine the treasury market reaction to the FOMC statement releases, so as to test the economic significance of the statements' information content, as provided by the LSA method, and after controlling for a number of factors that might affect treasury yield variability. We are mostly interested in whether the treasury market responds similarly to the different themes identified by the analysis of the content of FOMC statements. This is crucial to establish whether policy signals, as perceived by market participants, are direct and uniform or heterogeneous and multi-faceted.

The analysis is conducted through time-series regressions that are nested in the following equation:

$$\begin{aligned} \Delta y_t^m = & \alpha_0 + \alpha_1 I_{FOMC_S} + \alpha_2 I_{FOMC_M} + \alpha_3 I_{QE} + \alpha_4 I_{ZIRP} + \sum_{l=1}^6 (\beta_l + \gamma I_{QE} \\ & + \delta_l I_{ZIRP}) \times THEME_t^l + \sum_k (\xi_k + \varphi_k I_{FOMC_S} + \theta_k I_{FOMC_M} + \psi_k I_{QE} \\ & + \omega_k I_{ZIRP}) \times CONTROL_t^k + \sum_{l=1}^6 \sum_n \zeta_{lk} (THEME_t^l \times CONTROL_t^n) + e_t \end{aligned} \quad (2)$$

The dependent variables, Δy_t^m , are the absolute daily changes in treasury yields of maturity m . As in Fleming and Piazzesi (2005) and Boukus and Rosenberg (2006), this dispersion-like measure of absolute yield changes will be used to investigate the effect of any new information contained in the identified themes.

Indicators I_{FOMC_S} , I_{FOMC_M} , I_{QE} and I_{ZIRP} are dummy variables; $I_{FOMC_S} = 1$ on the days the FOMC statements are released and zero otherwise, and likewise, $I_{FOMC_M} = 1$ on the days the FOMC minutes are released and zero otherwise, $I_{QE} = 1$ during the period of quantitative easing and zero on the rest of the period and finally, $I_{ZIRP} = 1$ over the period that the Fed target rate is set to the zero lower bound (i.e. 0.00-0.25 per cent) and zero otherwise.

A number of control variables are included in the regression specifications we estimate. Their direct effect is captured by the ξ coefficients in equation (2), while we also allow for the possibility that their slopes are statistically different on the days the FOMC statements or minutes are released (the φ 's or θ 's), during the Fed's quantitative easing regime (the ψ 's) or during the Z.I.R.P. (the ω 's). In our base-case model specifications, we use as control variables the three-month Eurodollar implied volatility, as a measure of monetary policy uncertainty (Reinhart and Sack, 2005; Boukus and Rosenberg, 2006), CBOE's VIX to proxy for financial markets' stress, the "term spread" as a proxy for the economic conditions and prospects over the near term and the "credit spread" to proxy for the expectations about the business cycle and future changes in the economic activity. All control variables are calculated as described in Section 3.2.

Our variables of interest, $THEME_t^l$, $l = \{1, \dots, 6\}$, are the innovations (absolute value of residuals from first-order autoregressive models) of the six most significant themes that are identified and discussed in the previous section [17]. We are interested in whether the new information in the FOMC statements affects the variability in the yields of the treasury

market differently, depending on which theme appears most important for policymakers at a particular point in time. To explore the possibility that the effect of new information in $THEME_i^j$ is differentiated across different time or policy periods, we also include interaction terms of our variables of interest with the control and the dummy variables.

Table V summarizes the estimation results for a number of specifications nested in equation (2). In Panel A, the dependent variable Δy_i^m is the absolute daily change in the three-month treasury yields ($m = 3$ months), while in Panel B, it is the absolute daily change in the 10-year treasury yields ($m = 120$ months)[18].

An immediate observation from Table V is that there is a statistically significant change of treasury yield volatility on the days the FOMC statements are released, and this holds for all treasury maturities (reported and unreported), with the effect being more pronounced at longer maturities (e.g. 10-year). This is not however the case, on average, on the days the FOMC minutes are released, suggesting that in general the subsequent minutes releases do not seem to have incremental information, over and above that of the FOMC statements. This is exactly in line with our previous findings in Table I. Regarding the other two indicator variables, both the unconventional policies of large-scale asset purchases (I_{QE}) and the “zero-rates” policy (I_{ZIRP}) are associated, as expected, with lower yield volatility, with the effect of the “zero-rates” policy appearing more significant in our sample period.

When added in the regression in Specification (3), the identified textual themes from the FOMC statements appear to collectively and significantly add to the explanatory power of the model. This conclusion is strongly supported by a typical Wald test (and a corresponding log-likelihood ratio test of the same spirit) that clearly rejects (at the 1 per cent level) the null hypothesis that all $THEME_i^j$ coefficients are simultaneously equal to zero. This holds in both panels, as well as in all other (unreported) dependent variables of different maturities. What is equally interesting however (and a significant advantage of the proposed textual analysis approach) is that not all textual themes appear to equally affect the variation in the treasury yield curve: Themes 3 and 4 are statistically significant in Panel A for the three-month yield volatility, while Themes 3-6 in Panel B for the 10-year one.

The fact that different segments of the treasury yield curve respond significantly to different textual themes from the FOMC statements is an indication that the messages conveyed to market participants are heterogeneous and multi-faceted. The LSA approach to content analysis, that is proposed and applied in this paper and which can detect, rank by overall significance and track the intensity over time of the different Themes that dominate the FOMC statements, is well-suited, by construction, for reporting this heterogeneous and multi-faceted effect that the Fed’s communication to market participants has.

In virtually all estimated specifications, the selected control variables (Eurodollar implied volatility, CBOE VIX, “credit spread” and “term spread”) are highly statistically significant, as expected. In Specifications (4)-(10), we allow the effect of the identified textual themes to be conditioned on the underlying financial markets’ and economic outlook, by interacting our $THEME_i^j$ variables with the I indicators and the other $CONTROL_i^n$ variables. Results in Panel B for the 10-year treasury yield are quite robust to this “conditioning via interactions”; however, this is not the case in Panel A for the three-month treasury yield. We observe in Panel B that all interactions terms involving (mainly) Themes 3 to 6 are statistically significant in virtually all of Specifications (4)-(10). To see this, note that in the last rows of each panel, we report F -statistics from standard Wald tests under the null hypothesis that the overall effect of a given theme variable is equal to zero[19]. Unambiguously, Themes 4 and 6 (and to a lesser extent Themes 3 and 5) have a significant effect on the 10-year treasury yield volatility.

Variable	(1)	(2)	(3)	(4)	(5)
<i>Panel A. 3-month treasury yields</i>					
Intercept	0.00063****	0.00063****	0.00063****	0.00063****	0.00063****
Statement release indicator ($I_{FOMC,S}$)	0.00018****	0.00037*	-0.00011	-0.00012	-0.00018
Minutes release indicator ($I_{FOMC,M}$)	0.00004	0.00004	0.00004	0.00004	0.00004
Quantitative easing indicator (I_{QE})	0.00000	-0.00010****	-0.00010****	-0.00010****	-0.00010****
Zero interest rate policy (I_{ZIRP})	-0.00045****	-0.00043****	-0.00042****	-0.00042****	-0.00042****
Eurodollar implied volatility		-0.01069****	-0.01065****	-0.01067****	-0.01067****
Eurodollar implied volatility $\times I_{FOMC,S}$		-0.00436	-0.00260	-0.00124	0.00184
CBOE VIX		0.00415****	0.00417****	0.00416****	0.00416****
CBOE VIX $\times I_{FOMC,S}$		0.00487****	0.00180	0.00203	0.00324*
Term spread		0.00413****	0.00400****	0.00404****	0.00405****
Term spread $\times I_{FOMC,S}$		0.00084	0.00557	0.00501	-0.00457
Credit spread		0.00824****	0.00785****	0.00796****	0.00798****
Credit spread $\times I_{FOMC,S}$		-0.02966**	-0.00811	-0.01565	-0.02358
Theme 1			0.00155	0.00190	0.03843****
Theme 2			-0.00041	-0.00025	-0.02021
Theme 3			-0.00703****	-0.00717****	-0.01583
Theme 4			0.01187****	0.01215****	-0.00601
Theme 5			-0.00318	-0.00325	0.00448
Theme 6			0.00189	0.00178	0.00682

(continued)

Notes: The table summarizes the estimation results for a number of specifications nested in the time-series regression of equation (2). The dependent variable is the absolute daily changes in the three-month treasury yield in one set of estimations (in panel A) and the absolute daily changes in the 10-year treasury yield (in panel B). The theme variables are the residuals from first-order autoregressive models of the most significant textual themes (Themes 1 to 6), identified by applying the LSA approach to the statements released by the FOMC. All indicators and control variables are as defined in Sections 3.2 and 5. Statistical significance is indicated by *, **, *** and **** which correspond to significance levels of 10, 5, 2 and 1%, respectively. Moreover, under each regression specification, the table also reports the *t*-statistic and *chi*-square statistic of standard Wald tests under the null hypothesis that the coefficients of indicated added variables (“variables-numbered”) are collectively equal to zero, and the *chi*-square statistic of standard log-likelihood ratio tests that restrict (under the null hypothesis) the coefficients of indicated added variables (“variables-numbered”) to zero. Finally, in specifications where the theme variables are interacted with indicators or other control variables, the last rows of each panel report *F*-statistics of Wald tests under the null hypothesis that the overall effect of a given theme variable is zero. For example, in Specification (10), the *F*-statistic for theme 1 tests the hypothesis $H_0: \beta_1 + \xi_1 Eurodollar + \xi_2 VIX + \xi_3 Term + \xi_4 Credit = 0$ against the alternative (where *Control* indicates the sample mean of any interacted *Control* variable).

Table V.
Treasury market reaction to FOMC statement release and effect on daily absolute yield changes



Table V.

Variable	(6)	(7)	(8)	(9)	(10)
<i>Panel A, 3-month treasury yields</i>					
Intercept	0.00063****	0.00063****	0.00063****	0.00063****	0.00063****
Statement release indicator (I_{FOMC_S})	-0.00035	-0.00025	-0.00011	0.00028	0.00012
Minutes release indicator (I_{FOMC_M})	0.00004	0.00004	0.00004	0.00004	0.00004
Quantitative easing indicator (I_{QE})	-0.00010****	-0.00010****	-0.00010****	-0.00010****	-0.00010****
Zero interest rate policy (I_{ZIRP})	-0.00043****	-0.00042****	-0.00043****	-0.00043****	-0.00043****
Eurodollar implied volatility	-0.01065****	-0.01067****	-0.01066****	-0.01063****	-0.01065****
Eurodollar implied volatility $\times I_{FOMC_S}$	0.00609	0.00018	-0.00030	-0.00313	-0.00134
CBOE VIX	0.00416****	0.00416****	0.00416****	0.00415****	0.00415****
CBOE VIX $\times I_{FOMC_S}$	0.00099	0.00231	0.00207	-0.00491	-0.00479
Term spread	0.00404****	0.00406****	0.00406****	0.00405****	0.00408****
Term spread $\times I_{FOMC_S}$	-0.00796	0.00260	0.00229	-0.03483	-0.03523
Credit spread	0.00800****	0.00799****	0.00803****	0.00806****	0.00813****
Credit spread $\times I_{FOMC_S}$	-0.01517	-0.01537	-0.01887	0.06033	0.05867*
Theme 1	0.02959****	0.02204****	0.04459****	0.03755	0.03694
Theme 2	-0.01030	-0.01488	-0.02753*	-0.02361	-0.02032
Theme 3	-0.01074	-0.01125****	0.01442	-0.00818	-0.00245
Theme 4	-0.01703****	0.01303****	0.00088	-0.01416	-0.01055
Theme 5	0.02451**	-0.00710	-0.00942	0.00786	0.00569
Theme 6	-0.00696	0.00467	0.00910	-0.00737	-0.00897

(continued)

Variable	(1)	(2)	(3)	(4)	(5)
Theme 1 \times I_{QE}				0.00336	0.00296
Theme 2 \times I_{QE}				0.00541	0.01556
Theme 3 \times I_{QE}				0.00485	-0.00072
Theme 4 \times I_{QE}				-0.00991	-0.01469
Theme 5 \times I_{QE}				-0.00003	0.00015
Theme 6 \times I_{QE}				0.00253	0.00482
Eurodollar implied volatility \times Theme 1					-0.35908****
Eurodollar implied volatility \times Theme 2					0.13568
Eurodollar implied volatility \times Theme 3					0.09560
Eurodollar implied volatility \times Theme 4					0.22199*
Eurodollar implied volatility \times Theme 5					-0.08544
Eurodollar implied volatility \times Theme 6					-0.06570
CBOE VIX \times Theme 1					
CBOE VIX \times Theme 2					
CBOE VIX \times Theme 3					
CBOE VIX \times Theme 4					
CBOE VIX \times Theme 5					
CBOE VIX \times Theme 6					
Term spread \times Theme 1					
Term spread \times Theme 2					
Term spread \times Theme 3					
Term spread \times Theme 4					
Term spread \times Theme 5					
Term spread \times Theme 6					
Credit spread \times Theme 1					
Credit spread \times Theme 2					
Credit spread \times Theme 3					
Credit spread \times Theme 4					
Credit spread \times Theme 5					
Credit spread \times Theme 6					
Adjusted R -squared	0.09810	0.24069	0.24949	0.24825	0.25057
F -value	80.103****	77.842****	54.724****	41.026****	33.421****
Log likelihood (unRestr.)	17,103.58	17,357.99	17,377.97	17,378.59	17,386.12
F -probability	0.00000	0.00000	0.00000	0.00000	0.00000
Number of observations	2,910	2,910	2,910	2,910	2,910

(continued)



Table V.

Variable	(6)	(7)	(8)	(9)	(10)
Theme 1 × I _{QE}	-0.01015	0.01162	0.00443	-0.00318	
Theme 2 × I _{QE}	0.01256	-0.00249	0.01017	0.02287	
Theme 3 × I _{QE}	-0.00709	0.00071	0.00473	-0.01148	
Theme 4 × I _{QE}	-0.00827	-0.01239	-0.01465	0.00546	
Theme 5 × I _{QE}	0.00497	-0.00148	-0.00025	-0.00113	
Theme 6 × I _{QE}	0.00737	0.00636	0.00361	-0.00180	
Eurodollar implied volatility × Theme 1				-0.48631	-0.43419
Eurodollar implied volatility × Theme 2				-0.01754	-0.07142
Eurodollar implied volatility × Theme 3				0.17684	0.16327
Eurodollar implied volatility × Theme 4				0.15237	0.07593
Eurodollar implied volatility × Theme 5				-0.00021	0.05256
Eurodollar implied volatility × Theme 6				0.24220	0.24488
CBOE VIX × Theme 1	-0.12792****			0.07418	0.06515
CBOE VIX × Theme 2	0.05247			0.29450	0.24785
CBOE VIX × Theme 3	0.03087			0.11271	0.13316
CBOE VIX × Theme 4	0.15218****			0.19723****	0.19490****
CBOE VIX × Theme 5	-0.14821****			-0.23991****	-0.22481****
CBOE VIX × Theme 6	0.03558			0.00506	0.00734
Term spread × Theme 1		-0.99672****		1.30174	1.20223
Term spread × Theme 2		0.67097*		-0.42035	-0.28814
Term spread × Theme 3		0.28321		-0.20765	-0.18271
Term spread × Theme 4		-0.01330		0.39039	0.37312
Term spread × Theme 5		0.17809		-0.04412	0.01744
Term spread × Theme 6		-0.21592		0.38581	0.35566
Credit spread × Theme 1			-1.40480****	-1.22017	-1.24506
Credit spread × Theme 2			0.88338*	-0.99266	-0.59269
Credit spread × Theme 3			0.26537	-0.95459	-1.41902
Credit spread × Theme 4			0.61493	-1.57699	-1.36863
Credit spread × Theme 5			0.19113	1.56911*	1.24852
Credit spread × Theme 6			-0.30850	-0.88225	-0.80163
Adjusted R-squared	0.25795	0.25116	0.25210	0.25995	0.26114
F-value	34.708****	33.523****	33.685****	22.288****	25.479****
Log likelihood (unRestr.)	17,400.52	17,387.26	17,389.08	17,413.56	17,412.85
F-probability	0.00000	0.00000	0.00000	0.00000	0.00000
Number of observations	2,910	2,910	2,910	2,910	2,910

(continued)

Variable	(1)	(2)	(3)	(4)	(5)
		variables 06-13	Theme variables	variables 20-25	variables 26-31
Wald test (F -statistic)		69.190****	6.662****	0.204	2.490**
Wald test (χ^2 -square)		553.522****	39.972****	1.226	14.942**
Log-likelihood ratio test		508.813****	39.959****	1.237	15.064***
<i>Wald test (F-statistic)</i>					
Overall effect, Theme 1				0.049	0.040
Overall effect, Theme 2				0.040	0.112
Overall effect, Theme 3				0.065	0.449
Overall effect, Theme 4				0.032	0.021
Overall effect, Theme 5				0.210	0.294
Overall effect, Theme 6				0.712	0.822
<i>Panel B, 10-year treasury yields</i>					
Intercept	0.00085****	0.00029****	0.00029****	0.00029****	0.00029****
Statement release indicator (I_{FOMC_S})	0.00032****	-0.00049****	-0.00041***	-0.00052****	-0.00103****
Minutes release indicator (I_{FOMC_M})	0.00005	0.00006	0.00006	0.00006	0.00006
Quantitative easing indicator (I_{QE})	-0.00006**	-0.00002	-0.00002	-0.00002	-0.00002
Zero interest rate policy (I_{ZIRP})	0.00004	-0.00016****	-0.00016****	-0.00016****	-0.00016****
Eurodollar implied volatility		0.00044	0.00043	0.00046	0.00045
Eurodollar implied volatility $\times I_{FOMC_S}$		-0.00070	-0.00295	-0.00042	0.00600*
CBOE VIX		0.00208****	0.00208****	0.00209****	0.00208****
CBOE VIX $\times I_{FOMC_S}$		-0.00015	0.00058	0.00131	0.00301****
Term spread		0.00782****	0.00782****	0.00778****	0.00780****
Term spread $\times I_{FOMC_S}$		-0.00019	-0.00010	0.00270	0.00090
Credit spread		0.00124	0.00123	0.00113	0.00119
Credit spread $\times I_{FOMC_S}$		0.03357****	0.03585****	0.02172****	0.01167
Theme 1			-0.00259	-0.00254	0.01284*
Theme 2			0.00199	0.00374	0.00611
Theme 3			0.00583****	0.00442**	-0.00918
Theme 4			0.00093	0.00062	0.00888
Theme 5			-0.00298*	-0.00097	0.00995
Theme 6			-0.00226**	-0.00285****	-0.00258

(continued)

Table V.

Table V.

Variable	(6) variables 26-31	(7) variables 26-31	(8) variables 26-31	(9) variables 20-49	(10) variables 20-43
Wald test (<i>F</i> -statistic)	7.288***	2.870***	3.474***	2.362***	2.899***
Wald test (<i>chi</i> -square)	43.731***	17.219***	20.845***	70.855***	69.565***
Log-likelihood ratio test	43.869***	17.353***	20.994***	71.190***	69.765***
<i>Wald test (F-statistic)</i>					
Overall effect, Theme 1	0.055	0.297	0.226	0.051	0.152
Overall effect, Theme 2	0.227	0.019	0.050	0.401	0.011
Overall effect, Theme 3	1.375	0.255	0.059	0.459	0.035
Overall effect, Theme 4	0.125	0.001	0.036	0.510	2.547
Overall effect, Theme 5	0.004	0.451	0.368	0.002	0.011
Overall effect, Theme 6	1.840	1.573	0.768	0.017	1.448
<i>Panel B, 10-year treasury yields</i>					
Intercept	0.0029***	0.0029***	0.0029***	0.0029***	0.0029***
Statement release indicator (I_{FOMC_S})	-0.0073***	-0.0084***	-0.0086***	-0.00182***	-0.00074*
Minutes release indicator (I_{FOMC_M})	0.0006	0.0006	0.0006	0.0006	0.0006
Quantitative easing indicator (I_{QE})	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002
Zero interest rate policy (I_{ZIRP})	-0.0016***	-0.0016***	-0.0016***	-0.0016***	-0.0016***
Eurodollar implied volatility	0.0047	0.0045	0.0046	0.0046	0.0044
Eurodollar implied volatility $\times I_{FOMC_S}$	-0.0035	0.0093	0.0023	-0.00302	-0.01356***
CBOE VIX	0.00208***	0.00208***	0.00208***	0.00208***	0.00208***
CBOE VIX $\times I_{FOMC_S}$	0.00437***	0.00155	0.00157	0.00668***	0.00140
Term spread	0.00778***	0.00782***	0.00781***	0.00779***	0.00783***
Term spread $\times I_{FOMC_S}$	-0.00143	0.01501**	-0.00071	-0.00747	-0.01501
Credit spread	0.00118	0.00128	0.00123	0.00119	0.00130
Credit spread $\times I_{FOMC_S}$	0.00734	0.02275**	0.03562***	0.04868*	0.08612***
Theme 1	0.01475**	0.01520***	0.02238***	0.03014*	0.01948
Theme 2	-0.00983	-0.00331	-0.01088	0.01181	0.00123
Theme 3	-0.01571***	0.00058	-0.02153***	-0.01646	-0.03593***
Theme 4	0.00389	0.00627***	0.00307	0.02866**	0.02797***
Theme 5	0.00853	-0.00343	0.01088	0.03060***	0.01880*
Theme 6	0.00433	-0.00338	0.00671	0.00525	0.00573

(continued)

Variable	(1)	(2)	(3)	(4)	(5)
Theme 1 × I _{QE}				-0.01316	-0.02051
Theme 2 × I _{QE}				-0.02951 *	-0.03748**
Theme 3 × I _{QE}				0.01965****	0.00654
Theme 4 × I _{QE}				-0.02560****	-0.02675****
Theme 5 × I _{QE}				-0.01264****	-0.00865*
Theme 6 × I _{QE}				0.01398****	0.01979****
Eurodollar implied volatility × Theme 1					-0.12080****
Eurodollar implied volatility × Theme 2					-0.05660
Eurodollar implied volatility × Theme 3					0.15481**
Eurodollar implied volatility × Theme 4					-0.07533
Eurodollar implied volatility × Theme 5					-0.12787
Eurodollar implied volatility × Theme 6					-0.03641
CBOE VIX × Theme 1					
CBOE VIX × Theme 2					
CBOE VIX × Theme 3					
CBOE VIX × Theme 4					
CBOE VIX × Theme 5					
CBOE VIX × Theme 6					
Term spread × Theme 1					
Term spread × Theme 2					
Term spread × Theme 3					
Term spread × Theme 4					
Term spread × Theme 5					
Term spread × Theme 6					
Credit spread × Theme 1					
Credit spread × Theme 2					
Credit spread × Theme 3					
Credit spread × Theme 4					
Credit spread × Theme 5					
Credit spread × Theme 6					

(continued)

Table V.

Variable	(6)	(7)	(8)	(9)	(10)
Theme 1 × I _{QE}	-0.01653	-0.01784	-0.02550*	-0.00816	0.18814
Theme 2 × I _{QE}	-0.01804	-0.04439***	-0.02448	-0.04591**	-0.00126
Theme 3 × I _{QE}	0.01422**	0.01318*	-0.00394	0.00885	-0.25316
Theme 4 × I _{QE}	-0.02755***	-0.02490***	-0.01695**	-0.02505***	-0.40608***
Theme 5 × I _{QE}	-0.01285***	-0.01261***	-0.00535	-0.00811	0.37295**
Theme 6 × I _{QE}	0.01685***	0.01871****	0.01805***	0.01441****	0.23317**
Eurodollar implied volatility × Theme 1				0.04757	0.21714****
Eurodollar implied volatility × Theme 2				-0.30901	0.15536
Eurodollar implied volatility × Theme 3				-0.29834	0.14582****
Eurodollar implied volatility × Theme 4				-0.39539**	-0.07572**
Eurodollar implied volatility × Theme 5				0.03638	-0.03295
Eurodollar implied volatility × Theme 6				0.27490*	-0.10062****
CBOE VIX × Theme 1	-0.05060**			0.17922**	-0.12926
CBOE VIX × Theme 2	0.03882			0.02529	0.22864
CBOE VIX × Theme 3	0.08719****			0.09220	-0.52786*
CBOE VIX × Theme 4	0.00008			-0.05596	0.62077****
CBOE VIX × Theme 5	-0.03842			0.02106	-0.21769
CBOE VIX × Theme 6	-0.03777**			-0.13371****	0.59295****
Term spread × Theme 1		-0.75770****		-0.43091	-2.91178****
Term spread × Theme 2		0.32510		0.36529	-1.28536
Term spread × Theme 3		0.32867*		0.07792	1.47235****
Term spread × Theme 4		-0.39298****		0.36678	0.79596
Term spread × Theme 5		0.09022		0.10463	-1.61732****
Term spread × Theme 6		-0.14722		0.26879	-0.79291
Credit spread × Theme 1			-0.62855**	-2.29549***	
Credit spread × Theme 2			0.38327	0.35484	
Credit spread × Theme 3			1.12438****	0.86254	
Credit spread × Theme 4			-0.05298	0.72924	
Credit spread × Theme 5			-0.51441*	-1.45161****	
Credit spread × Theme 6			-0.49962***	-0.49694	

(continued)

Variable	(1)	(2)	(3)	(4)	(5)
Adjusted <i>R</i> -squared	0.01583	0.32844	0.33111	0.34280	0.35411
<i>F</i> -value	12.695****	119.560****	81.000****	64.223****	54.161****
Log likelihood (unRestr.)	18,241.72	18,801.84	18,810.65	18,839.33	18,867.60
<i>F</i> -probability	0.00000	0.00000	0.00000	0.00000	0.00000
Number of observations	2,910	2,910	2,910	2,910	2,910
Wald test (<i>F</i> -statistic)		variables 06-13	Theme variables	variables 20-25	variables 26-31
Wald test (<i>chi</i> -square)		170.038****	2.927****	9.571****	9.415****
Log-likelihood ratio test		1,360.302****	17,561****	57,423****	56,490****
<i>Wald test (F-statistic)</i>		1,120.233****	17,623****	57,352****	56,545****
Overall effect, Theme 1				1.200	1.824
Overall effect, Theme 2				2.704	5.120**
Overall effect, Theme 3				18,984****	4,543**
Overall effect, Theme 4				10,736****	11.132****
Overall effect, Theme 5				9,922****	6,789****
Overall effect, Theme 6				12,946****	16,842****

(continued)

Table V.

Table V.

Variable	(6)	(7)	(8)	(9)	(10)
Adjusted R-squared	0.35598	0.34940	0.35802	0.36212	0.35913
F-value	54.598****	53.074****	55.077****	35.404****	39.812****
Log likelihood (unRestr.)	18,871.83	18,867.03	18,876.45	18,894.89	18,885.03
F-probability	0.00000	0.00000	0.00000	0.00000	0.00000
Number of observations	2,910	2,910	2,910	2,910	2,910
Wald test (F-statistic)	variables 26-31	variables 26-31	variables 26-31	variables 20-49	variables 20-43
Wald test (<i>chi</i> -square)	10.840****	5.874****	12.399****	5.684****	6.265****
Log-likelihood ratio test	65.043****	35.246****	74.395****	170.533****	150.367****
	65.011****	35.409****	74.241****	168.481****	148.755****
<i>Wald test (F-statistic)</i>					
Overall effect, Theme 1	0.659	1.504	1.740	0.211	0.110
Overall effect, Theme 2	1.634	6.614***	2.476	5.152**	0.370
Overall effect, Theme 3	6.591***	12.888****	0.415	0.313	2.083
Overall effect, Theme 4	9.607****	12.010****	3.804**	4.489**	4.913**
Overall effect, Theme 5	7.081****	10.185****	3.130*	1.130	4.717**
Overall effect, Theme 6	17.701****	15.009****	13.711****	9.453****	9.247****

The same themes (4 and 6, followed by 3 and 5) appear robust in the (unreported) results that pertain to the yield volatility of medium to long-term treasury instruments (two-year, five-year, etc.). This is not the case however for shorter maturities; in Panel A, for the three-month yield, we observe that the overall effect of the $THEME_i^j$ variables is insignificant, as it appears subsumed by the control and indicator variables.

Overall, the results of our regression analysis indicate that the FOMC statements include new information content that has not been previously discounted in the treasury market, information that appears not to be included or subsumed by the extensive minutes that the FOMC releases weeks after the single-paged statements are made. The proposed LSA method produces independent (by construction) and objective (i.e. unaffected by reader's biases) textual themes that can explain the variation in the treasury yield curve (its long-term end predominantly) in a statistically significant way, even after controlling for a number of established factors that are known to affect the treasury market. In line with the findings of Boukus and Rosenberg (2006) and unlike the suggestions by Reinhart and Sack (2005), we find that the treasury market reaction is not homogenous or uniform and appears to depend on specific themes included in the FOMC statements, as these are evolving in intensity over time. In conclusion, our findings imply that the new policy information that is revealed by the FOMC statements exerts significant effects on the treasury market, thus suggesting that the policymakers are moving toward greater transparency and continuously enhanced "forward guidance" in communicating monetary policy effectively, and this serves the Fed's goals for "controlling" the moves of the treasury curve (by primarily flattening the long-term part of the curve) and provide the necessary impetus to the economy[20].

To better understand the treasury market reaction to the identified textual themes and to further examine whether the informational content of the FOMC statements has been affected by the recent financial crisis, we conduct additional sub-period analysis[21]. We divide our sample into sub-periods using two natural criteria: First, as our sample period embraces the financial crises of 2007-2009, it is natural to divide our sample into a "pre-crisis" period, a "financial crisis" period and a "post-crisis" period. We use the timeline from the "Financial Crisis Calendar" of the St. Louis Fed to define the three crisis-related sub-periods[22]. Second, over our sample period of 2003-2014, the Fed has had three different chairpersons, so it is intuitive to examine the intensity of the FOMC textual themes and their effect on the treasury yields for each chairperson's term separately[23].

We re-estimate the specifications nested in equation (2) for each of the three crises-related and the two chairperson-related sub-periods, and summarize the results in Figure 5. Again, for brevity, we make the results of all unreported treasury instruments and specifications available upon request. The results collectively seem to indicate that the informational content of the textual themes that dominate the FOMC statements has become more and more significant since the 2007-2009 financial crises. The effect of the statements' themes on the treasury market appears limited in the "pre-crisis" period (which largely overlaps with our "Greenspan" sub-period); however, this is entirely reversed during the recent financial crisis and the period that followed it. Virtually all identified themes appear statistically significant after 2006, and much in line with the results of Table V, the effect appears more pronounced in the yield volatility of the longer-term treasury instruments. In conclusion, the findings from the sub-periods appear in line with the declared intention of the Fed policymakers to continuously enhance "forward guidance" and transparency since the financial crisis.

Alan Greenspan [regressions (1) - (2)]					Pre-crisis period [regressions (5) - (6)]						
06-May-2003 to 31-Jan-2006					06-May-2003 to 26-Feb-2007						
→ 685 obs.					→ 953 obs.						
Ben Bernanke, Janet Yellen [regressions (3) - (4)]					Financial Crisis [regressions (7) - (8)]						
01-Feb-2006 to 31-Jan-2014					27-Feb-2007 to 13-Apr-2011						
→ 2205 obs.					→ 1037 obs.						
03-Feb-2014 to 17-Dec-2014					Post-crisis period [regressions (9) - (10)]						
→ 220 obs.					→ 920 obs.						
Panel A, 3-month Treasury Yields											
Variable	(1)	(2)	(3)	(4)	Variable	(5)	(6)	(7)	(8)	(9)	(10)
Interest	0.00102 ****	0.00102 ****	0.00064 ****	0.00064 ****	Interest	0.00030 ****	0.00030 ****	0.00114 ****	0.00114 ****	-0.00048 ****	-0.00048 ****
Statement release indicator (I _{FOMC,S})	0.00006	0.00009	0.00033	-0.00073 **	Statement release indicator (I _{FOMC,S})	0.00064	0.00029	0.00024	-0.00123 **	0.00042	0.00048
Minutes release indicator (I _{FOMC,M})	0.00006	0.00006	0.00004	0.00004	Minutes release indicator (I _{FOMC,M})	0.00006	0.00006	0.00004	0.00004	0.00004	0.00004
Eurodollar implied volatility	-0.00407 *	-0.00407 *	-0.01135 ****	-0.01135 ****	Eurodollar implied volatility	0.00368 ****	0.00368 ****	-0.02045 ****	-0.02045 ****	-0.01611 ****	-0.01611 ****
Eurodollar implied volatility ⁴ _{FOMC,S}	0.00561	0.00813	-0.00678	-0.00601	Eurodollar implied volatility ⁴ _{FOMC,S}	-0.00126	0.00480	-0.00378	0.01407	0.00151	0.00128
CBOE VIX	0.00171 **	0.00171 **	0.00584 ****	0.00584 ****	CBOE VIX	0.00060	0.00060	0.00708 **	0.00708 **	-0.00018	-0.00018
CBOE VIX ⁴ _{FOMC,S}	0.00312	-0.00856	0.00515 ****	0.00144	CBOE VIX ⁴ _{FOMC,S}	0.00384	-0.00379	0.00577 **	0.00113	0.00007	-0.00038
Term spread	-0.00383 **	-0.00383 **	-0.00355 ****	-0.00355 ****	Term spread	-0.00157	-0.00157	0.00532	0.00532	0.00602 ****	0.00602 ****
Term spread ⁴ _{FOMC,S}	0.01300	0.00912	-0.00261	0.01903 **	Term spread ⁴ _{FOMC,S}	0.01396	0.01031	-0.00354	0.00275	-0.00324	-0.00412
Credit spread	-0.02949 ****	-0.02949 ****	-0.00769 **	-0.00769 **	Credit spread	-0.01820 ****	-0.01820 ****	-0.00256	-0.00256	0.02595 **	0.02595 **
Credit spread ⁴ _{FOMC,S}	-0.05634	-0.00554	-0.01990	0.01405	Credit spread ⁴ _{FOMC,S}	-0.05719 **	-0.03391	-0.03350	-0.03074	-0.01889	-0.01746
Theme 1					Theme 1						
Theme 2					Theme 2						
Theme 3					Theme 3						
Theme 4					Theme 4						
Theme 5					Theme 5						
Theme 6					Theme 6						
Adjusted R-squared	0.08786	0.13239	0.18920	0.20546	Adjusted R-squared	0.02303	0.05991	0.21717	0.23248	0.08559	0.08127
F-value	7.589 ****	7.574 ****	52.895 ****	36.945 ****	F-value	4.150 ****	4.792 ****	28.741 ****	20.612 ****	9.602 ****	6.081 ****
Log likelihood (unRestr.)	4,591.82	4,612.38	12,953.09	12,978.65	Log likelihood (unRestr.)	6,469.19	6,486.16	5,711.86	5,725.14	6,837.40	6,838.27
F-probability	0.00000	0.00000	0.00000	0.00000	F-probability	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
No. of observations	685	685	2,225	2,225	No. of observations	953	953	1,037	1,037	920	920
Theme variables				Theme variables				Theme variables			
Wald test: F-statistic	6.887 ****		8.556 ****		Wald test: F-statistic	5.657 ****		4.410 ****		0.286	
Wald test: Chi-square	41.322 ****		51.334 ****		Wald test: Chi-square	33.940 ****		26.459 ****		1.719	
Log-Likelihood Ratio test	41.114 ****		51.137 ****		Log-Likelihood Ratio test	33.945 ****		26.557 ****		1.749	
Panel B, 10-year Treasury Yields											
Variable	(1)	(2)	(3)	(4)	Variable	(5)	(6)	(7)	(8)	(9)	(10)
Interest	0.00061 ****	0.00061 ****	0.00031 ****	0.00031 ****	Interest	0.00021 ****	0.00021 ****	0.00047 ****	0.00047 ****	-0.00027 ****	-0.00027 ****
Statement release indicator (I _{FOMC,S})	-0.00071	0.00025	-0.00054 ****	-0.00064 ****	Statement release indicator (I _{FOMC,S})	0.00088	0.00099	-0.00076 ****	-0.00104 ****	-0.00709 ****	-0.00441 ****
Minutes release indicator (I _{FOMC,M})	0.00015 *	0.00015 *	0.00002	0.00002	Minutes release indicator (I _{FOMC,M})	0.00011	0.00011 *	-0.00003	-0.00003	0.00008	0.00008
Eurodollar implied volatility	-0.01032 ****	-0.01032 ****	0.00107 ****	0.00107 **	Eurodollar implied volatility	-0.00530 ****	-0.00530 ****	-0.00032	-0.00032	0.00012	0.00012
Eurodollar implied volatility ⁴ _{FOMC,S}	0.00922	-0.00546	-0.00232	-0.00502	Eurodollar implied volatility ⁴ _{FOMC,S}	-0.00828	-0.01152	0.00184	-0.00005	-0.03327 ****	-0.02245 ****
CBOE VIX	0.00160	0.00160	0.00252 ****	0.00252 ****	CBOE VIX	0.00090	0.00090	0.00191 ****	0.00191 ****	0.00293 ****	0.00293 ****
CBOE VIX ⁴ _{FOMC,S}	0.01051 *	0.01176	-0.00018	0.00053	CBOE VIX ⁴ _{FOMC,S}	0.00891 **	0.00538	-0.00159	-0.00090	0.01131 ****	0.00065 ****
Term spread	0.00738 ****	0.00738 ****	0.00383 ****	0.00383 ****	Term spread	0.00706	0.00706	0.00599	0.00509	0.01268 ****	0.01268 ****
Term spread ⁴ _{FOMC,S}	0.01349	0.0292	-0.00533	0.00138	Term spread ⁴ _{FOMC,S}	0.01334 *	0.02781	-0.01444	-0.00602	0.11488 ****	0.04532 ****
Credit spread	0.03957 ****	0.03957 ****	-0.00587 ****	-0.00587 ****	Credit spread	0.04021 ****	0.04021 ****	0.00146	0.00146	0.00694	0.00694
Credit spread ⁴ _{FOMC,S}	-0.09075 **	-0.09593 *	0.04407 ****	0.04890 ****	Credit spread ⁴ _{FOMC,S}	-0.07625 **	-0.06728 **	0.05293 ****	0.05718 ****	0.21568 ****	0.15108 ****
Theme 1					Theme 1						
Theme 2					Theme 2						
Theme 3					Theme 3						
Theme 4					Theme 4						
Theme 5					Theme 5						
Theme 6					Theme 6						
Adjusted R-squared	0.21282	0.21547	0.35350	0.35801	Adjusted R-squared	0.25749	0.26043	0.26720	0.27746	0.31461	0.34337
F-value	19.492 ****	12.741 ****	122.608 ****	78.515 ****	F-value	34.014 ****	21.952 ****	38.775 ****	25.864 ****	43.185 ****	31.035 ****
Log likelihood (unRestr.)	4,446.82	4,451.04	14,357.09	14,367.89	Log likelihood (unRestr.)	6,271.28	6,276.22	6,534.86	6,545.22	6,110.43	6,133.19
F-probability	0.00000	0.00000	0.00000	0.00000	F-probability	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
No. of observations	685	685	2,225	2,225	No. of observations	953	953	1,037	1,037	920	920
Theme variables				Theme variables				Theme variables			
Wald test: F-statistic	1.380		3.591 ****		Wald test: F-statistic	1.624		3.429 ****		7.634 ****	
Wald test: Chi-square	8.279		21.544 ****		Wald test: Chi-square	9.746		20.574 ****		45.803 ****	
Log-Likelihood Ratio test	8.437		21.605 ****		Log-Likelihood Ratio test	9.872		20.709 ****		45.521 ****	

Notes: The Table re-estimates a number of regression specifications that are reported on Table 6 but this time for specific sub-periods of our entire sample more specifically, we divide our sample period (a) according to each Chairperson of the Fed, and (b) in periods before, during and after the financial crisis. The “precrisis” period, the “financial crisis” period and the “post-crisis” period are defined by following the “Financial Crisis Calendar” of the St. Louis Fed (available at <https://www.stlouisfed.org/financial-crisis>). Due to the lack of sufficient observations for the J. Yellen’s term, we conduct analysis for the “Greenspan” sub-period and the combined “Bernanke-Yellen” sub-period. The exact dates of each sub-period appear below. Again, the dependent variable is the absolute daily changes in the 3-month Treasury yield (in Panel A) and the absolute daily changes in the 10-year Treasury yield (in Panel B), and all other variables and diagnostic tests are as in Table 6. Statistical significance is indicated by *, **, *** and **** which correspond to significance levels of 10, 5, 2 and 1% respectively

Figure 5.
Treasury market reaction to FOMC statement release; sub-period analysis

6. Conclusions

Quantifying monetary policy inclination, as the latter is expressed in the FOMC statements, and understanding the way markets react to any new information in the statements is a challenging task, with apparent and important implications for monetary policy and financial stability. This is particularly important in the aftermath of the great financial crisis, as the Fed further intensified its communication tactics in its effort to improve policy communication and reduce the market uncertainty for the economy, financial conditions and future path of policy.

This study follows a fairly recent stream of research that combines specific textual and statistical techniques so as to conduct content analysis and measure the effects of certain policy communication on asset prices in financial markets. We contribute to this literature by examining the statements released by the FOMC through a statistical, language processing technique that allows identification of multiple, recurring and economically significant textual themes which are by-construction free of subjectivity and bias. Using all the FOMC statements released over the period from May 2003 to December 2014, we use the LSA technique to identify the policy themes incorporated in the statements, with six themes cumulatively explaining more than 60 per cent of the total policy variation. Furthermore, we attempt an interpretation of the most important identified themes via their key terms and phrases and examine the extracted themes' correlation with current and future economic conditions. We finally establish that the identified themes have a statistically significant effect on the yield dynamics (across the longer-term treasury maturities predominantly), even after controlling for a number of established factors that are known to affect the treasury market.

Our study adds to the establishment of LSA in terms of performing content analysis research in monetary economics, as this language processing technique enables one to produce a set of concepts (themes) that characterize the history of the FOMC statements and also record the prevalence of each theme over time. Moreover, our analysis suggests that the FOMC statements are highly comprehensive as a means of monetary policy communication, and that they include meaningful content for the treasury markets, which are found to react significantly and in different ways toward the several qualitative themes of information that the LSA technique can uncover.

Our findings that extent the work of Boukus and Rosenberg (2006) suggest that reaction in yields is rather nuanced and multi-faceted across the different thematic schemes or across specific periods. Based on our findings, it seems that increased communication and the multifaceted messaging from the Fed about their policy decisions, stance and objectives is meaningful to the markets in either understanding what the central bank is currently doing or on what can be expected in the future. Shaping market expectations through communication does appear a viable strategy the Fed. Finally, the increasing importance of the themes communicated from the FOMC, particularly after the financial crisis, shows that the increased "Fed speak" and "forward guidance" incorporated in the statements confirms the Central Bank's commitment to transparency going forward, with that being a crucial tool for maintaining credibility, reducing uncertainty and handling policy challenges that arise around the world.

Future work might focus on either the formation of a holistic view of the impact of the Fed's monetary policy communication across all markets (stocks, exchange rates and capital flows) or on the differentiation of monetary policy frameworks (including communication tactics) across the major Central Banks, by exploring their potential spillover effects on the global economy.

Notes

1. Table AI in the Appendix provides a quick overview of the types of monetary policy communication and the extent of transparency adopted from major Central Banks around the world. To conserve space, all the appendices of the manuscript are only made available online, at: <http://ssrn.com/abstract=2830825>
2. The minutes of the FOMC meetings are released three weeks after the statements are made public. Actually, the release of the detailed minutes three weeks after the meeting and the statement is a fairly recent FOMC decision to expedite their release (Federal Open Market Committee, 2004).
3. Also used in search engine procedures and information retrieval applications (Deerwester *et al.*, 1990; Berry *et al.*, 1995)
4. See Landauer *et al.* (1998) for an excellent review of the technique.
5. See Chappell and McGregor (2004) who not only present mixed evidence about the importance of the FOMC decision-making mechanics but also suggest that the detailed voting results within the Committee are of limited importance. Similarly, Thornton and Wheelock (2014) suggest that member dissents do not necessarily indicate different views on the economic conditions or prospects and as such, do not add further to the market's understanding for the future path of monetary policy.
6. See <http://provalisresearch.com/> for details regarding the software.
7. For interested readers, we make the complete, modified dictionary used in this study available upon request.
8. The Porter (1980) stemming algorithm is inbuilt in WordStat®. More details regarding the algorithm, as well as a great stemming vocabulary can be found at <http://tartarus.org/martin/PorterStemmer/>.
9. SVD is a generalized form of principal component analysis that can be used on arbitrary rectangular matrices. See Wall *et al.* (2003) for a review.
10. Such steps include, among others, the reporting of individual members' votes in the FOMC statement (2002), the accelerated release of the FOMC minutes (2005), the SEP report released once per quarter (2007) and the Fed Chair press conferences once per quarter (2011).
11. Fama and French (1989), Chan-Lau and Ivaschenko (2002) and Gilchrist *et al.* (2009) testify that treasury rates and credit spread data can be used to indicate the current and future state of the economy.
12. Estrella and Hardouvelis (1991) suggest that the term spread should be considered a significant predictor of the probability of recession in the near-term future.
13. Reinhart and Sack (2005) and Boukus and Rosenberg (2006) measure the effects of the FOMC minutes release on several financial market instruments, suggesting the three-month Eurodollar rates as an indicator of monetary policy uncertainty.
14. This is in line with policymakers' efforts to influence the long-term rates, as discussed in Bernanke *et al.* (2004).
15. This partition of the sample into three sub-intervals according to the respective presidential terms is merely made for illustration purposes, and any conclusions reached should be interpreted with caution, as the sub-periods are of unequal length.
16. It is usual in P.C.A. or similar factor-decomposition applications to only retain the factors/themes that pass certain "rules of thumb". One such "rule of thumb" is to only retain the factors that individually account for 5%, and above, of the variation; another (known as the Guttman–Kaiser criterion) is to retain any factors with eigenvalue greater than the average of all eigenvalues.
17. Fleming and Piazzesi (2005) suggest the absolute value of the yield change as the appropriate measure reflecting the new information released and that is relevant to the market.

18. To avoid cluttering the reader with tables, we only report estimation results for ten specifications nested in equation (2) and two dependent variables (the three-month and 10-year instruments) and make all other instruments (e.g. six-month, two-year, etc.) and specification results available upon request.
19. By the *overall effect* of any textual theme in these specifications, we mean the direct effect, as summarized by the $THEME_i^j$ coefficient estimate in the regression, and the effect that is conditioned on any interacted $CONTROL_i^n$ or indicator variable. Thus, for example, in Specification (10) the F -statistic for Theme 1 tests the hypothesis $H_0: \beta_1 + \zeta_1 \overline{Eurodollar} + \zeta_2 \overline{VIX} + \zeta_3 \overline{Term} + \zeta_4 \overline{Credit} = 0$ against the alternative (where $\overline{Control}$ indicates the sample mean of any interacted $Control$ variable). Rejection of the null hypothesis signifies a significant overall effect of the textual theme on the treasury yield volatility.
20. See Figure A2 in the Appendix that provides a graphical illustration of the treasury yield curve reaction to Fed policies (conventional and unconventional); see also the discussion in [Bernanke \(2006\)](#).
21. The authors are grateful to an anonymous reviewer for suggesting this additional analysis.
22. The “Financial Crisis Calendar” is available at: www.stlouisfed.org/financial-crisis, and according to it our “pre-crisis” period runs from May 6, 2003 to February 26, 2007, the “financial crisis” period from February 27, 2007 to April 13, 2011, and the “post-crisis” period from April 14, 2011 to the last day of our sample (December 17, 2014).
23. Note that due to the lack of sufficient observations for the J. Yellen’s term (that only started on February 3, 2014), we conduct analysis for the “Greenspan” sub-period (May 6, 2003 to January 31, 2006) and the combined “Bernanke-Yellen” sub-period (February 1, 2006 to December 17, 2014).

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