Federal Reserve Communications Sentiment's Impact on Target Rate Discovery

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ABSTRACT

We estimate the personal communication risk profile of the U.S. Federal Reserve (Fed) Chair by measuring a new dataset of the sentiment revealed by their public statements during their tenure. We analyze the impact of such Fed communications' sentiment risk on the uncertainty of the monetary policy, and the market price discovery process of interest rates, in the aftermath of the Federal Open Market Committee (FOMC) meetings. After controlling for the evolving state of the economy surrounding the meetings, we find that there is a significant statistical and economic difference in the communications' sentiment that is heterogeneous across Chairs, depending on their personal traits. The sentiment in the Chairs' communications plays a role in moderating the potential surprises in the Fed announcements, and it can be effectively used as a tool for controlling and measuring monetary policy shocks.

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I. Introduction

In recent years, the interaction between monetary policymakers and other economic agents through the application of a continuous stream of communications has been increasing. Bernanke and Reinhart (2004), in a policy predictive article, analyze the endogenous causal relationship between (i) the input that central banks receive from the macroeconomy and the financial markets' state, and (ii) the response of the central banks' actions towards monetary policy; they propose to use a communication process that they define as "optimal" under a constrained action environment (low interest rates). In financial markets, it is difficult to find a stronger relationship than the one that exists between assets and monetary policy announcements (see Bernanke and Kuttner, 2005); in practical terms, changes to the risk-free interest rates will affect the cost of opportunity of all asset valuation worksheets.[1] In a similar way, diverse studies have analyzed this causal effect between assets and monetary policy, and have developed theoretical and practical models for conducting this policy (Bernanke et al., 1999; Bernanke and Gertler, 2000; Clarida et al., 2000; Bernanke and Gertler, 2001; Myatt and Wallace, 2014).

In parallel, the measurement of sentiment in the media and in communications and its effect on financial markets has received growing attention since Tetlock (2007), Tetlock et al. (2008), and Loughran and McDonald (2011) introduced this type of analysis into the literature. In the central banks' textual analysis literature, Hansen et al.'s (2018) leading study reveals that, by analyzing the FOMC transcripts, the discipline channel has a stronger effect than the conformity channel when balancing the amount of transparency occurring during the deliberation process; similarly, Shapiro and Wilson (2019) used textual analysis techniques on FOMC transcripts, to estimate Federal Reserve inflation objectives.

Under such developments in monetary policy communications and sentiment analysis, two

[1] Blanchard (2018) reviews the "natural rate" hypothesis coined by Friedman (1968), that establishes how the monetary policy conducted by central banks might be irrelevant in the structural changes in the unemployment and inflation relationship under certain conditions (unemployment level at the natural rate). Nevertheless, short-term effects are of great importance for policymakers, as political systems measure their effectiveness in periods much shorter than 50 years.

questions draw our attention: (i) are the sentiments of the statements by the Chairs of the Federal Reserve different in tone, such that the institutional text processing mechanism does not erase the personal flavor? and, (ii) if there exists such a difference in the personal tone of the communication, can a single personal communication have a significant influence on the monetary policy process? In the present study, we try to respond to these questions by measuring the sentiment of Federal Reserve Chair communications, using a machine learning technique – Naïve Bayes classifier.

Our results show that there exists a significant difference in the sentiment of the Fed Chair statements, sufficient to create a *textual sentiment profile* of every Chair: Ben Bernanke's statements being more neutral (less sentimental), and Paul Volcker's statements being more emotional (more sentimental). We also find that the sentiment in statements and speeches[2] of the Chair of the Federal Reserve has a predictive power over the outcome of the monetary policy to be implemented during the FOMC meetings, in regard to the variable that measures the *surprise effect* of the policies over the interest rate.

Our main contribution to the central bank management communications' literature is that, by providing a *textual sentiment profile* of the Chair – that in the case of the Federal Reserve plays a leading role in the implementation of monetary policy – the institution can have an improved measure of efficiency in the implementation of an intended shock: a more neutral (less sentimental) statement will produce the biggest surprise in the market when a decision over monetary policy is made and finally transmitted. In addition, we provide a new measure of monetary policy uncertainty based on arbitrage relationships between the interest rate futures and the Federal Reserve Target Rate (FFTR).

The impact of communications' sentiment over the discovery process of the interest rate by market agents is analyzed, jointly with the equilibrium process that the communications

[2] In recent years, numerous studies that use recent advances in statistics and machine learning have tried to disentangle and extract information from large informal datasets: Thelwall et al. (2010) developed a new methodology defined as "SentiStrength" to predict the sentiment of informal messages in social networks, then they used this prediction to identify the opinion of the retail consumers; Young and Soroka (2012) quantify the sentiment of news in a political communications' context.

convey to the markets. Our dataset of sentiment is unique, as it starts from January, 1971 when Arthur Burns was Chair of the Fed. In the first identification method, we construct a uncertainty measure based on an arbitrage-free model, to estimate the effects of the sentiment of the speeches/statements in the reduction/increase of monetary policy uncertainty. Monetary policy uncertainty has been explored by Mueller et al. (2017), Husted et al. (2020), and Bauer et al. (2021), among others, following the leading papers on economic uncertainty approaches by Jurado et al. (2015) (macroeconomic variables based), Baker et al. (2016) (news/media based), and Ederington and Lee (1996) (options volatility based). In particular, the Husted et al. (2020) and Bauer et al. (2021) monetary policy uncertainty measures are related to ours. Husted et al. (2020) uncertainty measure is provided on a monthly, quarterly, and per FOMC meeting base. We need to measure the monetary policy uncertainty on a daily basis before the FOMC, to track changes during Fed Chair speeches/statements. In addition, news coverage before the 1990s is limited (and our dataset starts from 1971). Similarly, Bauer et al. (2021) provide a market measure of monetary policy uncertainty using the variance measure over a dataset of interest rate futures and options; in our case, we use an entropy measure from information theory that is more robust to multimodal distributions (that is relevant in the case of bi-modal monetary policy decisions – *Hawkish* vs. *Dovish*). In addition, the interest rate option prices dataset before the 1990s is limited, while interest rates future prices were available.

In the second identification method, we establish a relationship between the interest rate discovery process and the sentiment of the communication, by researching the effects of the Fed Chair last statement sentiment, and its correlation with interest rates after the FOMC meeting decision on the FFTR. To assess the effects of communications after the FOMC meeting decision, we construct a surprise variable that is measured after the FOMC announcements, following Kuttner (2001).[3] Bordo and Istrefi (2018) analyzed the personal characteristics of

[3]Textual analysis of the FOMC meetings' documents has been applied to post-meeting statements, searching for their effects on asset prices and monetary policy discovery (Lucca and Trebbi, 2009). Other FOMC documents over which textual analysis has been conducted include: FOMC meeting transcripts (Peek et al., 2016; Hansen et al., 2018; Schultefrankenfeld, 2019; Shapiro and Wilson, 2019) and FOMC economic projections (Arai, 2016).

the FOMC board members effects on FFTR estimation via a Taylor rule parametric model enhanced with the textual sentiment of the FOMC board members developed by Istrefi (2019).[4] Our contribution to this previous literature stands between behavioral economics and market equilibrium, as we found that personal characteristics influence the process of the Fed Chair communication, and then has an impact on the monetary policy transmission of information to the markets. We find four main results: (i) the communications' sentiment across Chairs of the Federal Reserve differs significantly, controlling for the economic conditions: the business cycle, inflation, industrial production, unemployment rate, stock and credit markets indices, (ii) Chair sentiment is rooted in personal characteristics: age, academic background, gender, (iii) Chair sentiment reduces uncertainty, and (iv) the existence of sentiment has an inverse effect on the interest rate surprise variable: the surprise of the interest rate after the FFTR change announcement, and during the market discovery process of its real value, is reduced by the existence of a positive/negative sentiment in the communications analyzed.

Our work differs from that of Bordo and Istrefi (2018) as: (i) we focus only on the individual Fed Chair contribution to the FFTR change decision (Bordo and Istrefi, 2018 considered a specification where the Fed Chair yields an 80% weight inside the board decision on the FFTR change), (ii) our two main identification methods are: one parametric but arbitrage-free based on market beliefs, and the other one non-parametric/non-dependent on the specification, (iii) we incorporate and analyze the second mandate of the Federal Reserve on maximum employment in the FFTR change function decision, and (iv) we yield an equilibrium result – in an asset pricing style: the Fed Chair statement neutral sentiment tone explains about 7%–8% of the FFTR surprise, controlling for macroeconomic variables and financial market variables of the state of the economy. Every additional 10% of neutral sentiment in the Fed Chair statement

For the specific case of FOMC meetings' minutes, Apel et al. (2019) analyzed the *Hawkish/Dovish* monetary policy stance of the FOMC members, and their disagreement. Apel et al.'s (2019) analysis is based on a dictionary constructed in Apel and Grimaldi (2012), where bigrams of words are used to characterize qualitative *Hawkish/Dovish* information from the Swedish Central Bank minutes.

[4]Istrefi (2019) provides a initial risk profile of the Fed Chair by tagging their *Hawkish/Dovish* monetary policy stance

contributes towards a 10% jump surprise.[5] Nevertheless, this linear impact in the surprise has been reduced from a window of observation of 2 weeks in the 1970s, to a couple of days in the 1990s–2000s, and to just a few hours in the 2010s (see for example Nakamura and Steinsson, 2018; Cram and Grotteria, 2020; Gorodnichenko et al., 2021): this is due to the advances of the market in processing the information faster. Still, the non-linear effects of the Fed Chair statement tone on the FFTR discovery process remain valid across the full sample. Our work differs from Harmon (2018), as we focus on the equilibrium/interest rates/asset pricing results and monetary policy implications, instead of the institutional implications of the management side. Our descriptive results and informational channel results on Fed Chair communications can be used jointly with Cieslak et al.'s (2019) results on the asset prices around the FOMC meeting, to further understand the role of the Fed Chair in the monetary policy communication process to the economy.

To identify the relationships between the Fed Chair statements' sentiment and the monetary policy decisions of the FFTR, we use two identification methods: (i) we construct a daily uncertainty measure based on the arbitrage relationships implicit between the interest rates futures market (Eurodollar) and the FFTR (see gray area in Figure 1), and then we measure the evolution of this uncertainty measure before and after a Fed Chair statement release, considering the sentiment tone of the speech/statement; (ii) we analyze the relationship of the last Fed Chair statement (before the FOMC meeting) tone and a surprise variable (J) that accounts for the unexpected change (surprise) by the market, defined in Section IV (see second analysis line in Figure 1).

[Place Figure 1 about here]

By mid 1980s the Federal Reserve started to introduce reforms in the monetary policy implementation process.[6] In line with these reforms, Taylor (1993) proposed a reduced form

[5]In the Online Appendix we provide these additional interest rate pricing results.

[6]In Figure A1 of the Online Appendix we notice the inconsistency in the monetary policy implementation

equation for the estimation of the response of interest rates to changes in the macroeconomic variables:

$$i_t = \pi_t + r_t^* + a_\pi (\pi_t - \pi_t^*) + a_y (y_t - \bar{y}_t), \quad (1)$$

where i_t is the short-term target nominal interest rate, π_t is the rate of inflation (PCE), π_t^* is the desired rate of inflation, y_t is the log real output (GDP), and $\bar{y}_t$ is the expected output. Since then, monetary policy has been more stable and predictable. Due to this new set of measres implemented by the late 1980s and early 1990s, we consider robustness checks on the datasets by splitting the results before and after the introduction of the FOMC statement release (1994).

The surprise variable constructed to disentangle the reaction of interest rates to the communications' sentiment uses the volatility of the interest rate market after the FOMC meeting decision release.[7] We analyze the impact of the Fed announcements (FOMC, Chair statements/press releases) by measuring the difference between the FFTR and the short-term/medium-term interest rate: every time the FFTR is adjusted during the FOMC meeting days or during other announcement days, there is an immediate adjustment of the short-term interest rate to eliminate the arbitrage possibility (Ahn and Melvin, 2007; Jiang et al., 2012); this immediate adjustment is observed in other maturities of the spot interest rate term structure and in the short-term interest rate futures contracts (Piazzesi and Swanson, 2008). This surprise variable measures the ratio of the difference between the closing price of the short-term interest rate of the week previous to the FFTR announcement, and the FFTR announced, and the absolute change in the FFTR; this ratio proxies the volatility generated by the structural changes to

by the Federal Reserve Officials during the turbulent times before the 1990s: between November 21, 1980 and January 16, 1981, the FFTR was eased and tightened in the space of these two months by at least as much as 400 basis points.

[7]Lucca and Moench (2015), Nakamura and Steinsson (2018), and Caldara and Herbst (2019) use a higher-frequency identification event study around the 30-minutes post-FOMC statement announcement to avoid spurious factors in the analysis. In our case, we consider a lag of 1 week – interest rates on the FOMC announcement and previous week average 1-month Eurodollar, as we are interested in identifying the "arbitrage surprise" on the general decision of the FOMC over the FFTR, and not high-frequency events that occur during the day of the announcement.

monetary policy. Our particular interest in studying the volatility of the structural shock over the interest rates is rooted in the importance of volatility risk for the markets.[8]

Our results are aligned with the Federal Reserve system of communications' hypotheses, where the communications that are produced by the Chair play a compelling role, and this role is not unusual in other governance structures.

The paper is organized as follows: Section II describes the datasets and the textual sentiment analysis methodologies used. Section III develops the new measure of uncertainty based in arbitrage-free relationships. Section IV constructs the variable that will proxy the causal relationship between the Fed Chair announcements and FOMC meeting decisions. Section V presents the results and Section VI concludes.

II. Data and Textual Analysis

A. Data Description

Two types of Federal Reserve documents are used to estimate the sentiment contained in communications issued by the Fed: (i) FOMC meeting statements and (ii) Federal Reserve Chair statements and press releases. The FOMC statements are included to have an institutional, objective reference point on which to leverage to infer the *personality*-driven contents of other Fed Chair's communications: while FOMC statements are the result of the Committee's deliberations and discussions, where every statement is carefully reviewed, discussed, and approved by all members of the FOMC board, the Fed Chairs' statements (may) display a more personal tone and therefore we use them to reveal the sentiment and personality of each Chairperson against the background of the formal FOMC statements. The data covering the personal Fed Chairs' statements span the period January 1, 1971 through December 31, 2015. The Fed Chairs' communication sentiment database is therefore constructed with reference to

[8]Bansal et al. (2014) find that increases in macroeconomic volatility produce an increase in the discount rate and a decrease in consumption; Bekaert et al.'s (2013) results show that easing monetary policy decreases the VIX, and its two components: uncertainty (stock market volatility) and risk aversion.

all speeches (released to the press) delivered by the Chairs Arthur Burns, William Miller, Paul Volcker, Allan Greenspan, Ben Bernanke, and Janet Yellen. The data on the formal FOMC statements in instead span the period from February 1, 1994, when they were first made available to the public, through December 31, 2015, even though the FFTR decisions are available since January 1971, of course.

Table I presents some descriptive statistics for the FOMC and Federal Reserve Chair statements. Panel A shows the statistics concerning the FOMC statements, that are classified in two groups: meetings (in the physical presence, that comprise about 93% of the sample), and telephone conferences (the remaining 7% of the sample). Phone conferences have been held during emergency situations, such as when crisis events erupted, and were typically shorter in terms of word count. Panel B shows descriptive statistics for the Federal Reserve Chair statements. The Fed Chairs' statements are much more diverse. We apply two types of classification: (i) per *type of document*, and (ii) per Chair. Sorting by the *type of document* allows us to explore the sentiment tones in different circumstances: it is different to offer a statement before the Congress –the House of Representatives, the Senate, or a Joint Committee, where the Chair is under oath– vs. speaking before the general public when delivering some prepared remarks at an event. The classification on a per-Chair basis matches our investigation goals, as we have discussed in the Introduction. Table I shows the existence of considerable heterogeneity in the average length and frequency of the communications by each Chairperson. For instance, in terms of average number of words, the range is between 2,442 average per document for Janet Yellen to 3,590 average per document for Paul Volcker; in the case of the average number of days in between communications, the spread goes between 10 days for William Miller and 21 days for Janet Yellen, which already emphasizes the existence of distinctly personal communication styles.

[Place Table I about here]

In our analysis use the 1-month Eurodollar interest rates, as proposed by Cochrane and Piazzesi (2002), to study the effects of the communications by the Fed's Chairpersons on interest rates and their volatility. In detail, we collect data for the sample January 01, 1971 – December 15, 2015. The FFTR is extracted from Bloomberg with reference to the period January 01, 1971 – December 15, 2008. From December 16, 2008 through December 31, 2015 the FFTR has changed from being announced as a pointwise rate to be communicated in the form of an interval defined by two rates, an upper and a lower target rate; for concreteness, after February 2008, we average the interval bounds and use the resulting mean as a proxy for the point FFTR. This assumption is unlikely to materially affect our results, as changes in the FFTR under the band system are conducted as parallel shifts: historically, the basis points increases of the upper and lower bands have always been equal. In the Online Appendix we present descriptive statistics on the interest rates' environment for our sample period, that allows us to establish an initial relationship between the set of FFTR decisions and the interest rate environment.

We use three sets of control variables in an attempt to obtain unbiased estimates of the sentiment expressed through the Fed Chairs' statements via their impact on interest rates and on proxies of rate volatility: (i) macroeconomic state variables, (ii) financial market state variables, and (iii) the personal characteristics of the Chairpersons.

As for the macroeconomic state variables, according to the Taylor rule in Equation (1), we include the inflation rate represented by the arithmetic first difference of the Personal Consumption Expenditure (PCE) inflation and the output growth rate represented by the arithmetic first difference of the Industrial Production Index. (in tables and plots we denote the arithmetic first difference by the symbol Δ to simplify the notation). We also include a few additional macroeconomic variables: the rate of growth in the money supply (the change in the log of M1) and the unemployment rate; these two variables of course reflect the Fed's dual mandate of price stability and of maximum employment. All macroeconomic variables are collected from ALFRED at the Federal Reserve Bank of St. Louis, considering *vintage* data to match the date of the announcement with their historical release. The use of vintage data is critical to our strategy, since it allows us to capture the effects of any statements on the day they are delivered and to provide unbiased estimates of the *impact of communication-related events*.

The financial market state variables are bound to reflect market expectations on the future state of the economy. We include stock market (the Standard & Poor's 500 lagged quarter returns since FOMC meetings are held every month and a half, and the financial variables reacts to expectations faster than macroeconomic indicators), and credit market (the spread between the yields on Baa-rated corporate bonds and that on 10-year Treasury notes) variables. The data are collected from FRED at the St. Louis Fed for our 1971– 2015 sample.

We consider an additional set of macroeconomic control variables, available at a higher-frequency but for a shorter period given that this dataset time-span is limited, April 27, 2000 – December 31, 2015: these are market surprises from macroeconomic news announcements, as in Faust et al. (2007). In practice, surprises are computed as the difference between the Thomson Reuters EIKON's macroeconomic survey average expected announcement and the final macroeconomic release (available in ALFRED). This set of macroeconomic news surprises concerns personal consumer expenditures (PCE) inflation, gross domestic output (GDP), consumer sentiment (CS), the unemployment rate (UR), initial job claims (IJC), non-farm payroll employment (NFP), retail sales (RS), the international trade balance deficit (TD), and housing starts (HS).

The final set of controls is related to the individual, personal traits of the Chairpersons under examination: their age (at the moment in which a public statement was issued), gender, and academic background (number of years in formal academic education).[9]

[9]Source: `https://www.federalreservehistory.org`.

B. Methodology for Inferring Sentiment

In behavioral economics, the first concern with any sentiment-driven research design is with finding a proper definition of a *sentiment.* In a social science perspective, "sentiment" may receive numerous definitions and the process of finding the correct one exposes a researcher to considerable lack of robustness of the ensuing empirical results. Because we focus on interpersonal comparisons of Fed Chairpersons' inferred sentiment, in this paper we draw our operative definition of sentiment from previous studies that have empirically estimated sentiment from managers' statements/communications. In particular, Jiang et al. (2019) is a recent paper that measures the sentiment of firm managers by calculating the textual tone of the 10Q and the 10K reports they submit, and the personal tone from the managers' conference calls. Their sentiment index is then simply built by adding up the differences between the total number of positive minus the total number of negative words, defined according to Loughran and McDonald (2011)'s sentiment dictionary.[10]

Our method for estimating sentiment follows a machine learning approach, a mixed approach between the "Bag of Words" (BoW) approach typical of earlier literature, and the *proxy function method*.[11] Following Li (2010), we use a Naïve Bayes classifier applied to a BoW feature set, trained with two widely used datasets for sentiment measurement: a sentiment database (including positive/negative tone), and a subjectivity database (neutral/not-neutral tone). As a robustness check, to make sure that our design based on an innovative machine learning research design is not the main driver of our empirical findings, we also include the Harvard IV General Inquirer dictionary (Tetlock et al., 2008) sentiment and Loughran and McDonald

[10]Loughran and McDonald's (2011) dictionary is a the result of filtering the positive/negative words from the Harvard IV General Inquirer dictionary, a general sentiment dictionary first used in financial applications by Tetlock et al. (2008). Tetlock et al. (2008) analyzes the sentiment of news media and its effects on stock returns. In the wake of Tetlock et al. (2008)'s groundbreaking research, Engelberg et al. (2012), Gurun and Butler (2012), and Garcia (2013), among others, have used the Harvard IV General Inquirer dictionary to assess the sentiment tone in a text. In contrast, Fang and Peress (2009), Engelberg and Parsons (2011), and Solomon (2012) avoid the daunting task of measuring sentiment through a word by word analysis, and use instead proxies that capture the sentiment in a text.

[11]Jurafsky and Martin (2019) is a primer to applications of machine learning to sentiment analysis.

(2011)'s dictionary.[12] Of course, to support the robustness of our empirical results, we expect that all these sentiment measures will lead towards homogeneous empirical findings.

C. Other Neutral Sentiment Proxies Based on the Harvard IV (Tetlock et al., 2008) and Loughran and McDonald (2011)'s Dictionary

The measure of neutral sentiment selected for the baseline empirical analysis in this paper is based on a supervised machine learning method, a Naïve Bayes classifier. Although results obtained from this measure have been used before in finance (Li, 2010) and extensively in other areas of applied sentiment analysis, we also consider simpler, more traditional measures, with the objective of testing the robustness of our findings. The two proxy measures of neutral sentiment tone that we use are the percentage of neutral words in a statement, where neutrality is established counting the proportuion of neutral words (not negative, and not positive) using the Harvard IV dictionary as in Tetlock et al. (2008), and using the Loughran and McDonald (2011)'s dictionary (see the Online Appendix for a full definition).

D. Analytical vs. Emotional Communications

An important debate in the behavioral social sciences concerns the *rational* contribution of *sentiment* to the economy. Angeletos and La'O (2013) develop a rigorous theoretical treatment and incorporate *"sentiment"* into a rational expectations model. Because our study is not committed to link the Fed Chairpersons' communications to departures from a rational expectations framework, we also incorporate additional measures of sentiment that may be considered *near-rational* or, as Angeletos and La'O (2013) define them, "extrinsic shocks". This second type of "sentiment" is defined as "analytical sentiment" as opposed to the "emotional sentiment" we have defined in Section II.B. Analytical sentiment is supposed to capture a dif-

[12] In an Online Appendix, we provide robustness checks based on textual sentiment measures of Hutto and Gilbert's (2015): "Valence Aware Dictionary and sEntiment Reasoner" (VADER). This is a tool developed for social media short communications, such as Tweets; then, our approach fits better the sentiment classification of the long statements typically released by the FOMC and by the Fed's Chairpersons.

ferent dimension of a central bank's communications, one that has been associated before to decisions in a rational expectations framework. In practice, it will consist of simple measure of the communications' bias towards an increase in interest rates – a *"Hawkish"* stance, or of a bias towards a decrease in the interest rate – a *"Dovish"* stance.

This second type of "rational" sentiment is built using Tetlock et al.'s (2008) and Loughran and McDonald's (2011) BoW methods: we use dictionaries of two opposite, near-rational tones, collecting words associated with a *Hawkish* monetary policy stance in one sub-set and with a *Dovish* monetary policy stance in the other. The *Hawkish* dictionary is built by looking into all synonyms of *tight* and *tightening*, and the *Dovish* set of words by synonyms of *ease* and *easing*. Table C3 in the Online Appendix displays the structure of the dictionary: a total of 63 words are expressions of a *Hawkish* stance, while 75 words match a *Dovish* tone.

In addition to helping assess the robustness of our empirical results, this additional *Hawkish* vs. *Dovish* sentiment analysis may be revealing in comparison to the *Neutral* vs. *Not-neutral* exercise to test whether the channel of neutral/not-neutral and positive/negative sentiment in Fed Chairpersons' communications may provide an additional "emotional" content that significantly contributes to explaining the impact of Fed sentiment in the prediction of interest rate movements over and above the classical dynamics of the sentiment of the Federal Reserve regarding the *Hawkish* and *Dovish* states over the business cycle.[13]

III. Arbitrage and Market Beliefs' Model: Effects on the Target Rate Discovery Process

Cochrane and Piazzesi (2002) in their concluding remarks posed a "puzzle" in which the market anticipation to the Federal Reserve decisions for the short-term interest rate might be due to an anticipation of a higher output in the future, making it somehow quite difficult to

[13] One may think that the majority of the *Dovish* communications ought to come after a crisis, and that the *Hawkish* ones ought to predominate after a boom or expansion period, therefore associating *Dovish* (*Hawkish*) sentiment with non-neutral negative (positive) sentiment, in the sense of Section II.B.

identify which of the two agents reacted first, if the Federal Reserve by implementing a shock that followed a long-term monetary policy decision, or the market by anticipating the next short-term interest rate decision of the FOMC.[14] In this Section we shed some light on solving the identification puzzle, by using the 1- and 3-month Eurodollar future instrument. Our approach follows a *grid of probability scenarios* to price the futures in the physical measure, similar to what Stutzer (1996) and Stutzer and Chowdhury (1999) did in the risk-neutral measure.

Consider the 1-month Eurodollar future of the short-term interest rate $f_t^{(1)}$, the Federal Funds Effective Rate $FFER_t$, the Federal Funds Target Rate $FFTR_t$, for $t = 1, \ldots, T$, the time in days. Assume that T represents the period during which the FOMC maintains the $FFTR_t$ without any change. The market expects that:

$$\text{average}_{t=1,\ldots,T}(FFER_t) = E\left(\sum_{t=1}^{T} \frac{FFER_t}{T}\right) = FFTR_1.$$

Given that the 1-month Eurodollar future reflects the expectations of the short-term interest rate for the next month, we have that, by arbitrage conditions, if there is no expected change of the FFTR for the next month, $T \geq 30$, and

$$\left(1 + \frac{f_1^{(1)}}{12}\right)^{1/12} = \left(1 + \frac{E\left(\sum_{t=1}^{T} \frac{FFER_t}{T}\right)}{12}\right)^{1/12} = \left(1 + \frac{FFTR_1}{12}\right)^{1/12},$$

[14] In an effective communication process, the central banks should signal their policies in advance and they should move forward in the direction they had signaled before to maintain their credibility (Bernanke and Reinhart, 2004). This process creates a trust in the decisions, and a smooth and "algorithmic" transition between the different states of the economy that we can describe – with many simplifications – in 4 stages: (i) the economy/financial markets have a condition/state, partially unknown to some agents including central banks, (ii) central banks analyze the actual condition/state by measuring different indicators (macroeconomic, interest rates, stock prices, consumer, credit), (iii) central banks take a decision and implement a monetary policy, and (iv) the economy/financial markets react to the policy implemented by central banks (Bernanke and Kuttner, 2005; Gürkaynak et al., 2005). We know that stage (i) occurs before (ii), but there is no certainty if stage (iii) occurs before (iv) or otherwise, as the financial markets might be reacting before the central bank announcements, in advance of the implementation of the policies. Using data from the U.S. interest rates and FFTR changes decisions of the Federal Reserve, Cochrane and Piazzesi (2002) defined this uncertainty of the timeline of stages (iii) and (iv) as a potential *puzzle*: in some cases markets are reacting to the monetary policy announced by the Federal Reserve (Romer and Romer, 2000, 2004; Bernanke and Kuttner, 2005), but sometimes the Federal Reserve is reacting to the observed evolution of the financial markets (Bernanke and Gertler, 2000, 2001),[15] and it is hard to determine which occurs first. In any case, the communication process continues to be fundamental for central banks in attaining their goals, and any quantitative measure of the content of a central bank communication, and its effect on the financial markets, is of crucial interest for policymakers.

that implies

$$f_1^{(1)} = \sum_{t=1}^{T} \frac{E\left(FFER_t\right)}{T} = FFTR_1, \tag{2}$$

and it will explain why on so many occasions the 1-month Eurodollar future has the same rate of the FFTR just after the FFTR announcement, considering that most of the FFTR decisions are taken at regular FOMC meetings held every month a half ($T \geq 30$). Nevertheless, decisions on the FFTR can appear before the regular scheduled FOMC meetings due to the economy or market conditions, and in that case $T \leq 30$.[16] Using an expectations' model the 1-month Eurodollar future should reflect the implied probability of the FOMC stepping forward and taking a decision before the 30-days' maturity of the future, or the implied probability of the month average $FFER_t$ not being equal to $FFTR_1$:

$$f_t^{(1)} = \mathbb{P}_t(T < 30)\left(\frac{T}{30}FFTR_t + \frac{30-T}{30}FFTR_{T+1}\right) + \left(1 - \mathbb{P}_t(T < 30)\right)\left(FFTR_t\right), \tag{3}$$

for $t < T$, where $\mathbb{P}_t(T < 30)$ is the probability at t that the FFTR change will occur in less than 30 days and $FFTR_{T+1}$ is the new FFTR, different to $FFTR_1$. If $\mathbb{P}_t(T < 30)$ is close to zero we have the equality between $f_1^{(1)}$ and $FFTR_1$, as in Equation (2). But if not, then the market is signaling a distrust that the FFTR will be maintained for one month. That difference might be due to two factors:

(i) There is policy shock and the market needs a time to absorb the shock, or

(ii) The market is not surprised by the shock but anticipates that the Federal Reserve will not be able to maintain the current monetary policy during the next month.

In a permanent observation and reaction process, the market adjusts the 1-month Eurodollar future every day, and that is reflected days after the FOMC policy decision, when the 1-month

[16]Notice that T refers to the date when the FOMC takes a decision to change the FFTR, not the date of the FOMC meeting; a FOMC meeting can be expected in less than 30 days but that does not imply the FFTR will be changed.

Eurodollar continues to decrease in the case the market has detected a *Dovish* policy by the Fed, or when the 1-month Eurodollar rate continues to increase in the case the market has detected a *Hawkish* policy (see Figure 2).

[Place Figure 2 about here]

In Equation (3), we know at time $t = 1$, $f_1^{(1)}$ and $FFTR_1$. $\mathbb{P}_t(T < 30)$, T and $FFTR_{T+1}$ are unknown, but they can be estimated by considering the monetary policy in place. In line with Stutzer (1996), we set a *grid of probabilities* in the physical measure for all the N future possible scenarios by setting an increasing/decreasing scale of policy shocks, $FFTR_{t+1} = FFTR_t \pm \delta = FFTR_t \pm 12.5bp, 25bp, 37.5bp, 50bp, \ldots, \max(change)bp, \delta \in (\delta_1, \ldots, \delta_N)$. A positive vector of probabilities is assigned for the future scenarios: $(\pi_{\delta_1}, \ldots, \pi_{\delta_N})$. Then, $FFTR_t + \delta_1$ has a probability of occurring of $\mathbb{P}_{t,\delta_1}$. We can estimate the probability of every $FFTR_{T+1}$ scenario change in comparison to the probability that the FFTR will remain the same for at least 30 days. Using this setup, define $\mathbb{P}_{t,\delta}(T < 30)$ as the probability at t of the change δ bp occurring in $T < 30$, then we will have N Equations similar to Equation (3), where every scenario has a probability of occurrence $\pi_{\delta_i}, i \in \{1, \ldots, N\}$, where N is the number of different FFTR changes:

$$
\begin{aligned}
f_{1,t}^{(1)} &= \mathbb{P}_{t,\delta_1}(T < 30) \left(\frac{T}{30} FFTR_t + \frac{30 - T}{30} \left(FFTR_t + \delta_1 \right) \right) + \left(1 - \mathbb{P}_{t,\delta_1}(T < 30)\right) \left(FFTR_t \right), \\
&\vdots \\
f_{N,t}^{(1)} &= \mathbb{P}_{t,\delta_N}(T < 30) \left(\frac{T}{30} FFTR_t + \frac{30 - T}{30} \left(FFTR_t + \delta_N \right) \right) + \left(1 - \mathbb{P}_{t,\delta_N}(T < 30)\right) \left(FFTR_t \right),
\end{aligned}
\tag{4}
$$

where $\delta_i = \{-\max(change)bp, \ldots, -12.5bp, +12.5bp, \ldots, +\max(change)bp\}$. Assume, without loss of generality, that the N scenarios have the same probability in the initial setup: this is similar to assuming a prior distribution in a Bayesian framework. Setting all the δ changes on average yields the expected change implicit in the 1-month Eurodollar future; then, Equation

(3) can be transformed into

$$f^{(1)}_{N+1,t} = (1/N)\sum_{\delta_i} \Bigg(\mathbb{P}_{t,\delta_i}(T<30)\left(\frac{T}{30}FFTR_t + \frac{30-T}{30}(FFTR_t+\delta_i)\right) + (1-\mathbb{P}_{\delta_i}(T<30))\,(FFTR_t)\Bigg). \tag{5}$$

But by arbitrage conditions, we have that:

$$f^{(1)}_{1,t} = f^{(1)}_{2,t} = \cdots = f^{(1)}_{N+1,t}. \tag{6}$$

Equations (5) and (6), jointly with the N Equations as (4) for each δ_i will produce $N+2$ equations, with $N+1$ unknowns $(\mathbb{P}_{t,\delta_1}(T<30), \mathbb{P}_{t,\delta_2}(T<30), \ldots, \mathbb{P}_{t,\delta_N}(T<30), T)$, and we can identify the N probabilities and T. In addition, expectations longer than the 1-month maturity of the 1-month Eurodollar future can be affected by the possibility of a FFTR change. The 3-month Eurodollar futures are included to balance those expectations:

$$f^{(3)}_{i,t} = \mathbb{P}_{t,\delta_i}(T<90)\left(\frac{T}{90}FFTR_t + \frac{90-T}{90}(FFTR_t+\delta_i)\right) + (1-\mathbb{P}_{t,\delta_i}(T<90))\,(FFTR_t), \tag{7}$$

for $i = \{1, \ldots, N\}$, and

$$f^{(3)}_{N+1,t} = (1/N)\sum_{\delta_i} \Bigg(\mathbb{P}_{t,\delta_i}(T<90)\left(\frac{T}{30}FFTR_t + \frac{90-T}{90}(FFTR_t+\delta_i)\right) + (1-\mathbb{P}_{t,\delta_i}(T<90))\,(FFTR_t)\Bigg). \tag{8}$$

Our set of Equations (4), (5), (6), (7), and (8) will produce an over-identified system of $2\,(N+1)+1$ equations with $2(N+1)$ unknowns. To close the system, we add an additional restriction on the minimum number of days for a change in the FFTR change to occur:

$$T \geq MinDaysNextChange/(\mathit{DiffDaysLastChange}_t + 2), \tag{9}$$

where $MinDaysNextChange_t$, is a variable that represents the number of days they FOMC board can take for deciding on changes to the FFTR, and $DiffDaysLastChange_t$ is the number of days at time t since the last interest rate change occurred. We select Equation (9) between several other candidates, given that (i) the optimization problem to solve Equations (4), (5), (6), (7), and (8) will implicitly reduce T, then we need a constraint based on an inverse function on T, and (ii) the inverse function on T must be on the number of days since the last FFTR change: while there are more days, the Equation (9) restriction on T is reduced, and the probability on FFTR is allowed to increase.[17] We use the daily close prices of the 1- and 3-month Eurodollar futures interest rate to solve the system of $2(N+1)+1$ equations, extracted from the Federal Reserve Economic Data (FRED) repository, from January, 1971 to December, 2015.

Figure 3 shows the resulting implicit probabilities' surface. We observe that, most of the time, the probability surface with the implicit relationship between the 1- and the 3-month Eurodollar futures with the FFTR, shows a bias towards an expected increase in the FFTR, principally during the quantitative easing period (November 2008–January 2014), but there are some particular periods where there is a bias towards a decrease in the interest rate: the U.S. inflationary period of 1974–1976 due to the Middle East oil wars, and the peak of the Dot-Com bubble business cycle in 2001.

[Place Figure 3 about here]

A. Entropy and Uncertainty in the Market Beliefs

The solution to the arbitrage model of the difference between the: 1- and 3-month Eurodollar future prices, and the FFTR in the previous section, provides a framework for understanding the interaction between the Federal Reserve decisions and the market expectations. But how can that analysis help in finding a Fed Chair textual sentiment profile (our first main question),

[17] The number selected is close to the average days between FFTR changes: in Table I in Section II we observe some descriptive statistics of the FFTR changes from which we estimate this number.

or in elucidating the impact of the Fed Chair statements' sentiment on the interest rates (our second main question)? We use information theory (Shannon, 1948), to explore a link between (i) the market expectations, (ii) the Federal Reserve decisions (Market Price Discovery feature), and (iii) the Fed Chair statements' sentiment signaling mechanism; this link will be useful in responding to our two main questions: the textual sentiment profile of the Fed Chair, and the Fed Chair statements' sentiment implications for the monetary policy.

Let $\mathbb{P}_{t,\text{Hawkish}} = \mathbb{P}_{t,\delta_1}(T < 30) + \ldots \mathbb{P}_{t,\delta_i}(T < 30)$ with $\delta_1, \ldots, \delta_i < 0$, be the probability at date t of a *Hawkish* decision in the next FOMC meeting occurring in less than 30 days, and $\mathbb{P}_{t,\text{Dovish}} = \mathbb{P}_{t,\delta_{i+1}}(T < 30) + \ldots \mathbb{P}_{t,\delta_N}(T < 30)$ with $\delta_{i+1}, \ldots, \delta_N > 0$ be the probability at date t of a *Dovish* decision in the next FOMC meeting occurring in less than 30 days. We define, following Richman and Moorman (2000), the sample entropy absolute growth in the market expectations between *Hawkish* and *Dovish* decisions, and between dates $t_1, t_2, t_1 \leq t_2$ as:

$$E_{t_1,t_2} = |\mathbb{P}_{t_2,\text{Hawkish}} - \mathbb{P}_{t_2,\text{Dovish}}| - |\mathbb{P}_{t_1\text{Hawkish}} - \mathbb{P}_{t_1,\text{Dovish}}|\,. \tag{10}$$

The sample entropy absolute growth number E_{t_1,t_2} increase is associated with an increase in the uncertainty, and a decrease with a reduction in the uncertainty of the markets about FFTR decisions in the next 30 days.

The next step is to measure the sentiment of the Federal Reserve communications, and associate that sentiment to the sample entropy growth E_t.

We use the results on the daily uncertainty to extend our identification method. Figure 1 shows the identification window in gray, where we explore the immediate effects of the Fed Chair statement's neutral sentiment on the interest rates. We choose to assess the uncertainty instead of the interest rates reaction, as our exploration of the effects of the Fed Chair statement's neutral sentiment over the interest rates is not in respect to the direction of the interest rates, but in respect to the "informativeness" that the sentiment provides to reduce the future decisions (that can be upward or downward measures over the FFTR).

IV. Fed Chairs' Sentiment as a Proxy of FOMC Decisions

In this section, we construct a surprise variable to analyze the effects on the term structure of interest rates of the sentiment revealed by the Fed Chairpersons' communications in the aftermath of FOMC decisions. We have two main research questions: (i) are the sentiments of the statements by the Chairs of the Federal Reserve different in tone, such that the institutional text processing mechanism does not erase the personal flavor? (ii) if there exists such a difference in the personal tone of the communication, can a single personal communication have a significant influence on the monetary policy process?

We measure the effects of the personal characteristics on the sentiment of the communication to answer the first question. To do it, we also control by the state of the economy and the financial market. From a technical point of view, we estimate an OLS model adding fixed effects. We answer the second question by constructing a variable that recovers the "jump surprise effect". This effect corresponds to the amount of "market overreaction" when the FOMC statement is released. In this way, we correlate the sentiment with the "jump surprise" of the market. From a technical point of view, we estimate logit with fixed/random-effects panel regressions to identify the effects of the communications' sentiment over the 1-month Eurodollar future.

A. Market Surprise to FOMC Meeting Decisions

Our market surprise variable is a modified version of the Kuttner (2001) monetary policy surprise variable. In our setting, we consider a "ratio" of the surprise by the size of the FFTR change that helps to account for changes during different interest rates periods (small changes during lower interest rates might have the same impact as larger changes during higher interest rates periods).

First, to start the variable construction, we consider the second differences, volatility, or surprise measures of the interest rates. Directional changes of the interest rates are important for traders, but it is harder to get statistically significant conclusions on the interest rate direction's relationship with Fed Chair statement information, considering that markets are efficient. Moreover, a surprise/volatility analysis can provide statistically significant results, even in an efficient markets framework (examples are the stylized facts on volatility clustering, tail dependent correlations, and VIX analyses).

Second, we control the impact implied by the Taylor's (1993) rule over the decisions, represented by the implementation[18] and the communication of monetary policy. From Equation (1), we can observe that prices (inflation) and output (GDP) are two of the most relevant macroeconomic variables analyzed by FOMC members when taking a decision on the FFTR.

Third, we control the endogeneity of the process. The decisions of the Federal Reserve on monetary policy are tracked by the market, the macroeconomic environment and financial market state are observed by the Fed officials. Usually both observations happen before a decision is made by them.[19] Rigobon and Sack (2003) and Rigobon and Sack (2004) solved the endogeneity between the stock market and interest rates by implementing a Structural VAR approach (SVAR) that controls endogeneity by using *synthetic* instruments built on the heterogeneous volatility of stock returns and interest rates. In our analysis, we consider a lag of 1 period to reduce the endogeneity. We also test a SVAR as a robustness check for endogeneity and the results are provided in the Online Appendix.

Considering all these previous elements and using weekly data to avoid asynchronous data problems, in the logit panel event study we define as the dependent variable the 1-week jump lagged difference between the FFTR on the day of the announcement (post-announcement) and

[18]Orphanides (2007) produced a institutional research document reviewing the previous uses and the implementation of the Taylor rule by the Federal Reserve.

[19]Sometimes the market has an advantage by being responsive in a 24x7x365 environment, such as in FX markets, but sometimes the Fed might react in the same 24x7x365 environment, as some call conferences by the FOMC meetings and their statements are released on Sundays before the opening of the market on Monday.

the 1-month Eurodollar future observed one-week before the announcement, $f^{(1)}_{t-1}$:

$$J_t = \left| \frac{FFTR_t - f^{(1)}_{t-1}}{FFTR_t - FFTR_{t-1}} \right|. \tag{11}$$

We aim to explore a *adjustment surprise* measure. For this reason, we consider an absolute value of the surprise, J_t, as the dependent variable.[20] We rely on the 1-Month Eurodollar instead of the 30-day Federal Funds Futures since we want to incorporate the risk-premium associated with the spread of the 1-Month Eurodollar and the 30-day Federal Funds Futures. For example, using the 1-Month Eurodollar we can understand better the increased spread signals problems or distortions in the economy – such as the deteriorated financial liquidity environment of September/October 2008. We can capture that effect using 30-day Federal Funds Futures. Moreover, this additional spread value is an intrinsic reaction from the market to the intensity of the monetary policy shock.

B. Federal Reserve Chair Opinion and FOMC Decisions

But, which causality are we trying to explore? How do we relate Fed Chair statements' sentiment to the J_t variable? And what does this variable mean for the markets and the Federal Reserve interaction? An answer to these questions comes by doing a historical review of the FOMC FFTR decision process. On one hand, from Thornton and Wheelock (2014) we know that from the last 755 FOMC meetings from April 19, 1939 to December 31, 2015, 100% of the time (755 meetings), the Chair decision was aligned with the decision taken by the FOMC to tighten or to ease the monetary policy. One the other hand, it is hard to think that Fed Chairs can preserve their leadership by changing their view during the meeting. Then, in line with Ehrmann and Fratzscher (2007), considering that the communication process of the

[20] Robustness checks were conducted considering regressions with J_t^2 in the Online Appendix. Results using this modified dependent variable were similar. Equivalently, the adjustment surprise might be inverted to analyze how efficient the transmission of monetary policy is to the markets. This measure, $(1/J_t)$, is defined as the adjustment efficiency and the results shown in the Online Appendix are equal to the ones obtained with J_t.

Federal Reserve decisions is done by the members, but the Chair is the leading voice in this process, then all the Chair's public opinions before the FOMC meeting are immediate proxies to the FOMC decisions.[21]

Given the importance of the Fed Chair opinions in the final FFTR decision during the FOMC meeting, we explore four dimensions of the communication process: we analyze the relationship of (i) *adjustment surprise* J_t with the neutral sentiment of the Chair statements, $NeutSentFRC_t$, (ii) the number of days between the last Chair statement release and the FOMC meeting decision on the FFTR change, (iii) the FOMC statement neutral sentiment, $NeutSentFOMC_t$, and (iv) the agreement between the Chair statement *Hawkish/Dovish* stance, FRC_Stance_t, and the previous *Hawkish/Dovish* stance on the FFTR decision, $FFTR\_Stance_{t-1}$ (See Figure A3 with corresponding sub-figures in the Online Appendix). The latter, the agreement dimension, is defined as:

$$FRC\_MPAgreement_t = \left| FRC\_Stance_t - FFTR\_Stance_{t-1} \right|, \tag{12}$$

where FRC_Stance_t is the *Hawkish/Dovish* tone of the Fed Chair statement, measured by counting the number of words in each category using the dictionary defined in Table C3 in the Online Appendix, and standardizing by by the total number of words of the two categories; and $FFTR\_Stance_{t-1}$ is the *Hawkish/Dovish* stance of the last FFTR decision. The Figures in the Online Appendix allows us to elaborate intuition on some initial conjectures: (i) Fed Chair sentiment neutrality seems to be associated with a higher jump surprise, days between the last statement and the FFTR decision seem to have a positive correlation (the closer the Fed Chair statement to the date, the higher the jump surprise), and (iii) changes in the tone of the Fed Chair sentiment neutrality seems to signal higher surprises.

[21] It is common to observe press conferences where one of the members of the FOMC discusses proposals by the Chair, and then the Chair responds to the FOMC member through a press release or an interview to the media.

C. Baseline Models – Controls

We divide our analysis in two: (i) first, we find the relationship between the state of the economy variables and the personal characteristics of the Fed Chair statement neutral sentiment; then, we construct a response variable that represents the surprise of the market to the FFTR changes, and we find the relationship between the control variables and the sentiment with the surprise (see Figure D5 in the Online Appendix for a causality diagram).

For the first stage, the sentiment of the statement is regressed by the following fixed-effects model:

$$\begin{aligned} NeutSentFRC_t &= \beta_0 + MacroVariables_{t-1} + FinancialVariables_{t-1} + \\ &\quad PersonalCharacteristics_{t-1}, \end{aligned} \tag{13}$$

where

$$\begin{aligned} MacroVariables_{t-1} &= BC_{t-1} + \beta_1 \Delta PCE_{t-1} + \beta_2 \Delta IP_{t-1} + \beta_3 \Delta M1_{t-1} + \beta_4 \Delta UR_{t-1}, \\ FinancialVariables_{t-1} &= \beta_5 \Delta SP500_{t-1} + \beta_6 Baa10YT_{t-1}, \\ PersonalCharacteristics_{t-1} &= CHAIR_{t-1} + \beta_7 AGE_{t-1} + \beta_8 EDUC_{t-1} + \beta_9 GEND_{t-1}, \end{aligned}$$

with BC the business cycle dummy (1 for expansion, 0 for recession), ΔPCE the change between the last two PCE announcements, ΔIP the change between the last two Industrial Production announcements, $\Delta M1$ the change between the last two $M1$ announcements, UR the unemployment rate, $\Delta SP500$ the return of the S&P500 during the last quarter, $Baa10YT$ the credit spread between the corporate "Baa" rated bonds and the 10-year Treasury notes, $CHAIR$ an index of the Fed Chairs sorted by the neutral sentiment (by Naïve Bayes classifier, Volcker=1, Greenspan =2, Yellen=3, Miller =4, Burns=5, Bernanke=6), AGE the age of the Fed Chair at the moment of the statement release, $EDUC$ the Fed Chair academic background, and $GEND$ the Fed Chair gender. In this analysis, we consider the weekly data defined in Section II.A. Given that the Fed Chair issues statements in a bi-weekly/monthly frequency (approximately), we maintain the Fed Chair statement neutral sentiment variable while the Fed Chair does not issue a new statement.

Next, in the second stage of our analysis, we study the *surprise jump* J_t of the market after the FFTR change decision. Initially, we want to test if the most simple classification of sentiment might have effects of the *surprise jump* J_t. Following Loughran and McDonald (2011), Huang et al. (2013), and Loughran and McDonald (2014), we create a jump surprise event with two categories, and regress the jump surprise as the dependent variable with a logistic regression over the neutral sentiment, in the following way: (i) expected: the *surprise jump* J_t is lower than 100%, which means that the difference between the last Friday 1-month Eurodollar rate before the FOMC meeting, and the FFTR decided during the FOMC meeting is less than the size of the change in the FFTR taken during the FOMC meeting, and (ii) surprised: J_t is greater than 100%. We produce robustness checks over this specification, changing the *surprise jump* J_t threshold to $\pm 20\%$, and the results are maintained.

To control the results for the macroeconomic environment we introduce fixed-effects with three sets of controls as explained in Section II.A, (i) macroeconomic state variables, (ii) financial market state variables, and (iii) the Fed Chair personal characteristics. Then, we test the following models:

$$\begin{aligned} J_t &= \beta_0 + MacroVariables_{t-1} + FinancialVariables_{t-1} + PersonalCharacteristics_{t-1} + \\ &\quad SentimentVariables_{t-1}, \qquad (14) \end{aligned}$$

for testing the effects that the Fed Chair statement neutral sentiment might have on the jump surprise J_t and the monetary policy price discovery by the market, where

$$SentimentVariables_{t-1} = \gamma_1 NeutSentFRC_t + \gamma_2 StanceFRC_t,$$

with $NeutSentFOMC_t$ the last Fed Chair statement neutral sentiment measured by any of the sentiment measures (emotional measures of sentiment in Equation (B1), (B2), and (B3) of the Online Appendix), $StanceFRC_t$ the Fed Chair statement agreement with the current monetary policy stance (Hawkish/Dovish), and,

$$J_t = \beta_0 + MacroVariables_{t-1} + FinancialVariables_{t-1} + \gamma_1 NeutSentFOMC_t, \quad (15)$$

with $NeutSentFOMC_t$ the current FOMC statement neutral sentiment, for testing the effects of the FOMC statement on the jump surprise J_t, as a baseline to measure the institutional sentiment level. Data for the logit panel event analysis of the model in Equation (14) are from January 01, 1971 to December 31, 2015, and of the model in Equation (15) are from February 01, 1994 to December 31, 2015 (first FOMC meeting statement release was from February 01, 1994).

V. Results

This section presents results on the textual sentiment profile per Federal Reserve Chair, and the results on the effects and the economic significance of the Fed Chair statements' sentiment on the interest rate price discovery by the market.

A. Sentiment of FOMC and Fed Chair Statements

Table II presents the results of the FOMC and Fed Chair statements' sentiment, using three different textual sentiment methodologies: Panel A.1 and B.1 results use the Naïve Bayes classifier, and Panel A.2 and B.2 results use the proportion of positive/negative words of the

Harvard General Inquirer IV (Tetlock et al., 2008) and the Loughran and McDonald (2011) dictionaries. Panel A.1 shows the proportion of documents that have as a final tag a neutral tag, or emotional (not-neutral) tag; the latter is tagged as positive or as negative. Panel A.2 shows the proportion of word count that every statement has. Panel B.1 shows the likelihood of every document being tagged as neutral or as emotional; and the latter as a positive or as negative; Panel B.2 shows the word proportion adjusted by the term weighting (tf.idf) standardization applied to the total number of words (over all documents). The results show, by the three different sentiment measures, that the Fed Chair statements have a greater amount of sentiment than the FOMC statements. In the case of FOMC statements, meetings tend to have more sentiment than telephone conferences, and this is expected as there is more space for discussion. Regarding the Fed Chair statements, when the Chair presents a statement in the Congress, it seems to have a bias for being more emotional and positive, than when presenting in other circumstances.

[**Place Table II about here**]

The next important analysis is over the first main question of this research: can Fed Chairs be tagged by their statements' sentiment? As in a textual risk-profile style? If that is the case, we should observe that their statements' sentiment cluster, and we will need every cluster to be statistically significant different from each other. Table III presents the results. Panel A.1 and B.1 results use the Naïve Bayes classifier, and Panel A.2 and B.2 results use dictionary methods. Panel A.1 counts the proportion of documents that have a neutral tag, or emotional (not-neutral) tag; the latter being a positive or negative tag. Panel A.2 shows the proportion of word count that every statement has. Panel B.1 presents the neutral or emotional, and for the latter the positive- and negative-likelihood of being tagged in such a category. Panel B.2 presents the word count adjusted by the tf.idf standardization method.

[**Place Table III about here**]

We provide the Kolmogorov–Smirnov test of sample differences in Table IV. The results show that there is a statistically significant difference (*** equals a p-value of less than 0.01) between the textual sentiment profile of every Chair: we can say that the *Fed Chairs have a personal tone profile in their statements, and that this textual sentiment profile differs significantly between Chairs, with Ben Bernanke the more neutral, and Paul Volcker the more sentimental.* Fed Chair statements' negative content is reduced: on average only 1% of the statements, as a whole, are tagged as negative, and the average negative words' content is only 7% in comparison to the 14% of positive content and 77–78% of neutral content by the Harvard IV dictionary. The Loughran and McDonald's (2011) dictionary reports a higher content of negative words than the Harvard IV (twice that of the positive), but this is due to the Loughran and McDonald's (2011) base dictionary size of negative and positive words: their negative base includes 2,337 words vs. 353 words in their positive base. We still need to check if the textual sentiment profile differences are due to the macroeconomic environment, or to other personal characteristics, and that is addressed in Section V.C, but by looking into the interest rate levels (see Figure A1 in the Online Appendix), and the macroeconomic situation during the two different regimes observed, the one between Burns, Miller and Volcker, and the other during Greenspan, Bernanke, and Yellen, we can infer that this result of the differences in textual sentiment profile will be maintained. For example, Arthur Burns and Paul Volcker experienced similar problems by the end of the 1970s and by the beginning of the 1980s, regarding the issue of high inflation and high unemployment rate. Nevertheless, the sentiment in their documents, on average, is quite opposite: while Burns has a very neutral position, Volcker was quite emotional and positive. This is the first important contribution of our study. The FOMC and Fed Chair statements that were tagged as negative documents, are almost not present, with less than 3% of the total sample.

[Place Table IV about here]

Given that we use three different sentiment methodologies, as a robustness measure, we explore the intersection of the two dictionary methodologies, by counting the words' proportion of the FOMC and Fed Chair statements, by each of the dictionaries.[22] Table B2 in the Online Appendix shows the results and we can observe that the different sentiment methodologies can extract the similar features, and this intersection is consistent in the different analysis we explore in this study.

B. Arbitrage Model and Market Beliefs

Figure 4 shows the resulting average sample entropy growth E_{t_1,t_2} of the market beliefs, as in Equation (10), conditional on the sentiment of the Fed Chair statement released, *neutral* in the gray line, and *emotional* in the blue line, with 95% confidence intervals in the shaded gray and the shaded blue, respectively. We use as a measure of sentiment the principal measure: the Naïve Bayes classifier.[23] The sample entropy growth is calculated between the day before the Fed Chair statement release ($t_1 = -1$), and the next four days: the day of the statement release ($t_2 = 1$), and the next three days after the statement release ($t_2 \in \{1, 2, 3\}$). For the day of the statement release, sample entropy growth E_{t_1,t_2} has a value different to zero (it is not the starting point of observation), given that we consider closing day prices, and during that day the interest rate closing prices had already been affected. Sub-figures 4b, 4c, 4d, 4e, 4f, and 4g present the sample entropy growth results for Chairs Burns, Miller, Volcker, Greenspan, Bernanke, and Yellen, respectively. The full period results in Sub-figure 4a shows that there is a clear and significant increase (interval confidence of 95% results not crossing is equivalent to a positive hypothesis test of the different means) in the *uncertainty* shock when the Fed Chair statement has a neutral sentiment, for at least three days ($t_2 = 0, 1, 2$) after the statement release, and a significant reduction of the *uncertainty* for almost three days ($t_2 = 0, 1, 2$) after the statement release. No other macroeconomic variable, nor the Hawkish/Dovish stance of the

[22] In line with Loughran and McDonald (2011) Table III, and Hansen et al. (2018) Figures III, IV, and V.

[23] We tested the other proxy measures of sentiment, Harvard IV and Loughran and McDonald (2011) dictionaries based as in Equations (B2) and (B3), but the results show no statistical significance in the intervals of confidence. We suspect those measures are just "proxies" of the sentiment and cannot really measure linear or non-linear relationships in the short frequency (1–2 days).

Fed Chair statement, is clear significant for changes in the uncertainty (see Online Appendix uncertainty figures). When analyzing the Fed Chair statements' sentiment effects on *uncertainty* per Chair, we observe a clear difference in terms of the textual sentiment profile: the statements of the two most emotional Chairs; as in Table III, Volcker and Greenspan have a statistically significant increase/decrease in the market *uncertainty* about FFTR decisions in the next 30 days, while the statements of the less emotional, Burns, Miller, Bernanke, and Yellen, do not impact market uncertainty. Textual emotional Chair statements results dominate, as they represent almost 60% (673/1134 statements) of the full sample.

[Place Figure 4 about here]

C. Federal Reserve Chair Statements' Sentiment and Personal Characteristics

Table V shows the results that confirm our conjecture on our first question: the sentiment of the Fed Chair public statements reflects a personal tone, that is recognizable given the personal characteristics, controlling for the state of the economy and the financial markets; the institutional mechanism is less important in these statements. The state of the economy and financial market explains 1% – 8% of the Fed Chair statement neutral sentiment, but personal characteristics explain an additional 3% – 14% (Adjusted R^2). The sub-panels in columns (1), (3), and (5) show the fixed-effects regressions of model in Equation (13) without the personal characteristics, and columns (2), (4), and (6) show model in Equation (13) controlling for personal characteristics. Columns pairs (1,2), (3,4), and (5,6) correspond to the measurement of the Fed Chair statement neutral sentiment by the Naïve Bayes classifier, Harvard IV (Tetlock, 2007), and Loughran and McDonald (2011) dictionaries' methods. The base model in the Naïve Bayes classifier case (column (1)) shows that money supply and labor market are the drivers of the sentiment, but the other two measures show that all macroeconomic and financial market state variables influence the sentiment of the Chair. Nevertheless, the most interesting result is that personal characteristics are also significant and important in finding the source of the sentiment in the Fed Chair statements.

[Place Table V about here]

D. Interest Rate Jump Surprise and Federal Reserve Chair and FOMC Statements Sentiment

In this section, the results to elucidate the effects of the Fed Chair statement neutral sentiment over the interest rate price discovery process by the market after the FOMC meeting, are presented. Table VI shows the main results on our second question: a single personal communication has a statistically significant influence on the monetary policy process. The economic explanation for our results is that the Fed Chair plays a leading role in constructing consensus withing the FOMC Board, but at the same time a leading role in signaling the decisions to be made during the FOMC meeting: the market reads carefully the public statements of the Fed Chair, and elaborates an expectation on the severity of the decisions based on this estimate; an increase in the neutrality of the statement sentiment creates more uncertainty on the market about the opinion of the Fed Chair about the economy, and in consequence on the expected consensus on decisions.

The results for the baseline models for the first set of controls, the macroeconomic state variables, the Models (14) and (15), are presented in Tables VI and E4, for the Fed Chair and the FOMC statements, respectively. The Table VI results on the Fed Chair statement effect are divided into nested sub-panels organized in columns: column (1) presents the results for the logit regressions of the jump surprise J_t for the base model in Equation (14) only with macroeconomic and financial state variables; columns (2), (4), and (6) are the results of model in Equation (14) adding the Fed Chair last statement neutral sentiment ($NeutSentFRC_{t-1}$) observation to the previous specification; columns (3), (5), and (7) are the results for the full model in Equation (14) when controlling for personal characteristics. Pair columns (2,3), (4,5), and (6,7) correspond to the measurement of the Fed Chair last statement neutral sentiment by the Naïve Bayes classifier, Harvard IV (Tetlock, 2007), and Loughran and McDonald (2011) dictionaries' methods.

The Table VI results show that higher unemployment reports are associated with a higher interest rate market surprise: the market tends to underestimate FFTR decisions based on the job market. This result is consistent with the Federal Reserve mandate on maximum employment and with results found by Piazzesi and Swanson (2008) on the significant relationship between employment growth and the Federal Funds interest rates' excess returns. Expectations of the market (last-quarter return) seem to have a minor effect. However, when we include the sentiment in the model (columns (2), (4), and (6)) there is an increase of an additional 5% – 7% in the deviance fit, and the Fed Chair last statement neutral sentiment is significant across the different sentiment measures (the principal and the proxies). Still, when we control results by adding the personal characteristics of the Fed Chair, we observe there is an additional increase in the fit of about 8% – 10%, but with the neutral sentiment still being significant. Our interpretation is that the Fed Chair last statement neutral sentiment does have an effect in the surprise jump J_t, and this effect, although it is personal to every Chair and situation, has a particular effect beyond the personal characteristics: Chairs use a personal tone in communications that is related to their personal characteristics, but in addition the tone has a personal flavor that they use as a personal signature. All the previous results on the importance of the Fed Chair last statement neutral sentiment are confirmed by analyzing the Granger causality of the variables on the jump surprise J over various lags (see Figure D6 in the Online Appendix).

[Place Table VI about here]

VI. Conclusions

The Federal Reserve communications' process is a delicate mechanism that the economic policy institution uses to control monetary policy. We find that there is sentiment present in the Federal Open Market Committee (FOMC) and the Federal Reserve Chair statements, that there exists a textual sentiment profile of the Fed Chairs that is produced by personal choice over the macroeconomic circumstances and personal characteristics, and that we have indications that the sentiment actually relates to the monetary policy uncertainty and that affects the market surprise in the interest rates price discovery process, at least during the day the Federal Fund Target Rate (FFTR) is changed. The Fed Chair statements' sentiment is significant and provides the markets with a signal of the future monetary policy decisions.

The Fed Chair statements' sentiment impact on monetary policy shocks has decreased over time, as the Federal Reserve has improved in the implementation of monetary policy, including the communications' mechanisms. The reduction of effects of the Fed Chair statements' sentiment is associated with a greater effectiveness in the implementation of the monetary shock, by reducing the sentiment and increasing the *"market uncertainty"*. Our results provide a framework for policymakers to ensure that future decisions are known to the market in advance only when there is no need to implement a shock. In the case a monetary policy shock is needed, the sentiment of the communications should be reduced.

Future analysis might explore the additional effects that other members of the FOMC board provide to the interest rate and asset price formation, or the relationship of the Fed Chair statements' sentiment under an unconventional monetary policy scheme, in light of the adoption of this system in recent years by the most important central banks, including the Federal Reserve. Additional sentiment analysis with other sources of non-digital information, such as audio and video recordings of the Fed Chair press releases could an interesting area for exploration.

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Table I
Federal Reserve Communications

The table shows a description of the two communications' documents analyzed, the FOMC and Fed Chair statements. Panel A shows the FOMC statements. The period for the Panel A sample is from February 01, 1994 to December 31, 2015 (first FOMC statement was made available to the public since January 01, 1994). Meetings are scheduled events, while telephone conferences are unscheduled. FOMC statements are released immediately after finishing the meeting/telephone conference, with the exception of 4 statements issued outside normal trading hourse due to the 2007/2008 financial crisis: August 17, 2007, January 22, 2008, March 11, 2008, and October 8, 2008. Panel B shows the Fed Chair statements statistics. Two sub-panels are presented, one with document statistics per type of document, and other sub-panel with per Chair statistics. The period for the Panel B sample is from January 01, 1971 to December 31, 2015. The Average days before the FFTR change is calculated with a sub-sample: only the last Fed Chair statement issued before an FFTR is included ($N = 244$ statements). The standard error of the average is between parentheses.

Panel A: FOMC Statements

	Number	(%)	Average Number of Words	Average Days Between Statements
FOMC Statements	164	100.00%	374.35	51.22
			(18.59)	(4.18)
Meeting	153	93.29%	384.64	54.93
			(19.49)	(4.38)
Telephone Conference	11	6.71%	231.18	586.50
			(38.33)	(235.38)

Panel B: Fed Chair Statements

	Number	(%)	Average Number of Words	Average Days Between Statements	Average Days Before FFTR Change ($N = 244$)
Fed Chair Statements	1134	100.00%	2870.50	14.77	16.64
			(58.40)	(0.49)	(1.04)
Per Type of Document					
Testimony before the House of Representatives	231	20.37%	2979.97	72.63	71.05
			(178.22)	(5.26)	(4.69)
Testimony before the Senate	196	17.28%	3005.53	84.17	83.48
			(176.04)	(6.43)	(5.21)
Testimony before a Joint Committee	76	6.70%	2705.08	222.99	152.05
			(358.41)	(18.75)	(9.89)
Remarks before an Institution	579	51.06%	2017.47	28.85	42.50
			(61.82)	(1.54)	(2.85)
Other (Press Briefing, Dedication, Interview)	52	4.59%	2292.08	317.55	295.64
			(289.03)	(45.05)	(14.91)
Per Chair					
Arthur Burns	146	12.87%	2951.19	20.12	18.06
			(118.95)	(1.60)	(1.88)
George W. Miller	50	4.41%	3018.54	10.14	12.95
			(157.26)	(1.64)	(3.28)
Paul Volcker	168	14.81%	3589.70	17.22	20.08
			(254.32)	(1.48)	(2.68)
Alan Greenspan	505	44.53%	2748.61	13.24	15.22
			(78.67)	(0.66)	(1.57)
Ben Bernanke	233	20.55%	2616.06	12.45	9.54
			(87.65)	(0.87)	(1.38)
Janet Yellen	32	2.82%	2442.41	21.29	13.00
			(303.74)	(4.04)	(0.00)

Table II
Federal Reserve Communications' Sentiment – Type of Communication

The table shows the sentiment of the FOMC and Fed Chair statements. The FOMC statements' sample is from February 01, 1994 to December 31, 2015 (first FOMC statement was made available to the public since January 01, 1994), and the Fed Chair statements' sample is from January 01, 1971 to December 31, 2015. Panel A.1 shows the proportion from the complete set of documents that are tagged as Neutral, Positive or Negative by the NLTK Naïve Bayes classification method. For example, for FOMC statements – Meeting, there are 76 documents tagged as Neutral (49.67%). Panel A.2 shows the average word count proportion per document using the Harvard IV (Tetlock et al., 2008) and Loughran and McDonald (2011) dictionaries. Panel B.1 shows the average sentiment Likelihood per document with the Naïve Bayes classification method. Panel B.2 shows the average tf.idf function per document normalized to the total tf.idf per tag. The standard error of the average is between parentheses.

Panel A: Communications' Sentiment Tone

	Panel A.1: Proportion			Panel A.2: Average Word Count					
	Naïve Bayes (NLTK) (%)			Harvard IV (Tetlock) (%)			Loughran & McDonald (%)		
	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg
FOMC Statements	50.61	46.34	3.05	85.47	10.97	3.56	94.27	2.76	2.97
				(0.27)	(0.25)	(0.16)	(0.19)	(0.11)	(0.15)
Meeting	49.67	47.71	2.61	85.16	11.19	3.65	94.15	2.89	2.96
				(0.27)	(0.25)	(0.17)	(0.19)	(0.11)	(0.15)
Telephone Conference	63.64	27.27	9.09	89.72	7.98	2.29	95.94	0.97	3.09
				(1.10)	(0.78)	(0.65)	(0.88)	(0.32)	(0.76)
Fed Chair Statements	51.50	46.65	1.85	77.82	14.91	7.27	90.37	3.68	5.95
				(0.09)	(0.07)	(0.06)	(0.05)	(0.03)	(0.05)
Testimony before the House of Representatives	41.99	56.28	1.73	78.08	14.55	7.37	90.23	3.43	6.34
				(0.18)	(0.13)	(0.11)	(0.11)	(0.06)	(0.10)
Testimony before the Senate	50.00	48.98	1.02	78.09	14.58	7.33	90.10	3.59	6.31
				(0.19)	(0.15)	(0.12)	(0.12)	(0.06)	(0.11)
Testimony before a Joint Committee	55.26	42.11	2.63	79.21	13.47	7.32	89.80	3.61	6.59
				(0.34)	(0.24)	(0.20)	(0.20)	(0.10)	(0.18)
Remarks before an Institution	55.09	43.52	1.38	77.35	15.38	7.28	90.50	3.83	5.67
				(0.12)	(0.11)	(0.09)	(0.08)	(0.05)	(0.08)
Other (Press Briefing, Dedication, Interview)	53.85	36.54	9.62	78.84	14.63	6.53	91.50	3.51	5.00
				(0.48)	(0.46)	(0.35)	(0.29)	(0.16)	(0.28)

Panel B: Communications' Sentiment Average Intensity Per Document

	Panel B.1: Likelihood			Panel B.2: tf.idf					
	Naïve Bayes (NLTK)			Harvard IV (Tetlock)			Loughran & McDonald		
	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg
FOMC Statements	51.51	66.36	33.03	86.46	72.67	27.33	89.13	43.27	56.73
	(2.19)	(0.95)	(0.88)	(0.26)	(1.14)	(1.14)	(0.43)	(2.18)	(2.18)
Meeting	50.95	66.71	33.29	86.16	72.55	27.45	88.99	44.67	55.33
	(2.25)	(0.89)	(0.89)	(0.25)	(1.14)	(1.14)	(0.44)	(2.23)	(2.23)
Telephone Conference	59.32	61.46	29.45	90.54	74.44	25.56	91.04	19.89	80.11
	(9.54)	(6.85)	(4.23)	(1.17)	(6.47)	(6.47)	(1.99)	(6.95)	(6.95)
Fed Chair Statements	51.51	72.76	26.98	76.55	63.94	36.06	86.86	30.40	69.60
	(0.87)	(0.41)	(0.39)	(0.10)	(0.25)	(0.25)	(0.10)	(0.37)	(0.37)
Testimony before the House of Representatives	45.87	70.03	29.11	76.91	62.94	37.06	86.09	26.75	73.25
	(1.93)	(0.93)	(0.84)	(0.20)	(0.45)	(0.45)	(0.16)	(0.54)	(0.54)
Testimony before the Senate	50.04	71.65	28.35	77.04	63.13	36.87	85.82	27.94	72.06
	(2.08)	(0.88)	(0.88)	(0.22)	(0.51)	(0.51)	(0.18)	(0.66)	(0.66)
Testimony before a Joint Committee	53.82	70.00	30.00	78.06	61.97	38.03	85.60	27.66	72.34
	(3.36)	(1.57)	(1.57)	(0.37)	(0.81)	(0.81)	(0.31)	(0.95)	(0.95)
Remarks before an Institution	53.79	75.32	24.68	75.92	64.72	35.28	87.54	32.71	67.29
	(1.21)	(0.53)	(0.53)	(0.14)	(0.38)	(0.38)	(0.17)	(0.58)	(0.58)
Other (Press Briefing, Dedication, Interview)	53.45	64.60	33.48	77.83	65.63	34.37	88.32	34.19	65.81
	(4.15)	(2.54)	(2.30)	(0.59)	(1.94)	(1.94)	(0.41)	(2.51)	(2.51)

Table III
Federal Reserve Chair Statements' Sentiment

The table shows the sentiment of the Fed Chair statements. The Fed Chair statements' sample is from January 01, 1971 to December 31, 2015. Panel A.1 shows the proportion from the complete set of documents that are tagged as Neutral, Positive or Negative by the Naïve Bayes classification method. For example, for Arthur Burns, there are 97 documents tagged as Neutral (66.44%). Panel A.2 shows the average word count proportion per document using the Harvard IV (Tetlock et al., 2008) and Loughran and McDonald (2011) dictionaries. Panel B.1 shows the average sentiment Likelihood per document with the Naïve Bayes classification method. Panel B.2 shows the average tf.idf function per document normalized to the total tf.idf per tag. The standard error of the average is between parentheses.

	Panel A: Communications' Sentiment Tone								
	Panel A.1: Proportion			Panel A.2: Average Word Count Per Document					
	Naïve Bayes (NLTK) (%)			Harvard IV (Tetlock) (%)			Loughran & McDonald (%)		
	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg
Before February 1994									
Arthur Burns	66.44	31.51	2.05	77.83	14.36	7.80	90.11	3.52	6.36
				(0.25)	(0.21)	(0.15)	(0.16)	(0.09)	(0.13)
George W. Miller	60.00	38.00	2.00	77.19	15.04	7.78	89.95	3.98	6.07
				(0.30)	(0.28)	(0.23)	(0.23)	(0.13)	(0.20)
Paul Volcker	28.57	68.45	2.98	76.68	15.29	8.03	89.62	3.69	6.70
				(0.21)	(0.16)	(0.12)	(0.15)	(0.07)	(0.12)
Alan Greenspan (I)	46.32	52.59	1.09	77.98	14.73	7.29	90.64	3.73	5.63
				(0.15)	(0.12)	(0.11)	(0.09)	(0.05)	(0.09)
After February 1994									
Alan Greenspan (II)	36.96	59.42	3.62	78.38	14.20	7.42	90.41	3.35	6.24
				(0.24)	(0.18)	(0.14)	(0.15)	(0.08)	(0.13)
Ben Bernanke	72.96	25.75	1.29	78.06	15.61	6.33	90.71	3.75	5.54
				(0.20)	(0.19)	(0.13)	(0.13)	(0.08)	(0.14)
Janet Yellen	56.25	43.75	0.00	78.64	15.22	6.14	90.56	4.15	5.30
				(0.63)	(0.62)	(0.36)	(0.24)	(0.23)	(0.29)

	Panel B: Communications' Sentiment Average Intensity Per Document								
	Panel B.1: Likelihood			Panel B.2: tf.idf					
	Naïve Bayes (NLTK) (%)			Harvard IV (Tetlock)			Loughran & McDonald		
	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg
Before February 1994									
Arthur Burns	62.71	69.41	30.59	76.33	61.40	38.60	86.22	27.50	72.50
	(2.33)	(1.20)	(1.20)	(0.29)	(0.71)	(0.71)	(0.24)	(0.77)	(0.77)
George W. Miller	59.44	71.35	28.65	75.60	62.80	37.20	86.30	31.05	68.95
	(4.31)	(1.70)	(1.70)	(0.36)	(1.00)	(1.00)	(0.36)	(1.41)	(1.41)
Paul Volcker	35.65	72.88	26.53	75.40	61.32	38.68	85.86	26.17	73.83
	(1.93)	(1.09)	(1.01)	(0.24)	(0.48)	(0.48)	(0.21)	(0.59)	(0.59)
Alan Greenspan (I)	47.59	72.52	27.21	76.58	64.09	35.91	87.62	31.65	68.35
	(1.46)	(0.69)	(0.66)	(0.18)	(0.43)	(0.43)	(0.14)	(0.63)	(0.63)
After February 1994									
Alan Greenspan (II)	40.74	71.81	27.47	77.28	61.94	38.06	86.28	26.88	73.12
	(2.25)	(1.20)	(1.10)	(0.26)	(0.62)	(0.62)	(0.50)	(0.88)	(0.88)
Ben Bernanke	66.47	75.80	24.20	77.07	68.15	31.85	87.17	34.51	65.49
	(1.74)	(0.87)	(0.87)	(0.22)	(0.62)	(0.62)	(0.24)	(1.08)	(1.08)
Janet Yellen	53.97	74.24	25.76	77.70	67.23	32.77	87.33	35.83	64.17
	(4.58)	(2.28)	(2.28)	(0.72)	(1.74)	(1.74)	(0.36)	(2.75)	(2.75)

Table IV
Federal Reserve Chair Statements' Sentiment – Kolmogorov–Smirnov Test

The table shows the Kolmogorov–Smirnov (KS) pair of samples test of the sentiment of the Fed Chair statements. The Fed Chair statements' sample is from January 01, 1971 to December 31, 2015. Panel A applies the KS test to the full sample of the Fed Chair statements, while Panel B applies the KS test to the sub-sample of the last Fed Chair statement before a FFTR change decision was made (Panel B is conditional on that FFTR is changed). Panel A.1 and B.1 shows the KS test results using Naïve Bayes classification method (Equation (B1)) to measure the neutral sentiment, with the rows and columns with the corresponding Fed Chair tested: the test of a Fed Chair in row i with a Fed Chair in column j tests the hypothesis: $H0 : NeutSent(FRC_i) = NeutSent(FRC_j), H1 : NeutSent(FRC_i) < NeutSent(FRC_j)$, as the rows and columns are sorted by the mean of the sample of each Fed Chair. The $*$, $**$, and $***$ represents the case when the null hypothesis is rejected with a p-values of less than $0.1, 0.05$ and 0.01, respectively. Panel A.2, B.2 and A.3, C.3 shows the the KS test results using the proportion of neutral words by the Harvard IV (Tetlock et al., 2008) and Loughran and McDonald (2011) dictionaries correspondingly (Equations (B2) and (B3)).

Panel A: All Statements

Panel A.1: Naïve Bayes (NLTK)

	Volcker	Greenspan	Yellen	Miller	Burns	Bernanke
Volcker	–	(<) ***	(<) ***	(<) ***	(<) ***	(<) ***
Greenspan		–	(<) **	(<) ***	(<) ***	(<) ***
Yellen			–	(<) *	(<) **	(<) ***
Miller				–	(≮)	(≮)
Burns					–	(≮)

Panel A.2: Harvard IV (Tetlock) (% Neutral)

	Volcker	Miller	Burns	Bernanke	Greenspan	Yellen
Volcker	–	(<) ***	(<) ***	(<) ***	(<) ***	(<) ***
Miller		–	(<) *	(<) **	(<) ***	(<) ***
Burns			–	(≮)	(<) *	(<) *
Bernanke				–	(≮)	(≮)
Greenspan					–	(≮)

Panel A.3: Loughran & McDonald (% Neutral)

	Volcker	Greenspan	Yellen	Miller	Burns	Bernanke
Volcker	–	(<) ***	(≮)	(<) ***	(<) ***	(<) ***
Greenspan		–	(≮)	(≮)	(<) ***	(<) ***
Yellen			–	(≮)	(≮)	(≮)
Miller				–	(≮)	(<) **
Burns					–	(<) *

Panel B: Only Last Statement Before FFTR Change

Panel B.1: Naïve Bayes (NLTK) –

	Volcker	Greenspan	Miller	Burns	Bernanke
Volcker	–	(<) ***	(<) ***	(<) ***	(<) ***
Greenspan		–	(≮)	(<) ***	(<) ***
Miller			–	(≮)	(<) **
Burns				–	(<) *

Panel B.2: Harvard IV (Tetlock) (% Neutral)

	Volcker	Miller	Burns	Greenspan	Bernanke
Volcker	–	(≮)	(≮)	(<) ***	(<) ***
Miller		–	(≮)	(<) ***	(<) ***
Burns			–	(<) ***	(<) ***
Greenspan				–	(≮)

Panel B.3: Loughran & McDonald (% Neutral)

	Volcker	Burns	Miller	Greenspan	Bernanke
Volcker	–	(<) ***	(<) **	(<) ***	(<) *
Burns		–	(≮)	(<) ***	(<) *
Miller			–	(≮)	(≮)
Greenspan				–	(≮)

Table V
Federal Reserve Chair Statements' Sentiment and Personal Characteristics

The table shows the fixed-effects regressions of the Fed Chair statement neutral sentiment as in baseline model Equation (13). The Fed Chair statements' sample is from January 01, 1971 to December 31, 2015. Panel A shows the nested model in Equation (13): columns (1), (3), and (5) only with macroeconomic and financial market variables, and columns (2), (4), and (6) with personal characteristics. The neutral sentiment dependent variable $NeutSentFRC_t$ in model in Equation (13) is measured in each of the pairs of columns (1,2), (3,4), and (5,6) by the Naïve Bayes classifier, Harvard IV (Tetlock, 2007), and Loughran and McDonald (2011) dictionaries. Macroeconomic variables with Δ are calculated with the first difference of the variable with respect to the previous announcement. The $*$, $**$, and $***$ represents statistical significance at a p-value of $0.1, 0.05$ and 0.01, respectively. The standard error is in parentheses.

Panel A: $NeutSentFRC_t$ Regressed by Macroeconomic and Personal Characteristics

	Naïve Bayes		Harvard IV (Tetlock)		Loughran & McDonald	
Model	(1)	(2)	(3)	(4)	(5)	(6)
Constant	60.3***	49.4**	81.2***	68.7***	92.5***	90.2***
	(3.3)	(20.4)	(0.3)	(1.9)	(0.2)	(1.1)
Macroeconomic						
Business Cycle	-1.1	0.5	-1.3***	-1.7***	-0.3**	-0.4***
	(2.2)	(2.2)	(0.2)	(0.2)	(0.1)	(0.1)
Δ PCE	-142.1	-1645.5	-135.0***	-34.4	-73.7***	-64.3*
	(230.8)	(1235.9)	(23.5)	(47.6)	(14.2)	(34.5)
Δ Industrial Production	-19.7	42.5	-4.0***	9.8	-3.1***	-1.9
	(15.0)	(66.4)	(1.5)	(16.1)	(0.9)	(1.2)
Δ M1	404.8***	326.7***	-38.5***	-27.9***	-24.9***	-16.7***
	(87.8)	(85.5)	(9.0)	(9.0)	(5.4)	(5.5)
Unemployment rate	-1.5***	-2.8	-0.2***	-0.1	-0.2***	-0.2***
	(0.4)	(1.0)	(0.0)	(0.1)	(0.0)	(0.0)
Financial						
Δ SP500	-7.7	3.9	5.0***	9.2**	1.4**	1.5
	(8.8)	(11.0)	(0.9)	(3.7)	(0.5)	(1.1)
Baa10YT	-7.0	1.4	-1.1	-2.0	-1.3***	-2.2*
	(6.8)	(9.3)	(0.7)	(1.5)	(0.4)	(1.2)
Personal Characteristics						
Chair		5.49***		0.06		0.11***
		(0.64)		(0.06)		(0.04)
Age		0.18		-0.03*		-0.02**
		(0.13)		(0.01)		(0.01)
Gender		10.90		-0.11		0.25
		(6.67)		(0.43)		(0.32)
Academic Background		-0.95		0.60***		0.15**
		(0.98)		(0.09)		(0.06)
N(weeks)	2381	2381	2381	2381	2381	2381
R^2	0.01	0.15	0.06	0.14	0.08	0.11

Table VI
The FFTR Change and the Fed Chair Statements' Sentiment

The table shows the logit regressions of the jump surprise of the 1-Month Eurodollar interest rate (J) during the FFTR change announcement from model in Equation (14). The Fed Chair statements' sample is from January 01, 1971 to December 31, 2015. Panel A shows the nested model in Equation (14). The neutral sentiment variable (NS_t) is the Fed Chair last statement neutral sentiment before the FFTR change. Column (1) is model in Equation (14) only with macroeconomic and financial variables, columns (2), (4), and (6) is model in Equation (14) including the neutral sentiment variable, measured by the Naïve Bayes classifier, Harvard IV (Tetlock), and Loughran and McDonald (2011) dictionaries, and columns (3), (5), and (7) is the full model in Equation (14), when controlling for personal characteristics. Macroeconomic variables with Δ are calculated with the first difference of the variable with respect to the previous announcement. The $*$, $**$, and $***$ represents statistical significance at a p-value of $0.1, 0.05$ and 0.01, respectively. The standard error is in parentheses.

Panel A: Jump Surprise J_t Regressed by Macroeconomic, Fed Chair Neutral Sentiment and Personal Characteristics

		Naïve Bayes		Harvard IV (Tetlock)		Loughran & McDonald	
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	-2.8***	-4.2***	-12.5***	-13.3**	-20.7***	-17.5**	-27.9***
	(0.9)	(1.2)	(3.2)	(5.2)	(6.3)	(8.7)	(10.0)
Macroeconomic							
Business Cycle	-0.3	-0.4	-0.0	-0.3	0.1	-0.4	-0.0
	(0.5)	(0.5)	(0.5)	(0.5)	(0.6)	(0.5)	(0.5)
Δ PCE	-31.6	-29.0	6.4	-3.2	25.4	-12.0	28.7
	(54.1)	(56.4)	(67.5)	(56.7)	(67.8)	(56.6)	(69.0)
Δ Industrial	-4.2	-2.1	-1.7	-1.7	-1.7	-2.3	-1.8
Production	(4.0)	(4.2)	(4.7)	(4.2)	(4.7)	(4.1)	(4.7)
Δ M1	-16.4	-20.7	-11.2	-7.8	0.1	-7.1	2.8
	(20.5)	(21.2)	(24.2)	(21.1)	(25.9)	(21.2)	(26.0)
Unemployment rate	0.5***	0.5***	0.7***	0.5***	0.8***	0.5***	0.8***
	(0.1)	(0.1)	(0.2)	(0.1)	(0.2)	(0.1)	(0.2)
Financial							
Δ SP500	-4.8**	-3.3	-2.3	-4.4*	-2.8	-3.8*	-2.4
	(2.2)	(2.4)	(2.6)	(2.3)	(2.6)	(2.3)	(2.6)
Baa10YT	-2.1	-1.4	-0.8	-1.6	-0.8	-1.3	-0.5
	(1.5)	(1.6)	(1.7)	(1.5)	(1.7)	(1.5)	(1.7)
Communications' Sentiment							
Fed Chair Statement		1.7***	1.2**	12.6**	11.1*	15.7*	17.0*
Neutral Sentiment		(0.5)	(0.6)	(6.2)	(6.7)	(9.2)	(9.9)
Fed Chair Statement		-0.0	-0.2	-0.1	-0.3	-0.0	-0.2
Stance(H/D)		(0.4)	(0.5)	(0.4)	(0.5)	(0.4)	(0.5)
Personal Characteristics							
Chair			0.3**		0.3**		0.3***
			(0.1)		(0.1)		(0.1)
Age			-0.1*		-0.0		-0.0
			(0.0)		(0.0)		(0.0)
Academic			0.5***		0.4***		0.5***
Background			(0.2)		(0.2)		(0.2)
N(weeks)	230	230	230	230	230	230	230
Deviance	275.76	255.08	233.61	260.65	235.06	261.98	234.85
Fit improvement	-	0.07	0.15	0.05	0.15	0.05	0.15

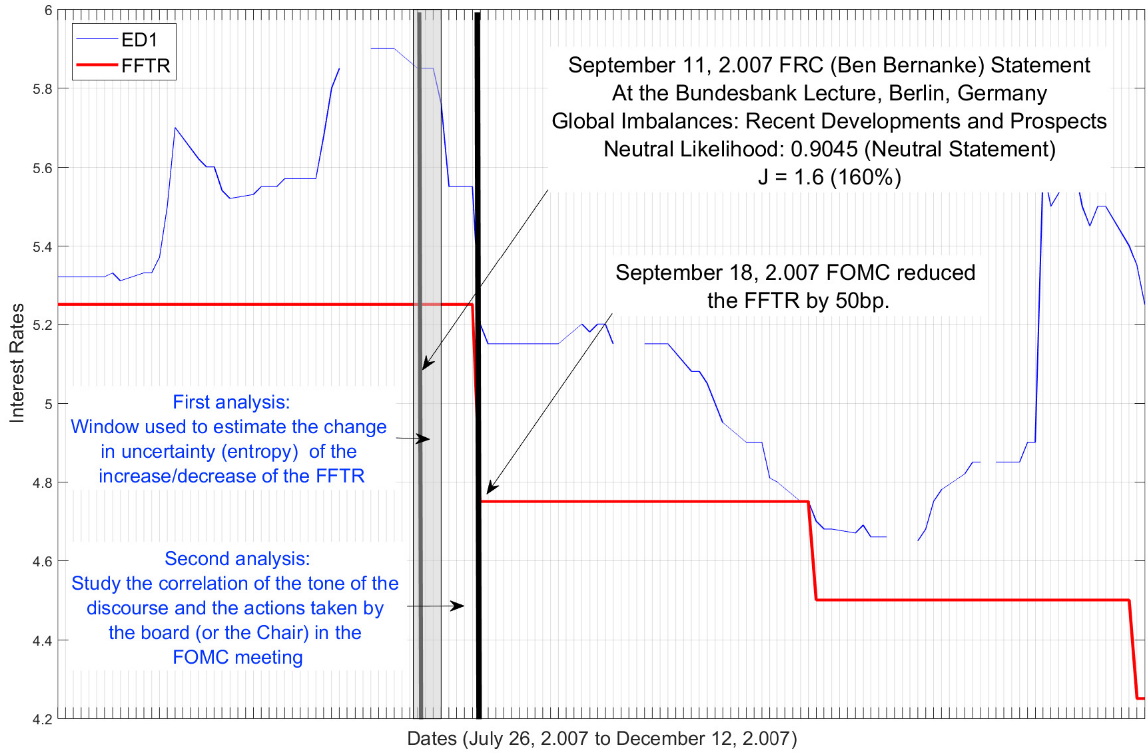


Figure 1. Identification method. The 1-month Eurodollar interest rate is in blue and FFTR is in red. The interest rates' sample is from July 26, 2007 to December 12, 2007.

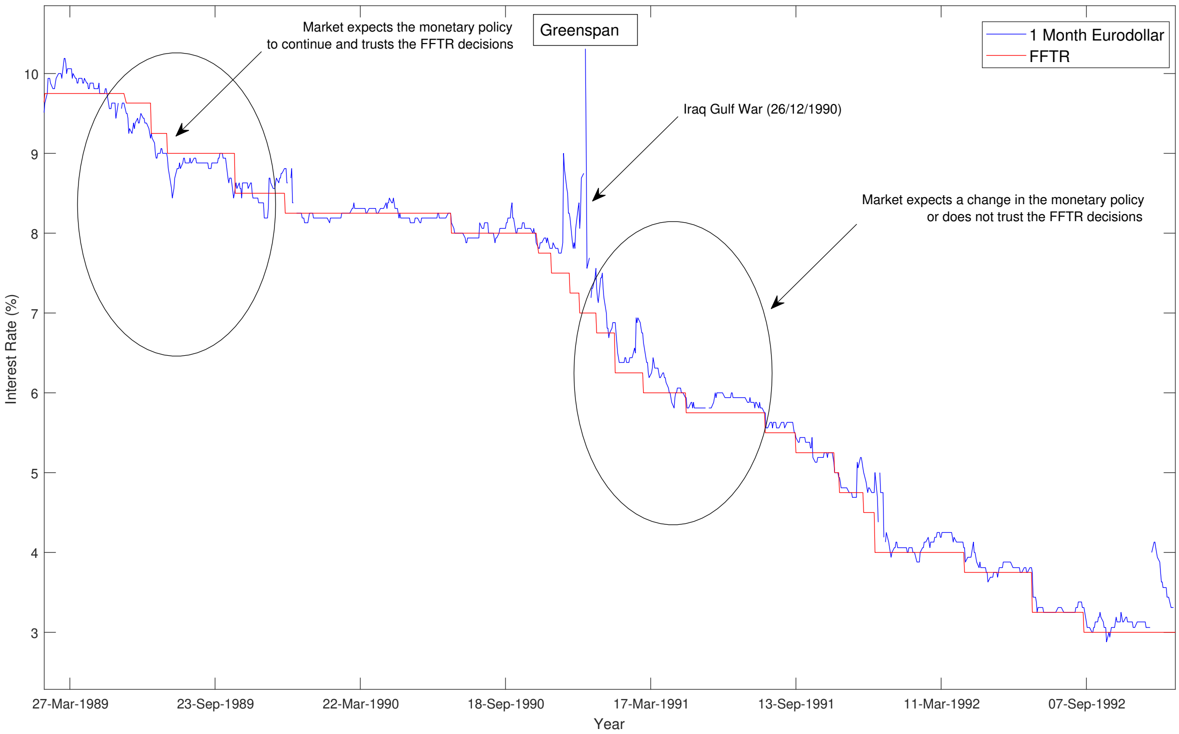


Figure 2. Market expectations over decisions of the FFTR by the FOMC. The 1-month Eurodollar interest rate is in blue and FFTR is in red. The interest rates' sample is from February 26, 2007 to December 12, 2007. The interest rates' sample is from January 23, 1989 to December 26, 1992.

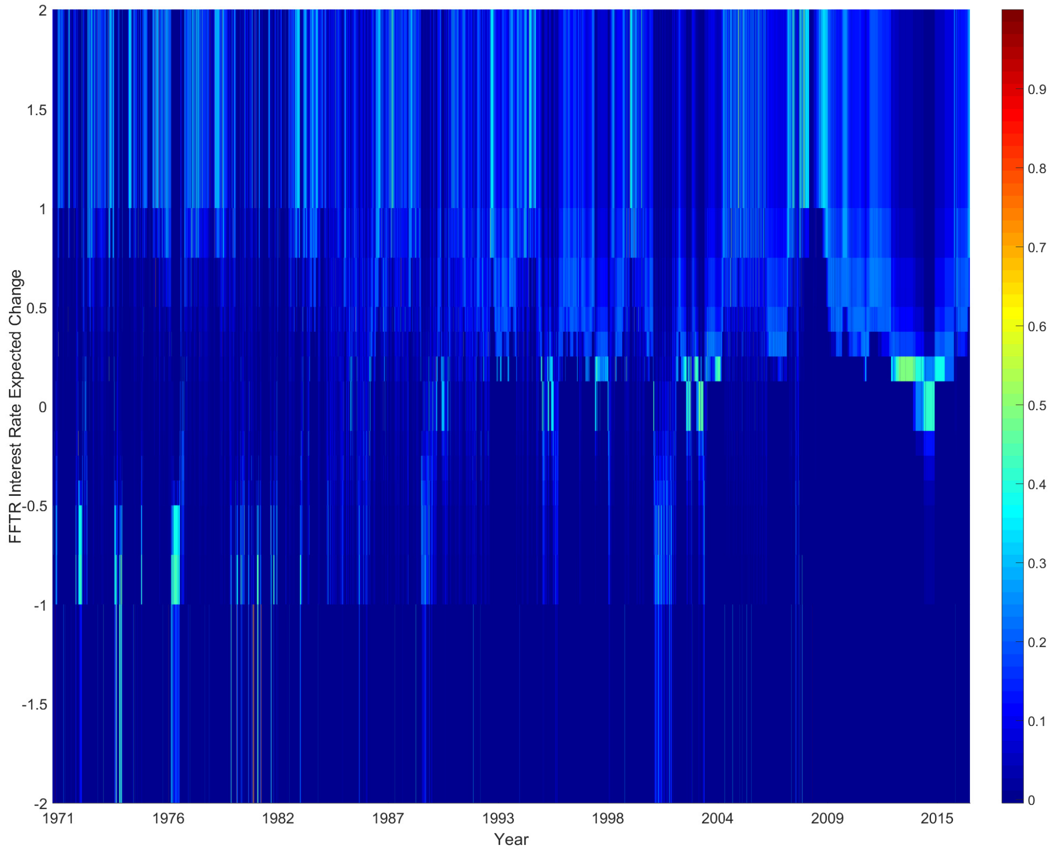
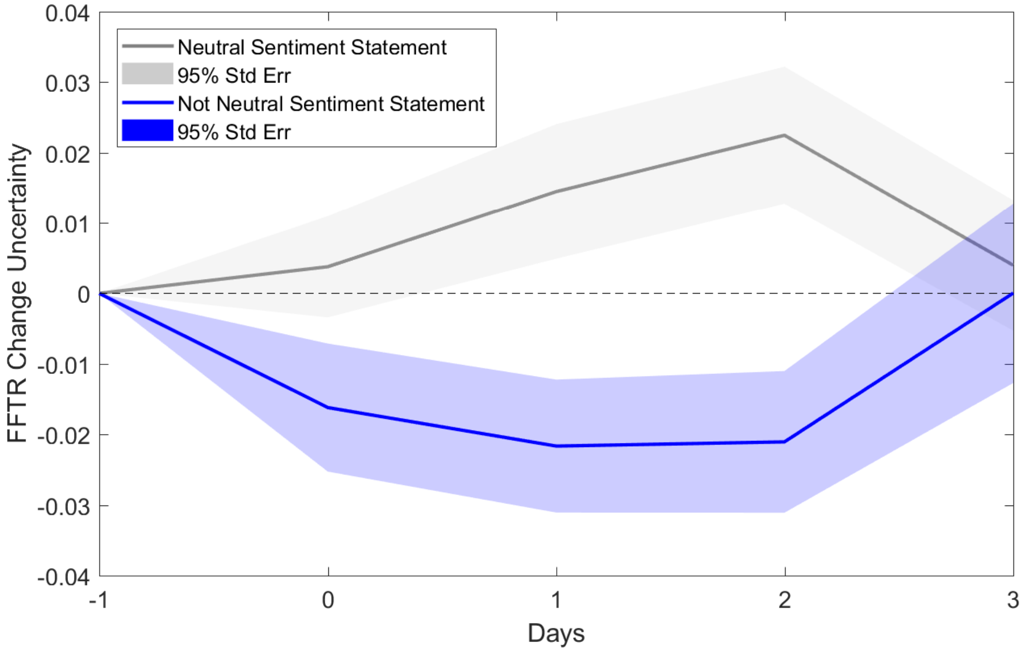
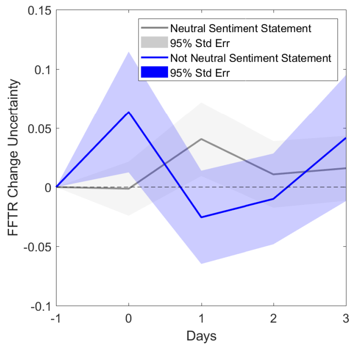


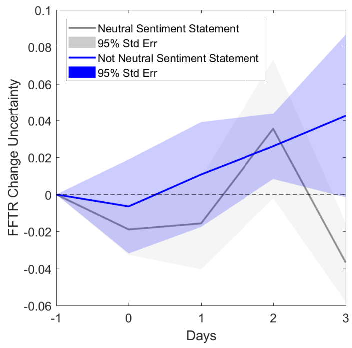
Figure 3. Implicit probability of the FFTR changes expected by the market for the next FOMC meeting . The implicit probabilities are calculated by solving Equations (4) (5), and (7), with the restrictions in (6). The 1-Month Eurodollar, 3-Month Eurodollar, and FFTR interest rates' sample is from January 01, 1971 to December 31, 2015.



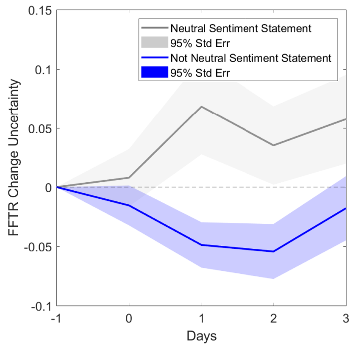
(a) Full Period



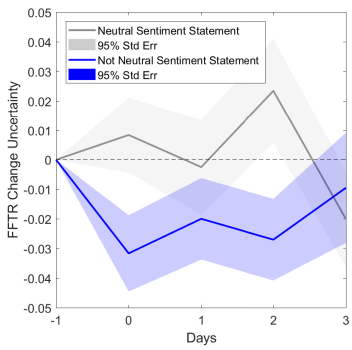
(b) Burns



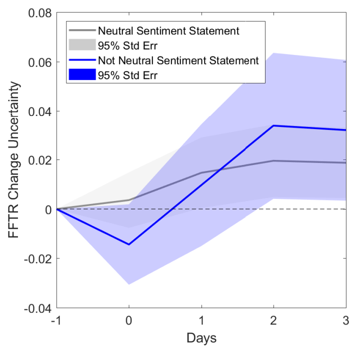
(c) Miller



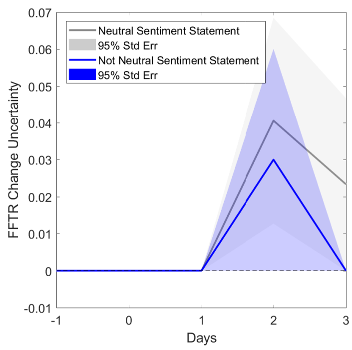
(d) Volcker



(e) Greenspan



(f) Bernanke



(g) Yellen

Figure 4. Uncertainty of the FFTR changes expected by the market for the next FOMC meeting after a Fed Chair statement release and Neutral sentiment of the Fed Chair statement. Uncertainty is calculated as the difference of the probability of and increase minus the probability of a decrease of the FFTR. The implicit probabilities are calculated by solving Equations (4) (5), and (7), with the restrictions in (6). The 1-Month Eurodollar, 3-Month Eurodollar, and FFTR interest rates' sample is from January 01, 1971 to December 31, 2015.

Federal Reserve Communications Sentiments' Impact on Target Rate Discovery

ONLINE APPENDIX

Appendix A. Interest Rates Descriptive Statistics and Jump Surprise J_t

Table A1 presents some descriptive statistics on the interest rates' environment for our sample period. We divide our analysis into two sub-periods, 1971–1993 and 1994–2015, to allow our analysis to reflect the remarkable changes implemented in the FOMC meeting rules and structure during 1994, for instance, with the immediate release of the Committee's decision through a public press release statement. Table A1 shows that, when compared to the first sub-sample, the 1994–2015 period was characterized by lower average rates, lower volatility, and consequently by a smaller number of FFTR changes (2.9 FFTR changes per year in comparison to 7.9 FFTR changes per year between 1971 and 1993).

[Place Table A1 about here]

Fed Chair Neutral Sentiment as a Proxy of the Jump Surprise

In this section, we explore with a descriptive analysis the relationship between the Fed Chair statement sentiment neutrality and the jump surprise J_t. Figure A2 shows the evolution of the J_t *adjustment surprise* variable. The variable J_t accounts for two effects: (i) one effect is the difference between the FOMC meeting announced rate, $FFTR_t$, and the market expected change, retrieved by measuring the 1-month Eurodollar Future closing prices of the previous week, $f_{t-1}^{(1)}$, and (ii) a second effect, that is how this *adjustment surprise* is representative for the decision in terms of the change. This effect works as a standardization of the first effect. For instance, suppose the first effect (numerator) is 50bp and the second effect is 50bp, then the variable reports $J_t = 1 = 100\%$ that means the *adjustment surprise* is of the same scale as the FFTR change. Meanwhile, if the numerator is 0bp, then there is no *adjustment surprise*, as we can observe in Figure A2 for some decisions between 1998 and 2004. The maximum value observed is about 10 (or 1000%), that means the *adjustment surprise* was 10 times the FFTR change announced: that might happen under two circumstances, a low-interest rate environment (for example, the 2007/2008 implementation of quantitative easing) and a high-inflationary period (for example, the Middle East oil wars during the 1970s). Still, during these periods, the market is able to predict the FFTR changes with some accuracy ($J_t < 1$).

[Place Figure A2 about here]

Figure A3 and Sub-figures A3a, A3b, and A3c show results of descriptive analysis relationships between Fed Chair statement neutral sentiment and the jump surprise J_t. By observing Sub-figures A3a, A3b, and A3c, we can infer some initial conjectures on our second question, on the effects of the Fed Chair statement neutral sentiment on the interest rate behavior during the FOMC meeting announcements; first, we explore conjectures on the direction of the surprise and the sentiment of the communication, and we find that a greater amount of *neutrality* in the communication's sentiment seems to be associated with a greater jump surprise. 'Neutral likelihood' refers to the probability that a communication will be tagged as neutral. Communications with a likelihood over 0.5 will be tagged as *neutral* and communications below that level will be tagged as *emotional* (not-neutral). Second, we explore the relationship of the number of days between the Fed Chair statement release and the FFTR decision; if the number of days were high (> 30 days), and those cases had a high jump surprise J_t from the market, there will be a need to condition the surprise analysis on the cases with only few days between the Chair statement release and the FFTR decision; however, we find that the more the number of the days between the Chair statement release and the FFTR decision, the lower the J_t variable is, signaling there is no need to condition,[24] and signaling as well that there might be an important information content for the market with the Chair statement.

[24]Still, we provide robustness checks in the Online Appendix to filter the sample to Fed Chair statements issued with 60 and 30 days or less before the FFTR change announcement. The mean number of days between the Fed Chair statement release and the FFTR decision is 15.93 days and the 90-*th* percentile is 37.5 days which means most of the sample is in a 40-day window before the FFTR change announcement.

Finally, the agreement between the *Hawkish/Dovish* tone of the Chair statement and the last monetary policy decision signals that changes in the tone by the Fed Chair signal a higher surprise variable J_t, indicating that changes in the *Hawkish/Dovish* tone might signal a shock.

[Place Figure A3 about here]

Table A1
Interest Rates and FOMC Decisions

The table shows statistics from the interest rates – Federal Funds, Eurodollar and Treasuries – during the period of the Fed Chair communications' sample, from January 01, 1971 to December 31, 2015. Since December 16, 2008, the FFTR is reported in a upper and lower limit, we consider the upper limit for our sample. Panel A shows the mean and the volatility of the interest rates, divided in two sub-panels: from January 01, 1971 to December 31, 1993 (before FOMC statements' availability), and between January 01, 1994 and December 31, 2015. Panel B shows the number of changes applied to the FFTR before and after February 01, 1994 when the FOMC statements were made immediately available after the FOMC Board FFTR decision, the average absolute change applied, and the unexpected 1-Month Eurodollar shock the day of the announcement. The standard error of the average is between parentheses.

Panel A: Interest Rates

	1971-1993		1994-2015	
	Mean Value	Volatility	Mean	Volatility
Federal Reserve				
FFTR	7.96	3.28	2.76	2.28
FFER	8.00	3.48	2.72	2.35
Short-Term				
1-Month Eurodollar Deposit	8.53	3.49	2.99	2.29
3-Month Eurodollar Deposit	8.70	3.39	3.12	2.26
6-Month Eurodollar Deposit	7.89	2.93	2.83	2.30
Long-term				
1-Year Treasury Constant Maturity	8.82	2.28	4.32	1.62
3-Year Treasury Constant Maturity	8.59	2.44	3.73	1.96
5-Year Treasury Constant Maturity	7.31	2.54	2.64	2.44
10-Year Treasury Constant Maturity	8.36	2.60	3.33	2.17

Panel B: FOMC Decisions

	# FFTR Changes	Average Abs FFTR Change (%)	1-Month Eurodollar Average Jump
Before February 1994			
Arthur Burns	63	0.54	1.18
		(0.08)	(0.12)
George W. Miller	20	0.19	0.65
		(0.03)	(0.11)
Paul Volcker	60	1.27	0.93
		(0.19)	(0.16)
Alan Greenspan (I)	40	0.28	0.37
		(0.02)	(0.06)
After February 1994			
Alan Greenspan (II)	47	0.33	0.19
		(0.02)	(0.02)
Ben Bernanke	13	0.44	1.10
		(0.06)	(0.39)
Janet Yellen	1	0.25	0.20
		(0.00)	(0.00)
Total	244		

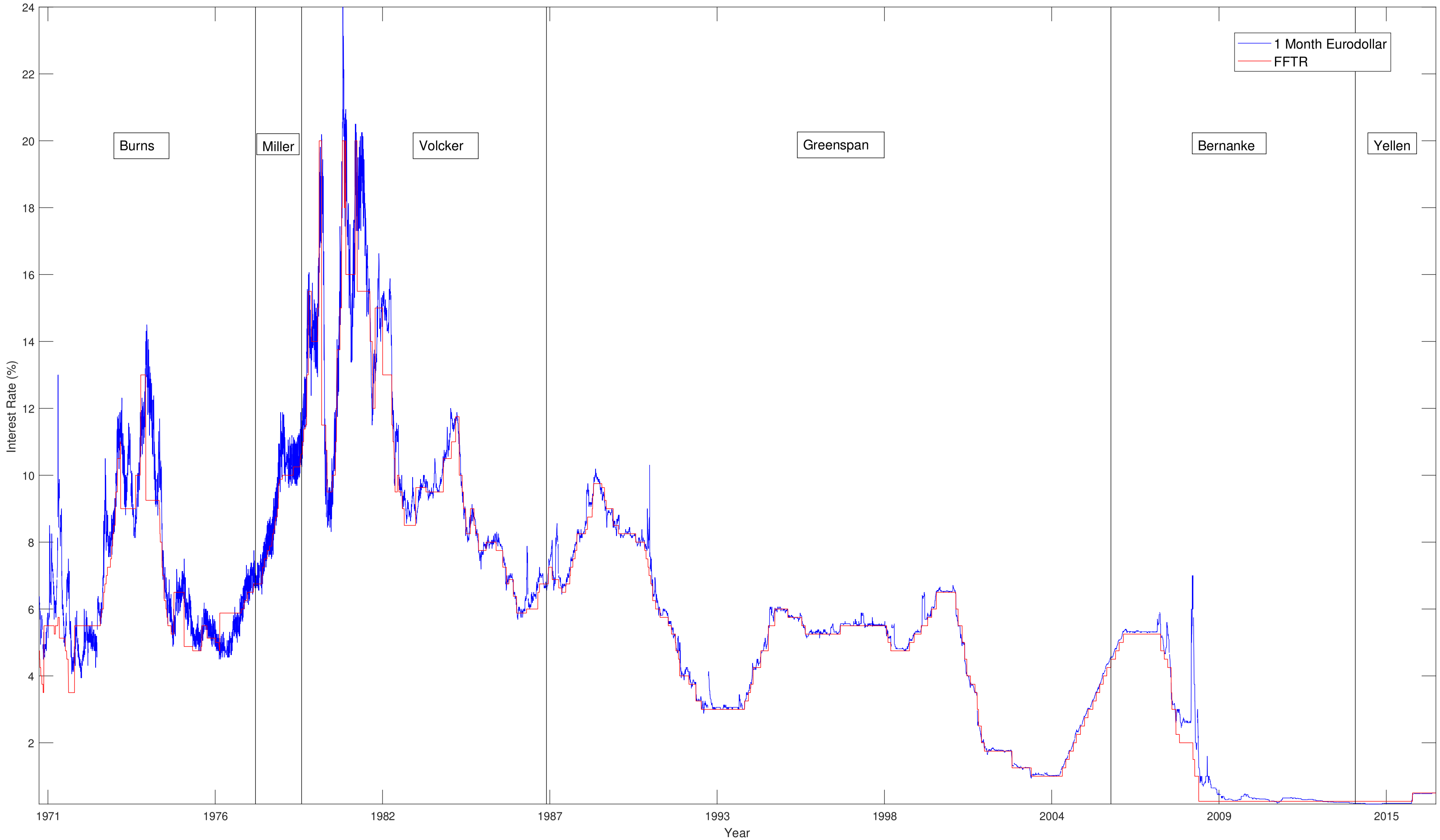
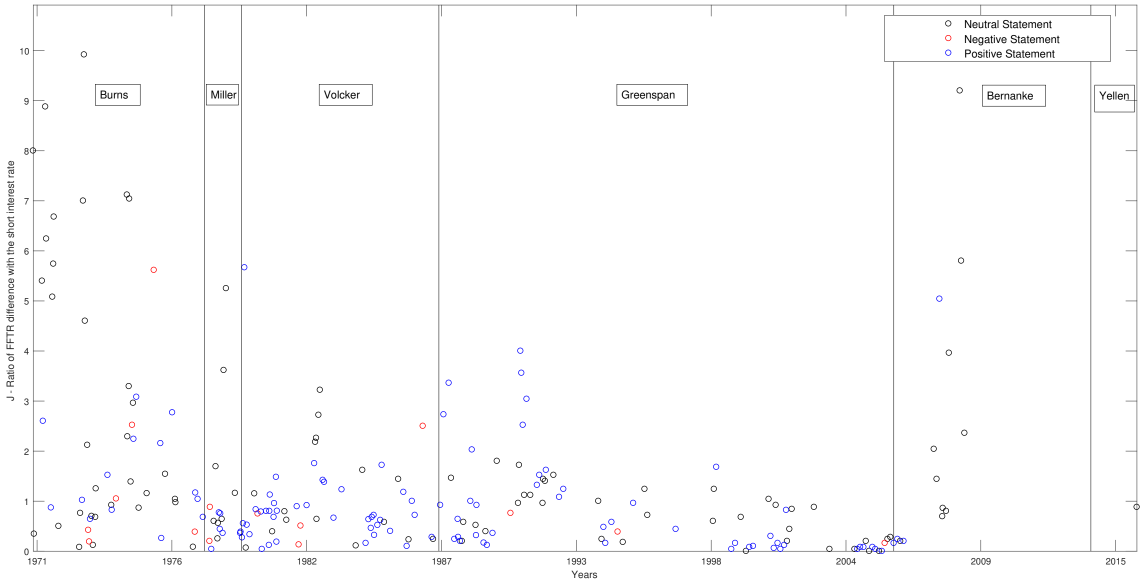
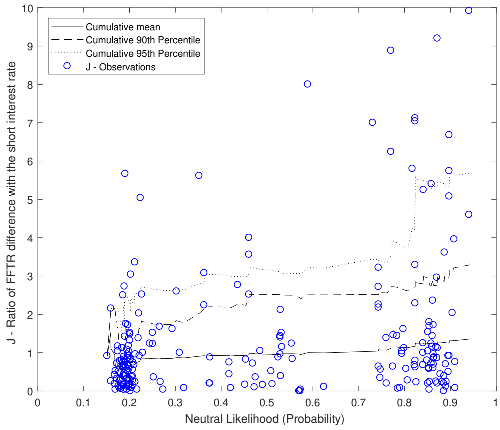


Figure A1. Interest rates (1-month Eurodollar – blue) and FFTR (red). The interest rates' sample is from January 01, 1971 to December 31, 2015. The graph is split by regions with the tenures of the different Fed Chairs.

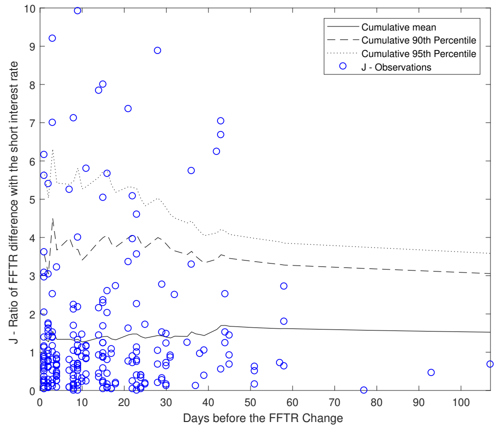


(a) Sentiment (Neutral, Positive, Negative) and FFTR-1-Month Eurodollar ratio (J)

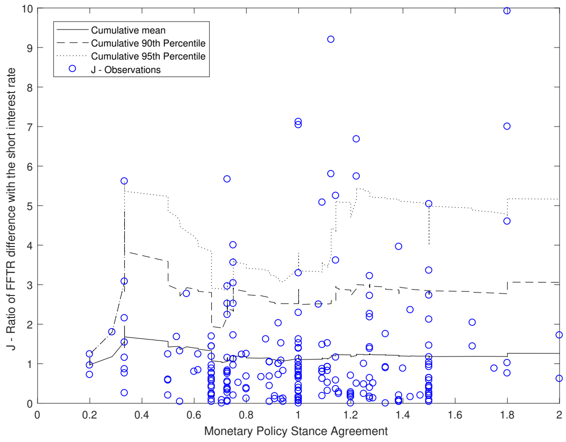
Figure A2. Jump surprise (J) ratio of difference between FFTR and the U.S. short-term interest rate (1-month Eurodollar) (in %) during the FFTR change announcement. Jump surprise (J) is calculated as in Equation (11). Sentiment is measured by the Naïve Bayes (NLTK) classifier. Jump surprises where the last Fed Chair statement was tagged as "Neutral" are in black, and when the last Fed Chair statement was tagged as "Non-neutral", it was tagged red for "Positive" ones, and blue for "Negative" ones. The data sample is from January 01, 1971 to December 31, 2015, and include $N = 244$ data points (FFTR changes occurred during the period).



(a) Sentiment (Neutral Likelihood)



(b) Days before FFTR change



(c) Agreement between the Fed Chair Statement Stance (H/D) and Previous Monetary Policy Decision

Figure A3. Jump surprise (J) of the U.S. short-term interest rate (1-month Eurodollar) (in %) during the FFTR change announcement. Jump surprise (J) is calculated as in Equation (11). Sentiment is measured by the Naïve Bayes (NLTK) classifier. The data sample is from January 01, 1971 to December 31, 2015, and include $N = 244$ data points (FFTR changes occurred during the period).

Appendix B. The Naïve Bayes of NLTK Sentiment Methodology

Following Pang et al. (2002), two sentiment databases (Polarity 2.0, and 3.0) were built by training a Naïve Bayes classifier on a database of 2000 movie critic reviews. Define the features as f_i, the Naïve Bayes training method consist of the estimation of the probability (prior and conditional) of the feature f_i of being classified in the category c, $P(f_i|c)$, using the fact that:

$$P_{NB}(c|d) = \frac{P(c)\left(\prod_{i=1}^{m} P(f_i|c)^{n_i(d)}\right)}{P(d)}, \tag{B1}$$

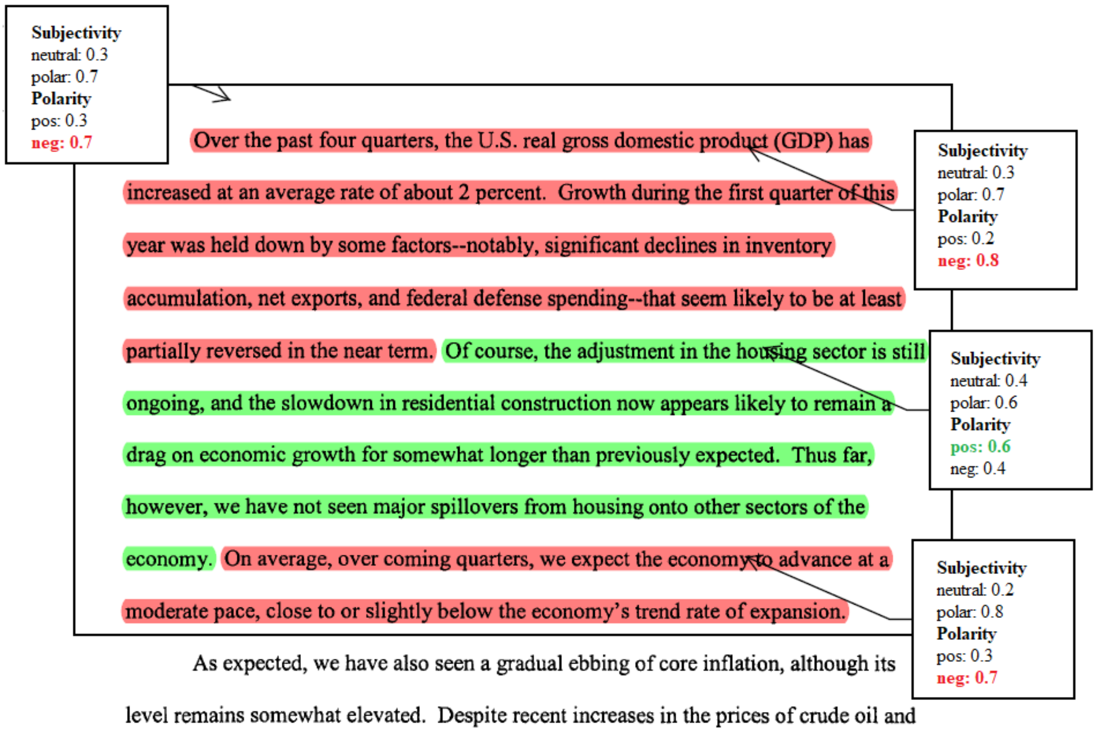
where d is the document containing the text being processed, f_i for $i = \{1, 2\}$ is the set of defining features, i.e., in this case the positive vs. negative or the neutral vs. non-neutral words, and $n_i(d)$ is the number of times f_i occurs in the document. Each document d will be represented by $d = (n_1(d), \ldots, n_3(d))$. The distinction among neutral and non-neutral words (the latter positive or negative) represents a key step in our research design: we are measuring the emotional effects that the markets may perceive from the Fed's official communications and one cannot rule out as a plausible outcome the fact that no such emotions are stirred by Fed's communications. As a result, the final tagging procedure encompasses two hierarchical steps: we first test the neutrality of a document; only if the document were to be classified as non-neutral, then the probability of a positive or negative tone of the document is estimated and recorded. Therefore our sentiment indicator may take three potential values:

- Neutral, when the sentiment of the document contains a mix of emotions (or lack of them), and the effective polarity of the document cannot be estimated,
- Not-neutral and Positive, when the set of expressions in the official communication is estimated to produce a positive emotion in the reader, and
- Not-neutral and Negative, when the set of expressions in the document is inferred to deliver negative feelings.

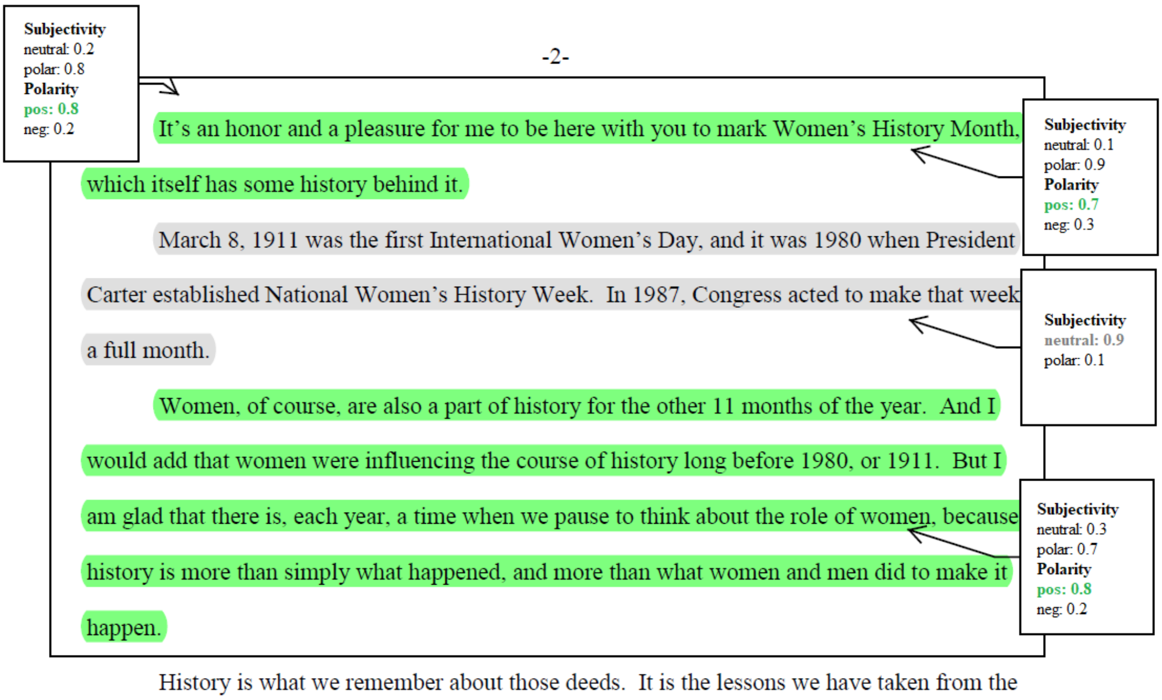
In this paper, we are mainly interested in analyzing the empirical effects of the neutrality of the Federal Reserve Chairpersons's statements: we therefore focus our attention on the existence or non-existence of sentiment as this represents the first stage of the hierarchical process of measurement illustrated above.

Figure B4 shows an example of the Naïve Bayes sentiment measure derived from two introductory sections of two different Fed Chair statements: the top panel B4a concerns the sentiment inferred from a section of Chair Bernanke's *"Remarks on the Housing Market and Subprime Lending"* from the *2007 International Monetary Conference* in Cape Town, South Africa, delivered on June 5, 2007. The bottom panel B4b illustrates the same methodology with reference to Janet Yellen's remarks titled *"Women's History Month Reception"* delivered in Washington D.C., U.S., on March 25, 2014. Interestingly, June 2007 was the year that preceded the great financial crisis, when the Federal Reserve started to raise the alarm for the possibly critical conditions of the US credit markets and this is noticeable from the introduction of the document that in fact receives a non-neutral, negative polarity tone classification with a likelihood of 0.7. In contrast, Yellen's remarks in June 2014 are classified as more neutral or even positive. As such Chair Yellen's statement is classified by our algorithm (with a likelihood of 0.8). It is plausible that as the financial crisis eased after 2010, there was decreasing pressure for the media to gain access to the Fed's opinions about the future outlook of the economy, and as a result considerable more space for the Chairperson at that time to speak about the peculiar details of the public event she had been invited to.

[Place Figure B4 about here]



(a) Sentiment of a Fed Chair statement extract (Remarks) from June 05, 2007.



(b) Sentiment of a Fed Chair statement extract (Remarks) from March 25, 2014.

Figure B4. The Fed Chair Statements' Sentiment. The figure shows two examples of the Naïve Bayes (NLTK) classifier output. Sub-sections of the extracts were analyzed separately, and the output reported in the left-side box. Sections of the text classified as Neutral are highlighted in gray, Positive in green, and Negative in red. A text classified as Neutral will get the "Neutral" likelihood over 0.5. A text classified as "Not-Neutral" will get a "Positive" or "Negative" tag. The sentiment of the full extract (the three paragraphs) is in the left-side box.

$$P_{\text{TETLOCK}} = \frac{\text{number of neutral words as classified by Harvard IV}}{\text{total number of words in a statement}}, \tag{B2}$$

where the neutral words are simply all words that do not belong in the Harvard IV positive/negative list. We also use the percentage of neutral words in a statement, where neutrality is established using Loughran and McDonald (2011)'s dictionary:

$$P_{\text{L\&M}} = \frac{\text{number of neutral words as classified by Loughran-McDonald dictionary}}{\text{total number of words of the statement}}. \tag{B3}$$

The Common Features in Different Sentiment Measurent Methods

Table B2 shows the proportion of common words in the intersection of words by using the different sentiment methods. The proportion is normalized by including only positive or negative words in the counting process. We can observe that there are common words in the statements, that will be tagged as positive for both dictionaries.

[Place Table B2 about here]

We observe in Table B2 that the three methods used (one main method and the two proxies) to measure the neutral sentiment converge in the words that define the positive/negative (emotion) tone of a document.

Table B2
Most Frequent Positive and Negative Words in the Statements

The table shows the most sentiments' significant words extracted from the FOMC and Fed Chair statements. The FOMC statements' sample is from February 01, 1994 to December 31, 2015 (first FOMC statement was made available to the public since January 01, 1994), and the Fed Chair statements' sample is from January 01, 1971 to December 31, 2015. The words are extracted by cross-checking the words of every document with the Harvard IV (Tetlock et al., 2008) and Loughran and McDonald (2011) dictionaries and counting the repetitions. The cumulative percentage is relative to the total words recognized by the dictionary (conditional frequency). Positive and common extracted words from both dictionaries are highlighted in green, negative and common extracted words from both dictionaries are highlighted in red.

Panel A: Positive

FOMC Statements				Federal Reserve Statements			
Harvard IV (Tetlock)	Cumulative %	Loughran & McDonald	Cumulative %	Harvard IV (Tetlock)	Cumulative %	Loughran & McDonald	Cumulative %
STABILITY	7.62%	STABILITY	17.40%	IMPORTANT	1.33%	GREATER	3%
SUPPORT	12.86%	STABLE	24.63%	EVEN	2.64%	STABILITY	5%
MODERATE	17.83%	IMPROVED	31.12%	INTEREST	3.87%	BETTER	7%
FOSTER	22.61%	PROGRESS	37.32%	SIGNIFICANT	5.01%	STRONG	10%
HELP	26.81%	IMPROVEMENT	43.51%	CREDIT	6.13%	GOOD	12%
CONSISTENT	30.49%	EXCEPTIONALLY	49.56%	STABILITY	7.16%	ABLE	14%
PRODUCTIVITY	33.98%	STRONGER	54.28%	SUPPORT	8.17%	EFFECTIVE	15%
ACCOMMODATION	37.34%	IMPROVE	58.55%	LIKE	9.13%	BEST	17%
STABLE	40.50%	ATTAINMENT	62.39%	EXPERIENCE	10.04%	PROGRESS	19%
UTILIZATION	43.60%	GAINS	65.93%	VALUE	10.92%	GREAT	21%
INTEREST	46.58%	STRENGTHENS	68.88%	ABILITY	11.79%	OPPORTUNITY	23%
IMPROVEMENT	49.29%	STRENGTH	71.24%	HELP	12.66%	DESPITE	25%
CREDIT	51.94%	DESPITE	73.30%	KNOW	13.50%	GAINS	26%
OBJECTIVE	54.20%	STRENGTHEN	75.22%	ABLE	14.31%	IMPROVE	28%
ENSURE	56.27%	STRENGTHENING	77.14%	BEST	15.12%	IMPROVED	29%
APPROACH	58.27%	EFFECTIVE	79.06%	EFFECTIVE	15.92%	ACHIEVE	31%
EVEN	60.21%	STRONG	80.83%	MEET	16.67%	STABLE	32%
ASSET	62.14%	FAVORABLE	82.45%	OPPORTUNITY	17.41%	PLEASED	34%
IMPROVE	64.02%	IMPROVING	84.07%	CONSISTENT	18.14%	IMPROVEMENT	35%
ROBUST	65.70%	BEST	85.40%	PRODUCTIVITY	18.86%	OPPORTUNITIES	36%
UPSIDE	67.38%	STRENGTHENED	86.73%	SHARE	19.56%	SUCCESS	38%
ATTAINMENT	69.06%	IMPROVES	87.91%	HOME	20.25%	STRENGTH	39%
GENERATE	70.67%	STABILIZE	88.94%	APPROACH	20.91%	EFFICIENCY	40%
RETURN	72.22%	STABILIZING	89.97%	IMPROVE	21.56%	BENEFIT	41%
BLOOM	73.71%	CONFIDENT	91.00%	RETURN	22.20%	ENCOURAGING	42%
SIGNIFICANT	75.06%	ADVANCES	92.04%	IMPORTANCE	22.84%	IMPROVING	43%
MODEST	76.29%	ADVANCING	92.92%	ACHIEVE	23.47%	ACHIEVING	44%
COMPENSATION	77.39%	SMOOTH	93.81%	SAVINGS	24.09%	STRONGER	45%
EFFICACY	78.49%	BETTER	94.69%	STABLE	24.70%	SUCCESSFUL	46%
NORMAL	79.46%	ACHIEVED	95.28%	EQUITY	25.29%	IMPROVEMENTS	47%

Panel B: Negative

FOMC Statements				Federal Reserve Statements			
Harvard IV (Tetlock)	Cumulative %	Loughran & McDonald	Cumulative %	Harvard IV (Tetlock)	Cumulative %	Loughran & McDonald	Cumulative %
INFLATION	30.24%	UNEMPLOYMENT	7.39%	DIFFICULT	2.44%	DIFFICULT	1.35%
LOW	47.46%	DECLINE	11.96%	INFLATION	4.37%	PROBLEMS	2.65%
DECLINE	54.30%	SLOWED	15.81%	COST	6.21%	DECLINE	3.77%
STERN	59.60%	WEAK	19.65%	LOW	8.02%	PROBLEM	4.83%
EXCESS	63.13%	SLOW	22.90%	TURN	9.76%	CONCERN	5.85%
DECREASE	66.00%	DECLINES	26.14%	DECLINE	11.43%	LATE	6.84%
COST	68.65%	DIMINISHED	29.39%	FOREIGN	13.02%	CRITICAL	7.84%
RELUCTANT	70.64%	DEPRESSED	32.64%	PROBLEM	14.59%	CONCERNS	8.81%
TURN	72.63%	DOWNWARD	35.89%	COMPETITIVE	16.10%	UNEMPLOYMENT	9.69%
LIMIT	74.39%	DECLINED	38.85%	DEAL	17.41%	QUESTION	10.52%
UNDERMINE	76.16%	WEAKNESS	41.80%	COMPLEX	18.69%	SHARPLY	11.32%
EXECUTE	77.70%	IMBALANCES	44.61%	FORCE	19.84%	FORCE	12.12%
STRESS	79.25%	STRAINS	47.42%	RECESSION	20.98%	RECESSION	12.92%
ORDER	80.57%	CONCERNED	50.07%	AVOID	22.11%	DIFFICULTIES	13.71%
CRUDE	81.90%	EASING	52.44%	DEFICIT	23.23%	SERIOUS	14.49%
FOREIGN	83.00%	SLOWING	54.51%	ORDER	24.34%	DEFICIT	15.27%
ADVERSE	84.11%	UNDERUTILIZAT	56.43%	COMPETITION	25.43%	CRISIS	16.01%
ABATE	85.21%	SLOWER	58.35%	CRISIS	26.51%	DECLINED	16.73%
NEED	86.09%	LATE	59.97%	EXCESSIVE	27.56%	LOSSES	17.44%
FAIL	86.98%	PERSISTENTLY	61.60%	DOUBT	28.56%	EXCESSIVE	18.15%
TRAGIC	87.86%	DISRUPTIONS	63.07%	HARD	29.56%	DECLINES	18.86%
CRISIS	88.52%	CONCERN	64.55%	ADVERSE	30.54%	DOUBT	19.56%
TURMOIL	89.18%	DIMINISHING	65.88%	WAR	31.50%	QUESTIONS	20.25%
TEMPORARILY	89.85%	CONTRACTION	67.21%	SEVERE	32.44%	CHALLENGES	20.92%
OMIT	90.51%	RELUCTANT	68.54%	FAILURE	33.35%	ADVERSE	21.59%
SLUGGISH	91.17%	UNWELCOME	69.72%	LIMIT	34.25%	DEFICITS	22.26%
DEPENDENT	91.61%	WEAKENED	70.90%	EXCESS	35.14%	SLOW	22.93%
BIT	92.05%	DECLINING	72.08%	LOSS	36.00%	CONCERNED	23.57%
SPOT	92.49%	SHORTFALL	73.26%	SERVE	36.81%	SEVERE	24.21%
EROSION	92.94%	UNDERMINE	74.45%		37.61%	FAILURE	24.84%

Appendix C. Analytical Sentiment: Hawkish/Dovish Fed Chair Statement Stance

Table C3
Hawkish and Dovish Words in the Statements

The Table shows the Hawkish and Dovish related words extracted as synonyms of the Tight, Tightening, Ease, and Easing words from the Roget's 21st Century Thesaurus (Kipfer, 2005). Only 1-grams (one word expression) are included (Two 2-grams and one 3-gram where excluded).

Panel A: Monetary Policy					
Hawkish (Tight, Tightening)			Dovish (Ease, Easing)		
BIND	INVULNERABLE	TOUGHEN	ABATE	IMPROVE	RESTFULNESS
BOUND	NARROW	UNBENDING	AFFLUENCE	INACTIVITY	SATISFACTION
CLASPED	PINCH	UNYIELDING	AID	INERTIA	SECURITY
CLENCH	PRESSURE		ALLAY	INERTNESS	SERENITY
CLOSE	QUICK		AMELIORATE	LEISURE	SIMPLIFY
CLOSE-FITTING	RIGID		ANESTHETIZE	LESSEN	SLACKEN
COMPACT	RIGIDIFY		APPEASE	LIFT	SMOOTH
COMPRESS	SCREW		ASSIST	LIGHTEN	SOFTEN
CONDENSE	SECURE		ASSUAGE	LUXURY	SOOTHE
CONGEAL	SET		ATARAXIA	MELIORATE	SPEED
CONSTRICTED	SKINTIGHT		CALM	MITIGATE	STILL
CONTRACT	SOLID		CALMNESS	MODERATE	SUPINITY
CONTRACTED	SQUEEZE		CHEER	MOLLIFY	TRANQUILITY
CRAMP	STABLE		COMFORT	NURSE	TRANQUILIZE
CRAMPED	STEADY		CONTENT	PACIFY	UNTIGHTEN
CROWDED	STIFF		CONTENTMENT	PALLIATE	
CRUSH	STIFFEN		CURE	PASSIVITY	
DENSE	STRAIN		DISBURDEN	PROMOTE	
DRAWN	STRAINED		DISENGAGE	PROSPERITY	
ENDURING	STRANGLE		DOCTOR	QUIET	
ESTABLISHED	STRETCH		EASINESS	QUIETNESS	
FAST	STRETCHED		ENJOYMENT	QUIETUDE	
FASTEN	STRONG		EXPEDITE	RELAX	
FIRM	STURDY		FACILITATE	RELAXATION	
FIX	TAUT		FORWARD	RELEASE	
FIXED	TAUTEN		FREE	RELENT	
GRIP	TENACIOUS		FURTHER	RELIEVE	
HARDEN	TENSE		GRATIFICATION	REPOSE	
HIDEBOUND	THICK		HAPPINESS	REQUIESCENCE	
INFLEXIBLE	TIGHTENED		IDLENESS	REST	

Appendix D. Endogeneity: Identification diagram, Granger causality tests, and VAR Conditional on FOMC meetings with FFTR Changes, and interest rates environment per Fed Chair tenure

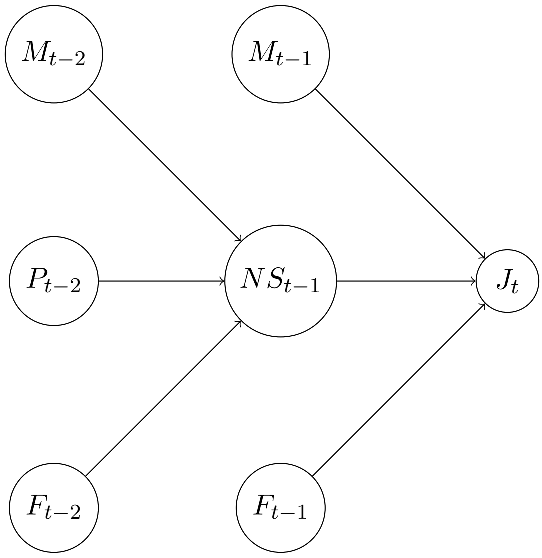


Figure D5. Identification diagram. M_i, F_i, P_i, NS_i, and J_i represent macroeconomic variables, financial variables, personal characteristics, Fed Chair neutral sentiment variable, and jump surprise at time i. Jump surprise (J) is calculated as in Equation (11). Sentiment likelihood is measured by the Naïve Bayes (NLTK) classifier, the Harvard IV (Tetlock, 2007) and Loughran and McDonald (2011) dictionaries as in Equations (B1), (B2), and (B3). The data sample is from January 01, 1971 to December 31, 2015.

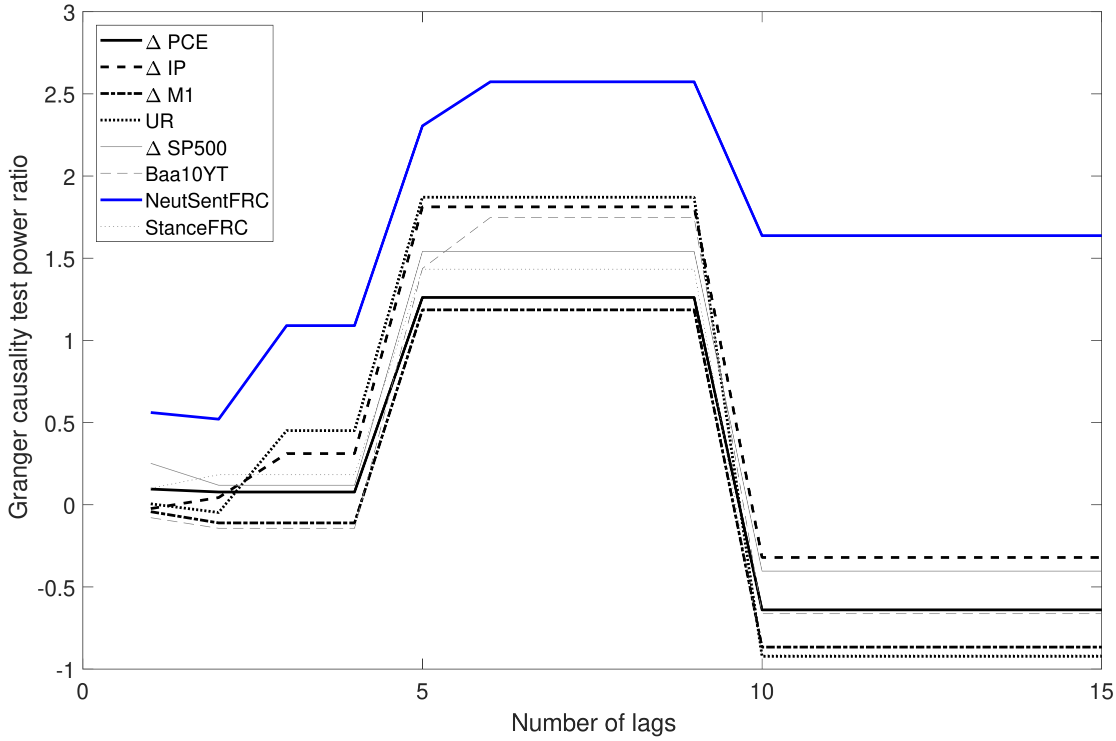


Figure D6. Granger causality test. The Granger causality tests power ratio are equal to $r_{GC} = (F - \text{critical\_value})/\text{critical\_value}$, where F is the resulting F-statistic, and critical_value is the F-distribution critical value at a p-value=0.01 over which the null hypothesis $H0$ of "no-causality" is rejected (The null hypothesis ($H0$) is that the variable to be tested – macroeconomic, financial, sentiment – does not Granger cause the jump surprise J_t. A rejection of the null hypothesis signals the existence of Granger causality. Real causality cannot be tested, but was built on the structural framework under which the Fed Chair disseminates his statements). The data sample is from January 01, 1971 to December 31, 2015, and include $N = 244$ data points (FFTR changes occurred during the period).

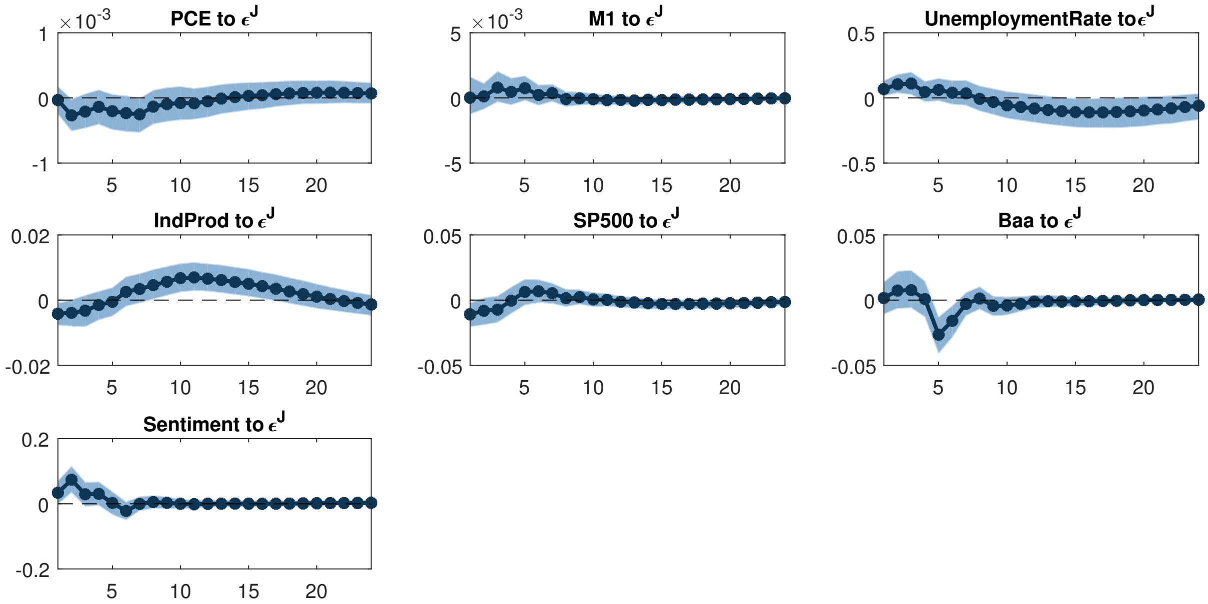


Figure D7. SVAR impulse response function. The structural-VAR (SVAR) considers the Jump surprise as the shock (instead of the FFTR), and analyze the effects of the macroeconomic variables (inflation - PCE, liquidity – M1, growth/industrial production – IndProd, and unemployment rate – UnemploymentRate), and the financial variables (stock market – SP500 and credit market – Baa). The periods (x-axis) are conditional on a FFTR change; then $t = 1, 2, \ldots, 20$ represents the next FFTR change decision. The data sample is from January 01, 1971 to December 31, 2015, and include $N = 230$ data points (FFTR weekly changes occurred during the period).

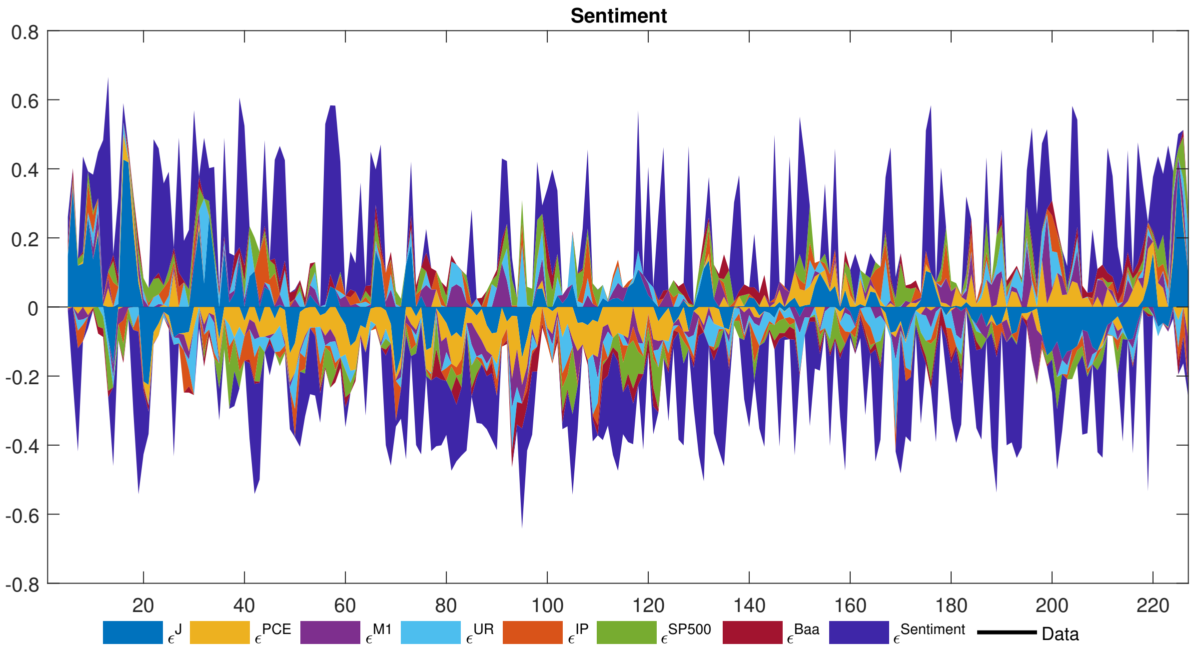


Figure D8. SVAR historical decomposition The structural-VAR (SVAR) considers the Jump surprise as the shock (instead of the FFTR), and analyze the effects of the macroeconomic variables (inflation - PCE, liquidity – M1, growth/industrial production – IndProd, and unemployment rate – UnemploymentRate), and the financial variables (stock market – SP500 and credit market – Baa). The periods (x-axis) are conditional on a FFTR change; then $t = 1, 2, \ldots, 20$ represents the next FFTR change decision. The data sample is from January 01, 1971 to December 31, 2015, and include $N = 230$ data points (FFTR weekly changes occurred during the period).

Appendix E. Robustness Checks: FOMC Statements Sentiment and FFTR, FFTR Changes and Federal Reserve Chair Statements' Sentiment Descriptive Statistics

We check on FOMC statements sentiment and changes on the FFTR. Table E4 shows the results when analyzing the FOMC statement neutral sentiment effect. Column (1) has the logit regressions with the base model in Equation (15) without the FOMC last statement neutral sentiment, and columns (2), (3), and (4) show the results when including the FOMC neutral sentiment measured by the Naïve Bayes classifier, the Harvard IV (Tetlock, 2007), and the Loughran and McDonald (2011) dictionaries' methods. We observe that the sentiment of the FOMC statements seems not to have any significant relationship with the surprise jump variable J_t when controlling for the macroeconomic and financial market state variables, that altogether can explain with a deviance of 37.99, most of the surprise, with the exception when the neutral sentiment is measured by the Loughran and McDonald (2011) dictionary as in Equation (B3); the neutral sentiment still not being significant in that specification. Although we find some sentiment in the FOMC statements (Table II), it is not relevant in the FFTR discovery process by the market. We provide two interpretations of these results: (i) the institutional mechanism of communication "enhancement" of the Federal Reserve during the FOMC meeting eliminates any signs of sentiment (emotion) that could signal more information that the Federal Reserve wants to signal, and (ii) the market might have absorbed previously any information by the FOMC board members' previous week statements' release. This result complements Lucca and Trebbi (2009) by exploring the market surprise at the FOMC neutral sentiment content: in Lucca and Trebbi (2009) the FOMC statements' analytical sentiment (inflation/monetary policy stance) is relevant for the market; we find that emotional sentiment is not.

[Place Table E4 about here]

Next, we explore the FOMC and Fed Chair statements sentiment, conditional on the FFTR changes.In Section IV and Section V we analyzed the effects of the statements sentiment tone in the interest rates surprise, after the FFTR decision, to test the hypothesis of Fed Chair statements sentiment origin, if it's induced by personal choice or it's a consequence of the circumstances; for that reason we need to explore the statements sentiment during different FFTR decisions. Table E5 and Table E6 show the results for the FOMC and the Fed Chair statements sentiment respectively. FOMC statements Table E5 is divided by sub-panels per business cycle expansionary/recessionary periods, and Fed Chair statements Table E6 is divided in sub-panels per different Fed Chair tenure period; every table presents additional panels for each of the different sentiment measures methodologies. Results show that Fed Chair statements sentiment conditional on FFTR changes seems not to have a clear trend when we condition on the FFTR changed/unchanged result by neutral/emotional categories. FOMC statements conditional on FFTR changed/unchanged result seem not to have a difference by neutral/emotional categories, nor by expansionary/recessionary periods, with the exception of FFTR changes beyond 50bp which report a sentiment trend disagreement between the Naïve Bayes and the dictionary methods: the FFTR change amount decision seems not to have any relationship with the sentiment tone/emotional strength of the FOMC and Fed Chair statements.

[Place Table E5 about here]

[Place Table E6 about here]

Figures E9 and E10 show the scatter plot equivalent to Figure A3a, but with the sentiment measured by the Harvard IV (Tetlock, 2007) dictionary, and the Loughran and McDonald (2011) dictionary methods. We observe the a non-linear relationship with the neutral sentiment, observed previously with the Naive Bayes classifier measure, is preserved: an increase in the interest rate market jump surprise J_t seems to be associated with an increase of the neutral sentiment.

[Place Figure E9 about here]

[Place Figure E10 about here]

Table E4
FFTR Change and FOMC Statements' Sentiment

The table shows the logit regressions of the jump surprise of the 1-Month Eurodollar interest rate (J) during the FFTR change announcement from model in Equation (15). The FOMC statements' sample is from February 01, 1994 to December 31, 2015 (first FOMC statement was made available to the public since January 01, 1994). Panel A shows the full model in Equation (15). Column (1) is model in Equation (15) without the neutral sentiment variable, and columns (2), (3) and (4) is model in Equation (15) with neutral sentiment included, measured by the Naïve Bayes classifier, the Harvard IV (Tetlock, 2007), and the Loughran and McDonald (2011) dictionaries. Macroeconomic variables with Δ are calculated with the first difference of the variable with respect to the previous announcement (monthly). The $*$, $**$, and $***$ represents statistical significance at a p-value of $0.1, 0.05$ and 0.01, respectively. The standard error is in parentheses.

Panel A: Jump Surprise J_t Regressed by Macroeconomic, and FOMC Neutral Sentiment

		Naïve Bayes	Harvard IV (Tetlock)	Loughran & McDonald
	(1)	(2)	(3)	(4)
Constant	-2.7	-2.8	-3.8	41.4
	(4.0)	(5.0)	(13.9)	(27.5)
Macroeconomic				
Business Cycle	0.0	0.1	0.1	0.2
	(0.4)	(0.7)	(0.4)	(0.5)
Δ PCE	26.4	25.6	31.2	-9.0
	(216.3)	(218.2)	(223.6)	(261.3)
Δ Industrial Production	-1.7	-1.5	-1.6	20.6
	(15.8)	(17.2)	(15.9)	(21.7)
Δ M1	-4.4	-4.7	-4.1	11.7
	(40.4)	(41.8)	(40.4)	(43.3)
Unemployment rate	0.0	0.0	0.0	0.2
	(0.8)	(0.8)	(0.9)	(0.9)
Financial				
Δ SP500	-3.3	-3.2	-3.1	-7.0
	(6.9)	(7.0)	(7.2)	(7.7)
Baa10YT	15.1**	15.1**	15.2**	14.4**
	(6.2)	(6.3)	(6.2)	(6.3)
Communication's Sentiment				
FOMC Statement Neutral Sentiment		0.1	1.1	-48.5
		(2.7)	(13.5)	(29.9)
N(weeks)	59	59	59	59
Deviance	37.99	37.98	37.98	35.09
Fit improvement	-	0.00	0.00	0.08

Table E5
FFTR Change and FOMC Statements' Sentiment

The table shows the sentiment of the FOMC statements conditional on changes to the FFTR. FOMC statements' sample is from February 01, 1994 to December 31, 2015 (first FOMC statement was made available to the public since January 01, 1994). Panel A shows the average sentiment Likelihood per document with the Naïve Bayes classification mehtod. Panel B shows the average tf.idf function per document normalized to the total tf.idf per tag using Harvard IV (Tetlock et al., 2008) dictionary. Panel C shows the average tf.idf function per document normalized to the total tf.idf per tag using Loughran and McDonald (2011) dictionary. Panels are divided by NBER defined business cycles, expansion and recession periods (pro-cyclical, counter-cyclical). The standard error of the average is between parentheses. Subsets with one observation report an standard error of zero.

	Full term 1994-2009			Expansion Feb 1994 - Mar 2001			Recession Apr 2001 - Nov 2001			Expansion Dec 2001 - Dec 2007			Recession Jan 2008 - June 2009		
Panel A: Statements' Sentiment - Naïve Bayes															
	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg
FFTR unchanged	53.0	73.7	26.3	46.0	72.8	27.2	43.4	80.7	19.3	53.9	74.7	25.3	71.3	73.2	26.8
	(2.7)	(1.1)	(1.1)	(3.8)	(1.8)	(1.8)	(23.2)	(4.7)	(4.7)	(4.5)	(2.0)	(2.0)	(5.6)	(2.1)	(2.1)
FFTR changed															
≤ 25bp	50.4	74.6	22.9	51.1	78.2	21.8	20.6	69.7	30.3	50.8	72.1	23.2	90.8	82.5	17.5
	(4.8)	(2.8)	(2.1)	(8.1)	(3.4)	(3.4)	(1.1)	(11.4)	(11.4)	(6.3)	(4.5)	(3.0)	(0.0)	(0.0)	(0.0)
25bp–50bp	56.7	76.4	23.6	33.0	77.2	22.8	60.0	75.4	24.6	88.4	85.6	14.4	85.1	69.9	30.1
	(8.2)	(2.8)	(2.8)	(9.8)	(4.3)	(4.3)	(16.9)	(6.6)	(6.6)	(2.0)	(4.1)	(4.1)	(1.7)	(3.5)	(3.5)
>50bp	69.0	45.8	29.2	18.8	0.0	0.0	–	–	–	–	–	–	85.8	61.1	38.9
	(16.8)	(15.7)	(10.4)	(0.0)	(0.0)	(0.0)	–	–	–	–	–	–	(0.4)	(5.2)	(5.2)
Panel B: Statements' Sentiment - Harvard IV (Tetlock)															
	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg
FFTR unchanged	78.5	14.7	6.8	78.1	14.7	7.1	78.8	16.7	4.5	79.0	14.5	6.5	78.6	14.5	6.9
	(0.3)	(0.2)	(0.2)	(0.5)	(0.3)	(0.3)	(2.2)	(1.4)	(1.1)	(0.5)	(0.4)	(0.4)	(0.6)	(0.7)	(0.4)
FFTR changed															
≤ 25bp	77.3	13.8	6.4	79.1	14.0	6.9	78.8	15.4	5.9	75.6	13.5	6.2	83.2	13.7	3.0
	(2.1)	(0.5)	(0.3)	(0.6)	(0.7)	(0.4)	(2.3)	(1.7)	(0.6)	(3.8)	(0.9)	(0.5)	(0.0)	(0.0)	(0.0)
25bp–50bp	78.8	15.1	6.1	78.6	15.4	6.1	78.4	15.9	5.8	80.4	14.3	5.3	78.9	13.8	7.3
	(0.6)	(0.6)	(0.5)	(0.5)	(1.0)	(0.9)	(1.4)	(0.9)	(1.4)	(3.5)	(3.2)	(0.3)	(1.5)	(1.4)	(0.2)
>50bp	58.9	10.1	6.0	0.0	0.0	0.0	–	–	–	–	–	–	78.6	13.4	8.0
	(19.7)	(3.4)	(2.0)	(0.0)	(0.0)	(0.0)	–	–	–	–	–	–	(1.1)	(0.9)	(0.3)
Panel C: Statements' Sentiment - Loughran & McDonald)															
	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg
FFTR unchanged	90.8	3.6	5.6	90.6	3.7	5.6	92.8	3.6	3.7	91.2	3.6	5.2	90.1	3.2	6.6
	(0.2)	(0.1)	(0.2)	(0.2)	(0.1)	(0.3)	(1.3)	(0.5)	(0.9)	(0.3)	(0.2)	(0.3)	(0.4)	(0.2)	(0.5)
FFTR changed															
≤ 25bp	89.2	3.4	4.8	91.4	3.6	5.0	90.8	3.8	5.4	87.1	3.4	4.7	96.1	1.4	2.5
	(2.4)	(0.2)	(0.3)	(0.4)	(0.2)	(0.4)	(0.5)	(0.0)	(0.5)	(4.4)	(0.3)	(0.4)	(0.0)	(0.0)	(0.0)
25bp–50bp	90.8	3.9	5.4	91.4	3.7	4.9	91.1	4.1	4.8	91.0	5.1	3.9	88.6	2.9	8.5
	(0.5)	(0.3)	(0.6)	(0.6)	(0.5)	(0.8)	(1.2)	(0.6)	(1.0)	(1.3)	(1.9)	(0.6)	(0.1)	(0.5)	(0.4)
>50bp	66.9	2.1	6.0	0.0	0.0	0.0	–	–	–	–	–	–	89.1	2.8	8.1
	(22.3)	(0.7)	(2.0)	(0.0)	(0.0)	(0.0)	–	–	–	–	–	–	(0.5)	(0.4)	(0.5)

Table E6

FFTR Change and Federal Reserve Chair Statements' Sentiment

The table shows the sentiment of the Fed Chair statements conditional on changes to the FFTR. The Fed Chair statements sample is from January 01, 1971 to December 31, 2015. Panel A shows the average sentiment Likelihood per document with the Naïve Bayes classification mehtod. Panel B shows the average tf.idf function per document normalized to the total tf.idf per tag using Harvard IV (Tetlock et al., 2008) dictionary. Panel C shows the average tf.idf function per document normalized to the total tf.idf per tag using Loughran and McDonald (2011) dictionary. Panels are divided by Chair of the Federal Reserve. The standard error of the average is between parentheses. Subsets with one observation report an standard error of zero.

	Arthur Burns			George W. Miller			Paul Volcker			Alan Greenspan			Ben Bernanke			Janet Yellen		
Panel A: Statements' Sentiment - Naïve Bayes																		
	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg
FFTR unchanged	63.5	66.7	27.8	57.8	70.6	29.4	40.3	69.6	25.8	45.6	71.6	27.2	64.3	71.1	25.0	55.0	73.1	26.9
	(2.9)	(2.1)	(1.5)	(6.1)	(2.7)	(2.7)	(2.9)	(2.2)	(1.5)	(2.3)	(1.2)	(1.0)	(3.1)	(2.2)	(1.6)	(5.6)	(2.4)	(2.4)
FFTR changed																		
≤ 25bp	59.4	64.8	29.5	55.7	65.5	34.5	40.6	66.5	22.4	46.0	73.3	25.2	54.4	78.1	21.9	52.5	72.2	27.8
	(4.8)	(3.5)	(2.7)	(6.3)	(3.7)	(3.7)	(10.4)	(9.3)	(5.0)	(3.3)	(2.0)	(1.7)	(15.1)	(4.8)	(4.8)	(0.0)	(0.0)	(0.0)
25bp–50bp	59.8	51.0	11.5	–	–	–	39.6	73.8	26.2	46.5	75.3	24.7	86.4	72.8	27.2	–	–	–
	(12.4)	(15.1)	(3.9)	–	–	–	(6.0)	(2.4)	(2.4)	(6.7)	(3.0)	(3.0)	(1.8)	(3.8)	(3.8)	–	–	–
>50bp	71.6	65.2	28.5	25.3	89.6	10.4	30.2	70.2	26.5	18.8	0.0	0.0	85.8	61.1	38.9	–	–	–
	(6.0)	(5.5)	(3.9)	(0.0)	(0.0)	(0.0)	(4.0)	(3.6)	(2.9)	(0.0)	(0.0)	(0.0)	(0.4)	(5.2)	(5.2)	–	–	–
Panel B: Statements' Sentiment - Harvard IV (Tetlock)																		
	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg
FFTR unchanged	73.7	13.4	7.5	76.0	15.9	8.1	72.9	14.8	7.7	77.5	14.3	6.9	75.4	14.5	6.2	80.0	13.8	6.2
	(1.8)	(0.4)	(0.3)	(0.7)	(0.6)	(0.3)	(1.7)	(0.4)	(0.2)	(0.8)	(0.2)	(0.2)	(1.8)	(0.5)	(0.3)	(0.7)	(0.6)	(0.4)
FFTR changed																		
≤ 25bp	72.7	13.8	7.8	77.4	15.1	7.5	67.7	14.8	6.4	77.9	13.5	7.0	80.9	14.5	4.6	81.9	12.1	6.0
	(2.9)	(0.6)	(0.4)	(0.5)	(0.3)	(0.3)	(8.5)	(2.0)	(1.0)	(1.3)	(0.4)	(0.2)	(0.8)	(1.1)	(0.7)	(0.0)	(0.0)	(0.0)
25bp–50bp	49.3	8.5	4.7	–	–	–	77.1	15.0	7.9	78.4	15.0	6.5	80.1	13.1	6.7	–	–	–
	(14.4)	(2.5)	(1.4)	–	–	–	(0.7)	(0.4)	(0.4)	(0.4)	(0.5)	(0.4)	(1.6)	(1.2)	(0.6)	–	–	–
>50bp	72.3	13.4	8.1	74.3	15.3	10.4	73.7	14.8	8.3	0.0	0.0	0.0	78.6	13.4	8.0	–	–	–
	(4.8)	(1.0)	(0.6)	(0.0)	(0.0)	(0.0)	(2.5)	(0.6)	(0.4)	(0.0)	(0.0)	(0.0)	(1.1)	(0.9)	(0.3)	–	–	–
Panel C: Statements' Sentiment - Loughran & McDonald																		
	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg	Neut	Pos	Neg
FFTR unchanged	85.3	3.3	6.0	89.5	4.2	6.3	85.5	3.5	6.4	89.5	3.5	5.7	87.1	3.4	5.6	90.8	3.9	5.3
	(2.0)	(0.1)	(0.2)	(0.4)	(0.3)	(0.2)	(2.0)	(0.1)	(0.2)	(0.8)	(0.1)	(0.1)	(2.0)	(0.1)	(0.3)	(0.3)	(0.3)	(0.3)
FFTR changed																		
≤ 25bp	84.7	3.3	6.3	90.3	3.9	5.8	80.1	3.3	5.5	89.5	3.3	5.6	93.1	3.1	3.8	91.6	3.1	5.3
	(3.4)	(0.2)	(0.3)	(0.4)	(0.2)	(0.3)	(10.0)	(0.5)	(0.8)	(1.4)	(0.1)	(0.2)	(0.8)	(0.4)	(0.7)	(0.0)	(0.0)	(0.0)
25bp–50bp	56.1	2.4	4.0	–	–	–	88.5	4.3	7.2	91.2	3.7	5.1	89.6	3.0	7.5	–	–	–
	(16.4)	(0.7)	(1.2)	–	–	–	(0.3)	(0.1)	(0.3)	(0.4)	(0.3)	(0.4)	(0.9)	(0.3)	(1.0)	–	–	–
>50bp	83.8	3.4	6.5	89.6	3.4	7.0	86.5	3.4	6.8	0.0	0.0	0.0	89.1	2.8	8.1	–	–	–
	(5.6)	(0.3)	(0.5)	(0.0)	(0.0)	(0.0)	(2.9)	(0.2)	(0.4)	(0.0)	(0.0)	(0.0)	(0.5)	(0.4)	(0.5)	–	–	–

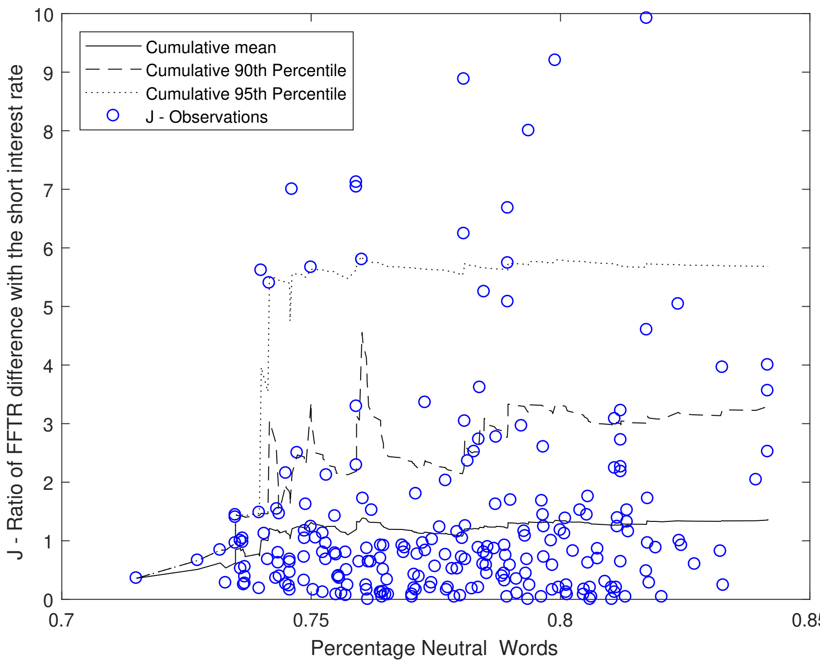


Figure E9. Jump surprise (J) of the U.S. short-term interest rate (1-month Eurodollar) (in %) during the FFTR change announcement – Sentiment by Percentage of Neutral Words by Harvard IV (Tetlock et al., 2008). Jump surprise (J) is calculated as in Equation (11). Sentiment is measured by the Naïve Bayes (NLTK) classifier. The data sample is from January 01, 1971 to December 31, 2015, and include $N = 244$ data points (FFTR changes occurred during the period).

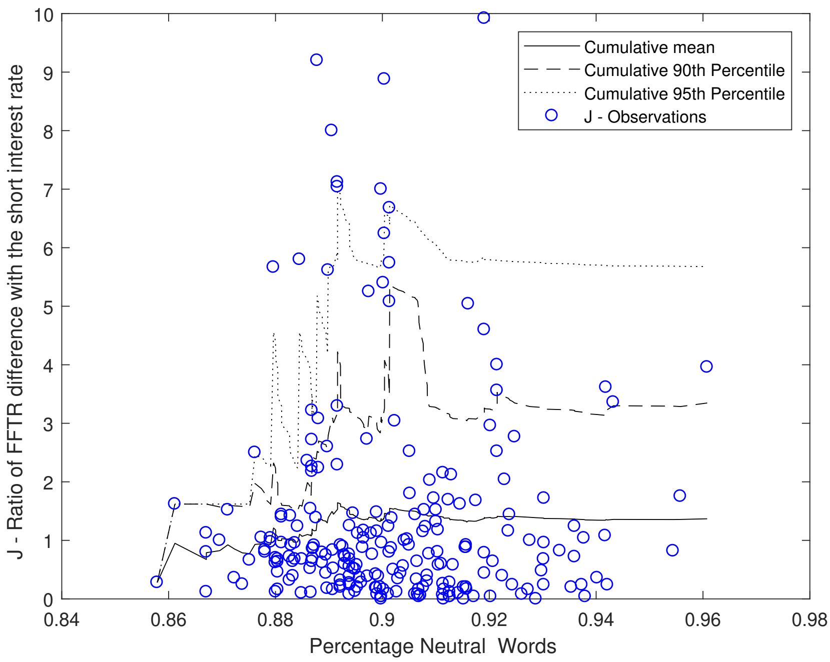


Figure E10. Jump surprise (J) of the U.S. short-term interest rate (1-month Eurodollar) (in %) during the FFTR change announcement – Sentiment by Percentage of Neutral Words by Loughran and McDonald (2011). Jump surprise (J) is calculated as in Equation (11). Sentiment is measured by the Naïve Bayes (NLTK) classifier. The data sample is from January 01, 1971 to December 31, 2015, and include $N = 244$ data points (FFTR changes occurred during the period).

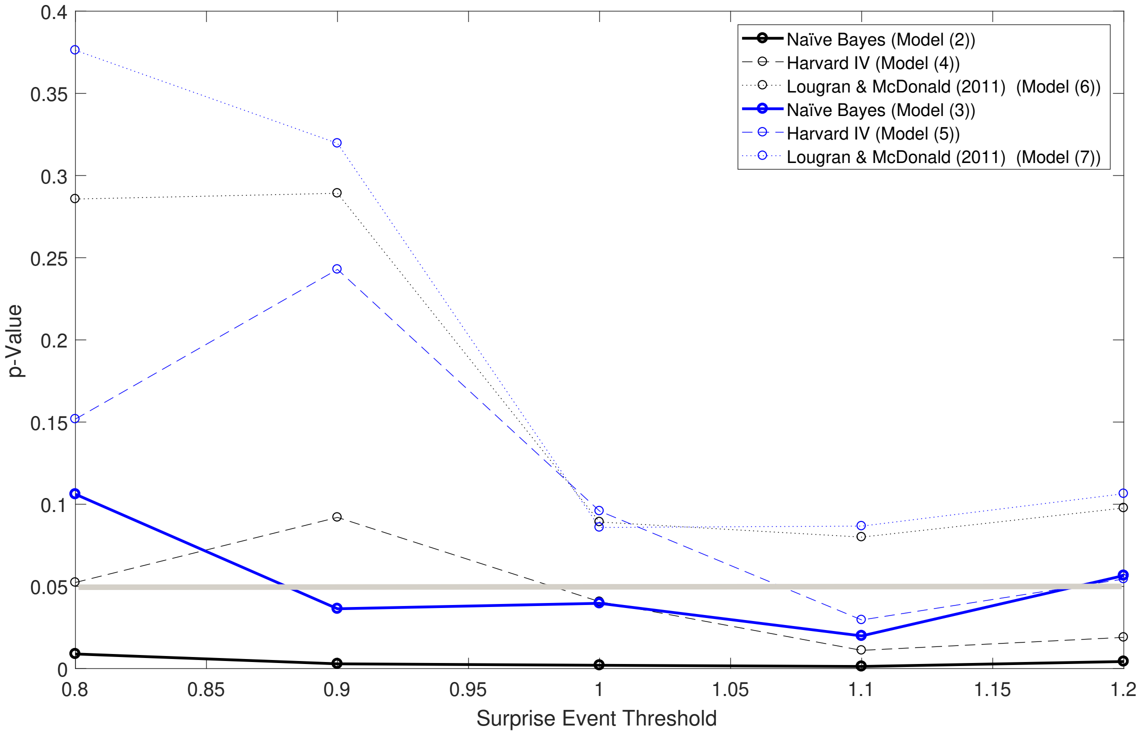


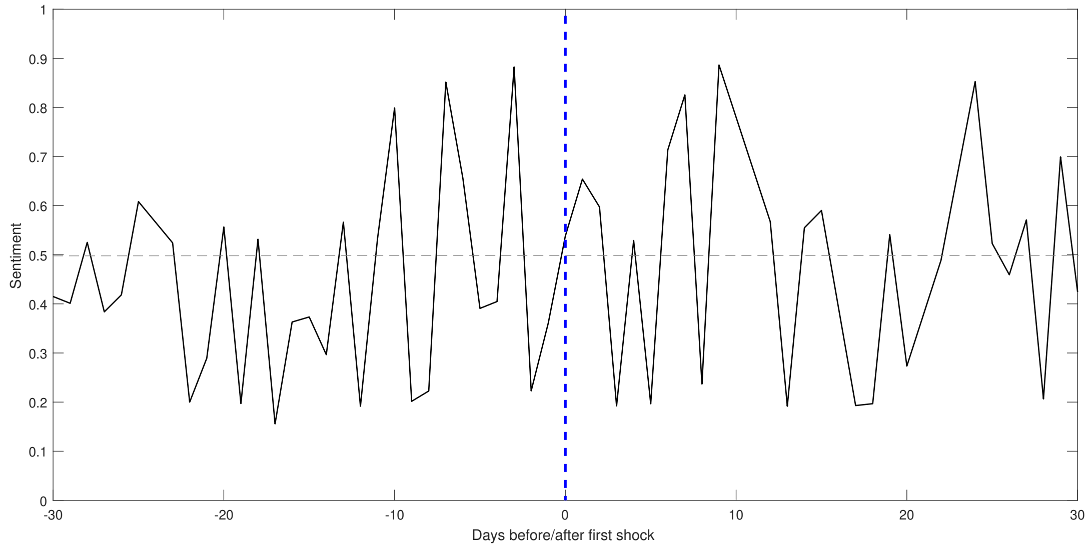
Figure E11. Robustness check – Event threshold. p-values of the $NeutSentFRC_t$ (Neutral sentiment of the FRC statements) variable in the logit regressions' robustness checks of Table VI; Models (2), (4) , and (6) are in black and Models (3), (5), and (7) in blue. The data sample is from January 01, 1971 to December 31, 2015, and include $N = 244$ data points (FFTR changes occurred during the period).

Appendix F. The Fed Chair Statement Sentiment Tone During a Change in the Monetary Policy Stance

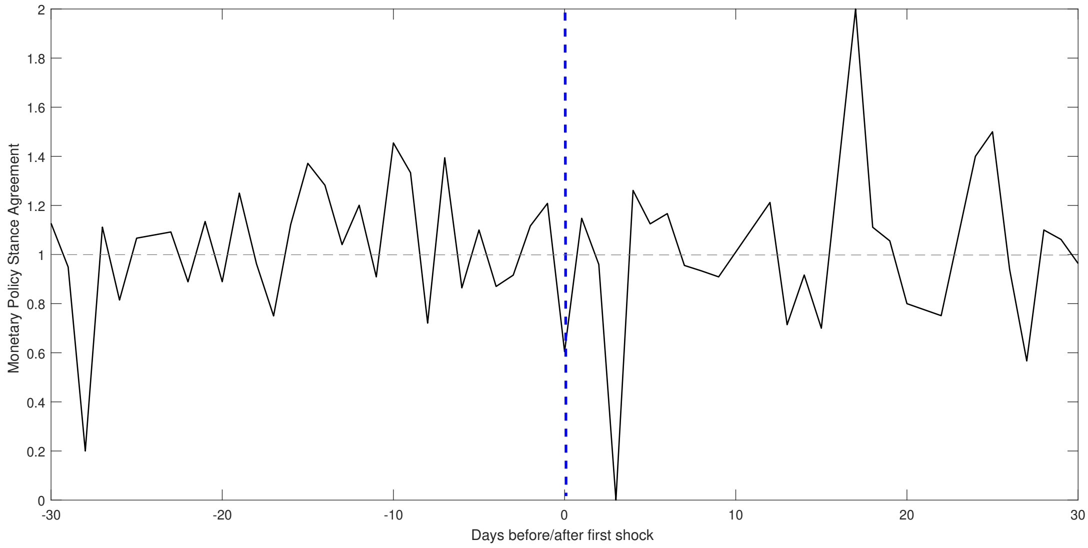
Every monetary policy decision on the FFTR by the FOMC board might be classified in two large classes: i) decisions that are taken as an emergency given a particular short-term situation – for example, corrections of the actual monetary policy as a result of a rapid deterioration of the economy, or ii) a program of consecutive FFTR changes to address a structural economic situation. When the economic cycle swings from growth to recession, or vice-versa, the FOMC might act to change its actual stance on the monetary policy (Change from Hawkish to Dovish, or vice-versa). The Fed Chair communications during these period might have a particular tone (sentiment, Hawkish/Dovish monetary policy stance).

In F12 we show the average tone of the Fed Chair statement, before and after a change in the stance of the monetary policy. The change is considered as two consecutive movements (increases/decreases) of the FFTR in the opposite direction to the actual monetary policy stance. We observe that the Fed Chair statement neutral sentiment during previous days to these changes have no pattern, nevertheless, the Hawkish/Dovish stance of the Fed Chair communication few days after the implementation of the new monetary policy stance, has a strong disagreement with he old monetary policy program, which suggests that the Fed Chair has a role in initiating the discussions after these major changes are implemented.

[**Place Figure F12 about here**]



(a) Sentiment



(b) Hawkish/Dovish Stance

Figure F12. Average Sentiment/Stance(Hawkish/Dovish) days before/after the first shock of a monetary policy program. A monetary policy program include at least two consecutive FFTR changes with at least 30 business days between them (1 month and a half - length between FOMC meetings). Sentiment of the Fed Chair statement is measured using the Naïve Bayes (NLTK) classification method. Monetary policy stance agreement is measured by Equation (12). The Fed Chair statements' sample is from January 01, 1971 to December 31, 2015.

Appendix G. Robustness Checks

Table G7
FFTR Change and Federal Reserve Chair Statements' Sentiment (Sample filtered to statements issued 60 days or less before the FFTR change announcement)

The Table shows the logit regressions of the jump surprise of the 1-Month Eurodollar interest rate (J) during the FFTR change announcement from model in Equation (14). The Fed Chair statements sample is from January 01, 1971 to December 31, 2015. Panel A shows the nested model (14). The neutral sentiment variable (NS_t) is the Fed Chair last statement neutral sentiment before the FFTR change. Column (1) is model in Equation (14) only with macroeconomic and financial variables, columns (2), (4) and (6) is model in Equation (14) including the neutral sentiment variable, measured by the Naïve Bayes classifier, Harvard IV (Tetlock), and Loughran and McDonald (2011) dictionaries, and columns (3), (5), and (7) is the full model in Equation (14), when controlling for personal characteristics. Macroeconomic variables with Δ are calculated with the first difference of the variable with respect to the previous announcement. The $*$, $**$, and $***$ represents statistical significance at a p-value of $0.1, 0.05$ and 0.01, respectively. The standard error is in parentheses.

Panel A: Jump Surprise J_t Regressed by Macroeconomic, Fed Chair Neutral Sentiment and Personal Characteristics

		Naïve Bayes		Harvard IV (Tetlock)		Loughran & McDonald	
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	-2.9***	-4.2***	-12.3***	-13.0**	-20.4***	-16.6*	-27.1***
	(0.9)	(1.2)	(3.2)	(5.3)	(6.4)	(8.7)	(10.1)
Macroeconomic							
Business Cycle	-0.3	-0.4	-0.0	-0.3	0.1	-0.4	-0.0
	(0.5)	(0.5)	(0.5)	(0.5)	(0.6)	(0.5)	(0.5)
Δ PCE	-36.0	-33.2	3.7	-8.3	22.4	-17.5	24.8
	(54.1)	(56.4)	(67.4)	(56.8)	(67.9)	(56.7)	(69.1)
Δ Industrial Production	-3.4	-1.4	-1.1	-1.0	-1.1	-1.6	-1.3
	(4.0)	(4.2)	(4.7)	(4.2)	(4.7)	(4.1)	(4.7)
Δ M1	-17.6	-21.4	-12.1	-8.9	-0.9	-8.6	1.6
	(20.5)	(21.2)	(24.2)	(21.2)	(25.9)	(21.3)	(26.0)
Unemployment rate	0.5***	0.6***	0.7***	0.5***	0.8***	0.5***	0.8***
	(0.1)	(0.1)	(0.2)	(0.1)	(0.2)	(0.1)	(0.2)
Financial							
Δ SP500	-4.6**	-3.2	-2.2	-4.3*	-2.7	-3.7	-2.3
	(2.2)	(2.4)	(2.6)	(2.3)	(2.6)	(2.3)	(2.6)
Baa10YT	-2.0	-1.4	-0.8	-1.5	-0.7	-1.3	-0.5
	(1.5)	(1.6)	(1.7)	(1.5)	(1.7)	(1.5)	(1.7)
Communication's Sentiment							
Fed Chair Statement Neutral Sentiment		1.6***	1.2**	12.2**	10.9	14.6	16.4*
		(0.5)	(0.6)	(6.2)	(6.7)	(9.2)	(10.0)
Fed Chair Statement Stance(H/D)		-0.0	-0.2	-0.1	-0.3	-0.0	-0.2
		(0.4)	(0.5)	(0.4)	(0.5)	(0.4)	(0.5)
Personal Characteristics							
Chair			0.2**		0.3**		0.3***
			(0.1)		(0.1)		(0.1)
Age			-0.0		-0.0		-0.0
			(0.0)		(0.0)		(0.0)
Academic Background			0.5***		0.4***		0.5***
			(0.2)		(0.2)		(0.2)
N(weeks)	230	230	230	230	230	230	230
Deviance	272.91	252.42	231.97	258.08	233.57	259.48	233.46
Fit improvement	-	0.08	0.15	0.05	0.14	0.05	0.14

Table G8

FFTR Change and Federal Reserve Chair Statements' Sentiment (Sample filtered to Fed Chair statements issued 30 days or less before the FFTR change announcement)

The Table shows the logit regressions of the jump surprise of the 1-Month Eurodollar interest rate (J) during the FFTR change announcement from model in Equation (14). The Fed Chair statements sample is from January 01, 1971 to December 31, 2015. Panel A shows the nested model (14). The neutral sentiment variable (NS_t) is the Fed Chair last statement neutral sentiment before the FFTR change. Column (1) is model in Equation (14) only with macroeconomic and financial variables, columns (2), (4) and (6) is model in Equation (14) including the neutral sentiment variable, measured by the Naïve Bayes classifier, Harvard IV (Tetlock), and Loughran and McDonald (2011) dictionaries, and columns (3), (5), and (7) is the full model in Equation (14), when controlling for personal characteristics. Macroeconomic variables with Δ are calculated with the first difference of the variable with respect to the previous announcement. The $*$, $**$, and $***$ represents statistical significance at a p-value of $0.1, 0.05$ and 0.01, respectively. The standard error is in parentheses.

Panel A: Jump Surprise J_t Regressed by Macroeconomic, Fed Chair Neutral Sentiment and Personal Characteristics

		Naïve Bayes		Harvard IV (Tetlock)		Loughran & McDonald	
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	-3.3***	-4.8***	-11.9***	-12.8**	-19.1***	-20.7**	-30.0***
	(1.0)	(1.3)	(3.5)	(5.8)	(7.0)	(9.4)	(10.8)
Macroeconomic							
Business Cycle	-0.4	-0.4	0.1	-0.4	0.1	-0.5	0.0
	(0.5)	(0.5)	(0.6)	(0.5)	(0.6)	(0.5)	(0.6)
Δ PCE	-76.0	-69.5	-35.5	-56.5	-26.1	-56.1	-16.7
	(59.9)	(62.9)	(75.7)	(62.6)	(75.8)	(62.9)	(77.3)
Δ Industrial Production	-2.3	-1.3	-2.3	0.1	-1.7	-0.7	-1.9
	(4.4)	(4.6)	(5.1)	(4.6)	(5.2)	(4.5)	(5.2)
Δ M1	-18.8	-24.5	-19.4	-12.1	-8.9	-8.6	-2.8
	(21.4)	(22.3)	(25.5)	(22.1)	(27.0)	(22.4)	(27.4)
Unemployment rate	0.6***	0.6***	0.8***	0.6***	0.8***	0.7***	0.9***
	(0.1)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)
Financial							
Δ SP500	-3.6	-2.4	-1.3	-3.1	-1.5	-2.5	-0.9
	(2.4)	(2.5)	(2.7)	(2.4)	(2.7)	(2.4)	(2.7)
Baa10YT	-1.6	-1.2	-0.3	-1.2	-0.3	-0.9	0.2
	(1.7)	(1.7)	(1.9)	(1.7)	(1.9)	(1.7)	(1.9)
Communication's Sentiment							
Fed Chair Statement Neutral Sentiment		1.5**	1.2*	11.2	10.0	18.3*	20.2*
		(0.6)	(0.6)	(6.9)	(7.4)	(9.9)	(10.7)
Fed Chair Statement Stance(H/D)		0.1	-0.1	0.1	-0.1	0.2	-0.1
		(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)
Personal Characteristics							
Chair			0.3**		0.4**		0.4***
			(0.1)		(0.1)		(0.1)
Age			-0.0		-0.0		-0.0
			(0.0)		(0.0)		(0.0)
Academic Background			0.4**		0.3**		0.4**
			(0.2)		(0.2)		(0.2)
N(weeks)	230	230	230	230	230	230	230
Deviance	232.50	215.66	198.42	219.78	200.00	218.99	198.12
Fit improvement	-	0.07	0.15	0.05	0.14	0.06	0.15

Table G9
FFTR Change and Federal Reserve Chair Statements' Sentiment (Results before the FOMC Statement release introduction in 1994)

The Table shows the logit regressions of the jump surprise of the 1-Month Eurodollar interest rate (J) during the FFTR change announcement from model in Equation (14). The Fed Chair statements sample is from January 01, 1971 to December 31, 1993. Panel A shows the nested model (14). The neutral sentiment variable (NS_t) is the Fed Chair last statement neutral sentiment before the FFTR change. Column (1) is model in Equation (14) only with macroeconomic and financial variables, columns (2), (4) and (6) is model in Equation (14) including the neutral sentiment variable, measured by the Naïve Bayes classifier, Harvard IV (Tetlock), and Loughran and McDonald (2011) dictionaries, and columns (3), (5), and (7) is the full model in Equation (14), when controlling for personal characteristics. Macroeconomic variables with Δ are calculated with the first difference of the variable with respect to the previous announcement. The $*$, $**$, and $***$ represents statistical significance at a p-value of $0.1, 0.05$ and 0.01, respectively. The standard error is in parentheses.

Panel A: Jump Surprise J_t Regressed by Macroeconomic, Fed Chair Neutral Sentiment and Personal Characteristics

		Naïve Bayes		Harvard IV (Tetlock)		Loughran & McDonald	
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	0.5	-1.3	-8.7**	-8.8	-19.1**	-11.7	-23.5*
	(1.3)	(1.6)	(3.6)	(6.4)	(7.7)	(10.8)	(12.2)
Macroeconomic							
Business Cycle	-0.6	-0.7	-0.4	-0.6	-0.2	-0.7	-0.4
	(0.6)	(0.6)	(0.6)	(0.6)	(0.7)	(0.6)	(0.6)
Δ PCE	-183.3**	-163.9**	-108.1	-133.9*	-79.9	-148.3*	-83.6
	(73.3)	(75.1)	(92.4)	(77.2)	(94.7)	(76.3)	(96.3)
Δ Industrial	-8.3*	-5.4	-7.6	-4.7	-7.1	-5.5	-7.5
Production	(4.7)	(5.1)	(6.2)	(5.0)	(6.3)	(4.9)	(6.2)
Δ M1	-75.7**	-81.5**	-58.6	-69.4*	-43.4	-72.4*	-47.0
	(38.5)	(39.4)	(43.2)	(39.8)	(44.9)	(39.5)	(44.3)
Unemployment rate	0.2	0.3*	0.4**	0.3*	0.5**	0.3*	0.4**
	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)
Financial							
Δ SP500	-5.8**	-3.7	-3.3	-4.5	-3.4	-4.3	-3.1
	(2.8)	(2.9)	(3.1)	(2.9)	(3.1)	(2.9)	(3.1)
Baa10YT	-3.8**	-3.2*	-2.4	-3.2*	-2.2	-3.3*	-2.2
	(1.7)	(1.8)	(2.0)	(1.7)	(2.0)	(1.7)	(1.9)
Communication's Sentiment							
Fed Chair Statement		1.5**	1.1*	10.5	13.4*	12.5	16.4
Neutral Sentiment		(0.6)	(0.7)	(7.4)	(7.9)	(11.4)	(12.1)
Fed Chair Statement		0.1	0.1	-0.0	0.0	0.0	0.1
Stance(H/D)		(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)
Personal Characteristics							
Chair			0.1		0.1		0.1
			(0.3)		(0.3)		(0.3)
Age			0.1		0.1		0.1
			(0.1)		(0.1)		(0.1)
Academic			0.0		0.0		0.0
Background			(0.3)		(0.3)		(0.3)
N(weeks)	230	230	230	230	230	230	230
Deviance	201.70	187.60	174.70	191.70	174.60	192.48	175.58
Fit improvement	-	0.07	0.13	0.05	0.13	0.05	0.13

Table G10
FFTR Change and Federal Reserve Chair Statements' Sentiment (1-Month Eurodollar – End of Week Price)

The Table shows the logit regressions of the jump surprise of the 1-Month Eurodollar interest rate (J) during the FFTR change announcement from model in Equation (14). The Fed Chair statements sample is from January 01, 1971 to December 31, 2015. Panel A shows the nested model (14). The neutral sentiment variable (NS_t) is the Fed Chair last statement neutral sentiment before the FFTR change. Column (1) is model in Equation (14) only with macroeconomic and financial variables, columns (2), (4) and (6) is model in Equation (14) including the neutral sentiment variable, measured by the Naïve Bayes classifier, Harvard IV (Tetlock), and Loughran and McDonald (2011) dictionaries, and columns (3), (5), and (7) is the full model in Equation (14), when controlling for personal characteristics. Macroeconomic variables with Δ are calculated with the first difference of the variable with respect to the previous announcement. The $*$, $**$, and $***$ represents statistical significance at a p-value of $0.1, 0.05$ and 0.01, respectively. The standard error is in parentheses.

Panel A: Jump Surprise J_t Regressed by Macroeconomic, Fed Chair Neutral Sentiment and Personal Characteristics

		Naïve Bayes		Harvard IV (Tetlock)		Loughran & McDonald	
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	-2.3***	-2.2**	-2.7	-12.5**	-13.9**	-19.0**	-22.4**
	(0.8)	(1.0)	(2.8)	(5.0)	(6.0)	(8.5)	(9.7)
Macroeconomic							
Business Cycle	-0.1	-0.3	-0.1	-0.2	0.2	-0.3	0.0
	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)
Δ PCE	92.9*	86.2*	23.4	117.0**	54.7	112.0**	54.3
	(51.2)	(51.8)	(62.7)	(54.8)	(64.2)	(54.4)	(64.3)
Δ Industrial Production	-0.5	2.5	0.3	3.4	0.8	2.8	0.9
	(3.8)	(4.0)	(4.6)	(4.1)	(4.7)	(4.0)	(4.7)
Δ M1	10.6	10.1	-4.2	23.7	9.3	25.0	12.4
	(19.4)	(19.8)	(24.6)	(21.1)	(26.6)	(21.2)	(26.6)
Unemployment rate	0.3**	0.3***	0.5***	0.4***	0.5***	0.4***	0.6***
	(0.1)	(0.1)	(0.1)	(0.1)	(0.2)	(0.1)	(0.2)
Financial							
Δ SP500	-2.0	-1.5	0.2	-2.2	0.1	-1.7	0.5
	(2.1)	(2.2)	(2.5)	(2.2)	(2.5)	(2.2)	(2.5)
Baa10YT	-1.4	-1.1	-0.7	-1.1	-0.5	-0.8	-0.2
	(1.4)	(1.4)	(1.5)	(1.5)	(1.6)	(1.5)	(1.6)
Communication's Sentiment							
Fed Chair Statement Neutral Sentiment		1.0**	0.3	13.4**	14.1**	18.8**	20.9**
		(0.5)	(0.6)	(6.0)	(6.5)	(9.0)	(9.8)
Fed Chair Statement Stance(H/D)		-0.8**	-1.0**	-0.9**	-1.1**	-0.9**	-1.1**
		(0.4)	(0.5)	(0.4)	(0.5)	(0.4)	(0.5)
Personal Characteristics							
Chair			0.5***		0.6***		0.6***
			(0.1)		(0.1)		(0.1)
Age			-0.0		-0.0		-0.0
			(0.0)		(0.0)		(0.0)
Academic Background			0.1		0.0		0.1
			(0.2)		(0.2)		(0.2)
N(weeks)	230	230	230	230	230	230	230
Deviance	297.80	280.27	251.60	279.35	247.08	280.05	247.13
Fit improvement	-	0.06	0.16	0.06	0.17	0.06	0.17

Table G11
FFTR Change and Federal Reserve Chair Statements' Sentiment (3-Month Eurodollar)

The Table shows the logit regressions of the jump surprise of the 3-Month Eurodollar interest rate (J) during the FFTR change announcement from model in Equation (14). The Fed Chair statements sample is from January 01, 1971 to December 31, 2015. Panel A shows the nested model (14). The neutral sentiment variable (NS_t) is the Fed Chair last statement neutral sentiment before the FFTR change. Column (1) is model in Equation (14) only with macroeconomic and financial variables, columns (2), (4) and (6) is model in Equation (14) including the neutral sentiment variable, measured by the Naïve Bayes classifier, Harvard IV (Tetlock), and Loughran and McDonald (2011) dictionaries, and columns (3), (5), and (7) is the full model in Equation (14), when controlling for personal characteristics. Macroeconomic variables with Δ are calculated with the first difference of the variable with respect to the previous announcement. The $*$, $**$, and $***$ represents statistical significance at a p-value of $0.1, 0.05$ and 0.01, respectively. The standard error is in parentheses.

Panel A: Jump Surprise J_t Regressed by Macroeconomic, Fed Chair Neutral Sentiment and Personal Characteristics

		Naïve Bayes		Harvard IV (Tetlock)		Loughran & McDonald	
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	-3.1***	-4.1***	-2.9	-13.5***	-13.2**	-15.4*	-16.3*
	(0.9)	(1.1)	(3.0)	(5.2)	(6.1)	(8.6)	(9.8)
Macroeconomic							
Business Cycle	-0.4	-0.4	-0.2	-0.3	0.1	-0.4	-0.1
	(0.5)	(0.5)	(0.5)	(0.5)	(0.6)	(0.5)	(0.5)
Δ PCE	68.5	73.6	-22.5	101.8*	7.4	90.3*	-0.8
	(51.8)	(52.4)	(65.7)	(55.3)	(66.9)	(54.5)	(66.9)
Δ Industrial	5.3	6.3	3.6	7.1*	4.3	6.4	4.2
Production	(3.9)	(4.1)	(4.7)	(4.1)	(4.7)	(4.0)	(4.7)
Δ M1	-9.3	-11.6	-34.6	-1.0	-26.9	-2.1	-26.1
	(19.9)	(20.1)	(23.9)	(20.6)	(24.6)	(20.7)	(24.6)
Unemployment rate	0.5***	0.5***	0.7***	0.6***	0.7***	0.6***	0.7***
	(0.1)	(0.1)	(0.2)	(0.1)	(0.2)	(0.1)	(0.2)
Financial							
Δ SP500	-4.9**	-3.8*	-2.0	-4.5**	-2.3	-4.0*	-1.7
	(2.2)	(2.2)	(2.5)	(2.3)	(2.5)	(2.2)	(2.5)
Baa10YT	-3.3**	-2.8*	-2.6	-2.9*	-2.5	-2.7*	-2.3
	(1.5)	(1.5)	(1.6)	(1.5)	(1.6)	(1.5)	(1.6)
Communication's Sentiment							
Fed Chair Statement		0.8	-0.2	12.2**	13.3**	12.7	14.4
Neutral Sentiment		(0.5)	(0.6)	(6.1)	(6.8)	(9.1)	(10.0)
Fed Chair Statement		0.3	0.4	0.2	0.3	0.3	0.4
Stance(H/D)		(0.4)	(0.5)	(0.4)	(0.5)	(0.4)	(0.5)
Personal Characteristics							
Chair			0.7***		0.7***		0.7***
			(0.1)		(0.1)		(0.1)
Age			-0.0		-0.0		-0.0
			(0.0)		(0.0)		(0.0)
Academic			-0.1		-0.2		-0.1
Background			(0.2)		(0.2)		(0.2)
N(weeks)	230	230	230	230	230	230	230
Deviance	288.06	276.58	237.75	274.82	233.84	276.98	235.69
Fit improvement	-	0.04	0.17	0.05	0.19	0.04	0.18

Table G12
FFTR Change and Federal Reserve Chair Statements' Sentiment (6-Month Eurodollar)

The Table shows the logit regressions of the jump surprise of the 6-Month Eurodollar interest rate (J) during the FFTR change announcement from model in Equation (14). The Fed Chair statements sample is from January 01, 1971 to December 31, 2015. Panel A shows the nested model (14). The neutral sentiment variable (NS_t) is the Fed Chair last statement neutral sentiment before the FFTR change. Column (1) is model in Equation (14) only with macroeconomic and financial variables, columns (2), (4) and (6) is model in Equation (14) including the neutral sentiment variable, measured by the Naïve Bayes classifier, Harvard IV (Tetlock), and Loughran and McDonald (2011) dictionaries, and columns (3), (5), and (7) is the full model in Equation (14), when controlling for personal characteristics. Macroeconomic variables with Δ are calculated with the first difference of the variable with respect to the previous announcement. The $*$, $**$, and $***$ represents statistical significance at a p-value of $0.1, 0.05$ and 0.01, respectively. The standard error is in parentheses.

Panel A: Jump Surprise J_t Regressed by Macroeconomic, Fed Chair Neutral Sentiment and Personal Characteristics

		Naïve Bayes		Harvard IV (Tetlock)		Loughran & McDonald	
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	-1.2	-2.3**	-2.8	-15.2***	-15.8***	-13.9	-16.2*
	(0.9)	(1.1)	(3.1)	(5.4)	(6.1)	(8.9)	(9.8)
Macroeconomic							
Business Cycle	0.1	0.1	0.4	0.4	0.7	0.2	0.5
	(0.5)	(0.5)	(0.5)	(0.5)	(0.6)	(0.5)	(0.5)
Δ PCE	-81.8	-72.6	-141.9**	-35.7	-103.9	-55.3	-117.1*
	(52.6)	(52.7)	(66.4)	(54.9)	(67.0)	(54.4)	(67.2)
Δ Industrial	5.0	3.9	2.0	4.8	2.0	4.1	2.6
Production	(4.1)	(4.2)	(4.8)	(4.2)	(4.8)	(4.1)	(4.8)
Δ M1	-44.1**	-46.3**	-60.1**	-34.9	-53.7**	-38.4*	-52.9**
	(21.3)	(21.8)	(24.6)	(22.0)	(25.1)	(22.3)	(25.0)
Unemployment rate	0.4***	0.4***	0.5***	0.4***	0.5***	0.4***	0.5***
	(0.1)	(0.1)	(0.2)	(0.1)	(0.2)	(0.1)	(0.2)
Financial							
Δ SP500	-3.6	-2.5	-0.9	-2.8	-1.0	-2.4	-0.4
	(2.2)	(2.3)	(2.5)	(2.4)	(2.6)	(2.3)	(2.6)
Baa10YT	-3.6**	-3.3**	-3.0*	-3.2**	-2.9*	-3.1**	-2.7
	(1.5)	(1.5)	(1.7)	(1.6)	(1.7)	(1.6)	(1.7)
Communication's Sentiment							
Fed Chair Statement		-0.0	-0.9	15.7**	17.1**	12.4	14.3
Neutral Sentiment		(0.5)	(0.6)	(6.4)	(6.8)	(9.5)	(10.0)
Fed Chair Statement		1.1**	1.2**	1.0**	1.2**	1.1**	1.2**
Stance(H/D)		(0.4)	(0.5)	(0.5)	(0.5)	(0.4)	(0.5)
Personal Characteristics							
Chair			0.6***		0.5***		0.5***
			(0.1)		(0.1)		(0.1)
Age			0.0		0.0		0.0
			(0.0)		(0.0)		(0.0)
Academic			-0.1		-0.1		-0.1
Background			(0.2)		(0.2)		(0.2)
N(weeks)	230	230	230	230	230	230	230
Deviance	274.97	263.19	238.49	256.85	234.43	261.44	238.92
Fit improvement	-	0.04	0.13	0.07	0.15	0.05	0.13

Table G13
FFTR Change and Federal Reserve Chair Statements' Sentiment (Adjustment Efficiency)

The Table shows the logit regressions of the adjustment efficiency of the 1-Month Eurodollar interest rate ($1/J$) during the FFTR change announcement from model in Equation (14). The Fed Chair statements sample is from January 01, 1971 to December 31, 2015. Panel A shows the nested model (14). The neutral sentiment variable (NS_t) is the Fed Chair last statement neutral sentiment before the FFTR change. Column (1) is model in Equation (14) only with macroeconomic and financial variables, columns (2), (4) and (6) is model in Equation (14) including the neutral sentiment variable, measured by the Naïve Bayes classifier, Harvard IV (Tetlock), and Loughran and McDonald (2011) dictionaries, and columns (3), (5), and (7) is the full model in Equation (14), when controlling for personal characteristics. Macroeconomic variables with Δ are calculated with the first difference of the variable with respect to the previous announcement. The $*$, $**$, and $***$ represents statistical significance at a p-value of $0.1, 0.05$ and 0.01, respectively. The standard error is in parentheses.

Panel A: Adjustment Efficiency $1/J_t$ Regressed by Macroeconomic, Fed Chair Neutral Sentiment and Personal Characteristics

		Naïve Bayes		Harvard IV (Tetlock)		Loughran & McDonald	
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	2.7***	4.0***	12.2***	13.5**	20.9***	19.1**	29.9***
	(0.9)	(1.1)	(3.3)	(5.3)	(6.4)	(8.8)	(10.2)
Macroeconomic							
Business Cycle	0.3	0.4	0.1	0.3	-0.0	0.5	0.1
	(0.5)	(0.5)	(0.5)	(0.5)	(0.6)	(0.5)	(0.5)
Δ PCE	27.0	25.2	-8.4	-1.8	-28.9	5.2	-35.1
	(54.1)	(56.5)	(68.0)	(56.9)	(68.3)	(56.9)	(69.7)
Δ Industrial Production	4.1	1.8	1.4	1.4	1.3	2.1	1.5
	(4.0)	(4.2)	(4.7)	(4.2)	(4.8)	(4.1)	(4.8)
Δ M1	20.3	24.5	17.1	11.3	6.4	9.8	2.4
	(20.6)	(21.3)	(24.3)	(21.1)	(25.9)	(21.2)	(26.0)
Unemployment rate	-0.4***	-0.5***	-0.7***	-0.5***	-0.7***	-0.5***	-0.8***
	(0.1)	(0.1)	(0.2)	(0.1)	(0.2)	(0.1)	(0.2)
Financial							
Δ SP500	4.7**	3.3	2.2	4.4*	2.6	3.8	2.1
	(2.2)	(2.4)	(2.6)	(2.3)	(2.6)	(2.3)	(2.6)
Baa10YT	2.0	1.4	0.7	1.5	0.7	1.2	0.3
	(1.5)	(1.6)	(1.7)	(1.5)	(1.7)	(1.5)	(1.7)
Communication's Sentiment							
Fed Chair Statement Neutral Sentiment		-1.6***	-1.1*	-13.0**	-11.6*	-17.5*	-19.4*
		(0.5)	(0.6)	(6.2)	(6.7)	(9.3)	(10.1)
Fed Chair Statement Stance(H/D)		0.1	0.2	0.1	0.3	0.0	0.2
		(0.4)	(0.5)	(0.4)	(0.5)	(0.4)	(0.5)
Personal Characteristics							
Chair			-0.3**		-0.3**		-0.3***
			(0.1)		(0.1)		(0.1)
Age			0.1*		0.0		0.0
			(0.0)		(0.0)		(0.0)
Academic Background			-0.5***		-0.4***		-0.5***
			(0.2)		(0.2)		(0.2)
N(weeks)	230	230	230	230	230	230	230
Deviance	274.21	253.49	230.69	258.44	231.44	259.31	230.60
Fit improvement	-	0.08	0.16	0.06	0.16	0.05	0.16

Table G14
FFTR Change and FOMC Statements' Sentiment (3-Month Eurodollar)

The Table shows the logit regressions of the jump surprise of the 3-Month Eurodollar interest rate (J) during the FFTR change announcement from model in Equation (15). FOMC statements' sample is from February 01, 1994 to December 31, 2015 (first FOMC statement was made available to the public since January 01, 1994). Panel A shows the full model in Equation (15). Column (1) is model in Equation (15) without the neutral sentiment variable, and columns (2), (3) and (4) is model in Equation (15) with neutral sentiment included, measured by the Naïve Bayes classifier, the Harvard IV (Tetlock, 2007), and the Loughran and McDonald (2011) dictionaries. Macroeconomic variables with Δ are calculated with the first difference of the variable with respect to the previous announcement (monthly). The $*$, $**$, and $***$ represents statistical significance at a p-value of $0.1, 0.05$ and 0.01, respectively. The standard error is in parentheses.

Panel A: Jump Surprise J_t Regressed by Macroeconomic, and FOMC Neutral Sentiment

		Naïve Bayes	Harvard IV (Tetlock)	Loughran & McDonald
	(1)	(2)	(3)	(4)
Constant	-6.3*	-5.7	-17.0	4.5
	(3.6)	(4.4)	(11.5)	(22.7)
Macroeconomic				
Business Cycle	0.2	0.1	0.4	0.3
	(0.4)	(0.7)	(0.4)	(0.4)
Δ PCE	147.2	152.2	155.7	151.1
	(191.9)	(192.1)	(194.0)	(196.8)
Δ Industrial Production	8.2	7.4	7.7	13.6
	(14.9)	(15.4)	(14.9)	(18.7)
Δ M1	24.1	27.6	21.2	28.5
	(38.4)	(41.9)	(36.9)	(39.7)
Unemployment rate	0.6	0.6	0.7	0.7
	(0.6)	(0.6)	(0.6)	(0.7)
Financial				
Δ S&P500	-8.9	-9.4	-7.4	-9.7
	(6.7)	(7.2)	(6.8)	(7.0)
Baa-10YT	5.8	5.8	6.5	5.5
	(4.9)	(4.9)	(5.0)	(4.9)
Communication's Sentiment				
FOMC Statement Neutral Sentiment		-0.6	11.2	-12.2
		(2.5)	(11.5)	(25.4)
N(weeks)	59	59	59	59
Deviance	44.75	44.70	43.78	44.52
Fit improvement	-	0.00	0.02	0.01

Table G15
FFTR Change and FOMC Statements' Sentiment (6-Month Eurodollar)

The Table shows the logit regressions of the jump surprise of the 6-Month Eurodollar interest rate (J) during the FFTR change announcement from model in Equation (15). FOMC statements' sample is from February 01, 1994 to December 31, 2015 (first FOMC statement was made available to the public since January 01, 1994). Panel A shows the full model in Equation (15). Column (1) is model in Equation (15) without the neutral sentiment variable, and columns (2), (3) and (4) is model in Equation (15) with neutral sentiment included, measured by the Naïve Bayes classifier, the Harvard IV (Tetlock, 2007), and the Loughran and McDonald (2011) dictionaries. Macroeconomic variables with Δ are calculated with the first difference of the variable with respect to the previous announcement (monthly). The $*$, $**$, and $***$ represents statistical significance at a p-value of $0.1, 0.05$ and 0.01, respectively. The standard error is in parentheses.

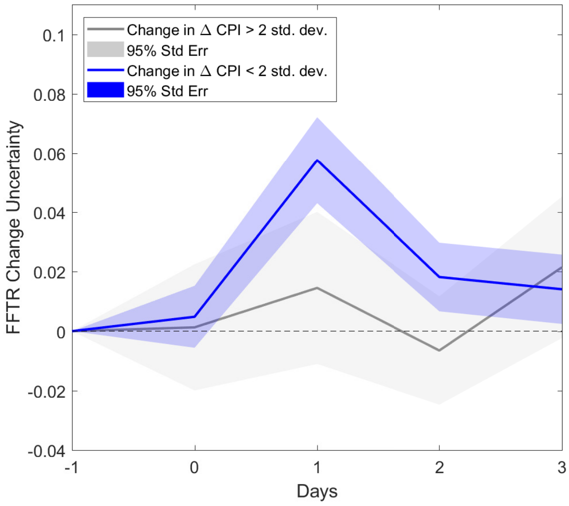
Panel A: Jump Surprise J_t Regressed by Macroeconomic, and FOMC Neutral Sentiment

		Naïve Bayes	Harvard IV (Tetlock)	Loughran & McDonald
	(1)	(2)	(3)	(4)
Constant	-3.2	-2.7	-5.9	-24.5
	(2.3)	(3.1)	(8.3)	(17.0)
Macroeconomic				
Business Cycle	0.6*	0.5	0.6*	0.6*
	(0.3)	(0.5)	(0.3)	(0.3)
Δ PCE	-85.8	-83.5	-84.0	-86.8
	(148.0)	(148.5)	(148.7)	(151.7)
Δ Industrial Production	18.5*	18.0	18.6*	9.1
	(11.2)	(11.5)	(11.2)	(13.4)
Δ M1	4.7	7.0	4.6	-2.2
	(33.1)	(34.4)	(32.9)	(34.2)
Unemployment rate	0.4	0.4	0.4	0.2
	(0.4)	(0.4)	(0.4)	(0.5)
Financial				
Δ S&P500	2.8	2.4	3.4	4.6
	(5.0)	(5.3)	(5.3)	(5.3)
Baa-10YT	-1.1	-1.2	-0.8	-0.2
	(3.7)	(3.7)	(3.8)	(3.8)
Communication's Sentiment				
FOMC Statement Neutral Sentiment		-0.4	2.8	23.7
		(1.6)	(8.5)	(18.7)
N(weeks)	59	59	59	59
Deviance	70.92	70.85	70.81	69.24
Fit improvement	-	0.00	0.00	0.02

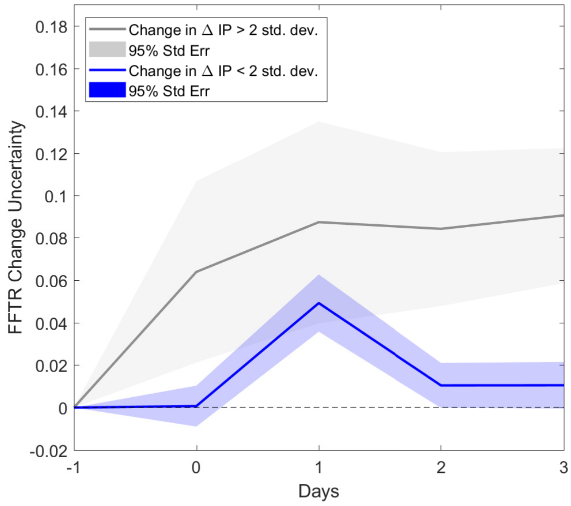
Table G16
FFTR Change and FOMC Statements' Sentiment (Adjustment Efficiency)

The Table shows the logit regressions of the adjustment efficiency of the 1-Month Eurodollar interest rate ($1/J_t$) during the FFTR change announcement from model in Equation (15). FOMC statements' sample is from February 01, 1994 to December 31, 2015 (first FOMC statement was made available to the public since January 01, 1994). Panel A shows the full model in Equation (15). Column (1) is model in Equation (15) without the neutral sentiment variable, and columns (2), (3) and (4) is model in Equation (15) with neutral sentiment included, measured by the Naïve Bayes classifier, the Harvard IV (Tetlock, 2007), and the Loughran and McDonald (2011) dictionaries. Macroeconomic variables with Δ are calculated with the first difference of the variable with respect to the previous announcement (monthly). The $*$, $**$, and $***$ represents statistical significance at a p-value of $0.1, 0.05$ and 0.01, respectively. The standard error is in parentheses.

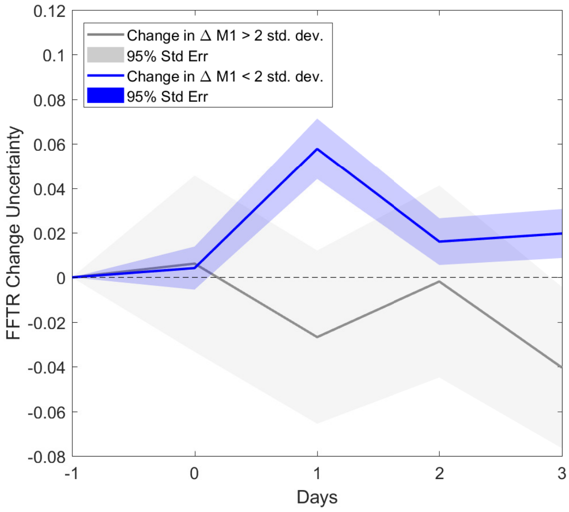
Panel A: Jump Surprise J_t Regressed by Macroeconomic, and FOMC Neutral Sentiment				
		Naïve Bayes	Harvard IV (Tetlock)	Loughran & McDonald
	(1)	(2)	(3)	(4)
Constant	2.7	2.8	3.8	-41.4
	(4.0)	(5.0)	(13.9)	(27.5)
Macroeconomic				
Business Cycle	-0.0	-0.1	-0.1	-0.2
	(0.4)	(0.7)	(0.4)	(0.5)
Δ PCE	-26.4	-25.6	-31.2	9.0
	(216.3)	(218.2)	(223.6)	(261.3)
Δ Industrial	1.7	1.5	1.6	-20.6
Production	(15.8)	(17.2)	(15.9)	(21.7)
Δ M1	4.4	4.7	4.1	-11.7
	(40.4)	(41.8)	(40.4)	(43.3)
Unemployment rate	-0.0	-0.0	-0.0	-0.2
	(0.8)	(0.8)	(0.9)	(0.9)
Financial				
Δ S&P500	3.3	3.2	3.1	7.0
	(6.9)	(7.0)	(7.2)	(7.7)
Baa-10YT	-15.1**	-15.1**	-15.2**	-14.4**
	(6.2)	(6.3)	(6.2)	(6.3)
Communication's Sentiment				
FOMC Statement		-0.1	-1.1	48.5
Neutral Sentiment		(2.7)	(13.5)	(29.9)
N(weeks)	59	59	59	59
Deviance	37.99	37.98	37.98	35.09
Fit improvement	-	0.00	0.00	0.08



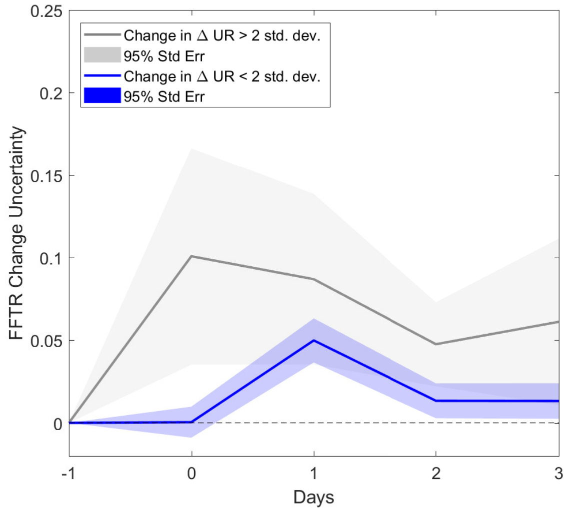
(a) Full Period – CPI Inflation



(b) Full Period – Industrial Production

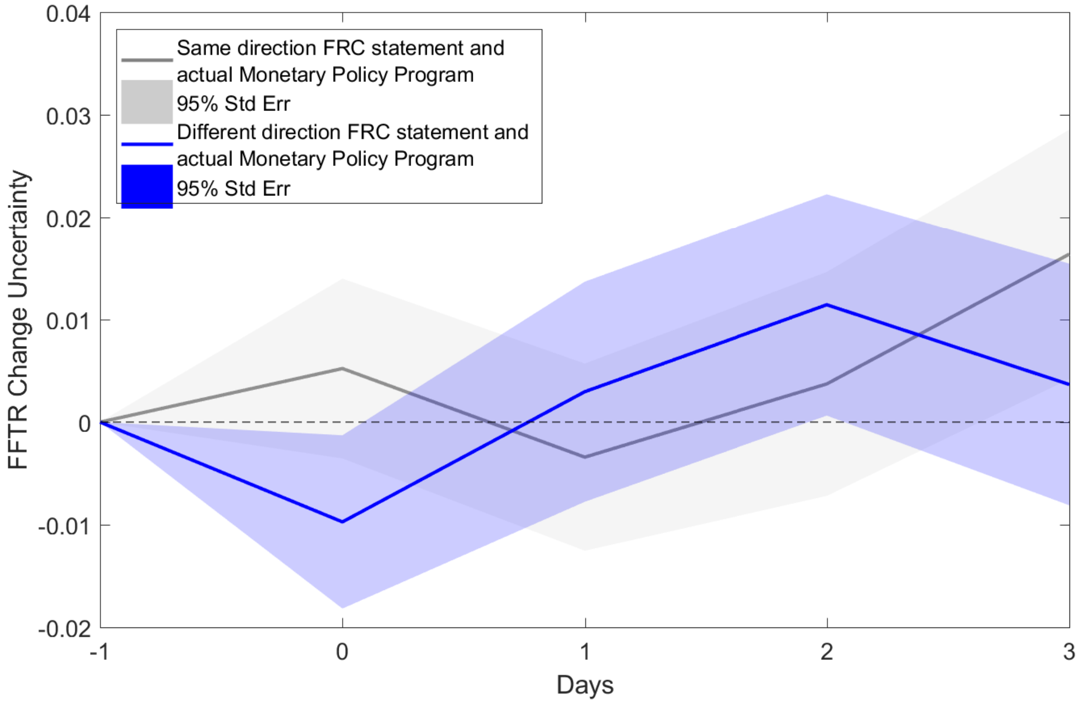


(c) Full Period – M1



(d) Full Period – Unemployment Rate

Figure G13. Uncertainty of the FFTR changes expected by the market for the next FOMC meeting after a Fed Chair statement release and macroeconomic variables with statistical significant changes. Uncertainty is calculated as the difference of the probability of and increase minus the probability of a decrease of the FFTR. The implicit probabilities are calculated by solving Equations (4) (5), and (7), with the restrictions in (6). The 1-Month Eurodollar, 3-Month Eurodollar, and FFTR interest rates' sample is from January 01, 1971 to December 31, 2015.



(a) Full Period – Hawkish/Dovish Sentiment Direction

Figure G14. Uncertainty of the FFTR changes expected by the market for the next FOMC meeting after a Fed Chair statement release and Hawkish/Dovish sentiment of the Fed Chair statement. Uncertainty is calculated as the difference of the probability of and increase minus the probability of a decrease of the FFTR. The implicit probabilities are calculated by solving Equations (4) (5), and (7), with the restrictions in (6). The 1-Month Eurodollar, 3-Month Eurodollar, and FFTR interest rates' sample is from January 01, 1971 to December 31, 2015.

Appendix H. Robustness Checks: Linear Relationships and Macroeconomic News Surprises – Market Expectations

In this appendix, we explore linear relationships between the jump surprise J_t and the state of the economy (macroeconomic and financial market variables), the Fed Chair last statement neutral sentiment and monetary policy stance (H/D), and the Fed Chair personal characteristics. We use same models in Equations (14) and (15), with the same dataset, but applying Ordinary Least Squares (OLS) regressions. This analysis will allow us to explore a stronger hypothesis: weather the relationship between the Fed Chair sentiment, stance, and the Fed Chair personal characteristics with the interest rate market jump surprise, is linear. We use as a measure of sentiment the principal measure: the Naïve Bayes classifier.[25]

Results: OLS regressions between jump surprise J_t and the Fed Chair and FOMC statement neutral sentiment

Linear relationship results for the baseline models for the first set of controls, the macroeconomic state variables, the models in Equations (14) and (15), are presented in Tables H7 and H8, for the Fed Chair and the FOMC statements respectively. Table H7, shows the effects of the Fed Chair statement neutral sentiment and the Fed Chair *Hawkish/Dovish* stance agreement over the jump surprise J_t. Results confirm our previous hypothesis with the logit regressions, where the Fed Chair last statement neutral sentiment explains in a linear way the surprise reaction of the market to the FFTR changes, (*** with an statistical significant p-value of 0.001), with an adjusted R^2 of 24%. The model with the individual variable of sentiment explains 8% of the linear variability for the full period, but there is a decay on the linear explanatory power of the Fed Chair neutral sentiment starting with Volcker tenure, although the non-linear explanatory power seems to remain given the logit regression results in Table VI of the paper. This decay in the linear explanatory power seems to coincide with an increase in explanatory power of the shorter term identification in the uncertainty reduction, measured in Figure 4: in a learning process manner, the market seems that has incorporated the linear explanatory power of the Fed Chair statement neutral sentiment faster, then it seems it took some days (1-2 weeks) during Burns and Miller tenures, but only a couple of days in the Volcker and Greenspan tenures. From Bernanke's tenure, it seems that there is not any more linear explanatory power by the market, and everything reduces to non-linear relationships (in the very high-frequency window of 30-60 minutes after the FOMC statement release. This learning process of the market seems to coincide with the introduction in 2011 of the FOMC Press conference after the FOMC statement release.

[**Place Table H7 about here**]

Equivalently, in Table H8 we present the results on the FOMC statement neutral sentiment effects over the jump surprise. These results are divided by sub-panels of the full period, and the business cycle expansionary/recessionary periods, and by sub-panels (A and B) with the nested models results. We observe that the sentiment of the FOMC statements seems not to have any significant relationship with the surprise jump variable J_t when controlling for the macroeconomic state variables, that all-together can explain with an adjusted R^2 of 48%, most the surprise. These results are expected, since the FOMC statement has to be clear in the direction of the monetary policy decisions, and any intended shock is reveled at their release time.

[**Place Table H8 about here**]

[25] We tested the other proxy measures of sentiment, Harvard IV and Loughran and McDonald (2011) dictionaries based as in Equations (B2) and (B3), but the results show no statistical significance in the intervals of confidence. We suspect those measures are just "proxies" of the sentiment and they cannot really measure linear or non-linear relationships in the short frequency (1-2 days).

Macroeconomic News Surprise

In addition, we produce an analysis concerned with the Fed Chair statements' effects when controlling for higher-frequency market expectations (Thomson Reuters macroeconomic announcements survey surprise).

Macroeconomic news announcements surprise: We consider an additional set of macroeconomic controls, with a higher-frequency but with a reduced time period, from April 27, 2000 to December 31, 2015, due to the reduced data availability: the set of market surprises, from the macroeconomic news announcements as in Faust et al. (2007). We extract the difference between the (i) Thomson Reuters EIKON's macroeconomic survey average expected announcement, and (ii) the final macroeconomic release. This set of macroeconomic news announcements surprise is composed of the surprises of: consumer price index (CPI), output (GDP), consumer sentiment (CS), unemployment rate (UR), initial job claims (IJC), non-farm payroll (NFP), retail sales (RS), international trade balance deficit (TD), and the housing starts (HS). Survey of expectations data is provided by Thomson Reuters EIKON. This reduced dataset serves to control for the macroeconomic environment expected surprise with a higher frequency effects.

The second set of controls, macroeconomic news announcements market surprise, is intended to explore a dimension that depends on having a *higher-frequency* in the data, the macroeconomic state *update* surprise: some macroeconomic variables are complex aggregate measures of the economic activity, such as the GDP, for which it is more difficult for the market to have a precise forecast, some other variables include expectations information that might be hidden to the market, such as consumer sentiment. We follow Jones et al. (1998), Faust et al. (2007), and Andersen et al. (2007) on the idea of the significant impact that news announcements surprises have when observed at a higher-frequency, to control our results by these announcements surprise effects. Baseline model in this case is,

$$\begin{aligned} J_t &= \beta_0 + \beta_1 SurpCPI_t + \beta_2 SurpGDP_t + \beta_3 SurpCS_t + \beta_4 SurpUR_t + \beta_5 SurpIJC_t + \\ &\quad \beta_6 SurpNFP_t + \beta_7 SurpRS_t + \beta_8 SurpTD_t + \beta_9 SurpHS_t + \\ &\quad \beta_{10} SentFRC_t + \beta_{11} StanceFRC_t, \end{aligned} \tag{H1}$$

where $SurpCPI_t$, $SurpGDP_t$, $SurpCS_t$, $SurpUR_t$, $SurpIJC_t$, $SurpNFP_t$, $SurpRS_t$, $SurpTD_t$, $SurpHS_t$ are the Thomson Reuters EIKON Survey market surprises for the the consumer price index (CPI), output (GDP), consumer sentiment (CS), unemployment rate (UR), initial job claims (IJC), non-farm payroll (NFP), retail sales (RS), international trade balance deficit (TD), and the housing starts (HS) announcements, and $NeutSentFOMC_t$ the last Fed Chair statement neutral sentiment measured by any of the sentiment measures (emotional measures of sentiment in Equations B1, B2, and B3), $StanceFRC_t$ the Fed Chair statement agreement with the current monetary policy stance (Hawkish/Dovish).

Results: Macroeconomic News Surprise

A final analysis, is concerned with the Fed Chair statements' effects when controlling for higher-frequency market expectations (Thomson Reuters macroeconomic announcements survey surprise), as in the model (H1). Table H9 shows the results. We have two panels, Panel A with the nested models, and Panel B with each single variable effects. The dataset available (survey) in this set of controls is limited for a reduced period of time, April 27, 2000 to December 31, 2015. Results indicate, when observing the higher-frequency survey effects, that the Fed Chair statement neutral sentiment is not significant, conditional on macroeconomic surprises, in explaining the market jump surprise, this result is in line with the results of Table H7, as the period under observation overlaps with Greenspan and Bernanke tenures, where there was no significance relationship between their statements sentiment and the jump surprise. The Fed Chair stance agreement, defined in Equation 12, has a minor relationship with the jump surprise (*=p-value of 0.1). In the macroeconomic variables side, expectations (CS), trade (TD), and labor market (UR, IJC and NFP) variables announcements surprises seem to have an impact on J_t during the period from April 27, 2000 to December 31, 2015, finding that contributes towards disentangling the interest rate price discovery process by the market.

[Place Table H9 about here]

Table H17
FFTR Change and Federal Reserve Chair Statements' Sentiment

The Table shows the OLS regressions of the jump surprise of the 1-Month Eurodollar interest rate (J) during the FFTR change announcement from model in Equation (14). The Fed Chair statements sample is from January 01, 1971 to December 31, 2015. Panel A shows the full model in Equation (14), with sub-panels for different Chairs. The Sentiment variable is the Fed Chair last statement neutral sentiment before the FFTR change. Panel B shows the model in Equation (14) by including only macroeconomic variables. Macroeconomic variables with Δ are calculated with the first difference of the variable with respect to the previous announcement. Panel C is the same Panel B, eliminating the personal characteristics. Panel D shows the model in Equation (14) by including only the personal characteristics variables. Panel E shows the model in Equation (14) by including only the Fed Chair statement neutral sentiment variable ($NeutSentFRC_t$). The $*$, $**$, and $***$ represents statistical significance at a p-value of $0.1, 0.05$ and 0.01, respectively. The standard error of the average is between parentheses.

Panel A: Macroeconomic, Personal and Sentiment						
	Full Period	Burns	Miller	Volcker	Greenspan	Bernanke
Constant	1.3	0.0	-1.5	1.5	-1.3	-46.0**
	(3.2)	(0.0)	(25.5)	(1.4)	(0.8)	(8.4)
Macroeconomic						
Δ CPI	-70.1	-339.4**	-494.4	-8.6	-67.3	1320.8***
	(45.3)	(163.5)	(370.3)	(54.4)	(58.6)	(76.4)
Δ Industrial	-6.6***	-8.1	-29.9	-6.0	2.4	-98.4***
Production	(2.3)	(5.7)	(41.2)	(4.9)	(3.3)	(9.4)
Δ M1	-17.1	-444.2***	93.8	6.8	-12.2	-250.5**
	(13.5)	(100.6)	(254.5)	(34.5)	(14.9)	(29.8)
Unemployment rate	0.1	-0.2	0.9	0.0	0.5***	10.0**
	(0.1)	(0.4)	(3.7)	(0.1)	(0.1)	(1.9)
Δ SP500	-2.7**	1.1	-6.1	-2.2	-2.2*	9.0
	(1.3)	(0.8)	(6.8)	(2.3)	(1.3)	(5.2)
Baa10YT	-0.1	-0.4	-0.6	-1.5	0.5	-1.5
	(1.0)	(4.3)	(3.0)	(0.9)	(1.3)	(2.5)
Personal Characteristics						
Age	-0.1***					
	(0.0)					
Education Years	0.2					
	(0.1)					
Fed Chair Statement	0.9***	1.2	1.1	0.1	-0.2	-0.9
Neutral Sentiment	(0.3)	(1.0)	(1.4)	(0.5)	(0.3)	(0.4)
Fed Chair Statement	0.4	1.0	2.9	0.2	-0.5**	0.9
Stance(H/D)	(0.3)	(0.8)	(3.2)	(0.5)	(0.2)	(0.4)
N(weeks)	230	55	19	58	84	13
R^2 (Adj)	0.24	0.35	0.42	0.04	0.25	0.99
Panel B: Macroeconomic and Sentiment						
Constant	-0.8	6.7*	-12.1	0.7	-1.0*	-11.1
	(0.6)	(4.0)	(18.7)	(1.3)	(0.6)	(28.1)
Macroeconomic						
Δ CPI	25.6	-381.8**	-329.4	-12.6	-63.5	955.3**
	(36.3)	(170.1)	(241.7)	(54.6)	(57.1)	(229.1)
Δ Industrial	-4.4*	-8.1	-24.7	-5.5	-0.2	-108.3**
Production	(2.3)	(5.7)	(33.3)	(4.1)	(2.8)	(37.1)
Δ M1	-9.3	-447.7***	54.4	-36.6	-5.4	-124.5
	(13.8)	(100.9)	(158.1)	(23.8)	(11.1)	(94.9)
Unemployment rate	0.2**	-0.3	2.2	0.0	0.5***	2.0
	(0.1)	(0.4)	(2.9)	(0.1)	(0.1)	(6.1)
Δ SP500	-3.6**	2.7	-5.8	-1.3	-2.3*	16.2
	(1.4)	(5.5)	(6.2)	(1.9)	(1.3)	(17.8)
Baa10YT	-0.4	5.5	-0.7	-1.5	1.2	11.5
	(1.0)	(6.0)	(2.7)	(0.9)	(1.2)	(6.3)
Fed Chair Statement	1.4***	1.0	1.6	0.3	-0.1	0.7
Neutral Sentiment	(0.3)	(1.0)	(1.2)	(0.5)	(0.3)	(1.0)
Fed Chair Statement	0.4	1.1	3.5	0.4	-0.5**	1.9
Stance(H/D)	(0.3)	(0.9)	(2.6)	(0.5)	(0.2)	(1.5)
Stance (H/D)	(0.3)	(0.9)	(2.6)	(0.5)	(0.2)	(1.5)
N(weeks)	230	55	19	58	84	13
R^2 (Adj)	0.12	0.35	0.51	0.02	0.24	0.92

Table H7
FFTR Change and Federal Reserve Chair Statements' Sentiment (Cont.)

The Table shows the OLS regressions of the jump surprise of the 1-Month Eurodollar interest rate (J) during the FFTR change announcement from model in Equation (14). The Fed Chair statements sample is from January 01, 1971 to December 31, 2015. Panel A shows the full model in Equation (14), with sub-panels for different Chairs. The Sentiment variable is the Fed Chair last statement neutral sentiment before the FFTR change. Panel B shows the model in Equation (14) by including only macroeconomic variables. Macroeconomic variables with Δ are calculated with the first difference of the variable with respect to the previous announcement. Panel C is the same Panel B, eliminating the personal characteristics. Panel D shows the model in Equation (14) by including only the personal characteristics variables. Panel E shows the model in Equation (14) by including only the Fed Chair statement neutral sentiment variable ($NeutSentFRC_t$). The $*$, $**$, and $***$ represents statistical significance at a p-value of $0.1, 0.05$ and 0.01, respectively. The standard error of the average is between parentheses.

Panel C: Macroeconomic						
Constant	0.6	11.4***	18.4	1.7	-1.6*	-56.7***
	(0.7)	(3.5)	(16.0)	(1.3)	(0.8)	(7.7)
Macroeconomic						
Δ CPI	12.2	-372.7*	-669.0**	-12.5	-73.1	1315.0***
	(42.4)	(219.2)	(292.6)	(52.5)	(59.3)	(99.5)
Δ Industrial	-7.9**	-22.8***	-9.5	-6.1	2.1	-81.0
Production	(3.1)	(6.3)	(31.6)	(4.7)	(3.3)	(10.1)
Δ M1	-19.0	-624.2***	113.2	9.2	-11.3	-274.4
	(20.1)	(162.0)	(237.0)	(32.6)	(15.1)	(33.2)
Unemployment rate	0.1	-1.0**	-1.7	0.0	0.5	12.3
	(0.1)	(0.4)	(2.6)	(0.1)	(0.1)	(1.6)
Financial						
Δ SP500	-5.8***	-5.7	-9.9	-2.4	-1.8	16.4
	(1.6)	(5.5)	(5.1)	(2.1)	(1.3)	(7.2)
Baa10YT	-1.3	1.5	-1.2	-1.4	1.0	-2.0
	(1.2)	(6.1)	(2.7)	(0.9)	(1.3)	(2.6)
N(weeks)	230	55	19	58	84	13
R^2 (Adj)	0.05	0.32	0.47	0.08	0.22	0.99

Panel D: Personal Characteristics	
Constant	-1.36
	(3.10)
Personal Characteristics	
Age	-0.08***
	(0.02)
Education Years	0.36***
	(0.13)
N(weeks)	230
R^2 (Adj)	0.20

Panel E: Sentiment						
Constant	0.53**	0.93	-0.18	0.84***	0.79***	1.53
	(0.39)	(0.81)	(0.53)	(0.21)	(0.19)	(2.16)
Fed Chair Statement	1.71***	2.75**	2.28**	0.35	-0.00	1.40
Neutral Sentiment	(0.39)	(1.20)	(0.91)	(0.48)	(0.34)	(2.82)
N(weeks)	230	55	19	58	84	13
R^2 (Adj)	0.08	0.08	0.23	-0.01	-0.01	-0.07
Constant	0.79**	1.74*	-2.36**	0.48	1.37***	0.35
	(0.32)	(0.91)	(1.00)	(0.45)	(0.27)	(3.09)
Fed Chair Statement	0.46	0.49	4.30***	0.47	-0.58**	1.80
Stance (H/D)	(0.30)	(0.78)	(1.24)	(0.42)	(0.26)	(2.49)
N(weeks)	230	55	19	58	84	13
R^2 (Adj)	0.01	-0.01	0.38	0.00	0.05	-0.04

Table H8
FFTR Change and FOMC Statements' Sentiment

The Table shows the OLS regressions of the jump surprise of the 1-Month Eurodollar interest rate (J) during the FFTR change announcement from model in Equation (H1). FOMC statements' sample is from February 01, 1994 to December 31, 2015 (first FOMC statement was made available to the public since January 01, 1994). Panel A shows the full model in Equation (15), with sub-panels for the NBER defined business cycles, expansion and recession periods (pro-cyclical, counter-cyclical). Macroeconomic variables with Δ are calculated with the first difference of the variable with respect to the previous announcement. Panel B shows the model in Equation (15) by including only the FOMC statement neutral sentiment variable ($NeutSentFOMC_t$). The $*$, $**$, and $***$ represents statistical significance at a p-value of $0.1, 0.05$ and 0.01, respectively. The standard error of the average is between parentheses.

Panel A: Macroeconomic and Sentiment			
	Full period	Expansion	Recession
		Feb 1994 – Mar 2001 Dec 2001 – Dec 2007	Apr 2001 – Nov 2001 Jan 2008 – Jun 2009
Constant	-2.3	1.3	-12.7
	(1.5)	(1.2)	(17.7)
Macroeconomic			
Δ PCE	150.2**	-12.7	334.8
	(63.6)	(69.3)	(1200.9)
Δ Industrial Production	-7.4	-0.6	-47.4
	(5.4)	(7.4)	(58.7)
Δ M1	22.9*	-19.9	69.7*
	(12.7)	(28.5)	(30.8)
Unemployment rate	0.29	-0.10	3.29
	(0.26)	(0.21)	(5.01)
Financial			
Δ SP500	-2.8	-3.0	8.2
	(2.7)	(2.7)	(10.9)
Baa10YT	3.9**	1.1	-8.6
	(1.9)	(2.1)	(41.3)
FOMC Statement Sentiment	-0.2	-0.3	-5.4
	(0.6)	(0.5)	(3.9)
N(weeks)	59	45	14
R^2 (Adj)	0.48	-0.07	0.62
Panel B: Sentiment			
Constant	0.6	0.5**	2.5
	(1.2)	(0.2)	(1.4)
FOMC Statement Sentiment	-0.21	0.05	-1.28
	(0.71)	(0.43)	(2.54)
N(weeks)	59	45	14
R^2 (Adj)	-0.02	-0.02	-0.06

Table H9
FFTR Change with Federal Reserve Chair Statements' Sentiment and Daily Macroeconomic News Announcements

The Table shows the OLS regressions of the jump surprise of the 1-Month Eurodollar interest rate (J) during the FFTR change announcement from model in Equation (H1). The Fed Chair' statements sample and Reuters Economic Surprise variables are from April 27, 2000 to December 31, 2015. Panel A shows results of five different models, nested by Prices and Output, Expectations, Labor Market, Trade and Housing Activity and the Fed Chair statement neutral sentiment categories. Panel B shows the model in Equation (H1) by including only one variable at a time. Constant results in this Panel B can be provided upon request to the authors. All the variables with the exception of the Fed Chair statement neutral sentiment are the difference between expected and realized variable announcement (surprise). The $*$, $**$, and $***$ represents statistical significance at a p-value of $0.1, 0.05$ and 0.01, respectively. The standard error of the average is between parentheses.

Panel A: Full Model Macroeconomic News Surprise

	(1)	(2)	(3)	(4)	(5)
Constant	-0.18***	1.08***	1.84***	1.87***	-0.20
	(0.31)	(0.30)	(0.52)	(0.52)	(1.79)
Prices and Output					
CPI	-0.18	-0.14	0.01	-0.06	-0.06
	(0.23)	(0.22)	(0.21)	(0.20)	(0.20)
GDP	-0.24	-0.16	-0.28	-0.38	-0.46
	(0.29)	(0.28)	(0.42)	(0.40)	(0.41)
Expectations					
Consumer Sentiment		-0.13**	-0.21***	-0.22***	-0.21***
		(0.06)	(0.07)	(0.07)	(0.07)
Labour Market					
Unemployment Rate			-5.35**	-5.03**	-4.68*
			(2.11)	(2.23)	(2.28)
Initial Jobless Claims			-5.03e-05**	-4.52e-05**	-4.23e-05*
			(1.83e-05)	(1.96e-05)	(2.00e-05)
Nonfarm Payrolls			7.42e-06*	8.17e-06**	6.29e-06
			(3.87e-06)	(3.85e-06)	(4.30e-06)
Trade And Housing Activity					
Retail Sales				0.00	-0.03
				(0.32)	(0.35)
Trade Balance				-1.55e-10*	-1.76e-10*
				(7.83e-11)	(8.53e-11)
Housing Starts				-1.67e-06	-1.90e-06
				(1.67e-06)	(1.70e-06)
Fed Chair Statement Sentiment					0.46
					(1.12)
Fed Chair Statement Stance(H/D)					1.29
					(1.27)
N(weeks)	41	41	41	41	41
R^2 (Adj)	-0.00	0.10	0.47	0.52	0.51

Panel B: Single Variable Regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
CPI	-0.2										
	(0.2)										
GDP		-0.1									
		(0.2)									
Consumer Sentiment			-0.1**								
			(0.1)								
Unemployment Rate				-4.3***							
				(1.5)							
Initial Jobless Claims					-9.4e-06						
					(1.4e-05)						
Nonfarm Payrolls						5.9e-06					
						(5.2e-06)					
Retail Sales							-0.2				
							(0.2)				
Trade Balance								-1.5e-10*			
								(7.5e-11)			
Housing Starts									7.1e-07		
									(1.8e-06)		
Fed Chair Statement Neutral Sentiment										1.7*	
										(0.9)	
Fed Chair Statement Stance(H/D)											0.9
											(1.0)
N(weeks)	41	41	41	41	41	41	41	41	41	41	41
R^2 (Adj)	0.01	-0.02	0.12	0.15	-0.01	0.01	0.00	0.07	-0.02	0.06	-0.00