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Central Bank Tone and the Dispersion of Views within Monetary Policy Committees[*]

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Abstract

Does policymakers' choice of words matter? We explore empirically whether central bank tone conveyed in FOMC statements contains useful information for financial market participants. We quantify central bank tone using computational linguistics and identify exogenous shocks to central bank tone orthogonal to the state of the economy. Using an ARCH model and a high-frequency approach, we find that positive central bank tone increases interest rates at the 1-year maturity. We therefore investigate which potential pieces of information could be revealed by central bank tone. Our tests suggest that it relates to the dispersion of views among FOMC members. This information may be useful to financial markets to understand current and future policy decisions. Finally, we show that central bank tone helps predicting future policy decisions.

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1. Introduction

A vast literature has shown that central bank communication matters as it influences private beliefs (see Guthrie and Wright, 2000).[1] In a seminal contribution, Gürkaynak, Sack and Swanson (2005) have shown the importance of information about the future policy path embedded in Federal Open Market Committee (FOMC) statements. The question of how central bank communication affects financial markets or helps predict policy decisions has given rise to an abundant literature surveyed by Blinder et al. (2008). One related question is whether policymakers' choice of language matters. For instance, ECB watchers followed closely the use of the term "*vigilance*" by the former ECB Governor Jean-Claude Trichet to predict future policy decisions (Jansen and De Haan, 2009). In a similar vein, the choice of words by the FOMC has been key to characterize the forward guidance policy. The switch in FOMC statements from "*some time*" to "*extended period of time*" and then "*considerable period of time*" has been used to signal the time frame of this policy.[2]

This paper aims to investigate whether the use of *positive* and *negative* words in central bank communication matters above and beyond the actual content of the message conveyed to the public. We quantify the tone conveyed by FOMC statements using computational linguistic methods and document whether this tone contains useful information for financial market participants. We also aim to shed light on the content of central bank tone.

Where would this central bank tone arise from? Central bank statements are cautiously prepared and drafted, so their content is directly attributable to policymakers' choices. There are multiple plausible factors that could explain why the tone of a statement may evolve. Policymakers could decide to disclose some signals beyond what they actually publish on that day. It could reflect private information about central bank staff forecasts (see Romer and Romer, 2000), the future policy path (Gürkaynak, Sack and Swanson, 2005), the outcome of policy votes (Meade, 2005), the content of deliberations (Hansen, McMahon and Prat, 2018), the committee's assessment of the balance of risks (Hanson and Stein, 2015), the dispersion of views within the committee, or some extrinsic sentiment. For any of these reasons, central bank tone could affect private beliefs about future policy.

An illustration of the purpose of this paper relates to the comparison of the choice of words in different FOMC statements in similar contexts. For instance, the August 2011 FOMC statement was augmented with the phrase: "*downside risks to the economic outlook have increased*" while the GDP growth Greenbook forecast for 2011Q3 was lowered by 1%. In the January 2006 FOMC meeting, the Greenbook forecast was lowered by the same amount but the statement was not accompanied by any discussion of downside risks. The first question this paper examines is whether adding "*downside risks*" to FOMC statements matter. Interestingly, the voting records of these two policy meetings shed some light on the potential information content of central bank tone. While the vote was unanimous for the January 2006 meeting, three members out of 10 voted against the proposed action in the August 2011 meeting. This piece of information could be of great importance as Madeira and

[1] Because long-term interest rates – a key driver of investment and consumption decisions – depend on expected short-term interest rates plus a term premium, central banks over the last decades have enhanced transparency of their actions and communication to the public to better signal future policy, shape private expectations and optimize policy outcomes (see e.g. Geraats, 2002; Woodford, 2005; King, Lu and Pasten, 2008; or Reis, 2013).

[2] See the Federal Reserve's timeline of of policy actions and communications about Forward Guidance: https://www.federalreserve.gov/monetarypolicy/timeline-forward-guidance-about-the-federal-funds-rate.html.

Madeira (2019) and Tillmann (2019) show that asset prices react to the inclusion of FOMC votes in the policy statements for the former and to hints about whether the decision was unanimous or not in ECB press conferences for the latter. These results suggest that information about the heterogeneity of views within the committee matters for market participants. However, there is a large literature on decision-making in policy committees that find evidence of a conformity bias and that these committees tend to favour consensus (see Belden, 1989; Sibert 2003; Meade, 2005; Swank, Visser and Swank, 2007; Meade and Stasavage, 2008; Riboni and Ruge-Murcia, 2010). Hence, the second question this paper examines is about whether FOMC tone could be a way to reflect the macroeconomic information contained in Greenbook forecasts since those are released with a 5-year lag, or whether it reflects the dispersion of views beyond dissenting votes.

The first empirical challenge for measuring such a concept as central bank tone is to convert policy statements into quantities that we can systematically analyse. We quantify the tone conveyed by FOMC statements using computational linguistic methods and more precisely dictionary methods. Their main advantages are automation and replicability. We use three different dictionaries that cover central banking, financial and everyday contexts, respectively the Apel and Blix-Grimaldi (2012) dictionary, the Loughran and McDonald (2011) dictionary and the General Inquirer's Harvard dictionary.

Investigating whether central bank tone affects interest rates requires overcoming a second empirical challenge. Our computed central bank tone measure is likely to be endogenous to the business cycle or financial stress. FOMC statements may have a more negative tone during recessions or periods of financial stress for instance. To correct for this potential endogeneity bias, we identify central bank tone shocks orthogonal to unemployment, financial stress, business confidence, and expectations of GDP growth and inflation.

We then use an event-study approach to isolate the effects of central bank tone shocks from other-days events. Because central bank tone is not the only piece of information released on the day of the FOMC statement is published, our specification controls for the policy decision and monetary news disclosed that same day. Because of evidence of "volatility clustering" (Mandelbrot, 1963) when using high-frequency financial variables, we use an autoregressive conditional heteroskedasticity (ARCH) model developed by Engle (1982) to properly account for the presence of heteroskedasticity. We estimate the effect of central bank tone on interest rates at the 1, 5 and 10-year maturity and on revisions in policy expectations, i.e. changes in private short-term interest rate expectations, measured with Overnight Indexed Swaps (OIS) at the same three maturities. Our sample covers the period from January 2003 to December 2013. The lower bound is determined by the availability of OIS rates whereas the upper bound is constrained by the availability of Greenbook forecasts that are released with a 5-year lag.

The first result of this paper is that central bank tone conveyed in FOMC statement affects interest rates above and beyond policy decisions and monetary news. This is consistent with Hansen and McMahon (2016), Jegadeesh and Wu (2017) and Schmeling and Wagner (2019). This finding suggests that there is some information content in the policymakers' choice of words of policy statements. More specifically, we find that an increase in FOMC tone has a positive effect on interest rates at the 1-year maturity. A one-standard deviation increase in central bank tone, that corresponds roughly to adding one positive word to a statement, pushes interest rates up by 2.3 basis points (bps) and OIS rates by 3.2 bps. One potential concern with this estimated effect is that it relies on a specific list of positive and negative words. However, the estimated effect of central bank tone is robust to alternative dictionaries. The main result does not depend on whether the list of positive and negative words comes from central banking, financial or everyday contexts. In addition, we show that this result holds for the European Central Bank (ECB) policy statements as well. Finally, we also provide evidence that this result is robust to various economic specifications or estimation methods, and is at work beyond the effect of forward guidance or quantitative easing announcements, different measures of monetary surprises or the policy stance, and financial stress measures.[3]

The previous finding raises the question of the nature of the information content of central bank tone. When writing the policy statement, multiple iterations between policymakers take place on the appropriate choice of words to use. These choices matter since central bank watchers analyse precisely how each statement has changed compared to the previous ones (see Ehrmann and Talmi, 2019) because of the signalling power of statements (see Gürkaynak, Sack and Swanson, 2005). These choices of words could convey multiple signals. We explore the question of the content of central bank tone by testing different hypotheses. Specifically, we test whether the FOMC tone reflects *(i)* staff macroeconomic signals unconditional to the future policy path (Greenbook forecasts), *(ii)* FOMC forecasts that would capture policymakers' signals about the future state of the economy conditional on FOMC members' "assessment of the appropriate path" for future policy, *(iii)* policymakers' subjective probabilities about the balance of risks or the dispersion of views within the monetary policy committee, and *(iv)* central bank information (à la Jarocinski and Karadi, 2019 and Miranda-Agrippino and Ricco, 2017) or policy news shocks (see Nakamura and Steinsson, 2018), that capture information about the future economic or policy outlook conveyed by policy announcements.

We find that central bank tone is strongly correlated to some dispersion and skewness measures of FOMC forecasts and weakly correlated (the p-value is just above the 10% level) to FOMC dissenting votes. These results suggest that central bank reflects some information about the dispersion of views within the FOMC. However, the effect of central bank tone on interest rates holds even when we control for these variables in our ARCH model. This finding in turn suggests that the content of central bank tone goes beyond these quantitative measures of dispersion of views. One explanation is that central bank tone reflects the dispersion of views that is not made explicit otherwise as policymakers with diverging views would see their assessment or opinions reflected in the policy statement. In the case of the "downside risks" example mentioned earlier, the use of more negative words is indeed reflected in the dissenting votes. Central bank tone could be viewed as a way to reflect the plurality of views among FOMC members, to make concessions to dissenters, or to signal shifting opinions to the public.

Eventually, one way to test for the relevance of this explanation is to examine when central bank tone is useful to private agents. We estimate state-dependent effects of central bank tone using interaction terms and find that the effect of central bank tone on interest rates is stronger when financial stress is high. We also find that private agents put more weight on central bank tone when the output gap is positive or inflation is above target. These

[3] In a standard Bayesian updating model of beliefs, the weight given to a signal should depend on the precision of this signal. This non-linearity would be shed light on whether the effect of central bank sentiment on interest rates works as a signal that is informative for the formation of private beliefs. We find that the effect of central bank sentiment is stronger when the precision of the signal conveyed is high and when the textual uncertainty, another linguistic measure of a text feature, of policy statements is low.

situations may reflect the standard central banking trade-off between higher inflation to reach higher growth. Overall, these findings support the idea that private agents pay more attention to these additional policymakers' signals when their future decisions seem unclear, so are not easily predictable. We test that hypothesis following the literature initiated by Krueger and Kuttner (1996) and Lapp and Pearce (2000) about the predictability of future policy decisions. We find that central bank tone helps predict the next monetary policy decision, consistent with this interpretation.

The closest papers to ours are Hansen and McMahon (2016), Jegadeesh and Wu (2017) and Schmeling and Wagner (2019). All three compute central bank tone measures and find evidence of its effect on interest rates. The first paper focuses on the tone analysis of some specific macroeconomic topics only in FOMC statements, not on the overall statement. The second paper uses FOMC minutes while the third one focuses on ECB communication. Our first result, about the effect of central bank tone, complements the findings of these three papers while our second result provides new insights about the content of central bank tone.

Some other papers have used computational linguistics in similar settings. Hansen, McMahon and Prat (2017) analyses how the internal deliberations during FOMC meetings have been affected by the release of FOMC transcripts after 1994. Correa et al. (2017) and Tillmann and Walter (2018) assess the tone in financial stability reports, or the difference in tones of ECB and Bundesbank policymakers. Tietz (2018) shows that the tone of speeches is a function of market misperceptions of future policy decisions. Finally, Ehrmann, Tietz and Visser (2019) analyse how the tone of FOMC members' speeches in the inter-meeting period is related to votes at the next meeting. Interestingly, they also find that the length of FOMC statements is positively correlated to dissenting votes.

Many other papers have coded indicators of the monetary policy stance conveyed by central bank communications (see e.g. Ehrmann and Fratzscher, 2007, Hayo and Neuenkirch, 2010, or Hubert, 2017). Lucca and Trebbi (2011) study how the stance of FOMC statements (whether they are hawkish or dovish) affects the yield curve. They focus on signals about the likely future policy path, whereas this paper focuses on central bank tone beyond these policy signals. In addition, many studies in finance have computed market sentiment measures (see e.g. Tetlock, 2007, Tetlock et al., 2008, Garcia, 2013, and Ferguson et al., 2015).[4]

This paper is also related to the literature that decomposes the informational content of central bank communication. Numerous works explore asset price responses to the information content of monetary policy announcements. Recently, Nakamura and Steinsson (2018), Jarocinski and Karadi (2019) and Cieslak and Schrimpf (2019), using sign restrictions, disentangle monetary surprises from central bank informational shocks embedded in policy statements. They show that non-monetary news account for a significant part of asset prices' reaction. In our approach, we aim to control for this information channel.

The rest of this paper is organized as follows. Section 2 describes the methodology to measure tone in central bank communication. Section 3 presents estimates of the effects of central bank tone on interest rates. Section 4 examines the nature of central bank tone. Section 5 concludes.

[4] In sociology, Fligstein, Brundage and Schultz (2014) use computational linguistics on FOMC transcripts to measure sense-making of deliberations, while Acosta (2015) also uses computational linguistics on FOMC transcripts and minutes to analyze the FOMC's responses to calls for transparency.

2. The tone of central bank communication

2.1. Central bank communication in policy statements

Central bank statements that follow monetary policy decision meetings appear to be a natural candidate to measure central bank tone for at least three reasons. First, policymakers announce policy decisions and their underlying reasons, so the tone can be linked to the most recent policy developments. Second, these statements act as a focal point for financial market participants, media, banks, monetary policy watchers and economists at the time when they are released, so these statements are made available to a large audience. They provide a detailed analysis of the central bank evaluation of the economic situation and of its assessment of risks to price and financial stability, and gives insights about the future likely policy path, so the tone can be linked to the most recent update of policymakers' information sets. Third, these statements are cautiously prepared and drafted, so their content is directly attributable to policymakers and changes in the choice of words should not be interpreted as communication mistakes. Speeches or press interviews could be a mix of a deliberate central bank tone and unwanted or unfortunate message.[5] This paper therefore focuses on the central bank tone as a conscious device of policymakers.

FOMC statements are released at the end of the two-day FOMC meetings that are scheduled eight times a year. The FOMC publishes statements since 1996 with a frequency of eight statements a year since January 2000. The FOMC introduced press conferences in April 2011 and only for meetings when the Summary of Economic Projections is published. We therefore limit our investigation to statements. Other types of communication could also reveal central bank tone such as the minutes or transcripts of the policy meetings. Nevertheless, the FOMC minutes, for instance, are available three weeks after the policy meeting and their circulation is not as large and their objective is more about the accountability of decisions than to communicate with the public. Given these considerations, we focus on statements to capture central bank tone.[6]

2.2. Quantifying central bank tone with dictionary methods

One major challenge for the analysis of central bank communication and for measuring central bank tone is to convert the raw policy statements into quantities that can be systematically analysed. The development of machine learning algorithms for language processing opens up the possibility of handling large unstructured text databases so as quantify the content of raw text data (see for instance Blei et al., 2003).[7] One advantage of the methods of this field is to be automated and replicable, which remove the subjectivity of human-reading coded indices.

Before running the lexicographic analysis, we perform a series of transformations on the original text. The text is first split into a sequence of substrings (tokens) whose characters are

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[5] However, because of their publicity, frequency, speaker, audience and context, the attention given by market participants to these communications is more difficult to control for.

[6] This choice means that we would leave out Mario Draghi's "Whatever it takes" speech. One could however argue that this speech, given on 26 July 2012, is an outlier in central bank communication. Altavilla, Giannone and Lenza (2016), among others, have studied the effect of that event specifically. The question of whether more or less attention is given to the central bank tone conveyed by speeches versus statements is left for future research.

[7] For instance, Ardia, Bluteau and Boudt (2019) use textual analysis-based sentiment indices for forecasting economic growth in the US.

all transformed into lower case. We remove English stop words and stem English words using the Porter stemming algorithm, which is an iterative, rule-based replacement procedure of word suffixes (see Hansen, McMahon and Prat, 2017, or Hansen and McMahon, 2016, for details). From there, we compute three measures for each FOMC statement: its tone, a clarity-weighted tone measure, and the precision of the tone signal conveyed.

To measure the tone of a document, we use "directional" word lists measuring words associated with positive and negative tone. We use the dictionary proposed by Apel and Blix-Grimaldi (2012) which has been specifically developed for central bank communication, and is therefore the most relevant for the present question. We also use two alternative dictionaries, each one capturing positive and negative tone in different environments. Loughran and McDonald (2011) have developed a list of words that reflect the tone in a financial context, while the General Inquirer's Harvard IV-4 psychosocial dictionary lists the seminal positive and negative words that reflect Osgood et al. (1957)'s basic and everyday language universals.[8] The three dictionaries comprise very different numbers of positive and negative words, from around 25, 300 and 2000 respectively (see Table A in the Appendix).

These three dictionaries have different characteristics and are complementary. Our preferred dictionary is the one of Apel and Blix-Grimaldi (2012) because of its focus, but we provide results using the three dictionaries in order to quantify central bank tone in various environment. Interestingly, almost three-quarters of negative words in the Harvard dictionary are not negative in a financial context according to the dictionary of Loughran and McDonald (2011). For illustration purposes, Table A in the Appendix shows the most illustrative positive and negative words identified in statements.

One would naturally note that policymakers could use a combination of positive and negative words together as "*solid decline*" for instance, that they could phrase a given message in opposite terms as "i*ncreasing growth*" versus "*decreasing unemployment*", or that they could use a negation to convey an opposite message such as with "*not improving*" versus "*worsening*". These cases constitute the substance of this analysis: our research question is exactly about these language choices and whether, for a given context, the use of some specific words rather than some others matters.

Once negative and positive words are identified and listed, we construct a tone variable based on the balance between the number of positive and negative words that appear in a given document divided by the total number of words included in the document:

$$\text{Tone}_{\text{j,t}} = \frac{\text{PositiveWords}_{\text{j,t}} - \text{NegativeWords}_{\text{j,t}}}{\text{TotalWords}_{\text{j,t}}} \tag{1}$$

The measure of tone, $\text{Tone}_{j,\text{t}}$, is bounded between [-1; 1] and j identifies the dictionary used (AB for Apel and Blix-Grimaldi, LM for Loughran and McDonald, and Harv for General Inquirer's Harvard IV-4). A positive value of the tone measure for a given statement reflects some optimism in the language used, whereas a negative value reflects some pessimism. From January 2003 to December 2013, the FOMC published 91 statements. Figure 1 shows the evolution across time of the $\text{Tone}_{\text{AB,t}}$ variable. Visually, central bank tone seems to evolve together with the business cycle and is positive over the period 2004-2007, drops in 2007 and

[8] Some additional dictionaries have been proposed but for different purposes. For instance, Picault and Renault (2017) create two measures of ECB communication about the policy stance and the state of the economy.

remains mostly negative up to 2010, when it becomes positive again at some periods. The highest value happens in 2006 whereas the lowest is reached in late 2008.

Table 1 provides descriptive statistics about the positive and negative words contained in FOMC statements according to the three dictionaries as well as the descriptive statistics for the respective tone measures. On average, the FOMC statements are 233 words long.[9] Based on the AB dictionary, they comprise 2.4 positive and 2.9 negative words on average. The $Tone_{AB}$ measure has a mean of -0.002 and a standard deviation of 0.011. This means that adding one positive word to a FOMC statement, all other things equal, generate an increase of the central bank tone measure of 0.005, so approximately half its standard deviation. Adding two positive words to a statement corresponds to an increase of around one standard deviation.

Many "*Fed watchers*" report which words changed between two statements and they show that FOMC statements are very similar from one policy meeting to the other. In the case that a statement is identical to the previous one except for the addition of "neutral" words (neither positive nor negative words). So the measured tone will be smaller because the total number of words has increased. In addition, a first 100-word statement with 5 positive words and 0 negative word and a second 100-word statement with 35 positive words and 30 negative words would yield the same tone score (0.05) based on equation (1), however the former statement may appear clearer than the latter since no negative words are used to overcome these two issues, we compute a clarity-weighted measure of tone:

$$\text{Tone}_{\text{AB2,t}} = \frac{\text{PositiveWords}_{\text{AB,t}} - \text{NegativeWords}_{\text{AB,t}}}{\text{PositiveWords}_{\text{AB,t}} + \text{NegativeWords}_{\text{AB,t}}} \quad (2)$$

This alternative measure uses the sum of positive and negative words at the denominator such that it would yield, for the previous example, a score of 1 for the former statement and of 0.08 for the latter statement. $\text{Tone}_{\text{AB2,t}}$ captures the clarity of the tone measure such that the message is equivocal ($\text{Tone}_{\text{AB2,t}}$ around 0) or unequivocal ($\text{Tone}_{\text{AB2,t}}$ close to -1 or 1). By extension, the absolute value of $\text{Tone}_{\text{AB2,t}}$, defined between 0 and 1, can be considered as a proxy for the precision of the signal conveyed by a given statement. We compute such a measure, labelled $\text{Sig}_{\text{AB,t}}$.

3. The effect of central bank tone

3.1. The high-frequency effect of central bank tone

We use an event-study methodology to estimate the effects of central bank tone on interest rates. This approach was initiated by Cook and Hahn (1989), Kuttner (2001), Cochrane and Piazzesi (2002) or Faust, Swanson and Wright (2004) and consists in focusing on movements in asset prices in a narrow window around FOMC policy announcements. The key assumption is that the reaction of interest rates that are continually affected by various factors can be specifically attributed to monetary news on the day of the policy announcement, or said differently that there is no other macroeconomic news during that window. Since interest rates adjust in real-time to news about the macroeconomy, movements in interest rates during the window of a policy announcement only reflect the effect of news about monetary policy. This is crucial for identification since it strips out the

[9] For comparison, over the same period, the ECB released 100 statements that are four times longer (881 words).

endogenous variation in asset prices associated with other shocks than monetary news.[10] To assess the effects of unexpected policy decisions on asset prices, the literature relies on the following regression:

$$\Delta y_t = \alpha + \beta_1 x_t + \varepsilon_t \quad (3)$$

where x_t denotes the surprise component of the policy decision announced by the FOMC, Δy_t denotes the change in an asset price considered over an interval that brackets the monetary policy announcement, and ε_t is a stochastic error term that captures the effects of other factors that influence the asset price in question. In the present case, x_t denotes the central bank tone, $Tone_{AB,t}$. We focus our analysis on a daily window (from the day before, close of business, to the given day, close of business) around FOMC policy announcements.

On these days, central bank tone is not the only piece of news conveyed to the public. Policymakers provide the policy decision and the policy statement explains their decision and their view about the current and future state of the economy. Following Gürkaynak, Sack and Swanson (2005), Campbell et al. (2012) and Hanson and Stein (2015), a large consensus has formed about the information content of central bank announcement days: a primary share of the news is about the expected path of future policy (whether it is the policy rate during a period of conventional monetary policy or asset purchases in the most recent period) over the next several quarters as opposed to surprise changes in the current policy stance. A simple and transparent way to capture revisions to the expected path of policy over a given horizon is to use the daily change in the nominal sovereign yield at this horizon on FOMC announcement dates as a proxy for monetary policy news.[11] We use a maturity of 2 years following Hanson and Stein (2015).[12] Since there is no observable measure of the overall monetary policy stance during times of unconventional policies, another advantage of this measure is that it allows encompassing in one single variable the multidimensional aspects of monetary policy such as liquidity provisions, forward guidance or asset purchases. Equation (3) rewrites:

$$\Delta y_{t,h} = \alpha + \beta_1 Tone_{AB,t} + \beta_2 MPS_t + \varepsilon_t \quad (4)$$

where MPS_t is the monetary policy surprises measured as the daily change in the nominal 2-year sovereign yield. Our dependent variables are nominal interest rates and OIS rates at maturities of 1, 5 and 10-year. We use the continuously compounded yields on a zero-coupon bond at different maturities estimated by Gürkaynak, Sack and Wright (2007) for our measure of nominal interest rates. OIS rates at a maturity *h* reflect financial market participants' expectations of the average short-term policy rate over the horizon corresponding to the maturity of the swap plus a term premium (Christensen and Rudebusch, 2012).[13] By using these two types of interest rates, we can decompose the yield

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[10] For example, a positive employment announcement that systematically occurs the day before a policy announcement will already have been factored into asset prices when the central bank makes its announcement. A key assumption is that all information flows before the event at date *t* have been incorporated in prices in *t-1*.

[11] The key point is that this measure captures news about the expected medium-term policy path as opposed to news about the contemporaneous policy decision only, meaning that it encompasses the so-called "target" and "path" factors (Gürkaynak, Sack and Swanson, 2005) of monetary news.

[12] For robustness purposes, we use the standard measure of Kuttner (2001) later on.

[13] The OIS rate being the average effective federal funds rate expected at a given maturity, OIS are good proxies of expectations of future short-term interest rates. OIS allow financial institutions to swap the interest rates they are paying without having to refinance or change the terms of loans they have taken from other financial institutions. When two financial institutions create an OIS, one institution is swapping a floating interest rate and the other a

curve in a potentially informative way. Nominal interest rates at a maturity h shed light on factors affecting private agents' beliefs up to this maturity h while OIS rates at a maturity h shed light on factors affecting monetary policy expectations. Because of data availability constraints for OIS rates across maturities, our sample starts in January 2003 so that our estimates are comparable across the term structure.[14,15]

We focus on FOMC announcement dates from January 2003 to December 2013. Table 2 presents OLS estimates of both equations (3) and (4). Since our database has a daily frequency, we estimate the effects of central bank tone and monetary policy surprises over all 2871 observations or for statement days only. Table 2 shows that OIS rates at the 1-year maturity responds significantly to central bank tone in all specifications. Nominal interest rates at the 1-year maturity responds significantly to central bank tone in only one of the four specifications: when considered without monetary policy surprises and over all observations. Central bank tone has no effect on medium (5-year) or long (10-year) maturities. Monetary surprises affect nominal interest rates at all maturities whereas they affect OIS rates at the 1-year maturity only.

These results suggest that central bank tone is positively correlated to interest rates. While these OLS estimates have the benefit of transparency and simplicity, they may suffer from two shortcomings. First, central bank tone may be endogenous to the state of the economy. It may reflect optimism about the future growth or correlates with financial stress for instance. Second, the variance of financial variables varies significantly over time, especially over a sample comprising the Great Financial Crisis, generating potential heteroskedasticity issues. The next subsections aim to deal with these endogeneity and heteroskedasticity concerns.

3.2. The identification of exogenous central bank tone shocks

Because central bank tone may well be correlated to macroeconomic and financial variables (Cannon, 2015), we identify central bank tone shocks to estimate causal effects of policymakers' choice of words. We estimate the following equation (5) on statement days:

$$Tone_{AB,t} = \alpha + \beta_1 \, Tone_{AB,t\text{-}j} + \beta_2 \, X_t + \beta_3 \, Z_t + \epsilon\_Tone_{AB,t} \qquad (5)$$

where *j* is the number of days between each policy statement, so $Tone_{AB,t\text{-}j}$ is the tone of the previous FOMC statement. The vector X_t includes the level of the VIX and the biannual change in business confidence measured by the ISM report on the Business Survey index (ISMBS). These variables capture both the level of stress in financial markets and the low-frequency dynamics in the real economy.[16] The vector Z_t includes the change in private expectations of 1-year real GDP growth, measured with the variation in the Survey of Professional Forecasters (SPF) forecasts between two waves of surveys, the change in the unemployment rate, and inflation expectations 1-year ahead, measured with SPF inflation

fixed short-term interest rate at a given maturity. The transaction involves only marginal counterparty risk since the principal amount is not exchanged between the parties, so OIS rates are free of default or liquidity risks.

[14] These series are made public by the Federal Reserve (from the ICE Benchmark Administration for OIS) at federalreserve.gov/releases/h15/default.html, federalreserve.gov/pubs/feds/2006/200628/200628abs.html.

[15] Tables B in the Appendix describes the data used in this papers and their sources and Table C in the Appendix reports descriptive statistics of these series.

[16] Survey measures of consumer confidence have also been tested, but they are not significant.

forecasts.[17,18] These variables aim to capture the current state of the economy and beliefs about its future state.[19] The residuals $\epsilon\_Tone_{AB,t}$ reflects unexpected central bank tone shocks.

Figure 2 plots the residuals $\epsilon\_Tone_{AB,t}$ that reflect the time series of central bank tone shocks with the AB dictionary.[20] Table 3 shows the estimated parameters of equation (5) for $Tone_{AB}$ and $Tone_{AB2}$ in columns 1 and 2 respectively. The lagged tone variable is positive and significant, consistent with the fact that statements do not change much between two meetings. A high level of financial stress is associated negatively with the tone of FOMC statements. At the opposite, positive changes in business confidence reduce policymakers' tone. Inflation expectations are not significant.[21] Increases in SPF GDP expectations are negatively associated with tone while increases in unemployment are positively associated with tone. This suggests that the central bank tone does not reflect directly the current or future state of the economy as can be expected at this date, but might rather reflect policymakers' belief about the trend-reverting process of the economy. Policymakers' tone is more optimistic when expected GDP decreases (or unemployment increases) whereas it is more pessimistic when these economic activity variables improve.[22] 60% of the variance of $Tone_{AB,t}$ is explained by this model.

From one meeting to another, the FOMC statement may not change, so the central bank tone measure would not change. However, in such a case, central bank tone shocks would change if economic or financial conditions have changed. This is comparable to an unchanged policy rate between two policy meetings while macroeconomic conditions have deteriorated, such that it would result in a restrictive monetary policy shock. One way to think of these central bank tone shocks is from the perspective of private agents. The fitted value of equation (5) reflects what private agents can expect the central bank tone to be in the next statement. Policy decisions, policy news and central bank projections are therefore not included in equation (5) because *(i)* they are not available to private agents up to the policy announcement day, and *(ii)* there is no clear identification assumption to single out central bank tone from other policy variables. Said differently, all these policymakers' variables might all be generated at the same time during FOMC policy meetings.

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[17] The use of forecasts enables us to deal with the fact that information sets include a large number of variables. Forecasts encompass rich information sets and Bernanke et al. (2005) show that a data-rich environment has important implications. Forecasts work as a FAVAR model as they summarize a large number of variables.

[18] The SPF is collected from approximately 40 panelists and published by the Federal Reserve Bank of Philadelphia. SPF forecasts are also published in February, May, August, and November, and CPI forecasts are provided as year-over-year percent changes. We consider the median of individual responses in our analysis.

[19] The variables in the vectors X_t and Z_t have different frequencies (quarterly, monthly and daily) and are included using the last figure available at the date of each statement.

[20] This series has a mean zero and is not correlated with monetary surprises. The Shapiro-Francia normality test, the Cumby-Huizinga test for autocorrelation and the Portmanteau test for white noise have been performed. Table 3 provides p-values for these statistics and shows that these central bank tone shocks have relevant properties to be used as instruments for our analysis of the causal effect of central bank tone on interest rates.

[21] Current and past inflation have also been tested, but these measures are not correlated to central bank tone.

[22] Table 3 also shows the estimated parameters of an augmented version of equation (5) with the output gap and the low-frequency changes in the Economic Policy Uncertainty (EPU) index of Baker, Bloom and Davis (2016), the St. Louis Fed Financial Stress Index (STLFSI), the Standard and Poor's 500 (SP500) price index, industrial production, and WTI oil prices. These additional controls are not significant and their inclusion does not affect the sign, magnitude of significance of the variables included in the baseline version of equation (5) described above.

3.3. The causal effect of central bank tone

Beyond endogeneity issues, we need to overcome two intertwined issues. First, as is common with financial variables, the variance of our dependent variables changes over time. We therefore use an ARCH (autoregressive conditional heteroskedasticity) model to properly treat heteroskedasticity and take into account this "volatility clustering".[23] Second, the estimated central bank tone shocks from equation (5) are generated regressors that might bias standard errors; we compute robust standard errors using the Huber-White-sandwich estimator.[24] The following ARCH model is estimated at the daily frequency:

$$\Delta y_{t,h} = \alpha + \beta_1 \,\epsilon\_Tone_{AB,t} + \beta_2 \,MPS_t + \varepsilon_t \,,\; \varepsilon_t \sim (0, \sigma_t^2) \quad (6)$$

$$\sigma_t^2 = \gamma_0 + \sum_{i=1}^{p} \gamma_i \,\varepsilon_{t-i}^2 \quad (7)$$

where $\Delta y_{t,h}$ is the change between t and t-1 in OIS and nominal interest rates at a maturity h, $\epsilon\_Tone_{AB,t}$ is the central bank tone shock estimated via equation (5), monetary surprises (MPS_t) are measured as the daily change in the nominal 2-year sovereign yield. Because central bank tone is conveyed to the public on the same day than policy decisions and different signals about future policy or the state of the economy, we include monetary surprises in equation (6) to control for the effect of monetary surprises - β_2 - on interest rates.[25] Monetary surprises aim to capture the contemporaneous policy surprise, signals about future policy and central bank information surprises. However, they could also capture the effect of central bank tone. We pay attention to this potential collinearity issue by estimating equation (6) with or without monetary surprises. The number of lags p=1 in the variance equation is determined by their significance.[26]

We estimate equations (6)-(7) with an ARCH specification on 2871 daily observations that comprise 91 FOMC announcements from January 2003 to December 2013. Table 4 presents estimates of both the mean (6) and variance (7) equations. Our dependent variables are nominal and OIS interest rates at maturities of 1, 5 and 10 years. The first panel shows estimates of the effect of central bank tone when equation (6) does not include monetary policy surprises. The β_1 coefficient associated with tone shocks is positive and significant for the 1-year horizon for both nominal and OIS rates. A one-standard deviation increase in central bank tone shocks pushes interest rates up by 2.3 bps and OIS rates by 3.6 bps.

The second panel of Table 4 shows our baseline estimates with equation (6) including monetary surprises. The β_1 coefficient associated with tone shocks is still positive and significant for the 1-year horizon for both nominal and OIS rates. The magnitude of the effect

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[23] Nakamura and Steinsson (2018) find that OLS estimates of daily surprises may lead to biased outcomes because central bank announcements can be "*confounded by substantial background noise*". They suggest using the heteroskedasticity approach of Rigobon (2003), but this procedure does not enable to measure the effect of central bank tone *per se* as it relies on increased volatility generated by the central bank communication event overall. We use an ARCH specification to deal with this background noise and disentangle the different signals.

[24] This issue is shared with all studies estimating unexpected shocks in a first step as in e.g. Romer and Romer (2004), but is more acute when the generated regressors are not normally distributed, which is not the case here.

[25] We could also include controls from equation (5) such that we would estimate equations (5) and (6) in one step. One issue with this specification is that eq. (5) is estimated at the FOMC meeting frequency whereas eq. (6) at the daily frequency what reduces the power of the orthogonalisation performed in the identification step. We nevertheless provide estimates of such a specification in the robustness section.

[26] We later augment the variance equation with a second lag or with TARCH terms to assess the robustness of the effect of central bank tone shocks to these alternative specifications.

is quite similar when controlling for the news surprises of policy announcements: a one-standard deviation increase in $\epsilon\_Tone_{AB,t}$ pushes nominal interest rates up by 2.4 bps and OIS rates by 3.2 bps. The tone of FOMC statements appears to be interpreted by private agents to provide relevant information at the short-term horizon – 1 year – rather than for medium- or long-term (5 and 10 years). Interestingly, this short-term horizon is below the shortest bound of transmission lags of monetary policy, estimated to be between 12 and 24 months by Bernanke and Blinder (1992) or Bernanke and Mihov (1998).[27] The β_2 coefficient associated with monetary surprises is positive as expected. The effect is significant for all three horizons for nominal interest rates, and is significant only for the 1-year horizon for OIS interest rates. This is consistent with the difference between nominal and OIS rates: a monetary surprise would affect the whole term structure through its effect on its short-term part.

The third panel of Table 4 shows estimates with the alternative measure of tone $\epsilon\_Tone_{AB2,t}$ that uses the number of positive and negative words at the denominator to compute $Tone_{AB2,t}$. We only show estimates for β_1 but equation (6) is estimated in its baseline form with monetary surprises. The β_1 coefficient associated with tone shocks is still positive and significant for the 1-year horizon for both nominal and OIS rates. The magnitude of the effect is marginally smaller: a one-standard deviation increase in $\epsilon\_Tone_{AB2,t}$ pushes nominal interest rates up by 2 bps and OIS rates by 2.4 bps. We also provide estimates with alternative tone shocks $\epsilon\_Tone_{LM,t}$ and $\epsilon\_Tone_{Harv,t}$ computed with the Loughran and McDonald (2011)'s and Harvard's word lists. The β_1 coefficient associated with tone shocks is still positive and significant for the 1-year horizon for both nominal and OIS rates. This is an important result to the extent that it shows that the main finding of this paper does not depend on the word lists used. While the LM dictionary is relevant for the financial context, the Harvard dictionary is dedicated to everyday language and the AB dictionary has been specifically developed to analyse central bank communication. Despite these differences in purpose and scope and whether central bank tone is computed based on various number of words, central bank tone affects identically interest rates at the same maturity of 1-year.

The fourth panel of Table 4 shows estimates with the alternative measure of monetary policy shocks. We use the intraday measures of Gertler and Karadi (2015) as well as the one of Miranda-Agrippino and Ricco (2017) that corrects for central bank information shocks to test the robustness of our main result. In addition, Gürkaynak, Sack and Swanson (2005) show that central bank communication about the future likely path of policy explains most of the variation of asset prices on policy announcement days. We use Nakamura and Steinsson (2018)'s measure of "policy news shock" to control for such an information transfer.[28] The main result that central bank tone affects interest rates at the 1-year maturity holds.

We assess the robustness in two ways. First, we replicate the same exercise using ECB statements (see section A in the Appendix). Second, we test alternative specifications of the empirical model with variations for central bank tone, monetary surprises and controls, and

[27] A possibility for explaining the effect of tone is that it works through the risk-taking channel and affect market participants' risk aversion, so the term premium. Because the latter can be proxied by financial indicators like the VIX, controlling in equation (6) for such variables that predict this term premium enables to isolate the effect on policy expectations (see Piazzesi and Swanson, 2008). We test such an alternative specification later on.

[28] This measure is supposed to capture the effects of announcements that convey information about the likely future policy path over the medium term (see Barakchian and Crowe, 2013, and Ben Zeev, Gunn and Khan, 2015).

variations of the econometric specification using OLS and TARCH models or estimating equations (5) and (6) in one-step for instance (see section B in the Appendix).

3.4. Some characteristics of central bank tone

We further investigate whether the effect of central bank tone depends on some features of FOMC statements. In a standard Bayesian updating model of beliefs, the weight given to a signal should depend on its precision. We assess whether the effect of central bank tone works as such a signal using two measures of signal precision. We augment equation (6) with a given state-variable and the interaction term between central bank tone shocks and this state-variable. Table 5 shows parameter estimates for different state-variables.

We first interact central bank tone shocks with $Sig_{AB,t}$, the measure of the precision of the signal – $Tone_{AB,t}$ – described in section 2.2. We expect the effect of tone shocks to be stronger if the signal is more precise and vice versa. The interaction parameter is positive and significant for both nominal and OIS rates at the 1-year horizon. When the tone signal is more precise, the effect of tone is more than twice the linear effect documented in the previous section. When the tone signal is imprecise (a lot of positive and negative words are used together), the effect of central bank tone is non-significant or even negative but only at the 10% level. Second, we interact central bank tone shocks with a measure of textual uncertainty based on a word list of Loughran and McDonald (2011) of uncertain words such as "approximate", "contingency", "depend", "indefinite", "uncertain" and "variability".[29] Consistent with the previous result, the parameter of the interaction term is negative and significant. A low textual uncertainty leads to a strong effect of central bank tone whereas a high textual uncertainty generates a negative effect of central bank tone. The signal conveyed to the public is reduced or even reversed when the text is uncertain.

4. The content of central bank tone

The main finding of the previous section can be illustrated by the FOMC statement of 7 August 2007. The $Tone_{AB}$ measure doubled on that day compared to the 28 June 2007 FOMC statement, with the increase being almost entirely exogenous to the state of the economy.[30] On this day, 1-year interest rates and 1-year OIS rates increased by 12 and 8 bps. However, the FOMC kept the policy rate unchanged as was expected and did not published macroeconomic forecasts together with its statement. The second question this paper explores is the reason for this increase in interest rates on that day.

One potential reason for the revision in investors' beliefs can be the fact that the following phrase "*supported by solid growth in employment and incomes and a robust global economy*" was added after the existing sentence "*The economy seems likely to continue to expand at a moderate pace over coming quarters*" in the FOMC statement. This addition led the Financial Times to write in its 7 August 2007 comment of the FOMC statement that "*The central bank expressed confidence that the US economy would grow at a moderate pace in coming quarters*" (Callan, 2007). Such an example would suggest that the tone of FOMC statements convey private

[29] This measure, computed as ratio of the number of uncertain words over the total number of words in a document, is used to take into account the overall uncertainty of the statement disclosed to the public.
[30] Our baseline tone measure moved from 0.008 in the June 2007 FOMC statement to 0.015 in the August 2007 FOMC statement while the exogenous tone measure was 0.007 for the August 2007 FOMC statement.

information about the state of the economy. We review different options of what central bank tone could capture and test different hypotheses related to them.

4.1. What could central bank tone capture?

Since central bank statements are cautiously prepared and drafted and policymakers know that central bank watchers will analyse each and any of the words included (see Ehrmann and Talmi, 2019), the choice of words is directly attributable to policymakers and cannot be seen as a random process. There are multiple potential factors that could explain why the tone of a statement would evolve. Policymakers could decide to disclose some signals beyond what they actually publish on that day. A burgeoning literature provides evidence of a central bank information channel and the revelation by policymakers of their macroeconomic information set through their policy announcements.[31] Central bank tone could be part of this channel and could reflect private information about central bank staff forecasts (see Romer and Romer, 2000), the future policy path (Gürkaynak, Sack and Swanson, 2005), the outcome of policy votes (Meade, 2005), the content of deliberations (Hansen, McMahon and Prat, 2018), the committee's assessment of the balance of risks (Hanson and Stein, 2015), the dispersion of views within the committee, or some extrinsic sentiment. For any of these reasons, central bank tone would in turn affect private beliefs about future policy.

We explore the question of the content of central bank tone by testing different hypotheses. Specifically, we test whether the FOMC tone reflects *(i)* staff macroeconomic signals unconditional to the future policy path (Greenbook forecasts), *(ii)* FOMC forecasts that would capture policymakers' signals about the future state of the economy conditional on FOMC members' "assessment of the appropriate path" for future policy, *(iii)* policymakers' subjective probabilities about the balance of risks or the dispersion of views within the monetary policy committee using FOMC dissenting votes and the dispersion and skewness of FOMC forecasts, and *(iv)* central bank information or policy news shocks, that capture information about the future economic or policy outlook.

To do so, we estimate the following equation in which we regress central bank tone shocks on different variables capturing different aspects of policymakers' environment:

$$\epsilon\_Tone_{AB,t} = \alpha + \beta_1 X_t + \varepsilon_t \quad (8)$$

where X_t contains the different proxies we use to test each hypothesis. We first test whether central bank tone is correlated with the level and change in Greenbook (GB) inflation and output forecasts 1- and 2-year ahead that would capture unconditional macroeconomic signals or with the level and change in FOMC inflation and output forecasts for current and next years, as a measure of the macroeconomic signals conditional on FOMC members' "assessment of the appropriate path" for future policy.[32] Second, we estimate the correlation

[31] See Romer and Romer (2000), Ellingsen and Söderström (2001), Baeriswyl and Cornand (2010), Campbell et al. (2012), Melosi (2017), Miranda-Agrippino and Ricco (2017), Jarocinski and Karadi (2019), Cieslak and Schrimpf (2019), Lakdawala and Schaffer (2019), Hubert and Maule (2019), or Hubert (2019).

[32] The FOMC publishes forecasts for inflation and real GDP growth in the Monetary Policy Report to the Congress since 1979. FOMC forecasts were released each year in late January/early February and late June/early July until 2007Q3, then in January, April, June and October until 2012Q4, and since then in March, June, September and December. For inflation, we consider the Personal Consumption Expenditures (PCE) measure. These forecasts are published as two ranges encompassing each individual FOMC member's forecasts: the "full

between central bank tone and the dispersion of views among FOMC members about macroeconomic outcomes. We compute a measure of the dispersion of FOMC forecasts (the distance between the upper and lower bound of the full range) and a measure of the skewness of FOMC forecasts (the difference between (i) the distance between the upper bands of the full range and of the central tendency and (ii) the distance between the lower bounds of the central tendency and of the full range). Third, we assess the correlation of central bank tone with the share of dissenting votes, and the balance of dissenting votes between tighter and easing votes using the database of Thornton and Wheelock (2014). Fourth, we estimate whether central bank tone is correlated to central bank information shocks (taken from Miranda-Agrippino and Ricco, 2017) or policy news shocks (taken from Nakamura and Steinsson, 2018), two pieces of information contained in policy decisions.

Equation (8) is estimated on statement days only. Table 6 shows the estimated parameters. The dispersion and skewness of FOMC forecasts are significantly correlated with central bank tone. More dispersion of inflation forecasts or more skewed inflation and output forecasts are negatively correlated with central bank tone. Dissenting votes are weakly correlated (just above the 10% level) with central bank tone. Neither the level and the change in Greenbook and FOMC forecasts nor central bank information and policy news shocks are correlated with the tone of FOMC statements. This result suggests that central bank tone could be a way to reflect the plurality of views among FOMC members.

We then estimate equation (6) augmented with these dispersion and skewness measures to explore whether central bank tone is simply a proxy for these measures or whether it does affect interest rates above and beyond these measures. Table 6 shows that, although they are correlated with central bank tone, these measures of the dispersion of FOMC members' views of the inflation and macro outlook do not affect the effect of central bank tone on interest rates. Taken together, these findings suggest that the content of central bank tone is somehow linked to the dispersion of views among FOMC members but captures some heterogeneity that goes beyond the dispersion in individual FOMC forecasts.

4.2. When does central bank tone matter?

One way to test for the relevance of this potential explanation is to examine when central bank tone is useful to private agents. We investigate whether private agents process central bank tone shocks differently conditional on different state-variables. We augment equation (6) with a given state-variable and the interaction term between central bank tone shocks and this state-variable. Table 7 shows parameter estimates for different state-variables.

Central bank tone is first interacted with a measure of financial stress, the VIX. The interaction term parameter is positive for both measures of interest rates but significant for OIS rates only. Central bank tone has significant and positive effect on interest rates when financial stress is high, but has no effect when financial stress is low. This can be interpreted as central bank tone being a complementary signal when uncertainty is high.

Second, we interact central bank tone shocks with two measures of business cycles. The former is discrete: NBER recession dummies and the latter is continuous: the output gap, computed as the difference between the actual real GDP – measured by the Bureau of

range" includes all forecasts while the "central tendency" removes the three highest and three lowest forecasts. As standard in the literature, we use the midpoint of the full range.

Economic Analysis – and the potential real GDP – measured by the Congressional Budget Office. In the first case, the parameter associated with the NBER interaction is negative, although only significant for OIS rates. During expansions, the effect of central bank tone is positive and significant, whereas it is not significant during recessions. The parameter associated with the output gap interaction is positive, although only significant for nominal interest rates. When the output gap is positive, the effect of central bank tone is positive and significant, whereas it is not significant when the output gap is negative.

Finally, we interact central bank tone shocks with the inflation gap, the difference between the level of CPI inflation and a 2% target. The interaction parameter is positive, although only significant for nominal interest rates. The effect of central tone is therefore positive and significant when inflation is above this 2% target, but not when inflation is below this target.

The fact that private agents give more weight to central bank tone when there is uncertainty and when the output gap is positive or inflation is above target suggests that private agents pay more attention to these policymakers' signals when their future decisions are unclear, so are not easily predictable. These situations may reflect a standard central banking trade-off between higher inflation to reach higher growth. In these situations, private agents seek additional information in central bank tone to form their beliefs about future policy.

4.3. The predictive power of central bank tone

The previous result raises the question of whether central bank tone helps predict the next monetary policy decision. Following Krueger and Kuttner (1996), a large literature has focused on the predictability of future monetary policy decisions using policy statements, central bank forecasts or communication indices (see e.g. Lapp and Pearce, 2000; Pakko, 2005; Heinemann and Ullrich, 2007; Rosa and Verga, 2007; Jansen and De Haan, 2009; Hayo and Neuenkirch, 2010; Sturm and De Haan, 2011). We test whether central bank tone from a given statement at date t adds useful information to predict the next policy decision at date t+1 beyond the information contained in the level of the policy rate and in FOMC inflation and output projections. We estimate the following equation on statement dates:

$$i_{t+1} = \alpha + \beta_1 \epsilon\_Tone_{AB,t} + \beta_2 i_t + \beta_3 \Omega_t + \varepsilon_t \quad (9)$$

where i_{t+1} is the variable capturing the next policy decision in t+1. We use either a continuous variable representing either the level or the change in the federal funds target rate or a discrete variable for when the policy interest rate increases (+1), is unchanged (0) or decreases (-1) to describe changes in monetary policy. In the former case, we estimate equation (9) with OLS while in the latter case, we use an ordered probit model to account for the discrete nature of the dependent variable. We investigate whether $\epsilon\_Tone_{AB,t}$ has some predictive power beyond the contemporaneous policy decision (i_t) and a vector (Ω_t) capturing the information set that can be used to predict the next policy decision. At minimum, this vector includes FOMC inflation and output forecasts.

Table 8 presents the estimates of different specifications of equation (9). The first column shows OLS estimates using the level of the federal funds target rate. The contemporaneous policy rate and FOMC forecasts are significant predictors of the future policy rate, but central bank tone is also strongly significant in determining i_{t+1}. The same result holds when predicting the change in the federal funds target rate (column 2) or using a probit model (column 3). We then replace $\epsilon\_Tone_{AB,t}$ by the measure controlling for the number of positive and negative words used – $\epsilon\_Tone_{AB2,t}$ – or by central bank tone – $Tone_{AB,t}$. Both variables are also significant predictors of future policy decisions (columns 4 and 5). We then augment the vector Ω_t to enrich the information set used to predict future policy. We consider the dispersion and skewness measure of FOMC forecasts, private inflation and output forecasts (measured with SPF), policy expectations measured with Fed Funds futures, 1-month OIS or 1-year OIS, and the policy news variable of Nakamura and Steinsson (2018). Columns 6 to 11 show that central bank tone has some predictive power beyond these variables. Finally, we include high-frequency variables – the VIX, SP500 returns and oil prices – in the vector Ω_t and still find that central bank tone helps predict the next policy decision (column 12).

5. Conclusion

This paper explores empirically the effect and rationale for such an effect of central bank tone on interest rates. We quantify the concept of central bank tone using computational linguistic methods. We document the fact that positive central bank tone increases interest rates at the 1-year maturity. The effect of central bank tone varies conditional to the precision of the signal or the uncertainty conveyed in the policy statement. In addition, central bank tone has a stronger effect on interest rates during periods of financial stress, and during expansions or when inflation is above target. The fact that private agents give more weight to central bank tone when the output gap is positive or inflation is above target or when there is uncertainty suggests that they pay more attention to policymakers' signals in the choice of positive and negative words when their future decisions are unclear, so are not easily predictable. The fact that central bank tone helps predict the next policy decision supports this interpretation.

Further, we find that while central bank tone is correlated to the dispersion of views among FOMC members but captures some heterogeneity that goes beyond the dispersion in individual FOMC forecasts. The choice of positive and negative words in policy statements could be seen as a way to reflect the plurality of views among monetary policy committee members, to make concessions to dissenters, or to signal shifting opinions. These results give policymakers some insights on how private agents interpret and respond to the tone conveyed by central bank communication.

References

Acosta, Miguel (2015). "FOMC Responses to Calls for Transparency", *Finance and Economics Discussion Series*, No. 2015-60.

Altavilla, Carlo, Domenico Giannone and Michele Lenza (2016). "The financial and macroeconomic effects of the OMT announcements", *International Journal of Central Banking*, 12(3), 29-57.

Apel, Mikael, and Marianna Blix-Grimaldi (2012). "The information content of central bank minutes", *Riksbank Research Paper Series*, No. 92.

Ardia, David, Keven Bluteau and Kris Boudt (2019). "Questioning the news about economic growth: Sparse forecasting using thousands of news-based sentiment values", *International Journal of Forecasting*, forthcoming.

Baeriswyl, Romain, and Camille Cornand (2010). "The signaling role of policy actions", *Journal of Monetary Economics*, 57(6), 682–695.

Baker, Scott, Nicholas Bloom, and Steven Davis (2016). "Measuring economic policy uncertainty", *Quarterly Journal of Economics*, 131(4), 1593-1636.

Barakchian, Mahdi, and Christopher Crowe (2013), "Monetary policy matters: Evidence from new shocks data", *Journal of Monetary Economics*, 60(8), 950-966.

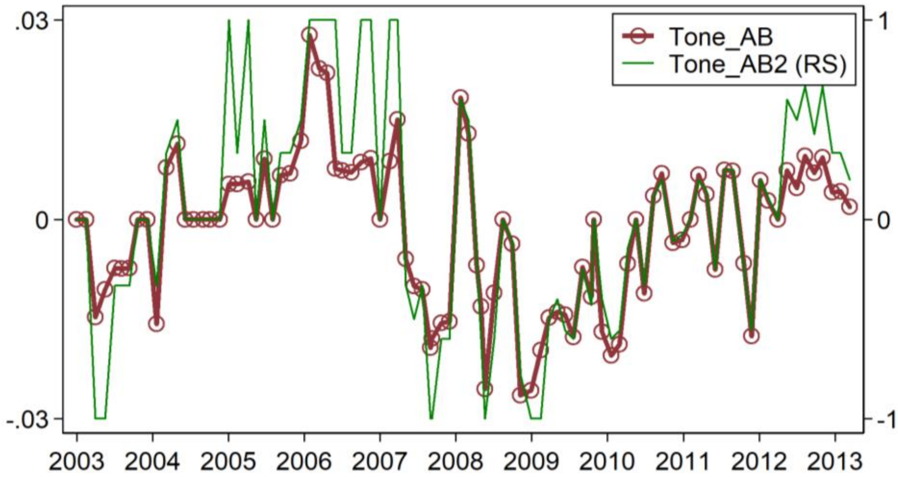
Belden, Susan (1989). "Policy Preferences of FOMC Members as Revealed by Dissenting Votes", *Journal of Money, Credit and Banking*, 21, 432-441.
Ben Zeev, Nadav, Christopher Gunn and Hashmat Khan (2015). "Monetary News Shocks", *Journal of Money, Credit and Banking*, forthcoming.
Bernanke, Ben, and Alan Blinder (1992). "The Federal Funds Rate and the channels of monetary transmission", *American Economic Review*, 82(4), 901–921.
Bernanke, Ben, and Ilian Mihov (1998). "Measuring monetary policy", *Quarterly Journal of Economics*, 113(3), 869–902.
Bernanke, Ben, Jean Boivin, and Piotr Eliasz (2005). "Measuring the Effects of Monetary Policy: A Factor-augmented Vector Autoregressive (FAVAR) Approach", *Quarterly Journal of Economics*, 120(1), 387–422.
Blei, David, Andrew Ng and Michael Jordan (2003). "Latent Dirichlet Allocation". *Journal of Machine Learning Research*, 3, 993-1022.
Blinder, Alan, Michael Ehrmann, Marcel Fratzscher, Jakob De Haan, and David-Jan Jansen (2008). "Central Bank Communication and Monetary Policy: A Survey of Theory and Evidence," Journal of Economic Literature, 46(4), 910–45.
Callan, Eoin (2007). "Fed keeps US rates on hold", Financial Times, 7 August.
Campbell, Jeffrey, Charles Evans, Jonas Fisher and Alejandro Justiniano (2012). "Macroeconomic Effects of Federal Reserve Forward Guidance", Brookings Papers on Economic Activity, Spring 2012, 1-80.
Cannon, San (2015). "Sentiment of the FOMC: Unscripted". Federal Reserve Bank of Kansas City Economic Review, (Fourth Quarter).
Christensen, Jens, and Glenn Rudebusch (2012). "The Response of Interest Rates to US and UK Quantitative Easing", *Economic Journal*, 122, F385-F414.
Cieslak, Anna, and Andreas Schrimpf (2019). "Non-monetary news in central bank communication". *Journal of International Economics*, 118, 293-315.
Cochrane, John, and Monika Piazzesi (2002). "The Fed and interest rates: A high-frequency identification", *NBER Working Paper*, No. 8839.
Coenen, Günter, Michael Ehrmann, Gaetano Gaballo, Peter Hoffmann, Anton Nakov, Stefano Nardelli, Eric Persson and Georg Strasser (2017). "Communication of monetary policy in unconventional times", *ECB Working Paper*, 2080.
Cœuré, Benoit (2018). "Central banking in times of complexity". Panel remarks at the on the Sveriges Riksbank's 350th anniversary conference, Stockholm, 25 May.
Cook, Timothy, and Thomas Hahn (1989). "The effect of changes in the federal funds rate target on market interest rates in the 1970s", *Journal of Monetary Economics*, 24(3), 331-351.
Correa, Ricardo, Keshav Garud, Juan Londono and Nathan Mislang (2017). "Sentiment in Central Banks' Financial Stability Reports", *International Finance Discussion Paper*, No. D2017-9.
Ehrmann, Michael, and Marcel Fratzscher (2007). Communication by central bank committee members: Different strategies, same effectiveness. *Journal of Money Credit and Banking*, 39(2-3), 509-541.
Ehrmann, Michael, and Jonathan Talmi (2019). "Starting from a Blank Page? Semantic Similarity in Central Bank Communication and Market Volatility", *Journal of Monetary Economics*, forthcoming.
Ehrmann, Michael, Robin Tietz and Bauke Visser (2019), "Strategic interactions in preparing for committee meetings", manuscript.
Ellingsen, Tore, and Ulf Söderström (2001). "Monetary policy and market interest rates", *American Economic Review*, 91(5), 1594-1607.
Engle, Robert (1982). "Autoregressive Conditional Heteroscedasticity with Estimates of Variance of United Kingdom Inflation", *Econometrica*, 50 (4), 987–1008.

Faust, Jon, Eric Swanson, and Jonathan Wright (2004). "Do Federal Reserve Policy Surprises Reveal Superior Information about the Economy?", *Contributions to Macroeconomics*, 4(1).
Ferguson, Nicky, Dennis Philip, Herbert Lam, and Jie Guo (2015). "Media content and stock returns: The predictive power of press", *Multinational Finance Journal*, 19(1), 1-31.
Fligstein, Neil, Jonah Brundage and Michael Schultz (2014). "Why the Federal Reserve Failed to See the Financial Crisis of 2008: The Role of "Macroeconomics" as a Sense-making and Cultural Frame", *mimeo*, University of California Berkeley.
Gertler, Mark, and Peter Karadi (2015). "Monetary policy surprises, credit costs, and economic activity", *American Economic Journal: Macroeconomics*, 7(1), 44-76.
Gürkaynak, Refet, Brian Sack and Eric Swanson (2005). "Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements", *International Journal of Central Banking*, 1(1), 55-93.
Gürkaynak, Refet, Brian Sack, and John Wright (2007). "The US Treasury yield curve: 1961 to the present", *Journal of Monetary Economics*, 54(8), 2291–2304.
Garcia, Diego (2013). "Sentiment during Recessions", *Journal of Finance*, 68 (3), 1267-1300.
Geraats, Petra (2002). "Central Bank Transparency", *Economic Journal*, 112, 532-565.
Guthrie, Graeme, and Julian Wright (2000). "Open Mouth Operations", *Journal of Monetary Economics*, 46, 489-516.
Hansen, Stephen, and Michael McMahon (2016). "Shocking Language: Understanding the Macroeconomic Effects of Central Bank Communication", *Journal of International Economics*, 99, S114-S133.
Hansen, Stephen, Michael McMahon and Andrea Prat (2017). "Transparency and Deliberation within the FOMC: a Computational Linguistics Approach", *Quarterly Journal of Economics*, 133(2), 801-870.
Hanson, Samuel, and Jeremy Stein (2015). "Monetary policy and long-term real rates", *Journal of Financial Economics*, 115(3), 429-448.
Hayo, Bernd, and Matthias Neuenkirch (2010). "Do Federal Reserve communications help predict federal funds target rate decisions?", *Journal of Macroeconomics*, 32(4), 1014-1024.
Heinemann, Friedrich, and Katrin Ullrich (2007). "Does it pay to watch central bankers' lips? The information content of ECB wording", *Swiss Journal of Economics and Statistics*, 143(2), 155-185.
Hubert, Paul (2017). "Qualitative and Quantitative Central Bank Communication and Inflation Expectations", *B.E. Journal of Macroeconomics*, 7(1), 1-41.
Hubert, Paul and Becky Maule (2016). "Policy and Macro signals as Inputs to Inflation Expectation Formation", *Bank of England Staff Working Paper*, No. 581.
Hubert, Paul (2019). "State-Dependent Effects of Monetary Policy: the Central Bank Information Channel", *OFCE Working Paper*, No. 2019-04.
Jansen, David-Jan, and Jakob De Haan (2009). "Has ECB communication been helpful in predicting interest rate decisions? An evaluation of the early years of the Economic and Monetary Union", *Applied Economics*, 41(16), 1995-2003.
Jarocinski, Marek and Peter Karadi (2019). "Deconstructing monetary policy surprises: the role of informations shocks", *American Economic Journal: Macroeconomics*, forthcoming.
Jegadeesh, Narasimhan and Di Wu (2017), "Deciphering Fedspeak: The information content of FOMC meetings", manuscript.
King, Robert, Yang Lu, and Ernesto Pasten (2008). "Managing Expectations", *Journal of Money, Credit and Banking*, 40(8), 1625-1666.
Kuttner, Kenneth (2001), "Monetary policy surprises and interest rates: Evidence from the Fed funds futures market", *Journal of Monetary Economics,* 47(3), 523-544.
Krippner, Leo (2013). "Measuring the stance of monetary policy in zero lower bound environments". *Economics Letters*, 118(1), 135-138.

Krueger, Joel, and Kenneth Kuttner (1996). "The fed funds futures rate as a predictor of Federal Reserve policy", *Journal of Futures Markets*, 16(8), 865-879.
Lapp, John, and Douglas Pearce (2000). "Does a bias in FOMC policy directives help predict intermeeting policy changes?", *Journal of Money, Credit and Banking*, 32, 435-441.
Lakdawala, Aeimit, and Matthew Schaffer (2019). "Federal Reserve Private Information and the Stock Market", *Journal of Banking and Finance*, 106, 34-49.
Loughran, Tim, and Bill McDonald (2011). "When is a Liability not a Liability? Textual Analysis, Dictionaries, and 10-Ks", *Journal of Finance*, 66(1), 35-65.
Lucca, David, and Francesco Trebbi (2011). "Measuring Central Bank Communication: An Automated Approach with Application to FOMC Statements", *NBER Working Paper*, No. 15367.
Madeira, Carlos, and João Madeira (2019. "The effect of FOMC votes on financial markets", *The Review of Economics and Statistics*, 101(5), 1–12.
Mandelbrot, Benoit (1963). "The Variation of Certain Speculative Prices", *The Journal of Business*, 36(4), 394-419.
Meade, Ellen (2005). "The FOMC: preferences, voting, and consensus", *Federal Reserve Bank of St. Louis Review*, 87, 93-101.
Meade, Ellen and David Stasavage (2008). "Publicity of debate and the incentive to dissent: evidence from the US Federal Reserve", *Economic Journal*, 118, 695–717.
Melosi, Leonardo (2017). "Signaling effects of monetary policy", *Review of Economic Studies*, 84(2), 853-884.
Miranda-Agrippino, Silvia, and Giovanni Ricco (2017). "The Transmission of Monetary Policy Shocks", *Bank of England Staff Working Paper*, No. 657.
Nakamura, Emi, and Jon Steinsson (2018). "High-Frequency Identification of Monetary Non-Neutrality: The Information Effect", *Quarterly Journal of Economics*, 133(3), 1283-1330.
Osgood, Charles, George Suci, and Percy Tannenbaum (1957). The Measurement of Meaning. Urbana: University of Illinois Press.
Pakko, Michael (2005). "On the information content of asymmetric FOMC policy statements: evidence from a Taylor - rule perspective", *Economic Inquiry*, 43(3), 558-569.
Piazzesi, Monika, and Eric Swanson (2008). "Futures Prices as Risk-adjusted Forecasts of Monetary Policy". *Journal of Monetary Economics*, 55(4), 677-691.
Picault, Matthieu, and Thomas Renault (2017). "Words are not all created equal: A new measure of ECB communication", *Journal of International Money and Finance*, 79, 136-156.
Reis, Ricardo (2013). "Central Bank Design", *Journal of Economic Perspectives*, 27(4), 17-44.
Riboni, Alessandro and Francisco Ruge-Murcia (2010). "Monetary Policy by Committee: Consensus, Chairman Dominance, or Simple Majority?", *Quarterly Journal of Economics*, 125, 363-416.
Rigobon, Roberto (2003). "Identification through Heteroskedasticity", *Review of Economics and Statistics*, 85, 777–792.
Romer, Christina, and David Romer (2000). "Federal Reserve Information and the Behavior of Interest Rates," *American Economic Review*, 90 (3), 429–457.
Romer, Christina, and David Romer (2004). "A New Measure of Monetary Shocks: Derivation and Implications," *American Economic Review*, 94(4), 1055–1084.
Rosa, Carlo, and Giovanni Verga (2007). "On the consistency and effectiveness of central bank communication: Evidence from the ECB", *European Journal of Political Economy*, 23(1), 146-175.
Schmeling, Maik and Christian Wagner (2019). "Does central bank tone move asset prices?", *CEPR Discussion Paper*, No. 13490.
Sibert, Anne (2003). "Monetary Policy Committees: Individual and Collective Reputations", *Review of Economic Studies*, 70(3), 649–665.

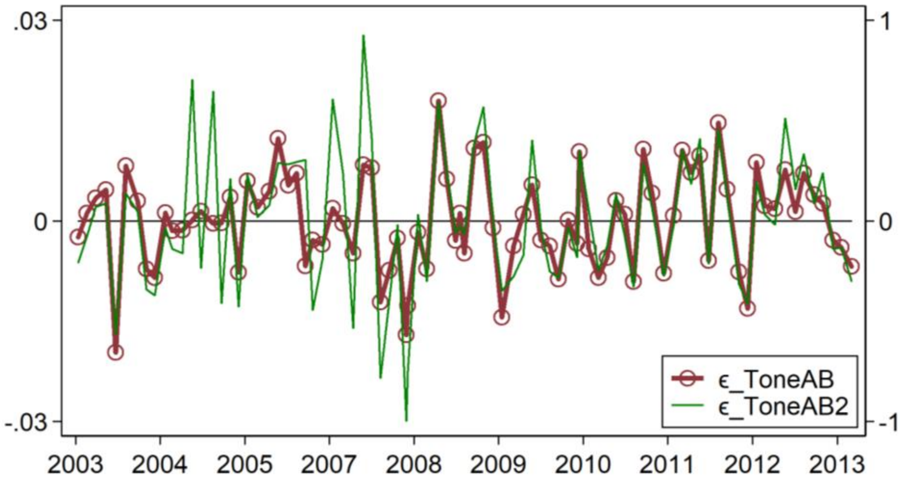
Sturm, Jan-Egbert, and Jakob De Haan (2011), "Does central bank communication really lead to better forecasts of policy decisions? New evidence based on a Taylor rule model for the ECB", *Review of World Economics*, 147(1), 41-58.
Swank, Job, Bauke Visser, and Otto Swank (2008). "How Committees of Experts Interact with the outside World: Some Theory, and Evidence from the FOMC", *Journal of the European Economic Association*, 6(2-3), 478-486.
Tetlock, Paul (2007). "Giving Content to Investor Sentiment: The Role of Media in the Stock Market", *Journal of Finance*, 62(3), 1139-1168.
Tetlock, Paul, Maytal Saar-Tsechansky and Sofus MacSkassy (2008). "More Than Words: Quantifying Language to Measure Firms' Fundamentals", *Journal of Finance*, 63(3), 1437-1467.
Tietz, Robin (2018). "How does the Fed manage interest rate expectations?", manuscript.
Tillmann, Peter, and Andreas Walter (2018). "ECB vs Bundesbank: Diverging Tones and Policy Effectiveness", *BSFA Working Paper Series*, No. 2018-4.
Tillmann, Peter (2019). "Dissent in the ECB's Governing Council", manuscript.
Thornton, Daniel, and David Wheelock (2014), "Making Sense of Dissents: A History of FOMC Dissents", *Federal Reserve Bank of St. Louis Review*, Third Quarter, 213-227.
Woodford, Michael (2005). "Central-bank communication and policy effectiveness". In F. R. City, The Greenspan era: Lessons for the future, 399-474.
Wu, Cynthia, and Fan Xia (2016). "Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound". *Journal of Money, Credit and Banking*, 48(2-3), 253-291.

Figure 1. Central bank tone



Note: The central bank tone series have been computed from equation (1) and (2) respectively, using the dictionary of Apel and Blix Grimaldi (2012).

Figure 2. Central bank tone shocks



Note: The series of shocks to central bank tone have been computed from equation (5) using the central bank tone measure from equation (1).

Table 1. Central bank tone

Descriptive statistics for FOMC statements

	Mean	Std. Dev.	Min	Max
All words	233	98	109	523
Positive_AB	2.42	1.73	0	6
Negative_AB	2.87	2.35	0	8
Positive_LM	7.27	5.26	1	21
Negative_LM	6.57	4.94	0	19
Positive_Harv	37.87	22.52	12	95
Negative_Harv	6.74	5.12	0	20

Descriptive statistics for FOMC tone

	Mean	Std. Dev.	Min	Max
ToneAB	-0.002	0.011	-0.03	0.03
ToneAB2	0.009	0.548	-1	1
ToneLM	0.003	0.017	-0.05	0.03
ToneHarv	0.126	0.030	0.04	0.18

Correlation table of FOMC tone

	ToneAB	ToneAB2	ToneLM	ToneHarv
ToneAB	1			
ToneAB2	0.92	1		
ToneLM	0.42	0.41	1	
ToneHarv	0.30	0.31	0.52	1

Note: The first panel shows descriptive statistics about the number of words (all, positive and negative) according to the three dictionaries (Apel and Blix-Grimaldi (2012) - AB, Loughran and McDonald (2011) - LM, and the General Inquirer's Harvard IV-4 dictionary - Harv) for the 91 FOMC statements considered. In the second panel, ToneAB, ToneLM and ToneHarv are computed based on equation (1), while ToneAB2 is based on equation (2).

Table 2. High-frequency OLS estimates of the effect of central bank tone

	(1) ir1y	(2) ir5y	(3) ir10y	(4) ois1y	(5) ois5y	(6) ois10y
All days - Tone						
ToneAB	0.704*	0.357	-0.052	0.842**	0.607	0.361
	[0.39]	[0.57]	[0.58]	[0.35]	[0.59]	[0.58]
R^2	0.00	0.00	0.00	0.00	0.00	0.00
N	2871	2871	2871	2871	2871	2871
All days - Tone + Monetary surprises						
ToneAB	0.519	0.111	-0.253	0.816**	0.615	0.362
	[0.38]	[0.56]	[0.57]	[0.35]	[0.59]	[0.58]
MP surprises	0.796***	1.062***	0.864***	0.112**	-0.033	-0.005
	[0.06]	[0.09]	[0.09]	[0.06]	[0.09]	[0.09]
R^2	0.06	0.05	0.03	0.00	0.00	0.00
N	2871	2871	2871	2871	2871	2871
Statement days - Tone						
ToneAB	0.691	0.386	-0.010	0.816*	0.649	0.402
	[0.65]	[0.90]	[0.88]	[0.42]	[0.46]	[0.49]
R^2	0.01	0.00	0.00	0.04	0.02	0.01
N	91	91	91	91	91	91
Statement days - Tone + Monetary surprises						
ToneAB	0.476	0.100	-0.242	0.786*	0.659	0.404
	[0.35]	[0.53]	[0.65]	[0.42]	[0.47]	[0.49]
MP surprises	0.798***	1.062***	0.864***	0.113*	-0.035	-0.007
	[0.05]	[0.08]	[0.10]	[0.06]	[0.07]	[0.08]
R^2	0.72	0.66	0.45	0.07	0.02	0.01
N	91	91	91	91	91	91

Note: Standard errors in brackets. *p < 0.1, ** p < 0.05, *** p < 0.01. Each column corresponds to a different OLS estimation of equation (4) for a different horizon with only the tone variable or both the tone and monetary suprises variables. The sample period goes from January 2003 to December 2013. ToneAB is computed based on equation (1). Monetary policy surprises are measured as the daily change in the nominal 2-year sovereign yield. Our dependent variables are nominal interest rates and OIS rates at maturities of 1, 5 and 10-year. The constant, equal to zero, has been removed.

Table 3. The identification of central bank tone exogenous shocks

	(1) ToneAB	(2) ToneAB2	(3) ToneAB
$Tone_{t-j}$	0.420***	0.423***	0.397***
	[0.10]	[0.10]	[0.10]
VIX_t	-0.001***	-0.040***	-0.001***
	[0.00]	[0.01]	[0.00]
$\Delta_{t,t-180}$ $ISMBS_t$	-0.001***	-0.044***	-0.001***
	[0.00]	[0.01]	[0.00]
$\Delta_{t,t-k}$ $SPF\_GDP\_1y_t$	-0.005*	-0.147	-0.006**
	[0.00]	[0.14]	[0.00]
$\Delta_{t,t-30}$ $Unemp_t$	0.013**	0.512**	0.016***
	[0.01]	[0.24]	[0.01]
$SPF\_CPI\_1y_t$	-0.009	-0.415	-0.008
	[0.01]	[0.29]	[0.01]
Constant	0.037**	1.759**	0.038*
	[0.02]	[0.73]	[0.02]
Add. Controls	No	No	Yes
N	86	86	86
R^2	0.60	0.59	0.62
Descriptive statistics of sentiment shocks			
	Mean	SD	AR(1) parameter
ϵ_ToneAB	0.00	0.01	0.088 [.11]
ϵ_ToneAB2	0.00	0.34	0.024 [.11]
ϵ_ToneAB'	0.00	0.01	0.051 [.11]
Correlation between sentiment shocks			
	ϵ_ToneAB	ϵ_ToneAB2	ϵ_ToneAB'
ϵ_ToneAB	1		
ϵ_ToneAB2	0.81	1	
ϵ_ToneAB'	0.97	0.79	1
Correlation with MP surprises			
	ϵ_ToneAB	ϵ_ToneAB2	ϵ_ToneAB'
MP surprises	0.051	0.051	0.046
Normality, Autocorrelation and White noise tests			
	Shapiro-Francia	Cumby-Huizinga	Portmanteau
ϵ_ToneAB	0.865	0.518	0.546
ϵ_ToneAB2	0.642	0.781	0.784
ϵ_ToneAB'	0.874	0.692	0.683

Note: Standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. OLS parameters are estimated based on equation (5). j is the number of days between each policy statement. The sample period goes from January 2003 to December 2013. ToneAB is computed based on equation (1) and ToneAB2 is computed based on equation (2). The bottom panel shows p-values for the Shapiro-Francia normality test, the Cumby-Huizinga test for autocorrelation and the Portmanteau test for white noise. ϵ_ToneAB' corresponds to the residuals from equation (5) with ToneAB as the dependent variable and augmented with additional controls. This specification is shown in column (3) of the first panel. Additional controls include the EPU, STLFSI, SP500, industrial production, oil prices and the output gap. None of these variables is significant. Estimates are available from the authors upon request.

Table 4. The effect of central bank tone shocks

	(1) ir1y	(2) ir5y	(3) ir10y	(4) ois1y	(5) ois5y	(6) ois10y
AB dictionary - Without MP surprises						
	Mean equation					
ϵ_ToneAB	2.216**	1.883	1.119	3.511***	2.366	2.086
	[1.04]	[1.21]	[1.08]	[1.05]	[2.02]	[2.70]
	Variance equation					
arch(1)	0.610***	0.188***	0.139***	0.395***	0.273***	0.213***
	[0.14]	[0.05]	[0.03]	[0.08]	[0.06]	[0.05]
N	2871	2871	2871	2871	2871	2871
R^2	0.03	0.01	0.00	0.02	0.01	0.00
AB dictionary - Baseline estimates						
	Mean equation					
ϵ_ToneAB	2.299**	0.815	0.560	3.093***	2.050	1.584
	[1.04]	[1.10]	[1.03]	[1.19]	[3.21]	[4.27]
MP surprises	0.553***	1.115***	0.849***	0.385***	0.313	0.200
	[0.07]	[0.13]	[0.18]	[0.12]	[0.29]	[0.37]
	Variance equation					
arch(1)	0.643***	0.176***	0.137***	0.486***	0.293***	0.218***
	[0.15]	[0.04]	[0.03]	[0.11]	[0.06]	[0.05]
N	2871	2871	2871	2871	2871	2871
R^2	0.68	0.66	0.45	0.05	0.00	0.00
Alternative dictionary measures						
Normalised measure based on eq. (2) - AB dictionary						
ϵ_ToneAB2	0.059***	0.016	0.000	0.071**	0.028	0.011
	[0.02]	[0.03]	[0.02]	[0.03]	[0.04]	[0.04]
LM dictionary						
ϵ_ToneLM	0.907**	0.090	0.156	2.358***	-0.020	0.147
	[0.46]	[0.46]	[0.55]	[0.60]	[0.60]	[0.88]
Harvard dictionary						
ϵ_ToneHarv	0.841*	0.308	0.314	1.457***	0.748	1.291
	[0.46]	[0.45]	[0.49]	[0.48]	[3.07]	[1.49]
Alternative monetary policy measures						
Gertler and Karadi (2015) monetary shocks						
ϵ_ToneAB	3.528**	2.073	1.319	4.928***	0.958	0.989
	[1.76]	[1.65]	[1.22]	[1.86]	[1.79]	[1.58]
Miranda-Agrippino and Ricco (2017) monetary shocks						
ϵ_ToneAB	3.185*	1.66	1.290	5.854***	2.194	2.767
	[1.89]	[1.97]	[1.43]	[2.22]	[1.90]	[2.05]
Including Nakamura and Steinsson (2018)'s policy news surprises						
ϵ_ToneAB	2.224**	1.319	1.123	2.580**	2.161	1.576
	[1.06]	[1.13]	[0.99]	[1.24]	[3.72]	[4.89]

Note: Robust standard errors in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Each column corresponds to a different ARCH estimation of equations (6) and (7) for a different horizon. The sample period goes from January 2003 to December 2013. ϵ_ToneAB is estimated from equation (5) based on ToneAB. Monetary policy surprises are measured as the daily change in the nominal 2-year sovereign yield. Our dependent variables are nominal interest rates and OIS rates at maturities of 1, 5 and 10-year. The constant, equal to zero, and ARCH terms for the lower panels have been removed for space constraints and are available upon request. Gertler and Karadi (2015) and Miranda-Agrippino and Ricco (2017) measures are available until 2010, so estimations are performed on 1827 observations.

Table 5. Some characteristics of central bank tone

	(1) ir1y	(2) ois1y	(3) ir1y	(4) ois1y
	Signal Precision		**Textual Uncertainty**	
Interaction	8.531**	11.911***	-194.356**	-208.566***
	[4.15]	[4.29]	[88.66]	[68.43]
ϵ_ToneAB	-1.759	-2.965	13.195**	13.513***
	[1.38]	[1.87]	[5.77]	[4.29]
State-variable	-0.022*	0.009	-0.028	0.117
	[0.01]	[0.01]	[0.05]	[0.08]
MP surprises	0.577***	0.416***	0.592***	0.434***
	[0.07]	[0.08]	[0.06]	[0.09]
Sentiment coefficient when:				
High state-var.	6.243**	8.208***	-2.898*	-3.756**
	[2.64]	[2.44]	[1.63]	[1.57]
Low state-var.	-2.488	-3.983*	6.351**	6.169***
	[1.72]	[2.21]	[2.67]	[1.95]

Note: Robust standard errors in brackets. *p < 0.1, **p < 0.05, ***p < 0.01. Each column corresponds to a different ARCH estimation of equations (6) and (7) for a different horizon, augmented with the relevant interaction term and state-variable. The sample period goes from January 2003 to December 2013. ϵ_ToneAB is estimated from equation (5) based on ToneAB. Monetary policy surprises are measured as the daily change in the nominal 2-year sovereign yield. Our dependent variables are nominal interest rates and OIS rates at the 1-year maturity. The constant, equal to zero, and ARCH terms for the lower panels have been removed for space constraints and are available upon request. Because the interaction term gives information when both interacted variables are at their average values, we e compute the coefficient of the effect of central bank sentiment when the state-variable at either a high (mean + 1.5 S.D.) or a low value (mean - 1.5 S.D.) to simplify the interpretion of non-linear effects with continuous variables.

Table 6. The content of central bank tone

Forecast Mode			Forecast Distribution		
	(1)	(2)		(3)	(4)
	ϵ_ToneAB	ϵ_ToneAB		ϵ_ToneAB	ϵ_ToneAB
	Level	**Change**		**Level**	**Change**
GB_CPI_1y	0.000	0.001	FOMC_CPI_cy_D	0.004	-0.007***
	[0.00]	[0.00]		[0.00]	[0.00]
GB_GDP_1y	0.000	-0.001	FOMC_CPI_cy_SK	0.003	0.005
	[0.00]	[0.00]		[0.01]	[0.01]
GB_CPI_2y	0.001	0.011	FOMC_CPI_ny_D	0.004	-0.004
	[0.00]	[0.01]		[0.00]	[0.00]
GB_GDP_2y	0.000	-0.002	FOMC_CPI_ny_SK	-0.015***	-0.005
	[0.00]	[0.00]		[0.00]	[0.00]
FOMC_CPI_cy	0.006	-0.004	FOMC_GDP_cy_D	-0.004	0.002
	[0.00]	[0.01]		[0.00]	[0.00]
FOMC_GDP_cy	0.000	0.000	FOMC_GDP_cy_SK	-0.005	-0.009***
	[0.00]	[0.00]		[0.00]	[0.00]
FOMC_CPI_ny	-0.009	-0.005	FOMC_GDP_ny_D	0.000	0.000
	[0.01]	[0.01]		[0.00]	[0.00]
FOMC_GDP_ny	0.001	0.000	FOMC_GDP_ny_SK	0.003	0.003
	[0.00]	[0.00]		[0.00]	[0.00]
N	91	91	N	91	91
R^2	0.04	0.07	R^2	0.18	0.12
FOMC votes			**ARCH model**		
	(5)	(6)		(9)	(10)
	ϵ_ToneAB	ϵ_ToneAB		ir1y	ois1y
	Level	**Change**		***Mean equation***	
FOMC_Dissent	0.017	0.001	ϵ_ToneAB	2.600**	3.229***
	[0.01]	[0.01]		[1.10]	[1.13]
FOMC_Balance	-0.014	-0.013	MP surprises	0.553***	0.383**
	[0.01]	[0.01]		[0.06]	[0.16]
N	91	91	FOMC_CPI_ny_SK	0.005*	0.005
R^2	0.02	0.02		[0.00]	[0.00]
Information from policy decisions			ΔFOMC_CPI_cy_D	0.012	-0.005
	(7)	(8)		[0.01]	[0.02]
	ϵ_ToneAB	ϵ_ToneAB	ΔFOMC_GDP_cy_SK	0.050**	0.05
CBI shocks	-0.015	-0.020		[0.02]	[0.03]
	[0.03]	[0.02]		***Variance equation***	
MAR / NS shocks	0.025	0.024	arch(1)	0.643***	0.485***
	[0.04]	[0.03]		[0.15]	[0.11]
N	58	58	N	2871	2871
R^2	0.06	0.06	R^2	0.69	0.06

Note: Robust standard errors in brackets. * p < 0.1, ** p < 0.05, *** p < 0.01. Each column corresponds to a different OLS estimation of equation (9) using all obersavtions or only on statement dates, and including FOMC and Greenbook (GB) forecasts in level or their change between two meetings. The sample period goes from January 2003 to December 2013. The constant, equal to zero, has been removed for space constraints. ϵ_ToneAB is estimated from equation (5) based on Tone_AB. Monetary policy surprises are measured as the daily change in the nominal 2-year sovereign yield. The policy news variable captures news about the future policy path and is estimated by Nakamura and Steinsson (2018). The dispersion of FOMC forecasts is computed as the distance between the upper and lower bound of the full range. The measure of the skewness of FOMC forecasts is computed as the difference between (i) the distance between the upper bands of the full range and of the central tendency and (ii) the distance between the lower bounds of the central tendency and of the full range. The variable Dissent measures the proportion of dissenting votes, and the variable Balance measures the difference between the proportion of dissenting votes in favor or a tighter policy and the proportion of dissenting votes in favor of an easier policy. Finally, CBI shocks are central bank information shocks derived from Miranda-Agrippino and Ricco (2017). MAR shocks are the measure of monetary policy shocks from Miranda-Agrippino and Ricco (2017) while NS shocks are the Nakamura and Steinsson (2018) measure of policy news shocks. The former two series are available up to 2010 only.

Table 7. State-dependent estimates

	(1) ir1y	(2) ois1y	(3) ir1y	(4) ois1y
	VIX		Inflation Gap	
Interaction	0.117	0.229**	2.163**	0.229
	[0.08]	[0.09]	[0.93]	[0.76]
ϵ_ToneAB	-0.535	-3.633	0.703	2.984**
	[1.80]	[3.66]	[0.72]	[1.24]
State-variable	-0.001***	-0.000*	0.000	0.001
	[0.00]	[0.00]	[0.00]	[0.00]
MP surprises	0.547***	0.459***	0.592***	0.365***
	[0.06]	[0.11]	[0.06]	[0.12]
Sentiment coefficient when:				
High state-var.	3.336**	3.912*	6.091**	3.555**
	[1.50]	[2.30]	[2.79]	[1.70]
Low state-var.	0.591	-1.439	-2.755**	2.617
	[1.17]	[3.03]	[1.23]	[2.12]
	NBER Recessions		Output Gap	
Interaction	-2.135	-5.262**	1.342**	0.674
	[1.38]	[2.06]	[0.61]	[0.69]
ϵ_ToneAB	2.564**	3.473***	5.083**	4.411**
	[1.19]	[1.18]	[2.13]	[1.85]
State-variable	-0.001	-0.003	0.000	0.001*
	[0.00]	[0.00]	[0.00]	[0.00]
MP surprises	0.556***	0.391***	0.564***	0.362**
	[0.07]	[0.12]	[0.06]	[0.15]
Sentiment coefficient when:				
High state-var.	2.564**	3.473***	6.003**	4.873**
	[1.19]	[1.18]	[2.54]	[2.23]
Low state-var.	0.428	-1.789	-1.675	1.015
	[0.64]	[1.69]	[1.07]	[2.40]

Note: Robust standard errors in brackets. *p < 0.1, **p < 0.05, ***p < 0.01. Each column corresponds to a different ARCH estimation of equations (6) and (7) for a different horizon, augmented with the relevant interaction term and state-variable. The sample period goes from January 2003 to December 2013. ϵ_ToneAB is estimated from equation (5) based on ToneAB. Monetary policy surprises are measured as the daily change in the nominal 2-year sovereign yield. Our dependent variables are nominal interest rates and OIS rates at the 1-year maturity. The constant, equal to zero, and ARCH terms for the lower panels have been removed for space constraints and are available upon request. Because the interaction term gives information when both interacted variables are at their average values, we e compute the coefficient of the effect of central bank sentiment when the state-variable at either a high (mean + 1.5 S.D.) or a low value (mean - 1.5 S.D.) to simplify the interpretion of non-linear effects with continuous variables. For instance, the effect of sentiment is provided when the VIX is equal to 34 (high state) or 10 (low state). For the interaction with the NBER recession dummy, the high state corresponds to expansions and the low state to recessions when the NBER recession dummy is equal to one.

Table 8. The predictive power of central bank tone

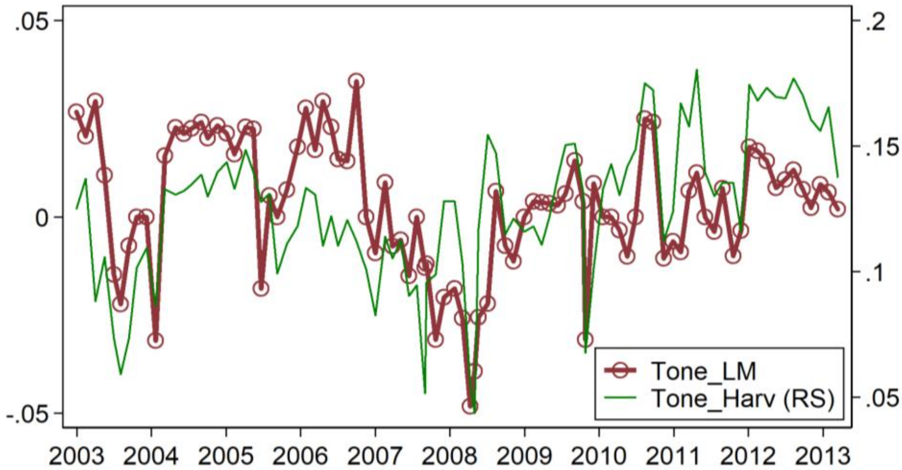
	(1) Baseline FFT_{t+j}	(2) Change ΔFFT_{t+j}	(3) Probit I^{FFT}_{t+j}	(4) ϵ_ToneAB2 FFT_{t+j}	(5) ToneAB FFT_{t+j}	(6) SK/Disp. FFT_{t+j}
ϵ_ToneAB	7.155***	7.155***	49.715**	0.149***	6.904***	8.605***
	[2.54]	[2.54]	[20.49]	[0.05]	[1.83]	[2.86]
FFT_t	0.989***	-0.011	-0.04	0.986***	0.979***	0.989***
	[0.01]	[0.01]	[0.10]	[0.01]	[0.01]	[0.01]
FOMC_CPI	0.169*	0.169*	1.733**	0.179*	0.056	0.173*
	[0.09]	[0.09]	[0.72]	[0.09]	[0.09]	[0.09]
FOMC_GDP	0.164***	0.164***	1.211***	0.166***	0.134***	0.152***
	[0.02]	[0.02]	[0.24]	[0.02]	[0.02]	[0.03]
N	90	90	90	90	90	90
R^2/Pseudo-R^2	0.99	0.39	0.26	0.99	0.99	0.99

	(7) SPF FFT_{t+j}	(8) Fut_FFT FFT_{t+j}	(9) ois1m FFT_{t+j}	(10) ois1y FFT_{t+j}	(11) NS_PolNews FFT_{t+j}	(12) HFC FFT_{t+j}
ϵ_ToneAB	7.096***	5.766**	7.406***	5.508**	6.665**	6.620**
	[2.57]	[2.39]	[2.55]	[2.39]	[2.59]	[2.54]
FFT_t	0.985***	-0.024	1.070***	0.812***	0.989***	0.981***
	[0.01]	[0.27]	[0.11]	[0.05]	[0.01]	[0.01]
FOMC_CPI	0.135	0.192**	0.098	0.183**	0.167*	0.096
	[0.11]	[0.08]	[0.10]	[0.08]	[0.09]	[0.10]
FOMC_GDP	0.167***	0.118***	0.182***	0.187***	0.160***	0.124***
	[0.04]	[0.03]	[0.03]	[0.02]	[0.02]	[0.03]
N	90	90	83	90	90	90
R^2/Pseudo-R^2	0.99	0.99	0.99	0.99	0.99	0.99

Note: Standard errors in brackets. * p < 0.10, ** p < 0.05, *** p < 0.01. Equation (8) is estimated with OLS for all columns, except column (3) that is estimated with an ordered probit model. The dependent variable is the level of the policy rate in all columns, except column (2) where it is the change in the policy rate and column (3) where it is a discrete variable when the policy rate moves by at least +/- 25 basis points (taking the value 1 for rate increases, 0 for statu quo and -1 for rate decreases). The sample period goes from January 2003 to December 2013. In all columns, the dependent variable is considered in t+1 while all explanatory variables are considered in t. In columns (4) and (5), ϵ_ToneAB is replaced by ϵ_ToneAB2 and ToneAB respectively. In column (6), we include FOMC_CPI_ny_SK, ΔFOMC_CPI_cy_D and ΔFOMC_GDP_cy_SK based on the results evidenced in Table 6. In columns (7) to (12), we augment equation (8) with SPF inflation and output forecasts, Fed Funds futures, 1-month OIS, 1-year OIS, the Nakamura and Steinsson (2018)'s policy news variable and high-frequency controls respectively. These high-frequency variables are the VIX, SP 500 returns and oil prices.

APPENDIX
FOR ONLINE PUBLICATION

Figure A. Central bank tone using alternative dictionaries



Note: The central bank tone series have been computed from equation (1) and (2) respectively, using the LM and Harvard dictionaries.

Table A. Dictionary word lists

Positive words	Negative words
Apel and Blix-Grimaldi (2012)	
25	26
Loughran and McDonald (2011)	
354	2349
General Inquirer's Harvard dictionary	
1915	2291
Most illustrative tokens	
increas*	decreas*
accelerat*	decelerat*
fast*	slow*
strong*	weak*
high*	low*
gain*	loss*
expand*	contract*
improv*	declin*
positiv*	negativ*
great*	question*
strength*	dampen*
solid*	concern*

Table B. Data description

Abbreviation	Description	Source	Frequency
ir1y	US 1-year nominal interest rate	Federal Reserve Board	Daily
ir5y	US 5-year nominal interest rate	Federal Reserve Board	Daily
ir10y	US 10-year nominal interest rate	Federal Reserve Board	Daily
ois1y	US 1-year OIS	Datastream	Daily
ois5y	US 5-year OIS	Datastream	Daily
ois10y	US 10-year OIS	Datastream	Daily
Tone_AB	Apel and Blix-Grimaldi (2012)	Authors' computations	Each FOMC statement
Tone_AB2	Apel and Blix-Grimaldi (2012)	Authors' computations	Each FOMC statement
Tone_LM	Loughran and McDonald (2011)	Authors' computations	Each FOMC statement
Tone_Harv	Harvard dictionary	Authors' computations	Each FOMC statement
MP surprises	Hanson and Stein (2015)	Daily change in 2-year nominal interest rate	Each FOMC statement
FFR	Effective Federal Funds Rate	Datastream	Daily
FFT	Federal Funds Rate Target	Datastream	Daily
WuXia	Shadow rate	Wu-Xia (2016)	Monthly
Krippner	Shadow rate	Krippner (2015)	Daily
NS_FFR	Shock to the policy rate	Nakamura-Steinsson (2018)	Each FOMC statement
NS_PolicyNews	Shock to monetary policy news	Nakamura-Steinsson (2018)	Each FOMC statement
CPI	CPI inflation rate (Year-over-Year %)	Bureau of Labor Statistics	Monthly
INDPRO	Industrial Production Index (YoY %)	Federal Reserve	Monthly
GDP	Real GDP	Bureau of Economic Analysis	Quarterly
PotGDP	Real Potential GDP	Congressional Budget Office	Quarterly
OutputGap	Difference between GDP and PotGDP	Authors' computations	Quarterly
VIX	Volatility Index of the CBOE	Datastream	Daily
EPU	Economic Policy Uncertainty Index	Baker-Bloom-Davis (2016)	Daily
STLFSI	St. Louis Fed Financial Stress Index	FRB of St. Louis	Weekly
ISMBS	ISM Report on Business Survey Index	Datastream	Monthly
Oil	WTI oil price growth (YoY %)	Datastream	Daily
SP500	Standard & Poor's 500 daily returns	Datastream	Daily
FOMC_cpi_*	FOMC inflation projections for current and next calendar years	Federal Reserve Bank of Philadelphia	Quarterly
FOMC_gdp_*	FOMC output projections for current and next calendar years	Federal Reserve Bank of Philadelphia	Quarterly
GB_cpi_*	Greenbook inflation projections for current and next calendar years	Federal Reserve Bank of Philadelphia	Quarterly
GB_gdp_*	Greenbook output projections for current and next calendar years	Federal Reserve Bank of Philadelphia	Quarterly
SPF_cpi_1y	SPF inflation forecasts 1-year ahead	FRB of Philadelphia	Quarterly
SPF_gdp_1y	SPF output forecasts 1-year ahead	FRB of Philadelphia	Quarterly
FOMC votes	Thornton and Wheelock (2014)	FRB of St. Louis	Each FOMC statement

Note: Weekly, monthly and quarterly data are constant-interpolated to daily frequency so as to respect the information structure.

Table C. Descriptive Statistics: Benchmark model

	Obs	Mean	Std. Dev.	Min	Max
ir1y	2871	1.76	1.74	0.10	5.30
ir5y	2871	2.73	1.30	0.59	5.13
ir10y	2871	3.76	1.01	1.46	5.29
ois1y	2871	2.13	1.85	0.26	5.76
ois5y	2871	3.14	1.45	0.73	5.76
ois10y	2871	3.87	1.17	1.54	5.85
ϵ_ToneAB	91	0.00	0.01	-0.02	0.02
MP surprises	91	0.00	0.07	-0.23	0.23
NS_FFR	91	0.00	0.04	-0.20	0.13
NS_PolicyNews	91	0.00	0.03	-0.13	0.10

Note: ϵ_ToneAB is estimated from equation (5) based on ToneAB. Monetary policy surprises are measured as the daily change in the nominal 2-year sovereign yield. The sample period goes from January 2003 to December 2013.

A. ECB estimates

We estimate the effects of the tone conveyed by another central bank using the same method. We assess the impact of ECB tone on the 1-year OIS rates in the euro area.[33] To do so, tone is quantified from the ECB statements provided on a monthly basis after each Governing Council using equation (1). For the identification of ECB tone shocks, we use the same methodology described in section 3.1 and estimate equation (5) with the Composite Indicator of Systemic Stress (CISS) computed by the ECB, the Economic Sentiment Indicator (ESI) of the European Commission and inflation and output forecasts of the ECB's Survey of Professional Forecasters. This model explains 72% of the variance of the ECB tone.

Table D. Euro area estimates with ECB tone

	(1)	(2)	(3)	(4)
	ois1y	ois1y	ois1y	ois1y
	AB	**AB2**	**LM**	**Harv**
	Mean equation			
ϵ_Tone	1.142**	0.027***	0.477**	0.052
	[0.50]	[0.01]	[0.24]	[0.14]
MP surprises	0.782***	0.784***	0.795***	0.800***
	[0.03]	[0.02]	[0.02]	[0.02]
	Variance equation			
arch(1)	0.311***	0.313***	0.308***	0.311***
	[0.03]	[0.03]	[0.03]	[0.03]
N	1927	1927	1927	1927
R^2	0.804	0.799	0.801	0.801

Note: Standard errors in brackets. * p < 0.1, ** p < 0.05, *** p < 0.01. Each column corresponds to a different ARCH estimation of equations (6) and (7) for different measures of central bank tone ϵ_Tone based each on a different dictionary. From column (1) to (4), the dependent variable is the 1-year Euribor interest rate, while it is the 1-year OIS rate for colums (5) to (8). The sample period is August 2005 - January 2013. Additional ARCH terms and the constant, that is equal to zero, have been removed for space constraints and are available upon request. Sent_i is estimated from equation (5).

We estimate the causal effect of central bank tone using the ARCH model described by equations (6)-(7). The number of lags in the variance equation is set to four, based on their significance. We estimate the effect of ECB tone for the different measures of central bank tone described in section 2 using the three dictionaries. Table D shows the estimated parameters for 1-year OIS. Consistent with baseline estimates, monetary surprises have a positive and significant effect on interest rates in all cases. We find that the effect of ECB tone is positive and significant in all cases, except with the Harvard dictionary. One interpretation of this latter result is that words used in the ECB statements are more technical or financial markets-oriented and less oriented towards the general public such that the ECB tone measured with the Harvard dictionary is less pronounced and have less impact on interest rates. Coenen et al. (2017) show, based on readability measures, that ECB statements are less understandable than FOMC ones for the general public over our sample period.[34] These estimates are consistent with those of Schmeling and Wagner (2019) and confirm the empirical fact documented in this paper that central bank tone affects interest rates.

[33] Due to the absence of a unique euro area sovereign bond securities, we perform the analysis on OIS rates only.
[34] Coeuré (2018) acknowledged that "*based on common measures of text readability, the introductory statement (…) was only accessible to university graduates, who constitute only around a third of the euro area population*".

B. Robustness tests

To further ensure the validity of the main result, we estimate alternative specifications of our baseline model. First, we include the VIX in equation (6) to control for changes in the risk premium that could affect interest rates. Second, we augment the set of controls to daily returns of the SP500 index and oil prices. Third, we allow the coefficients associated to these control variables to vary on statements days compared to non-statement days. Fourth, we replace the $\epsilon\_Tone_{AB,t}$ measure by the alternative measure estimated in column (3) of Table 5. Fifth, we include different measures of monetary policy in equation (6): monetary surprises as estimated by Kuttner (2001), and the shadow rates of Krippner (2013) and Wu and Xia (2016). Monetary policy has taken many different dimensions over the last years. One way to measure these various dimensions of monetary policy in a single variable expressed in interest rate space is to use shadow rates. Sixth, we include dummies for the major Forward Guidance and Quantitative Easing announcements to examine whether the main result is driven by these specific events. Table E in the Appendix shows parameter estimates in these different cases. The sign and magnitude of the effect of central bank tone is robust to all these alternative specifications.

We also proceed to variations related to the econometric specification. First, we estimate the effects of tone on a shorter sample during normal times, so before the implementation of the Forward Guidance policy and before the conventional monetary policy instrument has reached its Zero Lower Bound (ZLB). Second, we include a lag of the dependent variable in equation (6). Third, although this does not enable to properly account for heteroskedasticity, we estimate equation (6) with OLS on all days and then on statement dates only. Fourth, although the identification is not as precise because of the different frequencies and samples used in both equations, we estimate equations (5) and (6) in one–step by including the controls of equation (5) in equation (6). Fifth, we estimate a Threshold ARCH model which enables to take into account the asymmetric nature of positive and negative innovations: a positive shock will have a different effect on volatility than will a negative shock. On financial markets, downward movements (“bad news”) are followed by higher market volatility than upward movements (“good news”). Sixth, we test whether including an additional lag in the variance equation of the ARCH specification modifies the result. Estimates are presented in Table F. The effect measured with OLS is smaller, but the positive effect of central bank tone on interest rates at the 1-year maturity is confirmed.

Table E. Economic robustness

	(1) ir1y	(2) ir5y	(3) ir10y	(4) ois1y	(5) ois5y	(6) ois10y
Including the VIX						
ϵ_ToneAB	2.334**	0.826	0.535	3.126**	0.352	-0.736
	[1.00]	[1.08]	[1.02]	[1.25]	[7.08]	[5.50]
Including high-frequency controls						
ϵ_ToneAB	2.264**	0.692	0.071	2.871***	2.104	1.979
	[1.06]	[1.11]	[0.98]	[1.10]	[1.85]	[2.47]
Allowing coeffients of controls to vary on statement days						
ϵ_ToneAB	2.372**	0.879	0.246	2.482**	2.437*	1.399
	[0.98]	[1.03]	[1.05]	[1.01]	[1.40]	[1.37]
ϵ_ToneAB'						
ϵ_ToneAB'	2.246**	0.533	0.287	2.839	1.055	0.839
	[1.04]	[1.04]	[1.07]	[1.77]	[3.40]	[3.76]
Including Kuttner shocks						
ϵ_ToneAB	1.565*	1.706	1.135	2.971***	2.873	2.789
	[0.88]	[1.23]	[1.12]	[1.13]	[1.99]	[2.31]
Including Krippner (2013)						
ϵ_ToneAB	2.219**	1.879	1.118	3.520***	2.368	2.093
	[1.04]	[1.21]	[1.08]	[1.05]	[2.02]	[2.70]
Including Wu-Xia (2016)						
ϵ_ToneAB	2.219**	1.882	1.118	3.518***	2.371	2.092
	[1.04]	[1.21]	[1.08]	[1.05]	[2.02]	[2.70]
Including FG announcement dummies						
ϵ_ToneAB	2.363**	0.875	0.550	3.176***	2.526	2.14
	[1.07]	[1.12]	[1.02]	[1.20]	[2.09]	[2.20]
Including QE announcement dummies						
ϵ_ToneAB	2.379**	0.959	0.798	3.231***	2.388	1.932
	[1.09]	[1.13]	[1.01]	[1.19]	[3.20]	[4.33]

Note: Robust standard errors in brackets. *p < 0.1, **p < 0.05, ***p < 0.01. Each column corresponds to a different ARCH estimation of equations (6) and (7) for a different horizon. The sample period goes from January 2003 to December 2013. ϵ_ToneAB is estimated from equation (5) based on ToneAB. Our dependent variables are forward nominal interest rates and OIS rates at maturities of 1, 5 and 10-year. The constant, equal to zero, monetary policy surprises and ARCH terms have been removed for space constraints and are available upon request.

Table F. Statistical robustness

	(1) ir1y	(2) ir5y	(3) ir10y	(4) ois1y	(5) ois5y	(6) ois10y
Pre-ZLB subsample[a]						
ϵ_ToneAB	4.355**	2.053	1.515	3.952*	0.436	0.002
	[2.05]	[1.66]	[1.08]	[2.25]	[1.65]	[1.45]
Including a lag of the dependent variable						
ϵ_ToneAB	2.308**	0.826	0.580	3.145***	2.151	1.494
	[1.05]	[1.10]	[1.02]	[0.70]	[3.70]	[5.56]
OLS on all observations						
ϵ_ToneAB	1.147*	0.924	0.347	0.846	0.841	0.451
	[0.62]	[0.90]	[0.92]	[0.57]	[0.95]	[0.94]
OLS on statement days						
ϵ_ToneAB	1.146**	0.924	0.347	0.845	0.842	0.451
	[0.55]	[0.84]	[1.04]	[0.67]	[0.75]	[0.79]
Eq. 5 and 6 in one-step						
Tone_AB	1.122**	0.096	-0.129	0.430	0.601	0.745
	[0.50]	[0.67]	[0.63]	[0.85]	[1.07]	[1.21]
TARCH term						
ϵ_ToneAB	2.334**	0.802	0.541	3.120***	2.026	1.376
	[1.04]	[1.08]	[1.03]	[1.17]	[3.35]	[4.21]
ARCH(2)						
ϵ_ToneAB	0.042	0.839	0.598	2.612***	0.533	0.231
	[0.45]	[1.12]	[1.03]	[0.78]	[1.33]	[1.36]

Note: Robust standard errors in brackets. * p < 0.1, ** p < 0.05, *** p < 0.01. Each column corresponds to a different ARCH estimation of equations (6) and (7) for a different horizon. The sample period goes from January 2003 to December 2013. ϵ_ToneAB is estimated from equation (5) based on ToneAB. Our dependent variables are forward nominal interest rates and OIS rates at maturities of 1, 5 and 10-year. The constant, equal to zero, monetary policy surprises and ARCH terms have been removed for space constraints and are available upon request. a Sample of 1554 observations ending December 15, 2008.