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The financial market impact of ECB monetary policy press conferences - a text based approach

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Abstract

Using methods from natural language processing I create two measures of the monetary policy tilt of the ECB entitled the "Hawk-Dove Indices", that outline the beliefs of the ECB on the current state of the economy and the outlook for growth and inflation. These measures closely track interest rate expectations over the tightening and loosening cycle, and can provide a useful measure of monetary policy tilt at zero lower bound episodes and contains information about the state of the economy. I exploit the time lag between decision announcements and the ECB's monetary policy press conference to assess the immediate financial market impact of changes in communication within the press conference, free from the effects of the shock from the monetary policy decision. Consistent with the literature on the information channel of monetary policy, I find a non-negligible positive (negative) effect on stock prices of a more hawkish (dovish) tone in the press conference, indicating that the ECB reveals "private information" during these press conferences, and that market participants internalise this as good (bad) news regarding the future state of the economy, rather than internalising a future potential increase (decrease) in interest rates. This effect is stronger prior to the introduction of formal forward guidance, suggesting that since then ECB communication has been less surprising to markets in recent times.

JEL classification: E52, E58, C55

Keywords: Monetary policy, communication, machine learning, natural language processing, event study, information effects.

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Non-technical summary

The impact of central bank communication on financial markets has been a topic of increasing importance over the last number of years. From a monetary policy perspective, communication can be used to signal information about the future intended stance of monetary policy, but also to reveal information about the central bank's perspective about current economic developments.

This paper focuses on the ECB's monetary policy press conferences and the impact that communication during these can have on stock market indices. I create two measures of the "monetary policy tilt" of the ECB using text based methods examining the content of the press conferences. These indices, that I denote the "Hawk-Dove Indices" take on more positive (negative) values when the ECB is communicating a more "hawkish" ("dovish") stance regarding its macroeconomic beliefs. A hawkish (dovish) stance is consistent with beliefs that inflation and economic growth are likely to increase (decrease) and thus are consistent with a higher likelihood of a monetary policy tightening (loosening).

I connect these measures to the ever growing literature on the information channel of monetary policy. A number of papers to date have explored the existence of an "information effect" arising from policy announcements, whereby financial markets and forecasts update in response to a monetary policy announcement. From a stock market perspective, the announcement of a monetary policy tightening or an implied increased likelihood of such a tightening can have two offsetting effects. An implied increase in discount rates should put downward pressure on stock prices, while the complementary positive news regarding the state of the economy should put upward pressure on stock prices through higher expected dividends.

I exploit the fact that the ECB's monetary policy press conference takes place in a separate window forty-five minutes after the announcement of changes in monetary policy to exploit a pure communication effect using the two Hawk-Dove Indices. I examine the changes in stock prices in the narrow window before and after the press conference and show that movements are positively related to the Hawk-Dove Indices, suggesting the dividend channel is the more dominant effect. Moreover, no direct effect on OIS yields is discovered, lending further credence to the dominance of the dividend channel over the discount rate channel. Such effects are stronger prior to the introduction of explicit forward guidance by the ECB, suggesting that certainty surrounding policies may decrease the impact of such information effects.

1 Introduction and Background

One of the key challenges in the study of central bank communication is the quantification of the textual content of information releases in such a way that they can be used to examine key economic questions regarding their impact. Understanding the informational content of monetary policy communication can help shed light on the idea of the "information channel" of monetary policy, that is that while communicating, central bankers can release "private information" regarding their assessment of current economic conditions to the public, causing the public to update their beliefs about the state of the economy, as well as regarding the future path of monetary policy.

This concept has become more important in a euro area context, as the European Central Bank (ECB) has increased its emphasis on using communication as a policy tool to convey information about the macroeconomy, future economic policy intentions or to better clarify the rationale behind policy decisions. An important method of communication is the ECB's Governing Council press conference, held forty-five minutes after the announcement of its monthly monetary policy decision.[1] This press conference is followed closely by market participants and can influence greatly the public's overall economic assessment. Understanding the impact that the press conference can have on markets is therefore of great importance to both policymakers and analysts.

In this paper I present two methods of measuring the economic sentiment contained within the ECB monetary policy press conferences, which I denote as *Hawk-Dove Indices*. These measures proxy the "monetary policy tilt" of the ECB at a given time point, in which positive (negative) expectations regarding economic conditions or higher (lower) inflation are associated with a more *hawkish (dovish)* sentiment, and hence a tendency towards a monetary policy tightening (loosening). The first measure relies on a dictionary approach, in line with a methodology first developed by Tadle (2019), while the second method takes a topic modelling approach, using the dynamic topic model algorithm of Blei and Lafferty (2006) to classify paragraphs with economic information, and a list of modifiers to assess whether they convey a hawkish or dovish tone. Both measures strongly track market expectations of the ECB's monetary policy stance and survey measures of current economic conditions.

Next, using the simple information model of Miranda-Agrippino and Ricco (2015), I contextualise how the sentiment conveyed in these press conferences can have an impact on stock markets. In this model, both public agents and central banks have separate noisy information on the "true" state of the economy, and through policy decisions central banks can implicitly reveal private information, causing the public to update their beliefs using this information and in turn this can have an impact on asset prices. I argue that this model also extends to the information explicitly revealed in policy communication and as such I use the two "Hawk-Dove Indices" to quantify this information, and explore the impact of direct monetary policy communication on asset prices.

In this setup a more "hawkish" tone is associated with a belief that economic growth and inflation will be more pronounced in the future, and increased likelihood of a monetary policy tightening, while a more "dovish" tone is associated with a more subdued belief about the future of the economy, and a higher likelihood of accommodative monetary policy. The impact of such communication on stock markets is ambiguous. In one sense, a more hawkish (dovish) tone should indicate a higher probability of a tightening (loosening)

[1] Decisions have been every six weeks since 2015.

of monetary policy, suggesting that a more hawkish (dovish) tone should lead to a fall (increase) in stock prices owing to an increase (decrease) in the expected discount rate. On the other hand, if participants internalise this information as being indicative of better (worse) than expected economic conditions, the impact on stock markets of a more hawkish (dovish) tone may actually be positive (negative), owing to improvements in expected future dividends. This paper aims to shed light on which of these effects dominates.

Understanding the impact that monetary policy communication can have on stock markets is of a high degree of imporance to policymakers, given that movements in stock markets are important in that they can have a knock on effect on consumer behaviour, investment decisions and capital flows. Moreover, it is important to understand how monetary policy communication is in itself perceived, to help tailor future policy announcements to best steer the path of public expectations.

To evaluate the immediate market impact, I explore patterns in intradaily data before and after the ECB press conference in a period spanning from 1999 to 2020. ECB press conferences are held forty-five minutes after the announcement of the monetary policy decision. Any asset price movements during the "press conference window" should therefore be free of most of the direct effect of explicit changes in headline interest rates. Using the novel dataset of Altavilla et al. (2019), I measure market impact in an event study approach by exploring the relationship between these asset price changes and the sentiment as measured by the "Hawk-Dove Indices".

The impact measured in this study is the immediate market impact rather than longer term perseverence, and as such the impact of communication is only measured at this short-term margin. This is a trade off arising from the narrow nature of the event study window. While the results are likely free from the influence of external factors, I note that the long run impact of communication may be more ambiguous. Nonetheless, there is potential for short run fluctuations to pass through to longer term patterns and as such there are still policy implications for the manner in which communication can move markets.

My work confirms the findings of prior authors that ECB communication influences stock markets, but it also sheds light on what exactly drives these effects.

The main findings are as follows. Communication of a more hawkish (dovish) standpoint tends to increase (decrease) stock prices, suggesting the impact of communication on economic expectations dominates the impact of expected changes in interest rates. Moreover, the observed effect on stock markets was stronger prior to the introduction of formal forward guidance in 2013 by the ECB, suggesting market impacts have been more subdued since the ECB has implemented a more forward looking strategy to communicate information about the present state of the economy and likely future course of monetary policy. This suggests that since this more explicit steering of expectations, central bank private information revealed in the monetary policy press conference is less of a surprise to financial market participants. This is of interest in that it highlights how exactly the tone of each ECB press conference is interpreted by markets, and provides evidence that markets extract information regarding the ECB's private beliefs in relation to current macroeconomic conditions from the press conference itself, beyond information that is already available.

In addition, results are robust to the use of the alternative monetary policy sentiment dictionary of Apel et al. (2019), and no direct effect of sentiment on expected interest rates is found, providing further proof that information effects mainly manifest themselves

through updated economic expectations, rather than revised assessments of future monetary policy. The findings of this paper outline the transmission channels of monetary policy communication as a policy tool, and evidence for both the existence of an "information channel" for monetary policy, and the direction in which it impacts markets.

This paper is structured as follows. Section 2 outlines the current state of the literature. Section 3 outlines a simple model of the transmission of central bank private information to the public. Section 4 summarises the methodology used to measure informational content while Section 5 summarises the results obtained using these measures. Section 6 presents the event study approach and empirical findings of the paper and Section 7 concludes.

2 Motivation and Literature Review

The idea of central bank communication as a policy tool has recently come to the forefront of monetary policy literature. Interest has grown rapidly since the early 2000s (Hansen and McMahon, 2016b). Central banks can use communication to steer market expectations of their future actions, and as such the content of speeches and policy releases is analysed with much interest. This paper explores not just the impact of ECB communication on markets, but elucidates the *mechanisms* through which communication can impact markets. The impact of differing informational content *within* the ECB monetary policy press conference on markets is shown, rather than the net effect of such communication.

Literature on communication and information effects to date can be broadly split into two main categories: indirect measures of the overall effect of central bank communication using high frequency data to explore information effects and the transmission of private central bank information, and the direct measurement of the textual content of central bank policy releases using either manual classification or techniques from computational linguistics. By presenting novel measures of the informational content of ECB communication and examining the impact on financial markets in an event study approach motivated by a model of noisy information transmission, I contribute to both strands of literature.

The first strand of literature mainly concentrates on examining fluctuations in high frequency data in and around information releases to indirectly measure the impact of central bank communication on markets. Gürkaynak et al. (2005) show that on Federal Reserve Board (Fed) monetary policy decision days, policy statements move markets in a manner which is beyond the amount expected by changes in the Fed policy rate. The authors show that in particular, Fed statements have an important impact on longer term treasury yields, highlighting the role played by clear communication in steering market expectations. This stylised fact is reflected in a number of other papers. Ehrmann and Fratzscher (2009) show that ECB press conferences have a larger impact on financial markets than corresponding policy decisions, while the "question and answer" component of the ECB press conference fulfils a clarification role during periods of high economic uncertainty, while the work of Goodhead and Kolb (2018) uses federal funds futures data to show the importance of "surprise communication" as a component of U.S. monetary policy.

Similar studies examining the net effect of communication can be seen for the euro area in the work of Whelan et al. (2017), Altavilla et al. (2019) and Kerssenfischer (2019), for the Fed in the work of Nakamura and Steinsson (2018), Jarocinski and Karadi (2018)

or in a more general setting for 37 different central banks in the work of Born et al. (2014). Studies are unanimous in showing that communication shocks have an impact beyond that of standard monetary policy.

While it is clear that communication itself has an impact on markets, it is important to explore both the mechanisms through which communication can have an impact, and the impact of differing information within releases. Many papers such as the work of Nakamura and Steinsson (2018) and Miranda-Agrippino and Ricco (2015) explore the concept of an "information channel" for monetary policy. Under such models, private market participants update their prior on the state of the economy as a result of the communication of private central bank information. Jarocinski and Karadi (2018) expand on this concept by disentangling two channels through which an announcement can have an impact: through information on monetary policy, and the central bank's assessment of the economic outlook. They show that a surprise policy tightening raises interest rates and reduces stock prices, but the complementary positive information shock raises both.

Beyond the examination of the net effect of communication, it is also possible to quantify the information contained within the text of a policy release. This may be identified using manual coding of statements, or automated approaches from the field of computational linguistics. An example of the former approach can be seen in Ehrmann and Fratzscher (2009), where the authors manually classify real time newswire reports into categories to measure the relative importance of topics in each news release. The authors find the main topics that move markets are statements relating to inflation or interest rates. Similarly, Rosa and Verga (2007) measure the sentiment of ECB statements by hand coding each ECB Governing Council monetary policy statement. The authors show that their measure has predictive power for future ECB policy decisions. A similar manual approach is taken by Picault and Renault (2017). These methods are, however, highly subjective and are sensitive to any underlying bias that comes with human judgement. As a consequence, the literature has turned towards automated approaches.

The identification of the tone of central bank releases can be undertaken using pre-set dictionaries, or by developing unique word sets for central banking, rather than ex-post subjective measurement. Schmelling and Wagner (2019) use the Loughran-McDonald financial dictionary to measure the relative *negativity* of ECB press conferences. The authors find some evidence that a shift in tone to a more positive outlook increases stock prices. In the case of the Fed, Cannon (2015) finds a relationship between the tone of the Fed's minutes and contemporary measures of economic activity, evidence of some degree of an information effect. A number of other studies concentrate on the tone of economic and monetary policy releases such as Shapiro et al. (2017) and Jegadeesh and Wu (2013).

Other papers have created specific measures tailored towards monetary policy. In a methodology followed by this paper, Tadle (2019) creates a word list of hawkish and dovish terms, and contextualises them using positive and negative modifiers to create a measure of the monetary policy tilt of a document, and whether it has a more hawkish or dovish tone to create a continuous index. The author exploits the difference between the sentiment of policy statements and the full minutes released two weeks later to measure "surprise" shifts in sentiment and the interpretation of these by markets. A similar method is used by Apel et al. (2019), where words related to the Fed's monetary policy stance are contextualised using positive and negative word lists that occur within a seven word window to create a measure of the Fed's communicated stance. Other indices of hawkishness and dovishness are developed by Tobback et al. (2017) using newspaper

reports on ECB monetary policy and Lucca and Trebbi (2009) using "Google semantic scores" for Fed statements.

Alongside tone, an important factor to measure is the topical content of monetary policy releases. Topic models such as Latent Dirichlet Allocation (Blei et al., 2003) have begun to be increasingly used in the study of monetary policy communication. These models both identify latent topics that commonly occur within policy releases, but also classify bodies of text into these different topics in a probabilistic manner. This method has been used to show the importance of the topical content contained in the Bank of England Inflation Report (Hansen et al., 2019) and changes in informational content in Fed releases (Hansen and McMahon, 2016a). Other studies apply these methods to Turkish (Iglesias et al., 2017) and Japanese (Oshima and Matsubayashi, 2018) monetary policy statements.

This paper contributes to the literature along two key dimensions. First, I create two measures of the "hawkish" and "dovish" sentiment of the ECB's monetary policy tilt, which I denote the *Hawk-Dove Indices*. The first follows the dictionary based approach of Tadle (2019). The second uses the Dynamic Topic Model algorithm of Blei and Lafferty (2006) to extract latent topics from the ECB press conferences. I identify a number of topics that reveal information related to the monetary policy tilt of the ECB, and using the classification of each paragraph into each of these categories I create a measure of the direction of the tilt using positive and negative "shift words".

Second, I use these measures in an event study setting to build on the models of Nakamura and Steinsson (2018), Miranda-Agrippino and Ricco (2015) and Jarocinski and Karadi (2018) and explore further the information channel of monetary policy. By using an event study approach and analysing how changes in stock market prices react to the relative "hawkishness" or "dovishness" of the press conference, I can discern whether (a) there is evidence of a communication effect and (b) if such an effect exists, whether the impact of updated beliefs regarding the state of the economy or the internalisation of changes in the expected path of monetary policy dominates.

3 A simple model of noisy information

To illustrate further the role that central bank private information can play in the steering of public beliefs, I present a simple model in line with Miranda-Agrippino and Ricco (2015).

Suppose there are two players in the economy, central banks cb and private agents a. Let x_t be a vector of true macroeconomic fundamentals, evolving in line with the following AR process:

$$x_t = \rho x_{t-1} + \gamma_t, \gamma_t \sim N(0, \Sigma_\gamma) \tag{1}$$

where γ_t is the vector of structural shocks. Let each time period t be divided into two stage - an opening stage $\underline{t}$ and a closing stage $\bar{t}$.

In the opening stage $\underline{t}$, shocks are realised, but neither central banks nor agents directly observe the outcome. Using a Kalman filter, they form expectations about x_t based on noisy private signals $s_{cb,\underline{t}}$ and $s_{a,\underline{t}}$. Signals $s_{i,\underline{t}}$ are a function of the true x_t and some noise $v_{i,\underline{t}}$ that is non-uniform across both agents, shown in Equation 2.

$$s_{i\underline{t}} = x_{\underline{t}} + v_{i,\underline{t}}. \tag{2}$$

These signals inform forecasts of central banks and agents: $F_{cb,\underline{t}}$ and $F_{a,\underline{t}}$. The asymmetry of the noisy signals allows for central bank private information to exist (i.e. $v_{cb,\underline{t}} \neq v_{a,\underline{t}}$).

To relate this to financial assets, we suppose agents in an economy can trade futures contracts based on i_{t+h}, the interest rate at time $t+h$. The price of a futures conract $p_{\underline{t}}(i_{t+h})$ depends on aggregate expectations about future x_t and a stochastic component μ_t:

$$p_{\underline{t}}(i_{t+h}) = F_{\underline{t}} x_{t+h} + \mu_t \tag{3}$$

Next, consider the closing period $\bar{t}$. At the start of this period, a central bank sets its interest rate i_t that is conditional on its forecasts according to a set Taylor rule process outlined in Equation 4.

$$i_t = \phi_0 + \phi_x F_{cb,\underline{t}} x_t + u_t + w_{t|t-1} \tag{4}$$

In this case, u_t is a monetary policy shock and $w_{t|t-1}$ is a pre-announced deviation from the Taylor rule. This decision *implicitly* reveals information about $F_{cb,\underline{t}}$ to the public.

In addition to this, I argue that through a communication release (for the purposes of this study, the ECB press conference) the central bank *explicitly* reveals information about $F_{cb,\underline{t}}$, and this can act in addition to the implicit signal from the monetary policy decisions.

Having observed the change in monetary policy, and the accompanying communication release, agents re-assess their noisy forecasts based on this information both implicitly and explicitly conferred by the central bank. This process is equivalent to the private agents receiving a public signal with common noise: $\bar{s}_{cb,\underline{t}}$. The prices on futures contracts are update in line with this updated signal, and the new common forecast $F_{\bar{t}}$ (Equation 5).

$$p_{\bar{t}}(i_{t+h}) - p_{\underline{t}}(i_{t+h}) \propto (F_{\bar{t}} x_{t+1} - F_{\underline{t}} x_{t+1}) \tag{5}$$

Hence the asset price changes in a proportionate manner to the updated expectations regarding the future state of the economy. The policy decision and accompanying communication release reveal central bank private information, to create a new public signal that informs a less noisy forecast and hence can impact the price of assets. It is shown in Miranda-Agrippino and Ricco (2015) that forecasts are updated according to the process shown in Equation 6.

$$\begin{aligned} F_{\bar{t}} x_t - F_{\underline{t}} x_t =& (1-K_2)(1-K_1)[F_{\underline{t-1}} x_t - F_{\underline{t-1}} x_t] \\ &+ K_2(1-K_1)\gamma_t + K_2[v_{cb,\underline{t}} - (1-K_1)\rho v_{cb,\underline{t-1}}] \\ &+ K_2(K_{cb}\phi_x')^{-1}[u_t - \rho(2-K_{cb}-K_1)u_{t-1} + (1-K_1)(1-K_{cb})\rho^2 u_{t-2}] \end{aligned} \tag{6}$$

This implies that forecast updates arising from the monetary policy decision and surrounding communication are a function of the Kalman gains employed by agents in the forecast rounds $F_{i,\underline{t}}$ and $F_{i,\bar{t}}$ respectively, the central bank's Kalman gain K_{cb}, past and present monetary policy shocks, denoted u_{t-h}, $h \geq 0$, prior observational noise v_{t-h}, $h > 0$, structural shocks γ_t, Taylor rule decision weighting ϕ_x and the persistence of the vector of macroeconomic variables ρ. The release of direct central bank communication can be viewed as an additional step in this process, providing clearer information on the central bank's private information to the public, reducing the level of noise surrounding the state of the true state of the economy.

Information effects and stock prices

While it is clear from the above model that central bank private information can influence asset prices, it is important to discern the theoretical direction in which information can impact stock markets. I build on this by presenting a simple mathematical framework to highlight the ambiguous impact of information shocks on stock markets in line with Jarocinski and Karadi (2018).[2]

To illustrate, consider two kinds of monetary policy shock, a conventional shock ϵ_t and an information shock σ_t. The conventional shock ϵ_t is a typical monetary policy shock, that agents assess as a sudden deviation away from the Taylor rule of a central bank. The information shock σ_t relates to the reaction of agents with constrained information to an implicit or explicit communication regarding the state of the economy. In the following example I consider the impact of a contractionary shock (e.g. a sudden increase in the policy rate), but the logic generalises to that of an expansionary shock.

Let S_t be the price of a stock. This depends on both ϵ_t and σ_t through effects on the discount rate r_t and effects on future dividends X_t (Equation 7).

$$S_t(r_t(\epsilon_t, \sigma_t), X_t(\epsilon_t, \sigma_t)) \tag{7}$$

The effect of a conventional shock is unambiguous:

$$\frac{dS_t}{d\epsilon_t} = \frac{\partial S_t}{\partial r_t}\frac{dr_t}{d\epsilon_t} + \frac{\partial S_t}{\partial X_t}\frac{dX_t}{d\epsilon_t} \tag{8}$$

In this case, we know the following:

- $\frac{\partial S_t}{\partial r_t} < 0$, as stocks depend negatively on the discount rate.
- $\frac{dr_t}{d\epsilon_t} > 0$, as the conventional shock is an increase in headline interest rates, it also increases the discount rate.
- $\frac{\partial S_t}{\partial X_t} > 0$, as stock prices are positively related to expected dividend flows.
- $\frac{dX_t}{d\epsilon_t} < 0$, as a conventional tightening increases interest rates, and hence depresses expected future dividend flows.

As such, the net impact of a conventional contractionary shock is unambiguously negative on stock prices. On the other hand, consider the impact of the equivalent information shock σ_t (Equation 9).

$$\frac{dS_t}{d\sigma_t} = \frac{\partial S_t}{\partial r_t}\frac{dr_t}{d\sigma_t} + \frac{\partial S_t}{\partial X_t}\frac{dX_t}{d\sigma_t} \tag{9}$$

The sign of $\frac{dr_t}{d\sigma_t}$ is negative. This is due to the fact that a contractionary information shock reveals an increased probabiltiy of a rate increase, hence discount rates rise. On the other hand, the sign of $\frac{dX_t}{d\sigma_t}$ is positive, as a contractionary monetary policy shock can be internalised as the central bank having positive information regarding the state of the economy, and as such there is a perception of improved flows of dividends. Thus, the sign of the net effect of a contractionary information shock on stock prices, $\frac{dS_t}{d\sigma_t}$ is ambiguous.

[2] This concept was particularly highlighted in the discussion of this paper by Lakdawala (2018)

A challenge in monetary policy literature to date has been the isolation of pure information effects. Information effects generally are discussed in the context of revealed implicit information arising from interest rate decisions, and as such the net impact on financial markets is hard to discern as there is noise arising from the contemporaneous conventional shock. Through the introduction of ways to measure the information content of the ECB monetary policy press release, and exploiting the fact that the ECB's press conference takes place forty five minutes after the monetary policy decision announcement, I examine the changes in asset prices in the window before and after the press conference, to discern a "pure information effect". Through this, I aim to shed light on the sign of such information shocks. This is discussed in more detail in Section 6.

4 Data and methodology

The ECB Press Conference

This paper examines the information conveyed during the press conference following the ECB Governing Council's monetary policy decisions. This is usually conducted by the President of the ECB, assisted by the Vice-President.

The ECB's monetary policy decisions are published online and in a press release at 13:45 CET on the second day of the Governing Council meeting. This states concisely the policy change (or lack thereof).

The press conference begins at 14:30 CET and consists of two parts. First, there is the *Introductory Statement* which explains the rationale behind the ECB's decision. This is followed by the *question and answers* component with members of the media.

The Introductory Statement contains information on a number of components, and follows a set structure. First, the text contains information regarding the monetary policy decision announced at 13:45 CET. Prior to the period of unconventional monetary policy, this mainly related to information on interest rates. Since then there has been information on the operational aspects of unconventional monetary policy measures (for example PEPP, APP or TLTROs). From July 2013 onwards, this also contained explicit forward guidance to steer expectations of future policy decisions.

The next sections contain information on *economic* and *monetary analysis*, the two pillars on which the ECB bases its monetary policy decision. The economic analysis component of the Introductory Statement contains information regarding general macroeconomic conditions. Alongside this, there is an assessment of the *balance of risks* to the euro area economy and whether risks are "broadly balanced", "tilted to the downside" or "balanced to the upside". This section is indicative of the ECB's beliefs about the current state of the economy.

Following this, there is a *monetary analysis* section containing information on the broader monetary developments in the euro area, such as changes in credit or other monetary aggregates. This section is usually followed by a *cross check* of the monetary and economic analysis, linking the two strands.

In addition, from September 2004, four times per year in line with the release of the ECB's macroeconomic projections, the Introductory Statement contained the ECB's current year and one year ahead inflation and GDP projections. This is quantitative information which provides a clear signal of the ECB's views on future economic conditions. There is also a brief comment on *structural reforms* and *fiscal policies*,

contextualised within the wider fiscal and economic governance framework of the EU. This is immediately followed by the *question and answers* segment.

The sample covered in this paper consists of 225 Governing Council meetings, from 7th January 1999 to 4th June 2020. This period spans the leadership of four Presidents: Wim Duisenberg (June 1998 to October 2003), Jean-Claude Trichet (November 2003 to October 2011), Mario Draghi (November 2011 to October 2019) and Christine Lagarde (November 2019 to present). The press conference texts were sourced from the ECB website, and the question and answers section was cleaned of any media questions, to only have direct ECB communication in the sample.

The ECB press conference has a unique structure in that the policy decision is announced forty five minutes before the press conference outlining the decision. In the context of discerning the differing effects of conventional monetary policy shocks (ϵ_t) and information shocks (σ_t), this feature is crucial. Since the monetary policy decision is pre-announced, any information revealed during the press conference should be a pure information shock. I exploit the staggered nature of the ECB's decision and press conference in the event study approach outlined in Section 6.

Measuring sentiment

Measuring the tone of a body of text is a rather typical problem in the natural language processing literature. There are a number of conventional methods that use pre-chosen dictionaries of positive and negative terms, and calculate the sentiment as being the difference between the number of positive and negative terms in a piece. Two such methods are the approaches of Nielsen (2011) (AFinn) and Loughran and McDonald (2011) (Loughran-McDonald).

The AFinn method assigns values of between -5 and +5 to a list of words depending on how positive or negative they are perceived to be. A rolling sum is calculated and this, divided by the total number of words in the body of text is defined to be its sentiment score. Explicitly, let $Polarity_i t$ be the polarity of word i in document t from -5 to +5 and $Wordcount_t$ be the total number of words in document t. The AFinn sentiment score is:

$$AFinn_t = \frac{\sum^{\forall i} Polarity_{i,t}}{Wordcount_t} \tag{10}$$

A weakness of AFinn is that it was designed for the analysis of microblogs (such as Twitter), as such it may not be appropriate in an economic context. This weakness motivated the development of the Loughran-McDonald approach, which uses a list of sentiment words developed for the analysis of U.S. 10K filings to create a dictionary that is more focused on financial reporting. The Loughran-McDonald measure takes a simpler counting approach, where the difference between the raw number of positive and negative terms, divided by the total wordcount is the overall sentiment score. Explicitly, let $NumPos_t$ and $NumNeg_t$ be the count of the positive and negative terms in document t and $Wordcount_t$ be the total number of words in such a document. The Loughran-McDonald sentiment score is defined as:

$$LoughranMcDonald_t = \frac{NumPos_t - NumNeg_t}{Wordcount_t} \tag{11}$$

While these measures serve as a useful benchmark, both the AFinn and Loughran-McDonald measures are limited in their use for analysing monetary policy statements.

Negative or positive terms of interest to markets or related to monetary policy information are given the same weighting as superfluous polarised phrases that are uninformative to markets. The above measures are highly likely to be volatile and are very sensitive to the structure of the given document. For example, if there is a lot of discussion of operational concepts in a given press conference, this may be accompanied by polarised terms, but would not be informative from a monetary policy perspective. In addition, both methods are not robust to negation.

This motivates the development of targeted monetary policy approaches. I calculate two such measures. The first follows a dictionary approach, while the second follows a topic modelling approach.

Dictionary Based Hawk-Dove Index

To address the weaknesses of conventional sentiment measures I first propose the use of a monetary policy dictionary as outlined in the work of Tadle (2019). I use this dictionary to create a measure of the monetary policy tilt of the ECB for each press conference, which I denote as the "Dictionary Hawk-Dove Index".

The words in this dictionary are divided into four categories. First, words are classified as (i) "hawkish" or (ii) "dovish" in order to highlight the information contained within the text. Second, words are classified as (i) positive or (ii) negative. This method both controls for the polarity of the sentence, but also concentrates on information that is likely to be informative in a monetary policy setting.

The lists of categorical words are shown in Tables 1 and 2 and the lists of polarised terms are shown in Tables 3 and 4.

TABLE 1. Hawkish Terms

business	businesses	demand	economic
economy	employment	energy	equities
equity	expansion	financial	growth
housing	income	indicators	inflation
inflationary	investment	investments	labour
manufacturing	outlook	output	price
prices	production	recovery	resource
securities	slack	spending	target
toll	wage	wages	

TABLE 2. Dovish Terms

accommodation	devastation	downturn
recession	unemployment	

TABLE 3. Positive Terms

abating	accelerated	add	advance	advanced
augmented	balanced	better	bolsters	boom
booming	boost	boosted	eased	elevated
elevating	expand	expanding	expansionary	extend
extended	fast	faster	firmer	gains
growing	heightened	high	higher	improved
improvement	improving	increase	increased	increases
increasing	more	raise	rapid	rebounded
recovering	rise	risen	rising	robust
rose	significant	solid	sooner	spike
spikes	spiking	stable	strength	strengthen
strengthened	strengthens	strong	stronger	supportive
up	upside	upswing	uptick	

TABLE 4. Negative Terms

adverse	back	below	constrained	contract
contracting	contraction	cooling	correction	dampen
dampening	decelerated	decline	declined	declines
declining	decrease	decreases	decreasing	deepening
depressed	deteriorated	deterioration	diminished	disappointing
dislocation	disruptions	down	downbeat	downside
drop	dropping	ebbed	erosion	fade
faded	fading	fall	fallen	falling
fell	insufficient	less	limit	low
lower	moderated	moderating	moderation	reduce
reduced	reduction	reluctant	removed	restrain
restrained	restraining	restraint	resumption	reversed
slack	slow	slowed	slower	slowing
slowly	sluggish	sluggishness	slumped	soft
softened	softening	stimulate	strained	strains
stress	subdued	tragic	turmoil	underutilization
volatile	vulnerable	wary	weak	weakened
weaker	weakness			

Each document is analysed at the *sentence level*. First, the number of hawkish or dovish words in the sentence is counted. If there are more hawkish than dovish words, the sentence is classified as hawkish. Sentences containing none of these words are removed from examination as they have low relevant informational content. This controls for the noise created in the standard dictionary methods by administrative/operational sentences which are unlikely to be examined by markets.

Next, the polarity of the sentence is assessed by counting the number of positive and negative terms. If the sentence has majority positive and hawkish terms, it is classified as "hawkish", while if a sentence has majority negative and hawkish terms, it is classified as "dovish". Similarly, if a sentence has majority positive and dovish terms, it is classified as "dovish" and if it has a majority negative and dovish terms, it is classified as "hawkish".

To illustrate, consider the following four sentences, with hawkish terms in blue, dovish terms in orange, positive terms in green and negative terms in red:

1. Growth in inflation has been increasing.
2. Growth in inflation has fallen.
3. The risk of recession is elevated.
4. The risk of recession has fallen.

Sentences 1 and 4 are both interpreted as being *hawkish* for different reasons. The first sentence clearly expresses a sentiment which is hawkish regarding inflation, while the fourth sentence expresses an opinion that chances of an economic downturn are lower. These both indicate a tendency towards monetary tightening. Sentences 2 and 3 are more dovish in terms of content. Both sentences express concerns regarding low inflation or increased risk of economic downturn. Both can be interpreted as dovish, and indicate a sentiment that there is a tendency towards monetary accommodation.

More formally let $sent_{i,t}$ be the "Dictionary Hawk-Dove Index" score of sentence i in the press conference at time t. Let $pos_{i,t}$ be the number of positive words in the sentence, $neg_{i,t}$ the number of negative, $hawk_{i,t}$ the number of hawkish terms and $dove_{i,t}$ the number of dovish terms.

We define the "score" of this sentence to be:

$$sent_{i,t} = \begin{cases} 1 \text{ if } hawk_{i,t} > dove_{i,t} \text{ and } pos_{i,t} > neg_{i,t} \\ -1 \text{ if } hawk_{i,t} > dove_{i,t} \text{ and } pos_{i,t} < neg_{i,t} \\ 1 \text{ if } hawk_{i,t} < dove_{i,t} \text{ and } pos_{i,t} < neg_{i,t} \\ -1 \text{ if } hawk_{i,t} < dove_{i,t} \text{ and } pos_{i,t} > neg_{i,t} \\ 0 \text{ otherwise} \end{cases} \tag{12}$$

The total score for the press conference at time t is defined as:

$$DictionaryHawkDoveIndex_t = 100 \times \frac{\sum_{i=1}^{J}(sent_{i,t})}{J} \tag{13}$$

Where J is the number of sentences containing at least one hawkish or dovish word, and sentences are indexed $i = 1, \cdots, J$. Dividing by the number of sentences controls for the length of the press conference.

This defines an index between 100 and -100, where the more positive the value of this index, the more hawkish the sentiment, and the more negative the value of this index, the more dovish. This proxies the relative monetary policy "tilt" of the ECB at each point in time. The measure is both robust to negation and also considers the context of the sentences, and is consequently an improvement on the AFinn and Loughran-McDonald measures.

Topic Model Based Hawk-Dove Index

While the above index is based on words that are directly related to monetary policy, it is still dependent on a pre-chosen list. This motivates the construction of a complementary measure that is based on a topic modelling approach, which involves the extraction

of non-preselected topics. A topic model extracts latent groups of words that occur regularly together to create K topics, where K is chosen prior to fitting the algorithm. Each document is then classified into each of the topics with a given probability. For the purposes of fitting the model, I split the press conference outputs into paragraphs, with each individual paragraph making up a "document" D for these purposes. This is an approach common to a number of papers examining the content of central bank releases (for example Hansen et al. (2019) or Jegadeesh and Wu (2017)).

The most commonly used approach in economic literature to date is Latent Dirichlet Allocation (Blei et al., 2003), and has been widely applied since. It is performed on a "corpus" of documents D. There are $N = 9,840$ documents (paragraphs) in the sample across all press conferences. The algorithm proceeds as follows.[3]

Let V be the total number of unique words across all documents. These words form a total of K topics, where each topic $k \in 1, \cdots K$ has an associated probability vector $\beta_k \in \Delta^V$, which is a distribution over these V words. The vth element of the probability vector associated with topic k, β_k^v is the probability that a given word appears in topic k.

Each document is modelled as a distribution over topics. $\theta_d \in \Delta^K$ is defined as being the distribution of topics in document d, where θ_d^k represents the share of topic k in document d. θ_d can be considered a choice variable of the policymaker that generates document d.

Omitting the d subscript out of convenience, the word generation process for each document proceeds as follows. Each document has N words that fill N slots. In the first step, each slot $n \in 1, \cdots, N$ is independently allocated a topic assignment $z_n \in 1, \cdots, K$ according to the probability vector θ corresponding to the distribution over topics in the document. These topic assignments are unobserved, and are therefore latent variables in this model.

In the second step, a word is drawn for the nth slot in this document from the probability vector β_{z_n} corresponding to the assignment z_n. Given θ, the distribution of topics, and probability vectors β_k for topics $k = 1, \cdots, K$ are now observed, the overall probability of observing the list of words corresponding to the document d is:

$$\prod_{n=1}^{N} \sum_{z_n} Pr(z_n|\theta) Pr(w_n|\beta_{z_n}) \tag{14}$$

where the summation is over all possible topic assignments for individual word w_n.

Hansen et al. (2018) note that computations on Equation 14 are generally intractable. Direct maximum likelihood is therefore infeasible. Instead, the LDA approach assumes θ_d is drawn from the symmetric Dirichlet(α) prior over K dimensions. Each β_k is drawn from a Dirichlet(η) prior with V dimensions. Realisations of Dirichlet distributions with M dimensions lie within the M-simplex, and the hyperparameters α and η determine the concentration of these realisations. The higher they are, the more even the probability mass spread across the dimensions. A low value of α for example will lead to the spread of the probabilities across topics to be more concentrated in a select few topics, while a larger α will lead to a more even spread. Given these priors, the probability of observing the words in document d is shown in Equation 15. This can be estimated using Bayesian methods.

[3] Notation is consistent with the work of Hansen et al. (2018).

$$\int \cdots \int \prod_{k=1}^{K} Pr(\beta_k|\eta) Pr(\theta|\alpha) (\prod_{n=1}^{N} \sum_{z_n} Pr(z_n|\theta) Pr(w_n|\beta_{z_n})) d\theta d\beta_1 \cdots d\beta_K \tag{15}$$

There are some key items of note when using this methodology. Firstly, this is known as a *bag of words* approach. This means that each "document" (paragraph) is treated as a collection of words, rather than an ordered set. Since paragraphs are examined rather than modelling the text as a whole, some degree of ordering is defined, limiting information loss.

One of the issues with the LDA approach is that the set of probability vectors β_k associated with each topic k are not allowed to evolve over time. The text of each press conference is treated as independent, and topics are assumed to be static over the entire corpus. I address this by using use the *dynamic topic models (DTM)* approach of Blei and Lafferty (2006). This extension of the LDA algorithm allows each topic's probability vector β_k to evolve over time, by dividing the sample into time slices. For the purposes of this study the time slices are the four time periods associated with the leadership each of the four ECB presidents (at the time of writing).

Each topic's probability vector is thus expressed as $\beta_{t,k}$, where t refers to the relevant time slice, and k refers to the topic. The probability vectors underlying the topics evolve according to a form of Brownian motion (Equation 16), and topics evolve smoothly from slice to slice with Gaussian noise.

$$\beta_{t,k}|\beta_{t-1,k} \sim N(\beta_{t-1}, \sigma^2 I) \tag{16}$$

A strength of this approach is that it allows for the recognition of changes in which topics are discussed - it addresses the fact that monetary policy language is adaptive. For example, it can address the fact that "PEPP" will often be used during the leadership of President Lagarde in a way in which "APP" was used during the leadership of President Draghi. In a non-time sensitive model, the use of the term PEPP would be overlooked, due to its low use relative to the overall sample.

Implementation

Before estimating the above Dynamic Topic Model, a number of *pre-processing steps* are taken. These steps are consistent with the literature.[4]

Pre-processing steps are taken using the *quanteda* package for R (Benoit et al., 2018), and are as follows:

1. Each press conference is split into paragraphs.
2. A list of common stopwords are dropped from the text - these are very common words that add no informational content such as "the", "and", "or" etc.
3. A list of words common to ECB text that convey no major new information are dropped. These were selected after looking at a list of commonly occurring words

[4] I note that the topic model is fit on a slightly extended sample that includes data as far as October 2020. Results used in regressions only extend as far as June 2020, due to this being the end point of the latest version of the EA-MPD dataset of Altavilla et al. (2019) at the time of writing

after the removal of stopwords. This minimises ambiguity caused by the cross occurrence of common non-informative words across paragraphs.[5]

4. All numeric characters and punctuation are removed.
5. All characters are coerced to lowercase ensuring results are invariant to capitalisation.
6. Each press conference is split into paragraphs using the *corpus_reshape* function in quanteda. These were inspected for consistency.

It should also be noted that in the DTM algorithm, it is explicitly *tokens* not words which are examined. Each slot is filled by a token, which is a string of characters. These are not necessarily only words but can be combinations of words. As such, in an additional step, I identify a list of words that commonly occur together and can unambiguously be read as a single string (for example "deposit facility rate"), and treat these as single tokens. Strings of n words combined in such a way are referred to as *n-grams*. For example, "European Central Bank" is defined as a *3-gram*. This improves the fit of the model by enhancing the predictive power, addressing the limitation of the methodology being invariant to ordering. All *n-grams* are shown in Table 5. Words are combined using the *tokens_compound* function in quanteda. An underscore (_) character links words of interest.

Finally, the document is *stemmed* using the standard Porter stemming function in quanteda. This function converts the words to their English language root word. For example, inflation and inflationary would both be read as "inflat", while observe, observed and observing would be read as "observ". This improves fit by informing the algorithm of relationships between words that convey the same general meaning.

[5]These words are: Duisenberg, Noyer, Draghi, Trichet, said, see, regard, fact, mention, particular, time, know, look, also, number, since, m, month, January, February, March, think, one, discuss, April, May, June, July, August, September, October, November, December, way, now, want, first, Ladies, Gentlemen, today, here, ladies, gentlemen, question, disposal, questions, answer, answers, let, welcome, statement, press, second, report, take, say, clear, go, can, point, just, discussion.

TABLE 5. Common n-grams

euro area	interest rate	fiscal policy	business cycle
Governing Council	GDP growth	banking system	firm anchoring
price stability	outlook price	yield curve	futures prices
monetary policy	real economy	disposable income	global imbalances
interest rates	nonfinancial corporations	monetary developments	financial system
medium term	financing conditions	monetary accommodation	economic expansion
inflation expectations	fiscal policies	asset purchases	financial environment
structural reforms	labour market	low inflation	Executive Board
inflation rates	balance sheet	purchasing power	strong growth
exchange rate	commodity prices	full allotment	potential growth
monetary analysis	downside risks	accommodative monetary	labour costs
HICP inflation	money market	world economy	price inflation
economic growth	firmly anchored	Central Bank	sustained adjustment
price developments	macroeconomic projections	social partners	monetary growth
private sector	inflationary pressures	economic developments	productivity growth
central banks	inflation rate	gradual recovery	consumer prices
economic analysis	economic recovery	European Council	global demand
oil prices	oil price	Monetary Union	inflationary pressure
annual growth	credit growth	monetary credit	credit risk
real GDP	financial stability	asset purchase	nonstandard monetary
United States	nonstandard measures	developments remain	financial conditions
policy measures	sustainable growth	wage developments	wage growth
press conference	inflationary expectations	Federal Reserve	Euro area
central bank	European Union	Inflation expectations	employment growth
annual HICP	European Commission	European Parliament	monetary union
job creation	labour markets	structural reform	risk premia
financial markets	headline inflation	excess liquidity	capital markets
upside risks	public finances	single currency	consumer confidence
fiscal consolidation	global economy	monetary aggregate	longerterm inflation
financial market	bank lending	private consumption	structural unemployment
automatic stabilisers	monetary policy strategy	longerterm inflation expectations	oil price developments
ECB interest rates	annual inflation rates	oil price increases	higher oil prices
annual HICP inflation	asset purchase programme	credit private sector	HICP inflation rate
monetary policy measures	bank lending survey	fixed rate tender	exchange rate policy
real GDP growth	nonstandard monetary policy	labour market reforms	Federal Reserve System
staff macroeconomic projections	HICP inflation rates	sustainable economic growth	remain broadly balanced
interest rates unchanged	adjustment path inflation	potential output growth	anchor inflation expectations
growth rate loans	Eurosystem staff projections	balance sheet adjustment	support economic recovery
remain firmly anchored	longerterm refinancing operations	marginal lending facility	upside risks price stability
national central banks	annual growth rates	domestic price pressures	ECB staff macroeconomic projections
economic data	longterm interest	banking union	core inflation
wage moderation	labour product	fiscal imbalances	fiscal framework
excessive deficit	upward risks	foreign demand	emerging markets
labour productivity	liquidity conditions	price rises	Eurosystem staff macroeconomic projections
current account	credit standards	European economy	deposit facility rate
market expectations	growth prospects	appreciation euro	
economic conditions	stress tests	inflationary risks	
monetary aggregates	lending rates	Annual growth	
negative rates	liquidity situation	money markets	

The DTM algorithm is implemented using the *gensim* package in Python (Rehurek and Sojka, 2011). Prior hyperparameters are chosen as $K = 16$ and $\alpha = 0.5$, with η informed by initial runs of the model. The choice of $K = 16$ is partly informed ex-post by interpretability of the topics.[6] A relatively low value of α is chosen, as ECB press conference paragraphs are relatively short, and rarely about multiple topics.

Next, I denote each paragraph with subscript d, and each press conference with subscript t. The DTM algorithm returns $\hat{\beta}_{s,k}$, a set of vectors of probabilities of each word belonging to each topic $k = 1, \cdots, 16$ in time slice $s =, 1, \cdots, 4$ and $\hat{\theta}_{k,d,t}$ the associated probability of each topic k generating paragraph d in press conference t.

To allow for the fact that there are likely to be some paragraphs that do not fit into any of the topics, I make a slight adjustment to $\hat{\theta}_{k,d,t}$. If the fitted probability of paragraph d being in topic k is less than 0.2, I adjust this down to zero. This removes any noise from ambiguous paragraphs. Any remaining probabilities are normalised such that their total adds to one. This means that paragraphs are likely to be a mix of fewer topics, in line with the short nature of the paragraphs. It is a middle ground between "winner takes all classification", where paragraphs are assigned to the topic with highest

[6] The results of the empirical analysis in Section 6 are similar for other choices of K, and this low value of K is similar in size to the number of topics chosen by similar studies (for example Jegadeesh and Wu (2017) use 8 topics when analysing Fed minutes).

probability that allows for some degree of a mixture of topics to be discussed in a given paragraph. In addition, if no topic has a probability of greater than 0.2, this allows for a "null" classification of a paragraph. I denote this adjusted version of $\hat{\theta}_{k,d,t}$ as $\tilde{\theta}_{k,d,t}$.

Thus the formula in Equation 17 is used to calculate the proportion of press conference t dedicated to topic k.

$$TopicProportion_{k,t} = \sum_{d=1}^{D} \tilde{\theta}_{k,d,t} \times \frac{WC_{d,t}}{WC_t} \tag{17}$$

In Equation 17, D is the number of paragraphs in press conference t, WC_t is the total wordcount of press conference t, and $WC_{d,t}$ is the total wordcount of paragraph d in press conference t. Muliplying by $\frac{WC_{d,t}}{WC_t}$ controls for the relative importance of each paragraph in the overall scope of the press conference in that larger paragraphs are given higher weight. This tracks contributions of information from each of these estimated topics in each press conference.

The fitted topics

The topics extracted from the fitting of the topic model are for each of the four time points in Tables 6 to 9.

TABLE 6. Dynamic Topic Model - Extracted Topics, Time Slice 1 (Wim Duisenberg)

Topic Name	Structural Reforms	Institutions	Discursive	Fiscal Policy	Governing Council Meetings	Risk	Liquidity and Operations	Projections
Term 1	euro_area	euro_area	differ	countri	will	risk	relat	project
Term 2	economi	countri	bank	govern	govern_council	economi	rate	ecb
Term 3	structur_reform	will	certain	stabil	decis	develop	oper	staff
Term 4	competit	full	countri	fiscal	meet	concern	risk	eurosystem
Term 5	growth	implement	actual	growth	confer	world	main	forecast
Term 6	product	euro	mani	pact	presid	factor	liquid	reflect
Term 7	invest	european	go	fiscal_polici	vice-presid	unit_state	balanc	publish
Term 8	improv	area	effect	euro_area	outcom	well	refinanc	assess
Term 9	increas	order	thing	posit	ecb	us	financi_market	rang
Term 10	reform	econom	much	commit	discuss	market	possibl	revis
Term 11	market	singl	well	need	inform	uncertainti	interest_rate	euro_area
Term 12	employ	framework	now	confid	taken	global	will	broad
Term 13	wage	decis	quit	deficit	mr	far	money_market	intern
Term 14	unemploy	nation	two	plan	like	europ	may	compar
Term 15	support	step	part	consolid	member	futur	outlook	macroeconom_project
Topic Name	**Decisions**	**Credit**	**Long Term Inflation**	**Data Analysis**	**Price Developments**	**Asset Purchases**	**Monetary Policy Mandate**	**Inflation Expectations**
Term 1	central_bank	rate	price_stabil	year	price	measur	monetari_polici	price_stabil
Term 2	respons	loan	euro	will	euro_area	will	programm	remain
Term 3	institut	credit	exchang_rate	last	expect	end	polici	medium_term
Term 4	import	growth	will	figur	increas	use	ecb	close
Term 5	comment	continu	rate	observ	remain	inflat	object	continu
Term 6	will	annual_growth	market	regard	quarter	billion	condit	euro_area
Term 7	possibl	bank	deliv	chang	continu	instrument	mandat	monetari
Term 8	work	privat_sector	us	growth	year	interest_rate	act	monitor
Term 9	regard	corpor	interest_rate	level	growth	monetari_polici	word	confirm
Term 10	govern	household	credibl	cours	oil_price	purchas	greec	will
Term 11	alreadi	non-financi	appropri	mention	recent	period	place	inflat_expect
Term 12	european	money	exchang	ago	econom	necessari	say	assess
Term 13	author	remain	import	inflat	activ	forward	govern	monetari_polici
Term 14	done	increas	currenc	next	effect	continu	will	econom
Term 15	level	month	anchor	month	energi	non-standard	well	level

Notes: This table shows the 16 extracted topics, with the component words listed in descending order of size of $P(word|topic)$. This table is for the first time slice corresponding with the presidency of Wim Duisenberg.

TABLE 7. Dynamic Topic Model - Extracted Topics, Time Slice 1 (Jean Claude Trichet)

Topic Name	Structural Reforms	Institutions	Discursive	Fiscal Policy	Governing Council Meetings	Risk	Liquidity and Operations	Projections
Term 1	economi	euro_area	differ	countri	will	risk	risk	project
Term 2	structur_reform	countri	bank	govern	govern_council	economi	oper	staff
Term 3	euro_area	implement	certain	fiscal	decis	develop	relat	ecb
Term 4	competit	full	actual	stabil	meet	concern	rate	eurosystem
Term 5	growth	will	countri	growth	confer	world	liquid	reflect
Term 6	invest	order	mani	fiscal_polici	presid	factor	main	forecast
Term 7	improv	area	go	pact	vice-presid	global	balanc	assess
Term 8	product	european	effect	euro_area	outcom	unit_state	financi_market	revis
Term 9	increas	euro	thing	need	discuss	market	refinanc	rang
Term 10	reform	econom	much	commit	taken	well	possibl	publish
Term 11	market	singl	now	confid	ecb	us	outlook	euro_area
Term 12	employ	framework	well	deficit	inform	uncertainti	money_market	broad
Term 13	wage	decis	quit	posit	mr	major	will	macroeconom_project
Term 14	support	nation	two	debt	unanim	europ	interest_rate	collater
Term 15	unemploy	step	part	plan	like	far	may	compar

Topic Name	Decisions	Credit	Long Term Inflation	Data Analysis	Price Developments	Asset Purchases	Monetary Policy Mandate	Inflation Expectations
Term 1	central_bank	loan	price_stabil	year	price	measur	monetari_polici	price_stabil
Term 2	respons	credit	euro	will	euro_area	will	programm	remain
Term 3	import	rate	rate	last	expect	end	polici	medium_term
Term 4	institut	growth	will	observ	quarter	inflat	object	close
Term 5	comment	continu	deliv	figur	increas	use	ecb	continu
Term 6	will	annual_growth	market	regard	remain	instrument	condit	euro_area
Term 7	work	bank	us	chang	continu	purchas	mandat	monetari
Term 8	possibl	corpor	exchang_rate	level	year	billion	act	monitor
Term 9	regard	household	credibl	growth	growth	monetari_polici	say	confirm
Term 10	govern	non-financi	interest_rate	mention	activ	interest_rate	place	inflat_expect
Term 11	alreadi	privat_sector	appropri	cours	oil_price	forward	greec	will
Term 12	level	remain	import	ago	econom	necessari	govern	econom
Term 13	done	increas	anchor	inflat	recent	non-standard	will	level
Term 14	author	money	currenc	present	effect	continu	word	monetari_polici
Term 15	decis	month	definit	situat	energi	period	realli	assess

Notes: This table shows the 16 extracted topics, with the component words listed in descending order of size of $P(word|topic)$. This table is for the first time slice corresponding with the presidency of Jean Claude Trichet.

TABLE 8. Dynamic Topic Model - Extracted Topics, Time Slice 1 (Mario Draghi)

Topic Name	Structural Reforms	Institutions	Discursive	Fiscal Policy	Governing Council Meetings	Risk	Liquidity and Operations	Projections
Term 1	economi	euro_area	differ	countri	will	risk	oper	project
Term 2	structur_reform	countri	bank	govern	govern_council	economi	risk	staff
Term 3	euro_area	implement	actual	fiscal	decis	develop	relat	ecb
Term 4	invest	full	certain	fiscal_polici	meet	factor	rate	eurosystem
Term 5	competit	will	countri	stabil	confer	concern	liquid	reflect
Term 6	growth	order	mani	growth	presid	world	main	assess
Term 7	improv	area	go	euro_area	outcom	uncertainti	balanc	revis
Term 8	product	european	effect	pact	vice-presid	market	refinanc	macroeconom_project
Term 9	increas	euro	thing	need	discuss	well	financi_market	forecast
Term 10	reform	econom	much	debt	taken	us	outlook	collater
Term 11	recoveri	decis	now	commit	unanim	unit_state	possibl	euro_area
Term 12	support	singl	quit	confid	ecb	global	will	broad
Term 13	unemploy	step	well	fiscal_consolid	member	confid	downsid_risk	rang
Term 14	market	framework	two	plan	communic	major	money_market	compar
Term 15	employ	nation	part	posit	mr	far	interest_rate	publish
Topic Name	**Decisions**	**Credit**	**Long Term Inflation**	**Data Analysis**	**Price Developments**	**Asset Purchases**	**Monetary Policy Mandate**	**Inflation Expectations**
Term 1	central_bank	credit	price_stabil	year	price	will	monetari_polici	medium_term
Term 2	respons	loan	euro	last	euro_area	measur	programm	remain
Term 3	institut	rate	rate	will	expect	inflat	object	close
Term 4	import	continu	will	observ	quarter	end	condit	price_stabil
Term 5	work	growth	deliv	figur	increas	purchas	ecb	continu
Term 6	comment	bank	exchang_rate	chang	continu	instrument	polici	monetari
Term 7	will	annual_growth	market	regard	remain	use	mandat	level
Term 8	possibl	household	us	ago	growth	forward	act	euro_area
Term 9	govern	corpor	credibl	inflat	year	monetari_polici	place	confirm
Term 10	regard	non-financi	interest_rate	mention	econom	billion	realli	inflat_expect
Term 11	done	money	exchang	level	activ	interest_rate	say	monitor
Term 12	alreadi	increas	appropri	growth	oil_price	continu	govern	econom
Term 13	european	remain	import	cours	energi	necessari	will	inflat_rate
Term 14	author	privat_sector	currenc	next	support	period	thing	monetari_polici
Term 15	level	broad	anchor	two	inflat	guidanc	greec	line

Notes: This table shows the 16 extracted topics, with the component words listed in descending order of size of $P(word|topic)$. This table is for the first time slice corresponding with the presidency of Mario Draghi.

TABLE 9. Dynamic Topic Model - Extracted Topics, Time Slice 4 (Christine Lagarde)

Topic Name	Structural Reforms	Institutions	Discursive	Fiscal Policy	Governing Council Meetings	Risk	Liquidity and Operations	Projections
Term 1	economi	euro_area	differ	fiscal	will	risk	oper	project
Term 2	structur_reform	countri	actual	countri	govern_council	economi	relat	staff
Term 3	euro_area	implement	bank	govern	decis	factor	risk	ecb
Term 4	invest	full	certain	fiscal_polici	meet	develop	rate	eurosystem
Term 5	improv	will	countri	stabil	confer	concern	liquid	reflect
Term 6	growth	order	go	euro_area	presid	world	refinanc	assess
Term 7	competit	area	mani	growth	outcom	uncertainti	main	macroeconom_project
Term 8	recoveri	european	effect	pact	vice-presid	well	balanc	revis
Term 9	product	econom	much	debt	discuss	us	outlook	forecast
Term 10	support	euro	thing	need	taken	market	financi_market	collater
Term 11	increas	decis	now	commit	unanim	unit_state	possibl	euro_area
Term 12	reform	singl	well	confid	communic	global	will	broad
Term 13	unemploy	step	quit	plan	member	major	downsid_risk	compar
Term 14	employ	framework	two	fiscal_consolid	ecb	confid	interest_rate	rang
Term 15	market	nation	part	posit	mr	certain	money_market	publish
Topic Name	**Decisions**	**Credit**	**Long Term Inflation**	**Data Analysis**	**Price Developments**	**Asset Purchases**	**Monetary Policy Mandate**	**Inflation Expectations**
Term 1	central_bank	credit	price_stabil	year	euro_area	will	monetari_polici	medium_term
Term 2	respons	loan	euro	last	price	measur	programm	close
Term 3	work	continu	rate	will	expect	inflat	object	remain
Term 4	institut	rate	exchang_rate	observ	quarter	end	condit	price_stabil
Term 5	import	growth	will	figur	increas	purchas	ecb	continu
Term 6	will	household	deliv	chang	continu	use	mandat	level
Term 7	comment	bank	us	inflat	remain	instrument	polici	monetari
Term 8	possibl	corpor	market	ago	growth	monetari_polici	place	inflat_expect
Term 9	govern	annual_growth	credibl	regard	year	billion	act	monitor
Term 10	done	non-financi	interest_rate	mention	activ	continu	realli	confirm
Term 11	european	money	exchang	level	econom	interest_rate	say	euro_area
Term 12	regard	increas	appropri	cours	energi	forward	will	inflat_rate
Term 13	alreadi	remain	import	growth	inflat	necessari	govern	econom
Term 14	author	privat_sector	currenc	next	oil_price	period	thing	monetari_polici
Term 15	level	broad	mandat	two	demand	long	greec	line

Notes: This table shows the 16 extracted topics, with the component words listed in descending order of size of $P(word|topic)$. This table is for the first time slice corresponding with the presidency of Christine Lagarde.

Using these topics I propose the creation of the *DTM Hawk-Dove Index*. A number of fitted topics are likely to be about economic information that communicate the monetary policy tilt of the ECB. I label these topics as the "information topics". The "information" topics will have a function analogous to the "topical words" listed in the hawkish and dovish terms for the dictionary based approach (Tables 1 and 2). I identify six topics that seem to contain some direct informational content regarding the state of the economy, that I label *risk*, *projections*, *credit*, *long term inflation*, *price developments* and *inflation expectations*.[7] These relate to both the primary mandate of the ECB (price stability), but also broader conditions that make up the broader components of the ECB's assessment of economic conditions. For each of these topics, I create a list of positive and negative shifters to create an index in line with the dictionary based Hawk-Dove Index. The positive and negative shifters are identical to those in Tables 3 and 4 for all topics bar the risk topic. This is because terms such as "increased" or "elevated" are likely to have a negative tone when referring to the risk environment. The list of positive an negative shifters for the risk topic are shown in Tables 10 and 11.

[7]While the topic I label "data analysis" may seem to have some degree of information, a list of polarised words to gauge the tilt of this topic is hard to define, as the list is predominantly agnostic "analysis terms" rather than about specific economic concepts

TABLE 10. Positive Shifters - Risk Topic

abating	balanced	better	bolsters
boom	booming	boost	boosted
improved	improving	robust	recovering
less	reduce	reduced	reduction
upside	improvement	strength	strengthen
strengthened	strengthening	strong	stronger
supportive	up	upswing	uptick
decline	decreased	decrease	decreasing
low	lower		

TABLE 11. Negative shifters - Risk Topic

accelerated	elevated	heightened	high
higher	increase	increased	increases
increasing	raise	rapid	risen
cooling	correction	dampen	down
downbeat	downside	drop	dropping
ebbed	erosion	restrain	spike
adverse	back	below	constrained
contract	contracting	contraction	restrained
soft	rising	sluggish	stress
turmoil	tragic	underutilisation	volatile
weak	weaker	weakness	sluggishness
subdued			

The index is constructed as follows. Let I be the set of information topics. Let $i \in I$ be an individual topic denoted as an information topic. For a given paragraph d let $\tilde{\theta}_{i,d,t}$ be the adjusted probability that this paragraph belongs to a given information topic. If $\sum^{\forall i \in I} \tilde{\theta}_{i,d,t} = 0$, define that paragraph as being non informative and drop it from the sample. Then for a given paragraph, we calculate $\tilde{\Omega}_{i,d,t}$ as the "adjusted" contribution of each of the topics for a given paragraph to the overall index:

$$\tilde{\Omega}_{i,d,t} = \begin{cases} \tilde{\theta}_{i,d,t} \text{ if } pos_{i,d,t} > neg_{i,d,t} \\ -1 \times \tilde{\theta}_{i,d,t} \text{ if } neg_{i,d,t} > pos_{i,d,t} \\ 0 \text{ otherwise} \end{cases} \tag{18}$$

where $pos_{i,d,t}$ and $neg_{i,d,t}$ are the number of positive and negative shift words from the lists associated with information topic i in paragraph d.

The final step is to aggregate these to the document level, and this is shown in Equation 19. In this equation, i refers to the information topic, I the set of information topics, d the paragraph and t the press conference. $WC_{d,t}$ is the word count of paragraph d and WC_t is the word count of all paragraphs with some "information" content in press conference t.

$$DTMHawkDoveIndex_t = 100 \times \sum^{\forall d \in t} \left(\frac{WC_{d,t}}{WC_t} \times \sum^{\forall i \in I} \tilde{\Omega}_{i,d,t}\right) \tag{19}$$

This produces an index with upper bound of 100 and lower bound of -100, which is analogous in interpretation to the Dictionary Hawk-Dove Index in Equation 13. Positive values outline a more hawkish tilt, negative values a more dovish tilt.

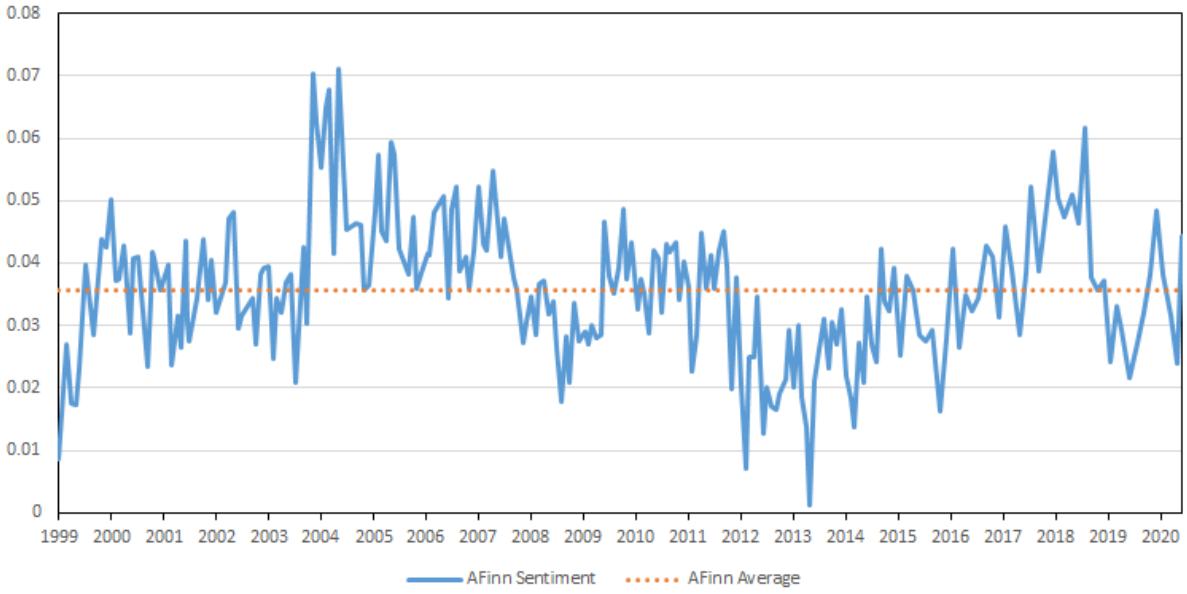
This measure should be seen as complementary to the dictionary based method rather than a preferred option. It has the strength of being agnostic prior to the fitting of the topics, and as such can exploit latent information that would be missed by a dictionary approach. On the other hand, it has the weakness of the topic probabilities being less clean than a simple word lookup approach. Some paragraphs may have spurious information that causes them to be classified into the information topics, which is less of an issue in the dictionary based approach. Together, however, both methods provide a relatively robust overview of the monetary policy tilt of the ECB.

5 Baseline Results

Conventional Sentiment Measures

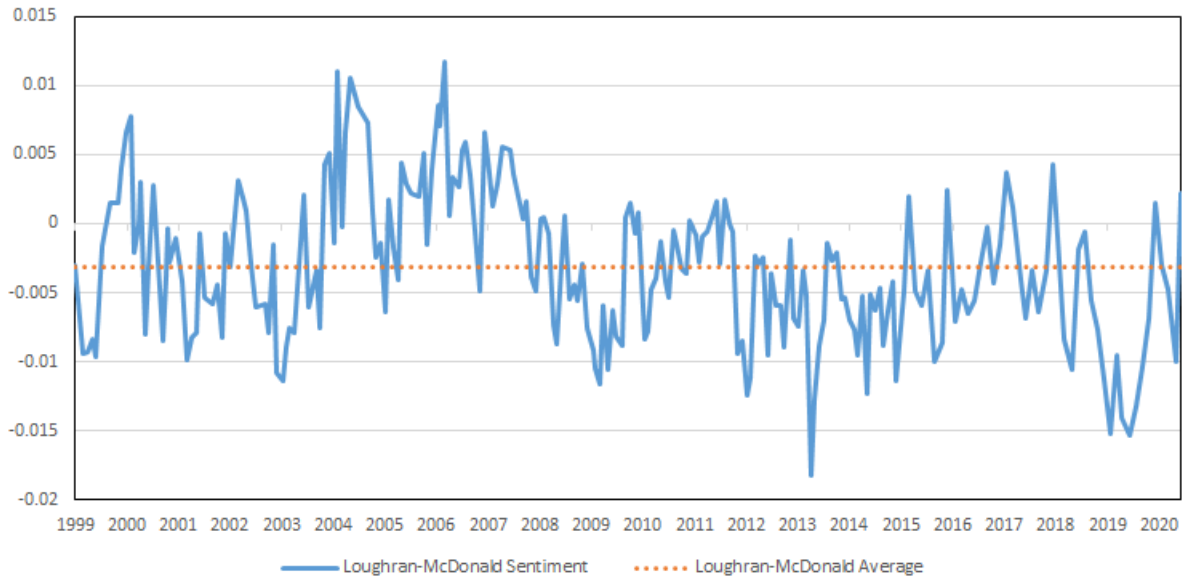
The time series for the AFinn and Loughran-McDonald are shown in Figures 1 and 2. In each case the series average is shown using an orange dotted line, to allow a clear indication of when sentiment was elevated relative to the long run average.

FIGURE 1. AFinn Sentiment Time Series



Notes: This figure shows the evolution of the AFinn method of sentiment applied to ECB Governing Council press conferences. The Y-axis shows the relative sentiment score, divided by the total word count of the document, with larger (smaller) numbers indicating a more positive (negative) sentiment.

FIGURE 2. Loughran Sentiment Time Series



Notes: This figure shows the evolution of the Loughran-McDonald method of sentiment applied to ECB Governing Council press conferences. The Y-axis shows the relative sentiment score, defined as the total number of positive terms less the number of negative terms, divided by the total words in the document. Larger (smaller) numbers indicate a more positive (negative) sentiment.

From the above, a number of observations are clear. First, the data are quite volatile. At times there are sustained trends in sentiment, but the meeting to meeting change is often quite large. Since monetary policy communication is quite consistent over time, it is unlikely that such movements should be so volatile. Between meeting changes may be driven by spurious changes in sentiment owing to language not related to monetary policy. This volatility motivates the development of a monetary policy specific measure of sentiment.

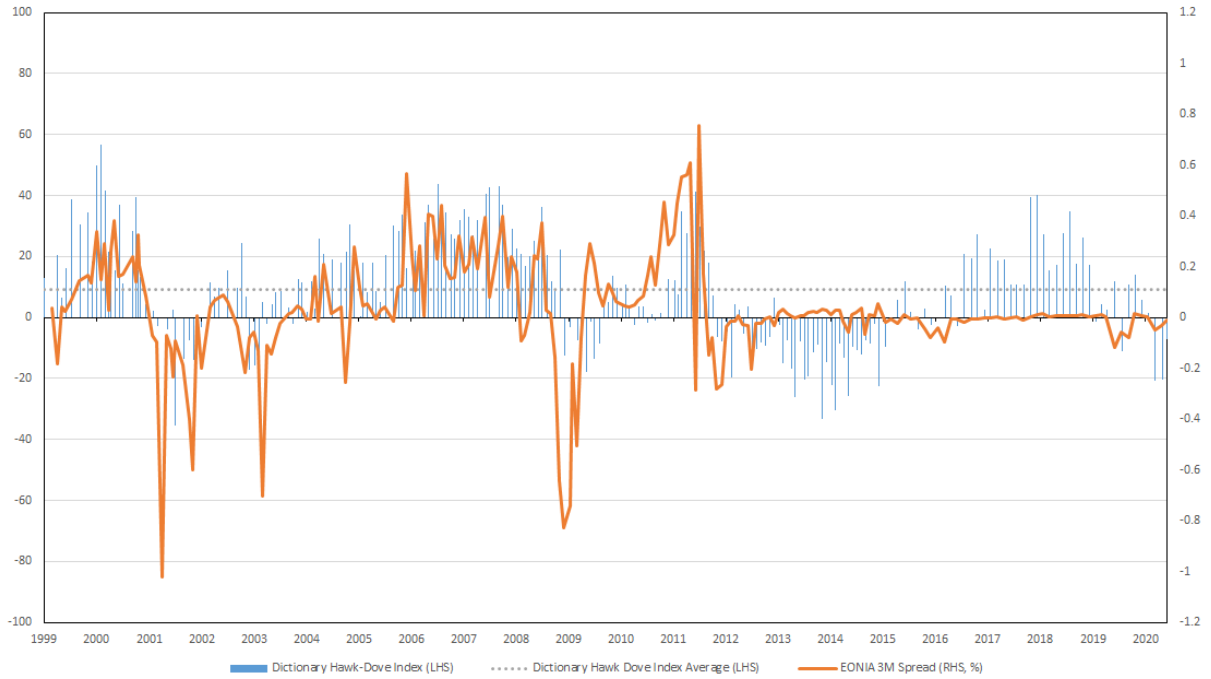
Second, it is that a number of key events can be accounted for in these measures. All measures are quite positive from 2005 to 2008, before turning negative during the Great Financial Crisis. Positive outlook also increases during the period between the Great Financial Crisis and the euro area Sovereign Debt Crisis, before turning rather negative again for this period. Finally, recent dynamics are clear. Sentiment began to become more elevated between 2016 and the first half of 2018 in light of positive economic data, but eventually turns more negative in 2019, and severely negative in early 2020 as the Covid-19 crisis took hold. Despite the volatility of these measures, they convey some descriptive information.

Hawk-Dove Indices

While conventional measures of sentiment are interesting from a baseline perspective, it is clear there is a lack of consistency in the measures. This motivates further the development of the Hawk-Dove Indices, as removing polarised but non informative terms can create a more consistent time series. Figures 3 and 4 plot the time series of the dictionary based and DTM based Hawk-Dove Indices respectively. Alongside these the difference between the EONIA 3-month swap rate and the EONIA spot rate is shown.

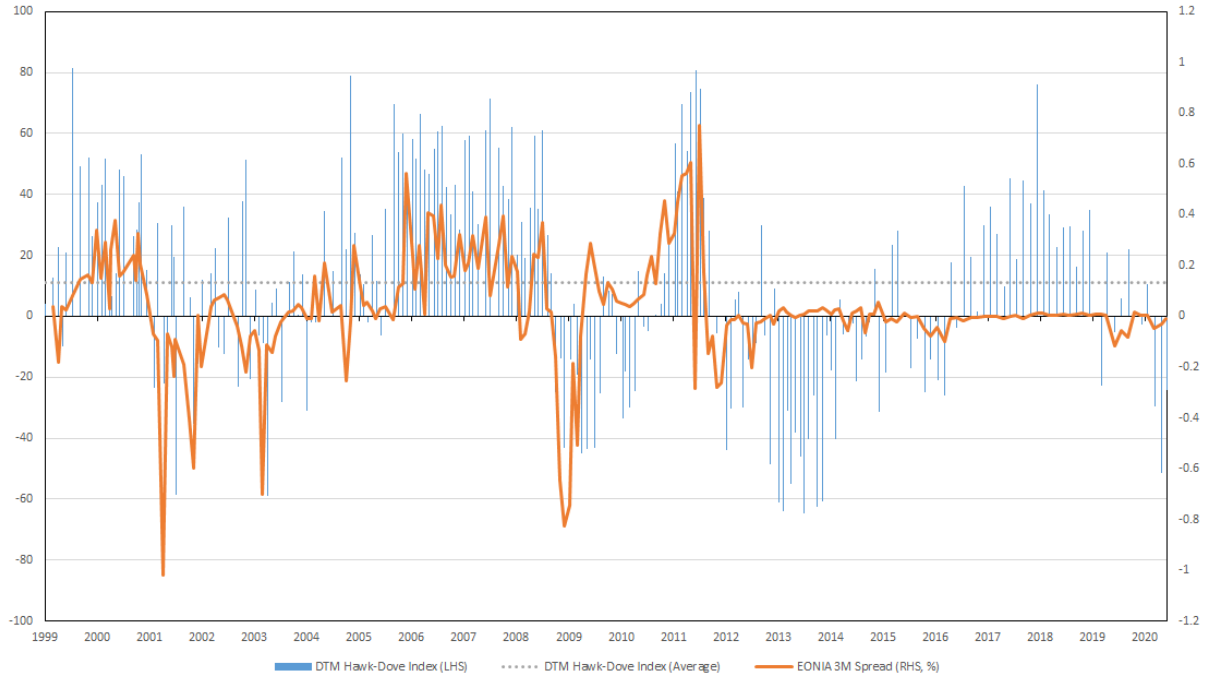
These are measured at market close the evening after the press conference. The EONIA rate is the overnight interest rate used as a benchmark for the euro area, while the three month swap rate is the average rate for a swap contract to be settled in three months. This acts as a measure of market expectations of future euro area monetary policy. If this is positive (negative), it is indicative of expected *interest rate increases (decreases)*, hence markets view policy as quite *hawkish (dovish)*. Moreover, this can be used as a tool for measuring the release of central bank private information regarding both the state of the economy and the future likely monetary policy stance, and hence it will highlight the potential role the information channel can play in monetary policy transmission.

FIGURE 3. Dictionary Hawk-Dove Index contrasted with euro area market interest rate expectations



Notes: This figure shows the estimated Dictionary Hawk-Dove Index scores, outlined in Equation 13 for each ECB press conference over time, with this scale being shown on the left hand Y-axis. On the right hand Y-axis the difference between 3-month OIS and Eonia rates are shown in percentage terms, as a form of measuring market expectations of upcoming changes in policy rates.

FIGURE 4. DTM Hawk-Dove Index contrasted with euro area market interest rate expectations



Notes: This figure shows the estimated DTM Hawk-Dove Index scores, outlined in Equation 19 for each ECB press conference over time, with this scale being shown on the left hand Y-axis. On the right hand Y-axis the difference between 3-month OIS and Eonia rates are shown in percentage terms, as a form of measuring market expectations of upcoming changes in policy rates.

The Hawk-Dove Index is less volatile and has more consistency between meetings than both the AFINN and Loughran measures. This marks an improvement, as the language of monetary policy releases tends to have a degree of consistency between releases, and tends to change quite incrementally. Second, the measure appears to track the market expectations of euro area monetary policy quite well, especially before interest rates hit the zero lower bound towards the latter end of the sample. This highlights a key advantage of this measure. From 2012 onwards, the ECB began to turn away from conventional monetary policy measures, as interest rates hit a zero lower bound. The ECB engaged increasingly in unconventional monetary policy as a key form of policy tool, such as asset purchase programmes or operations such as targeted long term refinancing operations (TLTROs). These are accommodative monetary policy actions consistent with a rather dovish stance, but would not be picked up on by examining the change in interest rate expectations. The Hawk-Dove Indices provides an alternative measure of ECB monetary policy tilt.

Further to this, the Hawk-Dove Indices clearly pick up on a number of key events in ECB monetary policy. In 2011, the ECB raised rates post crisis against the backdrop of an uptick in some inflation measures, and both indices clearly show a shift to a more "hawkish" tone at that time point. This is reversed in 2012, post the "whatever it takes" speech by President Draghi, as the more dovish tone that underlay the era of unconventional monetary policy is evident. Finally, in 2020, there is a clear, sudden, dovish shift, in line with the Covid-19 crisis.

To further compare the appropriateness of the Hawk-Dove Indices for measuring the stance of monetary policy communication, Table 12 presents the results of a descriptive regression of all four measures of sentiment on two indicators of interest.[8] The first is the difference between the 3-month EONIA swap rate and the EONIA spot rate as outlined above. The second is the ZEW measure of the current euro area economic situation. This is published monthly by the German ZEW economic research institute. This is a survey measure of market participants' assessment of current economic conditions. Both of these measures should be related directly to any measure of the tone of ECB press conferences, either through market expectations of future rates, or through the current positive or negative economic outlook.

As expected all measures have a positive and significant relationship with these two economic indicators. Most noteworthy, however, is the higher R^2 recorded by the regressions involving the Hawk-Dove Indices relative to the other non monetary policy specific measures. This is further evidence of the superior performance of the new index and the power of computational linguistics in quantifying tone of monetary policy communication.

TABLE 12. Descriptive Correlations Between Sentiment Measures and ZEW Indicator/OIS Spread

	Dict Hawk-Dove	Dict Hawk-Dove	DTM Hawk-Dove	DTM Hawk-Dove	Loughran	Loughran	AFinn	AFinn
EONIA 3M Spread	31.87***		65.10***		0.00905***		0.0103***	
	(5.124)		(7.902)		(0.00132)		(0.00235)	
ZEW Current Index		0.260***		0.482***		0.0000338***		0.0000637***
		(0.0162)		(0.0331)		(0.00000713)		(0.0000151)
Constant	7.971***	14.82***	8.699***	21.54***	-0.00352***	-0.00245***	0.0354***	0.0370***
	(1.105)	(0.931)	(2.080)	(1.717)	(0.000335)	(0.000377)	(0.000733)	(0.000703)
Observations	224	225	224	225	224	225	224	225
R^2	0.154	0.444	0.177	0.417	0.132	0.080	0.040	0.064

Dependent variables are the Hawk-Dove Index scores, Loughran-McDonald measure of net sentiment and AFinn sentiment measures outlined in Section 4 for each Governing Council press conference. The independent variables are the ZEW measure of current economic sentiment, measured the same calendar month as the Governing Council meeting, and the difference between the 3 month EONIA OIS rate and EONIA spot rate the evening after the press conference. These proxy macroeconomic conditions and market interest rate expectations respectively. Results are intended to be descriptive not causal. Standard errors in parentheses. *** denotes significance at 1% level, ** denotes significance at 5% level and * denotes significance at 10% level.

These descriptive results motivate the use of the Hawk-Dove Indices as appropriate measures of the ECB's monetary policy tilt, and overall viewpoint on the broader macroeconomy.

6 Econometric Specification and Empirical Results

While the results in Section 5 hold rich descriptive properties, of interest is the differential effect of topic and tone on financial markets. To examine this, I adopt an event study approach, concentrating on the variation in asset prices around the ECB press conference. As discussed in Section 4, the ECB press conference occurs at a time separate from the announcement of monetary policy decisions. Any movement in asset prices before and after the press conference can be interpreted as mostly a communication effect. This allows us to extract a net information effect free from the impact of a conventional monetary policy shock. This will allow the estimation of the impact of an information effect on stock prices, in line with the concepts outlined in Equation 9.

[8] Such regressions are not causal - simple correlations are examined to motivate the relationship of our measures to other summary measures.

This is examined using high frequency data from the "Euro area monetary policy database" (EA-MPD) dataset of Altavilla et al. (2019), which contains *the change in price* of a number of key assets from before to after the ECB press conference.[9] Since the time widow of interest is quite tight, it is unlikely that the analysis is influenced by confounding factors, while also being mostly free of any direct effect arising from the monetary policy decision.

The following regression is estimated in an event study setting:

$$\Delta AssetPrice_t = \beta_0 + \beta_1 HawkDoveIndex_t + \Phi X_t + \epsilon_t \tag{20}$$

where $\Delta AssetPrice_t$ is the change in the median price of a stock index before and after the press conference at time t. The two stock indices of interest are the Eurostoxx 50 index, which is a stock index of the fifty largest euro area stocks designed by the Deutsche Borse Group, and the SX7E index, an index of the banking component of the Eurostoxx 50 index. Both of these are measured in terms of their change in percentage points from before to after the press conference. $HawkDoveIndex_t$ is the value of either the dictionary or DTM based Hawk-Dove Index at time t, while X_t is a vector of controls. From an interpretation perspective, a value of $\beta > 0$ would imply that for a more hawkish tone, the impact of higher expected future dividends owing to the positive news dominates the impact of a higher discount rate on stock prices, while $\beta < 0$ implies the opposite. This regression should shed light on the net impact of the information channel of monetary policy as it transmits through communication releases.

All dependent variables are composed of changes in the short run window around the press conference. As such, any significant values for β in Equation 20 should be interpreted as such, rather than longer term persistent effects. The interpretation should highlight the information effect of the policy releases, rather than the longer term path determination of these financial series.

Baseline Results

Table 13 shows the results from a baseline regression without controls. The independent variables are the Hawk-Dove Indices for the press conference on each given date. Results show a positive and significant relationship between immediate movements in the Eurostoxx and SX7E stock indices and the Hawk-Dove Indices for both the dictionary and DTM based methods. All relationships are significant at the one percent level. This relationship also appears economically significant. For the dictionary based index, a one standard deviation increase in the dictionary Hawk-Dove Index is associated with a 0.13 percentage point increase in the Eurostoxx index, and a 0.22 percentage point increase in the SX7E index. Similarly, for the DTM method, the figures are 0.13 percentage points and 0.21 percentage points respectively. Given the average change in both series is 0.08 and 0.18 percentage points respectively, it suggests these results are non-negligible.

[9] This is defined as the change in median quote from the window 14:15-14:25 before the press conference to the median quote in the window 15:40-15:50 after it. The press conference takes place between 14:30 and 15:30.

TABLE 13. Baseline Regression of Stock Market Indices on Hawk-Dove Index Scores

	Eurostoxx	Sx7e	Eurostoxx	Sx7e
Dictionary Hawk-Dove Index	0.00751***	0.0128***		
	(0.00237)	(0.00447)		
DTM Hawk-Dove Index			0.00392***	0.00619***
			(0.00119)	(0.00209)
Constant	-0.154***	-0.305***	-0.129***	-0.256***
	(0.0536)	(0.0997)	(0.0470)	(0.0829)
Observations	225	225	225	225
R^2	0.048	0.048	0.047	0.041

The dependent variables are the change in a the Eurostoxx and SX7E indices before and after the ECB press conference. Eurostoxx measures the change in percentage points of the Eurostoxx 50 stock index of prominent euro area companies. SX7E measures the change in percentage points of the SX7E stock index of prominent euro area bank stocks. The independent variable is the value of the Dictionary and DTM Hawk-Dove Indices, derived in Equations 13 and 19. Robust standard errors in parentheses. *** denotes significance at 1% level, ** denotes significance at 5% level and * denotes significance at 10% level.

This reaction is consistent with the idea that markets do not react to a more hawkish (dovish) tone by internalising the idea that there will be a monetary tightening (loosening). Instead they react by interpreting the hawkish (dovish) tone as being indicative of the fact that central banks have positive (negative) news about future market prospects.

While the baseline results are indicative of some underlying relationships, to comment on a causal relationship in any direction I must control for potential omitted variables which can bias the above relationships.

First, it is natural to assume that the interest rate decision taken on the day of the press conference can have some impact on markets. Even though the event study is only conducted using changes around the press conference, there may be differing reactions as a result of delayed market reaction to the decision release. As such it is natural to control for changes in interest rates on the day of the press conference. This is controlled for using *change in the deposit facility rate* at the Governing Council meeting.

Second, from September 2004, the ECB began to release headline results of its macroeconomic projections exercise for the given quarter during four press conferences a year (March, June, September, December). Inflation and GDP projections for the current and next calendar years began to be announced at the press conference. This quantitative information can have market impacts, and as such must be controlled for. Due to confounding information from realised values that can impact current year forecasts, I choose to control for revisions to the forecasts of inflation and GDP for the next calendar year outlined during the press conference. In addition, a dummy variable is added to control for meetings when projections are announced.

Third, following the methodology of Altavilla et al. (2019), I control for the presence of a monetary policy shock during the period of interest. Altavilla et al. (2019) use intradaily data to develop a monetary policy shock that is composed of the first principal component of changes in EONIA Overnight Interest Rate Swap prices over the monetary policy decision window for maturities of one, three and six months, and one and two years. This

common factor can be interpreted as the unanticipated movement in the yield curve as a result of the monetary policy decision.

Of further interest are differing reactions of markets to changes in the Hawk-Dove Indices as the level of the monetary policy shock varies. For example, does a more hawkish sentiment following a hawkish (positive) monetary policy shock reinforce this effect, or are effects greater if hawkish sentiment follows a dovish (negative) monetary policy shock. To measure this, an interaction term is included between the Hawk-Dove Index and the monetary policy shock.[10]

A full list of control variables and sources is shown in Table 14.

TABLE 14. Control Variables

Code	Description	Unit of measure	Source
Change Deposit Facility Rate	The change in the ECB deposit facility rate at the meeting in question.	Change in percentage points	ECB SDW
Projections Released	A dummy variable if macroeconomic projections were released during the press conference.	Dummy variable	ECB Calendar
Medium Term Inflation Forecast Revision	The change in the inflation projection for the next calendar year in the macroeconomic projections if applicable.	Change in percentage points	ECB Documentation
Medium Term GDP Forecast Revision	The change in the real GDP projection for the next calendar year in the macroeconomic projections if applicable.	Change in percentage points	ECB Documentation
Monetary Policy Shock Shock	Monetary policy shock series calculated using the dataset of Altavilla et al. (2019).	Percentage points	Own Calculations

Tables 15 and 16 show the results of the full specification for the dictionary based method, while Tables 17 and 18 show similar for the DTM based approach. Across all specifications, the coefficient on the Hawk-Dove Index variable remains positive and highly significant. This is evidence in favour of the hypothesis that markets react to a more hawkish (dovish) tone as being indicative of positive (negative) economic news, and hence improved future dividends.

Surprisingly, there is no evidence of an interaction between monetary policy shocks and the Hawk-Dove Indices. It would have been expected that markets may be more reactive to the information conveyed by tone in a "surprise" decision environment.

[10]Due to missing data towards the start of the sample in the dataset of Altavilla et al. (2019), when including the monetary policy shock, there is a slightly smaller sample size

TABLE 15. Regression of change in the Eurostoxx Index on the Dictionary Hawk-Dove Index

	Eurostoxx	Eurostoxx	Eurostoxx	Eurostoxx	Eurostoxx
Dictionary Hawk-Dove Index	0.00751***	0.00767***	0.00767***	0.00795***	0.00893***
	(0.00237)	(0.00237)	(0.00237)	(0.00243)	(0.00286)
Change Deposit Facility Rate		-0.0579	-0.0576	-0.0352	-0.0774
		(0.261)	(0.262)	(0.257)	(0.334)
Projections Relased			-0.00516	-0.0125	0.0437
			(0.0894)	(0.0878)	(0.0876)
Medium Term Inflation Forecast Revision				-0.165	-0.207
				(0.286)	(0.295)
Medium Term GDP Revision				-0.0814	-0.105
				(0.133)	(0.139)
Monetary Policy Shock					-0.0119
					(0.0144)
Monetary Policy Shock × Dictionary Hawk-Dove Index					0.00122
					(0.000819)
Constant	-0.154***	-0.157***	-0.155***	-0.157***	-0.205***
	(0.0536)	(0.0535)	(0.0570)	(0.0576)	(0.0669)
Observations	225	225	225	225	192
R^2	0.048	0.048	0.048	0.051	0.074

The dependent variable measures the change in percentage points of the Eurostoxx 50 stock index of prominent euro area companies from before to after the ECB press conference. The independent variables are, in order of appearance in table, as follows. The value of the dictionary Hawk-Dove index, derived in Equation 13. The change in the ECB deposit facility rate, if any, at the monetary policy meeting. A dummy variable taking a value of one if macroeconomic projections were released, zero otherwise. The revision to inflation forecasts for the next calendar year in percentage points. The revision to GDP forecasts in the next calendar year in percentage points. A measure of monetary policy shocks, in line with Altavilla et al. (2019). An interaction between the Hawk-Dove index score and the monetary policy shock series. Robust standard errors in parentheses. *** denotes significance at 1% level, ** denotes significance at 5% level and * denotes significance at 10% level.

TABLE 16. Regression of change in SX7E Index on the Dictionary Hawk-Dove Index

	Sx7e	Sx7e	Sx7e	Sx7e	Sx7e
Dictionary Hawk-Dove Index	0.0128***	0.0132***	0.0132***	0.0133***	0.0162***
	(0.00447)	(0.00453)	(0.00453)	(0.00469)	(0.00553)
Change Deposit Facility Rate		-0.143	-0.139	-0.105	-0.0737
		(0.383)	(0.382)	(0.378)	(0.605)
Projections Relased			-0.0670	-0.0818	0.00528
			(0.157)	(0.155)	(0.147)
Medium Term Inflation Forecast Revision				0.00791	-0.104
				(0.450)	(0.483)
Medium Term GDP Revision				-0.198	-0.255
				(0.221)	(0.238)
Monetary Policy Shock					-0.0234
					(0.0341)
Monetary Policy Shock × Dictionary Hawk-Dove Index					0.00259
					(0.00224)
Constant	-0.305***	-0.310***	-0.291***	-0.292***	-0.369***
	(0.0997)	(0.0996)	(0.101)	(0.103)	(0.123)
Observations	225	225	225	225	192
R^2	0.048	0.049	0.050	0.052	0.086

The dependent variable measures the change in percentage points of the SX7E stock index of prominent euro area bank stocks from before to after the ECB press conference. The independent variables are, in order of appearance in table, as follows. The value of the dictionary Hawk-Dove index, derived in Equation 13. The change in the ECB deposit facility rate, if any, at the monetary policy meeting. A dummy variable taking a value of one if macroeconomic projections were released, zero otherwise. The revision to inflation forecasts for the next calendar year in percentage points. The revision to GDP forecasts in the next calendar year in percentage points. A measure of monetary policy shocks, in line with Altavilla et al. (2019). An interaction between the Hawk-Dove index score and the monetary policy shock series. Robust standard errors in parentheses. *** denotes significance at 1% level, ** denotes significance at 5% level and * denotes significance at 10% level.

TABLE 17. Regression of change in the Eurostoxx Index on the DTM Hawk-Dove Index

	Eurostoxx	Eurostoxx	Eurostoxx	Eurostoxx	Eurostoxx
DTM Hawk-Dove Index	0.00392***	0.00398***	0.00400***	0.00420***	0.00419***
	(0.00119)	(0.00126)	(0.00127)	(0.00129)	(0.00143)
Change Deposit Facility Rate		-0.0444	-0.0439	-0.0238	-0.0695
		(0.265)	(0.266)	(0.259)	(0.349)
Projections Relased			-0.0184	-0.0253	0.0160
			(0.0901)	(0.0884)	(0.0894)
Medium Term Inflation Forecast Revision				-0.212	-0.235
				(0.291)	(0.300)
Medium Term GDP Revision				-0.0612	-0.0721
				(0.140)	(0.148)
Monetary Policy Shock					-0.00336
					(0.0154)
Monetary Policy Shock × DTM Hawk-Dove Index					0.000387
					(0.000700)
Constant	-0.129***	-0.130***	-0.125**	-0.127**	-0.158***
	(0.0470)	(0.0473)	(0.0510)	(0.0515)	(0.0587)
Observations	225	225	225	225	192
R^2	0.047	0.047	0.048	0.052	0.054

The dependent variable measures the change in percentage points of the Eurostoxx 50 stock index of prominent euro area companies from before to after the ECB press conference. The independent variables are, in order of appearance in table, as follows. The value of the DTM Hawk-Dove index, derived in Equation 19. The change in the ECB deposit facility rate, if any, at the monetary policy meeting. A dummy variable taking a value of one if macroeconomic projections were released, zero otherwise. The revision to inflation forecasts for the next calendar year in percentage points. The revision to GDP forecasts in the next calendar year in percentage points. A measure of monetary policy shocks, in line with Altavilla et al. (2019). An interaction between the Hawk-Dove index score and the monetary policy shock series. Robust standard errors in parentheses. *** denotes significance at 1% level, ** denotes significance at 5% level and * denotes significance at 10% level.

TABLE 18. Regression of change in SX7E Index on the DTM Hawk-Dove Index

	Sx7e	Sx7e	Sx7e	Sx7e	Sx7e
DTM Hawk-Dove Index	0.00619***	0.00632***	0.00638***	0.00644***	0.00680***
	(0.00209)	(0.00218)	(0.00220)	(0.00224)	(0.00258)
Change Deposit Facility Rate		-0.0904	-0.0880	-0.0557	-0.00978
		(0.393)	(0.394)	(0.388)	(0.635)
Projections Relased			-0.0879	-0.101	-0.0457
			(0.158)	(0.157)	(0.154)
Medium Term Inflation Forecast Revision				-0.0461	-0.120
				(0.448)	(0.487)
Medium Term GDP Revision				-0.166	-0.197
				(0.227)	(0.247)
Monetary Policy Shock					-0.00805
					(0.0277)
Monetary Policy Shock × DTM Hawk-Dove Index					0.000691
					(0.00184)
Constant	-0.256***	-0.259***	-0.234***	-0.235***	-0.276***
	(0.0829)	(0.0824)	(0.0850)	(0.0859)	(0.102)
Observations	225	225	225	225	192
R^2	0.041	0.041	0.043	0.045	0.050

The dependent variable measures the change in percentage points of the SX7E stock index of prominent euro area bank stocks from before to after the ECB press conference. The independent variables are, in order of appearance in table, as follows. The value of the DTM Hawk-Dove index, derived in Equation 19. The change in the ECB deposit facility rate, if any, at the monetary policy meeting. A dummy variable taking a value of one if macroeconomic projections were released, zero otherwise. The revision to inflation forecasts for the next calendar year in percentage points. The revision to GDP forecasts in the next calendar year in percentage points. A measure of monetary policy shocks, in line with Altavilla et al. (2019). An interaction between the Hawk-Dove index score and the monetary policy shock series. Robust standard errors in parentheses. *** denotes significance at 1% level, ** denotes significance at 5% level and * denotes significance at 10% level.

Forward Guidance

From July 2013, the ECB began to introduce explicit monetary policy communication in the form of forward guidance. With this policy, the ECB aims to give an indication of the

future path of interest rates, as well as other operations such as future purchases under the APP. In general, this should be associated with increased market certainty. From the perspective of the noisy model of central bank private information presented in Section 3, the central bank has already revealed more of a signal regarding its perspective on the future path of monetary policy, implying there is less new information to be revealed during the press conference for the public to update their noisy beliefs regarding the state of the world. As such, it would be expected for there to be a stronger effect on asset prices in the period of time before formal forward guidance was introduced.

I therefore split the sample in two, with press conferences prior to July 2013 being defined as being in the "pre-forward guidance" sample, and all others as being in the "post forward guidance". Results are re-estimated and shown in Tables 19 and 20.

TABLE 19. Regression results prior to formal forward guidance

	Eurostoxx	Sx7e	Eurostoxx	Sx7e
Dictionary Hawk-Dove Index	0.0118***	0.0174***		
	(0.00332)	(0.00599)		
DTM Hawk-Dove Index			0.00506***	0.00677***
			(0.00136)	(0.00203)
Change Deposit Facility Rate	-0.177	-0.139	-0.125	-0.00395
	(0.301)	(0.493)	(0.340)	(0.580)
Projections Relased	0.210**	0.205	0.218***	0.233*
	(0.0815)	(0.140)	(0.0803)	(0.139)
Medium Term Inflation Forecast Revision	-0.802***	-0.589	-0.899***	-0.657
	(0.253)	(0.565)	(0.230)	(0.507)
Medium Term GDP Revision	0.0465	-0.0666	0.177	0.103
	(0.159)	(0.327)	(0.146)	(0.304)
Monetary Policy Shock	0.0106	0.0249	0.0152	0.0162
	(0.0115)	(0.0261)	(0.0103)	(0.0199)
Monetary Policy Shock × Dictionary Hawk-Dove Index	0.000469	-0.000610		
	(0.000749)	(0.00164)		
Monetary Policy Shock × DTM Hawk-Dove Index			-0.000445	-0.00177**
			(0.000463)	(0.000834)
Constant	-0.304***	-0.470***	-0.242***	-0.393***
	(0.0739)	(0.141)	(0.0581)	(0.104)
Observations	130	130	130	130
R^2	0.183	0.121	0.184	0.126

The dependent variables are the change in a number of variables before and after the ECB press conference. Eurostoxx measures the change in percentage points of the Eurostoxx 50 stock index of prominent euro area companies. SX7E measures the change in percentage points of the SX7E stock index of prominent euro area bank stocks. The values of the dictionary and DTM Hawk-Dove Indices, derived in Equations 13 and 19. The change in the ECB deposit facility rate, if any, at the monetary policy meeting. A dummy variable taking a value of one if macroeconomic projections were released, zero otherwise. The revision to inflation forecasts for the next calendar year in percentage points. The revision to GDP forecasts in the next calendar year in percentage points. A measure of monetary policy shocks, in line with Altavilla et al. (2019). An interaction between the Hawk-Dove index score and the monetary policy shock series. Robust standard errors in parentheses. *** denotes significance at 1% level, ** denotes significance at 5% level and * denotes significance at 10% level.

TABLE 20. Regression results during forward guidance

	Eurostoxx	Sx7e	Eurostoxx	Sx7e
Dictionary Hawk-Dove Index	0.00211	0.00988		
	(0.00422)	(0.00860)		
DTM Hawk-Dove Index			0.00218	0.00708
			(0.00299)	(0.00604)
Change Deposit Facility Rate	4.049	5.282	4.411	4.844
	(3.366)	(5.916)	(3.397)	(6.062)
Projections Relased	-0.149	-0.336	-0.193	-0.317
	(0.166)	(0.309)	(0.163)	(0.317)
Medium Term Inflation Forecast Revision	0.683	1.048	0.776*	0.894
	(0.452)	(0.769)	(0.435)	(0.712)
Medium Term GDP Revision	0.0558	0.0625	0.0882	-0.0316
	(0.266)	(0.318)	(0.239)	(0.301)
Monetary Policy Shock	-0.149***	-0.107**	-0.132***	-0.108
	(0.0340)	(0.0495)	(0.0469)	(0.0808)
Monetary Policy Shock × Dictionary Hawk-Dove Index	-0.00328**	0.00500		
	(0.00156)	(0.00317)		
Monetary Policy Shock × DTM Hawk-Dove Index			-0.00132	0.00305
			(0.00152)	(0.00341)
Constant	0.0308	0.00966	0.0626	0.00508
	(0.139)	(0.249)	(0.135)	(0.234)
Observations	62	62	62	62
R^2	0.347	0.299	0.333	0.295

The dependent variables are the change in a number of variables before and after the ECB press conference. Eurostoxx measures the change in percentage points of the Eurostoxx 50 stock index of prominent euro area companies. SX7E measures the change in percentage points of the SX7E stock index of prominent euro area bank stocks. The independent variables are, in order of appearance in table, as follows. The values of the dictionary and DTM Hawk-Dove Indices, derived in Equations 13 and 19. The change in the ECB deposit facility rate, if any, at the monetary policy meeting. A dummy variable taking a value of one if macroeconomic projections were released, zero otherwise. The revision to inflation forecasts for the next calendar year in percentage points. The revision to GDP forecasts in the next calendar year in percentage points. A measure of monetary policy shocks, in line with Altavilla et al. (2019). An interaction between the Hawk-Dove index score and the monetary policy shock series. Robust standard errors in parentheses. *** denotes significance at 1% level, ** denotes significance at 5% level and * denotes significance at 10% level.

The results of these regressions lend further credence both to the idea that central banks convey private information through monetary policy announcements, but also that in the presence of more certainty regarding the future path of policy and the information informing these decisions, the pass through of the information effect of monetary policy communication arising from policy announcements is weaker.

Robustness - OIS 1Y

In Section 3, the information shock σ_t was decomposed into two potential effects on stock prices - the impact on the discount rate $\frac{dr_t}{d\sigma_t}$ and the impact on the future flow of dividends $\frac{dX_t}{d\sigma_t}$. I have argued that from the initial shock that the future dividend effect dominates, but it is possible to extract direct information as to whether communication has a direct effect on interest rates. Using the dataset of Altavilla et al. (2019), I estimate an additional specification in which the dependent variable in Equation 20 is the change in the 1 year overnight interest rate swap rate (OIS 1Y) before and after the press conference. This should proxy the impact of a change in communication on the discount rate r_t.[11] Results are shown in Table 21.

As can be seen, there is no clear impact of a more hawkish or dovish tone on the OIS 1Y rate. This, combined with the robust evidence of a the impact of a change in the monetary

[11] I note that due to the fact the OIS1Y rate is used to calculate the monetary policy shock variable, it is not possible to include this in the set of control variables

policy tilt on both the Eurostoxx and SX7E indices is evidence in favour of the hypothesis that information effects mainly manifest themselves through changes in perceptions regarding the state of the economy, rather than changes in expected future interest rates.

TABLE 21. Regression of the OIS1Y rate on the Hawk-Dove Indices

	Ois1y	Ois1y
Dictionary Hawk-Dove Index	0.00230	
	(0.0165)	
DTM Hawk-Dove Index		-0.00317
		(0.00858)
Change Deposit Facility Rate	-2.756	-2.524
	(2.005)	(1.972)
Projections Relased	1.042*	1.055*
	(0.559)	(0.559)
Medium Term Inflation Forecast Revision	1.281	1.460
	(1.852)	(1.884)
Medium Term GDP Revision	-0.295	-0.310
	(0.891)	(0.900)
Constant	-0.242	-0.186
	(0.283)	(0.281)
Observations	225	225
R^2	0.032	0.032

The dependent variable is the change in the OIS 1Y rate before and after the ECB press conference. The independent variables are, in order of appearance in table, as follows. The values of the dictionary and DTM Hawk-Dove Indices, derived in Equations 13 and 19. The change in the ECB deposit facility rate, if any, at the monetary policy meeting. A dummy variable taking a value of one if macroeconomic projections were released, zero otherwise. The revision to inflation forecasts for the next calendar year in percentage points. The revision to GDP forecasts in the next calendar year in percentage points. Robust standard errors in parentheses. *** denotes significance at 1% level, ** denotes significance at 5% level and * denotes significance at 10% level.

Robustness - Alternative Measure

As a robustness check, I propose the use of an independent measure of the monetary policy tilt of a central bank, in line with Apel et al. (2019). This method is similar in ways to the dictionary based Hawk-Dove Index, but relies on much fewer keywords. Its interpretation is similar to both Hawk-Dove Indices, in that a more positive value denotes a more hawkish/positive tone, and a negative value denotes a more dovish/negative tone.[12]

Results for the specification in Equation 20 using the index of Apel et al. (2019) instead of the Hawk-Dove Indices are shown in Table 22. It should be noted that both measures are positive and significant at the 5% level. This gives a degree of external validity to the initial results using the derived Hawk-Dove indices, and provides further evidence in favour of communication of a more hawkish (dovish) tone being interpreted by the public as a signal of improved economic conditions, rather than being internalised as a higher probability of a future interest rate hike. In addition, similar results to the Hawk Dove-Indices emerge for the pre and post forward guidance timeline using this measure.

[12]For the purposes of fitting this dictionary to ECB communication I make one small edit to the keywords. Instead of "consumer price inflation", I use the terms HICP and prices, and in addition to "economic growth" I use "GDP growth" as a keyword. This is to adjust for the target words used by the ECB, as the original measure is designed for the Fed. In addition, I merge the polarity words for "inflationary pressures" and "ìnflation". Results are similar in both cases

TABLE 22. Regression using the measure derived by Apel et al. (2019)

	Eurostoxx	Sx7e
Apel et al. (2019) Index	0.253**	0.399**
	(0.102)	(0.182)
Change Deposit Facility Rate	-0.0344	0.0577
	(0.358)	(0.651)
Projections Relased	0.0437	-0.00112
	(0.0862)	(0.148)
Medium Term Inflation Forecast Revision	-0.229	-0.100
	(0.311)	(0.512)
Medium Term GDP Revision	-0.0716	-0.196
	(0.144)	(0.238)
Monetary Policy Shock	-0.0411	-0.0693
	(0.0393)	(0.0992)
Monetary Policy Shock × Apel Index	0.0450	0.0721
	(0.0433)	(0.101)
Constant	-0.400***	-0.657***
	(0.133)	(0.235)
Observations	192	192
R^2	0.051	0.046

The dependent variables are the change in a number of variables before and after the ECB press conference. Eurostoxx measures the change in percentage points of the Eurostoxx 50 stock index of prominent euro area companies. SX7E measures the change in percentage points of the SX7E stock index of prominent euro area bank stocks. The independent variables are, in order of appearance in table, as follows. The value of the monetary policy tilt measure of Apel et al. (2019). The change in the ECB deposit facility rate, if any, at the monetary policy meeting. A dummy variable taking a value of one if macroeconomic projections were released, zero otherwise. The revision to inflation forecasts for the next calendar year in percentage points. The revision to GDP forecasts in the next calendar year in percentage points. A measure of monetary policy shocks, in line with Altavilla et al. (2019). An interaction between the measure of Apel et al. (2019) and the monetary policy shock series. Robust standard errors in parentheses. *** denotes significance at 1% level, ** denotes significance at 5% level and * denotes significance at 10% level.

7 Conclusion

Communication has become, and remains a highly important tool as part of a modern suite of non-standard monetary policy measures. Many central banks have explored how to use communication to both explicitly guide markets and convey private information surrounding the central bank's beliefs regarding future economic conditions. Based on my results, it is clear that central bank communication can have market impacts beyond that of merely guiding future interest rate expectations, and to some extent provides evidence of the "information channel" of monetary policy, and helps to reconcile the manner in which communication of a more "hawkish" or "dovish" perspective regarding the state of the economy can pass through to financial markets. It is clear that in optimal conditions, the ECB can use the language in its press conferences or communication documents to have a real impact on financial markets. It also highlights the importance of selecting the right language to use in given scenarios, since the informational content contained in the ECB press conference can have a material impact on markets.

On the other hand, the results to some extent highlight the importance of clear and consistent communication. The fact that most effects arising from the sentiment of the press conference faded after the ECB introduced a policy of explicit forward guidance highlights the market assuring role that such a policy decision has made. If markets

react negatively to increased "dovish" sentiment, when policymakers wish to stimulate the economy, language may have unintended consequences. Clear and regular communication may mitigate these concerns and manage market volatility. Long term communication of aims and policy information can have the positive effect of maintaining market stability.

While this paper examines measures of the current policy stance communicated by the ECB in a systematic method, it only examines immediate market impacts. As such there is potential for further work along a number of dimensions. Further understanding can be gained through an analysis of the persistence of these market effects and to what extent they spill over to the wider economy.

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