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## Between hawks and doves: measuring central bank communication

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**Abstract**

We propose a Hawkish-Dovish (HD) indicator that measures the degree of 'hawkishness' or 'dovishness' of the media's perception of the ECB's tone at each press conference. We compare two methods to calculate the indicator: semantic orientation and Support Vector Machines text classification. We show that the latter method tends to provide more stable and accurate measurements of perception on a labelled test set. Furthermore, we demonstrate the potential use of this indicator with several applications: we perform a correlation analysis with a set of interest rates, use Latent Dirichlet Allocation to detect the dominant topics in the news articles, and estimate a set of Taylor rules. The findings provide decisive evidence in favour of using an advanced text mining classification model to measure the medias perception and the Taylor rule application confirms that communication plays a significant role in enhancing the accuracy when trying to estimate the bank's reaction function.

**JEL codes:** C02, C63, E52, E58

**Keywords:** Monetary policy, communication, data mining, quantitative methods

## Non-technical summary

In recent years communication became increasingly important in central banks. In particular, after the financial crisis, communication has increasingly qualified as a genuine policy tool able to steer interest rates in financial markets and drive expectations on the course of monetary policy. With official interest rates approaching zero and thereby reducing their effectiveness, various forms of forward guidance (i.e. a verbal commitment on the future course of monetary policy unconditional or conditional to some economic event) were added to the standard monetary policy toolkit existing out of interest rates and refinancing instruments for the banking sector. The growing relevance of communication in the conduct of monetary policy was mirrored by a rising interest of academicians and practitioners. In particular, a branch of economic research increasingly focused on the role of communication in adding valuable information besides what is already contained in macroeconomic variables, and in revealing policy makers preferences on the course of monetary policy with a view to enhance predictability. If the traditional approach consists in analysing how information events impact financial market developments and expectations of future policy moves, more recently analysis shifted towards analysing the language used by the central bank in its statements and how such message is perceived by its stakeholders. This paper contributes to the latter with a numerical indicator, called HD index (after the initials of hawkish and dovish), derived from media reports on the ECB press conference. Combining concepts and techniques developed in the context of computational linguistics and data mining, the indicator extracts relevant information on ECB monetary policy as reported by external observers and may therefore be interpreted as how media perceive the central banks monetary policy messages. For practical reasons, the perception is expressed on a numerical interval between -1 (most dovish) and +1 (most hawkish). In other words, the indicator indicates whether the perceived tone on monetary policy communication is predominantly on the tightening side (hawkish perception) or rather on the loosening side (dovish perception). Although the approach to quantify communication is not new, the approach proposed in this paper is original in various dimensions. First, the indicator does not measure directly official central bank communication but how such communication is received and interpreted with the crucial support of data mining techniques. Second, two different techniques are employed to compute the HD index: one based on the semantic orientation (SO) and the second on text classification using Support Vector Machines (SVM). The former, the most commonly used by researchers, measures how often the ECB is mentioned in a news article together with a number of given hawkish and dovish words or expressions, while the latter, computationally more complex, uses a classification model to predict the tone of an article. Both methods are applied to a data set of around 9,000 articles published between January 1999 and March 2016 in order to assess which methodology produces better results. Based on various criteria (event

analysis, correlations with actual interest rates and classification method) the SVM methodology tends to produce better and more reliable results. Third, in addition to its superiority on the SO, the SVM classification model can be used to analyse the terms most frequently employed by media in relation to a likely future course of monetary policy. Finally, an expanded Taylor rule framework including the HD index alongside traditional variables measuring inflation expectations and economic slack, is presented. Results suggest that the significance of the HD index as well as a relatively better fit confirm the positive role of ECB communication in enhancing the accuracy when trying to estimate the bank's reaction function, and thus that, on average, the ECB messages are correctly understood by its media watchers.

# 1 Introduction

*"In a market economy, transparency and communication are central to the effectiveness of our monetary policy."*

– Mario Draghi

During the financial crisis, monetary policy interest rates reached levels close to zero in most major central banks. As a result, communication has increasingly qualified as a powerful instrument able to influence financial market developments and drive expectations. Forward guidance, i.e. a form of verbal commitment to keep interest rates at a certain level for a period of time, possibly conditional to certain economic developments, became a genuine monetary policy instrument for many major central banks in addition to the standard toolkit of interest rates and refinancing instruments for the banking sector.

Mirroring the increased role of communication in central banks, economic research has started to focus on how central bank communication adds information to that which is already contained in macroeconomic variables and how it may reveal policy makers individual preference functions. The overall objective is to enhance predictability of monetary policy decisions. The traditional approach focuses mainly on how information events affect both financial market developments and expectations of future policy moves.

Media usually analyse central banks' communication with a view to extract information about likely future moves of monetary policy rates (Hayo & Neuenkirch, 2015). Unlike market indicators, extracting relevant information on monetary policy from media reports is not straightforward and requires the translation of words into a numerical representation. Ideally, the resulting quantitative indicator should represent the media's perception of the central banks message and should be able to indicate whether expectations are more on the tightening side (hawkish perception) or rather on the loosening side (dovish perception).

In recent years, a number of studies have developed quantitative tools to measure (or, at least, to express on a numerical scale) the information contained in official central banks' statements (see e.g. KOF Swiss Economic Institute (2007); Lucca & Trebbi (2009)). In other words, this approach can be characterized as an attempt to quantify information in communication, which is qualitative by nature. In this paper, we present the development of an index that measures the interpretation of the European Central Bank's official communication, using data mining techniques. Concretely, we want to distinguish articles that perceive the ECB's statement as predominantly hawkish - and thus pointing towards likely future policy rate increases - from articles that perceive the statement to be rather dovish, hinting at declines or no increases in policy rates. We use two different techniques to measure the tone expressed in an article published after the press conference: semantic orientation and text classification using Support Vector Machines. The former measures how often the ECB is mentioned in a news article together with respectively hawkish and

dovish words, the latter uses a classification model to predict the tone of a news article. We apply both methods to a data set of approximately 8,500 articles from the Dow Jones Factiva database, published between January 1999 and March 2016, in order to create the HD-indicator (after the initials of hawkish and dovish). This indicator represents the average hawkishness or dovishness of the ECB as perceived by the media after each press conference.

The contribution of this paper is four-fold. First and most obviously, we present a methodology to compute the quantitative indicator with the characteristics described above. Secondly, we demonstrate how data mining techniques, and more specifically text mining techniques, can bring value in the process of decision making for central bankers (in particular, on how communication is perceived). Thirdly, by constructing a specific Support Vector Machines (SVM) classification model, we can analyse which terms are most frequently used by the written media to refer to a likely future contraction or expansion of monetary policy. Finally, we show a number of potential uses of the HD indicator: assessing its relation to interest rates, the use of topic models for a qualitative assessment of text-based indicators, and a Taylor rule application.

## 2 Subjective versus automated indicators for central bank's communication

A broad distinction can be made between subjective measures and (semi-)automated measures developed in the economic literature. A subjective indicator is based on the subjective evaluation of official statements or documents by one or more expert analysts on given points in time. Especially when expert groups are involved, such evaluation is often expressed on a fixed scale expressing the intensity of dovishness/hawkishness as a suitable combination of the perceived tone by every single analyst. In general, the evaluation is not based on predefined procedures and therefore typically suffers from a low degree of repeatability and time-consistency. By contrast, an automated indicator is based on fixed numerical algorithms and can be replicated consistently. It should be stressed that an automated index should not be considered as being totally objective, since the choice of the predefined procedure is often made by analysts and the processing of the input may require subjective judgement such as the labelling of a training set. In this respect, all available indicators contain subjective elements in various degrees. However, automatic computational features generally allow a relatively high degree of repeatability.

Regarding the subjective measures, indicators based on the Introductory Statement of the ECB's press conferences were created by Berger et al. (2011); Musard-Gies (2006); Rosa & Verga (2007); Rosa et al. (2008). A relatively popular indicator within the subjective class is the KOF Monetary Policy Communicator (MPC), which is regularly produced by the KOF Swiss Economic Institute of the Swiss Federal Institute of Technology (ETH) in Zurich and fol-

lows the ECB press conference schedule (KOF Swiss Economic Institute, 2007). [1] The index is constructed by coding the ECB's statements on upside and downside risks to price stability as respectively hawkish (+1) and dovish (-1). The codings are provided by media analysts of Media Tenor, a media research institute. The KOF MPC is obtained by aggregating the single codings of the statements on risks to price stability, relative to all statements about price stability in the introductory statement, including neutral (or factual) statements. By construction, the KOF MPC is restricted to take values in the interval [-1; +1]: the larger a positive (negative) value of the KOF MPC, the stronger the ECB communicated that there are upside (downside) risks to price stability. As opposed to the HD-index, the KOF MPC measures the tone of the statements and not the media's perception of the statements.

Contributions to (semi)-automated measures are relatively scarce in the economic literature. Difficulties are mainly the repeatability of criteria used to classify texts (which by their nature relies on individual judgement) and the computational complexity often associated with employing expert algorithms. Most studies using objective measures focus on the text of the press statement itself. For example, Heinemann & Ullrich (2005) proposed a Wording Indicator that associates words and expressions, used in central bank communication, to monetary policy cycles; and Apel & Grimaldi (2012) proposed to measure the tone of monetary policy statements by counting a set of key words used in the Swedish Central Bank's minutes. A different approach was followed by Lucca & Trebbi (2009), who analysed Federal Reserve monetary policy statements by measuring the tone of the statement's media coverage and not the statement itself. They used semantic orientation to measure the degree of the news reports' hawkishness/dovishness in a three day window around the press conference. In this paper, we start from Lucca and Trebbi's approach to measure the media's *perception* of the ECB's monetary policy statements, which is why we analyse news articles and not the statement itself. To measure the perception captured by the HD-index, we limit the scope to three days around the press conference (one day before the press conference, the day of the conference and the day after) and use an adjusted version of semantic orientation rescaled in the interval [-1; +1]. Within the economic literature on (semi)-automated measures, researchers focus on the use of predefined key words and dictionaries to quantify the information contained in text. In this paper we propose advanced text mining techniques as alternative to the predefined word lists. We compare the use of text classification models to the semantic orientation method in order to investigate if more advanced computational techniques could lead to improved measurements of the media's tone.

[1] Based on the information provided by the KOF Institute, it is not clear if the index should be considered as purely subjective. However, given its low degree of reproducibility, the index is classified as subjective.

# 3 The HD-index

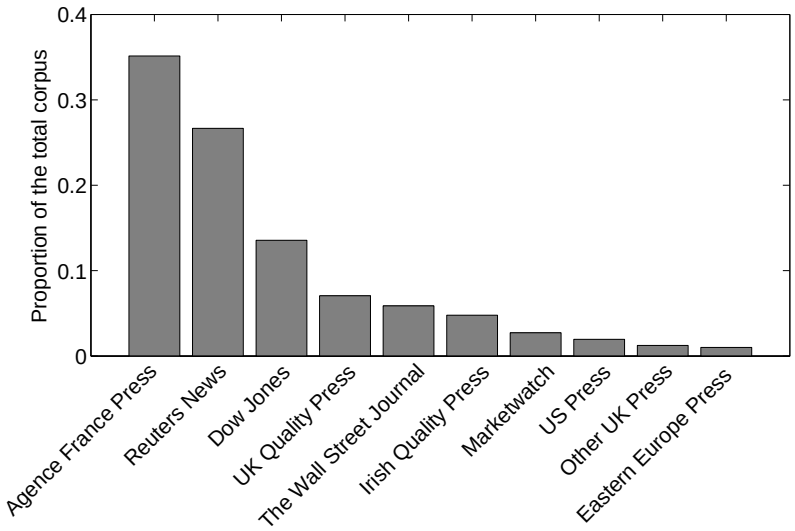
To compute the HD-index we apply two different methodologies: semantic orientation and text classification.

The semantic orientation approach was inspired by the methodology originally proposed by Lucca & Trebbi (2009), who analysed how Federal Open Market Committee (FOMC) monetary policy statements were reflected in press reports. Semantic orientation is a concept from computational linguistics and defines the position of a word or string of words between two opposite concepts. In the research literature this concept is most often used to measure the degree of positiveness or negativeness of a given word or set of words. Turney (2002) has used semantic orientation to classify reviews as positive or negative. For a given phrase, he defined its semantic orientation score as the difference between the strength of its association with a set of positive words and a set of negative words, using Pointwise Mutual Information as a measure for association. In this way, the indicator expresses the perception of the ECB's press statements on a numeric scale reflecting the relative frequency of two opposite concepts (in this case, dovish or hawkish) in a news article by counting the co-occurrences of strings referring to the ECB with words and expressions that are normally associated with these concepts. Using this method, we calculate the semantic orientation score for each article in our corpus of slightly less than 9,000 articles, published between January 1999 and January 2016. The HD-index created using the semantic orientation scores will be referred to as HD_SO and is explained in more detail next.

The alternative methodology presented in this paper, applies text mining techniques to the data set of articles in order to build a model that classifies each article as either hawkish or dovish, while simultaneously assessing the magnitude of the hawkishness or dovishness. Text mining is the process of deriving high quality information from text documents using techniques from data mining, statistics, information retrieval, machine learning and computational linguistics. We apply a Support Vector Machines classification model on the same data set, trained on a sample with a vocabulary of 6,245 words. The resulting HD-index will be referred to as HD_SVM.

To compute our HD-index, we used articles extracted from the Dow Jones Factiva database. We have crawled for articles that mention the ECB in a two-day window after the press conference. We have searched for articles in English, that mention the words 'ECB' or 'European Central Bank'. To select to news sources, we choose the categories 'Major News and Business Publications: Europe' and 'Major News and Business Publications: US'. Figure 1 shows the news sources represented by our crawled data set and their respective proportion of articles in the corpus.

**Figure 1: News sources and their respective proportion of articles in the corpus.**




## 3.1 Measuring media perception using semantic orientation

### 3.1.1 Semantic orientation

To compute the HD_SO, we measure the media's perception of the ECB's press statement by defining a dovish-hawkish scale and measuring whether a dovish rather than a hawkish tone prevails in some predetermined set of articles.

In concrete terms, for a given string of reference words $R$ (such as 'ECB' or 'Draghi'), we want to know both the probability that $R$ occurs with a hawkish word (such as 'raise' or 'increase') and that $R$ occurs with a dovish word (such as 'cut' or 'decrease') in the corpus of articles after each press conference. To calculate this probability, we have preset a list of hawkish ($H$) , dovish ($D$) and reference ($R$) words. These words can be found in Table 9 in Appendix A.

The following equation defines the semantic orientation score of a sentence $x$ as the difference in Pointwise Mutual Information of R and respectively a set of Hawkish/Dovish words.

$$SO(x) = log\left(\frac{\text{P(R \& Hawkish)}}{\text{P(R)P(Hawkish))}} - log(\frac{\text{P(R \& Dovish)}}{\text{P(R)P(Dovish)}}\right) \quad (1)$$

We assume that the occurrence of a hawkish word in a relevant sentence[2]

[2]We define a relevant sentence as a sentence that contains at least one word from R, i.e. a

justifies the attribution of a more hawkish score. Equation 4 shows the final equation to calculate our Hawkish-Dovish index of a press conference at time $t$. The index is a summation of the semantic orientation of all sentences $s_i(t)$ in the articles published around this press conference. The HD-index is deduced from the semantic orientation score (SO(x)) in equation 1 under the assumption that the probability of a hawkish word occurring in our data set of articles equals the probability of a dovish word occurring in that same data set. We replace P(R & Hawkish), P(R & Dovish) by the frequency of co-occurrences in a sentence $s$ as listed in equations 2 and 3. We calculate semantic orientation at sentence level and not at article level to avoid sentences not referring to the press conference influencing our HD-index. Since we are only interested in hawkish and dovish words that refer to the respective expectations, we add the condition that a word is only counted as $H$ or $D$ if it is not preceded by a negation ($N = 0$). We add this condition to avoid sentences such as '*The ECB did not raise interest rates*' to be considered as hawkish instead of neutral (stable). Table 9in Appendix A reports the possible negations $N$.

$$I[s, R, H|N = 0] = \begin{cases} 1, & \text{if } s \text{ contains at least a word from } R \text{ and} \\ & \text{a word from } H \text{ not preceded by a negation} \\ 0, & \text{otherwise} \end{cases} \quad (2)$$

$$I[s, R, D|N = 0] = \begin{cases} 1, & \text{if } s \text{ contains at least a word from } R \text{ and} \\ & \text{a word from } D \text{ not preceded by a negation} \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

$$HD_t = \frac{\sum_i (-1) \times I[s_i(t), R, D|N = 0] + \sum_i (1) \times I[s_i(t), R, H|N = 0]}{\sum_i I[s_i(t), R, D|N = 0] + \sum_i I[s_i(t), R, H|N = 0]} \quad (4)$$

As an example, Figure 2 shows an article published after the press conference on November 3rd 2011. To calculate the HD-value, we want to know the number of sentences that contain at least a word from $R$ and a word from $H$, respectively $D$. The words from $R$ are underlined. In the relevant sentences, i.e. those that contain a word from $R$, the hawkish words $H$ are capitalised, and the dovish words $D$ are in italics. The final calculation of the indicator's value is straightforward:

$$\sum_i \times I[s_i(t), R, D] = 2$$

$$\sum_i \times I[s_i(t), R, H] = 1$$

$$HD_t = \frac{-2 + 1}{3} = -0.33$$

sentence that refers to the ECB and its decision-makers.

**Figure 2: Article published after a press conference (Daily Mail, 2011-11-04). The reference words from $R$ are underlined. The sentences containing a word from $R$ are the relevant sentences. The HAWKISH words in these sentences are capitalised and the *dovish* words are written in italics.**

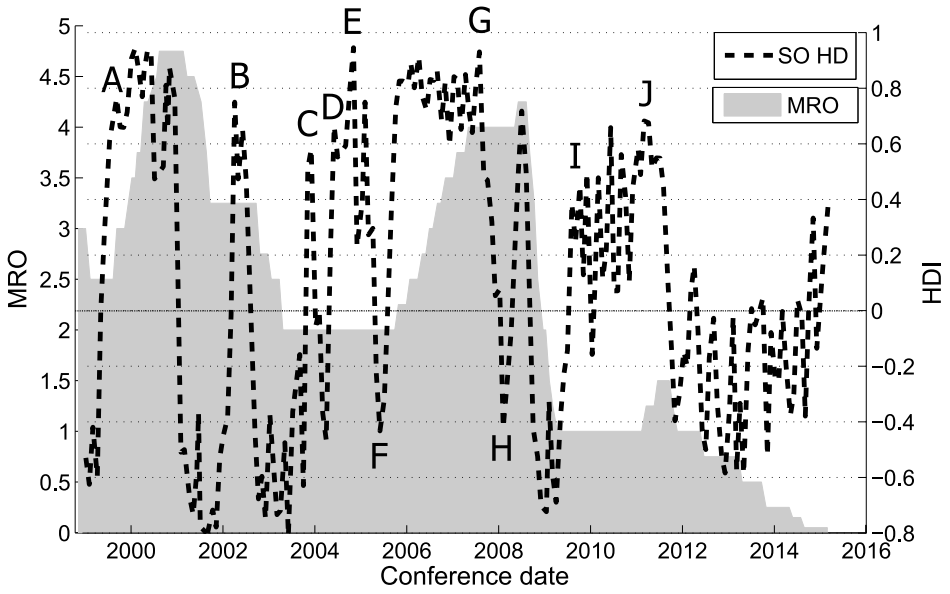
> The **European Central Bank** yesterday ***cut*** interest rates and warned that the crisis-torn **eurozone** is heading towards recession.The Frankfurt-based bank ***lowered*** **rates** for the 17-nation bloc from 1.5% to 1.25% as the debt crisis in the region threatened to spiral out of control. The surprise decision marked a decisive start for Mario **Draghi**, who took over the bank on Tuesday. It followed two rate **HIKES** earlier this year under former President Jean-Claude **Trichet** and came despite inflation running well above the 2% target at 3%. It came as world leaders and finance ministers held crunch talks in Cannes.

#### 3.1.2 The semantic orientation HD-index

Figure 3 plots HD_SO and the evolution of the main refinancing rate over time. Table 1 lists the title of the most hawkish or dovish article for 10 remarkable hawkish and dovish points of the indicator. As a general observation, the index tends to be characterised by large fluctuations. However, contrasting it with the monetary policy cycles (the grey shaded area in Figure 3), it appears at sight that the HD-index can anticipate movements in the Minimum Bid Rate/Main Refinancing Operations rate (MRO). In periods of decreasing or increasing interest rates, the media's perception usually coincides with the actual monetary policy stance, i.e. we notice in the graph that tightening cycles tend to be accompanied by hawkish levels and easing cycles by dovish levels of the HD-index. However, during neutral periods, the index is often erratic and the diverges from the actual monetary policy stance. Between June 2003 and December 2005, when rates were left unchanged, the index alternates abruptly between hawkish and dovish levels. The large fluctuations in the index show that perceptions can change rather drastically in a short period of time. Five months before the first rate cut of the 2003 easing cycle, media perceptions were hawkish (point B in Figure 3). Similarly, five months before the 2006-2007 tightening cycle, media perceptions were dovish (point F). It is also interesting to observe that the HD-index was hawkish in the first years of the European sovereign debt crisis, which started end 2009. The index moved in the negative (dovish) region only in 2012, after the intensification of the debt crisis and the adoption of a very accommodative policy stance by the ECB through purchases of a relatively wide set of debt securities and other financial assets.

The major downside of using semantic orientation, is that it focuses on the

**Figure 3: The HD-indicator developed using semantic orientation. Ten remarkable hawkish and dovish points of the index are indicated by letters A-J. The title of the highest scoring article published after the corresponding press conference is reported in Table 1. The grey shaded area is the Main Refinancing Operations (MRO) rate .**




words included in the list of hawkish and dovish expressions without taking into account the general context. The method is not able to capture more complex negations such as '*There is no reason to expect that the ECB will raise interest rates*' and it cannot differentiate between statements about the ECB and a different central bank, when they are both mentioned in the same sentence, such as '*The Bank of England raises its interest rates while the European Central Bank holds its rates steady.*' Another disadvantage is the high dependency on the list of hawkish and dovish words. The absence of certain keywords or presence of redundant words can heavily distort the HD-index. This is particularly evident after the ECB decision to engage in a large-scale asset purchase programme after January 2015 (commonly indicated as 'quantitative easing' in the press). The indicator moved in the hawkish territory during this period, in contrast with the dovish nature of the undertaken policy and the ECB's communication. These outcomes indicate most likely the inadequacy of the HD-index to capture and reflect a shift in the used language in the direction of less 'interest rate'-related expressions and more 'quantitative easing'-related expressions.

**Table 1: Legend to Figure 3. For ten press conferences, the title of the highest scoring article is reported.**

| Letter | Press Conference | Title highest scoring article |
|---|---|---|
| A | Sep 1999 | ECB keeps key rates steady, but insists growth prospects are good. (Morgan, 1999-09-09) |
| B | Jun 2002 | ECB holds key rates as stronger euro takes edge off inflation. (Morgan, 2002-06-06) |
| C | Nov 2003 | ECB rates seen on hold as Trichet makes debut. (Gould, 2003-11-06) |
| D | Jun 2004 | Eurozone rate futures dip ahead of ECB decision. (Reuters, 2004-06-03) |
| E | Nov 2004 | ECB flirts with idea of a rate boost. (Sims, 2004-11-05) |
| F | Jul 2005 | ECB holds rates steady, but says ready to act in wake of London attacks. (SPM, 2005-07-07) |
| G | Aug 2007 | ECB leaves key rate unchanged but hike likely in September. (ILP, 2007-08-02) |
| H | Feb 2008 | ECB keeps rates on hold, door ajar for cut later. (MacInnis, 2008-02-07) |
| I | Dec 2009 | ECB lending tweaks keeps it in control of rates. (Reuters, 2009-12-03) |
| J | Apr 2011 | ECB rate hike bets push Euribor rates to 21-months high. (Reuters, 2011-04-06) |

## 3.2 Measuring media perception using Support Vector Machines classification

### 3.2.1 Classification model

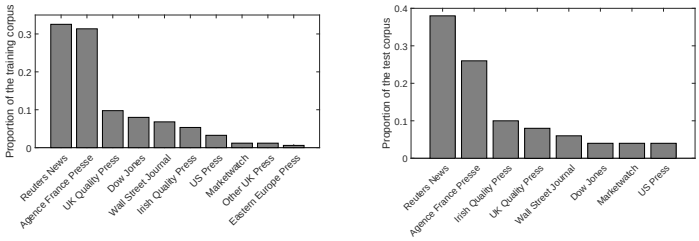
All the aforementioned issues can be resolved by replacing semantic orientation with a supervised classification model to construct the index. We use Support Vector Machines - a state-of-the-art classification method - to classify the media's perception as hawkish or dovish (Provost & Fawcett, 2013). This technique automatically looks for patterns in text documents to select the words with the highest discriminative power. As output, we get a linear model where each word is assigned a weight in favour of either class 1 (hawkish) or class -1 (dovish). A clear advantage is that this algorithm looks at every document as a whole and therefore tends to overcome the limitations of a predefined set of keywords.

We started by labelling 550 articles (as being either hawkish or dovish). These articles were randomly selected from our data set. To ensure an unbiased model and accurate predictions, we excluded articles of uncertain classification. This left us with 340 labelled articles in the training set and 50 labelled articles

**Table 2: Data characteristics of the training and test set.**

| | Training set | Test set |
|---|---|---|
| Maximum word count | 2500 | 1550 |
| Minimum word count | 20 | 73 |
| Average word count | 504 | 448 |
| Standard deviation word count | 326 | 300 |
| % articles Duisenberg | 20.41 | 12.00 |
| % articles Trichet | 58.88 | 60.00 |
| % articles Draghi | 20.71 | 28.00 |

**Figure 4: News sources and their respective proportion of articles in the training and test corpus.**




**(a) Training corpus** **(b) Test corpus**

in the test set. Table 2 reports the data characteristics of the training and test set. On average, articles in the training and test set are between 450 and 500 words long. The largest proportion of articles were published during the ECB presidency of Jean-Claude Trichet, due to the fact that he had an 8-year appointment. Figure 4 shows the proportion of the news sources in the training and test set. Similar to the total corpus, most articles are published by Agence France Presse and Reuters News.

An important step in text data mining is the transformation of text into a structured form. We start by representing an article as a 'bag-of-words' vector $[t_0 t_1 ... t_j ... t_n]$ that contains all $n$ unique words present in the training set, where $t_j$ denotes how often the $j^{th}$ word occurs in the article. The 'bag-of-words' vector is used to build a term-frequency matrix tf(m,n) with n the number of words and m the number of articles. In the term-frequency matrix each $\text{cell}_{ij}$ indicates the number of times the term $j$ occurs in article $i$. Each term count is multiplied by the inverse document frequency to diminish the weight of the words that occur very frequently in the training set of articles. The inverse document frequency measures the frequency of a term across all documents (Weiss et al., 2010).

$$idf(t,m) = log \frac{\text{Number of articles in the training set (m)}}{\text{Number of articles in the training set where term t occurs}}$$

The resulting tf-idf matrix is used as input to the SVM algorithm. SVM searches for the decision boundary that maximizes the margin between the two classes. Linear SVM tries to solve the following optimization problem (Fan et al., 2008):

$$min_{\mathbf{w}} \frac{1}{2}\mathbf{w}^T\mathbf{w} + C\sum_i max(1 - y_i\mathbf{w}^T\mathbf{x}_i, 0)^2$$

With vector $\mathbf{w}$ the weights of the model and $\mathbf{x}_i$ and $y_i$ representing the input vector and the label of the $i_{th}$ observation. $max(1 - y_i\mathbf{w}^T\mathbf{x}_i, 0)^2$ is the squared (L2) hinge-loss function. An out-of-sample grid search was performed to find the optimal value of $C$, the cost parameter.

The classification model has the following form:

$$f(\mathbf{x}_i) = w_0 + w_1x_{i1} + w_2x_{i2} + ... + w_jx_{ij} + ... + w_nx_{in}$$

With $w_j$ the weights and $x_{ij}$ the occurrence of the $j_{th}$ unique terms of the training set in the $i_{th}$ article. The sign of the resulting decision value $f(\mathbf{x}_i)$ is the predicted class the article belongs to. The size of the decision value approximates an article's degree of hawkishness/dovishness. The larger the decision value, the more certain the classifier is about the chosen class. E.g, if the classifier detects mainly hawkish expressions in the article, it will be more certain that the class is 'hawkish', resulting in a higher positive decision value compared to an article that has fewer hawkish expressions. The decision value can be interpreted as an indicator of the degree of hawkishness/dovishness of an article and can therefore be used as a quantitative indicator to assess the media's perception of the ECB's statement.

In the SO method, the discriminating words were defined exogenously. Text mining allows us to automatically find the words that discriminate between hawkish and dovish articles, thereby avoiding the inherent bias that occurs when the discriminating words are self-selected. The word clouds in Figures 5 and 6 illustrate the 30 most hawkish and the 30 most dovish words. These are the words with the highest positive (negative) weights in the classification model, meaning that their occurrence in an article increases the probability of the article being classified as hawkish (dovish).

### 3.2.2 The Support Vector Machines HD-index

Figure 7 plots the evolution of HD_SVM and the main refinancing rate over time. Table 3 lists the title of the most hawkish or dovish article for 9 remarkable peaks and troughs of the HD-indicator. The index is characterised by less marked fluctuations then the HD_SO-index and shows signs of neutrality as well, e.g. point E and G. The index seems to be anticipating the changes in the Main Refinancing Rate reasonably well, with the levels of the indicator reacting before easing and tightening cycles in the same direction as the official

**Figure 5: Word cloud of the 30 most discriminative hawkish words from the classification model.**


**Figure 6: Word cloud of the 30 most discriminative dovish words from the classification model.**


interest rates. In prolonged periods of stable interest rates, the expectations are less aligned with the actual monetary policy stance. E.g., in June 2004 and November 2004, the HD-index reports hawkish levels. Table 7 shows that the highest scoring articles of these days (point C and D) report expectations of a possible future rate hike. With the exception of the rate hike in April 2011, the index shows dovish perceptions from the first cut in October 2008 up to the final point reported in the graph, unlike the index based on semantic orientation.

**Figure 7: The HD-indicator developed using a SVM text classification model. Nine remarkable hawkish and dovish points of the index are indicated by letters A-I. The titles of the highest scoring articles published after the corresponding press conferences are reported in Table 3.**

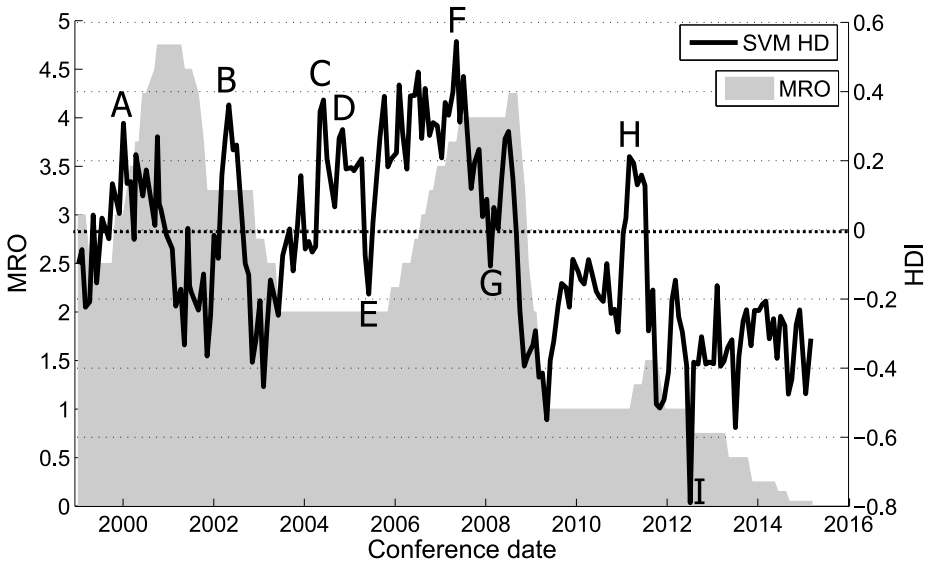



**Table 3: Legend to Figure 7. For nine press conferences, the title of the highest scoring article is reported.**

| Letter | Press Conference | Title highest scoring article |
|---|---|---|
| A | Jan 2000 | ECB begins the year with steady rates. (Morgan, 2000-01-05) |
| B | May 2002 | ECB keeps rate steady, more hawkish on inflation. (Gould, 2002-05-02) |
| C | Jun 2004 | ECB raises inflation forecasts on back of surging oil prices. (AFP, 2004-06-03) |
| D | Nov 2004 | ECB flirts with idea of rate boost. (Sims, 2004-11-05) |
| E | Jun 2005 | ECB rates still seen on hold for some time, but cut no longer ruled out. (AFP, 2005-06-02 |
| F | May 2007 | ECB's Trichet firmly signals June rate hike. (Hannon & Houston-Waesch, 2007-05-10) |
| G | Feb 2008 | France's finance minister says Euro too high. (AFP, 2008-02-07) |
| H | Mar 2011 | Trichet flags April ECB rate rise, stuns markets. (Reuters, 2011-03-03) |
| I | Jul 2013 | Surprise as BOE, ECB give forward guidance. (DJ, 2013-07-04) |

# 4 Validation of competing methods

Figure 9 in Appendix C plots the development of both indicators and the MRO rate over time. They appear to be closely correlated, with HD_SVM showing more moderate levels of hawkishness and dovishness and less volatility. The indicators have a correlation of approximately 0.78. The horizontal grid line cutting the right axis at zero indicates neutrality, i.e. the media expects that the interest rates will remain unchanged in the next few months. While HD_SO alternates quite abruptly between dovish and hawkish expectations, HD_SVM has less dramatic switches in expectations and shows signs of neutral expectations as well. Starting from 2009, the indicators tend to contradict each other, with HD_SVM showing a predominantly dovish tone (except during the surprise rate hike at the end of 2011), while HD_SO detects more periods of hawkish perception. This period coincides with the introduction of the various asset purchasing programmes. These signs of a looser monetary policy cannot be captured by the restricted list of expressions used by semantic orientation. A broad visual analysis of both indicators over time thus suggests that HD_SVM is better at measuring the media's expectations, especially the prevailing dovish expectations during the sovereign debt crisis. However, in order to assess which method performs better, a more in-depth analysis is needed. As there is no obvious validation method for an indicator of *perception*, the analysis is focused on three different evaluations: (i) we measure how well both methods can predict whether the tone of an article is predominantly hawkish or dovish, (ii) we investigate the indicators' reflect monetary policy cycles and to anticipate future movements of official ECB policy rates by measuring the correlations and (iii) we assess the indicators' performance qualitatively by extracting the most important topics mentioned in the news articles to investigate if they coincide with the indicators' values.

## 4.1 Performance analysis

To compare the performance of both methods, we classified the articles in the test set using the semantic orientation score and the SVM decision value. A positive orientation signifies a classification as hawkish, a negative orientation as dovish. We compared these classifications with our own, manual classifications using two performance metrics: AUC (Area under the Receiver Operating Curve) and accuracy. AUC is a standard evaluation metric for classification models that represents a model's discriminative power by measuring to what extent positively (hawkish) labelled observations are ranked higher than negatively (dovish) labelled observations (Fawcett, 2006). Contrary to accuracy, which represents the percentage of correctly classified observations, AUC is able to deal with unbalanced distributions. In order to assure a higher degree of robustness, the test set was classified independently by two authors: Ellen Tobback and Stefano Nardelli. The disagreement between the labellers is very small. The results in Table 4 are the average classification results of

the two methods. The results show that the SVM-model outperforms semantic orientation when classifying the test articles as hawkish or dovish. We find a difference in accuracy of 27 percentage points in favour of SVM.

In order to allow out-of-time testing as well, we have not included articles published in 2014 and 2015 in the training set. Table 5 reports the classification results on an out-of-time test set of 85 articles selected randomly from those published in 2014and 2015. AUC is not reported, as the test set includes only dovish articles. These articles are related to each press conference in 2014 and 2015, there is thus no reason to assume that the test set is not an accurate representation of the data set. The MRO-rate confirms the dovish stance that prevailed during these two years. The results show that SVM still outperforms semantic orientation, even when predicting the tone of articles that likely contain previously unused vocabulary.

Appendix B shows an example article that has a hawkish semantic orientation score, while the content of the article is clearly leaning towards dovishness. The author refers to low inflation expectations, a shrinking economic activity and the ECB's willingness to use unspecified measures to help the economy. The positive semantic orientation score is the result of the words from $H$, such as raise, that are used in a different context in this article. For instance, the sentence '*Mr Draghi warned that the eurozone might experience 'a prolonged period of low inflation' before price* ***rises*** *would accelerate'* is classified as hawkish when using semantic orientation due to the prevalence of the word *rises*, while the focus should be on the mentioned '*prolonged period of low inflation*' which points towards dovishness. The more advanced SVM-classification model is able to look at the broader context of an article, which results in a dovish classification for the example article.

**Table 4: Performance results of the SVM model (with words) and semantic orientation to classify out-of-sample articles.**

| Model | AUC | Accuracy |
|---|---|---|
| SVM-words | 98.36% | 92.00% |
| Semantic Orientation | 67.00% | 65.00% |

**Table 5: Performance results of the SVM model (with words) and semantic orientation to classify out-of-time articles.**

| Model | AUC | Accuracy |
|---|---|---|
| SVM-words | / | 98.82% |
| Semantic Orientation | / | 67.06% |

## 4.2 Correlation analysis

Visual analysis of Figure 9 in Appendix C shows that overall, the HD-indicators reflect the monetary policy stance rather accurately. In other words, changes in the tone of their communication to anticipate future rate movements tend to be understood appropriately, i.e. the indicators point to a more hawkish tone prior to and during tightening cycles, and to a more dovish tone prior to and during easing cycles. In particular, this is the case ahead of the 1999 and 2005 tightening monetary policy cycles, the 2001 loosening cycle, and the loosening cycle caused by the rapid deterioration of the crisis following Lehman's collapse in autumn 2008 (in particular HD_SVM moved from a very hawkish to a neutral/dovish stance already in late 2007). In this Section, we quantitatively assess whether both indicators reflect the policy stance and whether they anticipate future movements, by computing their correlation with three different interest rate variables: the ECB policy (MRO) rate, the euro Libor rate and the Wu-Xia shadow rate. The euro LIBOR interest rate reflects the futures market's expectations of the ECB's monetary policy. The Wu-Xia shadow interest rate operates as an alternative to the MRO rate when the key interest rates are at the zero lower bound (ZLB), i.e. when there is no variation in the actual policy rates (Wu & Xia, 2016). Frequency and duration of the ZLB period has been sufficiently long to justify the use of shadow rates and ensure a relatively high degree of accuracy to results with the caveat that measures of shadow rates for the Euro Area usually start after 1999 (Williams, 2014). Figure 10 plots the correlation between the interest rates and the HD-indicators with a lag of zero to twelve meetings. The correlations increase with the number of lags to level off after 6 to 7 meetings for HD_SVM and 8 to 9 meetings for HD_SO. The HD_SVM index displays a higher degree of correlation with the MRO rate than HD_SO. The high lagged correlation of HD_SVM indicates the indicator's ability to anticipate monetary policy cycles. Both indicators appear to be more correlated with the 12-month euro LIBOR rate with a lead of approximately 7 meetings and a peak correlation of about 0.7 for HD_SVM and 0.45 for HD_SO. Correlations were also computed using the Wu-Xia shadow rates instead of the actual interest rates. The overall picture does not change radically, however both HD-indicators show a higher correlation when the Wu-Xia shadow rates are considered, with a peak correlation of 0.8 at a lead of 4 Governing Council meetings in the case of HD_SVM and of 0.6 at a lead of 11 meetings for HD_SO. These results confirm that the indicators, in particular HD_SVM, reflect the current and future monetary policy stance. To assess whether the indicators anticipate future rate movements, we investigate the correlation between the indicators and the change in the interest rates with respect to the previous meeting. The correlograms are plotted in Figure 11. Correlations tend to be persistently lower when interest rates are taken in changes rather than in levels. In particular, correlations with euro LIBOR rates fall close to zero after a relatively short number of periods, which tends to confirm that the HD-indicators' ability to anticipate changes in official rates is somewhat more short lived.

## 4.3 Topic analysis

The qualitative validation of both methods necessitates further insight in the content of the corpus. The simplest, though most time consuming approach is reading a selection of articles for each press conference to assess the general tone and to see if it coincides with the level of the index. A more time-efficient, though computationally complex approach is the use of topic models to detect the topics present in the corpus in order to see the evolution of subjects mentioned by media over time. In this paper, we opted for the second approach and used Latent Dirichlet Allocation (LDA) (Blei et al., 2003) to derive the topics from our data set. This technique assumes that each document can be represented by a mixture of topics, where the topic distribution has a Dirichlet prior. Every topic has a probability of generating a set of words, which makes it possible for the end-user to name the topic according to the related words. For example, a topic that contains the words {raise,increase,rates} can be interpreted as a 'rate hike'-related topic. The model also assumes that words listed under the same topic are more likely to co-occur in a document, e.g. raise (from the topic 'rate hike') is more likely to occur in a news article with increase (from the same topic) than with cut (from the topic 'rate cut'). LDA assumes that documents are created following a generative process in which a document $d$ with $N$ words in a corpus $D$ is a mixture over latent topics, where each topic is a distribution over words. For each document $d$ in a corpus $D$ and a fixed set of topics $k$:

1. Choose a k-dimensional topic weight vector $\theta \sim Dir(\alpha)$
2. For each word $w_n$ with $n \in \{1 \dots N\}$ in a document $d$:
   (a) Choose topic: $z_n \in \{1 \dots k\} \sim$ Multinomial($\theta$)
   (b) Choose word: $w_n$ from multinomial probability conditioned on topic $z_n$ with parameters $\beta$

In order to find the topic model of our data set, we first need to define the number of topics $k$. Trial and error can help one find the right number that finds the balance between completeness and comprehensibility. Given the number of topics $k$ and a corpus $D$, we need to calculate the posterior distribution of the hidden variables $\theta$, i.e. the topic weight vector that indicates the prevalence of a topic in a document and $z$, the topics. Blei et al. (2003) propose the use of variational inference to find the document-specific variational distribution parameters $\gamma$ and $\phi$ as proxy to the prior Dirichlet and multinomial parameters $\alpha$ (used to find the topic weight vector) and $\beta$ (used to find the inferred topics). The variational parameters are document-specific and the Dirichlet parameters $\gamma$ provide a representation of a document in the topic simplex. $\gamma_i$ approximates the expected number of words in a document that are allocated to topic $i$[3].

[3]In theory, one should subtract the prior Dirichlet parameter $\alpha_i$ from the posterior Dirichlet parameter $\gamma_i$ to obtain the expected number of words allocated to topic $i$. However, $\alpha$ is usually small and constant over all documents in the corpus.

**Table 6: The top 3 topics from the topic model and the top 10 words with the highest probability of belonging to the underlying topic.**

| *Rate cut* | *Rate hike* | *Rate unchanged* |
|---|---|---|
| rate | rate | price |
| ECB | ECB | area |
| cut | Trichet | growth |
| euro | inflation | euro |
| bank | price | term |
| zone | rise | remain |
| inflation | bank | rate |
| expect | hike | economy |
| year | interest | monetary |
| economy | increase | medium |
| economist | month | risk |

Examining the $\phi_n$ parameters helps to give further insight into the topics. These parameters approximate the probability distribution of words for each of the $k$ topics.

We built a topic model with 25 topics and applied variational inference on the entire corpus to find the most popular topics per article/press conference. Figure 8 shows an example article from the corpus on which variational inference has been conducted. The article is colour coded according to the topic model. Each colour represents a topic from which the word is most likely generated. The example article consists of three topics, i.e. a topic on the asset purchase programmes, one on the reactions from stakeholders and one on the ECB's loans to banks and collateral. Table 6 reports the top three most used topics in the entire data set. Not surprisingly the dominant topics are those referring to the interest rate decisions, with 'rate cut' the most frequently used.

As previously mentioned, we want to use the topic model to gain insight in the data set and the indicators. Figure 9 is divided into thirteen periods in the monetary policy stance and denoted with the dominant topics. The topic subjects and a selection of the top 25 words for these topics can be found in Table 10 in Appendix E. The topics confirm the hawkish peaks between May and July 2002 and between June 2004 and April 2005, where the articles mentioned both the rise in oil prices (topic C) and a possible rate hike (topic A). However, in these periods topic B (rate cut) is discussed as well, indicating that there is a certain level of uncertainty or disagreement in periods of stable interest rates. During the tightening and easing cycles, the dominant topic is the one related to the interest rate decision, i.e. topic A or B. However, Figure 9 shows that the topics discussed in articles about the ECB's stance are not restricted to the interest rate decisions and price expectations. For example, during the 2013-2014 easing cycle, the most discussed topic is the one on bond purchases.

**Figure 8: Example article colour coded according to the topic model. The words in bold, red are part of the 'Asset purchasing'-topic, the words underlined and in blue are part of the 'Member's response'-topic and the words in italic, green of the 'Loans to banks and collateral'-topic. For these three topics the top words from the probability distribution are shown (highest $\phi_n$ parameters)**

**Government bond buying efforts** by **central banks** to help **struggling countries refinance** their **debt** only *increase dependency* of **eurozone** member states, a top official at Germany's *Deutsche* Bundesbank said Friday, in a critique of the European **Central Bank's latest bond buying effort**. '**Sovereign debt purchasing programs** *increase dependencies*, and **firewalls** are not a substitute for **restoring** the ability to pay and *investor* **confidence**,' Andreas Dombret, a board member with the Bundesbank said at a **conference** in Frankfurt. At the **ECB's monthly press conference Thursday**, President **Mario Draghi reiterated** that the **central bank** stood **ready** to **deploy** its **bond buying program**, but would **act** independently in doing so.

| **Asset purchases** | Member's response | *Loans to banks and collateral* |
|---|---|---|
| ECB | bank | bank |
| Draghi | ECB | Jones |
| bank | central | Dow |
| euro | European | ECB |
| rate | President | eurozone |
| bond | government | central |
| government | member | collateral |
| Mario | minister | financial |
| central | France | Weber |
| market | Germany | measure |
| policy | council | crisis |
| measure | finance | market |
| crisis | euro | European |
| cut | German | member |
| purchase | board | liquidity |

As the SVM indicator considers all words in the training set that discriminate between hawkish and dovish expectations, it will cover a wide range of relevant topics, including topic E. The SO indicator on the other hand, relies on words directly related to interest rate decisions and therefore only covers topics A and B. Whenever new topics arise, the SVM model can be retrained to cover the new vocabulary as well. Combined with the fact that the SVM indicator depends on endogenously selected discriminative words, while the SO indicator depends on an exogenously selected set of keywords, we would advise the use of a text classification model to construct the HD-indicator.

# 5 Taylor rule application

In this Section we assess whether the communication provided by the ECB as measured by the HD_SVM index adds a valuable contribution to the prediction of the policy rate. The exercise is inspired by the one presented in (Sturm & De Haan, 2011), where they use a set of five communication indicators, all based on the Introductory Statement, with a view to checking whether greater disclosure and clarity over policy may lead to greater predictability of central bank actions. Despite some differences across indicators, the results presented in the paper tend to support the conclusion that communication adds valuable information to the prediction of the ECB's next policy decision[4]. We test the forward guidance properties of the ECB's communication by comparing the fitted path of a standard specification of the Taylor rule for the ECB monetary policy rate with a Taylor rule including an additional lagged HD index term. The lagged HD is consistent with the leading properties of the index on interest rates shown in the previous Section. The exercise is conducted on both the MRO rate and the euro LIBOR rate. Specifically, the Taylor equation used for this exercise has the following structure:

$$i(t) = \rho_1 + \rho_2 i_{(t-1)} + \rho_3(PC\pi_t) + \rho_4(PCy_t) + v_t$$

where $i(t)$ indicates the interest rate (either MRO or EA LIBOR rate), $PC\pi_t$ the principal component measure of inflation expectations $\pi_t$ , and $PCy_t$ a principal component measure of economic slack. The standard formulation is compared with the following extended formulation which includes the HD index:

$$i_{HD}(t) = \rho_1 + \rho_2 i_{(t-1)} + \rho_3(PC\pi_t) + \rho_4(PCy_t) + \rho_5 HD_{(t-1)} + u_t$$

both for the overall HD and for the HD computed after the press conference.

[4]In Lucca & Trebbi (2009) a similar exercise is conducted on a Taylor-rule specification which incorporates partial interest rate adjustment, inflation forecasts, and output gap as determinants of interest rate decisions. The significance of a communication indicator similar to the HD_SO index is tested on the estimated residuals from the Taylor equation rather than directly on a communication variable in the Taylor equation.

Because of the previously mentioned advantages, the exercise is conducted only on HD_SVM and not on HD_SO. The results are shown in Table 7. The coefficients of the estimated Taylor equations are significant for almost all variables with the exception of inflation expectations which is only significant (at the 10%-level) in the standard Taylor rule equation for the LIBOR-rate. When HD is included, inflation expectations suffer from a further loss of significance in many equations, in particular for the MRO rate, while HD terms tend to be significant for all specifications. The signs of the estimated coefficients are positive, indicating that a rise in both economic slack and inflation expectations tend to be associated with rises in interest rates, which is consistent with the literature. As said, the lagged HD-index is statistically significant in all equations. Furthermore, a rise in $R^2$ is observed generally, indicating an improvement in the fit for all specifications. Such evidence tends to be consistent with similar results in the literature, in the sense that the HD-index is able to capture changes in the tone of communication anticipating movements in key interest rates. This is also moderately confirmed by the correlation between the residuals from the Taylor rule (with no lagged HD-index term) and the HD-index, as shown in Figure 12. For the overall HD index, correlations show a peak of close to 0.4 for the MRO rate and slightly above 0.3 for the Libor rate, in both cases at zero lags. Correlations tend to be slightly higher for the HD index computed after the press conference, though with a broadly unchanged pattern.

While the Taylor rule formulation as presented above is generally used in literature and in practise (see e.g. Lucca & Trebbi (2009); Sturm & De Haan (2011), non-stationarity of the variables could lead to spurious regressions and inconsistent parameter estimates Österholm (2005). An Augmented Dickey Fuller test shows that all variables used in the Taylor rule are integrated of order one. All pairwise Johansen cointegration tests between the independent variables and MRO/LIBOR accept the hypothesis of no cointegration. To ensure that the previously found significant relationship between communication and the future path of the interest rate is valid, we supplement our Taylor rule exercise with a set of Taylor rule regressions conducted using the first differences of all the included variables. The results are reported in Table 8. When taking first differences, the coefficient of the inflation expectations becomes significant for all equations. The coefficients of inflation expectations and economic slack remain positive, indicating that increasing output gap and increasing inflation expectations are associated with rises in the interest rates. $R^2$-values are lower than those reported in Table 7, especially for the MRO rate, yet a large proportion of the variance can still be explained by the models and model fit still increases when the HD-indicator is introduced in the equations. Both the overall $\Delta$HD_SVM and $\Delta$HD_SVM after the press conference are significant at the 5%-level for MRO and LIBOR.

Overall, these results tend to confirm the conclusion that communication plays a significant role in characterizing the ECB's reaction function. Furthermore, given how the HD-index is constructed, the empirical evidence tends to

**Table 7: Results of the three Taylor rule estimations: (i) the standard Taylor rule, (ii) the Taylor rule including HD_SVM, and (iii) the Taylor rule including HD_SVM measured after the press conference. Reported are the coefficients, p-values (between brackets) and $R^2$ values.**

| | Constant | smoothing | inflation expectations | output gap | HD_SVM | $R^2$ |
|---|---|---|---|---|---|---|
| | | | Standard Taylor rule | | | |
| MRO | 0.4142 | 0.7745 | 0.0460 | 0.3419 | n.a. | 0.9506 |
| | (0.001) | (0.000) | (0.516) | (0.000) | | |
| Libor | 0.6758 | 0.6980 | 0.1406 | 0.4685 | n.a. | 0.9557 |
| | (0.000) | (0.000) | (0.0626) | (0.000) | | |
| | | | Taylor rule including HD_SVM | | | |
| MRO | 0.3986 | 0.7966 | 0.0139 | 0.2190 | 0.5647 | 0.9526 |
| | (0.0013) | (0.000) | (0.845) | (0.037) | (0.057) | |
| Libor | 0.6697 | 0.7123 | 0.1098 | 0.3768 | 0.5398 | 0.9572 |
| | (0.000) | (0.000) | (0.1480) | (0.000) | (0.077) | |
| | | | Taylor rule including HD_SVM measured after the press conference | | | |
| MRO | 0.4042 | 0.7966 | 0.0159 | 0.2055 | 0.6031 | 0.9528 |
| | (0.001) | (0.000) | (0.823) | (0.055) | (0.049) | |
| Libor | 0.6728 | 0.7147 | 0.1081 | 0.3494 | 0.6392 | 0.9572 |
| | (0.000) | (0.000) | (0.1491) | (0.001) | (0.0419) | |

**Table 8: Results of the three Taylor rule estimations with first differences: (i) the standard Taylor rule, (ii) the Taylor rule including ΔHD_SVM, and (iii) the Taylor rule including ΔHD_SVM measured after the press conference. Reported are the coefficients, p-values (between brackets) and $R^2$ values.**

| | Constant | inflation expectations (Δ) | output gap (Δ) | ΔHD_SVM | $R^2$ |
|---|---|---|---|---|---|
| | | Standard Taylor rule | | | |
| ΔMRO | -0.0389 | 0.3424 | 0.7858 | n.a. | 0.5035 |
| | (0.208) | (0.003) | (0.000) | | |
| ΔLibor | -0.0392 | 0.3712 | 1.1178 | n.a. | 0.6568 |
| | (0.192) | (0.001) | (0.000) | | |
| | | Taylor rule including ΔHD_SVM | | | |
| ΔMRO | -0.0203 | 0.2314 | 0.6833 | 0.4358 | 0.5608 |
| | (0.495) | (0.0453) | (0.000) | (0.005) | |
| ΔLibor | -0.0192 | 0.2521 | 1.0077 | 0.4682 | 0.7052 |
| | (0.501) | (0.024) | (0.000) | (0.002) | |
| | | Taylor rule including ΔHD_SVM measured after the press conference | | | |
| ΔMRO | -0.0191 | 0.2292 | 0.6841 | 0.4108 | 0.5548 |
| | (0.528) | (0.051) | (0.000) | (0.0085) | |
| ΔLibor | -0.0173 | 0.2461 | 1.0055 | 0.4541 | 0.7026 |
| | (0.5505) | (0.0289) | (0.000) | (0.0026) | |

confirm that the media correctly perceive any significant deviations in the actual monetary policy decisions from the ordinary (standard Taylor) rule.

# 6 Conclusion

In this paper, we present the development of an index that reflects the media's interpretation of the ECB's official communication. The index represents the perceived degree of hawkishness or dovishness by analysing news articles that report on ECB monetary policy decisions, using both semantic orientation and a supervised SVM classification model. The resulting SO and SVM HD-indicators are closely correlated, however, the SVM indicator shows more moderate levels of hawkishness/dovishness. The SVM model performs better than semantic orientation when detecting the tone of the articles. Analysis of the most frequently used topics in the data set reveals that the media's focus has shifted from the actual interest rate decision towards the non-standard monetary policy measurements. Therefore, it is preferable to use a supervised text classification model to create a quantitative indicator that assesses the media's perception of the ECB, as it considers a wider range of words that discriminate between hawkish and dovish expectations. We show that the SVM HD-index is indeed better than the SO HD-index at capturing the dovish expectations during the sovereign debt crisis. Regarding the possible applications of the indicators, we find that the HD indicator can be a valuable tool to gauge how the ECB's message is perceived by an influential group of observers, such as the media, and to anticipate the future monetary policy stance. We find a high correlation between the HD-index and the MRO and LIBOR rate, with the HD_SVM index showing higher correlation and a longer lead for both interest rate series than HD_SO. Finally, the Taylor rule exercise confirms that communication plays a significant role in enhancing the accuracy when trying to estimate the bank's reaction function.

The method we presented can easily be applied to a wider set of articles, not necessarily limited to the press conference. At the moment the index represents the media's perception of the ECB's communication during the press conference. This could be extended to other official communications, such as speeches, or other channels, such as social media. Considering the multilingual nature of the European Monetary Union, another interesting extension is the analysis of articles in other languages than English. The country dimension could provide useful insights into the differences in national perceptions of the ECB's communication. Currently, the index provides a general overview as the articles originate from global news agencies. Including articles from national news agencies and in the national language would allow the creation of an HD-index for each EMU member.

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# Appendix A Hawkish and dovish words

**Table 9: Hawkish, dovish and reference words used to calculate the semantic orientation score. The last column on the right (N) lists the negations/negating expressions.**[5]

| Hawkish (H) | Dovish (D) | Reference (R) | Negations (N) |
|---|---|---|---|
| Raise | Cut | ECB | Not |
| Increase | Decrease | European Central Bank | Not expected to |
| Go up | Go down | Duisenberg | Unlikely to |
| Tighten | Ease | Draghi | No reason to |
| Head up | Head down | Trichet | No reason to expect a rate |
| Hike | Slash | eurozone | |
| Move up | Move down | euro area | |
| Put up | Put down | rates | |
| Rise | Reduce | | |
| Lift | Loosen | | |
| Boost | Slice | | |
| Bump up | Shave | | |
| Augment | Trim | | |
| Higher | Lower | | |
| Climb | Drop | | |
| Hawkish | Dovish | | |
| Tight | Loose | | |
| | Accommodation | | |
| | Accommodative | | |

[5] These words have been selected by the authors and are the result of both domain knowledge and a comprehensive study of the used relevant vocabulary in media reports.

# Appendix B Example

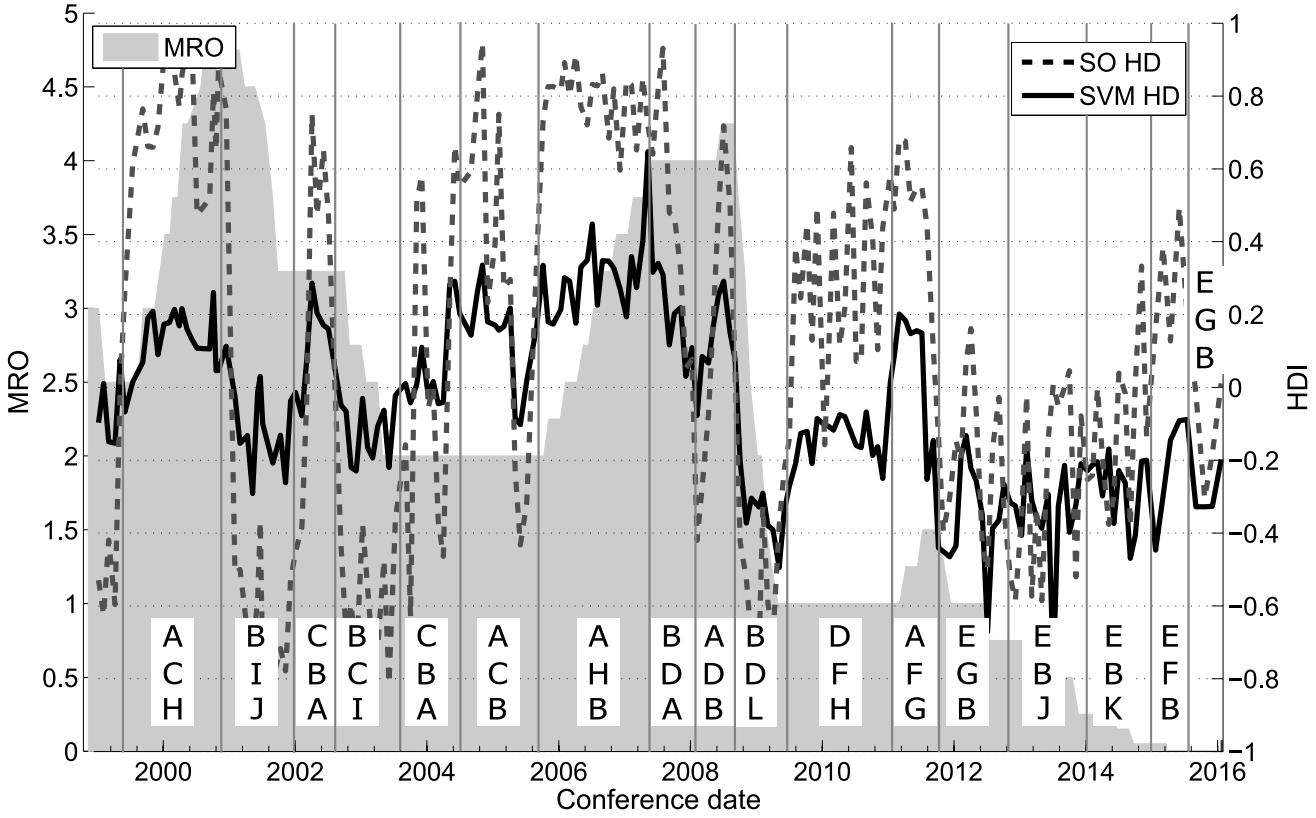
**Article published after a press conference (The Times, 2013-12-06). The reference words from $R$ are underlined. The sentences containing a word from $R$ are the relevant sentences. The HAWKISH words in these sentences are capitalised and the *dovish* words are written in italics.**

Forecasts for **eurozone** growth were **RAISED** slightly yesterday as the **European Central Bank** kept rates on hold after last months surprise ***cut*** to an historical low. Negative interest **rates** were discussed briefly at the monthly board meeting but the **ECB** declined once again to publish minutes of its deliberations. Mario **Draghi**, the President of the **ECB**, admitted that inflation would remain well below the target level of 2 per cent for years to come. He also gave little hope of an end to high unemployment levels while maintaining that the Bank was ready to use a number of unspecified measures to help the economy if necessary. The bank left its benchmark rate at 0.25 per cent. ***Lowering*** the **ECB**s inflation forecast to 1.4 per cent for 2013 and 1.1 per cent in 2014, Mr **Draghi** warned that the eurozone might experience 'a prolonged period of low inflation' before price **RISES** would accelerate. Mr **Draghi** added that the **ECB** had forecast inflation of 1.3 per cent in 2015. The bank **RAISED** its **eurozone** economic growth forecast from 1.0 to 1.1 per cent for next year and predicted growth of 1.5 per cent for 2015. Economic activity would shrink by 0.4 per cent this year in the 17-nation group, which is due to enlarge with the addition of Latvia on January 1. Asked when the **ECB** would make good on promises to publish board minutes in line with national central banks, Mr **Draghi** said: 'We have started working in the executive board - this is a complex issue, it has many dimensions'. The Bank of England left its benchmark rate unchanged at the record low of 0.5 per cent, and kept quantitative easing at the level of £ 375 billion.

- Semantic orientation score $= \frac{3-2}{5} = 0.2$
- Support Vector Machines score $= -0.17169$

# Appendix C HD-indicators

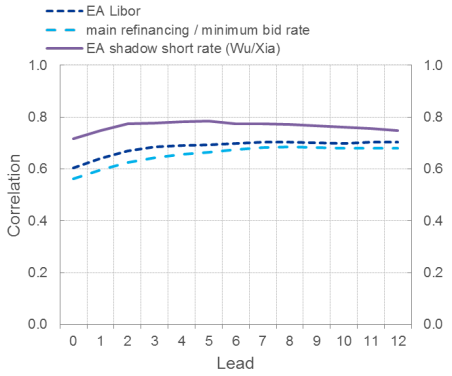
**Figure 9: Plot of the HD-indicators created with semantic orientation (dotted line) and text classification (solid line). The grey shaded area represents the levels of the main refinancing rate (=monetary policy stance). The graph is divided into 13 periods. For each period the most dominant topics are indicated by letters A-K. Table 10 lists the subjects of these topics.**



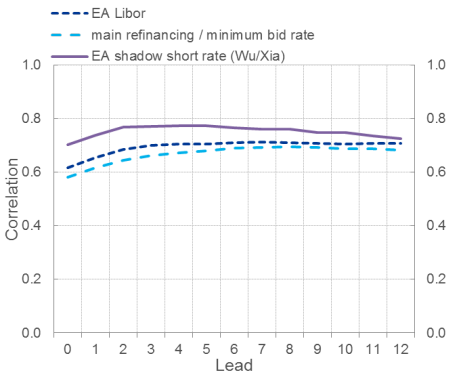
# Appendix D Correlograms

**Figure 10: Correlograms reporting the correlations between the HD-indicators (in levels) and the MRO, Libor, and WU-Xia interest rates (in levels) for 0 to 12 lags.**

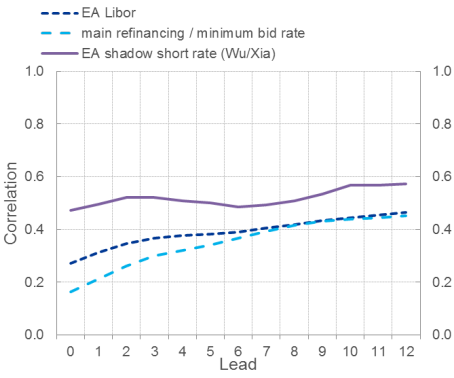
**(a) HD_SVM**




**(b) HD_SVM measured after the press conference**




**(c) HD_SO**




**(d) HD_SO measured after the press conference**

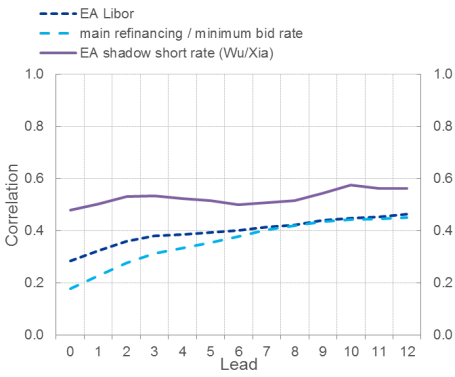
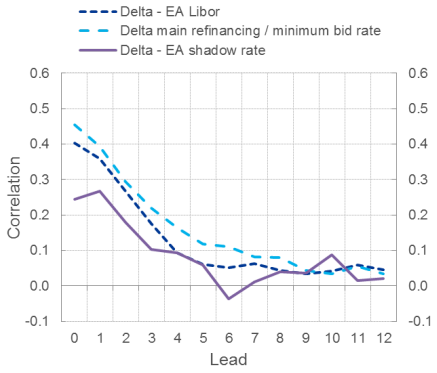
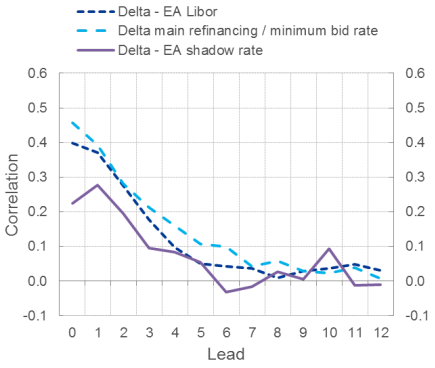


**Figure 11: Correlograms reporting the correlations between the changes in the HD-indicators and the MRO, Libor, and WU-Xia interest rates changes for 0 to 12 lags.**

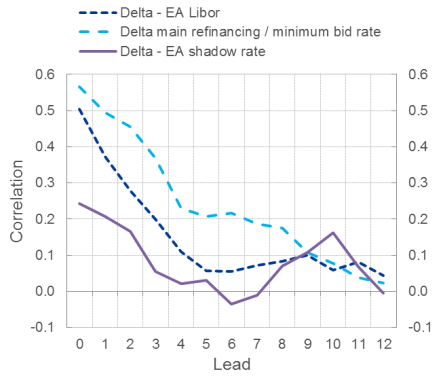
**(a) HD_SVM**




**(b) HD_SVM measured after the press conference**




**(c) HD_SO**




**(d) HD_SO measured after the press conference**

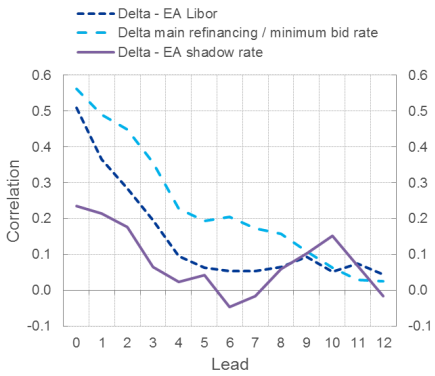
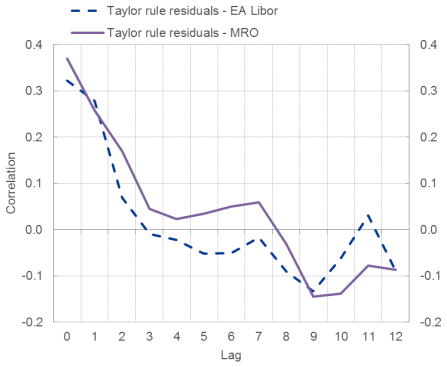
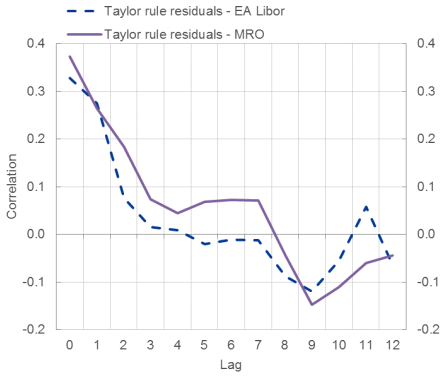


**Figure 12: Correlograms reporting the correlations between the HD_SVM indicator and the Taylor rule residuals for 0 to 12 lags.**

**(a) HD_SVM overall**




**(b) HD_SVM after the press conference**



# Appendix E Topics

**Table 10: A selection of the top 10 words for each of the most frequently used topics in the data set.**

| A<br>*Rate hike* | B<br>*Rate cut* | C<br>*Growth/Recovery* | D<br>*Crisis/Recession* | E<br>*Bond purchases* | F<br>*Greece bailout* |
|---|---|---|---|---|---|
| rate | rate | growth | Trichet | ECB | Greece |
| ECB | ECB | price | economy | Draghi | debt |
| Trichet | cut | euro | market | bond | Greek |
| inflate | euro | economy | lend | crisis | ECB |
| price | bank | rate | record | cut | crisis |
| rise | zone | ECB | low | purchase | bond |
| bank | inflate | inflate | credit | monetary | default |
| hike | expect | policy | recession | interest | bailout |
| interest | year | stability | financial | buy | plan |
| increase | economy | recovery | crisis | debt | fund |
| G<br>*Debt crisis* | H<br>*Stable outlook* | I<br>*Rate cut decision* | J<br>*Stock market* | K<br>*Money market* | |
| bond | price | cut | stock | rate | |
| market | growth | ECB | market | month | |
| yield | remain | rate | share | Euribor | |
| debt | medium | point | index | market | |
| govern | risk | decision | bank | ECB | |
| Spain | inflate | move | expect | lend | |
| purchase | stability | announce | rose | fixed | |
| crisis | expect | Thursday | trade | expect | |
| spread | develop | market | fell | overnight | |
| Italy | continue | dollar | gain | Eonia | |

# Appendix F Details on the Taylor rule

To select a formulation for the Taylor rule in Section 5 as general as possible, the terms for inflation expectations $\pi_t$ and for the measure of economic slack $y_t$ correspond to the first principal component computed on a set of different measures for respectively inflation expectations and economic slack. The list of variables employed for the two variables are listed in the two Tables below.

**Table 11: Inflation expectations (surveys, market based)**

| Indicator | Frequency | Transformation | Source | Background information |
|---|---|---|---|---|
| Retail selling price expectations | Monthly | Level | ECFIN Business and Consumer survey | |
| Household's inflation expectations | Monthly | Level | ECFIN Business and Consumer survey | |
| SPF 1y ahead | Quarterly | Level | ECB | rolling horizon |
| SPF 2y ahead | Quarterly | Level | ECB | rolling horizon |
| SPF 8y ahead | Quarterly | Level | ECB | fixed horizon |
| Consensus 1y ahead | Monthly | Level | Consensus Economics | fixed horizon |
| Consensus 6-10y ahead | Half-yearly | Level | Consensus Economics | Average inflation in 6 to 10 years |
| 1y1y inflation linked swap rate | Monthly average of daily series | Level | Thomson Reuters | Excluding tobacco |
| 1y2y inflation linked swap rate | Monthly average of daily series | Level | Thomson Reuters | Excluding tobacco |
| 1y4y inflation linked swap rate | Monthly average of daily series | Level | Thomson Reuters | Excluding tobacco |
| 1y9y inflation linked swap rate | Monthly average of daily series | Level | Thomson Reuters | Excluding tobacco |
| 5y5y inflation linked swap rate | Monthly average of daily series | Level | Thomson Reuters | Excluding tobacco |

**Table 12: Indicators for economic slack**

| Indicator | Frequency | Transformation | Source | Background information |
|---|---|---|---|---|
| ECB Output gap | Quarterly | Level | ECB | |
| IMF Output gap | Quarterly | Level | IMF | |
| EC Output gap | Quarterly | Level | European Commission | |
| Capacity utilisation in manufacturing | Quarterly | Level | ECFIN | Survey-based |
| Capacity utilisation in services | Quarterly | Level | ECFIN | Survey-based |
| Survey-based measure of slack | Quarterly | Level | ECFIN survey 'factors limiting production' | Survey on manufacturing, services and construction sectors managers. |
| ECB Unemployment gap | Quarterly | Level | Eurostat, ECB | Difference between actual unemployment and ECB NAIRU estimates |
| EC Unemployment gap | Quarterly | Level | Eurostat, ECB | Difference between actual unemployment and EC NAWRU estimates |
| Unemployment rate | Monthly | Level | Eurostat | |
| Short-term unemployment rate | Quarterly | Level | Eurostat | Difference between overall unemployment rate and long-term unemployment rate (above 2 years) |

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