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THE ROLE OF CENTRAL BANK COMMUNICATION IN INFLATION TARGETING EASTERN EUROPEAN EMERGING ECONOMIES

by Valerio Astuti*, Alessio Ciarlone+ and Alberto Coco+

Abstract

In this paper, we analyze whether central bank communication can be an additional tool to provide guidance on monetary policy, drive private agents' inflation expectations and financial asset prices in the main countries of Central and Eastern Europe. By applying natural language processing techniques to monetary policy statements and minutes, we first derive a series of salient topics on which central bank communications focused over the last two decades, and then develop indices of tone to gauge their respective degrees of hawkishness (dovishness) about the economic outlook. By using these indices in an econometric set-up, we find that a more hawkish (dovish) tone – reflecting a more positive (negative) assessment of the economic outlook – anticipates a more restrictive (accommodative) monetary policy decision, raises (lowers) short-term inflation expectations of private sector agents, increases (reduces) market interest rates across different maturities, and drives share prices down (up). Overall, our analysis suggests that communication may be a complementary and effective monetary policy tool available to central banks in emerging economies.

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Contents

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1. Introduction[1]

In this paper, we examine the role of central bank (CB) communication in the three main Eastern European countries that have adopted an inflation targeting (IT) regime, i.e. the Czech Republic, Hungary and Poland (CEE-3). In particular, our aim is to analyze whether, and to what extent, their communication strategies may be able to anticipate prospective monetary policy decisions, to shape the inflation expectations of private sector agents and to influence changes in market interest rates and stock market indices.

Our research starts from acknowledging that, in recent years, communication has become another key instrument available to modern CBs, especially those adopting full or partial IT frameworks.[2] Actually, two thirds of CBs worldwide - belonging to both advanced and emerging economies – have been adopting IT regimes, which have been able to successfully temper both wage and price pressures in line with the prescriptions of economic theory (Clarida *et al*., 2000; Gali and Monacelli, 2005).[3] Nevertheless, since the outbreak of the 2008-09 global financial crisis (GFC), IT regimes have been subject to new challenges, especially in those countries more exposed to large swings in capital flows and exchange rates, which may potentially mine their monetary policy independence as well as macroeconomic and financial stability.[4] A second big challenge was related to the constraint to operate in (or near to) a *zero lower bound* (ZLB) environment, which has reduced the scope of traditional monetary policy measures and imposed to modern CBs the search of other unconventional strategies to pursue the final objective of price stability.

Against this background, CBs have tended to communicate more, and more precisely, with the public in recent years, moving towards greater transparency in terms of objectives, procedures, rationales, models and data.[5] By doing so, CB communication may provide insights on two relevant dimensions: on the one hand, the assessment of the state of the economy based on past data; on the other hand, the appraisal of its likely evolution through forecast and projections. Both these backward- and forward-looking dimensions serve to fill the information deficit of the economic agents (Byrne *et al.*, 2021) and, hence, to boost the credibility and accountability of IT regimes (Blinder *et al*. 2008; European Parliament, 2018; Bottone *et al*. 2022). The use of verbal and textual communication is particularly relevant in periods characterized by higher uncertainty or by interest rates at (or near to) the ZLB. A clear communication strategy is also paramount when CBs operate with multiple tools (interest rates and foreign exchange interventions, complemented by macro-prudential tools) and

[1] We wish to thank Pietro Catte, Alfonso Rosolia, Giorgio Merlonghi, Laura Bartiloro, Emidio Cocozza, Marco Albori and two anonymous referees for their useful comments on earlier versions of this paper; any errors and omissions remain our own responsibility. The views expressed are those of the authors and do not necessarily reflect the views of the Bank of Italy.

[2] Where the target may be a band or a punctual target with a fluctuation margin.

[3] Supported by policies to strengthen economic fundamentals, overcome fiscal dominance, bolster banking system soundness and develop domestic financial markets, IT has coincided with a widespread reduction of inflation to lower and more stable level inflation rates, smoother growth and more stable financial systems.

[4] To cope with these challenges, most CBs in EMEs have accompanied IT regimes with a controlled floating exchange rate regime (Ilzetzki *et al*., 2019; Frankel, 2019) and the build-up of foreign exchange reserves (Crowley *et al*., 2018) to intervene in currency markets (Menkhoff, 2013). Besides, policymakers have added macro-prudential measures – such as reserve requirements, loan caps, countercyclical capital buffers (Claessens, 2015) – or capital flow management measures (Aizenman, 2019) to cope with the risks stemming from a more integrated global financial system.

[5] CBs nowadays reveal more information to the public by: i) describing the main features of the monetary policy strategy; ii) explaining the rationale underlying current policy decisions; iii) interpreting current and prospective economic conditions; iv) providing views on future economic outlook; v) making statements about the likely forthcoming policy course; and vi) shaping market expectations.

multiple objectives (price, macroeconomic and financial stability), as it happens in several emerging countries. In such a case, the communication strategy can be even more challenging, because different tools used to achieve objectives at different horizons may not always move in the same direction. Briefly, an effective communication can successfully contribute to confer credibility to the monetary authority, by this way it may anchor inflation expectations, and ultimately ease the achievement of inflation targets.

Hence, CB communication has begun to be followed closely by market participants, who now do pay attention not only to the *content* but also to the *tone* of CBs, whereas this *soft information* is conveyed in different formats including press-releases, statements, minutes, publications, interviews, speeches and so on. Since the choice and use of specific words rather than others appear to matter – since they provide information about CB *sentiment* or "waves of optimism and pessimism" – the analysis of the textual content of CB communication has been attracting greater and greater attention by the economic literature, that has tried to answer to relevant questions like: does CB communication have incremental information value? Can this *soft information* be used as an alternative predictor of economic and policy outcomes? How does the market react to CB communication?

We intend to face these questions in relation to the communication strategies adopted by the Česká Národní Banka (CNB), the the Magyar Nemzeti Bank (MNB) and the Narodowy Bank Polski (NBP), which seem to be well suited for our analysis for two main reasons. First, in addition to adopting an IT regime,[6] they have also developed modern communication tools and increased their transparency, regularly publishing press releases and minutes of their monetary policy meetings, alongside the more traditional macroeconomic projections. These tools may provide the market with a kind of *soft information* about the inclination of central bankers towards a more positive, or more negative, economic outlook and hence to affect private sector expectations and financial market asset prices. Second, from 2015 to mid-2021 official reference rates in CEE-3 economies have remained at historically low levels, especially in the Czech Republic and Poland; this circumstance would imply a potentially greater role for communication in affecting crucial economic variables compared to standard reference rates' changes. It has to be highlighted that the paper does not document last year developments, in particular the very rapid hike of inflation, reaching historically highs in CEE-3 economies, after the outbreak of the war between Russia and Ukraine, that also makes CB communication crucially important to keep inflation expectations anchored.

Against this backdrop, the objective of the empirical analysis is to assess whether and to what extent the CB communication in the CEE-3 economies impact the predictability of monetary policy, private agents' expectations and movements in financial asset prices. To pursue this goal, we rely on both the press releases and the minutes that traditionally follow monetary policy decisions.[7] We apply Natural Language Processing (NLP) techniques to extract indications about both the *content* (topics) and the *sentiment* (tone) of the textual communication contained therein. More precisely, we use the Latent Dirichlet Allocation (LDA) to assess the intensity of latent topics that occur in a set of

[6] More specifically, the NBP adopted a flexible IT regime in 1998; since 2004, the target has been set to an annual increase of the CPI index of 2.5%, with a fluctuation band of +/- 1% to contain undesirable volatility of output and employment. The CNB started in 1998 an IT regime and since 2010 its annual inflation target is 2% with a band of tolerance of +- 1%. Finally, the MNB adopted an IT framework in 2001, and the target - revised every 3-5 years - since 2005 is set to a CPI annual increase of 3% with tolerance band of ±1% since 2015.

[7] Press statements are the best candidate for three reasons: i) they announce the actual policy decisions; ii) they are available to a large audience at the time they are released; and iii) the schedule and timing of the meetings are extremely precise, making it possible to accurately identify their effects on our variables of interest. The minutes are traditionally released two weeks after the actual meeting and are available for a shorter time span.

documents across time and to analyze their tone through different dictionaries; this allows us to derive five quantitative indices on the average tone of the textual communication across time and CBs: higher (lower) values of the indices signal a more hawkish/positive (dovish/negative) tone. We then use these quantitative indices to different aims. First, to assess whether, and to what extent, CB communication in CEE-3 economies can affect the predictability of monetary policy decisions by adding the tone index in a Taylor rule as a further argument beyond the classic inflation deviations and output gaps. Second, to evaluate whether the tone time series are able to shape the formation of inflation expectations of private sector agents – which is indeed crucial in determining the actual inflation outcome. Finally, to appraise the extent to which changes in CB tone can affect the reaction of market interest rates, from shorter to longer-term maturities, as well as stock market prices.

Our contribution to the literature is threefold. First, to our knowledge this is the first paper that analyzes both the *content* and the *sentiment* of CB communication in CEE-3 economies, comparing different lexicon techniques and their significance in the tone evaluation. Moreover, it provides a very comprehensive picture of the effects of CB communication on the conduct of monetary policy, the formation of inflation expectations of private sector agents and the reaction of financial asset prices. Finally, by extending the analysis to the most recent releases of the relevant documents, it assesses the perception surrounding the outbreak of the COVID-19 pandemic.

The main results of the analysis may be summarized as follows. First, we find that from 2008 to 2020 the information content of CBs' communication can be efficiently summarized in four or five relevant topics, related to the different global and idiosyncratic developments they went through in such time span: the 2008-09 global financial crisis (GFC) and its aftermath, including the euro area sovereign debt crisis; the deflationary phase that hit the monetary union after 2013 along with the reaction by the ECB; the domestic strong recovery phase prevailing between 2016 and 2019; the disruptions caused by the outbreak of the COVID-19 pandemic. Second we find that the time evolution of the five tone indices that we built appears to follow closely the topics prevailing in the communication of CBs in CEE-3 economies from time to time, i.e. lower values of the indices prevail in those periods characterized by topics describing a more adverse situation - like the 2008-09 GFC and the COVID-19 pandemic, and vice versa. Finally, using these tone indices as a further independent variable in a monetary policy reaction function (i.e. a Taylor rule), we find that a more hawkish (dovish) communication – signaling a more positive (negative) economic outlook and, hence, higher (lower) inflationary pressures – can help anticipating a more restrictive (more accommodative) monetary policy stance. In the same vein, a more hawkish/positive (dovish/negative) tone may be associated with higher (lower) inflation expectations by private sector agents and, by this channel, with higher (lower) interest rates and lower (higher) stock market prices.

The paper proceeds as follows: Section 2 reviews the different strands of the existing literature our paper is related to; Section 3 describes the techniques used to analyze CB communication and it reports the results in terms of topics and sentiment analysis; Section 4 provides evidence about whether, and to what extent, CB communication in CEE-3 economies is able to affect monetary policy decisions, inflation expectations and financial market variables; Section 5 concludes.

2. Related literature

A large number of theoretical and empirical studies have flourished recently to quantify CB communication strategies, to assess whether they may provide incremental information in explaining the dynamics of relevant macroeconomic and financial variables as well as to uncover the likely

channels through which such an impact actually unravels. In what follows, we will focus our attention only upon the specific strands of the literature our research intends to deal with.

A first branch of literature copes with text mining techniques and how they can be used to extract the topics and the tone from the vast array of documents published by CBs. The former exercise is performed by recurring to the algorithm provided by the LDA. In this regard, the seminal paper by Blei, Ng and Jordan (2003) suggests to model every document as generated by a combination of a given number of topics, each topic being a probability distribution over a vocabulary. Their algorithm allows to identify how much content of a given document (i.e. the frequency of words) is dedicated to a given topic. In other words, LDA allows to find clusters or "recurring patterns" of words in a large corpus of texts. As an example of usage of this algorithm in the central banking context, Hansen and McMahon (2016) study how the multi-dimensional aspects of the information released by the FOMC has effects on both market and real economic variables. Using LDA they extract topics and represent their content in word clouds in which the size of words is proportional to the probability they appear in the topic.

While topics are captured using LDA, the tone is usually quantified by means of dictionary approaches, i.e. by counting words characterized by a *positive* vs. *negative* connotations. Two main methods have been used in the literature. First, the CB tone can be coded manually following the narrative approach suggested by Romer and Romer (1989) to uncover the occurrence of monetary policy shocks. While manual classification is relatively easy to implement, it presents several drawbacks: first, manual scoring is by definition subjective; moreover, converting a document into a discrete class variable prevents from taking into due account the smooth evolution of communication; finally, except when data used for classification are publicly available, results are not easily reproducible, therefore limiting comparability. To solve these issues, another strand of the literature relies on dictionary-based or word-counting approaches.[8] Text mining techniques use computational tools and statistical methods to handle large raw and unstructured text databases and quantify their content. The big advantage of these methods is to be fully automated and replicable, removing the subjectivity of human-reading-coded indices. At the same time, the major challenge for measuring CB "waves of optimism and pessimism" is to convert the raw policy statements into quantitative data: to address the issue, "directional" word lists are typically used, with the aim to assign a *positive* vs. a *negative* connotation to the textual content of CB communication using pre-defined dictionaries. Against this backdrop, the extant literature has tended to rely upon three main sources of information. Loughran and McDonald (2011 and 2015; LM) build a vocabulary focused on economic terms selecting words appearing in at least 5% of 10,000 10-K filings compiled from 1994 to 2008.[9] Once selected, they divided manually the words in categories of interest, the most important for our scope being "positive" (354) and "negative" (2,355); the clear mismatch between the number of positive and negative words usually produces a bias toward negative values for this vocabulary. Apel and Blix Grimaldi (2012 and 2014, ABG) develop a dictionary to measure the tone of the minutes of the Sveriges Riksbank, providing a list of 55 two-word combinations classified as expressing a *hawkish* vs. *dovish* tone. Examples of the expressions inclined toward hawkishness (i.e. towards raising interest rates) include "strong growth", "higher inflation" and "increasing employment", while the list of expressions inclined toward dovishness (i.e. towards a more accommodative stance) includes expressions like

[8] A different approach, totally unsupervised and not relying on a vocabulary, was applied in Astuti *et al*. (2021).

[9] A 10-k is a report filed annually by publicly-traded company in the U.S. to comply with U.S. Securities and Exchange Commission rules.

"decreasing inflation", "weakening growth" and "low wages". Finally, Bennani and Neuenkirch (2017, BN) develop a dictionary to extract the tone of the public speeches given by ECB Governing Council members. Contrary to ABG, it contains single word lists again expressing the hawkishness vs. dovishness of the monetary policy course as conveyed by the texts analyzed. Examples of hawkish (dovish) keywords include: "accelerat*", "better", "boom*" ("collaps*", "contraction", "dampen*").[10]

A second branch of the literature to which our paper is related to aims to assess whether value-relevant 'soft information', extracted from the textual content of CB communication, can affect the predictability of prospective monetary policy decisions; the main methodology consists of adding a tone index into traditional Taylor rule models of both a backward- and a forward-looking nature. In these exercises, CB communication generally appears to be significant, i.e. it helps increase the ability to anticipate future monetary policy decisions, with a more hawkish (dovish) textual content hinting to a more positive (negative) economic outlook and, consequently, to a more restrictive (more accommodative) monetary policy decision at the forthcoming interest-setting meeting. In these models, CB communication appears to provide complementary, rather than substitutable, significant information to anticipate prospective monetary policy decision with respect to the standard set of macroeconomic explanatory variables, including lagged values of the reference rates. In a nutshell, words seem to be followed by deeds/facts. Therefore, it seems worthwhile for financial market participants to read central bankers' lips, as this adds information about upcoming interest rate decisions that is not provided by expected traditional inflation and output gaps. Rosa and Verga (2007) prove that including CB communication in traditional Taylor rule models helps to improve the forecasts of ECB interest rate decisions. Heinemann and Ullrich (2007) also add an ECB wording indicator in both a backward- and a forward-looking Taylor rule and find that it improves the predictability of interest rate decisions based on standard explanatory variables. Hayo and Neuenkirch (2010) believe that CB communication can enter a Taylor-type monetary policy rule since it complements the information contained in other more traditional macroeconomic variables. Sturm and De Haan (2011) verify that these results hold even when forward-looking indicators and interbank interest rates are taken into account. Tobback *et al*. (2017) insert a content-based indicator of the media perception of ECB policies into an extended Taylor rule and find a positive role for its communication in enhancing the accuracy of market expectations. Finally, Baranowski *et al*. (2020a) compute a tone shock uncorrelated to the prevailing macroeconomic and financial conditions and find that this orthogonalised shock is significantly and positively related to future ECB interest rates decisions, even when controlling for market expectations of economic conditions and monetary policy.

A third strand of the literature focuses upon the question of whether, and to what extent, CB communication affects private sector agents' expectations: assessing this impact appears to be all the more important in periods when the conventional monetary policy instruments cannot be effectively relied upon (having reached, for instance, the ZLB). Also in this case, the empirical literature has reached a common conclusion according to which enhancing communication to the public makes the management of private sector expectations easier. CB tone, in fact, appears to affect inflation expectations with a strength similar to interest rate changes; by providing regular information about its view upon the economic outlook, for instance, CBs can influence expectations of forward-looking agents well before official interest rates actually change (and even in the absence of such a change). Also in these models CB communication appears to be a complement to, rather than a substitute for,

[10] The BN dictionary contains 26 entries reflecting hawkish monetary policy and 32 dovish keywords; the symbol (*) is used to denote a wildcard representing any possible ending, including an empty one.

the main reference rates in monetary policy transmission. Neuenkirch (2012, 2013) estimates the impact of ECB communication on a set of economic variables, including money market rates, and find both that it affects inflation expectations in the same vein of unexpected interest rate changes, and that it reduces the bias in money market expectations. Hubert and Labondance (2017) find that optimistic FOMC tone increases private interest rate expectations primarily at the one-year maturity. Baranowski *et al*. (2020b) show that monetary policy shapes the expectations of the private sector through both communication and interest rate decisions. In particular, they find that a more hawkish tone of policy minutes pushes interest rate forecasts up. By signaling higher inflationary pressure, this raises inflation expectations. Interestingly, the tone of the policy minutes affects expectations more at the shortest horizons, while GDP and inflation projections play a greater role for slightly longer horizons. They also suggest that CB words and deeds are substitutes: in order to influence private sector expectations, CBs can select the mix of measures to use, for example replacing interest rate decisions with communication. Results related to forecast accuracy and dispersion among professional forecasts of financial and macroeconomic variables do not point to unanimous results: on the one hand, Pescatori (2018) finds that a more hawkish tone decreases inflation-forecast dispersion among professional forecasters; on the other hand, Lustenberger and Rossi (2020) find that when the size of communication exceeds some threshold it may decrease forecast accuracy, having been true especially in the aftermath of the 2008-09 GFC.[11]

A final set of papers faces the issue of whether CB communication matters for asset prices (and financial markets more broadly) as compared to actual monetary policy actions: Ben Bernanke's statement in opening his Brookings blog in March 2015 according to which "monetary policy is 98% talk and 2% action" suggests that it should. In this regard, there may be two possible channels at play: CB communication, in fact, can affect market outcomes through "creating news" that are incorporated and reflected in market prices, on the one hand, and through "reducing noise" that typically influence investors' uncertainty and market volatility, on the other hand. Conrad and Lamla (2010), for instance, analyze the impact of ECB communication on the EUR/USD exchange rate: following statements about rising (falling) inflation rates – which are perceived by market participants as a clear indication for increasing (decreasing) prospective official interest rates – the EUR appreciates (depreciates) against the USD. The impact of CB communication on market interest rates is the focus of the empirical exercises of Leombroni *et al*. (2021) for the ECB and Hansen *et al*. (2019) for the Bank of England, according to which a more hawkish (dovish) tone is able to generate a downward (upward) shift of the yield curve even after controlling for more traditional monetary policy shocks. Finally, the impact of CB communication on stock market returns and volatility is the focus of the works of Rosa (2011) and Gorodnichenko *et al*. (2021) for the US, Picault and Renault (2017) and Schmeling and Wagner (2019) for the ECB and Bennani (2019) for the People's Bank of China (PBoC). Unfortunately, the empirical results have led to quite opposing conclusions about the direction of the impact. In the case of the US, both deeds and words have statistically significant and economically relevant effects on the stock market: an unanticipated hawkish (dovish) statement, when the market expects a neutral statement, is associated with a decrease (increase) in equity indices. Moreover, statements appear to have a much greater explanatory power of the reaction of stock prices compared to more traditional monetary decisions. The opposite appears to hold for both euro area and Chinese stock markets, where hawkish (dovish) statements about monetary policy by the ECB or the PBoC are accompanied by an increase (decrease) in stock market indices and a reduction (increase) in volatility on announcement day. These

[11] They relate this result to the redundancy of information provided since the onset of the financial crisis, a sort of over-communication (by speeches, reports) that gives rise to cacophony and decreases the precision of forecasts.

competing results can be explained by the different answers that could be given to the following question: is CB tone providing information about the future likely policy path or about the future state of the economy? According to the first hypothesis, tone shocks convey a (complementary) signal about the prospective policy direction, so positive shocks increase interest rate expectations, working as a standard monetary policy shock which negatively affects inflation, output and stock market prices. According to the alternative hypothesis, sentiment shocks convey signals about prospective fundamentals, so positive shocks would increase inflation, output and, as a consequence, stock market developments. Since there is no theoretical rule or model that predicts one outcome or the other, the conclusion is a matter of empirical results.

3. Communication analysis: extracting the topics and the tone from CB texts

This section is dedicated to the analysis of the textual content of the press releases and minutes of the CBs in the CEE-3 economies. By means of NLP techniques, both a topic modelling approach and a sentiment analysis is carried out. The former aims to extract a combination of different topics from all documents, each topic being represented by a probability distribution over the vocabulary, while the latter assesses the average tone provided by a list of selected words in each document.

3.1 How do CEE-3 CBs communicate?

The modern view of CB communication suggests that central bankers prefer to err on the side of saying too much rather than too little. In this vein, CB communication takes many forms, from economic forecasts and official reports, to speeches, interviews, testimonies before governmental bodies, and policy statements and press conferences immediately after policy meetings.

Indeed, some economists and analysts have argued that modern central bankers talk too much, the primary claim being that more information increases the probability of market mispricing. There are at least two counterarguments to the market mispricing view. The first is that the price of an independent CB is a set of independent voices to insure against group think. The second counterargument is that the pricing of financial instruments in markets is more efficient with more, not less, information. Regardless, CB communication is important because individuals' economic decisions are based on expectations of future policies; thus, clear communication of its policies and actions may help a modern CB achieve its mandated goals.

Although views may differ, the fundamental principles of CB communication are founded on the dual notions that increased transparency enhances the effectiveness of policy and the accountability of policymakers in a democratic society. In this article, we focus on the communication of CBs of CEE-3 economies, though the principles and practices are similar among many of the world's CBs.

Against this backdrop, the primary methods that the CNB, the MNB and the NBP use to communicate to the public their assessments of the current state of the economy, their expectations of the prospective one and, finally, their monetary policy decisions include the policy statements released at the end of the monetary policy meetings and the minutes released after these meetings, along with speeches, testimonies and media interviews by members of the respective Boards. Given the prominence of the policy statements as a communication instrument, the discussion contained in this article will mainly focus on this channel.

The Board of the CNB discusses monetary policy settings eight times a year. In exceptional cases, it holds extraordinary meetings. On the day of the rate decision, the outcome is published on the CNB

website and presented at a press conference in the afternoon, in the form of a statement. The ratio of the votes cast and the reasons for the decision are disclosed along with the decision itself. The minutes of the Bank Board meetings are published on the Friday following the monetary policy meeting (eight days later). They present key arguments attributed to specific Bank Board members so the public can learn about the arguments made during the meeting. When a new forecast (on GDP or inflation) is available (typically four times a year), a Monetary Policy Report is published together with the minutes of the meeting. It describes the forecast, the baseline and additional scenarios, as well as monetary policy considerations. When a new forecast is not available, a graph of risks to the inflation projection (GRIP) is published to capture the effect of newly available information on the inflation and interest rate outlook.

The Monetary Council of the MNB meets twice each month, with every second meeting of the month designated as a policy-decision meeting. Shortly after the end of each monetary policy meeting, the decision of the Monetary Council is published on the MNB website and presented at a press conference in the form of a statement that is accompanied by a second document describing the interest rate conditions effective from that date up to the forthcoming decision. Also in the case of the MNB, the ratio of the votes cast and the reasons for the decision are disclosed along with the decision itself. The abridged minutes of the scheduled policy meetings are published with a delay of fifteen days (typically, on Wednesday). From 2011, an Inflation Report is prepared in March, June, September and December (two days after the Monetary Council's interest rate-setting meeting) describing the forecast, the baseline and additional scenarios, as well as monetary policy considerations.

The communication tools of the NBP are structured in a different manner. Its Monetary Policy Committee holds eleven decision-making meetings per year and, in exceptional cases, it may also hold extraordinary meetings. Shortly after the end of each meeting, the decision is published on the website and presented at a press conference. Contrary to the CNB and MNB examples, the minutes of the NBP are published with a much greater lag with respect to the corresponding decision making meeting – in a range between 20 and 40 days – and always overlap with the subsequent convention of the Committee. Three times a year (March, July and November) an Inflation Report is published, which contains an assessment of the inflationary processes and underlying determinants, a description of the monetary policy conduct during the last three months and a projection of inflation and GDP for the current and two subsequent calendar years. At the beginning of each fiscal year, the NBP presents the Monetary Policy Guidelines – containing a characterization of the external and internal factors conditioning monetary policy, policy targets and the instruments for achieving them – to the Sejm. Within five months after the end of each fiscal year, a Report on Monetary Policy is submitted again to the Sejm: the document discusses the performance against inflation targets, the development of targeted monetary aggregates and monetary policy instruments.

3.2 The data set used for analysing CEE-3 CBs communication

From each CB website, we downloaded the two main sets of documents pertaining to monetary policy, i.e. the press releases and the minutes of the decision-making meetings of the Board/Monetary Policy Council/ Monetary Policy Committee (MPC). For the NBP and MNB we considered the press releases available from January 2004 to March 2021; for the CNB, as statements of the press conferences were available in English only since 2014, we limited our analysis to the interval February 2014 – March 2021. Most of the CBs' press releases have a similar structure, with the announcement of the interest rates decision at the beginning of the document, followed by a brief description of the direction of the policy expected in the medium-term and a synthesis of the decision process that brought

to the updated outcome. In addition, every document specifies when the meeting was held, so that one can time precisely the effects of policy news. The minutes related to the monetary policy meetings provide a much more detailed description of the discussion between the Board members, with the discussion behind every choice exposed in a transparent way. Though being a richer source of textual information, minutes are not as timely as the press releases, since they are published at least two weeks after the monetary policy meetings.

We downloaded 196 press releases for Poland, 201 for Hungary and 60 for the Czech Republic. In addition, we downloaded 144 minutes for Poland (from December 2007 to December 2020), 194 minutes for Hungary (from December 2004 to February 2021), and 156 minutes for the Czech Republic (from January 2004 to March 2021). These numbers depend on the availability on the CBs' websites and on our need to be able to assign a publication date to every edition of the minutes, so that we can evaluate additional effects on economic variables after the publication of the press releases. Thus, we discarded the documents without a publication date because they are not useful for our analysis.

Press releases have an average length of 1,029, 562 and 843 words for the Czech Republic, Hungary and Poland, respectively. Minutes are generally longer documents: for the Czech Republic they have an average length of 1,153 words, closer to that of the press releases, while for Poland and Hungary they have an average length of 1,761 and 2,254 words, respectively. For ease of reference, we summarize the statistics of the dataset in the **Tables 1** and **2**.

3.3 Topic analysis

Topic modelling aims at summarizing the information contained in a corpus of documents with a smaller set of prevailing topics; in other words, its purpose is to list the main topics covered in each document. For a human reader it is quite easy to identify the main themes of a text (at least if she/he is familiar with the subject covered) and to extract a set of keywords representing the content in a synthetic way. It seems much more difficult to translate this process into an algorithm, because of the blurred definition assigned to concepts like "topic" and "keyword". On the other hand, for *corpora* containing many documents the process would become very time-expensive without an automatic algorithm.[12] In order to address this problem, many NLP approaches were conceived to summarize the information provided by a large body of text. The underlying idea is that words carry strong semantic information, and documents discussing similar topics have to use similar sets of words. One of the most used approaches is LDA, pioneered by Blei, Ng and Jordan (2003), which allows discovering latent topics in a set of documents by identifying groups of words that consistently occur together. It is an *unsupervised learning* algorithm, meaning that it is not necessary to instruct the algorithm on how to select the topics contained in a set of documents. It automatically defines a set of topics by optimizing its performance in terms of prediction of the content of new documents. Specifically, the training of the algorithm aims at maximizing the probability of predicting the words contained in each document.

Every corpus has an associated vocabulary, consisting of all the words used at least in one document. Using each word in the vocabulary as a basis vector of a linear space, we can represent every document as a V-dimensional vector, where V is the dimension of the vocabulary and each component of every vector is the number of times the associated word is used in the given document. This is the so-called *bag of words* (BoW) representation. In a corpus consisting of many documents, the number of dimensions of this vector space can easily reach the hundreds of thousands; moreover,

[12] *Corpora* are ensembles of documents, usually sharing a common main theme, or a common source.

it will usually be a very sparse space, in that every document usually makes use of only a very small fraction of the vocabulary. Therefore, it is very useful to reduce the dimensionality of this representation, without losing much information, through a process called *pre-processing*. This process consists of a set of operations to standardize the text of a document: text normalization (i.e. removal of capital letters), *stop-words* removal (considering as stop-words function words like articles, pronouns or auxiliary verbs) and frequency-based filtering (for instance, we removed words appearing in less than 3 documents and in more than 90% of documents).[13] One of the issues of the BoW representation is that the concepts of proximity and order in a text are lost: for any two words in a document, it is not possible to know whether they are one next to the other and in which order they appear. To partially fix this limitation, it is possible to consider also frequent bi-grams,[14] for instance "monetary policy" as a single meaningful object in addition to the two words "monetary" and "policy".

To obtain a description of every document in terms of its topic, LDA describes the process of creation of each document as a random extraction of words from a given probability distribution. The basic assumption is that every document is composed of a statistical mixture of topics, and each word of the vocabulary is assigned to each topic with a given probability. The input of the generative model are the number of topics k = 1, 2, 3, …, K, the number of documents d =1, 2,.., D, and the number of words N_d for each document. In deciding the first word of the first document, the generative model extracts one of the K topics with a probability distribution $P_d(k|\theta)$ depending on the document and on some unknown parameters θ. Once a topic is selected, the model will pick a word w from the vocabulary with a probability distribution $P_k(w|\theta)$ dependent on the topic. The same operation is repeated until all the N_d words of the document are generated. In terms of this process, each document can be seen as a probability distribution over topics, which in turn are probability distributions over the vocabulary. To extract the pertinent topics from a given set of documents, we search over the space of parameters θ of the generating process in order to maximize the likelihood to obtain the observed documents. After the optimizing parameters θ are found, each topic is characterized by its probability distribution $P_k(w|\theta)$ over the vocabulary. It is a *latent variables* model, because the topics are never directly observed but only inferred in order to maximize the algorithm's ability to model the documents in the corpus. Usually, the parameter used to gauge the algorithm performance is the so-called *perplexity*, defined as the log-likelihood for the prediction of a document, divided by the number of words of the document. The outputs of the model are the topic composition of every document in the corpus and the word content of every topic (in terms of probability of appearance of each word). We show the topic distribution over time and the relative content in the form of a word-cloud for each of the topics detected from the analysis of the minutes: compared with press releases, in fact, the minutes seem to provide a clearer array of arguments and cluster of words, probably because they are more descriptive and detailed in nature.[15] Applying our model to the minutes of the three examined CBs, we obtained a perplexity of -6.9 with 4 topics for the NBP, a perplexity of -6.9 with 4 topics for the CNB and a perplexity of -7.2 with 5 topics for the MNB. The values are in line with the ones found in the literature for specialized texts.[16]

[13] As an example of text normalization and stop-word removal, the sentence "The discussion at the meeting focused on current inflation developments and the outlook for economic growth" can be restricted from 15 to 9 words: "discussion, meeting, focused, current, inflation, developments, outlook, economic, growth".

[14] An *n-gram* is an expression composed of *n* consecutive words.

[15] For reasons of space, results from press releases are not reported but are available upon request.

[16] For example for NBP documents a prediction of the model for a document composed of N words has a probability $P_N = exp(-6.9\ N)$ to output all the correct words.

We start our analysis from the NBP, for which we are able to detect four topics (**Chart 1**). The first topic prevailed in the time span 2008-2011, which we relate to the onset and the aftermath of the 2008-09 GFC. The associated word-cloud, in fact, suggests that in those years the NBP focused its communication and debate on the financial consequences of the crisis, in particular on the depreciation of the zloty exchange rate and on the tightening of lending and credit conditions (**Chart 2.a**). The second topic – that we call "post-GFC" – prevailed from 2012 to 2016, when the crisis in the euro area became real in nature involving strong risks of deflation. The NBP communication summarized in the word-cloud appears to change consistently (**Chart 2.b**), focusing more on the real side of the economy – in particular on the dynamics of the labor market – and putting more emphasis on global dynamics, such as the easing measures adopted in the euro area, when the ECB started its asset purchase programs in 2015. The third topic prevailed between 2016 and 2019, when Poland experienced a strong growth related to the gradually reducing slack in labor markets and the positive impact on domestic consumption, which benefited from the expansionary policies in the euro area. This phase of robust recovery is reflected in NBP communication as summarized in the word-cloud where words like "recovery", "favorable", "employment", "consumer" appear to be logically related (**Chart 2.c**). Finally, the fourth and last topic clearly concentrated in the last part of the sample, coinciding with the outbreak of the COVID-19 pandemic that prompted a cut of policy rates and an easing of fiscal measures on the backdrop of a lingering move towards de-globalization (**Chart 2.d**).

Also CNB minutes are characterized by a set of four topics, which however overlap more when compared to the case of Poland (**Chart 3**). The first topic is still prevailing in the period preceding and immediately following the GFC, but in the same period other topics are present as well. As regards its content, before 2008 the Czech economy experienced growth and inflation, thus CNB communication appeared quite balanced, containing some terms related to positive economic trends (**Chart 4.a**). The second topic prevailed both in the time span 2011-13 and in 2017-19, featuring an economic recovery and an accelerating inflation driven, on its turn, by a depreciating exchange rate and strong wage pressures in the labor market (**Chart 4.b**). From 2013 to 2017, the Czech Republic experienced a long period of deflation accompanied by rates close to ZLB, and the CNB decided to intervene in the foreign exchange market to stimulate the depreciation of koruna and to avoid a deflationary spiral; the communication reflected this new stance (**Chart 4.c**). Finally, since 2020 also the CNB communication focused on the effects and the responses to the pandemic (**Chart 4.d**).

In Hungary, our LDA analysis detected five topics (**Chart 5**). The first one prevailed before and during the GFC period, and it was characterized by a particular focus on exchange rates dynamics (**Chart 6.a**), while during the post-GFC the communication switched towards signaling the risks related to the forint depreciation, banking crisis (with recapitalization needs) and lingering debt problems (**Chart 6.b**). Between 2014 and 2016, deflationary trends and concerns about economic growth appear to have dominated MNB communication (**Chart 6.c**); the two year period 2017-18, on the contrary, was characterized by an overall positive communication, which pointed to the recovery in real growth and inflation favored by a looser monetary policy (**Chart 6.d**). Finally, the outbreak of the COVID-19 shock and its adverse effects became the main topic for the MNB from 2020 to present (**Chart 6.e**).

3.4 Sentiment analysis

One of the most consolidated techniques of text analysis is the extraction of the "mood" expressed in a given document. This was one of the first tasks assigned to a text-mining algorithm and it is still one of the most straightforward in its most basic form. We use a *vocabulary-based* (or *rule-based*)

approach, which consists in selecting a set of words or expressions and assigning them a sentiment score, usually equal to +1 for a "positive" mood and to -1 for a "negative" counterpart. Positive and negative words are then counted to assign an overall score (or an overall mood) to every document at hand. The absolute value of the sum of single-word scores grows (on average) linearly with the length of the document; thus, in order to avoid length-related effects, we have to normalize the scores. There are different possible choices for the normalization; one of the most common choice is to divide the sum of the single-word scores by the number of words considered in the sum:

$$S_i{}^v = \frac{1}{N_i{}^v} \sum_w S_w^v \tag{1}$$

where $S_i{}^v$ is the score of the document i evaluated with the vocabulary v, S_w^v are the scores assigned by the vocabulary v to every word w in the document, and $N_i{}^v$ denotes the number of words present both in the document i and in the vocabulary v. This normalization implies that the document score is the average of the scores of the words composing it. However, we lose part of the information about the overall tone of the document. For example, we may assign the same negative tone either to a document in which every word has a very negative score, or to a document in which most of the words are neutral, but the few ones carrying a tone have a negative one. To solve this issue we use a different normalization for the document's sentiment score: instead of dividing the sum of the scores by the number of words carrying a sentiment score (i.e. words in the document which are found in the vocabulary under consideration) we divide the sum by the length of the document i, denoted with L_i:[17]

$$s_i{}^v = \frac{1}{L_i} \sum_w S_w^v \tag{2}$$

The choice of the vocabulary of words to consider is driven by the features of the text to examine: in particular, we can consider either a "generic" tone for words of common use, or a "specialized" one relying on technical words or words characterizing a particular field. In our case – since we are focusing on texts with an economic meaning such as press releases or minutes – we adopt a vocabulary specialized in this field. Our starting point is the set of well-established vocabularies in the economic and financial literature anticipated in Section 2, i.e. the LM, the ABG and the BN dictionaries. A digression on the ABG dictionary appears to be necessary at this point. When applied to our data set, it appears to be very noisy, frequently assuming the two extremes 1 and -1, the reason being that the exact combinations defined in the ABG vocabulary are very rare compared to the single words of the LM or other vocabularies. To overcome this problem, we modified the ABG algorithm by considering word contexts (e.g. "wages are increasing") instead of exact combinations (e.g. "increasing wages"): for every noun in the ABG list (like "wages"), we considered the three preceding and subsequent words and counted the number of times that "hawkish" or "dovish" adjectives (like "increasing") appeared in the window. This may involve a slight sacrifice in the precision of the index in the face of gains in the smoothness and significance of the results.[18] In addition to these three sentiment indices based on economic language, we also added a fourth one built by means of a more generic dictionary (Hu and

[17] This normalized index will be comprised between 1 and -1 as well, but compared with the previous one, will have smaller absolute values because of the larger denominator.

[18] In other words, a score of 1, obtained for one hawkish combination only and zero dovish, is less reliable than a score of 0.8, obtained thanks to 9 hawkish and 1 dovish expression.

Liu 2004, HL), composed of more than 2,000 positive and almost 5,000 negative words as used in the common English language.[19]

In order to smooth the peculiarities of any of these indices and to avoid to assign extreme values to documents with few significant words, we built a fifth index, labelled as Global and calculated as a "consensus" weighted average of the tones extracted from the previous vocabularies. In particular, we considered an average of the sentiment scores evaluated with the standard normalization (the number of words found both in the document and in the vocabulary) with weights proportional to the number of words of the given vocabulary found in a document. As we already pointed out, in fact, the reliability of each score is higher with more expressions found in the documents analyzed: while a single occurrence of a positive or negative expression can be caused by chance or can be misinterpreted, finding many of them more likely reflects the positive or negative tone of the document. Thus, it seems meaningful to assign a greater significance to an index that is able to find in each document more occurrences of positive and negative words. As a consequence, the weights in the average index are defined as:

$$W_i{}^v = \frac{N_i{}^v}{L_i} \tag{3}$$

where $N_i{}^v$ is the number of words in the vocabulary v found in the document i, and L_i is the length of the document i. With such a normalization the value of each of the average index is:

$$G_i = \sum_v W_i{}^v S_i{}^v = \frac{1}{L_i} \sum_v \sum_w S_w^v = \sum_v s_i{}^v \tag{4}$$

This is obviously equivalent to considering the sum of the single sentiment scores already normalized with the length of the document. Thus, we have the same normalization for the single indices and the average one (both are weighed with a factor inversely proportional to the length of the document under consideration, and give scores with higher absolute values for documents in which a large fraction of words carry a non-zero sentiment score).

For each of the three CBs, we compare the five sentiment indices derived from the press releases.[20] As a general observation, in each country they appear all positively correlated with each other. In particular, the two tone indices calculated from vocabularies built to capture the language of CBs (BN for the ECB and ABG for the Riksbank) are more correlated with each other; as well, the two indices based on more common words (HL, LM) appear to be more correlated with each other. Another observation is that, as expected, the LM index shows a slight negative bias due to the greater number of negative words in the associated vocabulary.

Entering into the details of the dynamics of the tone of the three CBs, we notice that for all of them the sentiment indices reflect quite closely the topic distribution and the word content we analyzed in the previous paragraph. More specifically, in the case of the NBP (**Chart 7**), the tone became mostly negative in correspondence with the outbreak of the 2008-09 GFC, reaching a trough in 2012-13

[19] This vocabulary is available in the text mining Python library Natural Language Toolkit (NLTK).

[20] We have also calculated the corresponding indices stemming from the minutes, which are qualitatively similar to the ones reported in the text. Results are not reported here for the sake of brevity but are available from the authors upon request.

corresponding with the peak of the euro area sovereign debt crisis. Afterwards, it started to recover gradually and turned clearly positive from 2017 onwards, reaching a maximum in 2018-19 consistently with the phase of robust recovery documented in the topic analysis. In 2020, it collapsed again into negative territories due to the disruptive economic consequences of the COVID-19 pandemic, as reflected by the last topic. In the Czech Republic (**Chart 8**), the tone was mainly negative in the time span 2014-2016, consistently with the deflationary worries showed in the topic analysis. From 2017, it started improving in line with the recovery of the domestic economy, before collapsing again with the pandemic shock in 2020.[21] Finally, in Hungary (**Chart 9**) the MNB tone deteriorated following the 2008-09 GFC, to recover gradually and turning positive in 2017. Unlike the other two CBs, the calculated tone of the MNB appears to have a less negative bias during the COVID-19 period.[22] Finally, comparing the sentiment indices across the three CBs (**Chart 10**) we notice that they are also positively correlated with each other, especially those calculated for the NBP and the CNB (0.62); instead, the tone of the MNB appears to depart from its CEE-3 peers (the unconditional correlation is 0.51 with the tone of the NBP and 0.29 with that of the CNB).

4. The impact of CB communication

The goal of this Section is to analyze whether, and to what extent, the indices of tone – through their more hawkish/positive or dovish/negative inclination over time – may improve the predictability of monetary policy, influence the formation of private sector inflation expectations and affect the reaction of financial asset prices.

4.1 Monetary policy decisions

To study whether and how CB communication – captured by the indices built from the lexicon used in the press statements following the interest rate setting meetings – may help to predict forthcoming monetary policy decisions, we add the different indices of communication to the traditional explicative variables in a typical reaction function, which assumes the form of an augmented Taylor rule. The underlying idea is that CB communication, by influencing private sector expectations, may improve the predictability of monetary policy.

The calculated sentiment indices convert a qualitative content into a quantitative indicator in order to catch two relevant assessments by the CB: on the economic outlook (positive vs. negative); on the monetary policy stance (i.e. hawkish vs. dovish). In other terms, the tone indices are supposed to summarize both a backward-looking and a forward-looking dimension of the CB communication: the former is the assessment of the observed state of the economy; the latter is the assessment of its future evolution and, consequently, of the intended monetary policy reaction (hawkish vs. dovish). In traditional Taylor rule models, these backward- and forward-looking dimensions are captured, respectively, by past observations on economic data (inflation, output and exchange rate gaps) and by CB projections or private agents' expectations. The tone indices add new insight on both dimensions: a higher (lower) value of the index signals a prevalence of a textual content characterized by a positive

[21] Even if not reported in the text, the sentiment index extracted from the minutes (available since 2003), show that the CNB tone was negative during the GFC, like for the other two countries analyzed. Details are available from the authors upon request.

[22] Apparently, Hungary has developed a more rapid vaccination campaign in 2021; nevertheless, in 2020 it suffered from a higher number of fatalities compared to other countries. So, it is difficult to associate the more optimistic tone to a lower economic impact of the pandemic rather than to a different communication strategy by the MNB.

(negative) assessment of the economic outlook and a hawkish (dovish) tone by the CB. In turn, we expect that this anticipates a more restrictive (accommodative) decision at the next monetary policy meeting, therefore a positive relationship with policy rates: hence, the more hawkish/positive (dovish/negative) the tone, the higher (lower) the future policy rates.

Following the existing literature, we estimate two kinds of Taylor rule with data at monthly frequency:

$$i_t^{CB} = \alpha + \beta_1 i_{t-1}^{CB} + \beta_2(\pi_t - \pi^*) + \beta_3(y_t - y^*) + \beta_4(e_t - e^*) + \beta_5 s_{t-1} + \varepsilon_t \quad (5)$$

$$i_t^{CB} = \alpha + \beta_1 i_{t-1}^{CB} + \beta_2(\pi_t - \pi^*) + \beta_3(y_t - y^*) + \beta_4(e_t - e^*) + \beta_5 \pi_{t+12}^{cf} + \beta_6 y_{t+12}^{cf} + \beta_7 s_{t-1} + \varepsilon_t \quad (6)$$

Equation (5) adds tone indices to a backward-looking Taylor rule. The policy rate i_t^{CB} is regressed on: i) its lagged term, to control for the smoothing of monetary policy; ii) the inflation gap $(\pi_t - \pi^*)$, defined as the difference between the rate of inflation available at the time of the MPC meeting and the inflation target;[23] iii) the output gap $(y_t - y^*)$, measured by the difference between the industrial production data available at the meeting and its long-period trend calculated using a Hodrick–Prescott filter;[24] iii) the exchange rate gap $(e_t - e^*)$, measured by the difference between the monthly nominal spot exchange rate against the euro available at the meeting and its long-period trend (still calculated by a Hodrick–Prescott filter); and iv) the index of tone at the press statement of the previous meeting s_{t-1}. Equation (6), instead, describes a forward-looking Taylor rule, in which we add expectations of inflation and growth by financial analysts, proxied by the monthly series of the 12 months-ahead Consensus Forecast for both variables available at the meeting.[25] If communication is able to convey relevant information beyond that stemming from the other regressors, we would expect a positive coefficient attached to the tone variable s_{t-1}: a more hawkish (dovish) communication or a more optimistic (pessimistic) economic outlook will be associated with a restrictive (accommodative) monetary policy decision at the following MPC meeting. We compare the estimation results obtained by resorting to each of the five different indices of communication shown in the previous section: the HL, LM, BN, ABG and a "global" index (a weighted average of the previous ones). Regarding the dependent variable, in line with the literature we consider a discrete transformation of policy rate changes, estimating an ordered probit model with six different possible outcomes: -3 (corresponding to a 75 bps cut or higher); -2 (50 bps cut); -1 (25 bps cut or lower); 0 (policy rate unchanged); 1 (25 bps increase); 2 (50 bps increase).[26]

[23] We consider the last publication of the ICP inflation before the monetary policy meeting date. To account for publication delay, we consider the ICP data with a one-month lag.

[24] Again, we consider the last release of industrial production before the meeting and, to account for publication delay, we consider the IP data with a one-month lag. The smoothing parameter in HP filter is set to 14,400.

[25] We use Consensus Forecast because inflation projections at monthly frequency are not available for each CB. Our 12 month ahead series is built from the original Consensus Forecast for the current and next year by weighing the number of months ahead for each forecasting year. Since the series is published usually every third week of the month, we consider the latest data available at the moment of the monetary policy meetings of each CB.

[26] Baranowski *et al*. (2020a), Picault and Renault (2017), De Haan and Sturm (2011) apply the same methodology for the ECB choosing only three values for the dummy (-1, 0, +1) indicating respectively a cut, an unchanged rate and a hike, because they barely find a change higher than 25 bps. We prefer to distinguish between 75, 50 and 25 bps changes for the CEE-3 countries under examination because they occur more frequently. The observed variable i representing ordered or ranked categories is modelled as a latent variable i* that depends linearly on the explanatory variables.

We first estimate the model for the three countries separately. **Table 3** reports results for the NBP, with data ranging from March 2003 to March 2021, with the dependent variable indicating discrete changes of the policy rates and the independent variables taken either in levels or in first differences if we detect the presence of a unit root in the series.[27] In both standard backward- and forward-looking Taylor rules the main coefficients are statistically significant with a positive sign, as expected: interest rate smoothing is present; the higher the changes in inflation and the level of the output gap, the larger the probability that the NBP would raise the policy rate at the forthcoming meeting. On the contrary, exchange rate deviations do not appear to be significant in both specifications. In the forward-looking specification, consensus forecast appear to be significant for inflation expectations only. When the different indices of tone are added to the explanatory variables, they result significant and positive: a more hawkish/positive (dovish/negative) communication is associated with a higher probability of an increase (decrease) in reference rates at the forthcoming MPC meeting.[28] This is particularly true for the BN and ABG indices (their coefficients being higher and more significant), likely reflecting their ability to capture the hawkish/dovish inclination of NBP's tone better than the HL and LM ones. Finally, other explicative variables remain significant, although they reduce slightly their impact (past interest rate, inflation gap and expectations). To give an economic intuition of the estimated coefficients related to the sentiment index, we calculate the average marginal effects: the coefficient of the 'global' sentiment index in the last column of **Table 3**, for instance, indicates that one standard deviation increase (decrease) would raise (lower) the probability of a rate hike in the next monetary policy meeting by 3.4 (3) percentage points.

The results for the CNB are presented in **Table 4**. In the baseline model, with data ranging from January 2003 to March 2021, all independent variables are significant including the nominal exchange rate gap, with a depreciation anticipating an interest rate hike by the CNB. This outcome may be also related to the decision adopted between 2013 and 2017 to maintain an asymmetric floor on the koruna exchange rate as an exceptional tool to achieve further monetary policy easing when interest rates reached the lower bound. Inflation expectations are significant in the forward looking specification, while past inflation does not. As regards the tone indices, those obtained from press releases are only available from 2014 and the sample for estimation would shrink from 166 to 59 observations. To get better insights on the existing relationships, we replace the indices obtained from the press releases with those stemming from the minutes of the monetary policy meetings, which are instead available from 2003 onwards (although are published two weeks after monetary policy meetings). Against the backdrop of this new estimation set up, the BN and ABG indices are significant together with the global one, while the other explicative variables maintain significant with the expected sign. We find that one standard deviation increase (decrease) of the global sentiment index would raise (lower) the probability of a rate hike in the next monetary policy meeting by 3.4 (2) percentage points.[29]

Results for the MNB, with data starting in January 2004 until March 2021, are reported in **Table 5.** In the baseline model, all variables are significant. Like for the Czech Republic, inflation expectations in the forward-looking specification are strongly significant, while past inflation becomes not significant, as if the two variables were substitutes at some extent. When tone indices are introduced

[27] This is consistent with most of the literature (Hayo and Neuenkirch, 2010; Bennani, 2019).

[28] The interpretation of the estimated coefficients is not straightforward because in probit models they do not represent the marginal contribution of independent variables on dependent one, as in linear regressions. Their sign shows the direction of the change in the probability of falling in the endpoint rankings when the associated explicative variable changes.

[29] If we estimate the restricted sample of 59 observations with tone indices from press releases, we get that only the BN and ABG ones are significant, while other explanatory variables are not (results available on request).

in the regression, only the ABG one turns out being significant. In line with the other two countries, this is the index that better captures the orientation intrinsic in a CB communication. Average marginal effects indicate that a one standard deviation increase (decrease) of this sentiment index would raise (lower) the probability of a rate hike in the next monetary policy meeting by 1.3 (7.1) percentage points.

Finally, we test our conjecture in a panel set-up.[30] The estimation results of the ordered probit are presented in **Table 6**, which show that most variables are significant and with the expected signs, included the tone indices, especially those built from BN and ABG dictionaries. To give an idea of the economic impact, a one standard deviation increase in the global index (last column) raises (lowers) the probability of a rate hike in the next monetary policy meeting by 1.7 (2.6) percentage points; the ABG index, which results the most significant, indicates that one standard deviation increase raises (lowers) the probability of a rate hike in the next monetary policy meeting by 2.9 (3.9) percentage points. We also estimate a panel least square (results available from the authors upon request): although the whole significance is lower, the tone index from the BN dictionary is positively correlated to the policy rate. Fixed country effects suggest that in the Czech Republic reference rates are on average lower than in the other two countries, while time effects show a negative bias of policy rates in 2015-2016 (deflationary period in all economies akin in the euro area) as well as in 2020 (Covid shock), and a positive bias in 2018-19 (period of recovery and positive inflation in all the countries examined). Overall, the estimation in a panel setting – both with a probit and a least squares procedure – would tend to confirm the results obtained by individual country models: tone indices are indeed able to anticipate prospective monetary policy decisions in CEE-3 CBs, this conclusion being especially true for those which are derived from dictionaries built to better capture and interpret the CB stance.

Results have been submitted to robustness checks. On the one hand, individual-country ordered probit models have been replaced by individual-country OLS ones. On the other hand, tone indices derived from press releases have been replaced by those derived from MPC minutes. Results of these tests, available from the authors upon request, tend to confirm our main empirical findings: tone indices derived from the communication of the CBs in CEE3 economies play a role in anticipating monetary policy decisions, especially those based on dictionaries specifically designed to capture the language and terminology traditionally used by modern CBs. Overall, we confirm the conclusions of the literature according to which information conveyed at the press conferences following monetary policy meetings is an effective and complementary instrument to other traditional ones in the toolkit of CBs.

4.2 Inflation expectations

Turning to the impact of CB communication on private sector inflation expectations, empirical findings in the literature have diverged, with evidence of either an increase or a decrease of inflation expectations to a positive sentiment index. Hubert and Labondance (2017), for instance, find that a positive tone shock from the Fed negatively affects long-run inflation expectations, while it does not significantly move expectations at shorter horizons. The rationale is that inflation expectations at longer horizons are influenced by agents' perception about inflation risks and CB inflation objective, while at shorter horizons they are more affected by macroeconomic developments; thus, a hawkish/positive tone is interpreted as hinting to more contained long-run inflation risks or CB inflation objective,

[30] In such a case, we prefer to use tone indices from press releases for all CBs, therefore we estimate a balanced sample starting from 2014 (190 observations) and an enlarged sample starting from 2004 (498 observations), that is unbalanced because tone indices from the CNB are only available since 2014.

reducing inflation expectations. In contrast, Baranowski *et al*. (2020) find that a positive tone shock increases inflation expectations at very short horizons (1 or 2 quarters), the rationale being that it is perceived like a positive inflation surprise signaling rising inflationary pressures. To some extent, these opposite results are related to the different weights agents attribute to the information conveyed by the CB tone: if the signal about the policy path prevails, then a hawkish tone raises interest rate expectations and lowers expected inflation, akin to a standard monetary policy shock; if, on the contrary, the signal about the current state of the economy prevails, then a higher tone is associated to positive fundamentals and increases inflation expectations.

In the case of CEE-3 economies, we estimate the response of monthly inflation expectations for both the current (*y*) and the next year (*y+1*) to our set of communication indices. The dependent variable is measured by the forecasts gathered by Consensus Economics, the series of which are available for CEE-3 countries since 2000.[31] In line with the literature (Baranowski *et al.*, 2020b; Hubert and Labondance, 2017; Jung and Kuhl, 2021),[32] we add a set of control variables: the lagged value of dependent variable $\pi_{t-1}^{CF,y}$ and the latest available level of both the policy rate i_t^{CB} and the inflation rate π_t. Hence, the two equations to be estimated are the following:

$$\pi_t^{CF,y} = \alpha + \beta_1 \pi_{t-1}^{CF,y} + \beta_2 i_t^{CB} + \beta_3 \pi_t + \beta_4 s_t + \varepsilon_t \quad (7)$$

$$\pi_t^{CF,y+1} = \alpha + \beta_1 \pi_{t-1}^{CF,y+1} + \beta_2 i_t^{CB} + \beta_3 \pi_t + \beta_4 s_t + \varepsilon_t \quad (8)$$

We estimate the two equations for the three countries together relying on panel least squares. We take variables either in levels or in first differences to make them stationary,[33] and we consider the period from January 2014 to March 2021 to consider a balanced sample (since tone indices from press releases from Czech Republic start from 2014). **Table 7** reports the results for the consensus forecast of inflation for the current year. As expected, changes in private sector inflation expectations are positively affected by changes of realized inflation, while they do not result related to the policy rates. As regards the tone indices of the CEE-3 CBs, they are significant and positive in explaining consensus forecast of inflation, especially the HL and LM ones that are more related to the general state of the economy. The underlying intuition is that a higher tone index signals a positive assessment of the state of the economy by the three CBs or a favorable phase of the economic cycle, which may foster inflationary pressures (maybe through stronger wage pressures) and lead to raise private sector expectations in the short-run.[34] Finally, country fixed effects signal that on average inflation expectations by financial analysts are higher in Hungary than in the other two countries.

As regards the consensus forecast of inflation for the next year, **Table 8** signals that goodness of fit is lower and tone indices are not significant: inflation expectations at longer horizons are not sensitive to tone indices and are less sensitive to realized inflation too. This outcome seems to suggest

[31] Measures of inflation expectations surveyed by the central banks are available continuously only for the Czech Republic.

[32] Baranowski *et al*. (2020b) also add surprise components of monetary policy and CB projections, while Jung and Kuhl (2021) include monetary policy shocks.

[33] We use the Levin, Lin and Chu test to check for joint stationarity: the dependent variable given by consensus forecast for inflation results to be not stationary, so we take it in first differences.

[34] As explained before, this result, which may appear at first sight counter-intuitive if we believe that a hawkish stance by the central bank should signal future interest rate hikes and possibly reduce expected inflation (Bottone and Rosolia, 2019), depends on the prevailing interpretation of tone indices: the assessment of a positive economic outlook in the short term prevails on the future intentions by the CB, going to raise inflation expectations.

that inflation expectations are more stable for longer horizons, a feature that in the literature has been associated to a higher credibility of CBs.[35] But it has to be cautioned that the lower sensitivity of longer-term expectations may also be related to the fact that next year forecast are updated more slowly than current year's one.

For robustness check, we also repeat the panel estimation with all variables in levels, and confirm all the results: tone indices affect positively inflation expectations in the current year but not in the next one. We also repeat the regression on a country-by-country basis: in this set up, we find for Poland very similar results to those shown in the panel, while tone indices are somewhat less significant for the Czech Republic and Hungary.

Overall, our analysis shows that sentiment indices by CBs may have a role in shaping inflation expectations by financial analysts, although less significant compared with the influence on monetary policy decisions. The results we find in this section are in line with those reported by Baranowski *et al*. (2020b), who also find for Poland that tone shocks by the NBP have positive effects on inflation expectations at very short horizons (1 quarter), while they are not significant for inflation expectations above 2 quarters. Our outcome is that a hawkish/positive tone raises inflation expectations in the short-term (current year implies on average two quarters), the interpretation being that it conveys a message about a positive economic outlook and the potential arise of inflationary pressures. Instead, inflation expectations for the next year (on average six quarters) appear not to be responsive to tone indices, suggesting that the former become less sensitive to macroeconomic developments and more stable, in line with cited analyses in the literature.

4.3 Asset prices

To estimate the effect of CBs tone on interest rates and stock prices we use a high frequency methodology, such as in Kuttner (2001) and Cochrane and Piazzesi (2002), which consists in focusing on movements in asset prices in a narrow window around the MPC meeting. The papers closest to ours are those by Schmeling and Wagner (2019) and Bennani (2019), which use similar computational linguistics techniques to measure the tone of the statements of the ECB and the People's Bank of China, respectively, and to show their impact on the term structure of interest rates and stock market returns. The main difference with the existing literature lies on the fact that such a high-frequency approach is performed in a panel setting with country-fixed effects.

As anticipated, to explore how changes in the tone of the CBs in CEE-3 economies may affect domestic financial asset prices, we need to compute price changes around the dates of the press releases. The key idea behind this choice is that any price reaction in a short time window would likely to be caused by the information contained in, and conveyed by, the press conference itself once changes in reference rates occurring on the same day, as well as of other potential determinants of financial asset prices, are appropriately controlled for in the estimation procedure. The release of the press conference itself, in fact, may reflect the CB intention to manage market expectations or to guide market reactions in a certain direction. To evaluate the immediate impact of CB communication on asset prices at day t in country i, we compute the one-day changes using the closing prices of the day

[35] Gürkaynak *et al*. (2006); Cristadoro and Veronese (2011); Dovern *et al*. (2012); Kabundi and Mlachila (2019).

preceding the speech and the day in which the speech takes place. Speech-day changes are denoted by $ri,_t$, while the impact on them stemming from changes in tone $d\_s_{i,t}$ is estimated as follows:

$$r_{i,t} = \alpha_i + \beta_i d\_s_{i,t} + \gamma X_{i,t} + \varepsilon_{i,t} \quad (9)$$

where α_i is a country-specific constant, β_i captures the effect of changes in the tone of CB communication in country i, $X_{i,t}$ is the vector of the other control variables that may affect the behavior of financial asset prices and $\varepsilon_{i,t}$ represents any other pricing factors affecting the financial variables – such as revisions of the implicit short-term interest rates, term- and risk-premia and so on – not explicitly taken into account in the model regressions.

To explore the effects of communication on market interest rates, we use several daily data related to the yield curve: in particular, we consider both government bills (at 3- and 6-month maturity) and government bonds (at 1-, 5- and 10-year maturities). As regards the impact on stock markets, we take into account the closing prices of the Warsaw Stock Exchange Index (WIG), the Budapest Stock Exchange (BUX) and the Prague Stock Exchange (PX). Beyond the indices of tone, we strived to introduce in the model a list of potential other determinants of asset prices to overcome, as far as possible, any issue related to omitted variables. The annual change of the consumer price index and the industrial production index would control for the relationship between national inflation targets and the actual inflation outcome, on the one hand, and for macroeconomic fundamentals, on the other hand. Oil prices are added in the stock market model to control for supply shocks. Since financial spillovers from developed economies, such as the Euro Area and the US, may have a strong impact on emerging counterparts, we introduce the government bond yields (at the same maturities) of the two areas as external factors. Nominal spot exchange rates of the Czech Koruna, the Hungarian Forint and the Polish zloty against the Euro and the US dollar have been added to the interest rate models to account for a possible impact stemming from uncovered interest parity conditions. To control for foreign financial stress, we also introduce the VSTOXX volatility index in both the stock markets and interest rates models. Finally, we also control for domestic official reference rate to clean the impact of changes in tone from the concurrent one stemming from the monetary policy decisions occurring on the same date. First differences of all the variables are used in the estimation procedure to overcome any problem of unit root and co-integration; if data are not available at a daily frequency, we use the latest available data. As it is customary in the literature, both the models for the yield curve and stock market returns take into account the existence of a likely autoregressive process in both the dependent variable and the CB's tone.

To provide evidence that changes in the tone of CB communication contains additional information for market interest rates' changes and stock market returns beyond the broader set of economic and financial conditions, we estimate the model with and without the set of control variables. The results obtained by means of the Global version of the sentiment index are reported in **Table 9**.[36]

Changes in the tone of CB communication appear to have a statistically and economically significant effect on market interest rates and the stock markets even when controlling for economic and financial conditions, comprised changes in the conventional monetary policy instrument. In particular, positive changes of the tone – hinting to a more hawkish tone – would positively affect the yield curve, with coefficients comprised between 0.1 and 1.7. In economic terms, these values imply

[36] For space reasons we present results for Global sentiment index only. However, estimates for other sentiment indices mostly produce analogous results.

that a one standard deviation increase (decrease) in tone changes (i.e. a more and more hawkish communication) – where the sample standard deviation of tone changes is $\sigma(d\_s_t)=0.02$ – translates into positive (negative) changes in market interest rates of 1.2bp on press conference's days. With ten to twelve press conferences per year, this translates into a 14bp per annum. Overall, the results related to market interest rates are in line with those reported in section 5.1 on the Taylor rule estimates and, more broadly, with a classic monetary policy transmission mechanism: a more positive/hawkish tone goes along with an expectation of higher official reference rates and, as a consequence, of market ones as well.

Hawkish changes in CB tone would negatively affect stock market daily returns, with an average estimated coefficient of –0.08. In economic terms, these values imply that a one standard deviation increase (decrease) in tone changes translates into a negative (positive) return of around 16bp on press conference's days. Again, with ten to twelve press conferences per year this translates into a 1.9% per annum, which appears sizable as well. Although these results would lead to opposite conclusions than those reported in both the papers of Schmeling and Wagner (2019) and Bennani (2019) – which, in fact, would point to a positive impact of tone changes on stock market returns – they appear nevertheless coherent with the picture reported in previous sections for both policy and market interest rates. Since CB's tone provides soft information about the likely path of policy and market interest rates, especially those at longer maturities, positive shocks negatively affect stock market prices, working as standard monetary shocks.

Regarding the other control variables, estimation results show that CB policy actions are positively related to the short-term market interest rates, coherently with a traditional monetary policy transmission mechanism in place. At the same time, an appreciating exchange rate against both the Euro and the US dollar is negatively related to the same dependent variable via an uncovered interest parity condition. A higher investors' degree of risk aversion – proxied by the VSTOXX index – would tend to produce a negative impact on stock market returns, while a positive impulse would stem from both higher oil prices and US interest rates, likely reflecting a stronger global economy with positive fallouts for emerging markets.

When we replicate the estimates on a country-by-country basis, results still point to the sequence that we found in the panel setting: more hawkish (dovish) communication – positive (negative) interest rate changes – negative (positive) stock market returns.[37]

Overall, our findings show the existence of a significant relationship between tone changes and asset prices, quite robust when controlling for economic and financial conditions. They confirm that CB communication contains price-relevant information, beyond that suggested by the set of chosen control variables.

5. Conclusions

In this paper, we study the communication of CBs in the three main emerging East European economies belonging to the EU (the Czech Republic, Hungary and Poland). We estimate whether and to what extent their monetary policy decisions' press releases and minutes might impact predictability of monetary policy, private agents' expectations and financial markets.

[37] For the sake of brevity, results are not reported here but are available from the authors upon request.

First, through a comprehensive textual analysis conducted through machine learning and natural language processing techniques, we detected some relevant topics recurring in the communications instruments available to the three CBs in the years covering to period before the GFC to the outbreak of COVID-19. We found that topics change over time, being influenced by the great shocks hitting the CEE-3 countries in this time span: the 2008-09 GFC and its aftermath, in particular the euro area sovereign debt crisis and the subsequent deflationary period; the recovery phase and finally, almost inevitably, to the disruptions caused by the outbreak of the COVID-19 pandemic. Second, combining the most relevant dictionaries in the literature to the CB monetary policy decisions' press releases and minutes, we built five different indices capturing their hawkish/positive or dovish/negative tone, which appear to be coherent with and to follow closely the topics previously analyzed. Finally, we used these indices, together with other control variables, to estimate the effects of CB communication on the prospective monetary policy stance, private agents' inflation expectations and developments in financial markets.

The picture that we obtain is similar for the CBs of CEE-3 economies. A tone signaling a more hawkish (dovish) stance – or a more positive (negative) evaluation of the economic outlook – anticipates a tighter (more accommodative) monetary policy decision, the rationale being that it signals higher (lower) inflationary pressures, driving the CBs to raise (cut) policy rates. Further, a more hawkish/positive (dovish/negative) tone may be associated to higher (lower) inflation expectations by private agents, that is reflected into positive (negative) changes in market interest rates and lower (higher) stock prices in financial markets (in line with the inverse relation between market interest rates and stock prices). Overall, our analysis would tend to support the conclusion that communication represents a powerful complementary tool available to modern CBs, in addition to more traditional monetary policy instruments. In this regard, nevertheless, we also find differences among both sentiment indices and countries. On the one hand, in fact, those sentiment indices built on dictionaries specifically defined to capture the CB language turned out being more significant in anticipating monetary policy decisions than those derived from more generic economic dictionaries, that in turn appear more effective in shaping agents' expectations providing a more exhaustive picture of the state of the economy. On the other hand, the communication strategies appear to play a more significant role in Poland than in the other two countries. This may reflect, in our view, a host of factors not explicitly taken into account in our estimation strategies related, for instance, to the degree of credibility of monetary policy, to the weights of domestic and external factors in affecting domestic inflation, to the attention paid from time to time to exchange rate or GDP dynamics. We leave these features for future research.

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Appendix. Charts and Tables

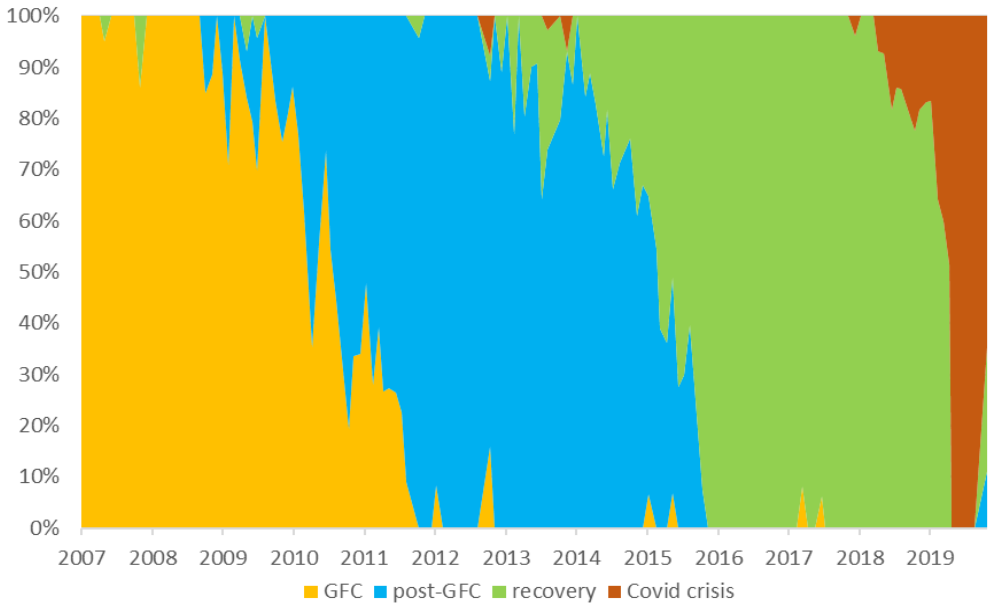
Table 1. Press releases

	Number	Starting month	Ending month	Average number of words
Czech Republic	60	February 2014	March 2021	1,029
Hungary	201	January 2004	March 2021	562
Poland	196	January 2004	March 2021	843

Table 2. Minutes

	Number	Starting month	Ending month	Average number of words
Czech Republic	156	January 2004	March 2021	1,153
Hungary	194	December 2004	February 2021	2,254
Poland	144	December 2007	December 2020	1,761

Chart 1. Distribution of topics from NBP minutes

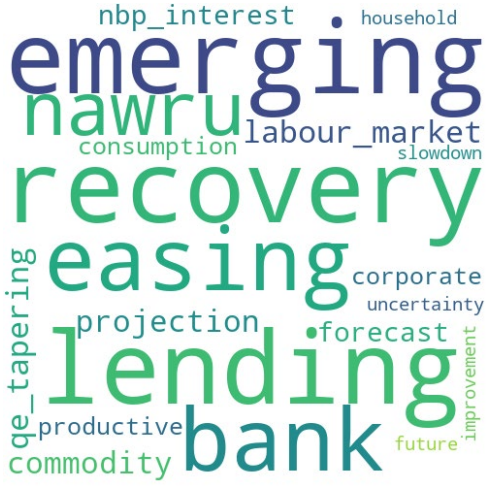


Note: the proportion of each topic in the NBP minutes is reported. Each topic is represented by a probability distribution over the vocabulary. The topic labelled 'Covid crisis' can appear before 2020 because some of the terms belonging to this topic are not exclusive and may recur in CB communication in other periods (see the main text for more details).

Chart 2. Content of topics from NBP minutes

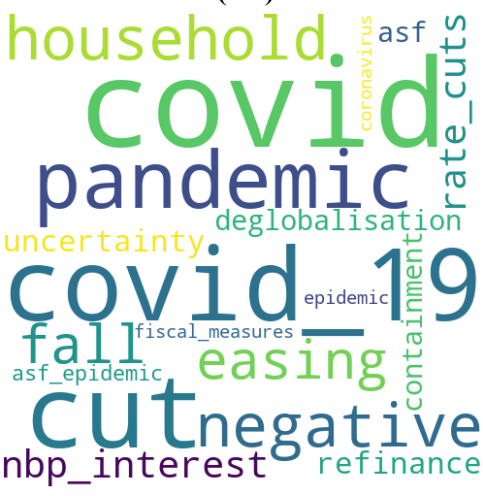
(2.a) GFC

(2.b) post-GFC



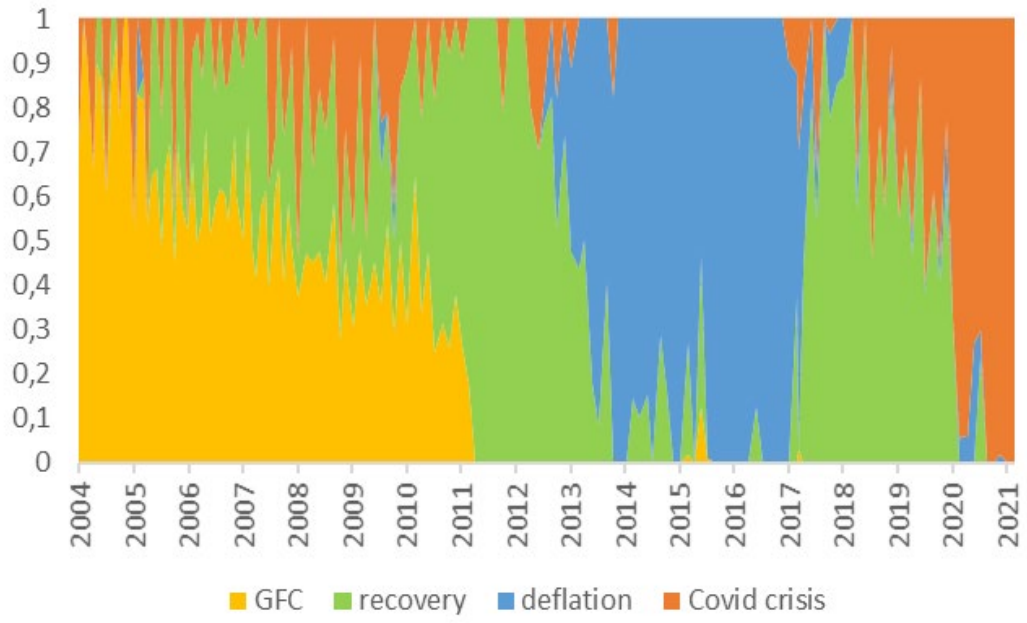
(2.c) Recovery

(2.d) Covid crisis



Note: the size of words in each cloud reflects the frequency distribution in each topic (see the main text for more details).

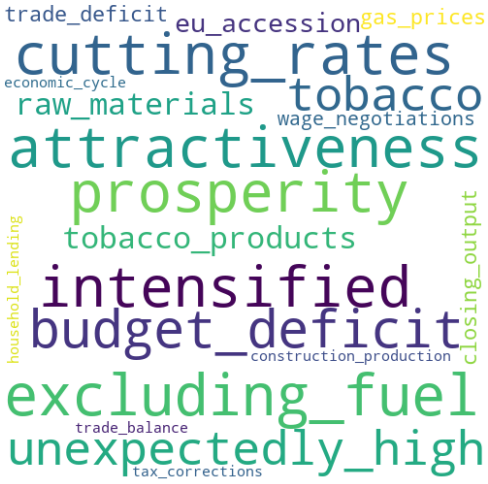
Chart 3. Distribution of topics from CNB minutes



Note: the proportion of each topic in the CNB minutes is reported. Each topic is represented by a probability distribution over the vocabulary. The topic labelled 'Covid crisis' can appear before 2020 because some of the terms belonging to this topic are not exclusive and may recur in CB communication in other periods (see the main text for more details).

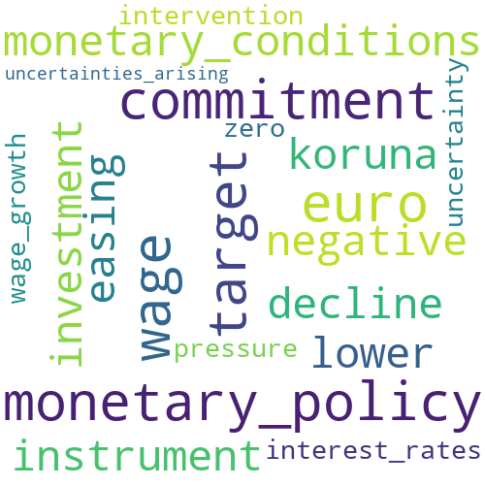
Chart 4. Content of topics from CNB minutes

(4.a) GFC

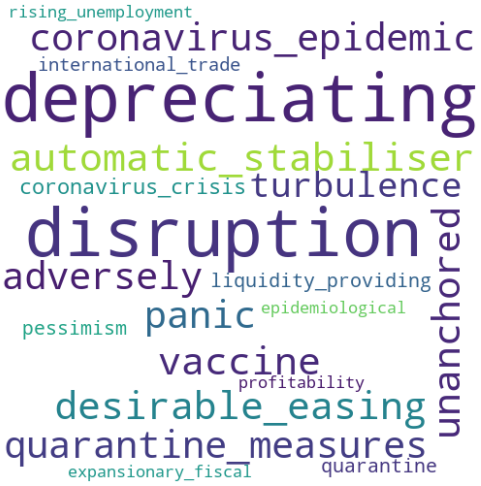


(4.b) recovery

(4.c) deflation

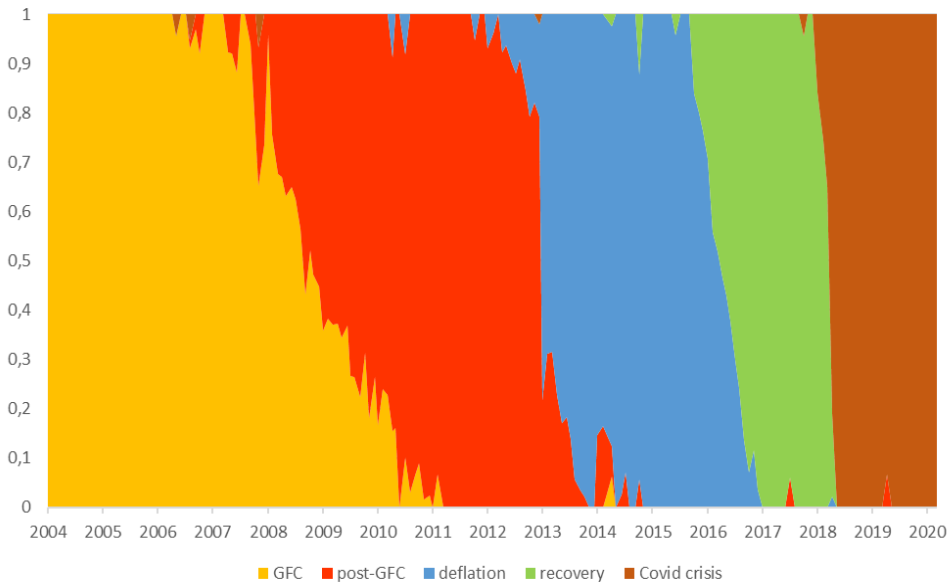


(4.d) Covid crisis



Note: the size of words in each cloud reflects the frequency distribution in each topic (see the main text for more details).

Chart 5. Distribution of topics from MNB minutes

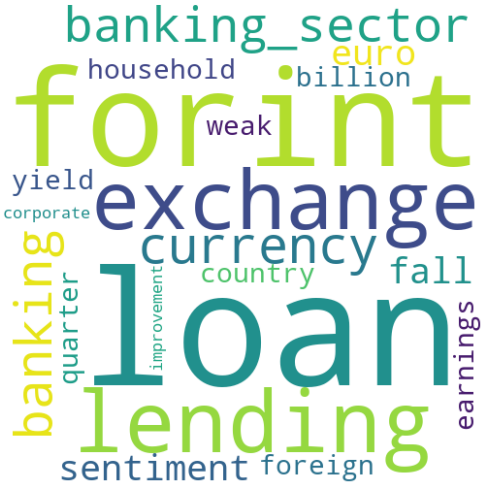


Note: the proportion of each topic in the CNB minutes is reported. Each topic is represented by a probability distribution over the vocabulary. The topic labelled 'Covid crisis' can appear before 2020 because some of the terms belonging to this topic are not exclusive and may recur in CB communication in other periods (see the main text for more details).

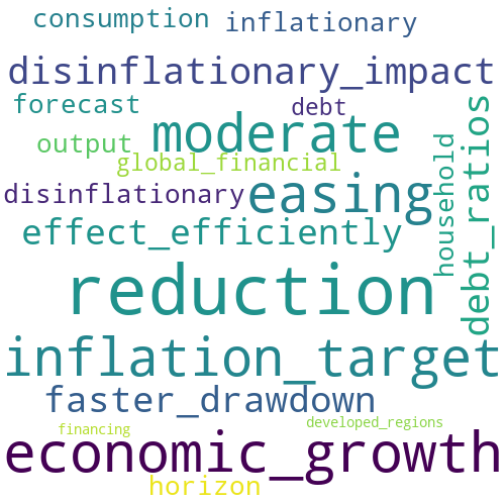
Chart 6. Content of main topics from MNB minutes.

(6.a) GFC

(6.b) Post-GFC

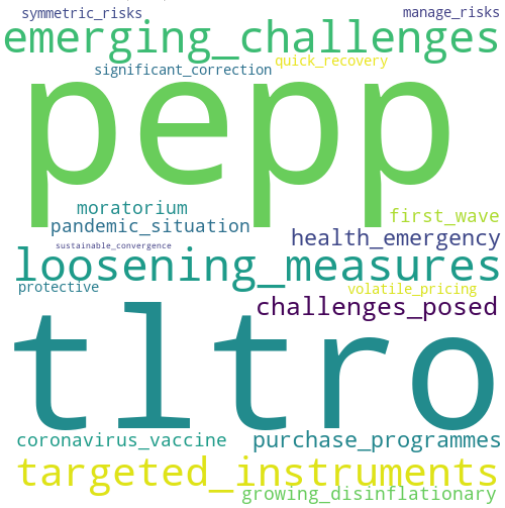


(6.c) Deflation



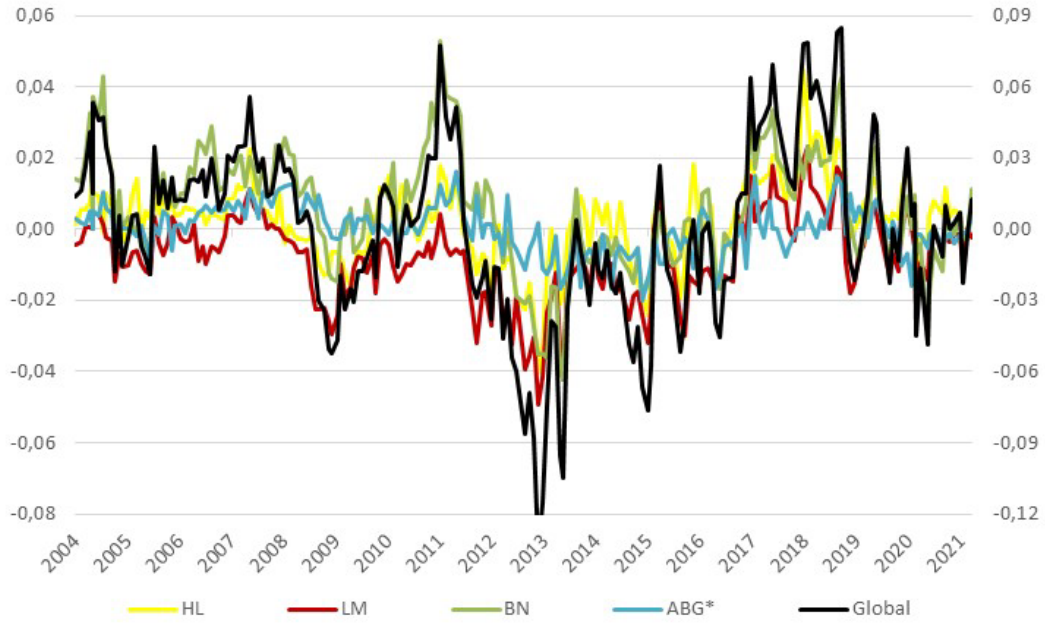
(6.d) Recovery

(6.e) Covid crisis



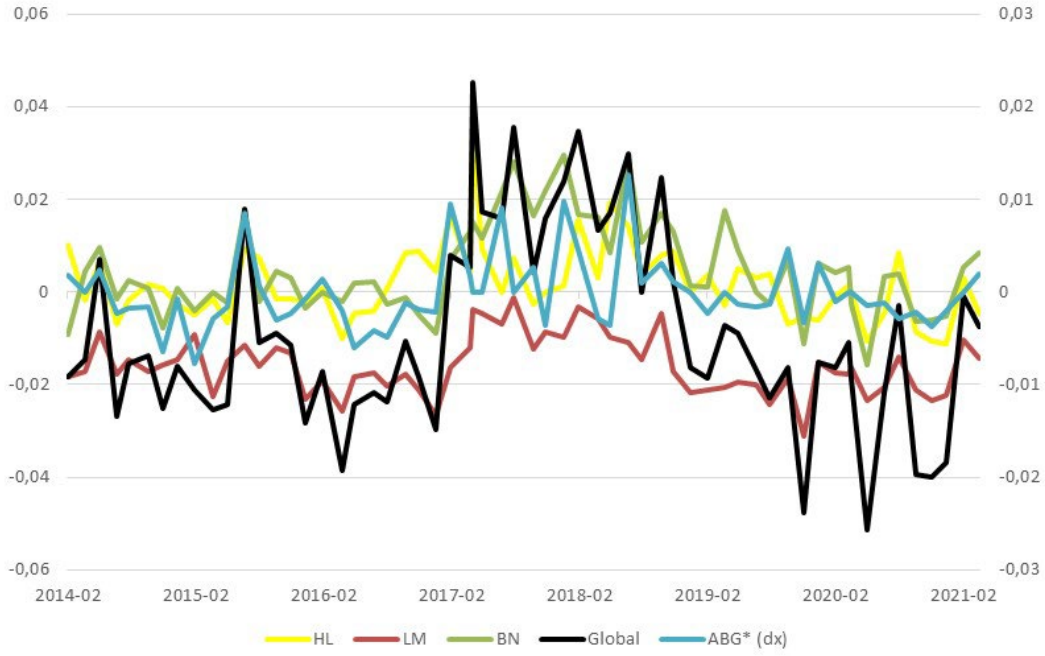
Note: the size of words in each cloud reflects the frequency distribution in each topic (see the main text for more details).

Chart 7. Sentiment indices from NBP press releases



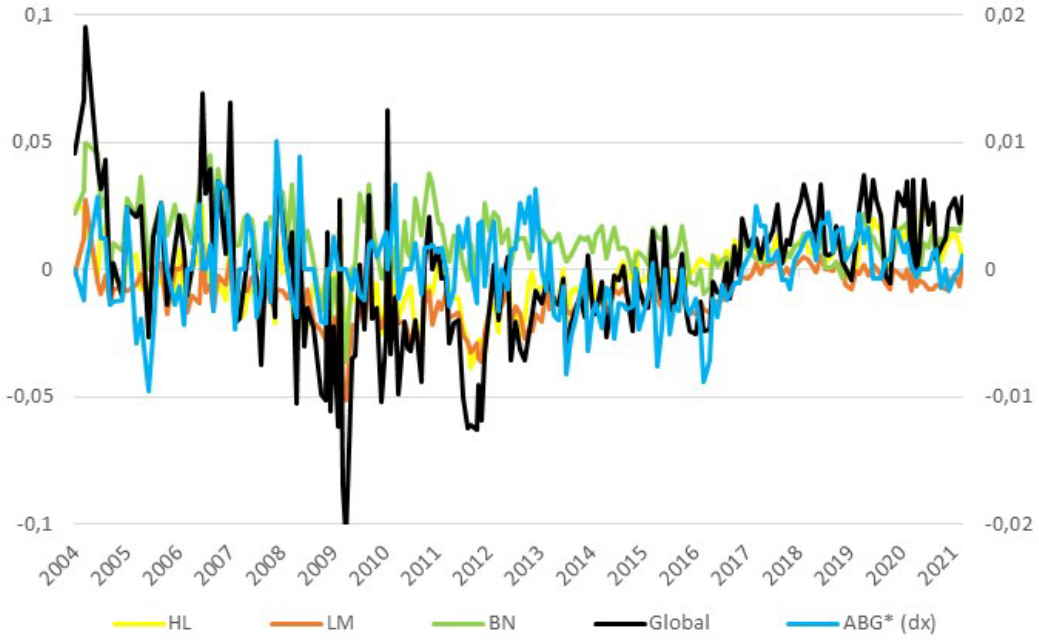
Note: the chart reports the evolution over time of each sentiment index derived from the press releases.

Chart 8. Sentiment indices from CNB press releases



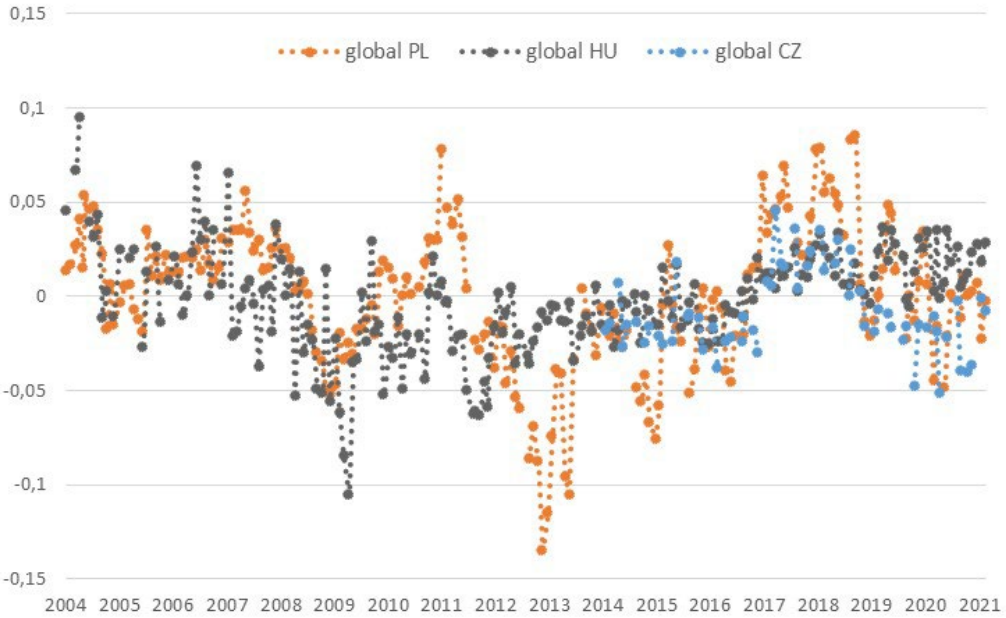
Note: the chart reports the evolution over time of each sentiment index derived from the press releases.

Chart 9. Sentiment indices from MNB press releases



Note: the chart reports the evolution over time of each sentiment index derived from the press releases.

Chart 10. Sentiment indices in CEE-3 CBs



Note: the chart compares the evolution over time of the global sentiment indices for the three CBs.

Table 3. Results for augmented Taylor rule in Poland through ordered probit model

	backward-looking						forward-looking					
variable	base	HL	LM	BN	ABG	global	base	HL	LM	BN	ABG	global
i_{t-1}^{CB}	0.60*** (0.15)	0.57*** (0.16)	0.52*** (0.16)	0.33** (0.17)	0.49*** (0.16)	0.44*** (0.16)	0.58*** (0.15)	0.55*** (0.15)	0.51*** (0.16)	0.32** (0.17)	0.48*** (0.15)	0.43*** (0.16)
$\Delta(\pi_t - \pi^*)$	83.4*** (27.1)	72.4*** (27.8)	65.3** (28.2)	48.6* (28.9)	74.9*** (27.7)	56.3** (28.7)	83.5*** (27.4)	73.0*** (28.1)	67.1** (28.4)	49.0* (29.3)	75.1*** (27.9)	57.9** (28.9)
$y_t - y^*$	12.3*** (3.4)	12.2*** (3.4)	12.7*** (3.5)	14.1*** (3.6)	12.9*** (3.5)	13.0*** (3.5)	13.1*** (3.8)	13.4*** (3.8)	14.1*** (3.8)	14.5*** (3.9)	13.3*** (3.8)	14.1*** (3.9)
$e_t - e^*$	-0.6 (2.2)	-0.2 (2.2)	-0.2 (2.2)	0.1 (2.2)	0.1 (2.2)	0.1 (2.2)	-0.8 (2.2)	-0.4 (2.2)	-0.3 (2.2)	-0.1 (2.3)	-0.1 (2.3)	-0.1 (2.2)
$\Delta\pi_t^{e,t+12}$							48.0* (29.7)	44.3 (30.3)	36.0 (30.7)	33.7 (31.5)	34.9 (30.6)	35.5 (31.2)
$\Delta y_t^{e,t+12}$							-16.2 (27.9)	-24.0 (28.3)	-25.7 (28.4)	-8.1 (28.4)	-7.2 (28.5)	-21.5 (28.3)
s_{t-1}		16.4** (9.0)	22.5** (9.2)	31.0*** (7.7)	50.4*** (16.7)	10.1*** (3.1)		16.7* (9.2)	22.1** (9.5)	29.9*** (7.8)	47.3*** (17.0)	9.8*** (3.1)
observations	206	206	206	206	206	206	206	206	206	206	206	206
pseudo R^2	0.23	0.24	0.25	0.29	0.26	0.27	0.24	0.25	0.26	0.29	0.27	0.27

Note: monthly observations on days of monetary policy meetings, March 2003-March 2021.
Estimates are obtained using ML ordered probit model where dependent variable considers discrete changes of policy rate.
Asymptotic standard errors reported in brackets; *, **, *** denotes significance at the 10%, 5% and 1% level, respectively.

Table 4. Results for augmented Taylor rule in Czech Republic through ordered probit model

	backward-looking						forward-looking					
variable	base	HL	LM	BN	ABG	global	base	HL	LM	BN	ABG	global
i_{t-1}^{CB}	0.25 (0.21)	0.25 (0.21)	0.25 (0.21)	0.13 (0.22)	0.18 (0.22)	0.19 (0.22)	-0.1 (0.25)	-0.1 (0.25)	-0.1 (0.25)	-0.2 (0.26)	-0.1 (0.25)	-0.1 (0.25)
$\Delta(\pi_t - \pi^*)$	51.8** (22.2)	49.4** (22.3)	51.4** (22.2)	53.2** (22.6)	53.6*** (22.6)	49.5** (22.5)	29.1 (25.2)	28.5 (25.2)	27.8 (25.3)	33.4 (25.8)	33.9 (25.7)	29.3 (25.6)
$y_t - y^*$	10.1*** (3.1)	10.1*** (3.1)	9.8*** (3.1)	9.1*** (3.2)	10.5*** (3.2)	9.5*** (3.2)	10.4*** (3.1)	10.4*** (3.1)	10.1*** (3.2)	9.2*** (3.2)	10.7*** (3.2)	9.8*** (3.2)
$e_t - e^*$	14.9*** (4.7)	14.4*** (4.7)	15.3*** (4.7)	16.6*** (4.8)	15.6*** (4.7)	15.8*** (4.8)	13.5*** (4.7)	13.2*** (4.7)	13.9*** (4.7)	15.5*** (4.8)	14.4*** (4.8)	14.5*** (4.8)
$\Delta\pi_t^{e,t+12}$							115.8** (60.4)	108.9* (60.9)	119.6** (60.6)	100.6* (61.5)	99.1* (61.4)	102.8* (61.4)
$\Delta y_t^{e,t+12}$							35.0 (24.5)	36.3 (24.7)	34.6 (24.7)	44.1* (25.1)	39.0 (24.8)	40.4 (25.1)
s_{t-1}		11.1 (9.6)	13.5 (16.5)	28.2** (12.2)	79.8** (31.7)	13.0** (5.9)		9.6 (9.7)	15.4 (16.7)	29.3** (12.5)	77.8** (32.4)	12.8** (5.9)
observations	166	166	166	166	166	166	166	166	166	166	166	166
pseudo R^2	0.17	0.18	0.18	0.20	0.20	0.20	0.20	0.20	0.20	0.22	0.23	0.22

Note: monthly observations on days of monetary policy meetings, March 2003-March 2021.
Estimates are obtained using ML ordered probit model where dependent variable considers discrete changes of policy rate.
Asymptotic standard errors reported in brackets; *, **, *** denotes significance at the 10%, 5% and 1% level, respectively.

Table 5. Results for augmented Taylor rule in Hungary through ordered probit model

	backward-looking						forward-looking					
variable	base	HL	LM	BN	ABG	global	base	HL	LM	BN	ABG	global
i_{t-1}^{CB}	0.52*** (0.09)	0.52*** (0.09)	0.52*** (0.09)	0.52*** (0.09)	0.52*** (0.09)	0.62*** (0.09)	0.47*** (0.09)	0.47*** (0.09)	0.47*** (0.09)	0.47*** (0.09)	0.47*** (0.09)	0.47*** (0.09)
$\Delta(\pi_t - \pi^*)$	28.9* (16.9)	28.8* (17.0)	28.9* (17.0)	28.0* (17.1)	26.1 (17.1)	28.0* (17.0)	14.8 (17.8)	14.8 (17.8)	16.3 (17.8)	14.9 (18.0)	13.3 (18.0)	15.7 (17.9)
$y_t - y^*$	7.7*** (1.8)	7.9*** (1.8)	7.7*** (1.8)	7.5*** (1.9)	7.8*** (1.8)	7.6*** (1.8)	6.1*** (2.0)	6.0*** (2.1)	5.6*** (2.1)	6.1*** (2.1)	5.9*** (2.1)	6.0*** (2.1)
$e_t - e^*$	8.1*** (3.0)	8.0*** (3.0)	8.1*** (3.0)	7.9*** (3.0)	8.8*** (3.1)	8.0*** (3.1)	6.0* (3.3)	6.1* (3.3)	6.3* (3.3)	6.0* (3.3)	7.2** (3.3)	6.2* (3.3)
$\Delta\pi_t^{e,t+12}$							112.6*** (39.2)	112.9*** (39.2)	111.0*** (39.2)	112.6*** (39.2)	101.8*** (39.4)	112.3*** (39.2)
$y_t^{e,t+12}$							9.6* (5.5)	10.3* (6.1)	14.0** (6.6)	9.6* (5.7)	11.7** (5.6)	11.1* (6.4)
s_{t-1}		4.9 (6.6)	0.9 (8.0)	3.1 (7.4)	71.9*** (26.4)	1.9 (3.0)		-1.9 (7.4)	-11.5 (9.8)	-0.3 (7.6)	73.6*** (27.1)	-1.6 (3.6)
observations	201	201	201	201	201	201	201	201	201	201	201	201
pseudo R^2	0.18	0.19	0.18	0.18	0.20	0.18	0.21	0.21	0.21	0.21	0.23	0.21

Note: monthly observations on days of monetary policy meetings, January 2004-March 2021.
Estimates are obtained using ML ordered probit model where dependent variable considers discrete changes of policy rate.
Asymptotic standard errors reported in brackets; *, **, *** denotes significance at the 10%, 5% and 1% level, respectively.

Table 6. Results for augmented Taylor rule in pooled countries through ordered probit model

	backward-looking						forward-looking					
variable	base	HL	LM	BN	ABG	global	base	HL	LM	BN	ABG	global
i_{t-1}^{CB}	0.67*** (0.06)	0.66*** (0.07)	0.67*** (0.07)	0.67*** (0.06)	0.64*** (0.07)	0.67*** (0.06)	0.63*** (0.07)	0.63*** (0.07)	0.64*** (0.07)	0.63*** (0.07)	0.60*** (0.07)	0.63*** (0.07)
$\Delta(\pi_t - \pi^*)$	29.6*** (11.3)	24.6* (13.1)	25.0** (13.2)	22.1* (13.2)	25.5* (13.1)	21.1 (13.3)	18.8* (11.6)	15.5 (13.4)	16.1 (13.5)	13.2 (13.5)	15.8 (13.4)	12.4 (13.5)
$y_t - y^*$	6.7*** (1.2)	6.1*** (1.3)	5.9*** (1.3)	5.6*** (1.4)	6.3*** (1.4)	5.8*** (1.4)	6.3*** (1.3)	5.5*** (1.4)	5.3*** (1.4)	5.0*** (1.4)	5.6*** (1.4)	5.2*** (1.4)
$e_t - e^*$	4.1*** (1.5)	2.9* (1.7)	2.9* (1.7)	3.2** (1.7)	3.7** (1.7)	3.3** (1.7)	3.0* (1.6)	1.6 (1.7)	1.5 (1.7)	1.8 (1.7)	2.3 (1.7)	2.0 (1.7)
$\Delta\pi_t^{e,t+12}$							90.5*** (22.9)	97.1*** (25.3)	97.9*** (25.3)	96.0*** (25.4)	98.2*** (25.6)	95.6*** (25.4)
$\Delta y_t^{e,t+12}$							2.0 (11.4)	6.6 (12.6)	6.4 (12.6)	6.8 (12.6)	7.4 (12.7)	6.1 (12.6)
s_{t-1}		10.6** (4.9)	7.6 (5.3)	10.9*** (4.0)	50.2*** (11.7)	5.2*** (1.9)		9.7* (5.0)	6.4 (5.4)	10.0** (4.0)	49.6*** (11.8)	4.8** (1.9)
observations	618	498	498	498	498	498	618	498	498	498	498	498
pseudo R^2	0.19	0.18	0.18	0.18	0.20	0.19	0.20	0.20	0.19	0.20	0.21	0.20

Note: monthly observations on days of monetary policy meetings, January 2004-March 2021.
Estimates are obtained using ML ordered probit model where dependent variable considers discrete changes of policy rate.
Asymptotic standard errors reported in brackets; *, **, *** denotes significance at the 10%, 5% and 1% level, respectively.

Table 7. Results from panel least squares for change of inflation expectations for current year $\Delta\pi_t^{CF,y}$

Variable	base	HL	LM	BN	ABG	global
$\Delta\pi_{t-1}^{Cf,y}$	-0.16**	-0.17**	-0.17**	-0.17**	-0.17**	-0.17**
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
i_t^{CB}	-0.01	0.00	0.01	-0.02	-0.02	-0.01
	(0.02)	(0.02)	(0.03)	(0.02)	(0.03)	(0.03)
$\Delta\pi_t$	0.13***	0.12***	0.13***	0.12***	0.13***	0.12***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
s_t		0.03**	0.05***	0.02*	-0.02	0.01**
		(0.01)	(0.02)	(0.01)	(0.03)	(0.01)
Observations	255	255	255	255	255	255
Pseudo R^2	0.77	0.77	0.77	0.77	0.76	0.77

Note: monthly observations, January 2014-March 2021.
Estimates are obtained using Panel Least Squares method; standard errors reported in brackets; *, **, *** denotes significance at the 10%, 5% and 1% level, respectively.

Table 8. Results from panel least squares for change of inflation expectations for next year $\Delta\pi_t^{CF,y+1}$

Variable	base	HL	LM	BN	ABG	global
$\Delta\pi_{t-1}^{Cf,y}$	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
i_t^{CB}	-0.01	-0.01	-0.01	-0.01	-0.02	-0.01
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
$\Delta\pi_t$	0.05*	0.05*	0.05*	0.05*	0.05*	0.05*
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
s_t		0.00	0.01	0.00	-0.03	0.00
		(0.01)	(0.01)	(0.01)	(0.02)	(0.00)
Observations	255	255	255	255	255	255
Pseudo R^2	0.66	0.65	0.65	0.65	0.66	0.65

Note: monthly observations, January 2014-March 2021.
Estimates are obtained using Panel Least Squares method; standard errors reported in brackets; *, **, *** denotes significance at the 10%, 5% and 1% level, respectively.

Table 9. CB sentiment/tone and asset prices

	Interest rates changes										Stock market returns	
	3M		6M		1Y		5Y		10Y			
Constant	0.001	-0.004	0.008	0.014	-0.001	0.000	-0.005	-0.002	-0.007	-0.005	0.001	-0.001
	(0.011)	(0.017)	(0.012)	(0.018)	(0.002)	(0.003)	(0.003)	(0.005)	(0.003)**	(0.005)	(0.001)	(0.001)
Dep. Vbl_{t-1}	-0.535***	-0.500**	-0.513***	-0.497***	0.401***	0.241**	0.330***	0.285***	0.328***	0.268***	0.006	0.083*
	(0.038)	(0.039)	(0.058)	(0.058)	(0.103)	(0.104)	(0.082)	(0.082)	(0.077)	(0.076)	(0.057)	(0.049)
D_tone_t	**0.406**	**0.624**	**1.719*** **	**1.659*** **	**0.112**	**0.091**	**0.351****	**0.331****	**0.436*** **	**0.452*** **	**-0.095*** **	**-0.068*** **
	(0.576)	**(0.575)**	**(0.592)**	**(0.594)**	**(0.110)**	**(0.107)**	**(0.164)**	**(0.159)**	**(0.175)**	**(0.167)**	**(0.034)**	**(0.029)**
$Inflation_t$		0.361		-0.351		-0.029		-0.299		-0.281		0.065*
		(0.766)		(0.812)		(0.144)		(0.214)		(0.226)		(0.037)
$D\_IndProd_t$												-0.013
												(0.016)
D_OIL_t												0.120***
												(0.028)
D_VSTOXX_t		-0.132		0.082		0.024		0.002		-0.010		-0.065***
		(0.161)		(0.170)		(0.024)		(0.046)		(0.049)		(0.009)
$D\_Rate\_GER_t$		0.754**		-1.099**		0.160		0.573***		0.607***		0.026
		(0.364)		(0.495)		(0.128)		(0.141)		(0.123)		(0.019)
$D\_Rate\_US_t$		0.934*		0.383		0.070		0.053		-0.025		0.046***
		(0.498)		(0.610)		(0.101)		(0.087)		(0.091)		(0.014)
$D\_FX\_EUR_t$		0.050*		0.062**		0.019***		0.017**		0.009		
		(0.031)		(0.032)		(0.006)		(0.009)		(0.009)		
$D\_FX\_USD_t$		0.006		0.029		-0.006*		-0.013**		-0.018***		
		(0.020)		(0.021)		(0.004)		(0.006)		(0.006)		
$D\_RefRate_t$		0.390***		0.135		0.109***		0.050		0.024		-0.006
		(0.143)		(0.149)		(0.028)		(0.041)		(0.043)		(0.004)
Observations	225	225	225	225	225	225	225	225	225	225	341	341
Adj. R-squared	0.47	0.50	0.27	0.30	0.06	0.14	0.07	0.16	0.09	0.20	0.01	0.29

Note: estimates relate to the use of the Global index of sentiment and are obtained using Newey-West robust standard errors, which are reported in brackets; *, **, *** denotes significance at the 10%, 5% and 1% level, respectively.

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