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Reading between the lines – Using text analysis to estimate the loss function of the ECB

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Abstract

We apply textual analysis to extract the tone (sentiment) from the introductory statements to the ECB's press conferences regarding economic outlook. By combining this information with Eurosystem/ECB staff macroeconomic projections, we are able to directly estimate the Governing Council's loss function. Our analysis suggests that prior to the new monetary policy strategy announced in July 2021, the *de facto* inflation aim of the ECB may have been considerably below 2%. We also find evidence that the loss function has been asymmetric, which would mean that the ECB has been more averse to inflation above 2% than below 2%. The ECB's new definition of price stability implies a symmetric loss function with a bliss point at 2.0%. Hence our results indicate that the new strategy will bring about a clear change in the Governing Council's policy preferences.

JEL Codes: E31, E52, E58

Keywords: central bank communication, ECB, monetary policy, textual analysis, inflation target, loss function

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1 Introduction

On July 8, 2021 the ECB Governing Council (GC) finalized the monetary policy strategy review which had been started in January 2020. The most important decision was to adopt a new definition of price stability. According to the GC, it '*considers that price stability is best maintained by aiming for a 2% inflation target over the medium term. This target is symmetric, meaning negative and positive deviations of inflation from the target are equally undesirable*'.[1]

In this paper we assess how much the ECB's new definition of price stability differs from the now 'old' definition, which was valid until July 2021. Until (very) recently, the ECB's monetary policy was guided by a double-key formulation of price stability by the GC: in 1998, the GC defined price stability as a '*year-on-year increase in the Harmonised Index of Consumer Prices (HICP) for the euro area of below 2%*' and in 2003, the GC clarified that '*in the pursuit of price stability it aims to maintain inflation rates below, but close to, 2% over the medium term*'. This old definition of price stability, 'close, but below, 2%' was somewhat unprecise, and open to interpretation. In particular, this definition had a certain feel of asymmetry, and the quantification of 2% may have appeared more of a ceiling than a central target. In its new strategy, the GC emphasizes that '*the two per cent inflation target provides a clear anchor for inflation expectations, which is essential for maintaining price stability*'.

To use the terminology of modern monetary economics and macroeconomics, we aim to estimate the ECB's objective function, or loss function, under the old definition of price stability (and monetary policy strategy) that was in place until July 2021. The ECB's new definition of price stability gives rather clear guidelines as to what the ECB's objective function/loss function looks like from now onwards: the loss function is symmetric with respect to inflation, with a bliss point at the inflation rate of 2.0%. Then our comparison of the old and new definitions of price stability boils down to the following questions: i) Was the *de facto* inflation aim, or the bliss point of the loss function, 2.0% under the old definition of price stability? And if not, how much did it differ from 2.0%? ii) Was the loss function of the ECB under the old definition of price stability symmetric or asymmetric with respect to inflation?

[1] https://www.ecb.europa.eu/home/search/review/html/ecb.strategyreview_monpol_strategy_statement.en.html.

We use text mining techniques (natural language processing) in order to "read between the lines" and infer the ECB's preferences in the form of a loss function, which measures the ECB's discontent to economic outlook during the policy decisions. We focus on the most important and most formal part of the ECB's qualitative communication, i.e. the introductory statements of the ECB's press conferences.[2] Compared with the speeches of individual governors, for example, introductory statement is the only source which reflects the views of all members in the Governing Council. Applying the dictionary-based "bag of words" approach we use Loughran and McDonald's (2011) finance-specific dictionary in order to measure a latent component, i.e. the general tone (sentiment) in the ECB's qualitative communication. We measure net negativity, i.e. the difference between the fraction of negative words and phrases and the fraction of positive words and phrases in each introductory statement. Then, following Shapiro and Wilson (2019) – who study the Federal Open Market Committee – we use the tone together with the HICP inflation and output gap projections of the Eurosystem/ECB staff to directly estimate the ECB GC's loss function. Our main results are based on the estimation of piecewise linear and more general linear-exponential (i.e. Linex) loss functions, but we also use simple non-parametric methods. A Linex function encompasses a quadratic loss function, which is the most common formulation of central bank preferences in the theoretically oriented optimal monetary policy literature. We repeat the estimations using an alternative proxy for the tone, which is based only on inflation-related texts in the introductory statements. The alternative proxy is constructed using the Latent Dirichlet Allocation (LDA) method. We also assess whether our findings are still valid, if we, instead of forward-looking macroeconomic projections, use real time monthly economic indicators, i.e. the latest estimates of euro area inflation and unemployment rates, as explanatory variables in loss functions.

Our results suggest that under the old definition of price stability either the targeted inflation rate was low (1.6% – 1.8%), or that the ECB targeted inflation rates close to the 2% ceiling, but the policy responses to inflation rates above the target were stronger than to inflation rates below the target (asymmetric policy). Our analyses indicate that if we assume *a priori* that the ECB conducted symmetric monetary policy,

[2] There is a separate, but related literature which focuses on strategic communication of central banks. The argument in this literature is that central banks may have incentives not to disclose all the information, or even bias it to certain direction in order to persuade the private sector to align their expectations with the central bank. For instance, Kawamura et al. (2019), who study strategic communication of the Bank of Japan, suggest that communication ambiguity increases when the economy is heading to a downturn. In this paper, we focus on the GC's introductory statements because we are specifically interested in what the GC wants to communicate to the public. Communication in the introductory statements is certainly intentional and strategic, and this aspect is rather a strength than weakness of our approach.

estimates of the *de facto* inflation target of the ECB are relatively low (1.7%). If, however, we fix the *de facto* inflation target to the upper bound of the old price stability definition (2%), the loss function estimation reveals asymmetric preferences to inflation. These results are robust to inclusion or exclusion of secondary targets (such as output gap or squared output gap) to the loss function, and to whether we estimate a piecewise linear or a more general Linex loss function. Also, estimations based on real time monthly indicators and non-parametric methods support the key findings of the quarterly analysis based on macroeconomic projections. Hence, our results indicate that the ECB's loss function under the old definition of price stability was clearly different from the loss function stipulated by the new definition of price stability (i.e. symmetric preferences, with a bliss point at the inflation rate of 2.0%).

Our findings are important for monetary policy in a low interest rate environment. Asymmetry and a low inflation aim under the old definition of price stability may have anchored inflation expectations and actual inflation to low levels, generating a low-inflation bias to policy. This may have increased the probability of the euro area economy to hit the effective interest rate lower bound and reduced the monetary policy space in the face of negative shocks.[3] Arguably, the symmetric preferences with a bliss point at 2.0%, under the new definition of price stability, may be better suited to guide monetary policy in a low interest rate environment – although evidently this remains to be seen.

Our paper contributes to the literature in several ways. First, we are among the first in assessing whether, and to what extent, the ECB's new definition of price stability will entail a change in the GC's policy preferences. Our empirical analysis of the ECB's preferences, under the old definition of price stability combines the ECB's real time qualitative (introductory statements and text analysis) and real time quantitative (macroeconomic projections) communication.

Second, our approach of estimating the ECB's loss function directly complements earlier, more indirect analyses based on estimated reaction functions in a novel way. Contrary to the reaction function-based approaches presented by Hartmann and Smets (2018), Paloviita et al. (2021) and Rostagno et al. (2019), we

[3]Rostagno et al. (2019) provide some narrative and econometric evidence on low inflation bias in the ECB's monetary policy. Their results suggest that while the ECB has tried to keep the headline inflation below the 2% ceiling, it has meant at the same time (in overall) that tighter policy has suppressed the underlying (core) inflation and inflation expectations in the euro area. While this policy has been stabilizing during the period of high inflationary pressures, it has turned out to be costly and destabilizing in the post-financial crisis years when inflationary pressures have been low, hence new strategy was needed.

do not have to make specific assumptions about the ECB's reaction function, its structure, stability of the economic relationships or transmission channels of monetary policy, in order to infer the parameters of the loss function. A text mining approach has also additional advantages because the dependent variable is the tone (sentiment) proxy instead of the policy instrument itself or policy-sensitive short-term market interest rates. When approaching the zero or negative effective lower bound and when introducing non-standard monetary policy measures, the usual linear policy reaction function breaks down (or alternatively, rather uncertain proxies, i.e. shadow rates must be used). Using the tone proxy as the dependent variable, the estimation period can be extended to periods of unconventional measures without a fear of non-linearity or discontinuity in the reaction function. Furthermore, in reaction function estimations using a policy instrument itself, the reaction function is identified only from incremental interest rate changes, measured in 0.1 or 0.25 percentage points, and not from a continuous mapping between economic outcomes and preferences.

Third, our paper relates to studies that use text mining techniques to study qualitative communication of monetary policy. This relatively new technique in economics refers to a large group of computational tools and statistical methods to quantify text, i.e. mapping text to some meaningful quantities. Contrary to human reading, a huge amount of written material can be analysed without any prior assumptions using automated text mining methods. Bholat et al. (2015) present a comprehensive summary of these techniques applied to central bank documents.[4]

In several recent studies, text mining techniques have been applied in order to study several aspects of central bank communication. For example, the questions of how communication predicts future monetary policy decisions (Bennani et al. (2020), Baranowski et al. (2021)), and how communication anticipates both future monetary policy actions and future economic conditions (Hansen and McMahon (2016), Picault and Renault (2017), Hubert and Labondance (2021)) have been analysed. Also, the impacts of central bank communication on financial market indicators (Kaminskas et al. (2021)), asset prices (Schmeling and Wagner (2019)) and market volatility (Ehrmann and Talmi (2020)) have been examined. Some studies have investigated the favourableness of the central bank's monetary policy decisions in the media (Berger et al. (2011)) and the accuracy of qualitative assessments of the central bank's forecasts relative to quantitative forecasts (Jones et

[4]For an introduction to text mining techniques, see Manning et al. (2008).

al. (2020). Other analysed themes include strategic central bank communication (Kawamura et al. (2019)), international spillovers from central bank communication (Armelius et al. (2020)) and sentiment in parliamentary hearings of central banks (Fraccaroli et al. (2020)) and emotions embedded in monetary policy communication (Gorodnichenko et al. (2021)).

The closest study to ours is the recent paper by Shapiro and Wilson (2019), who estimate objective functions of the U.S. Federal Open Market Committee (FOMC). They link the proxy for the FOMC's loss (net negativity) to the Federal Reserve's staff Greenbook forecasts of the PCE inflation and real economic variables as well as contemporaneous stock market variables. Shapiro and Wilson find that the FOMC's implicit inflation target has been about 1.5% in 2000 to 2011 and the FOMC's loss depends clearly on output growth and stock market performance, but it is not closely related to the FOMC's perception of the current economic slack.

While our analysis is largely inspired by Shapiro and Wilson (2019), there are some clear differences which reflect the different monetary policy strategies of the ECB and Fed: until July 2021, the ECB's monetary policy was guided by a double-key formulation of price stability, while the Federal Reserve has a dual mandate. Furthermore, unlike Shapiro and Wilson (2019), we study the potential asymmetry in central bank preferences; also this choice is motivated by the old double-key formulation of price stability. These two studies are crucially different also from the monetary policy communication point of view. Our proxy for the ECB tone reflects official communication at the time of monetary policy decision making, while the tone in Shapiro and Wilson (2019), which also reflects the sentiment of policy makers in monetary policy meetings, is published with a delay. The timing when forecasts are published is also different across these studies. The Greenbook forecasts are kept confidential for five years, while the ECB projections are essential part of real time monetary policy communication. They are released to the public in the same quarter in which they are produced. It is also worth noting that only our study covers also the most recent years characterized by persistently low inflation rates, effective interest rate lower bound and unconventional monetary policy measures.

Finally, our paper contributes to the literature on real time information and central bank forecasting which are essential in monetary policy making. Some authors have recently examined central bank forecasts

(Granziera et. al (2021)) and their impact on private sector forecasts and expectations formation (see e.g. Fujiwara (2005), Hubert (2014, 2015, 2017) and Lyziak and Paloviita (2017, 2018). The accuracy of published forecasts has been examined quite intensively in many studies (Potter (2011), Stockton (2012), Fawcett et al. (2015), Iversen et al. (2016), Kontogeorgos and Lambrias (2019)). Our analysis is based on a unique data set, which includes real time quarterly macroeconomic projections of the Eurosystem/ECB staff. The same information is presented to the GC in monetary policy meetings. Using Shapiro and Wilson's (2019) approach, we are able to link the proxy of the ECB's loss to the ECB's key policy objectives by estimating the loss function of the ECB.

The rest of the paper is organised as follows. Central bank communication, methodology and data are discussed in Sections 2 and 3. Estimation of the loss function is presented, and empirical analyses are reported in Sections 4 to 6. Concluding remarks are provided in Section 7.

2 Central bank communication and general tone

Central banks possess considerable amount of information on economic conditions, which goes beyond that available to the private sector.[5] Central banks have a clear incentive to disclose such information: the private sector can make more informed economic and financial decisions and the central bank can achieve its objectives more efficiently by steering the private sector expectations on interest rates and inflation to the direction it prefers.[6] A central bank's communication can be both quantitative (forecast numbers) and qualitative (formal statements/reports, informal speeches/interviews and social media such as Twitter). A good example of purely qualitative but powerful communication is the ECB President Draghi's speech in London in July 2012. In that speech, his statement that '*within our mandate, the ECB is ready to do whatever it takes to preserve the euro. And believe me, it will be enough*'[7] practically ended the discussion on the break-up of the euro area, and led to a massive re-pricing of euro area sovereign bonds. Another good example of both qualitative and quantitative communication is forward guidance, where the central bank

[5]See e.g. Romer and Romer (2000).
[6]See e.g. Blinder et al. (2008) and Haldane and McMahon (2018) for an extensive discussion on central bank communication.
[7]`https://www.ecb.europa.eu/press/key/date/2012/html/sp120726.en.html`

announces its commitment to a certain path of interest rates and links this decision to its public statements about current and projected economic conditions.[8]

Before the strategy review, the introductory statements of the press conferences (predecessors of the monetary policy statements currently published) were the most important form of formal communication of the ECB.[9] The content of both the introductory statements and monetary policy statements is highly relevant from the point of view of a monetary policy stance. They comprise carefully drafted announcements and explanations of the GC's decisions based on real time economic and monetary analysis of the ECB/ESCB staff. The introductory statements always included a summary of monetary policy decisions and economic analysis including short to medium term outlook. They also included monetary analysis, a cross-check paragraph combining conclusions from the economic and monetary analysis and sections focusing on fiscal policy issues and structural reforms. After every ECB press conference, key phrases and semantic changes in the official statement are intensively analysed by media and financial market participants in order to gain information about the central bank's policy objectives, future policy actions and its assessment of current and future economic conditions. For example, in December 2019, Martin Arnold assessed in the Financial Times that '*Lagarde follows Draghi's policy lead but sounds [sic] upbeat* <u>*tone*</u>'.[10] The introductory statements contained, as the monetary policy statements now contain, also the Eurosystem/ECB staff macroeconomic projections (quantitative communication) four times a year. These forecasts are prepared well in advance to the respective monetary policy meeting of the GC.

There are various ways to construct a proxy for the sentiment of qualitative communication and to measure an overall tone within a text. The most common techniques are based on traditional lexicon-based approaches, which use special dictionaries of words annotated with their semantic orientation. Semantic orientation can be understood as a measure of subjectivity and opinion, capturing positivity, negativity (or neutrality) and

[8] Fujiwara and Waki (2019) study welfare benefits of forward guidance in a setting where the central bank possesses exclusive information on economic conditions relative to the private sector.

[9] The new communication strategy of the ECB is based on streamlined and renamed introductory statements, i.e. monetary policy statements. See item 11 in the ECB's monetary policy strategy statement of 8 July, 2021: `https://www.ecb.europa.eu/home/search/review/html/ecb.strategyreview_monpol_strategy_statement.en.html`.

[10] In July 2019, Carsten Brzeski noted that '*the tone of the minutes reflects the ECB's concerns about the growth and inflation outlook*' (`https://think.ing.com/snaps/ecb-draghi-tltro-rates-qe-ing-carsten-brzesk-talk-june-minutes-meeting/`). In January 2020, the title of David Goodman's article was '*Trio of G-7 Central Banks May Set Tone for 2020*' (`https://www.bloomberg.com/news/articles/2020-01-19/trio-of-g-7-central-banks-may-set-tone-for-2020-eco-week-ahead`).

strength (the degree to which the text is positive or negative) on some topic, person, or idea (Osgood, Suci, and Tannenbaum, 1957). An advantage of lexicon-based methods is simplicity, as they do not require labelled training data. Machine learning techniques, especially Support Vector Machines (Sharma and Dey, 2012) and artificial neural networks (Moreas et al., 2013), are superior to lexicon-based techniques in terms of classification accuracy, especially when handling domain-specific language (e.g. central bank-specific) rather than general language (Kumar and Jaiswal, 2016). On the other hand, automatic polarity classification requires only a minor effort in terms of manual annotation.

A tone index has been defined in the literature in different ways. For example, Hansen and McMahon (2016) measure the tone in the FOMC's communication as a net positivity using the fractions of positive and negative words. Schmeling and Wagner (2019) also analyse communication of the FOMC, but they consider only the fraction of negative words and ignore negations.[11]

3 Methodology and data

In order to assess possible changes in the GC's preferences through the lens of the ECB's old monetary policy strategy, we extract the sentiment or tone from the ECB's introductory statements by means of text analysis. We have gathered press conference texts from the ECB's website[12] using automated web scraping. Our sample covers the period from July 1999 to December 2019. At the beginning of the sample, until December 2014, the GC had a monetary policy meeting every month, but after that the GC has made monetary policy decisions eight times a year.

First, we have pre-processed the introductory statement data using the most common techniques in textual analysis. To reduce noise in the data, we have merged some common word sequences into single terms (e.g. 'governing council, 'european central bank') and deleted paragraphs of less than 10 words. These short paragraphs mainly include only general expressions and thus do not concern economic analysis. We have

[11] Loughran and McDonald (2016) argue that with this approach the consideration of negations is not that critical.

[12] https://www.ecb.europa.eu/press/pressconf/html/index.en.html

also deleted first paragraphs of each introductory statement, as they represent greetings ('Ladies and gentlemen…'). The expression 'let me now explain our assessment in greater detail' has been explicitly excluded, since this sentence appears often and would be misclassified as positive with automatic classification. We have also converted upper cases into lower cases, removed punctuation, numbers, extra whitespaces and common English stopwords excluding negations, and finally stemmed the words.

In the next step, data are split into tokens (single words). Paragraphs are at first treated as separate documents (data points), but then documents are aggregated into a quarterly level. Even though it is relatively complicated to take the grammatical relations of terms into account when using a lexicon-based classification, we still consider negations as their impact on the overall tone is potentially significant. Since it is reasonable to assume that central banks do not announce good news via negative expressions combined with negations, e.g. 'confidence has not deteriorated', but instead bad news may be softened by expressing negative messages using positive words ('confidence has not improved'), we take into account only negations followed by positive words as suggested by Loughran and McDonald (2011). To handle negations, we treat each sentence separately. If a sentence consists of a negation and a positive word within three words after the negation, the sentiment of the word is reversed into negative, as suggested by Loughran and McDonald. As shown in Figure 1, the average length of introductory statements is 647 words, and the longest introductory statements are observed in the middle of the sample (2006Q4 – 2011Q4). Altogether, our corpus consists of 143,220 words.

Finally, to measure the general tone in the ECB's introductory statements, we use polarity classification to classify words into three classes (negative, positive and neutral) based on their sentiment. For classification, we use Loughran and McDonald's (2011) finance-dictionary, which we modify further by adding some central bank specific terms and expressions in order to improve accuracy.[13] We count negative and positive words found in the modified Loughran and McDonald dictionary and define the tone as a difference of the number of negative and positive words, normalized with the total number of words. We use the tone as a proxy of loss, as we want to measure negativity when estimating loss functions. Consequently, the measured tone

[13] Added positive words: 'ample', 'favourable', 'restructuring', 'robust', 'buoyant', 'dynamic'. Added negative words: 'disequilibria', 'deficit', 'tensions'. Added expressions: 'unemployment' + 'decline'/'fall'/'decrease', 'risk to price stability' + 'low'/'high'/'increase'/'decrease'.

index gets larger values as negative sentiment increases, corresponding to a net negativity percentage of the total corpus. More specifically, we follow Shapiro and Wilson (2019) and determine the tone index as

$$N_t = \frac{\#Neg - \#Pos}{\#Tot}. \tag{1}$$

See Appendix 1 for an example of scored text. Figure 2 shows the evolution of the tone, i.e. net negativity in the introductory statements of the ECB. Broadly speaking, the net negativity in the ECB's introductory statements gradually decreased in the pre-financial crisis years, but the financial crisis contributed to a huge increase in the net negativity, as may be expected. In the post-financial crisis years, a gradual decrease in the net negativity is observed until 2017Q4, but in the end of the sample the tone is more negative again. On average, the net negativity index is slightly below zero in the whole sample. Overall, movements in the tone are clearly associated to economic developments in the euro area. In estimations, we use the tone as a dependent variable and hence it is a proxy for the short-term loss of the ECB.

As a preview to loss function estimations in the next Section, Figure 3 illustrates how the general tone and level of inflation at the time of the GC monetary policy meetings were related, providing a simple non-parametric indication on (the shape of) the GC's loss function. We first calculate the level of inflation in every quarter. It is proxied by the average of the nowcast inflation rate and one-quarter-ahead projected inflation rate of the Eurosystem/ECB staff. Then, using the inflation ranges on x-axis, we combine the mean inflation rates with corresponding mean tones over all quarters of the sample on y-axis. In the resulting Figure 3, the corresponding observations on x-y plane broadly speaking form a V or U -shape. The tone is at its most positive (minimum values of the net negativity index are reached) in the inflation range 1.6% - 1.8%, while the further inflation deviates from this range the higher the net negativity index becomes and therefore the more discontent the ECB tends to be about economic outlook.

4 Estimation of loss functions

In this section, we attempt to quantify how the GC's old definition of price stability was reflected in its policy preferences. In particular, we try to answer the questions raised in the introduction: i) Was the *de facto* inflation aim, or the bliss point of the loss function, 2.0% under the old definition of price stability? And if not, how much did it differ from 2.0%? ii) Was the loss function of the ECB under the old definition of price stability symmetric or asymmetric with respect to inflation? Since the ECB's new definition of price stability implies symmetric preferences with a bliss point at 2.0%, addressing these questions allows us to compare the ECB's old and new definitions of price stability.

We estimate the parameters of a loss function by linking the tone in the introductory statements to deviations of inflation from some *de facto* inflation aim. Our choice to focus on inflation as a key determinant of the loss reflects the fact that price stability was – and still is – the primary objective of the ECB's monetary policy. However, we also control for a measure of output gap as an additional determinant of the loss.

In the first step, we estimate piecewise linear specifications of the loss function. While piecewise linear functions are statistically less demanding to capture possible asymmetries, the caveat is that they do not allow for convexity in the preferences; the loss increases linearly with respect to a distance from, say, an inflation target. Therefore, in the second step we estimate linear-exponential (i.e. Linex) loss functions which are more flexible, as they nest both quadratic and asymmetric (convex) preferences. For example, Surico (2003) estimates Linex loss functions for the ECB and Surico (2007) for the Federal Reserve. The same approach is applied for the UK and Canada by Caglayan et al. (2016) and for Australia and New Zealand by Karagedilkli and Lees (2004). Capistran (2008) uses staff of the Board of Governors forecasts (Green Book) in order to study asymmetries of the loss function of the Federal Reserve. None of these studies uses textual analysis to construct a proxy for central bank preferences. Instead, Capistran (2008) exploits the biases in the Federal Reserve's forecasts and links them to possible asymmetries in the Federal Reserve's preferences, while the remaining studies attempt to infer a central bank's loss function based on an estimated monetary policy reaction function.

4.1 Piecewise linear loss function

Considering Figure 3, we start by assuming a V-shaped, piecewise linear loss function. This is in line with the idea that the central bank has a preference to keep inflation close to its inflation aim and it does so by minimizing the deviation, i.e. distance of actual inflation from the targeted level of inflation subject to some constraints and trade-offs. A V-shaped loss function is not restricted to be symmetric, unlike a quadratic loss function, which is a typical (but not necessarily the most realistic) assumption in traditional models of central bank preferences and optimal monetary policy (see e.g. Woodford (2003), Walsh (2003), and Gali (2015)).

We start with a general short run loss function expressed as follows:

$$L_t = |\tilde{\pi}_t| \,. \tag{2}$$

In Equation (2), the inflation gap, i.e. the term $\tilde{\pi}_t = \pi_t - \pi^*$ is defined as the difference between inflation π_t and the inflation aim π^*. We proxy the central bank loss by the tone, i.e. we assume that there is a linear correspondence between the tone and central bank's loss function such that $N = \alpha + \delta L$.[14] As explained above, the tone N measures net negativity in the introductory statements of the ECB's press conferences. We add an i.i.d. error term in order to take measurement error in the loss into account and to relate the tone into inflation outcomes (and forecasts) in the following way:

$$N_t = \alpha + \delta \, |\tilde{\pi}_t| + \varepsilon_t. \tag{3}$$

Next, we split the linear loss function into two separate segments using a dummy variable. The dummy D is equal to zero if the real time estimate of inflation is below the inflation aim of the central bank (i.e. the inflation gap is negative). Correspondingly, the dummy D is equal to one if the real time estimate of

[14] Parameter α is a regression constant, but it can be thought of capturing any possible systematic direction/bias of the measured tone over the sample. Such a systematic direction in the tone could reflect e.g. long-lasting deviations of inflation from the target or other biases in communication.

inflation rate is above the inflation aim of the central bank (i.e. the inflation gap is positive). This gives rise to a more general loss function

$$N_t = \alpha + \delta_B \tilde{\pi}_t (1 - D) + \delta_A \tilde{\pi}_t D + \varepsilon_t. \tag{4}$$

First, we use the constraint $\delta_B + \delta_A = 0$ to estimate a symmetric loss function. Then, we repeat the estimation without this constraint in order to allow for asymmetry, i.e. so that the parameters δ_B and δ_A can take different positive and negative values. Later on, we also add terms of output gap $\Delta \tilde{y}_t$ and squared output gap $\Delta \tilde{y}^2$ on the right hand side such that the most general form of the loss function reads as

$$N_t = \alpha + \delta_B \tilde{\pi}_t (1 - D) + \delta_A \tilde{\pi}_t D + \beta_1 \Delta \tilde{y}_t + \beta_2 \Delta \tilde{y}_t{}^2 + \varepsilon_t. \tag{5}$$

To measure inflation at the time of decision making, we use the Eurosystem/ECB inflation projections presented to the GC in the monetary policy meetings. Macroeconomic projections of the Eurosystem/ECB staff, which include all real time economic information available at the time, contain information on both the short run and long run economic outlook. As emphasized by Shapiro and Wilson (2019), Romer and Romer (2004) and Coibion and Gorodnichenko (2011), short run economic forecasts can be treated as exogenous to policy since monetary policy impacts on the economy only with some delay. Short-term forecasts are also less susceptible to endogeneity and possibly strategic aspects of longer run forecasts. Longer run forecasts for inflation are shown to be biased towards intended inflation target (see e.g. Charemza and Ladley (2016)), reflecting perhaps more the desired outcomes and assumptions, rather than purely unconditional projections. In Paloviita et. al (2021), we show that the Eurosystem/ECB staff projection errors for inflation increase towards longer forecast horizon, but mean error is very small for short term inflation forecasts.[15] Furthermore, the economic outlook is prepared and finalized by the Eurosystem/ECB staff well before the GC's policy meetings.

In what follows, we focus on short run inflation forecasts when estimating the loss function. We proxy the

[15] The mean errors (defined as projection minus realized) for one to four-quarters-ahead inflation projections (real GDP growth projections) are -0.02, -0.06. -0.11 and -0.13 (-0.11, 0.07, 0.29 and 0.51), while the root mean squared forecast errors for inflation are 0.37, 0.59, 0.78 and 0.95 and for real GDP growth 0.96, 1.33, 1.68 and 1.96.

inflation perception of the ECB (π_t) by the average of the nowcast inflation rate and one-quarter-ahead projected inflation rate, following Shapiro and Wilson (2019). We measure output gap $\Delta\tilde{y}_t$ by the difference between the average of the nowcast and one-quarter-ahead output growth projections and potential output growth, which is proxied by the medium term (eight-quarters-ahead) GDP growth projection. The underlying assumption is that the medium run growth projection for the euro area corresponds to the assessed real time euro area growth potential.[16] The introductory statements have been published once a month or eight times a year. Since our estimations are based on the quarterly inflation projections of the Eurosystem/ECB staff, we calculate the net negativity (N_t), i.e. the tone, by combining all the text in the introductory statements held during each quarter.

We estimate π^* by doing a grid search for a linear Ordinary Least Squares (OLS) regression model. To obtain π^*, we first search for the best estimate by stepping through all possible values of π^* between 0 and 3 with a step size of 0.01. Then we choose those specifications that minimize the sum of squared residuals (SSR) in Equations (3) to (5). See Appendix 2 for the corresponding SSR plots. From the chosen specifications, we report estimation results in Table 1. We also obtain the confidence interval for π^* using a bootstrap procedure. Using the F-test and likelihood ratio tests, we compare the empirical relevance of the unrestricted (asymmetric) and restricted (symmetric) specifications of the V-shaped loss function.

4.2 Results from piecewise linear loss function

Estimation results are summarized in Table 1. In the first step, we assume that under the old definition of price stability, the ECB's monetary policy responses to negative and positive inflation gaps were equal, and estimate a symmetric piecewise linear loss function, i.e. Equation (3). For this specification, the estimated slope parameter $\hat{\delta}$ is positive and statistically significant and the point estimate for the implicit *de facto* inflation aim is 1.66%, which is substantially below the current inflation aim of 2.0% (see column (1)). The 90% confidence interval of the estimated inflation aim is relatively tight, ranging from 1.35 to 1.85. Hence

[16] Another option would have been to use potential output estimates. However, the real time estimates for euro area potential output are only available from 2009Q2 at a quarterly frequency and from 2006 at an annual frequency in the ECB projection data. It is also worth noting that in the ECB's New Area-Wide Model (NAWM), the reaction function has been specified in terms of deviations of output growth from its long-run empirical mean (Christoffel et al. 2008).

the 90% confidence interval does not include the inflation aim of 2.0%. The positive slope coefficient suggests that as inflation (the average of HICP inflation nowcast and one-quarter-ahead projection) has been further away from 1.66%, net negativity in the tone (loss) has increased considerably. Adding the squared and linear output gap terms does not change the results, and in fact, the point estimate for the *de facto* inflation target remains the same (see column (2) in Table 1).

In the second step, we relax the restriction that the loss function has been symmetric, and estimate Equation (4), i.e. including separate parameters for negative and positive inflation gaps, but we fix the inflation aim to 1.66% (see columns (3) and (4)). According to column (3), the point estimates for coefficients $\hat{\delta}_B$ and $\hat{\delta}_A$ are somewhat different in absolute value, but still relatively close to each other as well as to the corresponding point estimate in the symmetric loss function. Adding the output gap terms into the loss function yields more distinct slope coefficients, pointing to more asymmetric preferences as regards to inflation outcomes (column (4)).

In the third step, in columns (6) and (8), we consider how the loss function is changed if the *de facto* inflation aim of the ECB was assumed to be at the upper bound of the old price stability definition. We set exogenously the inflation target equal to 2.0% in line with the current definition of price stability and re-estimate an unrestricted (i.e. possibly asymmetric) specification of the loss function (i.e. Equations (3) and (4)). It turns out that the difference between the estimated slope coefficients is substantial and statistically significant in columns (6) and (8). These parameter estimates suggest that when inflation increased further above 2%, the net negativity in the tone increased $2\frac{1}{2}$ times or 5 times faster than when inflation was falling further below 2%, depending on whether the estimation excludes or includes the output gap terms. This is perhaps the most direct evidence of changed preferences of the GC: contrary to the current symmetric preferences, the ECB used to be more averse to inflation rates above 2% than below 2% in our dataset, pointing to an asymmetric loss function.

Finally, we have estimated an asymmetric specification without fixing in advance the inflation aim of the ECB. Columns (5) and (7) of Table 1 indicate that without (with) the output gap terms, the point estimate of the implicit *de facto* target of the ECB stood at 1.7% (2.3%). When interpreting the results from the estimation with the output gap terms (column (7)), it is worth noting that the sum of squared residuals

(SSR) criterion we use for selecting the estimate of the *de facto* target is more or less indifferent between any values over the range 2.0% to 2.3% (see Figure A2.4 in the Appendix). The estimated loss functions without the output gap terms are presented graphically in Figures 4 to 6. In Appendix 3 we discuss likelihood ratio tests related to the estimations in Table 1.

Overall, these results provide evidence that the ECB's new definition of price stability does indeed differ from the old definition of price stability, as interpreted by the GC. The estimations indicate that the ECB's loss function under the old definition of price stability was not symmetric, with a bliss point at 2.0%.

4.3 Linear exponential loss function

We continue the comparison of the ECB's old and new definitions of price stability by estimating linear-exponential (Linex) loss functions. We assume that the ECB's preferences for inflation can be expressed in the following form:

$$L_t = \frac{exp\left[\theta\left(\pi_t - \pi^*\right)\right] - \theta\left(\pi_t - \pi^*\right) - 1}{\theta^2}. \tag{6}$$

Here the parameter θ captures the possible asymmetry and convexity of the preferences (with respect to deviations of inflation from the target). Inflation outcomes above the target are increasingly more costly when θ is large, while as θ approaches zero, preferences take a usual quadratic − and symmetric − form. Once again we proxy the central bank loss by the tone, and we assume that there is a linear correspondence between the tone and the central bank's loss function such that $N = \alpha + \gamma L$. Hence, we relate the tone to inflation deviation in the following way:

$$N_t = \alpha + \gamma\frac{exp\left[\theta\left(\pi_t - \pi^*\right)\right] - \theta\left(\pi_t - \pi^*\right) - 1}{\theta^2} + \varepsilon_t. \tag{7}$$

Nobay and Peel (2003) show theoretically, in a simple static optimal monetary policy model, that a central bank's asymmetric preferences (such as those presented in Equation (6)) can lead to inflationary or deflationary bias relative to the inflation target.[17] Deflationary bias arises when the central bank is more averse to high inflation. More specifically, they show that when the central bank optimizes subject to the above preferences and the Lucas supply curve[18] $y = \beta(\pi_t - E\pi) + \epsilon_t$, expected (average) inflation is

$$E\pi = \pi^* - 0.5 * \theta\sigma_\pi^2, \tag{8}$$

where σ_π^2 is the variance of conditionally normally distributed inflation. The above equation says that inflation expectations fall below the target in particular when the central bank is strongly averse to high inflation (i.e. high θ) and when inflation is volatile. When preferences are quadratic (and symmetric), the expected inflation equals the target.

4.4 Results from Linex loss function

In Table 2, we report the estimates of the parameter θ and *de facto* inflation target π^*, together with the estimates of the parameters α and γ, based on a linear-exponential loss function, with and without controlling for output gap and squared output gap as in Table 1. The estimated loss functions are presented graphically in Figures 7 and 8. The results are very much consistent with the findings from the simpler approach of a piecewise linear loss function. When we estimate all the parameters (including π^*) jointly, the *de facto* inflation target is in the neighborhood of 1.7% and θ is positive, but not statistically different from zero (see column (4), Table 2), suggesting rather symmetric preferences, but with a bliss point well below 2,0%. The same is true for θ when we fix the *de facto* inflation target to 1.66% or 1.70% (see columns (1) and (2) in Table 2). On the contrary, when we fix the *de facto* inflation target to 2.0, the parameter θ is significantly different from zero, pointing to strong asymmetry in central bank preferences (column (3)). When we include the output gap and estimate the specification

[17] See also Orphanides and Wilcox (2003), Ruge-Murcia (2007) and Cassou et al. (2012) for monetary policy and inflation biases in models with non-quadratic preferences.

[18] y denotes output, β is the slope of the Lucas supply function, and ϵ an exogenous supply shock.

$$N_t = \alpha + \gamma \frac{exp\left[\theta\left(\pi_t - \pi^*\right)\right] - \theta\left(\pi_t - \pi^*\right) - 1}{\theta^2} + \beta_1 \Delta\tilde{y_t} + \beta_2 \Delta\tilde{y_t}^2 + \varepsilon_t, \tag{9}$$

where β_1 and β_2 are parameters, we obtain similar results. When we estimate all the parameters jointly, the point estimate of the *de facto* inflation target is 1.63%; θ is positive, but not statistically different from zero (see column (8), Table 2), suggesting symmetric preferences. When we fix the *de facto* inflation target to 2.0%, in line with the new definition of price stability, the parameter θ is significantly different from zero (column (7) in Table 2), suggesting asymmetric preferences with respect to inflation.

Finally, applying the likelihood ratio test, we cannot reject the null hypothesis that the ECB's preferences before adopting new monetary policy strategy were characterized by a *de facto* target of 2.0%, combined with strong aversion to inflation above the target (see columns (3) and (7) in Table 2), pointing to asymmetry.[19] This asymmetry can be seen in Figure 8, which plots the estimated Linex loss function: the net negativity increases strongly for inflation rates above 2%, and clearly less so when inflation rates are below 2%. Using the simple formula for expected inflation in Equation (8), the point estimate for the parameter θ from column (3) in Table 2, and the realized variance of inflation during 1999M1-2020M1, expected inflation would be equal to $E\pi = 2 - 0.5 * 1.15 * 0.83 = 1.52\%$, rather close to the actual average inflation over the same period (1.70%).

Once again, these results provide evidence that the ECB's preferences under the old definition of price stability differ from the preferences implied by the new definition. The estimations with the Linex specifications suggest that, before the strategy review, the loss function was not symmetric, with a bliss point at 2.0%.

[19]The likelihood ratio test compares the restricted model (with prefixed inflation aim) to the unrestricted model with the same set of explanatory variables. Hence we compare the restricted specification in column (3) ((7)) to the unrestricted specification in column (4) ((8)).

5 Loss function estimations with alternative tone based on inflation texts

Next, we repeat our estimations using an alternative proxy for the ECB's tone. Instead of measuring the general tone based on all text in the introductory statements, we focus on a subsample of the total corpus associated only with inflation, the primary objective of monetary policy of the ECB.

In this exercise, we combine probabilistic topic modelling and dictionary-based sentiment analysis. First, we extract paragraphs of the introductory statements concerning inflation by employing Latent Dirichlet Allocation (LDA) introduced by Blei et al. (2003). Then, we calculate the tone (net negativity) based on the inflation relevant-texts. Finally, we estimate loss functions as above.

LDA is a hierarchical Bayesian model for dimensionality reduction that summarizes documents as a mixture of topics and topics as a mixture of words. The basic idea of LDA is to define a probability for each word in a corpus of being generated from a specific topic and to define each document as a distribution over a collection of topics. As a result, each word w in a document d is allocated into topic k based on topics in a document and how frequently w appears in a particular topic k. LDA model assumes exchangeability and thus is a bag-of-words method as a lexicon-based sentiment analysis. One benefit of using such unsupervised clustering for topic classification is the reduction in manual work as documents do not need to be read by humans. Even though, as a Bayesian model, LDA requires some subjective decisions when defining priors, subjectivity is still reduced compared to manual classification since it is not predefined which words describe each topic.

LDA has recently become a common technique to cluster textual data among authors examining central bank communication. Using LDA, Hartmann and Smets (2018) find 50 separate topics in the ECB's speeches over time, while Tobback et al. (2017) utilize LDA to extract topics in the news articles concerning the ECB's press conferences. Most recently, Edison and Carcel (2020) employ LDA to the Federal Open Market Committee (FOMC) transcripts in order to examine the evolution of topics over time, whereas Hansen et al. (2019) use LDA to identify main topics in the Bank of England's Inflation Report.

5.1 Alternative tone based on inflation texts

As explained above, we separate inflation texts from the rest of our textual dataset using an unsupervised clustering algorithm, LDA (see Appendix 3 for details). Our collection of documents consists of all the introductory statements. As we treat each paragraph as a single document, our corpus consists of 3,183 documents and 143,220 words in total.

After creating a corpus of inflation texts, we calculate an alternative tone with the same procedure as we calculated the general tone. Figure 9 shows the history of the alternative tone index based only on inflation texts in the introductory statements. Comparison of Figures 2 and 9 indicates that, broadly speaking, the evolution of the general tone and the alternative tone have been quite similar even though inflation texts comprise a smaller amount of text compared to all the text in the introductory statements. The average share of inflation texts out of all the text is 18% (Figure A4.2), and the correlation between the two indexes is 0.85. There is some more quarter-to-quarter variation in the inflation tone and it seems that the inflation tone lags the general tone. This has been especially true in the aftermath of the European sovereign debt crisis. While the general tone started to deteriorate at the end of 2013, there is a visible deterioration in the inflation tone not earlier than at the end of 2015, when deflation pressures started to increase.

5.2 Results using alternative tone

Estimation results for V-shaped loss functions acquired by using the inflation tone are reported in Table 3. In the case of a symmetric piecewise linear loss function, the estimated slope parameter $\hat{\delta}$ is statistically significant and the implicit inflation aim is estimated to be 1.67% (see column (1)). Hence the level of the *de facto* inflation aim before July 2021 was practically the same as the corresponding estimates based on the general tone with a similar specification (see Table 1).

In column (2) of Table 3, we consider an asymmetric specification. We fix the inflation aim to 1.67% and estimate separate parameters for negative and positive inflation gaps. In this case, the estimated coefficients $\hat{\delta}_B$ and $\hat{\delta}_A$ remain relatively close in absolute value to the corresponding point estimate $\hat{\delta}$ in the symmetric loss function and the F-test does not reject the hypothesis of symmetry. Hence, the results are qualitatively unchanged compared to those based on the general tone with a fixed target inflation rate of 1.66% (see column (3) of Table 1).

We have also estimated an asymmetric specification without fixing in advance the inflation aim of the ECB. According to column (3) of Table 3, the implicit *de facto* target of the ECB is again 1.7%, The F-test does not reject the hypothesis that before adopting new monetary policy strategy, the GC had symmetric preferences with respect to inflation below and above this *de facto* target. Recall that in column (5) of Table 1, we obtained similar results, using the general tone.

In column (4), the *de facto* inflation aim of the ECB is fixed to 2.0%, in line with the new definition of price stability. The estimated slope coefficients $\hat{\delta}_B$ and $\hat{\delta}_A$ are quite different in absolute value (-0.50 and 0.97). However, contrary to the corresponding results in Table 1 (column (8) and, to some extent, column (6)), the F-test does not reject the hypothesis according to which the ECB had symmetric preferences, even if the *de facto* inflation aim is (assumed to be) 2.0%. The LR test does not reject a *de facto* inflation aim being at 2.0%.

Table 4 summarizes our findings when the alternative tone is used in the estimation of linear-exponential loss functions. The results are consistent with Table 3, in which we report estimation results based on piecewise linear loss functions. When we estimate all the parameters, the *de facto* inflation target of the ECB is 1.81% and the parameter θ is roughly zero, pointing to symmetric preferences (see column (4) in Table 4). After fixing the *de facto* aim of inflation to 1.67%, 1.70% or 2.00%, we also find that the parameter ϑ is not significantly different from zero (see columns (1) to (3) of Table 4, respectively). Hence, when using the tone based on inflation text only, we cannot reject (in any of the estimated specifications) the hypothesis according to which the ECB's preferences were symmetric.

Overall, the results with the alternative tone provide some evidence that the ECB's preferences under the old definition of price stability differed from the preferences implied by the new definition, although this evidence is somewhat weaker than what we obtained using the general tone. In both cases (i.e. using the general tone and the alternative tone), our results point to an inflation aim well below 2.0% under the old definition of price stability. However, the estimations using the general tone support the view according to which ECB preferences were asymmetric if the inflation aim is set to 2.0%, while with the alternative tone we do not find evidence in favor of such an asymmetry.

6 Loss function estimations based on monthly real time economic indicators

Real time economic analysis is an essential part of monetary policy making. In addition to quarterly forecasts, a large variety of real time economic indicators are carefully monitored and analysed in every monetary policy meeting of the GC. In this section, we consider how the general tone and inflation text-based tone of the ECB's introductory statements reflected the most recent real time monthly economic information available at the time of a policy meeting. More specifically, we estimate loss functions in which we use the HICP flash estimate and the latest available estimate of euro area unemployment as explanatory variables.[20] The cyclical variable that we use in our estimations is the annual change in the unemployment rate (i.e. the difference between the current month unemployment rate and the unemployment rate one year earlier). Using these real time economic indicators, we obtain a substantially larger sample (about 200 vs. 80 data points in the quarterly set-up), in which each introductory statement presents a separate data point.

Estimation results with monthly data and the general tone are reported in Tables 5 and 6. Table 5 shows estimation results for V-shaped loss functions (including confidence intervals for symmetric specifications). Compared to Table 1 with quarterly projections, we now obtain systematically slightly higher *de facto* inflation aims for the ECB. For all asymmetric specifications, the F-test rejects the null hypothesis of symmetry, and the parameter estimates for positive inflation gaps are clearly higher than those for negative inflation gaps. In Table 6, the estimation results for the linear-exponential loss function also strongly support an asymmetric loss function.

[20] Since 2001M10, the HICP flash estimate for the previous month has been available for the GC in every meeting with only three exceptions: 2001M12, 2005M1 and 2006M1. In these cases, the latest available HICP estimate was the HICP inflation rate for the month before the previous month.

Estimations based on monthly data and the alternative tone are reported in Tables 7 and 8. Comparing Tables 3 and 7 reveals that higher frequency data suggest somewhat higher *de facto* inflation targets, and more pronounced differences between positive and negative inflation coefficients when the target is assumed be fixed. Contrary to Table 3, in which the null hypothesis of symmetric preferences is never rejected, the F-test now rejects symmetry, when the target is relatively high (1.9% or 2.0%). The results reported in Table 8 give more support for asymmetric preferences of the ECB than those reported in Table 4: when estimating a Linex loss function with higher frequency data and the alternative tone, the hypothesis of symmetry is rejected, if the target is fixed to 2%.

All in all, estimation results for the loss functions based on monthly real time economic indicators are broadly speaking in line with the analysis based on quarterly macroeconomic projections even though they suggest a somewhat higher level of the *de facto* inflation aim of the ECB and give more support for asymmetric preferences.

Finally, the estimation results with monthly observations indicate that the ECB's preferences under the old definition of price stability were not symmetric, with a bliss point at 2.0%. Hence, also these results provide evidence that the ECB's new definition of price stability genuinely differs from the old definition.

7 Concluding remarks

We have used text analysis methods to assess the characteristics of the ECB's Governing Council's (GC) loss function, its possible asymmetry, and the *de facto* inflation aim prior to the new strategy, which was announced in July 2021. In the estimations, we proxy the ECB's loss by the general tone (net negativity) in the ECB's introductory statements. The tone has then been regressed on the inflation gap, which is constructed by using real time inflation projections of the Eurosystem/ECB staff, available to the GC at the time of the actual policy decisions. Various robustness checks were conducted such as allowing for the tone to depend on real time economic outlook, using an alternative proxy for the tone based only on inflation texts and repeating estimations at a higher frequency, having each monetary policy meeting as a separate data point.

While the preceding monetary policy strategy centered around the double-key-formulation of price stability, according to the new strategy, the GC is now committed to aim at 2% inflation symmetrically in the medium term. This change in the strategy is welcome, and it *de facto* means that the ECB has a higher inflation aim relative to the preceding definition. The GC has also strongly emphasized the symmetry of the target in its communiqué after the announcement of new strategy. The higher inflation target provides an additional buffer against disinflationary shocks and alleviates the problem of a reduced monetary policy space, due to the effective lower bound and a lower natural rate of interest.

Our analysis reveals a clear change in the GC's preferences, at least from an *ex ante* perspective. However, it is too early to assess how the new symmetric 2% inflation target will affect future price developments and inflation expectations in the euro area. The final impacts will largely depend on the way the GC will put the new strategy into practice (future monetary policy decisions). Also, the ECB monetary policy communication will play a central role, as it affects the way financial market participants, experts and the general public interpret and understand the ECB's new strategy.

The very first indication of how the GC views its new strategy can be found from the revision of the Governing Council's rate forward guidance after the strategy review: '*In support of its symmetric two per cent inflation target and in line with its monetary policy strategy, the Governing Council expects the key ECB interest rates to remain at their present or lower levels until it sees inflation reaching two per cent well ahead of the end of its projection horizon and durably for the rest of the projection horizon, and it judges that realised progress in underlying inflation is sufficiently advanced to be consistent with inflation stabilising at two per cent over the medium term. This may also imply a transitory period in which inflation is moderately above target.*'[21]

Lane (2021)[22] emphasizes that both the reformulation of the price stability objective and the conditional commitment to take into account the implications of the effective lower bound on monetary policy warranted the revision to forward guidance. The updated rate forward guidance conditions monetary policy to inflation outlook and provides a possibility of allowing inflation to overshoot the two percent target.

[21] https://www.ecb.europa.eu/press/pressconf/2021/html/ecb.is210722~13e7f5e795.en.html.
[22] https://www.ecb.europa.eu/press/blog/date/2021/html/ecb.blog210819~c99d1b768d.en.html.

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Table 1. Estimated V-shaped loss function, general tone

	(1) Symmetric V	(2) Symmetric V	(3) Asymmetric V	(4) Asymmetric V	(5) Asymmetric V	(6) Asymmetric V	(7) Asymmetric V	(8) Asymmetric V
α	-1.0552***	-1.5695***	-1.0909***	-1.6508***	-1.0776***	-0.8711***	-1.4469***	-1.4895***
δ	1.1035***	0.7475***						
$\delta_B\ (D=0)$			-1.0392***	-0.5477*	-0.9977***	-0.6342**	-0.2216	-0.3086
$\delta_A\ (D=1)$			1.2525***	1.0967***	1.3002***	1.5286***	2.2903***	1.6002***
β_1		-1.2599***		-1.2286**			-1.3024***	-1.3154***
β_2		-0.1161**		-0.0970*			-0.1054**	-0.1097**
Observations	81	81			81	81	81	81
Adjusted R^2	0.1	0.50	0.09	0.51	0.09	0.08	0.55	0.58
$\widehat{\pi^*}$	1.66	1.66			1.70		2.3	
π^*_{fixed}			1.66	1.66		2		2
F-test symmetry p-value	-	-	0.6032	0.082*	0.4684	0.0897*	0.0001***	0.0014***
Likelihood-ratio test p-value			0.3848	0.008***		0.1204		0.2218
90% C.I.	[1.35, 1.85]	[0.25, 2.05]						

90% confidence interval is obtained using bootsrap procedure
Likelihood – ratio test is performed between restricted model (π^*_{fixed}) *and unrestricted model* ($\widehat{\pi^*}$)
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 2. Estimated Linex loss function, general tone

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
α	-0.6629***	-0.6555***	-0.6063***	-0.6477***	-1.3352***	-1.3300***	-1.2888***	-1.3391***
θ	0.420	0.4986	1.1463**	0.5815	1.1768	1.2322	1.8470**	1.1372
γ	1.0600***	1.0585***	1.0396***	1.056***	0.6180	0.6287	0.6492	0.6072
β_1					-0.1018**	-0.1028**	-0.1064**	-0.1009**
β_2					-1.2683***	-1.2701***	-1.2763***	-1.2667***
Observations	81	81	81	81	81	81	81	81
$\widehat{\pi^*}$				1.74				1.63
π^*_{fixed}	1.66	1.70	2		1.66	1.70	2	
Likelihood-ratio test p-value	0.7895	0.8924	0.4417		0.913	0.807	0.2255	

Likelihood – ratio test is performed between restricted model (π^*_{fixed}) *and unrestricted model* ($\widehat{\pi^*}$)
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 3. Estimated V-shaped loss function, inflation text based tone

	(1) Symmetric V	(2) Asymmetric V	(3) Asymmetric V	(4) Asymmetric V
α	0.3214	0.3166	0.3263	0.4999*
δ	0.8474**			
$\delta_B\ (D=0)$		-0.8392**	-0.8108**	-0.4976*
$\delta_A\ (D=1)$		0.8678*	0.8871*	0.965
Observations	81	81	81	81
Adjusted R^2	0.05	0.04	0.04	
$\widehat{\pi^*}$	1.67		1.70	
π^*_{fixed}		1.67		2
F-test symmetry p-value	-	0.9469	0.8607	0.4205
Likelihood-ratio test				0.7979

Likelihood – ratio test is performed between restricted model (π^*_{fixed}) *and unrestricted model* ($\widehat{\pi^*}$)
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 4. Estimated Linex loss function, inflation text based tone

	(1)	(2)	(3)	(4)
α	0.0064***	0.006***	0.007***	0.0065
θ	0.1936	0.2544	0.9090	0.4771
γ	0.0078*	0.0078*	0.0080*	0.0078*
Observations	81	81	81	81
$\widehat{\pi^*}$				1.81
π^*_{fixed}	1.67	1.70	2	
Likelihood-ratio test p-value	0.7676	0.8183	0.7117	

Likelihood − ratio test is performed between restricted model (π^*_{fixed}) *and unrestricted model* ($\widehat{\pi^*}$)
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 5. Estimated V-shaped loss function, monthly real time indicators

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Symmetric V	Symmetric V	Asymmetric V	Asymmetric V	Asymmetric V	Asymmetric V	Asymmetric V
α	-0.7399***	-0.3364**	-0.8279***	-0.4944	-0.7752***	-0.4203***	-0.4791
δ	0.8988***	0.7431***					
δ_B $(D = 0)$			-0.7564***	-0.5835 **	-0.6391***	-0.4406***	-0.5581**
δ_A $(D = 1)$			1.2931***	1.1943***	1.5799***	1.7815 ***	1.3126***
β_1		1.4007***		1.3040***		1.3455***	1.3156
β_2		-0.3078***		-0.1754***		-0.1903	-0.1845
Observations	214	214	214	214	214	214	214
Adjusted R^2	0.08	0.41	0.10	0.42	0.11	0.44	0.43
$\widehat{\pi^*}$	1.80	1.92			2	2.28	
π^*_{fixed}			1.80	1.92			2
F-test symmetry p-value	-	-	0.0347**	0.0096***	0.0009***	0.0003***	0.0020***
Likelihood-ratio test p-value			0.055*	0.0102**			0.0466**
90% C.I.	[1.41, 1.93]	[1.70, 2.07]					

90% confidence interval is obtained using bootsrap procedure
Likelihood − ratio test is performed between restricted model (π^*_{fixed}) *and unrestricted model* ($\widehat{\pi^*}$)
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 6. Estimated Linex loss function, monthly real time indicators

	(1)	(2)	(3)	(4)	(5)	(6)
α	-0.4221***	-0.3893***	-0.4416***	-0.1780	-0.1425	-0.1781
θ	0.6648**	0.9589***	0.5182	0.7667**	0.9926***	0.7665
γ	0.7943***	0.7785***	0.7976***	0.6288***	0.6602**	0.6287***
φ_1				1.3220***	1.3473***	1.3220***
φ_2				-0.1629	-0.1954	-0.1628
Observations	214	214	214	214	214	214
$\widehat{\pi^*}$			1.69			1.80
π^*_{fixed}	1.80	2		1.80	2	
Likelihood-ratio test p-value	0.6234	0.1747		0.9989	0.3615	

Likelihood − ratio test is performed between restricted model (π^*_{fixed}) *and unrestricted model* ($\widehat{\pi^*}$)
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 7. Estimated V-shaped loss function, monthly real time indicators, inflation text based tone

	(1) Symmetric V	(2) Asymmetric V	(3) Asymmetric V	(4) Asymmetric V
α	0.4275**	0.4058**	0.372	0.4697**
δ	0.7762***			
$\delta_B\ (D=0)$		-0.5829***	-0.6639***	-0.4933**
$\delta_A\ (D=1)$		1.1753***	1.0224***	1.2155
Observations	214	214	214	214
Adjusted R^2	0.05	0.06	0.06	0.06
$\widehat{\pi^*}$	1.75	1.90		
π^*_{fixed}			1.75	2
F-test symmetry p-value	-	0.0388**	0.1823	0.018**
Likelihood-ratio test p-value			0.2358	0.2657

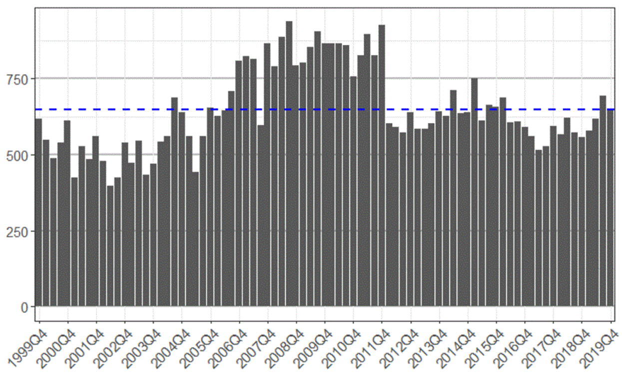
Likelihood − ratio test is performed between restricted model (π^*_{fixed}) and unrestricted model ($\widehat{\pi^*}$)
$*p < 0.10, **p < 0.05, ***p < 0.01$

Table 8. Estimated Linex loss function, monthly real time indicators, inflation text based tone

	(1)	(2)	(3)	(4)
α	0.7314***	0.7537***	0.7672***	0.7146***
θ	0.7314	0.7419	0.8930*	0.386
γ	0.6268***	0.6125***	0.600	0.6330**
Observations	214	214	214	214
$\widehat{\pi^*}$				1.64
π^*_{fixed}	1.75	1.90	2	
Likelihood-ratio test p-value	0.7198	0.4006	0.253	

Likelihood − ratio test is performed between restricted model (π^*_{fixed}) and unrestricted model ($\widehat{\pi^*}$)
$*p < 0.10, **p < 0.05, ***p < 0.01$

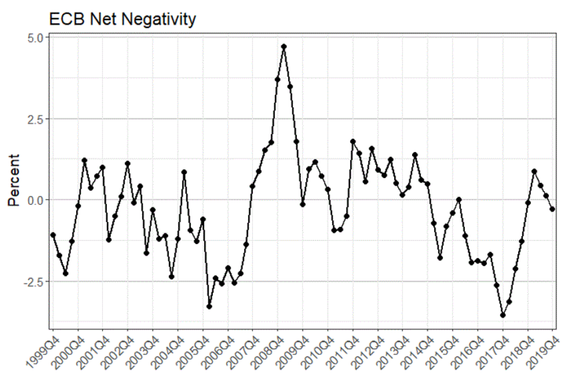
Figure 1. Quarterly average of the number of words in the ECB's introductory statements 1999Q4-2019Q4



Note: The dashed blue line corresponds to the overall mean.

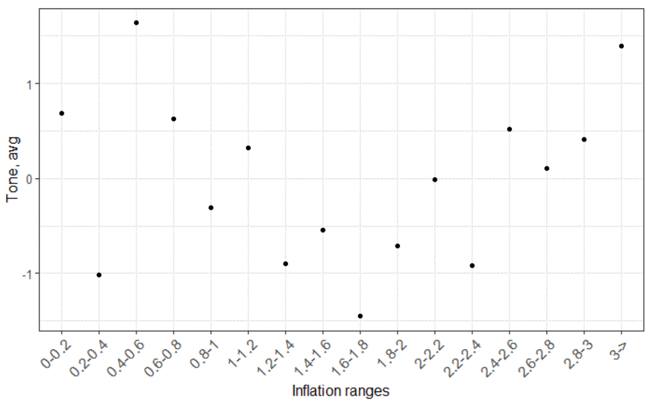
Sources: ECB and authors' own calculations.

Figure 2. General tone



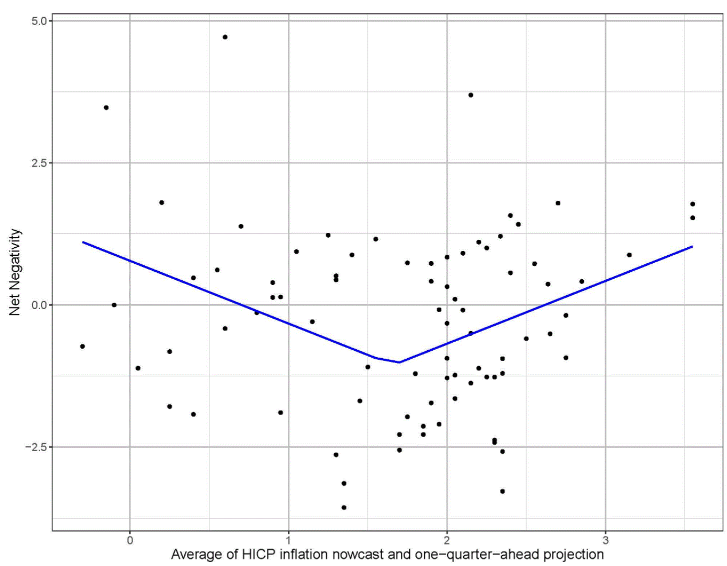
Sources: ECB and authors' own calculations.

Figure 3. Average tone in each inflation range over the whole sample



Sources: ECB and authors' own calculations.

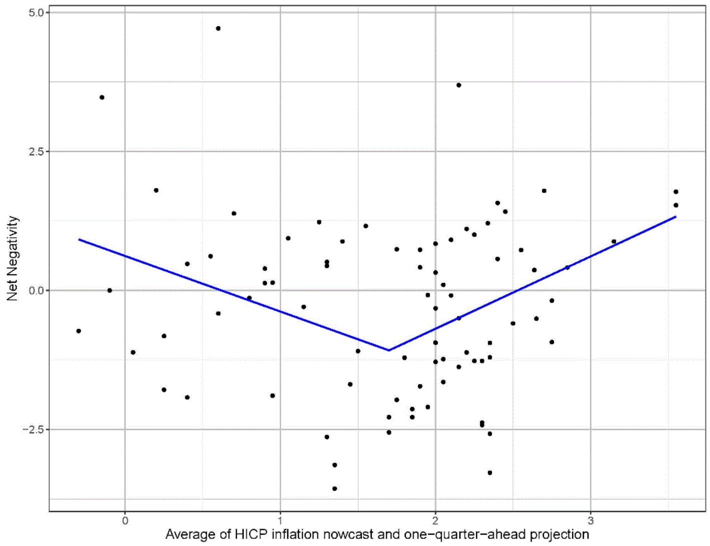
Figure 4. Estimated symmetric linear loss function



Note: The estimated loss function of Figure 4 corresponds to column (1) in Table 1.

Sources: ECB and authors' own calculations.

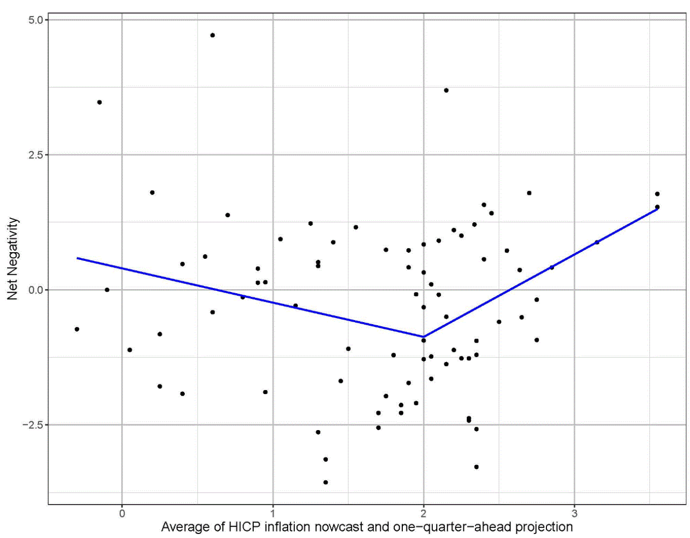
Figure 5. Estimated asymmetric piecewise linear loss function



Note: The estimated loss function of Figure 5 corresponds to column (5) in Table 1.

Sources: ECB and authors' own calculations.

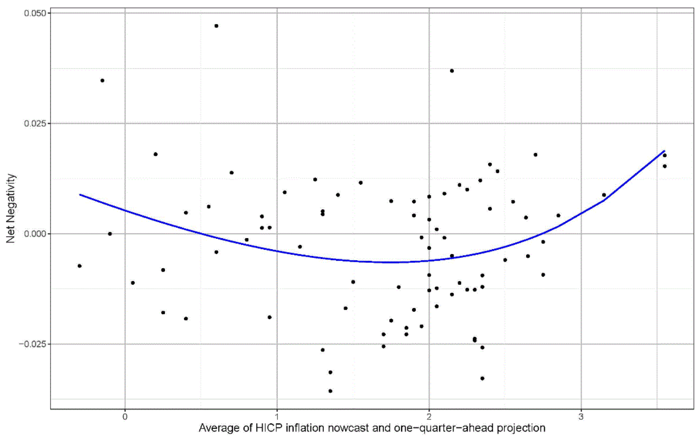
Figure 6. Estimated asymmetric piecewise linear loss function, fixed π^*=2.0



Note: The estimated loss function of Figure 6 corresponds to column (6) in Table 1.

Sources: ECB and authors' own calculations.

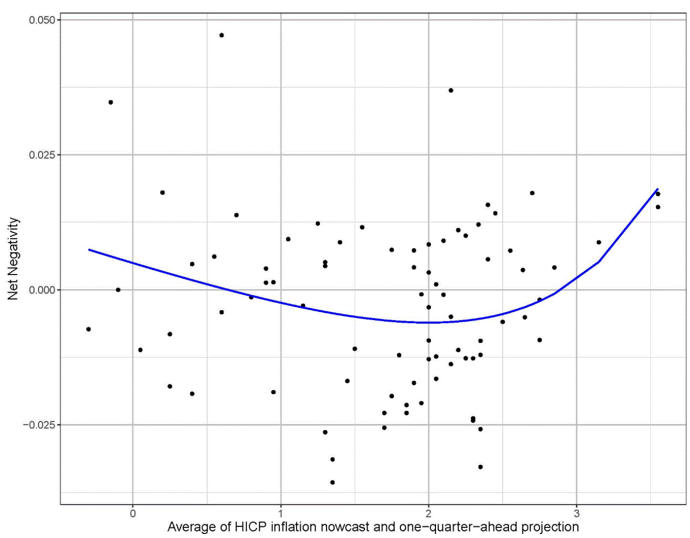
Figure 7. Estimated linear exponential loss function



Note: The estimated loss function of Figure 7 corresponds to column (4) in Table 2.

Sources: ECB and authors' own calculations.

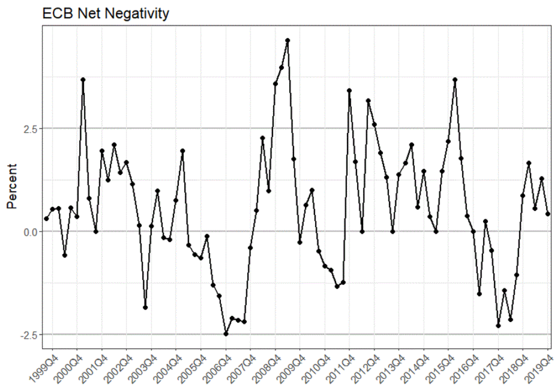
Figure 8. Estimated linear exponential loss function, fixed π*=2.0



Note: The estimated loss function of Figure 8 corresponds to column (3) in Table 2.

Sources: ECB and authors' own calculations.

Figure 9. Alternative tone based on inflation texts



Sources: ECB and authors' own calculations.

APPENDIX 1

Example of scored text, the ECB's introductory statement

December 12, 2019

[. . .]

"The incoming data since our last meeting are in line with our baseline scenario of ongoing, but moderate, growth of the euro area economy. In particular, the weakness in the manufacturing sector remains a drag on euro area growth momentum. However, ongoing, albeit decelerating, employment growth and increasing wages continue to support the resilience of the euro area economy. While inflation developments remain subdued overall, there are some signs of a moderate increase in underlying inflation in line with expectations.

The unfolding monetary policy measures are underpinning favourable financing conditions for all sectors of the economy. In particular, easier borrowing conditions for firms and households are supporting consumer spending and business investment. This will sustain the euro area expansion, the build-up of domestic price pressures and, thus, the robust convergence of inflation to our medium-term aim."

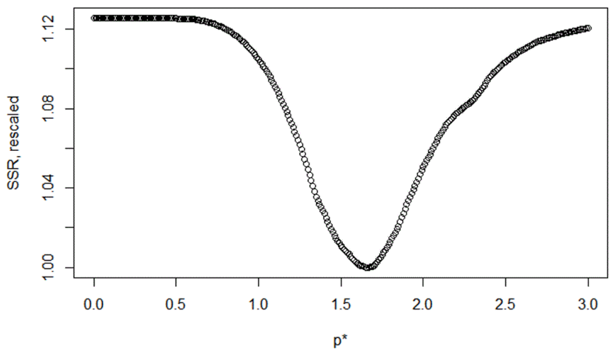
[. . .]

"Euro area annual HICP inflation increased to 1.3% in December 2019, from 1.0% in November, reflecting mainly higher energy price inflation. On the basis of current futures prices for oil, headline inflation is likely to hover around current levels in the coming months. While indicators of inflation expectations remain at low levels, recently they have either stabilised or ticked up slightly. Measures of underlying inflation have remained generally muted, although there are further indications of a moderate increase in line with previous expectations. While labour cost pressures have strengthened amid tighter labour markets, the weaker growth momentum is delaying their pass-through to inflation. Over the medium term, inflation is expected to increase, supported by our monetary policy measures, the ongoing economic expansion and solid wage growth."

[. . .]

APPENDIX 2

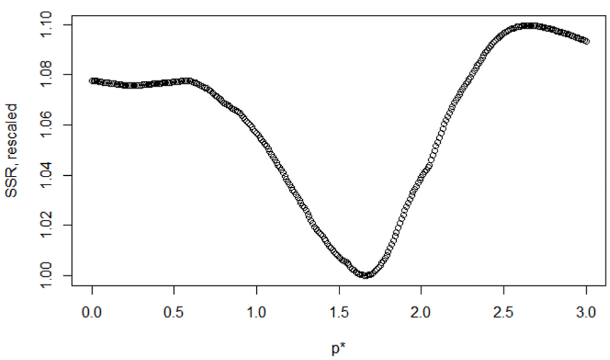
Figure A2.1. Sums of squared residuals



Note: The sums of squared residuals (SSR) for column (1) of Table 1. The SSRs are rescaled so that a value of 1 corresponds to the minimum.

Source: Authors' own calculations.

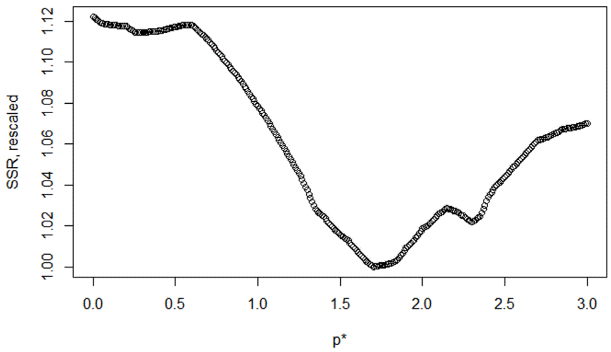
Figure A2.2. Sums of squared residuals



Note: The sums of squared residuals (SSR) for column (2) of Table 1. The SSRs are rescaled so that a value of 1 corresponds to the minimum.

Sources: Authors' own calculations.

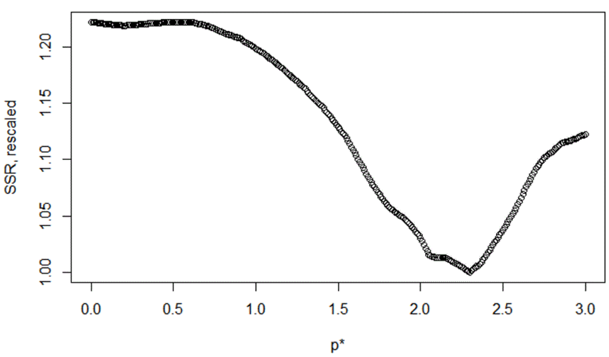
Figure A2.3. Sums of squared residuals



Note: The sums of squared residuals (SSR) for column (5) of Table 1. The SSRs are rescaled so that a value of 1 corresponds to the minimum.

Source: Authors' own calculations.

Figure A2.4. Sums of squared residuals



Note: The sums of squared residuals (SSR) for column (7) of Table 1. The SSRs are rescaled so that a value of 1 corresponds to the minimum.

Sources: Authors' own calculations.

APPENDIX 3

This appendix discusses the likelihood ratio tests presented in Table 1.[23]

We use the F-test and likelihood ratio test in order to assess how the targeted inflation rate and possible asymmetry of the loss function have been related. We compare symmetric and asymmetric specifications by taking the target inflation rate (1.66%) obtained from the specifications in columns (1) and (2), and fix it to be used in the specifications of columns (3) and (4), which allow for asymmetry. In Table 1, the p-value of the F-test indicates that the specification in column (3), which combines a relatively low targeted inflation rate and asymmetry, does not lead to a significantly improved fit over the corresponding symmetric (restricted) model in column (1). Once the output gap terms are included in the regression (when comparing columns (2) and (4)), the F-test rejects the assumption of symmetry at a 10% significance level. When the inflation aim is fixed to 2.0%, the null hypothesis of symmetric preferences is rejected at the 10% significance level in the specification of column (6) (with no output gap terms), and at the 1% significance level in the specification of column (8) (with output gap terms). At the same time, the likelihood ratio test does not reject the restriction of setting the *de facto* inflation rate exogenously to 2.0%. This suggests that, in terms of statistical criteria, a 2.0% inflation aim combined with asymmetry is, to an extent, a plausible specification of the ECB's preferences under the old definition of price stability.

[23]The likelihood ratio test compares the restricted model (with a pre-fixed inflation aim) to the unrestricted model with the same set of explanatory variables. To this end, we compare the restricted specification in column (6) ((8)) to the unrestricted specification in column (5) ((7)) in Table 1 of the main text.

APPENDIX 4

This appendix provides details on the methods used to separate inflation texts from total corpus.

Following the literature, we assume that in each document, a fraction of topics λ follows a Dirichlet distribution with a parameter ρ and for each topic in a document, a distribution of words ν also follows a Dirichlet distribution with a parameter σ. We assume that our corpus does not include rare topics that would be less common than other topics, hence we select a symmetric prior over ρ. Since symmetric prior over word-topic distribution has been shown to be equivalent or superior to asymmetric (Wallach et al. 2009, Syed and Spruit, 2018), we choose symmetric prior also over σ. These Dirichlet distributions are used as conjugate priors for a multinomial posterior distribution of topics and conditional multinomial probability of words. Generative process repeats three steps until convergence (Blei et al., 2003):

1. For each topic k, choose the word distribution $\nu_k \sim Dir(\sigma)$
2. For each document d, choose the topic distribution for each topic $\lambda_d \sim Dir(\rho)$
3. For each N words w_n,
   (a) Choose a topic $z_n \sim Multinomial(\lambda)$
   (b) Choose a word w_n from $p(w_n|z_n, \sigma)$

Exact inference of posterior distribution is intractable to approximate a posterior distribution. Consequently, we use a Markov-chain Monte Carlo method, collapsed Gibbs sampling (Griffiths & Steyvers, 2004). There are three hyperparameters that need to be chosen in advance when applying LDA model: parameters $\rho$and σ for Dirichlet prior distributions and a number of topics K. Since introductory statements follow a known structure where each topic is discussed in a specific paragraph and vocabulary is focused on economic and finance terms, we assume that in our dataset topic-word and document-topic distributions should be rather narrow than smooth. Narrow distributions result in topics that are described by only a few key terms and documents that include only a few topics. Using a grid search we consider different values of $\rho$and σ with each number of topics K and choose values that minimize the perplexity score[24]. As a result of a grid search, we choose $\sigma = 0.05$ and $\rho = 0.1$as our hyperparameter values for symmetric Dirichlet priors. We choose the number of topics based on numerical measures and our interpretation of topics. Perplexity score reflects the fact that the bigger K gets, the better the LDA model performs. On the other hand, the coherence score[25] suggests $K = 15$ as an optimal number of topics. With 15 topics we are able to identify known topics of the introductory statements and most importantly, we are able to identify topics related to inflation and price stability. As interpretability is considered the most important evaluation criteria for the LDA (George and Doss, 2017), we can confirm that the number of topics $K = 15$ suggested by coherence score can be interpreted as an optimal choice for a final LDA model. The list of identified topics and fractions of topics are presented below.

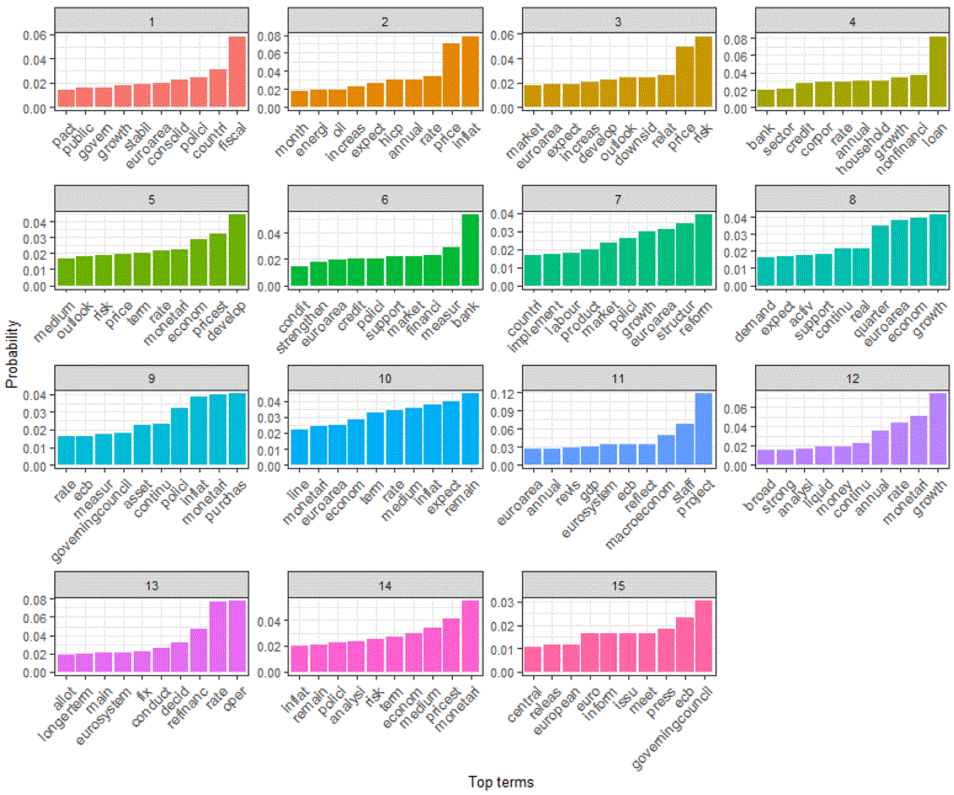
[24] Perplexity measures a prediction performance of a model and is defined as

$$Perplexity = \exp\left\{-\frac{\sum_{d=1}^{M} logp(w_d)}{\sum_{d=1}^{M} N_d}\right\}$$

where M = number of documents, w_d = words in document d, and N_d= number of words in document d.

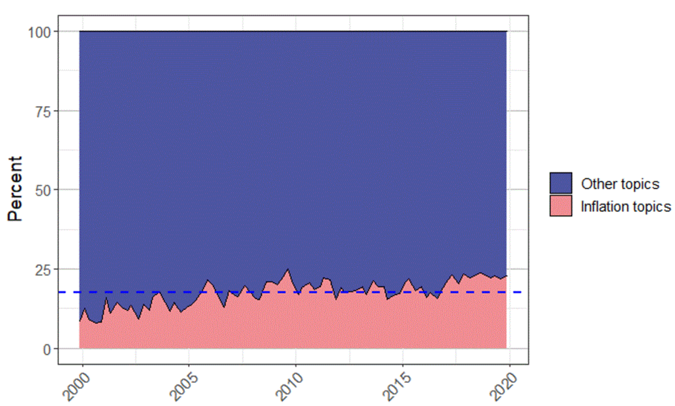
[25] Topic coherence measures the similarity of words within each topic. Unlike perplexity, topic coherence has been shown to correlate with human interpretability (Röder et al., 2015).

Figure A4.1. Topics discovered by LDA



Sources: ECB and authors' own calculations.

Figure A4.2. Fractions of topics in the ECB's introductory statements



Sources: ECB and authors' own calculations.

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