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Abstract

This paper examines the anchoring of inflation expectations in the euro area based on data from the Survey of Professional Forecasters (SPF). The analysis shows that the overall distribution of medium- and long-term inflation forecasts has changed considerably following the global financial crisis. Moreover, micro level expectations of professional forecasters are found to be sensitive to short-term economic developments. These patterns suggest that euro area inflation expectations are significantly less anchored to the ECB's definition of price stability in recent years compared to the pre-crisis period.

JEL Code: E31, E52, E58
Keywords: Inflation expectations, anchoring, euro area, ECB, financial crisis

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1 Introduction

The anchoring of inflation expectations plays a key role in modern inflation-targeting economies. As emphasized by macroeconomic models, inflation expectations are an important determinant of actual inflation, since firms incorporate their beliefs about future price developments into their pricing decisions today. Therefore, the formation of expectations is also crucial for an effective transmission of monetary policy. Anchoring is commonly defined as the central bank's ability to manage inflation expectations and is closely related to the notion of credibility. Under credible monetary policy, private agents anticipate deviations of inflation to be transitory and longer-term inflation expectations stay firmly anchored to the central bank's target. For the euro area, the European Central Bank (ECB) has committed itself to an inflation objective of below, but close to, 2% over the medium-term. However, monetary developments after the global financial crisis in 2008 have led to concerns whether the ECB is able to deliver on its promise. As inflation rates have been persistently low in recent years, policy makers have expressed worries that these episodes could cause a de-anchoring of expectations.[1] This issue seems to be even more relevant since the ECB's main policy rate has reached the effective lower bound (ELB). When the nominal interest rate is fixed, any fall in inflation expectations effectively rises the real interest rate, which is equivalent to a monetary tightening. Given the developments in recent years, a key question for policy makers is, whether medium- and long-term inflation expectations have remained tightly anchored to the ECB's definition of price stability.

This study investigates the inflation expectations anchoring in the euro area by employing two empirical approaches based on data from the Survey of Professional Forecasters (SPF). The first part tests for structural changes in the distribution of medium- (2-years ahead) and long-term (5-years ahead) inflation forecasts. Several theoretical arguments suggest that not only mean expectations, but also higher moments of the distribution are informative about the degree of anchorage. These arguments relate to learning behaviour of agents from past inflation realizations and to the emergence of multiple equilibria at the ELB. After deriving distributional measures for the first four moments at the individual level from SPF density forecasts, I analyse the time series behaviour of these moments by taking the average across forecasters. In particular, I apply the testing procedure developed by Bai and Perron (1998, 2003) to identify structural breaks in the aggregate mean,

[1] Draghi (2014) emphasized "the risk that a too prolonged period of low inflation becomes embedded in inflation expectations."

standard deviation, skewness and excess kurtosis of inflation expectations. The sample period is 1999Q1 - 2020Q3, which covers the global financial crisis, the low inflation regime after the crisis and the initial impact of the coronavirus pandemic. Any significant breaks in the distribution detected over this time span would hint at a change in the level and degree of anchoring. The procedure applied closely follows Dovern and Kenny (2020) and updates and extends their analysis.

The second part of the paper exploits the micro dimension of the SPF data set and examines the responsiveness of individual expectations to short-term economic developments. By applying a fixed effects within-group estimator, I investigate the sensitivity of mean medium- and long-term forecasts to (1) short-term forecasts and (2) changes in actual inflation. Moreover, I consider how uncertainty about near-term inflation outcomes translates into uncertainty at longer horizons. If the central bank's objective is perfectly credible, long-term inflation expectations should be insensitive to macroeconomic developments and shocks. Therefore, any significant correlation between those variables may hint at a lack of anchoring. In order to assess the potential time-varying degree of anchoring, I consider such correlation over sub-periods and rolling horizons. By using individual, forecaster-specific data, the analysis can shed some light on changes in the expectation formation process at the micro level.

Overall, this study finds evidence that medium- and long-term inflation expectations are significantly less anchored in the aftermath of the global financial crisis compared to the pre-crisis period. As indicated by the breakpoint tests, the aggregate distribution of SPF forecasts has changed considerably. Both the level of expectations and the distribution around it are not fully in line with the ECB's objective any more. A lack of anchoring is confirmed by SPF micro level evidence, which finds that medium- and long-term expectations respond significantly to short-term developments and past inflation dynamics. Such observations suggest that professional forecasters do not fully believe in the central bank's commitment or ability to achieve its inflation target over the time horizons considered here. Moreover, the findings indicate that the anchoring of expectations in the euro area has further deteriorated in recent years, which represents a major challenge for monetary policy going forward.

This paper is organized as follows: Section 2 reviews the empirical literature. Section 3 discusses the theoretical background underlying the anchoring of expectations. Section 4 presents the data and the technical details on how to derive distributional measures from density forecasts. Time series evidence on distributional changes in SPF forecasts is discussed in section 5, while section

6 investigates micro evidence on the expectation formation process. Chapter 7 concludes with a summary of the findings.

2 Literature review

The empirical literature has examined the anchoring of inflation expectations using similar approaches as the ones applied in this study. The first group of papers analyses potential breaks in the mean and dispersion of inflation expectations over time, while the second set of papers investigates the sensitivity of long-term expectations to short-term ones or to macroeconomic news. Moreover, some researchers have used financial market data, while others employed survey data.

Concerning evidence based on survey data, Ehrmann (2015) analyses forecast data from Consensus Economics in ten countries and notices some de-anchoring of inflation expectations under permanently low inflation rates. Using the same data, Buono and Formai (2018) examine the link between short- and long-term inflation expectations. They find a lack of anchoring in the euro area in a short period during the global financial crisis and again starting from 2014 onwards until the end of their sample in 2017. The SPF conducted by the ECB has also attracted much attention by the empirical literature on anchoring. As an example, Łyziak and Paloviita (2017) use a variety of approaches to investigate the SPF data at the aggregate level and find signs of de-anchoring in the euro area during the post-crisis period. More specifically, they document a rising sensitivity of long-term forecasts to short-term ones and lagged inflation, and a diminishing role of the ECB's target in the expectation formation process. While the researchers mentioned so far analyse data at the aggregate level by taking the average across forecasters, some papers exploited the micro data directly. In addition to their time series evidence presented above, Dovern and Kenny (2020) examine the sensitivity of SPF long-term expectations to a large number of macroeconomic developments. While they detect substantial co-movement with these indicators over the whole sample, they do not find any signs of a strengthening of the relationships after the global financial crisis. Glas and Hartmann (2016) and Rich and Tracy (2018) investigate uncertainty and disagreement among SPF forecasters and identify a rise in individual uncertainty during periods of expansionary monetary policy. Apokoritis et al. (2020) use micro data from a survey performed by De Nederlandsche Bank at weekly frequency and find that expectations have remained well-anchored to the

ECB's inflation target.[2]

In contrast to financial market data, survey data is not biased by inflation risk and liquidity premia. However, a main disadvantage of survey data relates to its availability at a low frequency (monthly or quarterly). Therefore, the literature has also employed market-based measures such as five-year forward inflation-linked swap rates, which are available on a daily basis. Using high-frequency financial data, Beechey et al. (2011) employ a news-regression approach and argue that inflation expectations are better anchored in the euro area than in the United States, but their sample relates to the pre-crisis period. Nautz et al. (2017) find structural breaks in the response of long-term inflation expectations to news in the euro area and conclude that they have been de-anchored ever since 2011. Natoli and Sigalotti (2018) study the tail comovements of market-based inflation expectations at different horizons and find that, since 2014, negative tail effects in short-term expectations have increasingly impacted longer-term ones.

Interestingly, market-based measures of longer-term inflation expectations had fallen to new lows in 2020, reaching values of below 1% in the euro area. As pointed out above, however, a significant part of this drop may be related to rising risk premia during the coronavirus crisis. In contrast, the survey data of the SPF offers an unbiased perspective on recent developments. Given that this study employs a variety of approaches that have been used in former research, it provides a comprehensive and robust view on a potential de-anchoring of inflation expectations in the euro area. Moreover, the current paper contributes to the empirical literature by analysing the entire distribution of expectations and by including forecasts at various horizons.

3 Theoretical considerations

Before investigating the empirical evidence on a potential de-anchoring of inflation expectations in the euro area, two questions arise from a theoretical point of view: First, why might expectations of private agents de-couple from the central bank's inflation target? Second, what are the implications of de-anchoring for the distribution of longer-term inflation expectations and the responsiveness of expectations to macroeconomic shocks? In order to derive testable predictions for the empirical analysis, this section reviews the theoretical literature that addresses these two questions.

[2] In general, we would prefer to evaluate long-term expectations of firms or households, as these agents are the ones making the relevant economic decisions. However, to date there is no such data in the euro area with a sufficient time dimension. Therefore, most of the literature relies on surveys based on professional forecasters.

As a starting point, consider a canonical monetary model (see e.g. Beechey et al. (2011)). In such a framework, private agents form their expectations based on rational expectations, which implies that they know the structure of the economy, including its structural parameters, and the central bank's reaction function. The dynamics of the economy are determined by random shocks and the central bank adjusts its policy rate, which is assumed to be fully flexible, in order to accommodate these shocks. Short-term inflation expectations are typically revised in response to shocks, given that there is some persistence in inflation and a lag in policy effectiveness. However, if the monetary authority announces an inflation target and has full credibility in the sense that the public believes that the central bank has the willingness and ability to achieve its objective, long-term inflation expectations will be firmly anchored around the target. As shown by Capistrán and Ramos-Francia (2010), inflation expectations for long-term horizons will then be equal to the announced inflation target. While being an illustrative textbook case, the assumptions of rational expectations and full flexibility of the policy rate are rather unrealistic.

In order to explain a potential de-anchoring of expectations, the literature has extended this framework by adding two aspects. The first adjustment concerns the formation of expectations and assumes that private agents have imperfect knowledge rather than full knowledge, as required by the rational expectations assumption. As first introduced by Orphanides and Williams (2004), agents use adaptive learning and effectively act like econometricians who incorporate past inflation realizations to form their expectations.[3] Following unfavorable shocks, public's inflation expectations may persistently de-couple from the authority's objective, which cannot occur in the perfect knowledge framework. Building on the idea by Orphanides and Williams (2004), the simulation results by Busetti et al. (2014) and Busetti et al. (2017) suggest that a sequence of deflationary shocks can induce a downward revision of the perceived central bank's inflation objective, as agents learn from past outcomes. Similarly, Beechey et al. (2011) point out that an explicit and credible inflation target serves as a focal point for long-term expectations when agents have imperfect knowledge. However, they show that under two extensions, long-term inflation expectations are considerably less anchored. These extensions include that the inflation objective is only implicit and time-varying. Under such conditions, there is a more uncertainty about the distribution of future inflation outcomes. Moreover, using model simulations of shocks arriving the economy, they show that long-term inflation expectations covary little with these shocks, if the central bank

[3]Based on recursive least squares, agents update the parameters of their perceived law of motion each period.

has an explicit and constant inflation objective which is credible. In contrast, a high sensitivity of long-term inflation expectations to shocks may hint at de-anchored inflation expectations.

A second extension to the simplified framework above acknowledges the existence of the effective lower bound (ELB) on nominal interest rates, i.e. the interest rate policy is not fully flexible as soon as negative demand shocks have driven it to zero. It is well-known that under the ELB constraint, the stabilization ability of the central bank is subject to asymmetry: while a positive demand shock can be accommodated by increasing the interest rate, a negative shock cannot be stabilized using the conventional interest rate instrument.[4] As first highlighted in the rational expectations model by Benhabib et al. (2001 a, b), the Taylor rule in combination with the ELB causes the emergence of multiple equilibria: In one equilibrium, called the "targeted-inflation" equilibrium, the nominal interest rate is strictly positive and inflation equals the target value of the central bank. In the second equilibrium, called the "liquidity trap" equilibrium, the nominal interest rate is zero and the inflation rate is below target.

Several papers have emphasized the implications of the ELB for the distribution of inflation outcomes and expectations. Aruoba et al. (2018) construct a stochastic two-regime equilibrium in which the economy may switch between a targeted-inflation and a deflation regime. Similar to the idea above, the latter one is associated with lower inflation outcomes, while the ELB is binding. Hommes and Lustenhouwer (2019) create a New Keynesian model in which heterogeneous agents choose between two forecasting heuristics based on relative performance. Fundamentalists trust the target of the central bank, while naive agents base their forecast on past inflation observations. In their framework, the central bank's credibility is determined endogenously and given by the fraction of fundamentalists relative to naive agents. They illustrate that a contractionary shock in combination with a binding ELB can result in a self-fulfilling deflationary spiral and an expectation-driven liquidity trap. Therefore, a de-anchoring of inflation expectations would be associated with a smaller fraction of fundamentalists and lower average inflation expectations.

While the former paper predicts a lower mean of long-term inflation expectations, others have also addressed the higher moments of the distribution. In the imperfect-credibility model by Bodenstein et al. (2012), inflation and output volatility is higher at the ELB if the central bank has low credibility. Hills et al. (2019) argue that the recent lower bound period has led agents to increase

[4] At this point, we abstract from the possibility of unconventional monetary policy measures. However, it is clear that once the nominal interest rate hits the ELB, the monetary authority loses its core policy instrument.

their assessment of the ELB risk, i.e. their judgement about the likelihood that the ELB will be binding in the future again even if interest rates have reversed to strictly positive values. By creating tail risk in future inflation, the ELB introduces a downward bias in the distribution of inflation expectations. They conclude that achieving the inflation target is now more difficult compared to the pre-crisis period. Recently, Armenter (2018) formulates the interaction between the monetary authority and the private sector as a strategic game and finds that, under the ELB constraint, two Markow equilibria emerge. He shows that in the good equilibrium, inflation is normally distributed around its mean, while in the bad equilibrium, the distribution of inflation rates has a lower mean, higher volatility and is skewed to the left. Therefore, we can expect that forecasters incorporate the possibility of such a bad equilibrium in their beliefs. Moreover, Coenen and Warne (2014) derive model-based predictive distributions using the ECB's New Area-Wide Model and analyze the implication of the ELB for the distribution of long-term inflation expectations. Following the financial crisis, their results suggest that expectations have become asymmetric and heavily skewed to the left, as the ELB has limited the central bank's reaction to deflationary shocks.[5]

The theoretical literature above helps us to formulate testable implications to assess the anchoring of inflation forecasts in the euro area. If long-term expectations are well-anchored, they should be close to constant and equal to the central bank's target. Moreover, they should exhibit a low and time-constant variance and a symmetric distribution around its mean. Alternatively, learning on the part of agents from low inflation outcomes and the emergence of multiple equilibria under the ELB may imply that inflation expectations have become de-anchored from the ECB's inflation target. In this case, the level of anchoring, represented by the mean of forecasts, would diverge from the monetary objective. Moreover, the degree of anchoring may deteriorate, which would be reflected in an increase of inflation uncertainty, a skewed distribution or larger tail risks. Therefore, section 5 tests for distributional changes in the moments of density forecasts over time.

A second implication from the theory is that well-anchored longer-term inflation expectations should be insensitive to macroeconomic shocks (see Beechey et al. (2011)). Any substantial co-movement between the two would indicate some lack of anchoring. For this reason, section 6 analyses the responsiveness of forecaster-specific expectations to short-term economic developments and potential changes in the expectation formation process.

[5] As pointed already out by Reifschneider and Williams (2000), normally distributed shocks would produce symmetric distributions of inflation if monetary policy is not constrained. However, when incorporating the ELB, the inflation outcomes are skewed to the left.

4 Data

This section outlines monetary developments in the euro area over the last twenty years and describes the data from the Survey of Professional Forecasters (SPF). Moreover, it presents the methods employed to derive the moments of a distribution from density forecasts.

4.1 Monetary policy and inflation in the euro area

The ECB's main objective is to maintain price stability in the euro area as a whole. Specifically, it aims to keep inflation below, but close to, 2% over the medium term. The inflation target relates to the Harmonized Index of Consumer Prices (HICP). In order to achieve its objective, the ECB adjusts its conventional policy instruments, namely three key interest rates. These are the rates on the main refinancing operations, the deposit facility and the marginal lending facility. Figure 1 shows the development of the main refinancing operations (MRO) rate of the ECB over the last 20 years.[6] The interest rate fluctuated between 2.0 and 4.75% in the pre-crisis period until 2008. Following the global financial crisis, the ECB responded to the demand shock by rapidly reducing the rate to 1.0% in May 2009. After two small hikes in 2011, the main refinancing rate was further lowered, reaching the historically low 0.25% in November 2013. From 2014 onwards, the rate has been bounded by the ELB and has been essentially zero ever since.

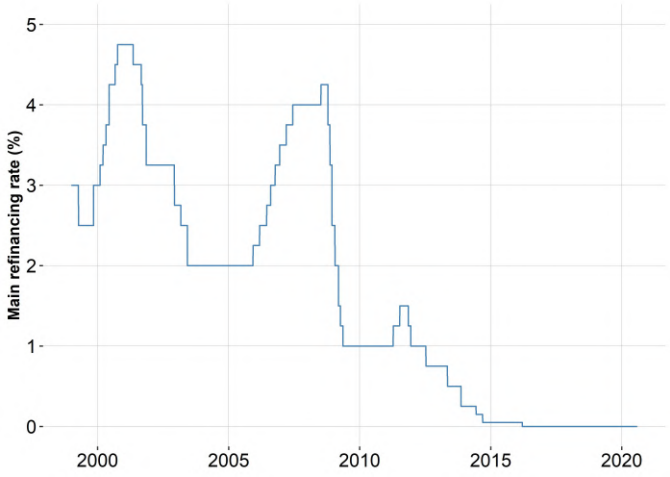
The ECB's expansionary monetary policy stance during and after the global financial crisis was a response to low inflation rates in the euro zone, which are depicted in figure 2. The graph presents year-on-year HICP inflation rates at monthly frequency in the euro area. Between 2000 and 2007, inflation rates were moderate and largely in line with the ECB's inflation target. In the aftermath of the global financial crisis and the sovereign debt crisis, inflation dynamics became much more volatile: At the beginning of the crisis, also called the period of "missing disinflation", euro area inflation was surprisingly high, but later during the recovery, inflation rates were repeatedly lower than expected. After a short period of normalization, HICP inflation fell throughout 2013 and 2014 and entered deflationary episodes between December 2014 and March 2015 and between February and May 2016. Since then, euro area inflation has been below the ECB's target for most of the time and is currently again close to zero, which reflects the impact of the coronavirus pandemic.

Given that the conventional interest rate instruments were bounded, the ECB has employed a

[6]The MRO rate is the interest rate banks have to pay when borrowing liquidity from the ECB for one week.

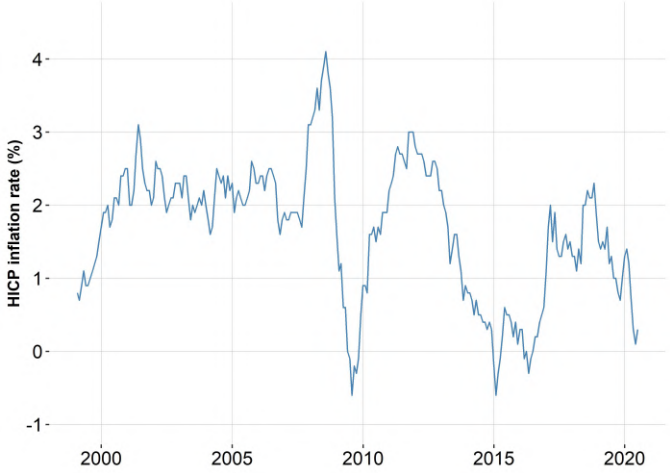
sequence of unconventional monetary policy tools. While initial measures after the crisis focused on liquidity provision to the banking sector (such as longer-term refinancing operations), the ECB introduced forward guidance in 2013 and an asset purchase program in 2014. Overall, the size of the ECB's balance sheet increased massively during these years. Recently, the central bank announced the implementation of the pandemic emergency purchase programme in response to the crisis induced by the coronavirus pandemic. As communicated by the ECB, these non-conventional measures were also targeted to stabilize inflation expectations. Despite of the unprecedented easing of monetary conditions, euro area inflation rates have been remarkably low in recent years.

Figure 1: Main refinancing operations rate of the ECB over time



Source: ECB Statistical Data Warehouse

Figure 2: HICP inflation rate in the euro area over time (annual rate of change)



Source: ECB Statistical Data Warehouse

4.2 Data from the Survey of Professional Forecasters

The subsequent empirical analysis is based on data from the Survey of Professional Forecasters (SPF), which is conducted by the ECB at a quarterly frequency since 1999.[7] In every survey round, forecasters from both financial and non-financial institutions are asked to report their expectations on euro area HICP inflation, core inflation, GDP growth and the unemployment rate for various horizons. Survey respondents provide both point forecasts and density forecasts for the annual rate of change in the HICP index, which is the main variable of interest in this study. The analysis will focus on the 1-year and 2-years ahead rolling horizon forecasts and the 4-5-years ahead fixed-event forecasts, which will be referred to as short-, medium-, and long-term inflation expectations, respectively.[8] Referring to the number of quarters, we denote these forecast horizons as $h \in \{4, 8, 20\}$. The data set covers the period 1999Q1 - 2020Q3 (T = 87) and hence contains a sufficient number of periods before and after the global financial crisis.[9] The SPF is conducted at the beginning of each quarter, after the actual HICP inflation rate for the last month of the previous quarter has been released. Moreover, forecasters are tracked by an anonymous ID, that allows identifying individual behavior over time.

It is important to note that the panel is unbalanced, since forecasters can enter and exit to and from the SPF and do not have to provide forecasts in each survey round. Table 1 covers descriptive statistics on response rates for HICP inflation probability forecasts. The mean number of observations for the density forecasts across all periods is 43.6, 39.3 and 38.9 for 1-year, 2-years and 5-years ahead expectations, respectively. The response rates vary across horizons because participants are not obliged to provide forecasts for each horizon. Overall, the number of forecasters in the sample decreases over time. Given that sample attrition is present in the data, later analysis will check for the robustness of the results by accounting for the most regular SPF participants only.

While we would prefer to examine data on firms' long-term inflation expectations, as they are the price setters in the economy, there is not sufficient data available yet for the euro area. The SPF is one of the best survey data sets on long-term inflation expectations available in the euro area

[7] The data set is publicly available at https://www.ecb.europa.eu/stats/ecb_surveys/survey_of_professional_forecasters/html/index.en.html.

[8] Specifically, in the July 2020 (2020Q3) survey, 1-year and 2-years ahead forecasts referred to the year-on-year HICP rate in June 2021 and June 2022. The long-term forecasts refer to a fixed annual outcome, in this example to the year 2025. The long-term horizon is defined as 4-years ahead forecast in the Q1 and Q2 survey rounds and as 5-years ahead forecast in the Q3 and Q4 rounds. For the sake of simplicity, I denote long-term expectations by h = 20.

[9] Note that the long-term forecasts have not been surveyed in the 1999Q2-1999Q4 and 2000Q2-2000Q4 rounds.

Table 1: Summary statistics for response rates on HICP probability forecasts across all periods

Number of observations	Mean	Minimum	Maximum
1-year ahead	43.6	33	63
2-years ahead	39.3	27	58
5-years ahead	38.9	30	59

and provides a rich longitudinal basis for empirical research. Moreover, the fact that participants provide density forecasts makes the data particularly suitable for analysing the overall distribution of inflation expectations.

4.3 Constructing density moments

In order to exploit the distributional information contained in the SPF density forecasts, some assumptions need to be made. The survey elicits subjective probability distributions in the form of histograms. Formally, for the h-step ($h \in \{4, 8, 20\}$) ahead forecast, respondent i ($i = 1..., N$) reports in survey round t the probability $p^b_{i,t+h|t} \in [0, 1]$ that future inflation will be within a certain bin b ($b = 1, ..., B$). To compute the moments of the distribution, I follow the usual convention and assume that all the probability mass in each bin b is centered at the midpoint of the interval, which is denoted by m_b.[10] For the interior bins, which have a length of 0.5 percentage points, this methodology is straightforward to implement. As an example, I assign the value 1.7 to the interval [1.5, 1.9). For the outer, open bins, I follow the ECB's methodology and close them by assuming that they have the same length as the interior intervals, i.e. 0.5 percentage points.[11] Given these assumptions, the first four moments of the individual density distribution are given by:

$$\mu_{i,t+h|t} = \sum_{b=1}^{B} p^b_{i,t+h|t}\, m_b \tag{1}$$

$$\sigma^2_{i,t+h|t} = \sum_{b=1}^{B} p^b_{i,t+h|t}\, (m_b - \mu_{i,t+h|t})^2 \tag{2}$$

$$s_{i,t+h|t} = \sum_{b=1}^{B} p^b_{i,t+h|t}\, \frac{(m_b - \mu_{i,t+h|t})^3}{\sigma^3_{i,t+h|t}} \tag{3}$$

[10] As shown by Glas (2020) in the context of the SPF, alternative distributional assumptions (such as a uniform distribution) do not change the results much when deriving the moments.

[11] Note that the bins have been changing across time as a response to low inflation outcomes during the global financial crisis and the coronavirus crisis.

$$k_{i,t+h|t} = \sum_{b=1}^{B} p_{i,t+h|t}^{b} \frac{(m_b - \mu_{i,t+h|t})^4}{\sigma_{i,t+h|t}^4} \tag{4}$$

Equations 1, 2, 3 and 4 refer to the estimated mean, variance, skewness and excess kurtosis of forecaster i's distribution, respectively. The standard deviation σ is derived by taking the square root of equation 2. We can construct aggregate measures for each moment $M = \{\mu, \sigma, s, k\}$ by computing the cross-sectional average as $\overline{M}_{t+h|t} = 1/N_{t+h|t} \sum_{i=1}^{N_{t+h|t}} M_{i,t+h|t}$, where $N_{t+h|t}$ refers to the number of forecasters reporting probabilities for forecast horizon h in period t. While the time series analysis in chapter 5 is based on these aggregate measures, the micro evidence in chapter 6 uses the individual estimates of moments from equations 1 to 4.

As an alternative measure to the the density mean in equation 1, one could also employ the point forecasts provided by survey respondents. In theory, the two measures should be the same if agents use a symmetric loss function. In practice, however, it is not clear whether respondents base their point forecast on the mean, median or mode of the histograms. As pointed out by Dovern and Kenny (2020), the density mean may contain more information because it draws on all probability forecasts from respondents. For the sake of comparability, I show both kind of measures when analysing structural breaks in the aggregate time series. Furthermore, the dispersion around expectations may be also measured based on the cross-sectional standard deviation of point forecasts, which reflects disagreement across respondents. However, as pointed out by Rich and Tracy (2018) and Glas (2020), disagreement seems to be a poor proxy for uncertainty. In contrast, the variance measure based on equation 2 and the corresponding standard deviation reflects an individual's confidence in forming its expectations, which is a natural measure of uncertainty around inflation expectations.

5 Time series evidence on the distribution of inflation expectations

This section presents time series evidence on the anchoring of inflation expectations in the euro area by testing for structural breaks in the distribution of SPF forecasts. The theoretical arguments in section 3 suggest that not only the level of anchoring, as measured by the mean of the distribution, but also the degree of anchoring is important. The latter can be evaluated based on higher moments, namely the standard deviation, skewness and excess kurtosis of the distribution. The

current approach closely follows the one by Dovern and Kenny (2020) on SPF long-term inflation expectations, but makes two extensions. First, it updates the analysis to the most recent data vintage (2020Q3), whereas their sample ends in 2017Q1. Recent developments in the distribution of the SPF forecasts justify the need for such an update. Second, the analysis in this paper does not only consider long-term (5-years ahead) inflation expectations, but also medium-term (2-years ahead) expectations. As the ECB's inflation target refers to the medium-term and credible monetary policy has shown to be effective over such horizons (see e.g. Romer and Romer (2004)), the analysis of 2-years ahead expectations seems to be policy relevant as well. Moreover, any similarities or discrepancies in the evolution of medium- and long-term forecasts help us to shed more light on the anchoring of inflation expectations in the euro area.

5.1 Testing for structural break points

To examine the stability of the first four moments of the aggregate distribution of inflation forecasts, I employ the method developed by Bai and Perron (1998, 2003). Their procedure identifies possible structural changes by employing a linear regression model, which allows for multiple unknown breaks. The method selects the number of significant breaks and the corresponding dates. These break points define different regimes and their associated parameters. Formally, I consider an AR(1) model for each moment of the distribution:

$$\overline{M}_{t+h|t} = \alpha_{M,r} + \beta_{M,r}\, \overline{M}_{t+h-1|t-1} + \epsilon^{M}_{t+h|t}, \tag{5}$$

where $\overline{M} = \{\mu, \sigma, s, k\}$ are the average moments of the distribution from before, $\alpha_{M,r}$ and $\beta_{M,r}$ are regime-specific parameters (where $r = 1, ..., R$) and $\epsilon^{M}_{t+h|t}$ is an i.i.d. error term. Dovern and Kenny (2020) include the intercept term to account for the persistence in the moments, which would otherwise induce autocorrelation in the residual term.

The number of breaks is determined based on the sequential SupF-test by Bai and Perron (2003). Broadly speaking, this method selects a break point if the parameters of the AR(1) model change significantly. More specifically, the technique starts with the full sample and tests for breaks under the null hypothesis that the parameters of the model are constant. If the test rejects the null hypothesis, it divides the sample at the break date and repeats the procedure for each subsample. Hence, the method sequentially tests the null hypothesis of l breaks versus $l + 1$ breaks until all of the subsamples can no longer reject the null hypothesis. As a robustness check, I also consider an

information criterion to select the number of breaks. In particular, I employ the modified Schwarz criterion (LWZ) by Liu et al. (1997), which is suggested in the presence of a lagged dependent variable (see Bai and Perron (2003)). Moreover, the Bai-Perron method requires to specify a minimum distance between two break points. The trimming parameter is chosen to equal 0.10, which implies a minimum distance of about 7 quarters.

For each moment, we can compute the regime-specific average as $\alpha_{M,r}/(1-\beta_{M,r})$. If medium- and long-term expectations are tightly anchored, we would expect the first moment of the distribution, the mean, as being in line with the ECB's inflation target and the estimates of $\alpha_{\mu,r}$ and $\beta_{\mu,r}$ remaining constant over time. The term $\alpha_{\mu,r}/(1-\beta_{\mu,r})$ can be interpreted as a regime-specific measure of forecasters' perceived inflation objective. Similarly, the parameters of the higher moments of the distribution should be also time-invariant. Any breaks of the standard deviation, skewness or kurtosis may signal a change in the degree of anchoring.

Figures 3 and 4 present the evolution of the average moments (blue lines) for long- and medium-term expectations, respectively. I also depict the regime-specific means (black line), which are selected based on the SupF-test. Table 2 shows the formal results of the break point test outlined above with corresponding break dates and F-statistics. The following sections will discuss the identified structural changes for each of the first four moments. Due to missing values in long-term expectations at the beginning of the sample, the analysis is constrained to the period between 2001Q1 and 2020Q3. For the sake of comparability, the sample for medium-term expectations is restricted to the same survey rounds.

5.2 Breaks in the mean

This subsection focuses on the break point analysis regarding the mean based on density and point forecasts, as shown in panel (a) and (b) of figures 3 and 4. Between 2000 and 2007, both medium- and long-term means have been largely in line with the ECB's definition of price stability. Afterwards, expectations became more volatile. According to the supF-test, the density mean of long-term inflation expectations features one significant break point in 2013Q2 (see table 2). The date of the downward shift in the mean corresponds to the beginning of the disinflation period in 2013. In quantitative terms, the regime-specific mean is falling to 1.64% from 1.90% before. Recently, the density mean at the 5-years horizon has continued the downward trend and reached new all-time lows (1.56% in 2020Q3). While these new levels may be still viewed as consistent

with the ECB's inflation target of below, but close to, 2.0%, the lack of recovery to former values, in spite of the accommodative monetary policy stance, suggests a potential de-anchoring of long-term expectations. Importantly, the recent drop is not entirely related to a short-lived impact of the coronavirus pandemic. As these trends have been in place for quite some time already, it rather represents a fundamental change in forecasters' expectations. The evolution of the long-term mean based on point forecasts is similar, albeit the structural break associated with a downward shift is dated later, in 2018Q4, and may relate to the recent disinflationary episode. The observation that long-term forecasts are revised upon observing low levels in actual inflation supports the claims of models with learning from past outcomes (e.g. Orphanides and Williams (2004)). However, the results for mean long-term expectations are weakened by the fact that the information criterion test based on the LWZ criterion does not select any breaks.

Despite a quantitatively more pronounced drop in mean 2-years ahead expectations, the Bai-Perron test fails to identify any breaks for this horizon. The finding may relate to the larger volatility of the medium-term time series compared to the long-term one, which makes it more difficult to detect stable regimes. Nevertheless, both, the density and point means of 2-years ahead expectations are very low in recent quarters, currently standing at about 1.2%. Therefore, mean medium-term expectations of SPF forecasters deviate even more from the ECB's definition of price stability compared to long-term ones.

For the sake of completeness, figure 8 in the appendix shows the evolution of 1-year ahead point mean expectations and the actual HICP inflation rate, together with the 2-years and 5-years ahead point means from above. In general, the actual HICP rate is much more volatile compared to mean expectations, but there is substantial co-movement between them. Moreover, 1-year ahead expectations are below 2-years and 5-years ahead expectations for most of the time since the global financial crisis, which is not true for the pre-crisis period.

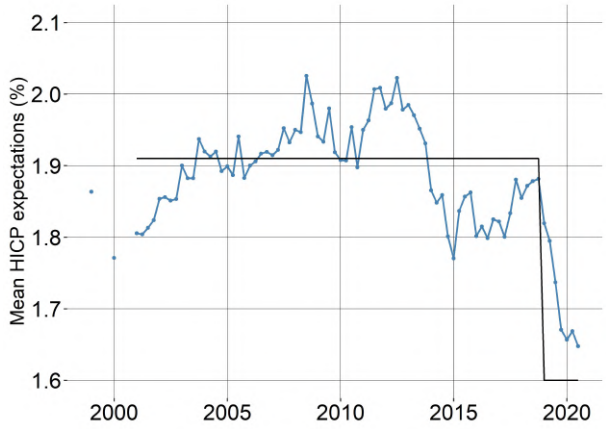
5.3 Breaks in the standard deviation

As pointed out above, not only the level, but also the degree of anchoring, as measured by the second moment, may be important for monetary policy transmission. Panel (c) in figures 3 and 4 document a significant increase in inflation uncertainty at long- and medium-term horizons in the midst of the global financial crisis. Surprisingly, the rise has been very persistent and uncertainty remained at high levels even after the acute phase of the crisis was over. The break-point analysis

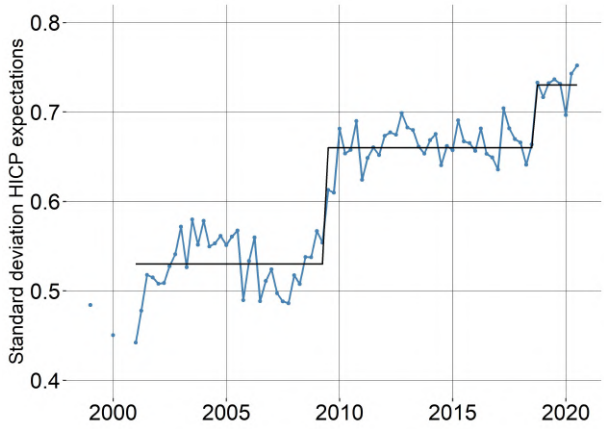
Figure 3: Break points for moments of long-term (5-years ahead) expectations

(a) Density mean

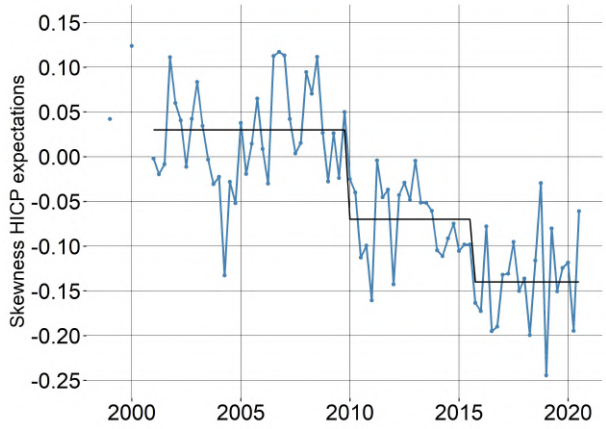
(b) Point mean



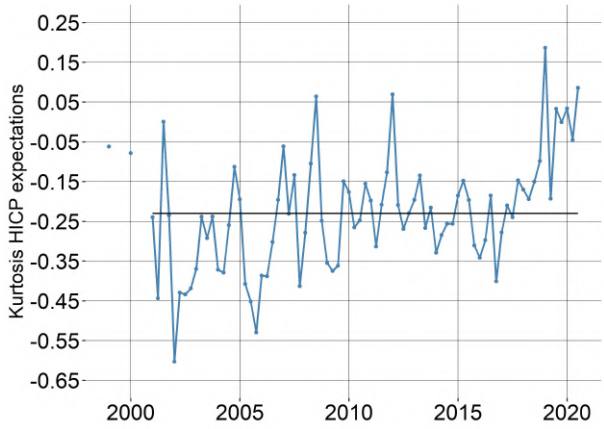
(c) Standard deviation



(d) Skewness



(e) Kurtosis



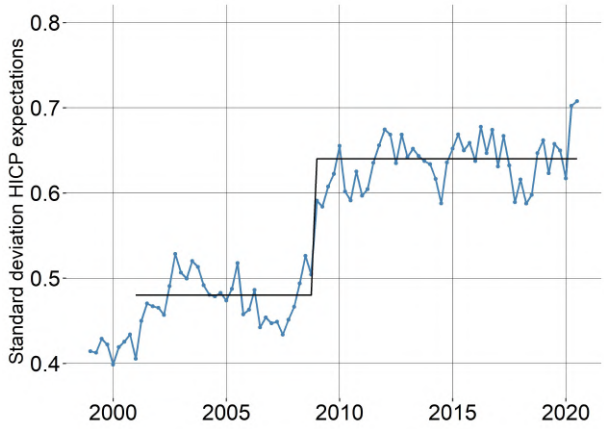
Note: The blue lines show the evolution of the various moments over time. The black lines represent the implied means of the respective regimes, with break points chosen by the Bai and Perron (2003) procedure using the supF-test.

Figure 4: Break points for moments of medium-term (2-years ahead) expectations

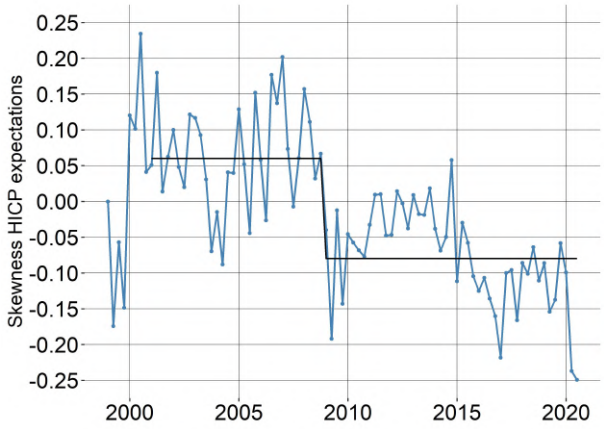
(a) Density mean

(b) Point mean

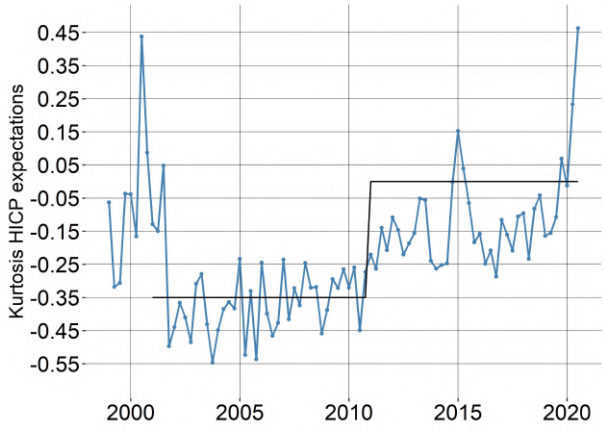
(c) Standard deviation



(d) Skewness



(e) Kurtosis



Note: The blue lines show the evolution of the various moments over time. The black lines represent the implied means of the respective regime, with break points chosen by the Bai and Perron (2003) procedure using the supF-test.

Table 2: Break points for average moments of long- and medium-term inflation expectations

	Long-term (5-years ahead) inflation expectations				
	Sequential supF			LWZ	
	Period	F test	Implied mean	# chosen bp	Period
Density mean 5y					
	2001Q1-2013Q2		1.90	0	2001Q1-2020Q3
	2013Q3-2020Q3	7.04*	1.64		
Point mean 5y					
	2001Q1-2018Q4		1.91	0	2001Q1-2020Q3
	2019Q1-2020Q3	8.35*	1.60		
Standard deviation 5y					
	2001Q1-2009Q2		0.53	0	2001Q1-2020Q3
	2009Q3-2018Q3	12.03*	0.66		
	2018Q4-2020Q3	11.80*	0.73		
Skewness 5y					
	2001Q1-2009Q4		0.03	1	2001Q1-2015Q3
	2010Q1-2015Q3	16.77*	-0.07		2015Q4-2020Q3
	2015Q4-2020Q3	8.05*	-0.14		
Excess kurtosis 5y					
	2001Q1-2020Q3		-0.23	0	2001Q1-2020Q3
	Medium-term (2-years ahead) inflation expectations				
	Sequential supF			LWZ	
	Period	F test	Implied mean	# chosen bp	Period
Density mean 2y					
	2001Q1-2020Q3		1.57	0	2001Q1-2020Q3
Point mean 2y					
	2001Q1-2020Q3		1.62	0	2001Q1-2020Q3
Standard deviation 2y					
	2001Q1-2008Q4		0.48	1	2001Q1-2008Q4
	2009Q1-2020Q3	15.23*	0.64		2009Q1-2020Q3
Skewness 2y					
	2001Q1-2008Q4		0.06	0	2001Q1-2020Q3
	2009Q1-2020Q3	11.37*	-0.08		
Excess kurtosis 2y					
	2001Q1-2010Q4		-0.35	1	2001Q1-2010Q4
	2011Q1-2020Q3	13.80*	0.00		2011Q1-2020Q3

Note: The results relate to the AR(1) model in equation 5. The dependent variable is the average moment as indicated by the respective row. The dates refer to the periods which are separated by a significant break. Implied means are computed for each regime using $\alpha_{M,r}/(1-\beta_{M,r})$. The number of breaks and their dates are selected based on the sequential supF-test by Bai and Perron (2003) (left column) and the modified Schwarz criterion (LWZ) (right column). * indicate that breaks in the parameters are jointly different from 0 at the 2.5% level.

based on the supF-test identifies structural breaks in the standard deviation of 2-years ahead expectations in 2008Q4 and of 5-years ahead expectations in 2009Q2. The latter exhibits a second break towards the end of the sample in 2018Q4, which reflects the fact that long-term inflation uncertainty has reached even higher levels recently. The average standard deviation around 5-years expectations has increased to 0.73 percentage points, a rise of more than 35% compared to the pre-crisis regime (0.53 percentage points). The coronavirus pandemic seems to have further increased inflation uncertainty, as the standard deviations of 2-years and 5-years ahead expectations reached new all-time highs in 2020Q3. While the supF test finds significant breaks for both long- and medium-term inflation uncertainty, the LWZ statistic chooses a break point only in the case of the 2-years ahead standard deviation.

Overall, the rise in average inflation uncertainty signals that expectations are now substantially less anchored around the ECB's definition of price stability compared to the pre-crisis period. This may reflect concerns of high future inflation given the unclear effects of new unconventional monetary policy measures, as well as fears of a prolonged period of low inflation. It is also in line with the consequences of uncertainty about the central bank's objective, as suggested by Beechey et al. (2011). Interestingly, the rise in uncertainty correlates with the increase in volatility of actual inflation following the 2008 crisis (see section 4.1).

5.4 Breaks in higher moments

Panels (d) and (e) of figures 3 and 4 show the evolution of the skewness and excess kurtosis in inflation expectations. Concerning the skewness, the time series charts suggest that the density distribution, while being largely symmetric in the early 2000s, became skewed to the left in the aftermath of the crisis. This observation is supported by the break point analysis using the supF-test, which identifies significant breaks in symmetry in 2009Q4 for 5-years ahead and in 2008Q4 for 2-years ahead expectations. The average skewness of long-term expectations turned even more negative afterwards and exhibits a second significant break point in 2015Q3. The latter is the only one that is found by the LWZ test as well. This suggests that, since the global financial crisis, forecasters view the downside risks to inflation weighting stronger than the upside risks. The findings are consistent with macroeconomic models which emphasize the role of the ELB for the overall symmetry of inflation expectations. The first break identified happened soon after the ECB rapidly lowered the interest rate in 2008 and 2009, albeit the the lower bound constraint was not

binding yet. This may imply that forecasters already anticipated the risk that the ELB may be reached at some point in the near future. The second break takes place in a period in which the interest rate constraint was binding for some time already. A potential explanation is that agents updated their beliefs on the future likelihood of staying at or returning to the ELB after having observed deflationary outcomes.

Forecasters' assessment of tail risks, as measured by the excess kurtosis, follows a general upward trend since the early 2000s. However, the Bai-Perron method does not detect any break in the tail risk of long-term expectations. In contrast, both the sequential supF-test and the LWZ statistic identify a significant break for the medium-term tail risk in 2010Q4. The implied mean of the excess kurtosis increased from -0.35 to 0.00 after the regime switch, which indicates that the distribution got heavier tails. Recent observations in both medium- and long-term expectations indicate that forecasters attach non-negligible weight to future inflation outcomes that are far off the ECB's target.

5.5 Summary of the distributional changes

The time series evidence on distributional changes in medium- and long-term inflation expectations reveals interesting results. During the pre-crisis period until about 2007, inflation expectations were relatively firmly anchored. The mean of forecasts was in line with the ECB's target and the distribution around the mean was symmetric and exhibited a low variance. In the aftermath of the global financial crisis, however, the overall distribution has changed considerably. Figure 9 in the appendix helps to summarize these changes by showing the average probability mass attached to various intervals of long-term (5-years ahead) inflation outcomes. The weight attached to the inflation interval between 1.5% to 2.4%, which is closest to the ECB's target rate, has steadily decreased since 2008. At the same time, the weight on the interval below 1.5% has grown substantially since then, i.e. forecasters attach more than 40% probability mass to low inflation outcomes in the long-term today. While high inflation outcomes, measured by the interval above 2.5%, were perceived to be more likely during the global financial crisis, the attached density mass has returned to pre-crisis levels. This demonstrates that the higher risk of tail events and the negative skewness of the distribution from before reflect the fact that forecasters speculate now about very low inflation rates in the future, even at long-term horizons. The finding is supported by figure 10, which shows the average probability mass attached to negative inflation rates in the long-term. While agents viewed

5-years ahead deflation risk as virtually negligible before the crisis, deflationary episodes seem to be much more likely now. Overall, the two figures demonstrate that the results above do not depend on the distributional assumptions made ("mass-at-midpoint").

As a robustness test, I also consider the time charts from figure 3 and 4 including only forecasters that have been very active before and after the global financial crisis.[12] As an extreme example, suppose that a fixed group of forecasters exit the sample before the global financial crisis started, and a second group of respondents with higher average inflation uncertainty entered the panel in midst of the crisis. One would interpret the break point in the standard deviation from above as a regime-change in the underlying expectation formation process, while in reality it just reflects a structural change in forecasters' characteristics. Therefore, it is reassuring to see that the same trends are valid when focussing only on the most active forecasters, as shown for long-term expectations in figure 11 in the appendix.

As pointed out by Dovern and Kenny (2020), forecasters may still believe that the ECB can achieve its ultimate goal of price stability over longer horizons than the five years considered here. A comparison between medium- and long-term expectations lends support to this hypothesis: The analysis has revealed that mean 5-years ahead forecasts are still closer to the ECB's target rate than the 2-years ahead predictions. This finding indicates that survey respondents have postponed their expectations when the target will be reached. Overall, there seems to be a lack of agents' trust in the ECB's ability to achieve its objective over the horizons considered here. A comparison to the results of Dovern and Kenny (2020) shows that the mistrust of SPF forecasters has increased during the last few years, as the current analysis finds additional breaks in the point mean, standard deviation and skewness of long-term expectations, which were not detected by their sample before. These structural changes indicate that the degree of anchorage has further deteriorated in recent years.

[12] Active forecasters are defined as those that have contributed at least 20 times to the SPF both before and after the global financial crisis.

6 Micro level evidence on the responsiveness of inflation expectations

As a second approach to evaluate anchoring in the euro area, I analyse the sensitivity of medium- and long-term inflation expectations to short-term developments. A large literature has argued that firmly anchored expectations should be unresponsive to macroeconomic news, which are driven by shocks (see e.g. Gürkaynak et al. (2010), Beechey et al. (2011)). In line with such propositions, I exploit the SPF panel data on the individual, forecaster-specific level in order to assess overall anchoring and potential changes in its degree over time. This will also help to shed more light on the expectation formation process at the micro level that can potentially explain the patterns in the aggregate distribution of chapter 5. While the first part of this section focuses on the effects of macroeconomic shocks on the individual density mean, the second part looks at the responsiveness of forecaster-specific uncertainty.

6.1 Responsiveness of mean inflation expectations

This subsection analyses the co-movement of forecaster-specific mean inflation forecasts and economic news by employing two tests that have been commonly applied in the literature: The sensitivity of medium- and long-term expectations to (1) short-term expectations and to (2) current inflation rates. The first approach has been implemented by a large number of empirical papers, including Strohsal et al. (2016), Łyziak and Paloviita (2017), Buono and Formai (2018) and Apokoritis et al. (2020). The idea is that transitory shocks to the economy, such as an oil price shock, should influence short-term inflation expectations, but should have no effect on expectations at longer horizons. In this view, changes in short-term forecasts represent a proxy for all macroeconomic news and surprises relevant to inflation. If expectation at longer horizons are firmly anchored to the central bank's inflation target, they should be insensitive to news-driven short-term expectations. Therefore, any significant co-movement between the two can be seen as a sign of de-anchoring.[13] Using the notation introduced above, I apply fixed effects within-group panel estimation to a model of the form

$$\Delta\mu_{i,t+h|t} = \alpha_{SR} + \beta_{SR}\,\Delta\mu_{i,t+4|t} + u_i + \epsilon_{i,t} \;\;, h \in \{8, 20\}, \tag{6}$$

[13] Given that forecasts at various horizons are elicited in the same survey round, they can be assumed to be conditional on the same information set.

where $\Delta\mu_{i,t+h|t} = \mu_{i,t+h|t} - \mu_{i,t-1+h|t-1}$ represents the change in the medium- ($h = 8$) or long-term ($h = 20$) mean expectation of forecaster i at survey round t, α_{SR} is a constant, $\Delta\mu_{i,t+4|t}$ is the change in the short-term forecast and $\epsilon_{i,t}$ is an error term.[14] Moreover, I include an individual fixed effect u_i to capture any time-invariant heterogeneity among survey respondents. Following Dovern and Kenny (2020), the error term is allowed to exhibit both temporal and spatial correlations (Driscoll and Kraay (1998)).[15] The main coefficient of interest, β_{SR}, is often referred to as "pass-through" coefficient (Jochmann et al. (2010)) and should be close to zero and constant if inflation expectations are perfectly anchored. While this is particularly true for long-term (5-years ahead) expectations, medium-term (2-years ahead) expectations may exhibit some positive value for β_{SR}. For instance, a shock that drives short-term forecasts may be persistent enough to influence also medium-term predictions. In this context, changes in the pass-through coefficient β_{SR} over time are indicative of differences in the degree to which expectations are anchored. In line with the idea that the anchoring of expectations may have changed after the global financial crisis, I split the sample and allow the parameter β_{SR} in equation 6 to break after 2008Q3.[16] To this end, I apply an F-test under the null hypothesis that the pass-trough coefficients before and after the crisis are of same size. A significant increase of the coefficient over time would hint at a lower degree of anchoring.

A second empirical test examines the sensitivity of inflation expectations to changes in current inflation. Such an approach has been chosen by Ehrmann (2015), Łyziak and Paloviita (2017) and Apokoritis et al. (2020), among others. According to Bomfim and Rudebusch (2000), well-anchored expectations should be unresponsive to recent changes in observed inflation rates. In contrast, if there is uncertainty around the central bank's inflation objective and doubts about monetary policy effectiveness, private agents may learn from lagged inflation values as in Orphanides and Williams (2004). Analogously to equation 6, we estimate the model

$$\Delta\mu_{i,t+h|t} = \alpha_\pi + \beta_\pi \, \Delta\pi_{t-1} + u_i + \epsilon_{i,t} \;\; , h \in \{8, 20\}, \tag{7}$$

[14] The model could be estimated using levels of each variable. However, the time series is non-stationary in levels, such that the difference specification is preferred.

[15] Dovern and Kenny (2020) argue that both features are important because forecasters are surveyed simultaneously and forecast revisions are autocorrelated due to information rigidities.

[16] This date is chosen because 2008Q4 was the first survey round after the collapse of Lehmann Brothers in September 2008. The constant and the fixed effects are not allowed to break.

where $\Delta\pi_{t-1}$ denotes the recent change in HICP inflation and $t-1$ refers to the last month of the previous quarter.[17] Any estimate of the coefficient β_π that is significantly different from zero can be interpreted as a lack of credibility and anchoring. Besides running equation 7 over the whole sample period, a second specification allows again for a break in the coefficient β_π in the midst of the global financial crisis.

Before turning to the results, note that the estimates of β_{SR} and β_π do not have a causal interpretation, as we cannot control for a large number of latent factors. However, the variables considered here should capture the effects of unobservable shocks that drive the near-term economic outlook and, hence, should be good proxies for what is relevant for inflation in the short-term. By analysing the co-movement of longer-term expectations and these short-term developments, one can get an informative estimate on the degree of anchoring. Also note that the specifications above are closely related to Łyziak and Paloviita (2017), which use the SPF data and apply the same tests as above to the medium- and long-term forecasts. However, they estimate the relationships at the aggregate level using averages across forecasters for each period. Besides having a low number of observations, a main disadvantage of their approach is that the aggregate numbers may be biased due to non-random dropouts or partially missing answers of forecasters. In contrast, the micro level approach chosen here controls for heterogeneity across forecasters and only includes an individual at a given survey round if it has submitted density estimates for all three time horizons. Therefore, the current analysis employs a more consistent set of forecasts, with an overall observation count of 2145.

Table 3 shows the responsiveness of medium- and long-term forecasts to short-term ones, as given by equation 6. When considering the whole sample between 2001Q1 and 2020Q3, changes in both 2-years and 5-years ahead expectations are positively correlated to 1-year ahead ones. As suggested by previous literature (e.g. Mehrotra and Yetman (2018)), the pass-trough coefficient is larger for the medium-term horizon, given that short-term shocks may persist for some time. The positive and significant estimate for coefficient β_{SR} suggests that inflation expectations of SPF forecasters are not perfectly anchored, but react substantially to macroeconomic developments. On average, forecasters revise their long-term inflation expectations by about 0.08 pp, when they adjust their short-term expectations by 1 pp. The second specification in table 3 suggests a mild increase

[17] The HICP inflation rate in the previous month gets published before the SPF forecasters make their predictions at the beginning of each quarter. Therefore, this is part of their information set when forming expectations.

Table 3: Sensitivity of individual medium- and long-term expectations to short-term expectations

	Whole sample			Whole sample with split in 2008Q3				
Dep. var.	α_{SR}	β_{SR}	R^2 adj.	α_{SR}	β_{SR}^{BC}	β_{SR}^{AC}	R^2 adj.	H_0: β_{SR}^{BC}=β_{SR}^{AC} [p-value]
Δ 5y (LR)	0.000	0.083***	0.026	0.000	0.066***	0.089***	0.026	0.520
expectations	(0.000)	(0.021)		(0.003)	(0.025)	(0.027)		
Δ 2y (MR)	0.000	0.303***	0.170	0.001	0.233***	0.328***	0.173	0.076*
expectations	(0.000)	(0.030)		(0.005)	(0.043)	(0.034)		

Note: Estimation results of equation 6 including fixed effects for each forecaster. Number of observations is 2145. Dependent variables are the change in long-term (5-years) or medium-term (2-years) expectations. Standard errors are shown in parentheses and are calculated based on the method by Driscoll and Kraay (1998), which are robust against spatial and temporal dependence. *, **, *** denote statistical significance at 10 percent, 5 percent, and 1 percent level, respectively. The last column displays the p-value of an F-test of the hypothesis that β_{SR} is the same before and after 2008Q3.

in the pass-through from short-term to long-term predictions following the global financial crisis. However, a F-test of the hypothesis that the coefficients do not change significantly before (β_{SR}^{BC}) and after (β_{SR}^{BC}) the crisis does not reject this hypothesis. In contrast, the increase in the sensitivity of medium-term forecasts to short-term ones after the crisis is significant at the 10% level. As argued above, such an observations hints at a change in the degree of anchoring after 2008Q3.[18]

While the analysis above assumes that the pass-through coefficient changed in midst of the global financial crisis, the process of de-anchoring may be a more gradual one. Therefore, another way to examine possible changes in the expectation formation process is to estimate rolling window regressions of equation 6, similar to Buono and Formai (2018). Figure 5 presents the pass-trough coefficient β_{SR} over rolling horizons with a size of 24 quarters, again employing fixed-effects within-group panel estimation.[19] The rolling coefficients show that the pass-through to long-term expectations actually got smaller during the acute phase of the crisis, while the sensitivity of medium-term forecasts to short-term ones increased during that time. For both horizons, the pass-trough coefficient is larger towards the end of the sample, suggesting that the degree of anchoring has gradually decreased in recent years.

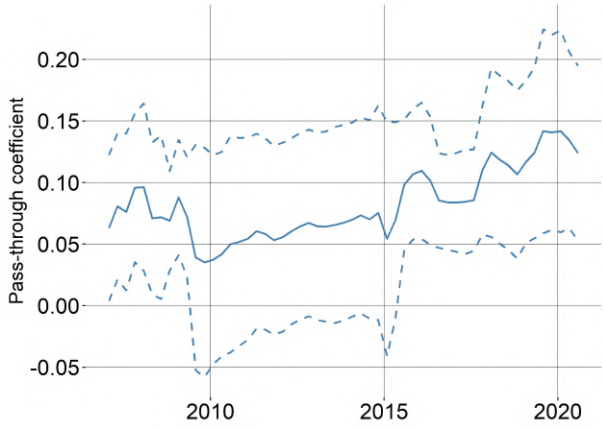
Table 4 presents evidence on the sensitivity of medium- and long-term expectations to current inflation. Over the whole sample, both medium- and long-term expectations have responded significantly to recent changes in inflation rates. For instance, forecasters adjust their long-term

[18] As a robustness check, I repeated the analysis using the individual point forecasts for each horizon instead of the mean density forecasts. The results remain unchanged.

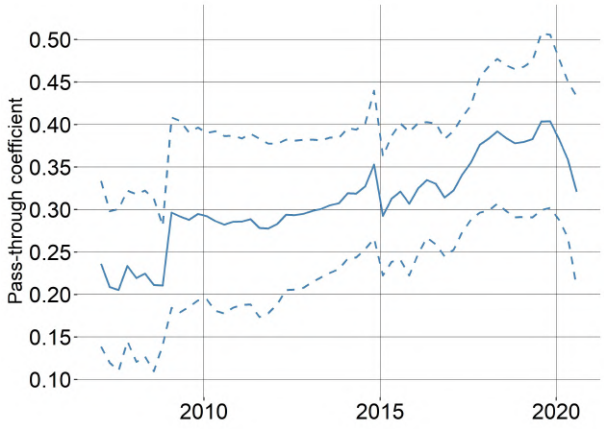
[19] The sample period of the first rolling horizon is 2001Q2-2007Q1, the sample period of the last one is 2014Q4-2020Q3.

Figure 5: Rolling horizon estimation of the pass-through coefficient β_{SR}

(a) 5-years ahead expectations



(b) 2-years ahead expectations



Note: Solid lines represent the inflation pass-through coefficient from 1-year ahead to 5-years/ 2-years ahead expectations over rolling windows of 24 quarters. Dashed lines show 95% confidence intervals.

predictions upwards by 0.03 percentage points, when actual HICP inflation rates increased by 1 percentage point in the last month relative to the previous quarter. This implies that long-term expectations are somewhat backward-looking. Such behaviour is in line with models of uncertainty about the central bank's objective and learning from past inflation realizations (e.g. Orphanides and Williams (2004)). When splitting the sample into pre- and post-crisis periods, I do not find any evidence that the coefficient β_π has changed for 5-years ahead expectations. By contrast, 2-years ahead predictions are significantly more sensitive to changes in current inflation after the crisis, as the F-test indicates a significant break after 2008Q3.[20] It suggests that the role of the ECB target rate has somewhat declined over time and agents give greater consideration to past HICP rates when forming expectations. This finding is confirmed in figure 6, which depicts the rolling horizon estimates of β_π from equation 7. While there is no clear trend in the response of long-term expectations to current inflation rates, the sensitivity of medium-term forecasts increased in midst of the crisis and even more in recent years.

Summing up, individual mean inflation expectations of SPF forecasters respond significantly to short-term developments and past inflation rates. This implies that the ECB's price stability objective is not a fully credible anchor point, but agents revise their forecasts in response to macroe-

[20]The results are similar when taking the 3-months average HICP inflation rate of the previous quarter instead of the last month's rate only.

Table 4: Sensitivity of individual medium- and long-term expectations to current inflation rates

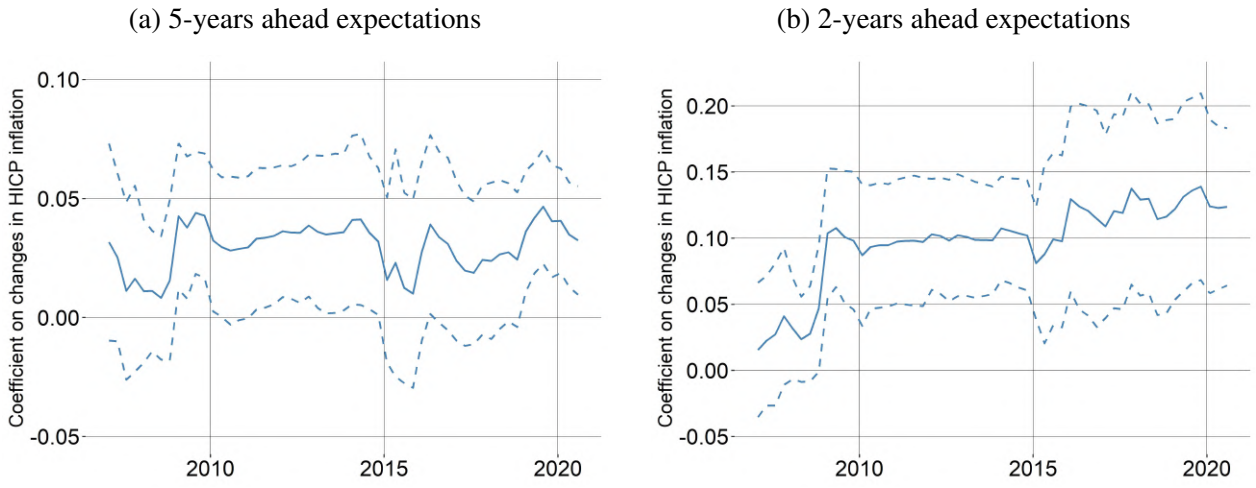
	Whole sample			Whole sample with split in 2008Q3				
Dep. var.	α_π	β_π	R^2 adj.	α_π	β_π^{BC}	β_π^{AC}	R^2 adj.	H_0: β_π^{BC}=β_π^{AC} [p-value]
Δ 5y (LR)	-0.000	0.034***	0.009	-0.000	0.034*	0.034***	0.009	0.987
expectations	(0.004)	(0.010)		(0.004)	(0.018)	(0.012)		
Δ 2y (MR)	0.000	0.088***	0.033	0.002	0.029	0.112***	0.038	0.002***
expectations	(0.007)	(0.020)		(0.006)	(0.019)	(0.020)		

Note: Estimation results of equation 7 including fixed effects for each forecaster. Number of observations is 2145. Dependent variables are the change in long-term (5-years) or medium-term (2-years) expectations. Standard errors are shown in parentheses and are calculated based on the method by Driscoll and Kraay (1998), which are robust against spatial and temporal dependence. *, **, *** denote statistical significance at 10 percent, 5 percent, and 1 percent level, respectively. The last column displays the p-value of an F-test of the hypothesis that β_π is the same before and after 2008Q3.

conomic developments. For long-term inflation predictions, I find at most weak evidence that the sensitivity to shocks has changed after the crisis. In contrast, medium-term forecasts respond significantly stronger to changes in short-term expectations and developments in actual inflation rates in recent years compared to the pre-crisis period. The rolling horizon estimates show that these trends are not limited to a short episode following the global financial crisis, but are also valid and even stronger in recent years. While such an observation could also mean that forecasters anticipate shocks to be more persistent now than in the past, it still implies that they have less confidence in the central bank's commitment or ability to fully accommodate such shocks over the medium-term. Hence, the results in this section indicate that agents have postponed their expectations of when the ECB's target will be reached. This argument has been also made above, when I have established that mean long-term expectations are closer to the ECB target than medium-term ones.

The results at the micro level also offer some potential factors explaining the trends in aggregate mean expectations in chapter 5. As medium- and long-term expectations are found to be backward-looking to some extent, low inflation realizations following the global financial crisis have induced forecasters to revise their predictions downwards. Similarly, as the short-term economic outlook has deteriorated over time, they adjusted their expectations also at longer horizons. These observations add to our understanding how inflation expectations are formed and why they show some degree of de-anchoring in recent years.

Figure 6: Rolling horizon estimation of the coefficient on current inflation β_π



Note: Solid lines represent the coefficient on the response of 5-years/ 2-years ahead expectations to changes in current inflation over rolling windows of 24 quarters. Dashed lines show 95% confidence intervals.

6.2 Responsiveness of inflation uncertainty

Since the SPF density forecasts allow us to derive the full probability distribution at the individual level, one can also look at the co-movement of higher moments and macroeconomic developments. Uncertainty about the inflation outlook may be of particular interest, as it speaks to the degree of anchoring even if mean expectations are in line with the ECB's target. Several papers have examined the determinants of uncertainty in the context of the SPF panel. For instance, Glas and Hartmann (2016) argue that individual inflation uncertainty increases during periods of expansionary policy. While the current study does not address the determinants underlying uncertainty, it tries to shed more light on the degree of anchoring by applying an appropriate adjustment to the analysis used in the context of mean expectations. In particular, I examine the question whether uncertainty about the short-term outlook in inflation translates into uncertainty at longer horizons. If forecasters are certain about the central bank's objective and its ability to reach the target, uncertainty about the inflation rate in the medium- and long-term should be insensitive to an increase of risk in the short-term outlook, which is driven by shocks. Again, significant co-movement between the variables or any change in the relationship over time may hint at some de-anchoring of expectations. In line

with former analysis, I use within-group panel estimation in order to estimate the model

$$\Delta\sigma_{i,t+h|t} = \gamma_{SR} + \lambda_{SR}\,\Delta\sigma_{i,t+4|t} + u_i + \epsilon_{i,t} \;\; , h \in \{8, 20\}, \tag{8}$$

where $\Delta\sigma_{i,t+h|t} = \sigma_{i,t+h|t} - \sigma_{i,t-1+h|t-1}$ denote the change in the medium- ($h = 8$) or long-term ($h = 20$) standard deviation of forecaster i, γ_{SR} is a constant, $\Delta\sigma_{i,t+4|t}$ is the change in short-term standard deviation and u_i and $\epsilon_{i,t}$ are defined as above. The coefficient λ_{SR} measures the degree of co-movement between risk at longer-term and short-term horizons and is expected to be small and constant if inflation expectations are well anchored around the ECB's objective.

Table 5 shows that there is a positive and significant correlation between medium- or long-term and short-term uncertainty. The large coefficient λ_{SR} implies that forecasters adjust their risk outlook at longer horizons substantially in response to shocks driving short-term uncertainty. When splitting the sample after 2008Q3, I cannot identify any significant change in λ_{SR} between the two episodes for long-term assessments of risk. In contrast, the sensitivity of medium-term inflation uncertainty to changes in short-term risks is larger in the aftermath of the global financial crisis, as indicated by a significant F-test. However, figure 7 demonstrates that these long-term averages disguise important changes over time. When applying rolling horizon estimates of equation 8, I find a substantial increase of the pass-trough from short-term to both medium- and long-term uncertainty from the the start of the global financial crisis until 2015. In recent years, however, the coefficient λ_{SR} has returned to its pre-crisis level.

Summing up, the analysis shows that forecasters update their assessment of longer-term inflation uncertainty in response to changes in short-term risks. These co-movements increased during the global financial crisis, suggesting that the degree of anchoring deteriorated for some period.

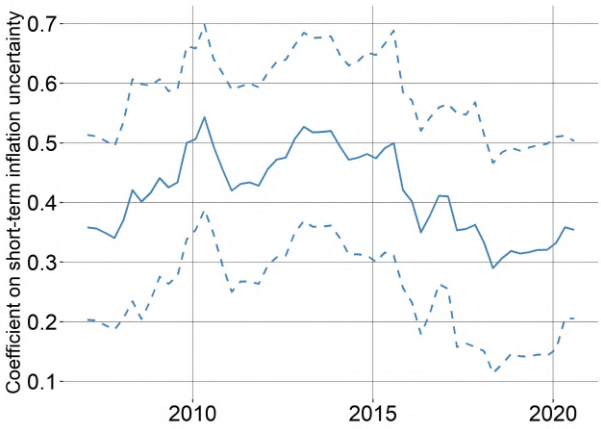
Table 5: Sensitivity of individual medium- and long-term inflation uncertainty to short-term uncertainty

	Whole sample			Whole sample with split in 2008Q3				
Dep. var.	γ_{SR}	λ_{SR}	R^2 adj.	γ_{SR}	λ_{SR}^{BC}	λ_{SR}^{AC}	R^2 adj.	H_0: λ_{SR}^{BC}=λ_{SR}^{AC} [p-value]
Δ 5y (LR)	0.000	0.420***	0.160	-0.000	0.416***	0.422***	0.160	0.949
uncertainty	(0.002)	(0.046)		(0.002)	(0.076)	(0.057)		
Δ 2y (MR)	0.000	0.623***	0.396	-0.000	0.546***	0.659***	0.399	0.043**
expectations	(0.002)	(0.031)		(0.002)	(0.041)	(0.037)		

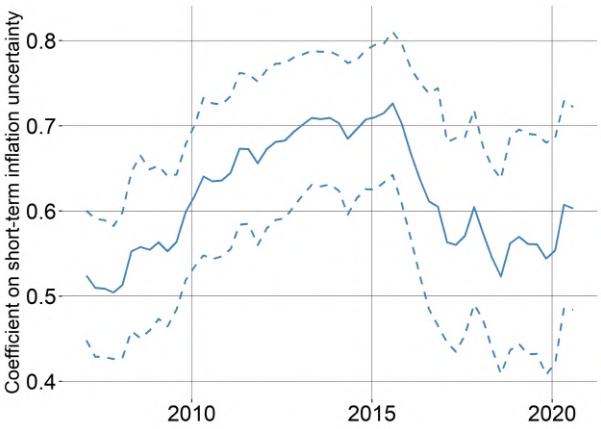
Note: Estimation results of equation 8 including fixed effects for each forecaster. Number of observations is 2145. Dependent variables are the change in long-term (5-years) or medium-term (2-years) inflation uncertainty. Standard errors are shown in parentheses and are calculated based on the method by Driscoll and Kraay (1998), which are robust against spatial and temporal dependence. *, **, *** denote statistical significance at 10 percent, 5 percent, and 1 percent level, respectively. The last column displays the p-value of an F-test of the hypothesis that λ_{SR} is the same before and after 2008Q3.

Figure 7: Rolling horizon estimation of the coefficient on short-term inflation uncertainty λ_{SR}

(a) 5-years ahead uncertainty



(b) 2-years ahead uncertainty



Note: Solid lines represent the inflation pass-through from 1-year ahead to 5-years/ 2-years ahead inflation uncertainty over rolling windows of 24 quarters. Dashed lines show 95% confidence intervals.

7 Conclusion

This study presents novel and comprehensive evidence on the degree of inflation expectations anchoring in the euro area. Based on data from the Survey of Professional Forecasters, I find strong indications that expectations are less tightly anchored to the ECB's inflation target since the global financial crisis compared to the pre-crisis period. The overall distribution of inflation forecasts has

significantly changed over time, reflecting the fact that professional forecasters attach considerable probability to low inflation outcomes even at long-term horizons today. Similarly, forecaster-specific medium- and long-term expectations are found to be responsive to short-term developments. Overall, such patterns are in line with macroeconomic models that emphasize the role of learning from past inflation outcomes (e.g. Orphanides and Williams (2004)) and the emergence of multiple equilibria at the ELB (e.g. Reifschneider and Williams (2000)).

Another important conclusion is drawn from the comparison between medium-term and long-term forecasts. While mean 2-years ahead expectations are well below the ECB's inflation target for most of the time after the global financial crisis, 5-years predictions are still closer to the target rate. Similarly, medium-term expectations are more responsive to short-term economic developments after the crisis than before, but long-term expectations show at most weak signs of higher sensitivity. These observations suggest that survey respondents have postponed their assessment of when the central bank target will be reached. Therefore, forecasters may still believe in the ECB's ability to achieve its objective eventually, but they doubt its ability to achieve the target over the horizons considered here.

The degree of anchoring seems to have further deteriorated in recent years, given that some of the breaks in the distribution of forecasts are detected towards the end of the sample. These developments pose some real risk that the euro area may enter a self-fulfilling liquidity trap with a prolonged period of low inflation rates and a binding ELB. Both macroeconomic theory (e.g. Armenter (2018)) and anecdotal evidence from Japan during the 1990s suggest that such episodes can come with high economic costs. Under such circumstances, strong monetary policy actions seem to be justified in order to restore confidence. Given its crucial role, the degree of anchoring in the euro area needs to be closely monitored by policy makers and further analysed by future research.

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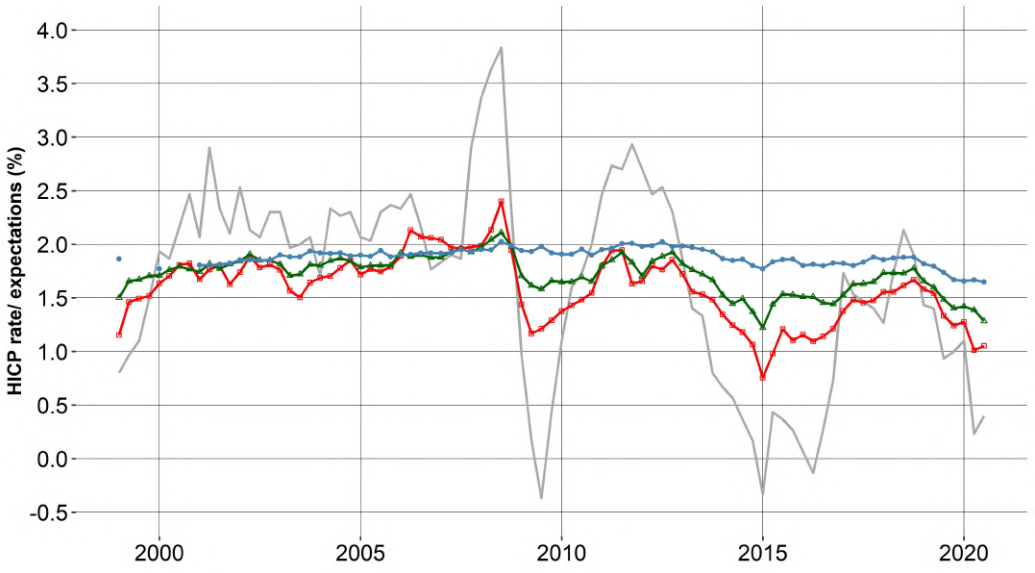
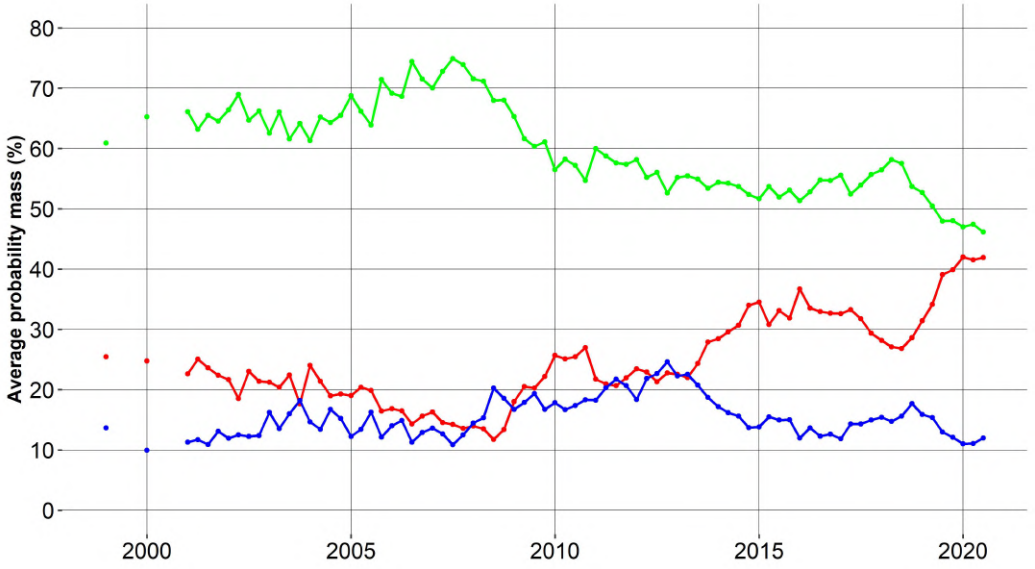
Appendix

Figure 8: Evolution of point means for various horizons and actual HICP inflation



Note: Grey line: quarterly HICP inflation rate (3-months average). Red line: 1-year ahead point mean expectations. Green line: 2-years ahead point mean expectations. Blue line: 5-years ahead point mean expectations.

Figure 9: Average probability mass attached to various intervals for long-term inflation expectations



Note: The green line presents the probability mass attached to the interval between 1.5% and 2.4%, the red line the interval below 1.5% and the blue line the interval above 2.5%.

Figure 10: Average probability mass attached to deflationary outcomes (inflation below 0%) for long-term inflation expectations

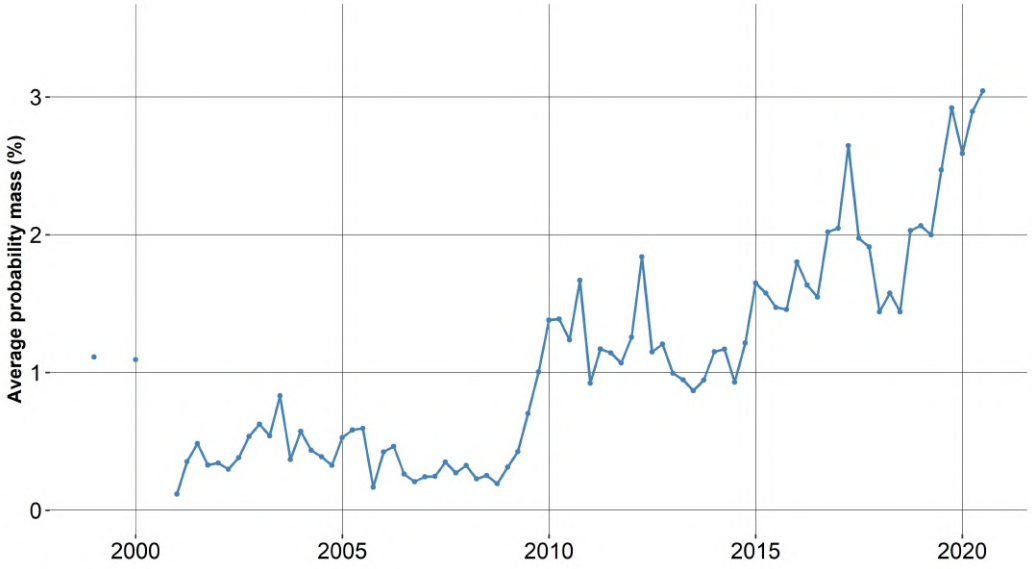
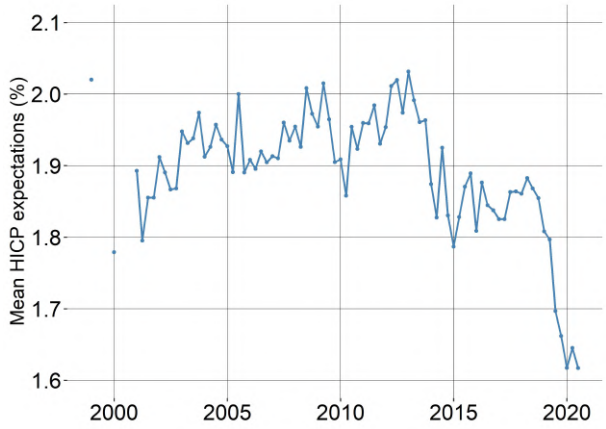


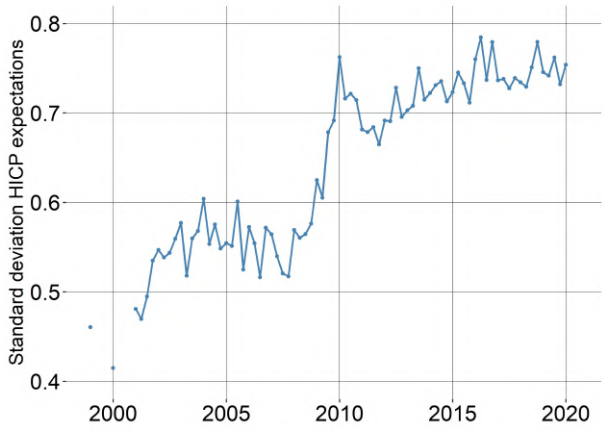
Figure 11: Break points for moments of long-term (5-years ahead) expectations including only the most active forecasters

(a) Density mean

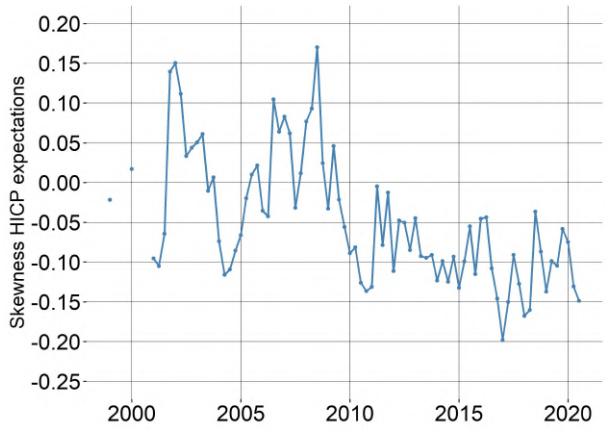
(b) Point mean



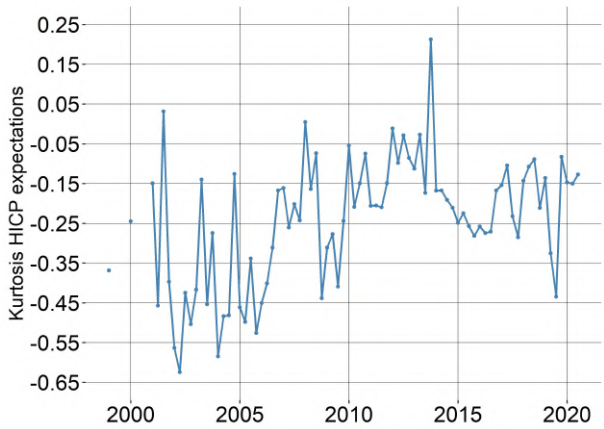
(c) Standard deviation



(d) Skewness



(e) Kurtosis



Note: Robustness check for former results by including only the most active forecasters, defined as those that participated at least twenty times both before and after the global financial crisis. The blue lines show the evolution of the various moments over time. The black lines represent the implied means of the respective regimes, with break points chosen by the Bai and Perron (2003) procedure using the supF-test.