

Anchoring Inflation Expectations in Unconventional Times: Micro Evidence for the Euro Area[†]

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Abstract: We exploit micro data from professional forecasters to examine the stability of the distribution of long-term inflation expectations in the euro area following the Great Recession. Although mean expectations declined somewhat, they remained quite well anchored to the ECB's price stability objective. Also, their degree of co-movement with other variables did not increase noticeably following the Great Recession. In contrast, we document an increase in long-term inflation uncertainty and a clear shift toward a more negatively skewed distribution. Such findings are in line with the predictions of theoretical models emphasizing the impact of the lower bound on policy rates and uncertainty about monetary transmission. For example, controlling for other factors, announcement dates for non-standard monetary policy measures are shown to be associated with an increase in long-term inflation uncertainty.

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1 Introduction

A tight anchoring of medium- to long-term inflation expectations around the central bank's target is commonly seen as crucial for steering inflation toward this target without suffering substantial economic costs. However, during recent years, large macroeconomic and financial shocks associated with the Great Recession and the fact that policy rates reached their Effective Lower Bound (ELB) have led to concerns about a possible de-anchoring of long-term inflation expectations in the major currency areas. In the case of the euro area, concerns have focussed on persistently too low inflation or even deflationary risks and an associated departure of inflation expectations from levels consistent with the ECB's objective.¹ For example, Draghi (2014) highlights "the risk that a too prolonged period of low inflation becomes embedded in inflation expectations". Indeed, recent unconventional monetary policies are often motivated as addressing such risks.

Much of the recent economic literature attempting to quantify the evidence and risks of such a de-anchoring - both in the euro area and elsewhere - has focussed only on the *mean* or first moment of the distribution of long-term inflation expectations (Demertzis *et al.*, 2009; Gürkaynak *et al.*, 2010; van der Cruysen and Demertzis, 2011; Beechey *et al.*, 2011; Demertzis *et al.*, 2012; Dräger and Lamla, 2013; Mehrotra and Yetman, 2014).² In this paper, we provide new empirical evidence about the anchoring of inflation expectations in the euro area considering the *full probability distribution* surrounding such expectations.³ Strong theoretical arguments justify the need to study the properties of the full distribution and not simply focus on mean expectations. In particular, shifts in the variance of this distribution, its skewness or tail risk can offer additional evidence of any change in agents' beliefs about future inflation over the longer term and the factors that may be shaping them. For example, the model of imperfect credibility in Bodenstein *et al.* (2012) suggests that achieving the central bank's inflation objective may

¹ Like many other major central banks, the European Central Bank (ECB) is committed to achieve a particular rate of inflation. In the case of the ECB, this objective is publically announced and defined as an annual increase in the Harmonised Index of Consumer Prices (HICP) that is "below but close to 2.0%" and it is intended that this is to be achieved over the "medium run".

² In particular such studies have focused on possible changes in the mean or in the strength of its co-movement with other economic variables. The evidence emerging from this literature suggests that long-term inflation expectation were impacted by the Great Recession. For the US economy, Galati *et al.* (2011); Nautz and Strohsal, (2014), Autrup and Grothe, (2014), Ciccarelli and Garcia (2015) all suggests that inflation expectations in the US started to react more strongly to macroeconomic news. Ehrmann (2015) also reports evidence of a similar increased sensitivity during periods of low inflation. For the euro area, Galati *et al.* (2011) identify a structural break in the responsiveness of European inflation expectations to macroeconomic news and Lyziac and Palovitta (2016) conclude that there are "some signs of de-anchoring". However, Strohsal and Winkelmann (2015), Autrup and Grothe (2014) and Speck (2016) have argued that the degree of anchoring did not change around that time.

³ Mehrotra and Yetman (2014) highlight the importance of the full distribution, noting that there are "at least two dimensions to anchoring ... both the level at which expectations are anchored and how tightly expectations are anchored at that level". Only the full distribution can speak directly to the latter aspect.

become more challenging following a period such as the Great Recession as central bank credibility becomes more relevant compared to “normal” times (2012). In a similar vein, Beechey *et al.* (2011) demonstrate how imperfect information and potential time-variation in the central bank’s objective can be associated with a sizeable increase in long-term inflation uncertainty, i.e. in the variance of the distribution for long-term expected inflation.⁴ However, it is the incidence of the ELB that makes the strongest case for studying the full distribution. Under the ELB, models of the business cycle exhibit multiple equilibria, implying that the distribution of long-term inflation expectations may change and attach non-negligible probabilities to quite distinctive outcomes. For instance, Benhabib *et al.* (2001) highlight the existence of a deflationary equilibrium where the ELB is binding and inflation is stuck below target.⁵ Clearly, the risks of such bad equilibria will tend to first show up in increased long-term inflation uncertainty or tail risks, i.e. in the second and fourth moments of the distribution. In addition, models which take account of the ELB also emphasise that limitations in the central bank’s ability to respond to deflationary shocks lead to a negatively skewed distribution for long-term expectations (see for example, Coenen and Warne, 2014; Hills *et al.*, 2016).

To address our central question, we proceed in three steps. In a first, we test for possible structural change in the moments of the expected distribution of long-term inflation, exploiting the methods of Bai and Perron (1998, 2003) to shed light on both the size and timing of possible shifts. This provides direct evidence about whether or not the Great Recession and its aftermath resulted in any significant changes in key features of that distribution. In a second step, we exploit the available micro data in a panel setting and attempt to explain changes in long-term inflation expectations by studying their co-movement with other macroeconomic variables. Our use of micro data contrasts with most other recent studies mentioned above which have focussed on average measures of expectations or representative proxies extracted from asset prices. Although we do not claim a causal interpretation, the analysis of such co-movements sheds light on possible changes in the degree to which the distribution is anchored. For example, allowing for uncertainty

⁴ There has been considerable discussion in the wake of the financial crisis about the need for central banks to consider adjusting upwards their inflation objectives and the euro area has not been immune to these discussions. For example, Ball *et al.* (2016), recently make this recommendation as a means to avoid the incidence, severity and costs of hitting the ELB constraint. This discussion is conceptually distinct from other recommendations which have emphasized increasing short-run inflation expectations as a demand management device at the ELB.

⁵ For instance, Benhabib *et al.* (2001) highlight the existence of a deflationary equilibrium where the ELB is binding and inflation is stuck below target. More recently, Aruoba and Schorfheide (2015) construct a two-regime stochastic equilibrium in which the economy may alternate between a “targeted inflation” and a “deflation” regime.⁵ Buseti *et al.* (2014) also study the risks of such a regime in a model with learning and show that it may imply considerable risks of a de-anchoring of long-term inflation expectations and give rise to a period of sustained low growth in real output.

about the central banks objective, and learning on the part of private agents about its ability to hit that objective, we can expect some positive co-movement between short-term macroeconomic news and long-term inflation expectations (e.g. as in Beechey *et al*, 2011). In the spirit of Levin *et al.* (2004), we also consider the co-movement of long-term expectations with an ex post measure of central bank performance to assess whether agents partly update their future long-term expectations by taking into account the rate of inflation that the central bank has actually delivered. Also, in line with recent discussions about secular stagnation and deflationary equilibria with simultaneously weak trend growth and excessively low inflation expectations, e.g. as discussed in Summers (2014) and Eggertson and Mehrotra (2014), we also examine the co-movement between long-term inflation expectations and corresponding long-term expectations about the real economy. Using matched individual level expectations, our panel data allows us study these interrelationships whilst also controlling for other sources of variation that are common to all forecasters such as observed inflation rates as well as non-standard monetary policy measures in the wake of the Great Recession. In addition, we provide direct tests of whether these interrelationships have changed following the Great Recession and during the more recent period when the ELB has been binding and the ECB has employed non-standard monetary policy. In a third and final step, using a similar set of appropriately transformed co-variates, we extend the above micro-level analysis to shed light on the factors which co-move with changes in long-term inflation uncertainty. Again, such an analysis speaks directly to the question of anchoring because higher uncertainty about long-term inflation prospects implies that the distribution is less tightly anchored even if overall mean expectations remain unchanged.

The layout of the remainder of the paper is as follows. In Section 2, we briefly describe our dataset and the manner in which we estimate key moments of the probability distribution surrounding the long-term inflation expectations. Section 3 presents the evidence for breaks in these moments. In Section 4, we turn to the analysis of the variables which co-move with changes in long-term mean expectations and uncertainty and analyse whether the strength of this co-movement has changed following the Great Recession. Section 5 concludes by discussing the economic significance of our findings and their implications for monetary policy.

2 Data and Estimation of Density Moments

We base our analysis on the densities of individual forecasters as provided by the ECB's SPF which has been conducted and published by the ECB at a quarterly frequency since the beginning of 1999. Since we are interested in long-term inflation expectations, we primarily focus on those forecasts that have a forecast horizon of roughly five years (i.e. twenty quarters or $h = 20$). Our sample period ranges from 1999Q1 to 2017Q1.⁶ Reflecting its survey origins, the SPF data set is heavily unbalanced because forecasters leave the panel or enter later and because they are not required to report their forecasts in every survey round. The number of individual respondents therefore varies from one quarter to the next. We focus on the analysis of this unbalanced panel and, in particular, do not attempt to interpolate any missing observations. The number of respondents providing the histograms depicting the probabilities they assign to a range of future outcomes averages 39.1 in our sample. Although this is slightly lower than the number of respondents who report point forecasts for inflation (44.6 on average), it nonetheless provides a rich cross-sectional basis for econometric analysis. Moreover, when considering co-movement with other variables, we are able to match the estimated moments for inflation at the individual level with corresponding individual moments estimated from equivalent histograms for GDP growth and the unemployment rate. Appendix I provides further information on the SPF and other data sources used in the empirical analysis.

Before attempting to study the properties of the full distribution for long-term expected inflation, it is necessary to estimate the key moments summarizing the distribution's location, spread, symmetry, and tail risks. The density forecasts are provided as histograms for which every forecaster reports probability forecasts that reflect their assessment of the likelihood that future inflation will fall within certain intervals. Formally, denote with $p_{i,t+h|t}^j$ the probability that forecaster i ($i = 1, \dots, N$) in survey period t attaches to the event that the inflation rate in period $t+h$ falls into a particular interval j ($j = 1, \dots, J$).⁷ To compute mean long-term expectations, the corresponding inflation uncertainty, and higher moments of the density forecasts, we adopt the most common approach which is non-parametric and assumes that all the

⁶ Note that during the first two years of the SPF long-term forecasts were only surveyed on an annual basis in 1999Q1 and 2000Q1. We make use of these observations whenever possible. However, we have to drop them from our econometric estimation whenever we relate long-term expectations to lagged information from the SPF.

⁷ Note that K changes over time as the survey design was changed at several points in time. We tackle this issue by assigning a probability of 0 to intervals that were not included in a particular survey round.

probability mass in a particular interval j is compressed at the midpoint of this interval, which we denote by μ_j . The first four moments are then computed recursively and are given by

$$(2.1) \quad \text{Mean:} \quad \pi_{i,t+h|t} = \sum_{j=1}^J p_{i,t+h|t}^j \mu_j$$

$$(2.2) \quad \text{Variance:} \quad \sigma_{i,t+h|t}^2 = \sum_{j=1}^J p_{i,t+h|t}^j (\mu_j - \mu_{i,t+h|t})^2$$

$$(2.3) \quad \text{Skewness:} \quad s_{i,t+h|t} = \sum_{j=1}^J p_{i,t+h|t}^j (\mu_j - \mu_{i,t+h|t})^3 / \sigma_{i,t+h|t}^3$$

$$(2.4) \quad \text{(Excess) kurtosis:} \quad k_{i,t+h|t} = \sum_{j=1}^J p_{i,t+h|t}^j (\mu_j - \mu_{i,t+h|t})^4 / \sigma_{i,t+h|t}^4 - 3$$

For each moment $m = \{\pi, \sigma^2, s, k\}$, we construct the cross-sectional average as $\bar{m}_{t+h|t} = 1/N_{t+h|t} \sum_{i=1}^{N_{t+h|t}} m_{i,t+h|t}$, where $N_{t+h|t}$ denotes the number of density forecasts with a forecast horizon of h quarters available at time t . As highlighted in Engelberg *et al.* (2009), it must be acknowledged that our moment estimates are subject to measurement error reflecting the random variation in response rates, panel composition and the assumptions we make regarding the allocation of probability mass to the midpoints of the surveyed intervals. However, alternative approaches, such as the fitting of a flexible parametric distribution as in Engelberg *et al.* (2019), yield very similar estimates.

Note that an estimate of $\pi_{i,t+h|t}$ is also available directly from the reported point forecasts that are collected in the SPF. However, by relying on the estimate based on the histograms we can ensure consistency of our results across the different moments. A focus on mean expectations from equation (2.1) is also justified because it draws on all the probabilities collected from respondents. As such, it may contain more information than the long-term point forecasts that are also collected in each survey round.⁸ Figure 1 plots the mean estimated according to equation (2.1) together with two other measure of central tendency taken from the survey. The first is the mode computed as the mid-point of the interval which is assigned the maximum probability, again averaged across the responding forecasters in a given round. The second alternative measure is simply the average point forecast. Overall, one observes a very clear co-movement and similarity between these three measures of central tendency. In particular, the average point forecast and the estimated mode are very closely related, suggesting that when they give their point

⁸ García and Manzanares (2007) provide evidence that the density forecasts from the SPF are more reliable than the point forecasts.

forecasts survey respondents may be giving a modal prediction. However, in the period since the financial crisis mean expectations dropped slightly below both the estimated average mode and the reported point forecasts. Given this divergent pattern we also include the estimated mode of the probability distributions in our empirical analysis of potential shifts in the distribution's location.

[Insert Figure 1 about here]

3 Identifying Breaks in the Distribution of Long-term Inflation Expectations

In this section we report our empirical analysis of possible structural breaks in the distribution of long-term inflation expectations. We first discuss the econometric specification used to estimate possible breaks in the distribution before reporting the main findings.

3.1 Testing for Breaks in Density Moments

A powerful set of conditions for inflation expectations to be fully anchored is that their distribution is stable around the central bank's inflation target. To examine this, we test for evidence of any breaks in the first four moments estimated above. We employ the method of Bai and Perron (1998, 2003), who consider the linear regression model with a finite number of possible regimes defined by unknown breaks in the model parameters. Their method yields estimates of the unknown regression coefficients associated with each regime together with estimates of the unknown break points. To select the number of significant breaks and to date their occurrence, we apply these methods by regressing a given moment on its first lag and an intercept term. The inclusion of the latter is intended to account for the strong persistence in such long-horizon moments when estimated at a quarterly frequency and which would otherwise cause substantial residual autocorrelation in our regressions.⁹ Formally, the considered model is

$$(3.5) \quad \bar{m}_{t+h|t} = \alpha_{m,r} + \beta_{m,r} \bar{m}_{t+h-1|t-1} + \varepsilon_{t+h|t}^m$$

where $\alpha_{m,r}$ and $\beta_{m,r}$ are regime-specific parameters (with $r = 1, \dots, R$) and $\varepsilon_{t+h|t}^m$ is an *iid* error term. The mean of each moment $m = \{\pi, \sigma^2, s, k\}$ conditional on being in specific structural regime can be

⁹ According to the Ljung-Box test, we can reject the null hypothesis of residual autocorrelation at the five percent level for both the specification without structural breaks and the one with breaks for all moments with one exception: in the case of inflation uncertainty, the large structural break causes mild negative autocorrelation in the residuals of the specification that does not allow for this break.

computed as $\alpha_{m,r}/(1 - \beta_{m,r})$. For the case of mean long-term expectations ($m = \pi$), for instance, this yields an estimate of the average expected rate of long-term inflation in a given regime. Under the assumption that forecasters believe that, in general, the central bank is able to achieve its inflation target in the absence of further shocks such an estimate provides a regime-specific measure of the perceived inflation objective. In the absence of any structural breaks, we have $\alpha_{\pi,r} = \alpha_{\pi}$ and $\beta_{\pi,r} = \beta_{\pi}$ which implies that the long-term expectation for inflation is constant. In a similar way, for each of the three higher order moments, $\alpha_{m,r}/(1 - \beta_{m,r})$ is an estimate for the average perceived future variance, skewness and tail risk embodied in the distribution in any given regime. Breaks of these higher order moments may additionally signal changes in the degree to which the distribution of long-term inflation expectations is anchored.

In implementing the Bai-Perron procedure it is necessary to specify a *minimum* required distance between any two potential break dates. We set this minimum distance between breaks at a relatively conservative level of eight quarters in order to avoid overfitting and possibly finding an implausibly large number of spurious breaks for each moment. We determine the number of structural breaks by looking at a modified Schwarz criterion (LWZ) which is suggested for the case of models that include a lagged dependent variable and the sequential SupF-test which is the overall preferred test according to Bai and Perron (2003).¹⁰

3.2 Breaks in the Mean

Using the approach outlined in the previous section, we analyse whether there have been any substantial regime changes in the distribution of long-term inflation expectations in the euro area. Figure 2 shows the evolution of the modal expectation discussed above together with the first four moments given by equations (2.1) to (2.4). In each panel, the regime-specific estimates $\hat{\alpha}_{m,r}/(1 - \hat{\beta}_{m,r})$ are also plotted (as identified by the LWZ statistic). The break-point analysis of density moments is further detailed in Table 1. In particular, we report a list of the estimated break dates and the corresponding F-statistics indicating the significance of each break as well as complementary results based on the sequential test.

¹⁰ The sequential test is based on the idea of sequentially testing the null hypothesis of l breaks versus $l + 1$ breaks until the null hypothesis can no longer be rejected. In particular, given a set of l break points, Bai and Perron (1998) suggest to apply $l + 1$ tests of the null hypothesis of no structural break against the alternative hypothesis of a single structural break to the $l + 1$ segments of a time series defined by the l breaks.

[Insert Figure 2 about here]

[Insert Table 1 about here]

For the mean expectations, we find one significant breaks in 2013Q2 according to the LWZ statistic reported in Table 1. The break is downward and occurs in the wake of the Great Recession and euro area sovereign debt crisis. Although quantitatively modest it is noticeable with the regime-specific mean falling to 1.69% from 1.90% prior to the break. The drop in mean expectations is found to be statistically significant given the low overall volatility of the time series. The case for a significant downward shift of long-term inflation expectations is weakened, however, by two additional findings. First, the sequential SupF-test does not identify any breaks in the dynamics of mean expectations and as a result the estimate for the average over the full sample is constant at 1.83. Second, both tests do not identify any breaks in the case of modal expectations which average 1.89% over the full sample. A finding of a downward break in the mean combined with a stable modal value is consistent with a shift toward a more negatively skewed distribution and we examine this hypothesis directly below by applying the same test to the estimated third moment.

Overall, our results for mean expectations provide at most only weak evidence for a quantitatively modest decline in long-term inflation expectations toward the end of our sample. Mean inflation expectations also remain in a range that can be considered consistent with price stability as defined by the ECB's price stability objective of "below but close to 2.0%". Hence, our analysis provides no grounds to think that the central tendency of euro area long-term inflation expectations became unanchored. This finding is in line with other recent studies that use market-based inflation expectations, as, for instance, Strohsal and Winkelmann (2015), Autrup and Grothe (2014) and Speck (2016).

3.3 Breaks in the Variance

Figure 2 and Table 1 report equivalent results for higher moments. In the case of long-term inflation uncertainty, both tests identify a break in 2009Q2 that is associated with an increase in uncertainty about long-term inflation. In relative terms, this shift is quantitatively more noticeable compared with the shift in mean expectations. After the break, i.e. in the immediate wake of the Great Recession, average uncertainty about the long-term inflation at 0.66 percentage points (pp) had increased by about 25% compared with its

level in the pre-crisis regime (0.53 pp). Following this increase, long-term inflation uncertainty has been quite stable at the new level and has shown no tendency to decline. This pronounced and persistent increase in the variance of the distribution signals that forecasters perceive the long-term inflation outlook to be more uncertain now than before the Great Recession.¹¹ As a result, the distribution has become less concentrated around levels that are consistent with the definition of price stability. The increase correlates well with an increase of the historical variance of annual inflation rates in the euro area when computed recursively based on an expanding sample starting in 1997; the latter increases from about 0.2 in 2007 to a little below 0.6 in 2014. Thus, it seems as if forecasters anticipate that the increase in inflation volatility which emerged after the Great Recession will be highly persistent – or even permanent – rather than being relevant only to recent years or the short-term outlook for inflation.

Overall, the identified upward shift in the variance could be taken to imply that the *degree* to which long-term inflation expectations are anchored has diminished. The shift in the variance is also consistent with macroeconomic theories highlighting the implications of uncertainty surrounding the central bank's objective (Beechey *et al.*, 2011) and, in particular, the potential effects of the lower bound on nominal interest rates (Benhabib *et al.*, 2001). However, the higher variance is also consistent with the view that forecasters believe it may take longer for the central bank to achieve its price stability objective, e.g. as a result of more persistent and volatile shocks in the future or a perceived change in the transmission of monetary policy. It does not necessarily imply that they have reduced their belief in the ECB's ability to ultimately achieve that objective over a longer horizon than the five years to which the survey data relate. Nonetheless, our findings highlight an important challenge for monetary policy and its communication; namely to limit any further the rise in the uncertainty surrounding long-term inflation prospects.

3.4 Breaks in Symmetry and Tail Risk

Figure 2 and Table 1 also report the results of the break analysis for the skewness and tail risk in the distribution of long-term expected inflation in the euro area. The time path of the average skewness provides insight on possible changes in the overall symmetry of the distribution and may thus signal concerns among forecasters about long-term inflation risks either to the upside or the downside. Figure 2

¹¹ It is noteworthy that the upward adjustment came quite soon after the Great Recession and the sovereign debt crisis was not associated with any further rise in long-term inflation uncertainty.

suggests that, since 2010Q1, the forecast densities are negatively skewed, on average, whereas prior to this date they were broadly symmetric. This means that since the Great Recession forecasters have been more concerned about deviations in the direction of lower inflation and less concerned about deviations in the direction of higher inflation. This finding of a negatively skewed distribution is in line with our previous result of a possible downward break in mean expectations with a higher and more stable mode. It is also precisely what is predicted by macroeconomic models which incorporate a lower bound constraint on nominal interest rates (e.g., Coenen and Warne, 2014; Hills *et al.*, 2016). Interestingly, according to the LWZ test results reported in Table 1, the break in skewness occurred relatively soon after the Great Recession and prior to the break in mean expectations. The tendency toward a negatively skewed distribution has also been highly persistent and has lasted up to the end of our sample in 2017Q1. At the same time, these results have to be taken with some caution because the alternative SupF-test identifies no break in skewness. For the kurtosis, we also find no significant break. However, the long-term inflation density is platykurtic, which means that forecasters believe that, relative to a normal distribution, less of the inflation uncertainty is associated with infrequent tail events. Overall, therefore, the survey data tends to give relatively small weight to tail risks for inflation.¹²

Together with the increased variance, the above distributional changes that we have identified imply a marked rise in the probability of very low future inflation rates at long-horizons. Figure 3 provides a summary of how shape, symmetry and tail risk implicit in the survey indicators have changed over time. The left plot shows how much probability weight the forecasters attributed, on average, to long-term outcomes of inflation below 0.0%, below 1.0%, and above 3.0%. It is clear that while the risk of a sustained outright deflation with a falling price level is still perceived as being very low, the perceived probability that inflation will be below 1.0% has climbed steadily from very low levels prior to 2007 to around 10.0% in the period 2009 to 2012 and to roughly 12.5% recently. In contrast, the probability that inflation will be above 3.0% has recently declined to its pre 2007 level after an intermezzo of slightly higher values over the period 2008 to 2013. The right plot shows the inflation-at-risk measure that is proposed by Andrade *et al.* (2012). For each wave of the survey, this indicates the 5th and 95th percentiles

¹² This is a well know finding in the literature exploiting such data. It is a direct consequence of the fact that many participants in the SPF attach positive probability weights to only a very limit number of the provided bins (see Kenny *et al.*, 2015).

of the reported long-term density forecasts for inflation.¹³ Again, while the 95th percentile (that is informative about the upper tail of the distribution) is currently more or less unchanged compared to its value in 2007, the 5th percentile (that is informative about the lower tail of the distribution) declined from above 1% in 2007 to 0.7% in the first quarter of 2017.¹⁴ Overall, forecasters see more risks on the downside which corresponds to our finding of a structural break in the skewness of long-term forecast densities after 2010.

[Insert Figure 3 about here]

4 Co-movement of Distributional Moments with other Variables

The previous section provided evidence that the distribution of long-term inflation expectations in the euro area may have changed in the period since the Great Recession. In particular, our analysis shows that it experienced a modest downward shift in its mean, a more sizeable and significant increase in its dispersion, and a persistent negative skewness. As discussed in the introduction, a second way to shed light on how well-anchored long-term inflation expectations are is to examine the strength of their co-movement with other economic variables. In a perfect world with no uncertainty about monetary policy effectiveness, we might expect to observe no correlation between moments of the distribution of expectations and other macroeconomic developments. However, in a world with uncertainty and learning on the part of private agents, some co-movement even with short-term macroeconomic developments at business cycle frequencies can be expected. In such circumstances, an increased sensitivity of long-term inflation expectations to such factors would be indicative of a change in the degree to which expectations are anchored.

In this section, we examine the co-movement between the first two moments of the distribution of expected long-term inflation with other economic variables.¹⁵ In particular, we exploit the individual expectations in a panel setting to address the following questions: Are there factors that co-move strongly with long-term inflation expectations and uncertainty? Did the role of such factors change after 2007, the

¹³ To extract these percentiles, we follow Engelberg *et al.* (2009) and use the approximation of the true density forecasts derived by fitting the generalized Beta distribution. Hence, results are not directly comparable to other results presented in this paper. The 5th and 95th percentiles are then computed as the average across all individual forecaster.

¹⁴ This means that forecasters, on average, expect inflation five years ahead to be below 0.7% with a probability of 5%.

¹⁵ We focus on the first two moments because these are the ones for which we can identify a set of appropriate co-variates. However, given the results of the break test analysis in Section 3 above, the examination of co-movement with the skewness of the distribution of long-term inflation expectations represents an important area for future empirical research.

year in which the financial crisis began to unfold? Can we identify any coincidences between recent monetary policy events – such as the hitting of the ELB on nominal interest rates or the introduction of non-standard monetary policies – and changes in the first two moments of the distribution? We first present the results for the mean and then turn to the analysis of the variance.

4.1 Long-term Mean Inflation Expectations

To examine the co-movement between mean expectations and other macroeconomic developments, we consider the following set of variables: First we consider, forecaster specific short- and medium-term inflation expectations at horizons of 1 and 2-years ahead ($dE_i[\pi(1y)]_t$ and $dE_i[\pi(2y)]_t$). In addition, we look at the reaction of long-term expectations to past short- and medium-term forecast errors for inflation, again at the individual level ($\pi - E_i[\pi(1y)]_{t-4}$ and $\pi - E_i[\pi(2y)]_{t-8}$). To capture perceived structural changes linked to possible concerns about secular stagnation and deflationary equilibria, we include the change in long-term expectations for GDP growth ($dE_i[\text{GDP}(5y)]_t$) and the unemployment rate ($dE_i[U(5y)]_t$) from the SPF. In the spirit of Levin *et al.* (2004) who show that long-term inflation expectations in the US and the euro area were highly correlated with a slow moving average of inflation over the period 1994 to 2003, we also consider an inflation “performance gap” as the difference between recent long-term expectations and a (five-year) moving average of past inflation ($\text{MA}(\pi)_{t-1} - E_i[\pi(5y)]_{t-1}$). In addition to these individual-specific variables, we also consider the possible co-movement with factors that are common across forecasters, such as shocks to the inflation process itself as reflected in the recently observed change in the inflation rate ($d\pi_{t-1}$) and in oil prices ($dOil_{t-1}$).¹⁶ Also, we consider the change in the volume of the ECB’s balance sheet ($d\text{CBBS}_{t-1}$) as a monetary policy indicator that is associated with recent quantitative easing, with the expectation that an expansion of the balance sheet might potentially lead agents to change their expectation of the long-term inflation rate upwards. To control for important monetary policy changes, we additionally include a dummy variable for quarters following the announcement of important non-standard monetary policies (MPA_t)¹⁷ and a dummy capturing the hitting of the effective lower bound (ELB_t).¹⁸

¹⁶ Beechey *et al.* (2011) and Badel and McGillicuddy (2015) document a substantial co-movement of long-term US inflation expectations with oil prices.

¹⁷ The events are: the introduction of enhanced credit support on May 7, 2009; the introduction of the Security Market Program (SMP) on May 10, 2010; the introduction of the Outright Monetary Transaction (OMT) program on August 2, 2012; the

We use an unbalanced pooled panel regression with fixed effects to look at the co-movement discussed above and to test whether the correlation structure has changed since the Great Recession. Let $\Delta\pi_{i,t+20|t} = \pi_{i,t+20|t} - \pi_{i,t-1+20|t-1}$ denote the change in the long-term inflation expectation of an individual forecaster. We regress this change on forecaster-specific fixed effects and the set of proposed co-variates. Collecting the forecaster specific variables in a vector $X_{i,t}$ and the common co-variates in Y_t , the linear panel regression is given by

$$(4.1) \quad \Delta\pi_{i,t+20|t} = \alpha_i + MPA_t\beta_{MPA} + ELB_t\beta_{ELB} + X_{i,t}\beta_X + Y_t\beta_Y + \varepsilon_{i,t}$$

where $\varepsilon_{i,t}$ is an error term that we allow to exhibit both spatial and temporal correlation (Driscoll and Kraay 1998).¹⁹ The parameter vectors β_{MPA} , β_{ELB} , β_X and β_Y measure the extent to which long-term expectations co-move with the other variables. For perfectly anchored inflation expectations, we would expect the effect of the two dummy variables to be insignificant and also both $\beta_X = 0$ and $\beta_Y = 0$.

Before proceeding to the results of this full panel analysis, it is of interest to examine the simple bi-variate co-movement in our dataset. Table 2 reports some basic summary statistics depicting the pair-wise correlations between mean expectations and the above-proposed regressors. Because we are dealing with panel data, we can distinguish between the total correlation which is based on the pooled data set, the between-forecaster correlation which is the correlation between the sample averages for individual forecasters, and the within correlation which we compute as the mean of the correlations obtained for each forecaster individually. From an economic point of view, the latter is of greatest interest because expectations are formed at the individual level. We show the mean, minimum, 10th percentile, 90th percentile and maximum value for those forecasters in our sample with at least 8 observations. Total and between correlations that are statistically significant are marked with *. The last two columns of Table 2 indicate which fraction of forecaster-specific correlations is significantly different from zero or significantly different from zero *and* positive (both as a % of the total number of forecasters for which we can compute the pair-wise correlations).

introduction of forward guidance on July 4, 2013; and the introduction of the enhanced asset purchase program (APP) on January 22, 2015.

¹⁸ This dummy takes a value of one for the two survey rounds that follow the dates when the ELB was reached for the ECB deposit rate (on July 11, 2012) and for the main financing rate (on June 5, 2014), respectively, and zero otherwise.

¹⁹ Given that forecasters form their predictions simultaneously and that professional forecasts are usually found to be subject to information rigidities (Coibion and Gorodnichenko, 2012; Dovern *et al.*, 2015), which cause forecast revisions to be autocorrelated, both features are important. Ignoring them and assuming independently distributed error terms is likely to result in an underestimation of the true long-term covariance.

From the ten variables that we consider, nine have a significant total correlation with the change in long-term inflation expectations, suggesting that long-term inflation expectations are not perfectly anchored but indeed get revised frequently in response to shocks. These correlations range from 0.05 (in absolute values) to 0.31 (see Table 2). More interestingly, however, are the within correlations that provide a more nuanced picture. While the mean correlation is higher (in absolute values) in all cases than the corresponding total correlation, for most variables a relatively small fraction of the underlying correlations are significantly different from zero. For example, less than 10% are so in the case of both lagged forecast errors, the change in inflation, the change in oil prices, and the change in the volume of the ECB' balance sheet. We obtain the largest fraction of significant correlations in the case of short- and medium-term inflation expectations (17.3% and 26.9%, respectively) and the central bank performance index (26.9%). Looking at the last column of Table 2 it is evident that the significant co-movements usually have the expected sign. For example, for all of the 26.9% of forecasters with a significant co-movement with the inflation performance gap, the correlation implies that a deviation of actual inflation above the central bank's target is associated with an upward revision in long-term inflation expectations. One exception is the co-movement with the change in long-term growth expectations which is negative in almost one third of the significant cases. In terms of heterogeneity across forecasters we see a wide range of estimates, ranging from substantially negative to very large positive correlations in all but one case.

[Insert Table 2 about here]

Table 3 lists the results of estimations of equation (4.1). Specification (1) reports full sample results. To avoid a potential problem of multicollinearity between the change in the inflation rate and the change in oil prices, we drop the latter variable from the panel estimation in line with the idea that the impact of oil prices can be adequately captured through its effects on headline inflation. Specification (2) allows all parameters in the equation (except for the fixed effects) to break after 2007Q3, which we chose because it represents the start of the Great Recession and the launch of monetary policy measures aimed at mitigating turbulences in financial markets. Note that results in the second and third column refer to one regression and are listed in two columns only for expositional purposes.

[Insert Table 3 about here]

Looking first at the full sample results, we observe that only few of the marginal correlations remain significantly different from zero. In particular, those are the correlations with the change in 2-year inflation expectations and with the inflation performance gap. For example, long-term inflation expectations are revised by roughly 0.17 pp, on average, when two-year-ahead expectations move by 1 pp. Thus, the co-movement is relatively strong, supporting evidence from US household expectations provided by Dräger and Lambla (2013). According to the estimated parameter values, a 1.0 pp deviation of the past inflation trend above the announced price stability objective is associated with an upward revision in long-term inflation expectations of just below 0.15 pp. This highlights the importance of actually hitting the inflation target in the medium-run if long-term inflation expectations are to be stabilised. The observed co-movement is in line with macroeconomic theories which allow for uncertainty about the central bank objective. For example, if private agents are uncertain about the true inflation objective held by the central bank they may adjust their long-term inflation expectations upward in response to past inflation trends (see, for example, Beechey *et al*, 2011).

In our panel regression results, we also find some quantitatively less important but significant co-movement with the change in actual inflation.²⁰ The only other significant parameter estimate corresponds to the change in the size of the ECB's balance sheet. The negative sign appears counterintuitive at first and demonstrates that the estimates should not be interpreted causally. In this particular case, a valid interpretation is not that expanding the balance sheet causes inflation expectations to decline. Instead reverse causality is the most plausible explanation, and also, possible omitted variable bias. For example, a plausible explanation of the negative co-movement is that the ECB anticipated a decline in expectations and responded with expansionary measures that were associated with an expansion of the balance sheet. On the other hand, both the ECB and the forecasters included in our panel could simply respond to macroeconomic news that we do not capture with our variable selection. Turning to the additional monetary policy dummies, we find no evidence for any impacts on our measure of mean long-term expectations. This implies that the hitting of the ELB or the announcement of non-standard measures were not immediately followed by a change in inflation expectations. This result is not so surprising given the other controls and co-movement that we have captured in the regressions. For example, it is entirely

²⁰ This is in contrast to Beechey *et al*. (2011) who find a response of long-term inflation expectations to inflation news for the US but not for the euro area. However, the sample period used in this study did not cover the period associated with the aftermath of the Great Recession.

plausible that the effects of the ELB and the announcement of non-standard measures are captured via the co-movement with 2-year-ahead expectations. The result may also be due to the low frequency of the SPF data which makes it harder to connect changes in expectations to specific events. Based on data of higher frequency around such announcements, Karadi (2017) shows that non-standard measures by the ECB may have helped to prevent long-term inflation expectations from becoming unanchored after 2013.

The second set of estimates suggests that the estimated co-movement did not change much after the Great Recession. An F-test of the joint hypothesis that none of the model's coefficients exhibits a structural break in 2007 does not reject this hypothesis. Testing each of the coefficients separately reveals that the coefficient change is significantly different from zero only in the case of the change in the ECB's balance sheet.²¹ The pre-2007 estimate is strongly negative and highly significant, suggesting that this period also drives the full-sample results.²² In contrast, the estimate for the sample since 2007Q4 is much smaller and only significant at the 10% level. Another interesting effect in the post crisis sample is a negative correlation of mean inflation expectations with changes in long-term unemployment expectations that are not already captured by the other co-variates. Such negative co-movement is consistent with concerns about secular stagnation, with simultaneously higher expectations for long-term unemployment being associated with weak overall inflation expectations. The impact is, however, quantitatively small compared with the co-movement with other variables.

In summary, the panel regressions suggest that the process governing the mean of the distribution of long-term inflation expectations is far away from a simple stylized case where the inflation objective is a universal constant and where there is "blind faith" in the ability of the central bank to achieve this objective. Instead, this process is more in line with theories emphasising uncertainty about the monetary policy transmission mechanism in which agents update their beliefs about long-term inflation in response to relevant shocks. However, there is no evidence of a substantially higher sensitivity to the main co-variates following the Great Recession. This result is also in line with previous results in Section 3, where we identified at most only weak evidence that mean inflation expectations had declined following the

²¹ These results are clearly a reflection of the major structural break in the balance sheet data after the onset of the financial crisis; changes in the balance sheet size were very small and regular before 2007 and larger and also more volatile afterwards.

²² Given that changes in the size of the balance sheet during this period were largely determined endogenously by the demand for currency and the minimum reserve requirements, the observed correlation should not be interpreted as a genuine "policy effect".

Great Recession. At the same time, the co-movement that we have identified highlights that the anchoring of the mean of this distribution can in no way be taken for granted.

4.2 Long-term Inflation Uncertainty

We now turn to the co-movement of long-term inflation uncertainty with other variables. We follow the same analytic approach but adjust the set of variables that we consider to correspond to the new variable of interest. In particular, we now look into the co-movement with the change in short- and medium-term inflation uncertainty (instead of expectations), and with the *absolute value* of lagged forecast errors and the difference between recently held long-term expectations and the five year moving average of past inflation. We also consider the co-movement with long-term uncertainty about growth and the unemployment rate (instead of expectations), and with the *absolute value* of changes in the inflation rate, oil prices and the size of the ECB balance sheet size. As with mean expectations, we use a panel regression to analyse co-movements of long-term inflation uncertainty to the considered variables jointly. Denoting by $\Delta\sigma_{i,t+20|t}^2 = \sigma_{i,t+20|t}^2 - \sigma_{i,t-1+20|t-1}^2$ the change in the long-term inflation uncertainty of an individual forecaster, we use - analogously to equation (4.1) - the following panel specification:

$$(4.2) \quad \Delta\sigma_{i,t+20|t}^2 = \alpha_i^* + MPA_t \beta_{MPA}^* + ELB_t \beta_{ELB}^* + X_{i,t}^* \beta_X^* + Y_t^* \beta_Y^* + \varepsilon_{i,t}^*$$

where $X_{i,t}^*$ denotes the set of appropriately transformed forecaster specific covariates and Y_t^* the set of covariates that are common across forecasters. As a precursor to the results of the main panel regressions, we again present the between and within forecaster pairwise correlations with the 10 variables considered (Table 4). There is evidence of substantial and significant co-movement between long-term inflation uncertainty and short- and medium-term inflation uncertainty (total correlation of 0.39 and 0.52 respectively), long-term uncertainty about growth (0.53), and long-term uncertainty about the unemployment rate (0.44). Thus, uncertainty about the inflation rate in the long-term co-moves primarily with uncertainty about the nearer-term inflation outlook and with uncertainty relating to real prospects for growth and unemployment. Also the corresponding within forecaster co-movement is high for each of these four variables. Heterogeneity across forecasters is again large, but roughly one quarter to one third of individual forecasts exhibit correlations that are significantly different from zero and, of these, the overwhelming number of cases have the expected positive sign.

[Insert Table 4 about here]

Table 5 reports the results of estimations of equation (4.2). Overall and compared to mean expectations, a higher share of variation of long-term inflation uncertainty can be explained by movements in the covariates considered in our study (R^2 of 0.39 for the full sample). The main findings are as follows: First, long-term inflation uncertainty co-moves strongly with inflation uncertainty at a two-year horizon. Second, absolute changes in the current inflation rate are positively correlated with long-term inflation uncertainty. Thirdly, we find a strong and highly significant positive co-movement with the perceived uncertainty about long-term growth rates and the long-term unemployment outlook.

The panel regressions for uncertainty also reveal some important co-movement with the indicators linked to monetary policy. In the full specification, active monetary policy – associated with large changes in the volume of the assets held by the ECB – tends to be associated with, on average, a reduction in long-term inflation uncertainty. This result suggests that monetary policy has, in absolute terms, contributed to reducing inflation uncertainty over our sample. However, when one considers the persistent rise in long-term uncertainty highlighted in Section 3, monetary policy was not able to fully insulate long-term inflation uncertainty from the other factors discussed above. Looking at the coefficients corresponding to the monetary policy dummies, we find that the announcement dates for non-standard measures were generally associated with an increase in inflation uncertainty although this effect is quantitatively less important than the above-mentioned downward effects. On the one hand, this might indicate that the announcement of these monetary policy measures, as a side effect, led to a slight increase in long-term inflation uncertainty because forecasters had no historical experience on which to assess their transmission and the long-term implications for inflation. However, the co-movement may also reflect factors that our regression have failed to control for and which simultaneously led to an increase in uncertainty and to the monetary policy announcements of in these quarters.

[Insert Table 5 about here]

The second specification in Table 5 that allows for a break in the coefficients after 2007 reveals that many of the above effects are common to both sub-samples and that the estimated coefficients do not change dramatically. There are, however, three exceptions: First, the correlation with medium-term (2-year) inflation uncertainty drops significantly after 2007. Second, we also find a positive correlation with short-

term (1-year) inflation uncertainty after 2007 that was not observed prior to the Great Recession. Finally, the negative correlation with volume changes of the central bank balance sheet is no longer significantly different from zero in both sub-samples. The joint hypothesis that none of the coefficients change after 2007 is not rejected (p-value: 0.19). Thus, similar to our results for mean expectations, we do not find evidence of an unanchoring of the distribution that is associated with an increased in the co-movement of long-term inflation uncertainty with other variables after the Great Recession. Nonetheless, the co-movement that we do identify highlights a number of potentially important forces that may be behind the rise in long-term inflation uncertainty that was highlighted in Section 3.

5 Discussion and Conclusions

In this paper we have exploited microdata to study the key properties of the distribution of long-term inflation expectations in the euro area and the co-movement of key moments of this distribution with other variables. Our primary purpose has been to assess the extent to which the Great Recession and its aftermath, including the onset of a period in which the effective lower bound on nominal interest rates started to bind, led to any perceptible changes in this distribution. Our main findings add to the recent evidence provided in Autrup and Grothe (2014), Strohsal and Winkelmann (2015) and Speck (2016) and fall into three broad categories which we discuss below.

First, and in contrast to most existing studies which have focused only on mean expectations or representative indicators extracted from financial markets, our analysis jointly targets the first four moments of this distribution. Hence, we can provide additional information about how long-term inflation uncertainty, the balance of long-term inflation risks and the risk of extreme inflation events may have changed since the Great Recession. We find significant breaks in each of the first three moments of the distribution and all of them point toward a heightened risk of lower inflation outcomes. Although we document a small downward shift in the mean long-term inflation expectations around 2013 toward the end of our sample, the most likely inflation outcome as represented by the mode of the distribution has been much more stable. Also, both the mean and the mode remain aligned with the ECB's definition of its price stability objective of "below but close to 2.0%". Importantly, however, our analysis of higher moments of the distribution points to a reduction in how tightly expectations are anchored at that level. For example, we document a substantial increase in uncertainty about long-term inflation prospects

compared with the period prior to the Great Recession and also a tendency towards a negatively skewed long-term distribution. The finding of a negatively skewed distribution is precisely what is predicted by macroeconomic models which incorporate a lower bound constraint on nominal interest rates (see, for example, Coenen and Warne, 2014 or Hills *et al.*, 2016).

Second, our study has uncovered substantial co-movement between the first two moments of the distribution of long-term inflation expectations and various macroeconomic indicators, including other expectations and indicators capturing the effects of monetary policy. Such co-movement implies that the process governing the distribution is far away from a simple stylized case where the inflation objective is a universal constant and where there is “blind faith” in the ability of the central bank to achieve this objective. Instead, the co-movement that we identify is in line with theories in which agents update their beliefs about long-term inflation in response to certain shocks (Orphanides and Williams, 2004 and 2007). For example, we find that persistent periods of lower than expected inflation are associated with a downward revision in long-term inflation expectations. In this sense, our results suggest that long-term inflation expectations are not completely forward looking. Ultimately, they tend to be influenced by the ex post historical track record of the central bank relative to its announced objective. Such results provide strong support for recent concerns about inflation remaining “too low for too long” (e.g., Draghi, 2014) and the motivation behind unconventional monetary policies aimed at avoiding a persistent undershooting of the price stability objective. Regarding our central question, however, these mechanisms existed also prior to the Great Recession and, overall, they do not appear to have strengthened in its aftermath.

Thirdly, our analysis sheds light on how forecasters’ update their assessment of long-term inflation uncertainty in response to macroeconomic developments. Factors which influence this assessment include the volatility in recent inflation rates and perceptions of increased inflation uncertainty at shorter horizons. Also, calling to mind the correlated long-term risks associated with the prospect of secular stagnation discussed in Summers (2014) and Eggertson and Mehrotra (2014), our results suggest that longer-term uncertainty about growth and unemployment can spill over into increased uncertainty about long-term inflation. Such mechanisms help explain the large upward shift in long-term inflation uncertainty in the euro area following the Great Recession. Concerning the role of recent non-standard monetary policies, our sample is such that we must limit ourselves to an assessment of how inflation uncertainty changed

after key monetary policy announcements. Once we control for other factors, we find that the announcement dates for non-standard measures were generally followed by a modest increase in inflation uncertainty. Although this result must be interpreted with caution, it may highlight how such measures led to a slight increase in long-term inflation uncertainty because forecasters had no historical experience on which to assess their transmission and the long-term implications for inflation.

In conclusion, by focussing on the full distribution and by exploiting individual level data, we have been able to make an innovative contribution to the empirical literature trying to understand the process governing the formation of long-term inflation expectation. Nonetheless, a number of open questions remain for future research. These include a careful analysis of which causal effects the different measure implemented recently by the ECB had on key features of long-term inflation expectations and an analysis of whether expectations of other agents such as private households or financial market participants show similar tendencies to the ones that we have identified. Lastly, many of our findings are well-predicted by macroeconomic theory stressing the effects of uncertainty about monetary policy and the implications of constraints such as the lower bound on nominal interest rates. However, further work is needed to jointly model monetary policy, the business cycle, and the formation of inflation expectations in ways which can help identify more precisely the causal mechanisms that may be behind our empirical results.

References

- Andrade, P., E. Ghysels, and J. Idier (2012), Tails of Inflation Forecasts and Tales of Monetary, Document de Travail, 407, Banque de France, Paris.
- Aruoba, S. B. and F. Schorfheide (2015), Inflation During and after the Effective Lower Bound, Paper prepared for the 2015 Jackson Hole Economic Policy Symposium.
- Autrup, S. L. and M. Grothe (2014), Economic Surprises and Inflation Expectations: Has Anchoring of Expectations Survived the Crisis?, Working Paper Series 1671, European Central Bank, Frankfurt.
- Badel, A. and J. McGillicuddy (2015), Oil Prices and Inflation Expectations: Is There a Link?, *The Regional Economist*, Federal Reserve Bank of St. Louis, July 2015, 12-13.
- Ball, L., Gagnon P., P. Honohan, and S. Krog (2016), What Else Can Central Banks do?, Geneva Reports on the World Economy, No. 18, ICMB and CEPR.
- Bai, J. and P. Perron (1998), Estimating and Testing Linear Models with Multiple Structural Breaks, *Econometrica*, 66(1), 47-78.
- Bai, J. and P. Perron (2003), Computation and Analysis of Multiple Structural Change Models, *Journal of Applied Econometrics*, 18(1), 1-22.
- Beechey, M. J., B. K. Johansson, and A. T. Levin (2011), Are Long-Run Inflation Expectations Anchored More Firmly in the Euro Area than in the United States?, *American Economic Journal: Macroeconomics*, 3(2), 104-129.
- Benhabib, J., S. Schmitt-Grohé, and M. Uribe (2001), Monetary Policy and Multiple Equilibria, *American Economic Review*, 91(1), 167-186.
- Bodenstein, M., J. Hebden, and R. Nunes (2012), Imperfect Credibility and the Effective Lower Bound, *Journal of Monetary Economics*, 59(2), 135-149.
- Buseti, F., G. Ferrero, A. Gerali, and A. Locarno (2014), Deflationary Shocks and De-Anchoring of Inflation Expectations, Bank of Italy Occasional Paper, No. 252, November 2014.
- Ciccarelli, M. and J. A. García (2015), International Spillovers in Inflation Expectations, Working Paper Series 1857, European Central Bank, Frankfurt.
- Coenen G. and A. Warne (2014), Risks to Price Stability, the Effective Lower Bound, and Forward Guidance: a Real-Time Assessment, *International Journal of Central Banking*, 10(2), 7-54.
- Coibion, O. and Y. Gorodnichenko (2012), What Can Survey Forecasts Tell Us about Informational Rigidities?, *Journal of Political Economy*, 120, 116-159.
- van der Crujssen, C. and M. Demertzis (2011), How Anchored Are Inflation Expectations in EMU countries?, *Economic Modelling*, 28(1-2), 281-298.
- Demertzis, M., M. Marcelino, and N. Viegi (2009), Anchors for Inflation Expectations, DNB Working Paper, No. 229, De Nederlandsche Bank, Amsterdam.
- Demertzis, M., M. Marcelino, and N. Viegi (2012), A Credibility Proxy: Tracking US Monetary Developments, *The B.E. Journal of Macroeconomics*, 12(1), Article 12.
- Dovern, J., U. Fritsche, P. Loungani, and N. Tamirisa (2015), Information Rigidities: Comparing Average and Individual Forecasts for a Large International Panel, *International Journal of Forecasting*, 31, 144-154.
- Dräger, L. and M. J. Lamla (2013), Anchoring of Consumers' Inflation Expectations: Evidence from Microdata, KOF Working Papers, 13-339, ETH Zurich.
- Draghi, M. (2014), Monetary Policy in the Euro Area, speech by Mario Draghi at the Frankfurt European Banking Congress, Frankfurt am Main, 21 November 2014.
- Driscoll, J. and A. Kraay (1998), Consistent Covariance Matrix Estimation with Spatially Dependent Panel Data, *The Review of Economics and Statistics*, 80(4), 549-560.
- Ehrmann, M. (2015), Targeting Inflation from Below: How Do Inflation Expectations Behave?, *International Journal of Central Banking*, 11(S1), 213-249

- Eggertsson, G. B. and N. R. Mehrotra (2014), A Model of Secular Stagnation, Working Paper 20574, NBER Working Paper Series, October.
- Engelberg, J., C. F. Manski, and J. Williams (2009), Comparing the Point Predictions and Subjective Probability Distributions of Professional Forecasters, *Journal of Business and Economic Statistics*, 27(1), 30-41.
- Galati, G., S. Poelhekke, and C. Zhou (2011), Did the Crisis Affect Inflation Expectations?, *International Journal of Central Banking*, 7(1), 167–207.
- García, J. A. and A. Manzanares (2007), Reporting Biases and Survey Results. Evidence from European Professional Forecasters, ECB Working Paper Series, 836, European Central Bank.
- Gürkaynak, R. S., A. T. Levin, and E. Swanson (2010), Does Inflation Targeting Anchor Long-Run Inflation Expectations? Evidence from the U.S., UK, and Sweden, *Journal of the European Economic Association*, 8(6), 1208–1242.
- Hills, T. S., T. Nakata, and S. Schmidt (2016), The Risky Steady State and the Interest Rate Lower Bound, ECB Working Paper Series, 1913, European Central Bank.
- Karadi, P. (2017), The ECB's announcements of non-standard measures and longer-term inflation expectations, Research Bulletin No. 33, European Central Bank.
- Kenny, G., T. Kostka, and F. Masera (2015), Density Forecast Features and Density Forecast Performance: A Panel Analysis, *Empirical Economics*, 48(3), 1203-1231.
- Levin, A. T., F. M. Natalucci, and J. M. Piger (2004), The Macroeconomic Effects of Inflation Targeting, Review, Federal Reserve Bank of St. Louis, 86(4), 51-80.
- Lyziak, T and M. Palovita (2016), Anchoring of Inflation Expectations in the Euro Area: Recent Evidence Based on Survey Data, ECB Working Paper Series, 1945, European Central Bank.
- Mehrotra, A. and J. Yetman (2014), Decaying Expectations: What Inflation Forecasts Tell Us about the Anchoring of Inflation Expectations, BIS Working Papers, No. 464, Bank for International Settlements, Basel.
- Nautz, D. and T. Strohsal (2014), Are US Inflation Expectations Re-Anchored, SFB 649 Discussion Paper 2014-060, Humboldt University, Berlin.
- Orphanides, A. and J. C. Williams (2004), Imperfect Knowledge, Inflation Expectations, and Monetary Policy. In: Bernanke, B. S. and M. Woodford (eds), *The Inflation Targeting Debate*, 201-48, University of Chicago Press, Chicago.
- Orphanides, A. and J. C. Williams (2007), Inflation Targeting under Imperfect Knowledge, *Federal Reserve Bank of San Francisco Economic Review*, 1-23.
- Speck, C. (2016), Inflation Anchoring in the Euro Area, Discussion Paper No 04/2016, Deutsche Bundesbank.
- Strohsal, T. and L. Winkelmann (2015), Assessing the Anchoring of Inflation Expectations, *Journal of International Money and Finance*, 50, 33-48.
- Summers, L. (2014), US Economic Prospects, Secular Stagnation, Hysteresis and the Effective Lower Bound, *Business Economics*, 49(2), National Association for Business Economics.

Appendix I – Data Sources

SPF data: The SPF panel of point and probability forecasts for euro area GDP, HICP inflation and the unemployment rate at long, medium, and short horizons were obtained from the ECB website (which is accessible via <http://www.ecb.europa.eu/stats/prices/indic/forecast/html/index.en.html>). The website also contains a detailed description of the dataset.

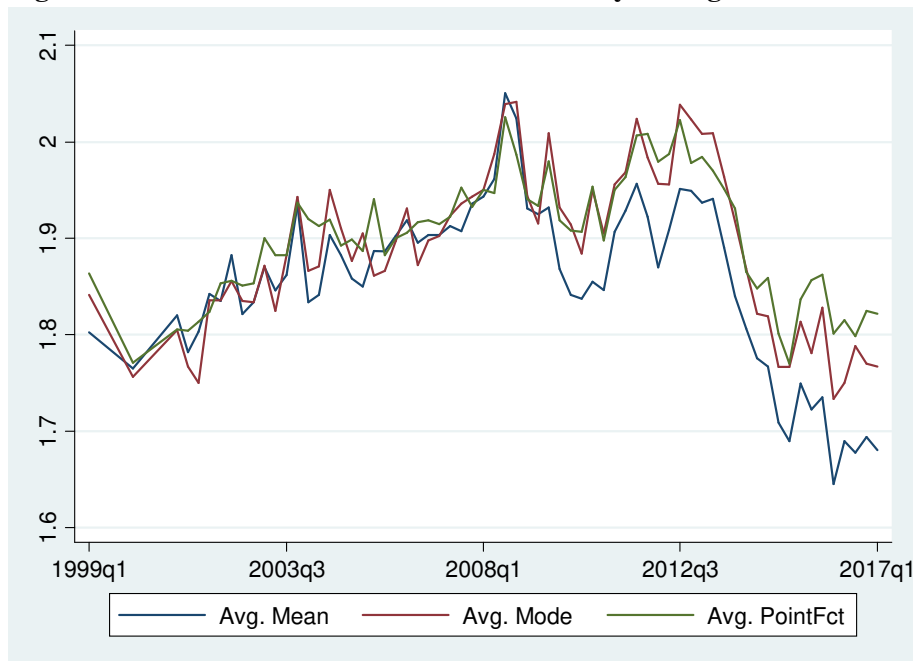
Oil prices: Monthly data on the price of oil (Brent) in US dollar were downloaded from Datastream. We include the most recent change over three months (approximated by the log difference) that was known to the forecasters at the time they submitted their forecasts to the SPF.

ECB Balance Sheet: Monthly data were obtained from Datastream. We include the most recent change of the total volume of the ECB's assets and liabilities over a period of three months that was known to the forecasters at the time they submitted their forecasts to the SPF.

Inflation rate: We use inflation rates based on the Harmonised Index of Consumer Prices (HICP). Monthly data were obtained from Datastream. In the regressions, we use the most recent change of the annual inflation rate over a period of three months that was known to the forecasters at the time they submitted their forecasts to the SPF.

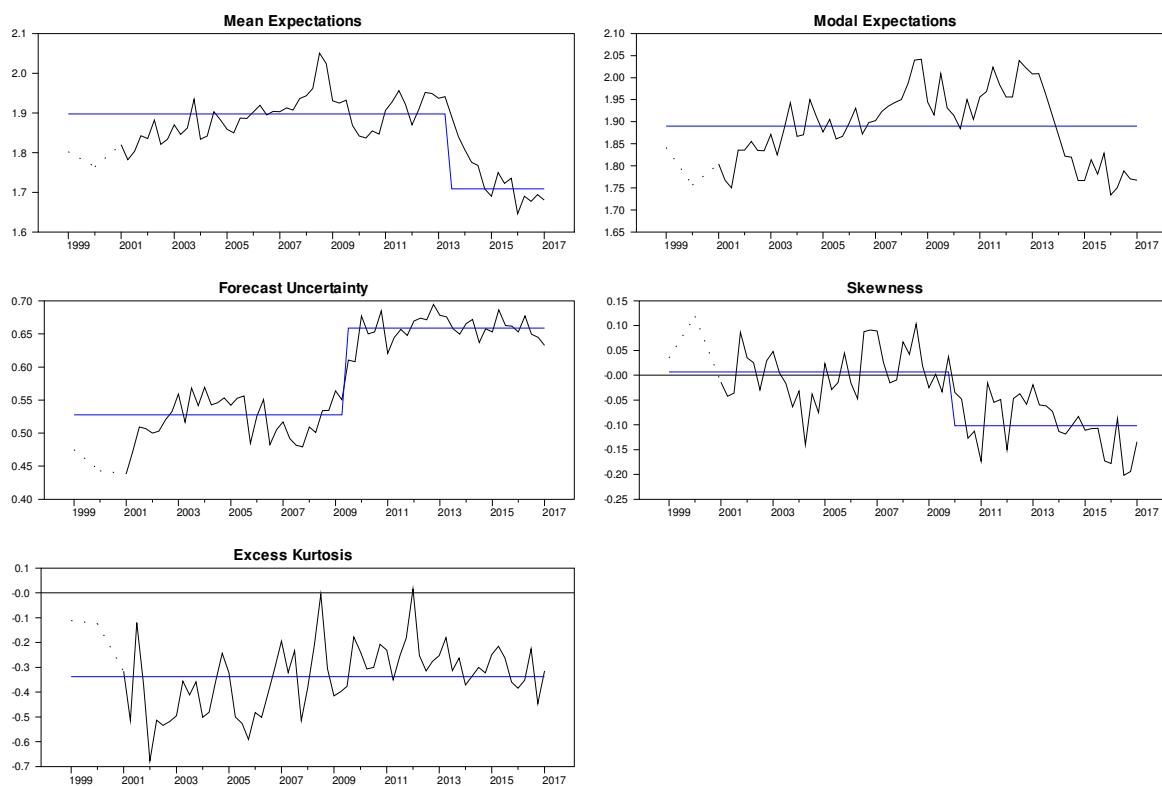
Figures and Tables

Figure 1 – Different measures of central tendency of long-term inflation expectations



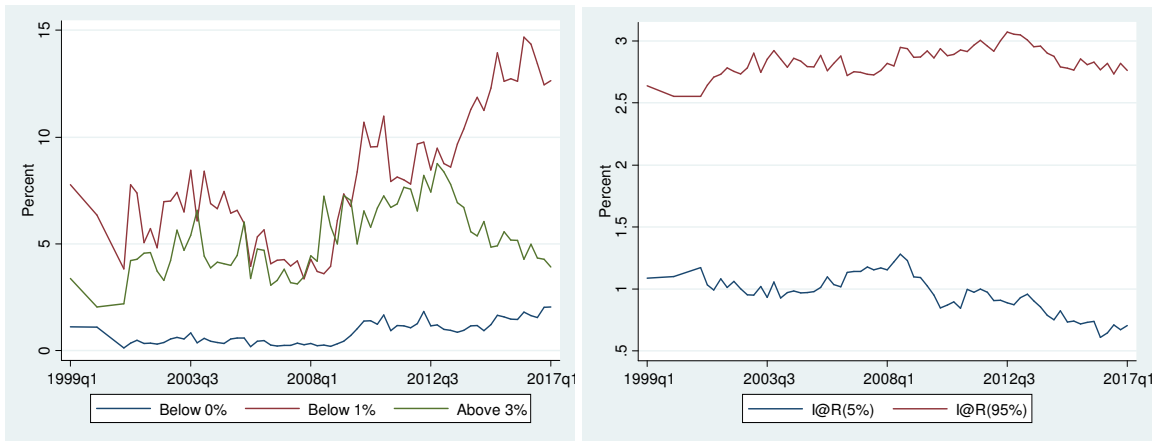
Notes: Avg. mean expectations and avg. modal expectations are computed based on the reported density forecasts. The avg. point forecasts are computed based on the reported individual point forecasts.

Figure 2 – Break points for moments of density forecasts



Notes: Selection of break points based on Bai and Perron (2003). The black lines refer to the average moments of the density forecasts of the individual SPF participants. The blue lines show the implied unconditional means for different sub-periods, with breaks in AR(1) models for the average moments selected using the LWZ statistic. The minimum distance between two break points was set to eight quarters.

Figure 3 – Long-term expectations about tail inflation events



Notes: The left plot refers to the average (across all panellists) probability mass (corresponding to the long-term inflation expectations) assigned to the respective bins. The right plot shows the 5th and 95th percentile of the long-term inflation density forecasts, averaged across individual panellists. The method is taken from Andrade *et al.* (2012).

Table 1: Break points for average moments of density forecasts

	LWZ			Sequential supF		
	Period	F test	Implied mean	Period	F test	Implied mean
Mean Expectations						
	1999Q1–2013Q2		1.90	1999Q1–2017Q1		1.83
	2013Q3–2017Q1	7.89***	1.69			
Modal expectations						
	1999Q1–2017Q1		1.89	1999Q1–2017Q1		1.89
Inflation uncertainty						
	1999Q1–2009Q2		0.53	1999Q1–2009Q2		0.53
	2009Q3–2017Q1	16.56***	0.66	2009Q3–2017Q1	16.56***	0.66
Skewness						
	1999Q1–2009Q4		0.01	1999Q1–2017Q1		-0.05
	2010Q1–2017Q1	8.05***	-0.10			
Excess kurtosis						
	1999Q1–2017Q1		-0.34	1999Q1–2017Q1		-0.34

Notes: Based on the test by Bai and Perron (2003). Dependent variables are the average moments of the density forecasts of the individual SPF participants. Dates refer to periods in which we observe a significant change in the parameters of an AR(1) model for the different moments. Implied unconditional means are computed for every break segment based on the estimated coefficients. The number of breaks and their location is selected based on the modified Schwarz criterion (LWZ) and the sequential supF test respectively. The minimum distance between two breaks is set to eight quarters. *** indicate that breaks in the model parameters are jointly different from 0 at a 1% significance level.

Table 2: Correlations of change in long-term mean inflation expectations with other variables

	Total	Between	Within						
			Mean	Min	P10	P90	Max	F(pv<.05)	F(pv<.05&+)
$dE_i[\pi(1y)]_t$	0.13*	0.21	0.24	-0.37	-0.10	0.51	0.96	17.3	16.3
$dE_i[\pi(2y)]_t$	0.31*	0.27*	0.36	-0.61	-0.02	0.75	0.95	26.9	26.0
$\pi - E_i[\pi(1y)]_{t-4}$	0.09*	0.16	0.10	-0.40	-0.26	0.34	0.75	5.8	5.8
$\pi - E_i[\pi(2y)]_{t-8}$	0.08*	0.19	0.10	-0.57	-0.18	0.36	0.79	2.9	2.9
$MA(\pi)_{t-1} - E_i[\pi(5y)]_{t-1}$	0.31*	0.06	0.36	-0.28	0.13	0.72	0.91	26.9	26.9
$dE_i[GDP(5y)]_t$	0.10*	0.32*	0.11	-0.71	-0.37	0.47	0.96	14.4	10.6
$dE_i[U(5y)]_t$	-0.05*	0.01	-0.08	-0.80	-0.44	0.35	0.97	11.5	2.9
$d\pi_{t-1}$	0.09*	-	0.09	-0.52	-0.16	0.35	0.56	5.8	4.8
$dOil_{t-1}$	0.09*	-	0.10	-0.47	-0.22	0.41	0.62	8.7	7.7
$dCBBS_{t-1}$	-0.01	-	-0.02	-0.63	-0.28	0.28	0.47	5.8	2.9

Notes: Total correlation is based on the pooled data. Between correlations are based on forecaster-specific averages for those forecasters with at least 8 observations. Within correlations are based on forecaster-specific computations. We show the mean, minimum, 10th percentile, 90th percentile and maximum value for those forecasters with at least 8 observations. Total and between correlations that are statistically significantly different from 0 are marked with *. The last two columns indicate which fraction of forecaster-specific correlations (in %) is significantly different from zero or significantly different from zero and positive.

Table 3: Co-movement of long-term expectations with other variables

	(1)	(2)	
	Full Sample	Before 2007Q4	Since 2007Q4
$dE_i[\pi(1y)]_t$	0.015 (0.017)	0.005 (0.036)	0.024 (0.017)
$dE_i[\pi(2y)]_t$	0.174*** (0.024)	0.189*** (0.053)	0.151*** (0.019)
$MA(\pi)_{t-1} - E_i[\pi(5y)]_{t-1}$	0.149*** (0.024)	0.199*** (0.043)	0.152*** (0.029)
$\pi - E_i[\pi(1y)]_{t-4}$	-0.007 (0.013)	0.002 (0.021)	-0.004 (0.016)
$\pi - E_i[\pi(2y)]_{t-8}$	0.006 (0.014)	0.040 (0.031)	0.002 (0.016)
$dE_i[GDP(5y)]_t$	0.012 (0.027)	0.024 (0.031)	0.011 (0.044)
$dE_i[U(5y)]_t$	-0.014 (0.011)	-0.008 (0.019)	-0.020* (0.012)
$d\pi_{t-1}$	0.030** (0.015)	0.027 (0.023)	0.028 (0.019)
$dCBBS_{t-1}$	-0.147** (0.060)	-1.157*** (0.387)	-0.115* (0.062)
<i>MPA dummy</i>	-0.010 (0.013)	-	-0.012 (0.013)
<i>ELB dummy</i>	0.006 (0.007)	-	0.007 (0.007)
Constant	0.000 (0.006)	0.006 (0.006)	0.006 (0.006)
Observations	1180	1180	
R ²	0.190	0.201	
pv(Coeff. break)		0.173	

Notes: Dependent variable is the change in long-term inflation expectations. Both models include fixed-effects for each forecaster. The constant is identified by restricting the average of the fixed-effects to equal 0. Standard errors are computed using the method by Driscoll and Kraay (1998) and are robust against general forms of spatial and temporal dependence. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. The last row states the p-value of an F-test of the hypothesis that none of the coefficients change from the first to the second sub-sample.

Table 4: Correlations of change in long-term inflation uncertainty with other variables

	Total	Between	Within						
			Mean	Min	P10	P90	Max	F(pv<.05)	F(pv<.05&+)
$dV_i[\pi(1y)]_t$	0.39*	0.54*	0.35	-0.5	-0.03	0.71	0.98	32.7	30.8
$dV_i[\pi(2y)]_t$	0.52*	0.51*	0.45	-0.53	0.04	0.82	0.98	33.7	33.7
$abs(\pi - E_i[\pi(1y)]_{t-4})$	0.06*	0.16	0.09	-0.45	-0.19	0.38	0.59	3.8	3.8
$abs(\pi - E_i[\pi(2y)]_{t-8})$	0.04	0.12	0.06	-0.52	-0.30	0.42	0.71	2.9	2.9
$abs(MA(\pi) - E_i[\pi(5y)]_{t-1})$	-0.02	-0.03	-0.02	-0.55	-0.28	0.26	0.53	3.8	1.0
$dV_i[GDP(5y)]_t$	0.53*	0.54*	0.38	-0.99	-0.21	0.81	0.96	33.7	30.8
$dV_i[U(5y)]_t$	0.44*	0.49*	0.34	-0.52	-0.12	0.78	0.99	25.0	24.0
$abs(d\pi_{t-1})$	0.04	-	0.00	-0.56	-0.35	0.27	0.48	5.8	3.8
$abs(dOil_{t-1})$	0.02	-	0.02	-0.63	-0.27	0.31	0.64	7.7	6.7
$abs(dCBBS_{t-1})$	-0.01	-	-0.01	-0.53	-0.28	0.32	0.56	6.7	5.8

Notes: Total correlation is based on the pooled data. Between correlations are based on forecaster-specific averages for those forecasters with at least 8 observations. Within correlations are based on forecaster-specific computations. We show the mean, minimum, 10th percentile, 90th percentile and maximum value for those forecasters with at least 8 observations. Total and between correlations that are statistically significantly different from 0 are marked with *. The last two columns indicate which fraction of forecaster-specific correlations (in %) is significantly different from zero or significantly different from zero and positive.

Table 5: Co-movement of long-term inflation uncertainty with other variables

	(1)	(2)	
	Full Sample	Before 2007Q4	Since 2007Q4
$dV_i[\pi(1y)]_t$	0.065 (0.051)	-0.015 (0.076)	0.120** (0.061)
$dV_i[\pi(2y)]_t$	0.268*** (0.046)	0.409*** (0.083)	0.193*** (0.040)
$abs(MA(\pi) - E_i[\pi(5y)])_{t-1}$	0.007 (0.013)	-0.008 (0.015)	0.013 (0.018)
$abs(\pi - E_i[\pi(1y)]_{t-4})$	0.003 (0.007)	0.005 (0.015)	0.005 (0.009)
$abs(\pi - E_i[\pi(2y)]_{t-8})$	-0.003 (0.006)	-0.008 (0.011)	-0.001 (0.008)
$dV_i[GDP(5y)]_t$	0.248*** (0.036)	0.273*** (0.047)	0.210*** (0.047)
$dV_i[U(5y)]_t$	0.110*** (0.027)	0.098*** (0.036)	0.120*** (0.034)
$abs(d\pi_{t-1})$	0.021*** (0.006)	0.028** (0.013)	0.018** (0.008)
$abs(dCBBS_{t-1})$	-0.084** (0.042)	-0.278 (0.192)	-0.037 (0.046)
<i>MPA dummy</i>	0.023*** (0.005)		0.025*** (0.006)
<i>ELB dummy</i>	-0.003 (0.006)		-0.000 (0.006)
Constant	-0.001 (0.002)	-0.004 (0.003)	-0.004 (0.003)
Observations	1180		1180
R ²	0.391		0.402
pv(Coeff. break)			0.188

Notes: Dependent variable is the change in long-term inflation uncertainty. Both models include fixed-effects for each forecaster. The constant is identified by restricting the average of the fixed-effects to equal 0. Standard errors are computed using the method by Driscoll and Kraay (1998) and are robust against general forms of spatial and temporal dependence. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. The last row states the p-value of an F-test of the hypothesis that none of the coefficients change from the first to the second sub-sample.