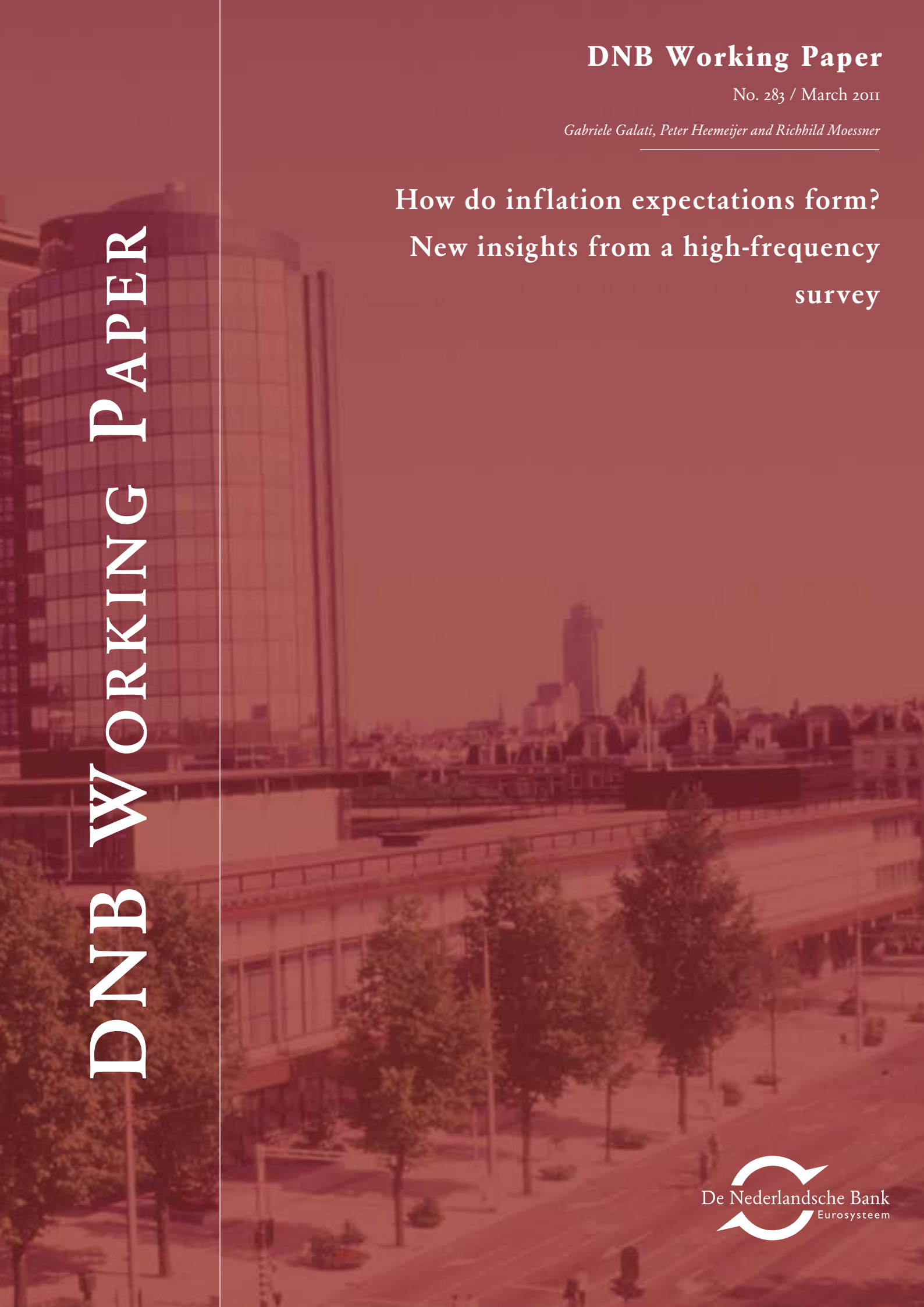

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De Nederlandsche Bank
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* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

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How do inflation expectations form? New insights from a high-frequency survey[1]

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Abstract

We provide new insights on the formation of inflation expectations – in particular at a time of great financial and economic turmoil – by evaluating results from a survey conducted from July 2009 through July 2010. Participants in this survey answered a weekly questionnaire about their short-, medium- and long-term inflation expectations. Participants received common information sets with data relevant to euro area inflation. Our analysis of survey responses reveals several interesting results. First, our evidence is consistent with long-term expectations having remained well anchored to the ECB's definition of price stability, which acted as a focal point for long-term expectations. Second, the turmoil in euro area bond markets triggered by the Greek fiscal crisis influenced short- and medium-term inflation expectations but had only a very small impact on long-term expectations. By contrast, long-term expectations did not react to developments of the euro area wide fiscal burden. Third, participants changed their expectations fairly frequently. The longer the horizon, the less frequent but larger these changes were. Fourth, expectations exhibit a large degree of time-variant non-normality. Fifth, inflation expectations appear fairly homogenous across groups of agents at the shorter horizon but less so at the medium- and long-term horizons.

JEL classification: E31, E32, E37, E52, C53.

Key words: Inflation expectations, monetary policy, crisis.

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1. Introduction

Both the academic literature and policy discussions have highlighted the crucial importance of inflation expectations for the inflation process and hence central banks' ability to achieve price stability (Bernanke, 2007). At the same time, evidence on the process through which agents form expectations is hard to obtain. Our paper takes an innovative route that provides important new insights on this topic. The main novelty is that we provide empirical evidence on inflation expectations based on a survey that is both "accurate" and frequent, and in which we can assess the role of common information sets. The survey is accurate in the sense that we follow the experimental economics methodology and reward survey participants based on the accuracy of their responses. It is frequent because it is conducted on a weekly basis. We conducted our study from July 2009 through July 2010, which has the additional advantage of capturing information on inflation expectations formation at a time of great financial and economic turmoil.

Our survey is set up as a field experiment, based on three elements. First, participants answer a short questionnaire about short-, medium- and long-term inflation expectations at weekly frequency over a period of one year. Second, each week participants get new information on relevant macroeconomic and financial data. This allows us to analyze how inflation expectations depend on past expectations, realized inflation data and other relevant economic and financial variables. It also allows testing the role of focal points, such as the ECB's definition of price stability or the inflation predictions published by Consensus Economics.

We had 129 participants divided into three groups, with roughly equal weights in the experiment: central bankers (consisting of economists and research assistants from the Dutch Central Bank), academics and students. The experiment lasted one calendar year, which gives enough time variation to conduct time series regressions on the experimental results. The questionnaire is short and easy to fill in, comprising three questions on euro area inflation expectations at different horizons (2010, 2011 and 2019).

In order to obtain results accurately reflecting inflation expectations, participants were, as much as practically possible, motivated to submit their subjective beliefs by means of rewards linked to the ex-post accuracy of their expectations. This follows standard practice in the experimental economics literature.

Our main results are as follows. First, our evidence is consistent with long-term expectations having remained well anchored to the ECB's definition of price stability, which acted as a focal point for long-term expectations. Second, the turmoil in euro area bond markets triggered by the Greek fiscal crisis influenced short- and medium-term inflation expectations but had only a very small impact on long-term expectations. By contrast, long-term expectations did not react to developments of the euro area wide fiscal burden. Third, participants changed their expectations fairly frequently. The longer the horizon, the less frequent but larger these changes were. Fourth, expectations exhibit a large degree of time-variant non-normality. Fifth, inflation expectations appear fairly homogenous across groups of agents at the shorter horizon but less so at the medium- and long-term horizons. Moreover, we find that expectations of the central bank's staff are the least volatile, and that they Granger cause those of academics and students.

The remainder of the paper is organized as follows. In Section 2 we provide an overview of the relevant literature on the formation of inflation expectations and discuss alternative measures of inflation expectations. Section 3 describes the main features of our survey. In Section 4 we present our empirical approach and the main results. Section 5 concludes.

2. Literature review

Theory

Expectations play a central role in macroeconomics. If the central bank's objective function, minimizing deviations of inflation from target and, possibly, output gap volatility, is known and constant, the Rational Expectations Hypothesis (REH) implies that long-term inflation expectations do not change in response to the arrival of new information. Models with rational expectations typically assume homogeneous expectations, given the conceptual and technical difficulties of dealing with rational expectations models under heterogeneous information (Pesaran and Weale, 2006). In recent years, a series of papers departed from the REH and the assumption of a known and constant central bank objective function. These studies typically allow for heterogeneous expectations. This literature can be divided into a number of strands.

One strand, which has received increasing attention, relies on learning and assumes that people do not have full information about the economy or the objectives of the central bank. Instead, they make statistical inferences about the unknown parameters of the economy. Orphanides and Williams (2005), for example, model agents who do not know the true model of the economy but rather constantly update their estimates based on all information available to them. As a result, inflation expectations are sensitive to economic shocks.

Another strand is based on the assumption that agents use rules of thumb ("heuristics") to make inflation forecasts. Brazier et al. (2008), for example, consider two heuristics: one is based on lagged inflation and the other on an inflation target announced by the central bank. In their model, agents switch between these two heuristics based on an imperfect assessment of how each has performed in the past.

A third strand models monetary policy as an information game in which individuals form their expectations based on all (public and private) available information, which will be noisy. In Demertzis and Viegi (2008), agents know that inflation depends both on monetary policy and on the average expectation formed by all agents. The relative weight that is assigned to these two factors in agents' expectations is determined within a higher-order expectations setup.

A number of papers rely on the concept of *self-control* (Gul and Pesendorfer, 2001) to derive the expectation formation process from assumptions about the form and type of agents' utility function. These papers formalize biases in expectations, and in particular model over-optimism or over-pessimism. In Brunnermeier and Parker (2004), for example, agents care about expected future utility flows, so they derive higher current felicity if they believe that better outcomes are more likely in the future. They then form optimal expectations by weighing the felicity gains from optimism against the losses incurred due to poor decisions and worse than expected realized outcomes. In this framework, agents tend to be overoptimistic, and aggregate forecasts tend to exhibit overconfidence and overoptimism.

Rational inattention (Sims, 2003, 2005; Mackowiak and Wiederholt, 2009) is a microfounded approach to expectation formation. The objective of modelling economic agents as being "rationally inattentive" is to capture the fact that people are constrained in their ability to acquire and process information. Agents have limited capacities to process information, and hence receive only noisy signals of actual shocks hitting the economy. In these models, the form of the observational errors is itself predicted by the theory and can be derived from the structure of the individuals' optimization problems.

Once the REH is abandoned, the way information is disseminated becomes crucial. In an influential study, Mankiw and Reis (2001) assume that information is disseminated slowly

throughout the population. As result, the response of decision makers to new information is staggered. In their paper, the rate at which media news reaches economic agents determines the cross-sectional dispersion of expectations.

Information dissemination and absorption is a reason for *sticky expectations*: Caroll (2003) shows that while empirical household expectations are not rational in the usual sense, expectational dynamics are well-captured by a model in which households' views derive from news reports on the views of professional forecasters, which in turn may be rational. The model's estimates imply that people only occasionally pay attention to news reports; this inattention generates 'stickiness' in aggregate expectations, with important macroeconomic consequences.

Over the past decade, a large number of papers have modelled heterogeneous expectations by boundedly rational agents (Hommes, 2006; Pesaran and Weale, 2006).

Empirical work

The empirical literature on inflation expectations has relied on two measures of expectations: measures based on inflation surveys and measures derived from financial market instruments.

Surveys provide the most direct method for measuring expectations and have been commonly used in the literature. ECB (2006) provides a detailed overview of survey measures of euro area inflation expectations at different horizons. For one-year ahead expectations, surveys are available at monthly or quarterly frequency from the *European Commission Consumers Survey*, the ECB's *Survey of Professional Forecasters (SPF)* and the *Euro Zone Barometer*.[2] Survey data for medium-term horizons are available at quarterly frequency from the SPF. Figure 4.1.1 shows the time series of SPF data on expectations of euro area inflation over a five year horizon. The main source for longer-term expectations is *Consensus Economics*, which twice a year collects data on six to ten year ahead expectations for a number of countries including the euro area from a panel of some 30 professional forecasters.

Survey measures have several important shortcomings.[3] First, given their low frequency, survey measures appear well-suited for analyzing long-run properties of inflation expectations but less so for identifying the process of expectation formation. Second, survey results may not be reliable to the extent that respondents do not have to act on the basis of their responses – i.e. "do not put their money where their mouth is".[4] Third, survey results are sensitive to the wording of the questions (Van der Klaauw et al, 2009). Fourth, different types of survey measures may produce very different results. Mankiw et al. (2003), for example, looked at 50 years of data on inflation expectations in the United States, and documented substantial disagreement among both consumers and professional economists about expected future inflation. They found that this disagreement varied substantially through time, depending on the level of inflation, the absolute value of the change in inflation, and relative price variability. Fifth, survey measures of consumer inflation expectations provide useful information on the distribution of expectations across survey participants but not necessarily precise information on the uncertainty around individual agents' expectations (Bruine de

[2] The SPF collects forecasts by a panel of some 70 professional forecasters on euro area HICP.

[3] For a careful analysis of the properties of survey measures, see Thomas (1999) and Clark and Davig (2008).

[4] This point is emphasised in the experimental economics literature (Smith, 1982, 1992).

Bruin et al, 2009). Based on regular surveys of US consumers included in the RAND American Life Panel, they find that while the two measures are positively correlated, disagreement and uncertainty have distinct features.

A second strand of the literature extracts inflation expectations from inflation-indexed financial market instruments, and looks at the relationship between inflation expectations and macroeconomic variables at high (daily or intraday) frequency (Swanson, 2006; Gürkaynak et al., 2005; Gürkaynak et al. (forthcoming); Gürkaynak et al., 2006, Beechey et al., 2007).[5] One important advantage of this type of measure is that, given its high frequency, it allows examining more formally changes in the behaviour of expectations over a relatively short horizon. Galati, Poelhekke and Zhou (2011) applied this empirical strategy to investigate whether the behaviour of long-term inflation expectations changed around the crisis.

One major shortcoming of inflation measures based on financial instruments is that backing out the expectation component requires strong assumptions. The reason is that break-even rates, i.e. the difference between the yields of conventional and inflation-indexed bonds, can be decomposed into four main factors: expected inflation, inflation risk premia, liquidity premia, and technical factors (Hördahl, 2009).[6]

There is a rich empirical literature that has tested the rationality of expectations, which has relied mostly on survey measures of expectations.[7] The results are generally mixed and depend, among other things, on the sample period and the types of participants of surveys. Mehra (2002), for example, analyzed the Michigan Survey and found that the median inflation forecasts of households outperform those of professional economists and forecasters in the period covering the 1980s and 1990s. In particular, he documented that households' forecasts are more accurate, unbiased, have predictive content for future inflation, and are efficient with respect to economic variables generally considered pertinent to the behaviour of inflation.

In terms of forecasting power, survey measures have been found to dominate other types of methods. Bekaert et al. (2009) compared the out-of-sample forecasting power of four alternative methods of forecasting U.S. inflation: time-series ARIMA models; regressions using real activity measures motivated from the Phillips curve; different types of term structure models; and survey-based measures. They found that surveys outperform the other forecasting methods. Moreover, there is little evidence that combining forecasts produces superior forecasts to survey information alone.

A number of papers have explored the variability of expectations across survey respondents (Mankiw and Reis, 2003; Carroll, 2003b; Khan and Zhu, 2002; Capistran and Timmermann, 2009). Carroll (2003b), for example, analyzes the evolution of the standard deviation of inflation expectations in the Michigan Survey. Carroll (2003b) provides an epidemiological model of inflation expectations in which "expert opinion" slowly spreads person-to-person much as disease spreads through a population. Bonham and Cohen (2000) argue that parameter estimates in consensus regressions are either inconsistent or can lead to false acceptance of the unbiasedness hypothesis due to the averaging of individual biases.

[5] For an overview of methods to extract inflation expectations from inflation-indexed bonds or inflation swaps, see e.g. Swanson (2006) and Hurd and Relleen (2006).

[6] Hördahl (2009) argues that the same applies, albeit to a lesser extent, to inflation-indexed swaps.

[7] See Thomas (1999) for an example.

Badarinza and Buchmann (2010) examine the heterogeneous nature of individual forecasts and the determinants thereof.

The empirical literature on drivers of inflation expectations – surveyed carefully in a paper by Clark and Davig (2008) – has documented the role of past inflation and of macroeconomic variables. Demertzis et al. (2008), for example, tested whether long-run inflation expectations – derived from the Fed's FRB model and quarterly survey-based measures – are influenced by short-run inflation dynamics. They found that in recent years, the role of short-run dynamics has increased in the United States, but only slightly.

Levin et al. (2004) analyzed the behaviour of private-sector inflation forecasts at horizons up to ten years – measured by quarterly Consensus forecasts – in the United States and the euro area over the period 1994–2003. They found that expectations were highly correlated with a three-year moving average of lagged inflation. By contrast, in industrial countries that have adopted inflation targeting (United Kingdom, Sweden, Canada, Australia and New Zealand), inflation expectations were found not to be sensitive to actual inflation. Levin et al. (2004) concluded that inflation targeting has played a significant role in anchoring long-run inflation expectations. Clark and Nakata (2008) found evidence of a declining impact of unexpected increases in inflation on long-term expectations in recent years in the United States.

Forsells and Kenny (2004) analyze survey data on consumers' inflation expectations in the euro area and find that they appear to incorporate – though not always completely – the information contained in a broad set of macroeconomic variables. In particular, past price developments as well as various cost and activity indicators do not explain consumers' prediction errors.

The role of macroeconomic news is highlighted in the literature on the anchoring of long-term expectations. The periodical announcements of data on the state of the economy and forecasts released by various (statistical) offices and agencies form a steady source of information. To the extent that the information is unanticipated, beliefs about future inflation may be updated. If expectations are perfectly anchored, long-run inflation expectations should not be responsive to news about actual inflation, or more generally about macroeconomic conditions.

3. The survey

The data source for our analysis of inflation expectations is a new survey, which we carried out over the period July 2009 – July 2010. The survey has three novel features compared to existing surveys of inflation expectations. First, it has a considerably higher frequency than other surveys, especially those for long-term inflation expectations. This allows us to study more carefully some aspects of expectation formation, such as the frequency with which expectations at different horizons are revised. Second, participants in our survey are provided with common information sets. We can exploit this characteristic to provide new evidence on the role of information asymmetries in explaining the observed heterogeneity of expectations and to test for the role of focal points. Third, we introduce a pecuniary incentive for survey participants to respond as accurately as possible.

The main part of our survey consists of a short questionnaire about short-, medium- and long-run inflation expectations for the euro area, which 129 participants filled in each week for a year, starting on 22 June 2009. Participants were divided into three groups: staff from the Dutch central bank (De Nederlandsche Bank, DNB), Netherlands-based academics and students from Dutch universities. Every Monday morning, participants received an email asking them to answer the following three questions by 5pm that day:

1. What annual HICP inflation do you expect for 2010?
2. What annual HICP inflation do you expect for 2011?
3. What annual HICP inflation do you expect for 2019?

The email also contained an attachment with new information on euro area inflation that had arrived in the previous week. This information set consisted of three elements: an updated graph of euro area HICP inflation, a table with new data releases on national and euro area-wide HICP, and – for a subset of participants, namely DNB staff, only – an updated table with Consensus mean forecasts for euro area inflation for 2010, 2011 and 5-10 years ahead.[8]

Participants were promised an accuracy-based reward for each forecast of 2010 inflation, to be paid out at the end of 2010. In addition, given that the accuracy for 2- and 10-year ahead expectations would be known only in the more distant future, participants were promised to be paid a flat reward for each answer to Questions 2 and 3. These rewards are also paid out at the end of 2010.

To get more background information about the participants, we also asked participants to fill in two questionnaires. The first was sent to participants at the beginning of our exercise, and contained questions based on the test proposed by Schwartz et al. (2002) to identify maximizers and satisficers. The full questionnaire is provided in Appendix 1. Based on the answers to this test, we classify survey participants into these two types and investigate whether the way they form inflation expectations differs significantly.

The second questionnaire, which participants filled in at the end of the exercise, included general questions on the respondents (e.g. on economic literacy, age, gender), on the way they formed expectations (e.g. the time they spent on answering the weekly questions, the importance of pecuniary rewards, the role of past expectations for current expectations) and the inputs, i.e. the type of information used to form expectations.

4. Results

4.1 An overview of the survey data

Means and medians

We first organize participants' inflation expectations into three panel data sets associated with the horizons 2010, 2011 and 2019 respectively. Figures 4.1.1 and 4.1.2 show two measures of the central tendency in the data sets – the mean and median – over time. These are shown in comparison with inflation expectations based on Consensus surveys and the ECB's Survey of Professional Forecasters (SPF).

[Figures 4.1.1, 4.1.2 about here.]

Figures 4.1.1 and 4.1.2 highlight three interesting findings. First, there are important differences in the behaviour of inflation expectations at different horizons: both the mean and median increase with the forecast horizon. This seems to suggest that participants considered the observed low levels of inflation in 2009 and early 2010 to be temporary and believed the economic climate in the euro area to gradually normalize. In particular, for the

[8] For licensing reasons, survey participants outside DNB were not allowed to receive the Consensus Forecasts.

one-year horizon, expectations means follow a clear upward trend.[9] For the two-year horizon they seem to be fluctuating around a constant, which is visibly higher than the means of one-year expectations.

Second, while the means and medians of short-term inflation expectations substantially increased from the end of 2009, longer-term expectations look fairly stable. This suggests that factors affecting short-term expectations have not structurally affected longer-term expectations, which is consistent with long-term inflation expectations remaining well anchored. This is evident in particular from the fact that even though the 2019 means (Figure 4.1.1) are all above 2%, the 2019 medians are equal to 2% in 91% of weeks, which coincides with the ECB's comfort zone for medium-term HICP inflation.

Third, our survey measure of inflation expectations provides information not contained in either existing survey measures or market-based measures. In particular, Figures 4.1.1 and 4.1.2 show that while mean expectations track Consensus survey and SPF expectations relatively closely at the short horizon, they lie consistently above Consensus survey and SPF expectations at the medium- and long-term horizons. Moreover, Figure 4.1.3 shows that at the medium- and long-term horizons, mean expectations tended to be closest to those implied by inflation-indexed swaps, and less close to breakeven inflation rates extracted from nominal and index-linked government bond yields (with and without adjusting for term premia as in Hördahl, 2008). [10]

[Figure 4.1.3 about here.]

Disagreement

The availability of inflation expectations for a fairly large number of participants allows us to gain interesting insights on disagreements across survey participants. The evolution of standard and robust measures of disagreement is shown in Figures 4.1.4 and 4.1.5, in comparison with the corresponding measures for the Consensus surveys and the ECB's SPF. Three results stand out. First, we find that disagreement within our survey is smaller at the long-term horizon than at the short and medium horizons. Moreover, disagreement – as measured by the interquartile range – at the 10-year horizon was remarkably stable. One interpretation is that long-term expectations are driven by focal points – such as the ECB's definition of price stability – while people form their short- and medium-term expectations based more on time-varying information. Second, we find that disagreement decreased in the course of 2010 at the short horizon, especially on the robust measure of interquartile range, probably because available information on actual information in 2010 was factored in. Third, disagreement at the two-year horizon exceeded that at the one-year horizon.

[Figures 4.1.4 and 4.1.5 about here]

[9] Figure 4.6.1 shows that this behaviour is fairly similar across groups of participants.

[10] At the short horizon, the maturity mismatch between the one-year market rate and expectations for 2010 is relatively larger, so the comparison is not as good.

Higher moments and non-normality

In Figures 4.1.1 and 4.1.2, we observe broad differences between means and medians at different horizons, suggesting the presence of skewness in the expectations distribution across participants at any one time and, possibly, outliers.

Skewness can be measured by Pearson's second skewness coefficient, i.e. 3(mean-median)/standard deviation. An analysis of the Pearson coefficients reveals several interesting results. First, there is positive skewness, which increases as the horizon increases (Figures 4.1.1 and 4.1.2). More specifically, the longer the forecast horizon, the more differences between means and medians are positive, implying that the expectation distributions tend to be more positively skewed according to Pearson's second coefficient.[11] Second, we find evidence of some change in the skewness of one-year expectations in the course of 2010. In the first half of the sample, one-year expectations are positively skewed in 89% of cases, while in the second half this drops to only 46%. This suggests that when inflation means and medians were low at the beginning of the survey, on balance more participants expected positive outliers than negative ones. Later on, when means and medians had risen noticeably, the balance shifted to the point of being slightly in favour of negative outliers.

Time series of standard measures of skewness and excess kurtosis, shown in Figure 4.1.6, provide evidence of substantial non-normality of the distributions of inflation expectations at different horizons.[12] Interestingly, the standard skewness measure[13] is negative much more often than Pearson's coefficient discussed above, creating ambiguity about the way in which the expectations distributions should be characterized. The Jarcque-Bera test of normality, which is based on these measures, rejects normality at the 1% significance level in all but nine weeks at the medium-term horizon, and in all weeks at both the short- and long-term horizons, as also shown in Figure 4.1.6. These results are evidence for a large degree of non-normality of the survey inflation expectations. These standard measures of higher moments are quite volatile, since they place a relatively large weight on outliers.

By contrast, robust measures of skewness and excess kurtosis (as defined in Appendix I) shown in Figure 4.1.7 are more stable over time. Robust measures of higher moments are particularly useful in cases of fat-tailed distributions with a large number of outliers. Both skewness and kurtosis on these robust measures show a clear pattern across horizons. Robust skewness becomes more positive as the horizon increases, for both the measure based on quartiles and octiles (see Appendix I).[14]

Interestingly, robust skewness and excess kurtosis based on octiles are highly correlated at the short horizon, with a correlation coefficient in changes of 0.80. These measures are also

[11] For the 2010 horizon, Pearson's coefficient is positive in 68% of weeks, while for the 2011 and 2019 horizons these percentages are 94% and 100% respectively.

[12] A definition of these measures is provided in Appendix I.

[13] A positive skew indicates that the tail to the right of the mean is longer than that to the left, and that the bulk of the values (including the median) lie to the left of the mean – i.e. the risk of values far above the mean is seen as greater than the risk of values far below the mean.

[14] For robust skewness based on octiles, the average over all weeks increases from 0.07 at the short horizon to 0.29 at the medium- and 0.79 at the long-term horizon. Similarly, robust excess kurtosis increases at longer horizons (with an average over all weeks of -1.11, -0.69 and 0.25 at the short-, medium- and long-term horizons, respectively).

evidence of non-normality of the expectations. They also show that, depending on the measure considered, results can differ on the direction of skew, since different measures probe different parts of the distribution, being for example more or less sensitive to outliers. The non-normality of expectations is illustrated in the histograms for the distribution of inflation expectations in the first and last weeks of the survey, and in the last week of 2009, which are shown in Figure 4.1.8.

Frequency of changes in inflation expectations

One distinguishing feature of our survey is that it is conducted at weekly frequency for all three horizons, including for long-term expectations, whereas existing surveys on long-term expectations are at lower (typically quarterly or semi-annual) frequency. Figure 4.1.9, which shows the proportion of changes in inflation expectations per week, suggests that the weekly frequency carries useful information over and above that available at lower frequencies.[15] First, on average, each week about a third of survey participants change their one-year expectations. Second, the longer the horizon, the lower the proportion of survey participants that revise their expectations, which indicates that long-term expectations are revised less frequently in response to news. The average over all weeks of the proportion of changes in inflation expectations decreases from 38.5% at the short horizon to 37.0% and 23.5% at the medium and long horizons.

A complementary measure is the duration of spells over which inflation expectations remain unchanged, for which histograms are shown in Figure 4.1.10. We can see from these histograms that the short-duration spells of unchanged expectations are less frequent at the long-term horizon. Consistent with this, the mean duration of spells over which inflation expectations remain unchanged increases from around 2.4 weeks at the short and medium horizons to around 3.4 weeks at the long horizon, which suggests that long-term expectations are revised less frequently in response to news, consistent with our results above for the proportion of changes in expectations per week.

The distribution of changes in inflation expectations is shown in Figure 4.1.11. Again, we find a clear pattern as a function of the horizon, with the mean absolute change increasing with the horizon. At the long horizon respondents change their expectations less frequently: the mode at the interval containing no change is higher. But if they do change their expectations (i.e. excluding weekly changes of zero, for which histograms are shown in Figure 4.1.12), the magnitude of the change is larger. In particular, the mean absolute change in expectations at the longer horizon is 0.54 percentage points, compared with 0.40 percentage points at the short, and 0.47 percentage points at the medium horizon.

4.2 Has the central bank remained credible?

An important issue is whether the crisis has influenced the ECB's credibility in pursuing stable inflation around its definition of price stability of below but close to 2%, i.e. whether long-term inflation expectations have remained firmly anchored below but close to 2%. One conjecture is that the unprecedented monetary easing – through both conventional and unconventional monetary policies – coupled with the accumulation of a large fiscal debt, may have undermined market participants' confidence in the ability of central banks to keep inflation at target in the longer run.

[15] This analysis is based on the approach described in Baumgartner et al. (2005) for investigating the frequency of price changes.

In order for the ECB to have remained credible, two conditions must hold. First, long-run inflation expectations must remain stable and centre on the central bank's definition of price stability. Graphical evidence suggests that this condition broadly holds. Survey participants' mean long-run expectations were stable and close to, albeit slightly above, 2% during the whole sample period (Figure 4.1.1), while the median of long-term inflation expectations remained virtually flat at 2% (Figure 4.1.2). The difference between mean and median expectations reflects the positive skewness of the distributions of long-term expectations (see Section 4.1). Statistical tests indicate that the difference between the mean of 10-year expectations and 2% is statistically significant.

Second, if long-term inflation expectations are well-anchored, they should not change in response to news about macroeconomic indicators, in particular inflation. To test this, proceed in three steps. First, we study whether changes in long-term inflation expectations have been associated with changes in Eurostat's flash estimates of the next euro area HICP data release, $\pi^{f,EA}_t$, in the week prior to the circulation of the survey on Monday of week t,[16]

$$\pi^{mean,h}_t - \pi^{mean,h}_{t-4} = \beta_1 + \beta_2 (\pi^{f,EA}_t - \pi^{f,EA}_{t-4}) + \epsilon_t, \qquad (4.2.1)$$

where h=2010, 2011 or 2019 denotes the short-, medium- or long-term horizon of the mean inflation expectations, $\pi^{mean,h}_t$. In weeks where no new flash estimate was released, the latest available flash estimate is carried over in the weekly time series for $\pi^{f,EA}_t$. Results are shown in Table 4.2.1. We find that while mean inflation expectations are significantly affected at the short- and medium-term horizons by changes in HICP flash estimates (at the 1% and 5% levels, respectively), they are not affected at the long-term horizon. This suggests that inflation expectations were well-anchored and monetary policy remained credible over the sample period.

[Table 4.2.1. here]

Second, we study whether surprises in HICP data releases have affected mean inflation expectations. Here, surprises in HICP data releases in the week before the DNB survey, π^{EA}_t, are calculated relative to the median of the most recent Bloomberg survey, $\pi^{BB,EA}_t$,

$$\pi^{mean,h}_t - \pi^{mean,h}_{t-1} = \beta_1 + \beta_2 (\pi^{EA}_t - \pi^{BB,EA}_t) + \epsilon_t. \qquad (4.2.2)$$

Results are shown in Table 4.2.2. The surprises in the euro area HICP based on Bloomberg surveys are not significant. Note however that the variation in the euro area HICP surprises is very low (see Figure 4.2.1). We therefore do not put much weight on this result.

[Figure 4.2.1 about here]

Third, we study the influence of the mean of short- and of medium-term inflation expectations on the mean of long-term expectations. The idea is that if long-term inflation expectations are well-anchored, they should not react to economic developments that influence short- and medium-term inflation expectations. To verify this, we perform Granger causality tests for mean expectations at the three different horizons of our survey. We find no evidence at the 10% level for pairwise Granger causality between mean survey expectations at any two of the three horizons, both for levels and weekly changes (see Tables 4.4.1 and 4.4.2). This

[16] This ensures that we consider information available to all survey respondents, including to those filling in the survey on the day of its circulation on Monday.

finding is consistent with the view that long-term inflation expectations in the euro area are well-anchored in our sample period.

Overall, the regression of long-term inflation expectations on macroeconomic news and on inflation expectations for shorter horizons support the hypothesis that long-term expectations have remained firmly anchored to the ECB's definition of price stability.

4.3 Have concerns about public deficits and debt affected inflation expectations?

To investigate whether market participants' concerns about public deficits and debt have affected inflation expectations, we check whether changes in inflation expectations have been significantly related to changes in CDS spreads of euro area economies.

We first test whether market perceptions of the debt burden of the euro area as a whole have influenced inflation expectations at different horizons.[17] To do this, we estimate the following regression equation

$$\pi^{mean,h}_{t} - \pi^{mean,h}_{t-4} = \beta_1 + \beta_2 (CDS^{EA}_{t} - CDS^{EA}_{t-4}) + \epsilon_t, \qquad (4.3.1)$$

where CDS^{EA}_{t} denotes the euro area CDS spread on the Friday in the week prior to the survey (normalized by its standard deviation over the sample period), i.e. it contains information available to survey participants before the circulation of the survey on the Monday of each week.[18] The weekly time period is labelled by t, and changes are taken over four weeks. A caveat with this approach of using CDS spreads as measures of perceived risk of debt monetization through higher inflation is that expectations of debt monetization via the printing of money by central banks, and associated expectations of higher inflation, could be associated with lower sovereign risk, since higher inflation would lower the real burden of debt. The results, shown in Table 4.3.1, indicate that changes in short- and medium-term mean DNB survey inflation expectations were significantly related to changes in euro area CDS spreads, while long-term expectations were not.

[Table 4.3.1 here]

We also study the reactions of mean DNB survey inflation expectations to changes in Greek CDS spreads,

$$\pi^{mean,h}_{t} - \pi^{mean,h}_{t-4} = \beta_1 + \beta_2 (CDS^{GR}_{t} - CDS^{GR}_{t-4}) + \epsilon_t, \qquad (4.3.2)$$

which we consider separately since the focus of concern about public debt sustainability during the sample period was on Greece. CDS^{GR}_{t} denotes the Greek CDS spread on the Friday in the week prior to the survey, normalized by its standard deviation over the sample period. Table 4.3.2 shows that the coefficient on changes in Greek CDS spreads is again

[17] CDS spreads for euro countries are taken from Markit. The euro area aggregate is a weighted average of national CDS spreads using 2005 PPPs.

[18] This ensures that we consider information available to all survey respondents.

significant at the short- and medium-term horizons of inflation expectations, but now it is also significant at the long-term horizon (at the 5%-level).

These results suggest that short- and medium-term inflation expectations have not been immune to concerns about possible debt monetization in order to deal with excessive public debt in Greece, and in the euro area as a whole. Moreover, our results suggest that concerns about the Greek sovereign debt crisis have affected euro area long-term inflation expectations as measured within the DNB survey, though less so than at the shorter horizons. The effect on inflation expectations is statistically significant, although very small in economic terms. This would suggest that the anchoring of inflation expectations is not completely insensitive to the turmoil in peripheral sovereign bond markets in the euro area.

[Table 4.3.2 here]

4.4 Focal points

Recent research has highlighted the role of focal points in coordinating beliefs of economic agents (Sudgen 1995, Morris and Shin, 2002). To test for the existence of such a coordination mechanism for inflation expectations, we examine four potential focal points. In light of the research on inflation targets as focal points (Demertzis and Viegi, 2008), one potential focal point is the ECB's definition of price stability as referring to inflation being below but close to 2%. The evidence presented in Section 4.2 on the anchoring of long-term inflation expectations suggests that the ECB's definition of price stability acts as a focal point for long-term expectations.

A second possible focal point consists of Consensus survey expectations, which were circulated to one of the groups of participants in our survey. To investigate this, we perform pairwise Granger causality tests on mean Consensus survey expectations for 2010 and 2011(both levels and weekly changes) and mean expectations from our survey for the short-, medium- and long-term horizons (also both levels and weekly changes). The timing of the series for which we perform Granger causality tests is as follows. Date t specifies the survey results of the Monday of week t, and the latest Consensus survey expectation available prior to the Monday of week t.

We find no evidence that Consensus forecasts for 2010 or 2011 Granger-cause mean survey expectations at any horizon in a statistically significant way (see Tables 4.4.1 and 4.4.2). On the other hand, we do find evidence that mean survey expectations at the medium horizon Granger-cause Consensus forecasts at the corresponding horizon of 2011. However, this result could be due to the timing assumption of our two series: DNB survey expectations at date t-1 could help to predict Consensus forecasts at date t since they incorporate newer information than the previous Consensus forecast.

[Tables 4.4.1 and 4.4.2 about here]

Market participants' inflation expectations, which are reflected in inflation swaps or inflation indexed bonds, are a third possible focal point. We therefore study whether pairwise Granger causality exists between mean survey expectations and expected inflation rates implied by inflation-indexed swaps at the 1-, 2- and 10-year maturities, again both for levels and weekly changes in expected inflation rates (see Tables 4.4.3 and 4.4.4). The inflation rates implied by inflation-indexed swaps are taken on Monday of each week, coinciding with the survey date.

We find some evidence for Granger causality in both directions.[19] At the 5% significance level, short-term mean inflation expectations Granger-cause 10-year inflation rates implied by inflation-indexed swaps, and 2-year inflation rates implied by inflation-indexed swaps Granger-cause short-term mean inflation expectations. Moreover, at the 5% significance level, changes in 10-year inflation rates implied by inflation-indexed swaps Granger-cause changes in medium-term mean inflation expectations. At the 10% significance level, there is evidence that changes in medium-term mean inflation expectations Granger-cause changes in 2-year implied inflation swap rates, and that changes in long-term mean inflation expectations Granger-cause changes in 10-year implied inflation swap rates.

[Tables 4.4.3 and 4.4.4 about here]

In sum, we find evidence that the ECB's definition of price stability plays a role as focal point for long-term inflation expectations. By contrast, we do not find clear-cut evidence that inflation expectations measured from other sources (surveys by Consensus Economics or measures derived from financial instruments) act as a focal point.

4.5 Rationality tests

In future research we plan to perform tests of unbiasedness and weak efficiency of the survey expectations. Figure 4.5.1 suggests that short-term aggregate mean and median survey expectations were lower than both inflation on average for 2010, and than inflation in December 2010 on a year ago.

[Figure 4.5.1 here]

4.6 Are inflation expectations homogenous across agents?

The availability of a fairly large number of cross-sectional observations allows us to investigate whether expectations are heterogeneous across agents or groups of agents, as suggested in both theoretical and empirical research. We proceed in four steps.

In the first step, we look at graphs and sample statistics on the first and second moment of the distribution of inflation expectations across different groups of survey participants (central bank staff, academics and students). Figure 4.6.1 shows expectation means differentiated by participant group and horizon, and highlights three main results.

For the level of expectations means, we find strong homogeneity across groups over the one-year and ten-year horizon but visible heterogeneity over the two-year horizon. In particular, for short- and medium-term expectations, the only difference is that the means are slightly higher for academics compared to the other groups of participants. By contrast, for the two-year horizon, the means of expectations of the academics are consistently higher than those of the students and central bank staff, which fluctuate in a similar range.

[19] The same conclusion is reached when we conduct pairwise Granger causality between mean survey expectations and breakeven inflation rates implied by nominal and real government bond yields (see Tables 4.4.5 and 4.4.6). We find evidence that at the 1% significance level, 2-year breakeven inflation rates Granger-cause medium-term survey inflation expectations, and short-term survey inflation expectations Granger-cause 10-year breakeven inflation rates. Regarding changes, we find evidence that at the 5% significance level, changes in 2-year breakeven inflation rates Granger-cause changes in medium-term survey inflation expectations. At the 10% level, we also find that changes in short-term survey inflation expectations Granger-cause changes in 10-year breakeven inflation rates.

[Figure 4.6.1 about here.]

For the volatility of expectations, we see consistent differences across groups of survey respondents. For all three horizons, the standard deviation of the inflation means is smallest for the central bank staff and highest for students.[20]

In terms of dispersion of inflation expectations within groups of respondents at each point in time, we also see visible differences between groups. Figure 4.6.2 shows inflation prediction means differentiated by group and horizon with 95% and 99% confidence intervals added. The figure highlights that central bankers are most in agreement about their predictions, followed by the academics and students.[21]

[Figure 4.6.2 about here.]

Note that as a result of the relative tightness of confidence intervals for central bank staff, the hypothesis that the mean of long-term inflation expectations is equal to 2% is rejected, even though in absolute terms it is closest to 2% compared to the means of academics and students.

Figure 4.6.2 also shows that disagreement within the three groups follows similar patterns over time. For each group, the disagreement tends to decrease at the 2010 horizon, suggesting that all three groups were able to integrate accumulating economic data into their predictions. Moreover, the disagreement is on average highest at the two-year horizon for all three groups, possibly indicating that incoming economic data on balance created new uncertainty, pushing within-group predictions further apart. Disagreement at the 10-year horizon is stable and relatively small for each group, suggesting that for all groups, long-term expectations are driven by focal points such as the ECB's definition of price stability.

In a second step, we examine systematic divergences in expectations across groups by calculating the correlation between group expectation means for each prediction horizon. The results, reported in Tables 4.6.1–4.6.3, provide evidence of some homogeneity only for one-year expectations. While the means of one-year inflation expectations are correlated across all three groups of survey participants, this is in part driven by the common positive trend in short-term inflation expectations during the sample period. Once this trend is removed, we find a statistically significant correlation of 0.40 between DNB staff and academics and of 0.34 between academics and students. By contrast, we do not find any sizeable co-movement of expectation means across groups for the two-year and ten-year horizon.

[Tables 4.6.1(a), 4.6.1(b), 4.6.2 and 4.6.3 about here.]

In a third step, we investigate whether the (partial) homogeneity we find across the three participant groups reflects expectation formation spreading gradually throughout the population. We test this hypothesis by running pairwise Granger causality tests for the means of inflation expectations across groups for each horizon.

[20] The standard deviations for DNB staff, academics and students respectively are as follows: 0.014, 0.092, 0.16 for the one-year horizon (with a linear trend removed by OLS); 0.065, 0.086, 0.11 for the two-year horizon; 0.047, 0.072, 0.12 for the ten-year horizon.

[21] Mean widths for the 98% confidence bounds of central bank staff, academics and students respectively are: 0.32, 0.55, 1.13 (2010 horizon); 0.57, 0.84, 1.16 (2011 horizon), 0.39, 0.58, 1.04 (2019 horizon).

The Granger-causality results reported in Tables 4.6.4–4.6.6 show that DNB staff expectation means Granger-cause the expectation means of academics at all three horizons, and those of the students at the long-term horizon. By contrast, the inflation expectation means of DNB staff are not Granger-caused by either the academics of students. These results are consistent with the view that inflation expectations of central bank staff are originated independently, and then disseminated to the academics and students. One interpretation is that central bankers tend to have the best access to economic data and policy information that are relevant for explaining the behaviour of inflation, and that they incorporate this informational advantage into their expectation formation.

[Tables 4.6.4, 4.6.5 and 4.6.6 about here.]

Fourth, we test whether the influence of short- and medium-term inflation expectation means on the long-term means differs across groups of participants. In particular, we test for which group long-term expectations are anchored, in the sense that they are insensitive to economic developments manifesting themselves through short- or medium-term expectations. Table 4.6.7 shows the results of OLS regressions for the long-term expectation means of the three groups.[22]

[Table 4.6.7 about here.]

The coefficient estimates indicate that the DNB staff's long-term expectation means are significantly influenced by their short-term means, while those of the academics and students are not.[23] This suggests that long-term inflation expectations are anchored for academics and students but not for DNB staff. This finding is not completely in agreement with the evidence from confidence intervals on the mean of ten-year inflation expectations per group (see Figure 4.6.1) based on t-tests under the assumption of normality. According to those t−tests, the students are the only group with long-term expectations consistent with expectations anchoring, while Table 4.6.7 identifies the academics as another group with long-term expectations consistent with expectations anchoring. We conclude that the evidence on inflation expectations anchoring across participant groups is ambiguous.

Prediction rules

We also investigated heterogeneity of expectations by estimating prediction rules for all participant groups and horizons in terms of variables from the common information set we provided to participants each week. These variables include, most notably, the most recently published monthly inflation number (flash or actual) and the Consensus Economics forecast (available only to the DNB staff). We also included Credit Default Swap prices for either the euro area or Greece (divided by their standard deviations). In our specification we added two lags of the dependent variables to improve its performance, which is verified by the diagnostic tests on the right-hand side.[24] Diagnostic tests fail to reject these prediction rules, suggesting that the chosen linear prediction rule specification appears useful in capturing the main elements of participants' expectation formation.

[22] A lagged dependent variable was added to the regression equation in order to improve the quality of the specification, as checked by the diagnostic tests on the right-hand side of the table.

[23] A caveat for these results is that Ramsey's misspecification test is rejected for the academics, and White's heteroskedasticity test is rejected for the students.

[24] For each group and horizon, the least significant regressor was successively dropped, unless this worsened the specification as measured by the diagnostic tests, or led to nonsensical estimates.

[Table 4.6.8 about here.]

The estimates of the linear prediction rules, which are reported in Table 4.6.8, show remarkable similarities across groups of respondents and differences across prediction horizons. At the one-year horizon, the constant and the coefficient on the most recent inflation figure are positive and statistically significant, and fairly similar across groups. We found evidence that Consensus Economics forecasts, which were added only in the regressions for the DNB staff, do not significantly influence their short-term expectations. This is consistent with the finding that Consensus forecasts for 2010 (or 2011) do not Granger-cause mean survey expectations at the 5% level (see Tables 4.4.1 and 4.4.2). We find evidence of a statistically significant impact of Greek CDS prices on short-term expectations of DNB staff and the academics, but not of students.

For the two-year horizon, estimated prediction rules for all three groups have significant constants, which are substantially higher than for the one-year horizon. Second, the latest monthly inflation number is no longer significant in all three cases. While we find that Greek CDS prices have a statistically significant impact on academics' two-year inflation expectations, we do not find evidence that they matter in the prediction rule estimates for DNB staff and students.

At the ten-year prediction horizon, the estimated constants look fairly similar across groups and higher than for the one- and two-year horizons. The latest inflation number has no significant impact on expectations, while Greek CDS prices have a statistically significant impact of academics' and DNB staff's ten-year expectations.

Apparently, the Greek fiscal crisis has influenced inflation expectations at short-, medium- and long-term horizons. The only group in our survey that has, according to the prediction rule estimates, remained unaffected by the CDS price developments, are the students. A further interesting observation is that the euro area CDS prices nowhere seem to significantly influence inflation expectation formation, suggesting that the fiscal burden in the euro area as a whole did not influence people's views on macroeconomic stability.

5. Conclusions

Academic research and policy discussions have highlighted the importance of inflation expectations for the inflation process and monetary authorities' ability to achieve price stability. However, evidence on how agents form expectations is hard to obtain. This paper provides important insights on inflation expectations based on a new survey, which has three distinguishing features. First, it is conducted at weekly frequency for all three horizons, including for long-term expectations, while surveys of long-term expectations are typically conducted at quarterly or semi-annual frequency. Second, we can assess the role of common information sets. Third, following the experimental economics methodology we reward survey participants based on the accuracy of their responses.

Our analysis of the survey results highlights a number of interesting findings. We find that the mean and median rose for short- and medium-term inflation expectations – suggesting that participants expected the economic climate in the euro area to gradually normalize – but remained stable for long-term expectations.

We find that the disagreement around these means and mediums was smallest at the long-term horizon. This is consistent with our finding that long-term expectations have remained well anchored, as suggested by stable first moments close to the ECB's definition of price stability and the fact that long-term expectations have not been sensitive to news about HICP inflation or changes in short-term or medium-term inflation expectations. We also find that the ECB's definition of price stability is the only focal point for long-term expectations.

Sovereign debt concerns triggered by the Greek fiscal crisis had some influence on short- and medium-term inflation expectations, and, albeit to a very small degree, long-term expectations. By contrast, we do not find evidence that long-term expectations reacted to developments of the euro area wide fiscal burden.

The weekly frequency of our survey is important, since participants changed their expectations quite frequently. Each week, more than a third of the participants updated their one-year inflation expectations, while about a quarter of survey respondents changed their ten-year expectations. The longer the horizon, the less frequent but larger the revisions are.

We find evidence of a large degree of non-normality, which is time-variant, with skewness increasing with the length of the horizon.

Inflation expectations appear fairly homogenous across groups of agents at the shorter horizon but less so at the medium- and long-term horizons. At the one-year horizon, expectations appear homogenous to the extent that the mean and median of expectations are similar across groups. Moreover, the most recent actual inflation figure is an important driver of short-term inflation expectations for all three groups. At the same time, we find visible heterogeneity of the levels of expectations means and medians at the two-year horizon. Moreover, the variability of expectations over time differs visibly across groups of survey participants: we find that expectations by central bank staff's are the least volatile. We also find that DNB staff's expectations Granger cause those of academics and students.

In future work, we plan to test if survey participants are rational and further investigate the heterogeneity of inflation expectations across groups of respondents.

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Tables and Figures

Table 4.2.1
Reactions of changes in mean inflation expectations to changes in flash estimates of euro area HICP, Equation 4.2.1

Horizon:	**2010**	**2011**	**2019**
Constant, β_1	0.001 (0.02)	-0.014 (0.01)	0.002 (0.008)
Change in flash estimate for next euro area HICP release, β_2	0.12*** (0.04)	0.05** (0.023)	-0.01 (0.04)
R^2	0.21	0.04	0.006
Number of observations	49	49	49

***, ** and * denote significance at the 1%, 5% and 10% levels, respectively; standard errors are given in brackets; Newey-West adjusted standard errors.

Table 4.2.2
Reactions of changes in mean inflation expectations to surprises in euro area HICP based on Bloomberg surveys, Equation 4.2.2

Horizon:	**2010**	**2011**	**2019**
Constant, β_1	-0.01 (0.02)	0.01 (0.03)	-0.002 (0.02)
Surprise in euro area HICP release, β_2	-0.53 (0.35)	-0.43 (0.45)	0.19 (0.32)
R^2	0.18	0.08	0.03
Number of observations	12	12	12

***, ** and * denote significance at the 1%, 5% and 10% levels, respectively; standard errors are given in brackets.

Table 4.3.1
Reactions of changes in mean inflation expectations to changes in euro area CDS spreads, Equation 4.3.1

Horizon:	**2010**	**2011**	**2019**
Constant, β_1	0.01 (0.02)	-0.02 (0.01)	0.000 (0.01)
Change in euro area CDS spread, β_2	0.07*** (0.02)	0.05*** (0.01)	-0.002 (0.01)
R^2	0.20	0.13	0.001
Number of observations	49	49	49

***, ** and * denote significance at the 1%, 5% and 10% levels, respectively; standard errors are given in brackets; Newey-West adjusted standard errors.

Table 4.3.2

Reactions of changes in mean inflation expectations to changes in Greek CDS spreads, Equation 4.3.2

Horizon:	**2010**	**2011**	**2019**
Constant, β_1	0.0005 (0.02)	-0.02* (0.01)	-0.005 (0.01)
Change in Greek CDS spread, β_2	0.08*** (0.03)	0.06*** (0.02)	0.022** (0.01)
R^2	0.21	0.15	0.03
Number of observations	49	49	49

***, ** and * denote significance at the 1%, 5% and 10% levels, respectively; standard errors are given in brackets; Newey-West adjusted standard errors.

Table 4.4.1

Granger causality tests for mean inflation expectations

Pairwise Granger Causality Tests
Sample: 6/22/2009 7/11/2010
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Probability
MEAN2011_ALL does not Granger Cause MEAN2010_ALL	51	1.73603	0.18757
MEAN2010_ALL does not Granger Cause MEAN2011_ALL		0.27158	0.76339
MEAN2019_ALL does not Granger Cause MEAN2010_ALL	51	0.88636	0.41908
MEAN2010_ALL does not Granger Cause MEAN2019_ALL		0.46503	0.63104
CE_2010 does not Granger Cause MEAN2010_ALL	51	2.04431	0.14107
MEAN2010_ALL does not Granger Cause CE_2010		1.68985	0.19580
CE_2011 does not Granger Cause MEAN2010_ALL	51	2.90063	0.06510*
MEAN2010_ALL does not Granger Cause CE_2011		0.98250	0.38209
MEAN2019_ALL does not Granger Cause MEAN2011_ALL	51	0.10643	0.89926
MEAN2011_ALL does not Granger Cause MEAN2019_ALL		0.77305	0.46751
CE_2010 does not Granger Cause MEAN2011_ALL	51	0.13481	0.87423
MEAN2011_ALL does not Granger Cause CE_2010		2.03243	0.14262
CE_2011 does not Granger Cause MEAN2011_ALL	51	0.66753	0.51787
MEAN2011_ALL does not Granger Cause CE_2011		4.42442	0.01748**
CE_2010 does not Granger Cause MEAN2019_ALL	51	1.84025	0.17028
MEAN2019_ALL does not Granger Cause CE_2010		0.52043	0.59772
CE_2011 does not Granger Cause MEAN2019_ALL	51	0.44688	0.64237
MEAN2019_ALL does not Granger Cause CE_2011		0.17557	0.83954
CE_2011 does not Granger Cause CE_2010	51	2.57761	0.08689*
CE_2010 does not Granger Cause CE_2011		0.47522	0.62476

Note: Mean20xx_ALL denotes mean DNB survey expectations at the 20xx horizon; CE_20xx denotes mean Consensus survey expectations at the 20xx horizon. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table 4.4.2

Granger causality tests for changes in mean inflation expectations

Pairwise Granger Causality Tests
Sample: 6/22/2009 7/11/2010
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Probability
D(MEAN2011_ALL) does not Granger Cause D(MEAN2010_ALL)	50	0.10134	0.90383
D(MEAN2010_ALL) does not Granger Cause D(MEAN2011_ALL)		0.30501	0.73862
D(MEAN2019_ALL) does not Granger Cause D(MEAN2010_ALL)	50	0.97045	0.38670
D(MEAN2010_ALL) does not Granger Cause D(MEAN2019_ALL)		0.32962	0.72092
D(CE_2010) does not Granger Cause D(MEAN2010_ALL)	50	1.58259	0.21666
D(MEAN2010_ALL) does not Granger Cause D(CE_2010)		1.50343	0.23332
D(CE_2011) does not Granger Cause D(MEAN2010_ALL)	50	0.10363	0.90178
D(MEAN2010_ALL) does not Granger Cause D(CE_2011)		1.14610	0.32698
D(MEAN2019_ALL) does not Granger Cause D(MEAN2011_ALL)	50	0.09747	0.90732
D(MEAN2011_ALL) does not Granger Cause D(MEAN2019_ALL)		0.94196	0.39741
D(CE_2010) does not Granger Cause D(MEAN2011_ALL)	50	1.44525	0.24642
D(MEAN2011_ALL) does not Granger Cause D(CE_2010)		2.33634	0.10830
D(CE_2011) does not Granger Cause D(MEAN2011_ALL)	50	1.36947	0.26463
D(MEAN2011_ALL) does not Granger Cause D(CE_2011)		6.64945	0.00295***
D(CE_2010) does not Granger Cause D(MEAN2019_ALL)	50	1.39714	0.25782
D(MEAN2019_ALL) does not Granger Cause D(CE_2010)		0.94184	0.39746
D(CE_2011) does not Granger Cause D(MEAN2019_ALL)	50	1.68391	0.19713
D(MEAN2019_ALL) does not Granger Cause D(CE_2011)		0.03119	0.96931
D(CE_2011) does not Granger Cause D(CE_2010)	50	0.52125	0.59732
D(CE_2010) does not Granger Cause D(CE_2011)		0.05385	0.94764

Note: d(Mean20xx_ALL) denotes weekly change in mean DNB survey expectations at the 20xx horizon; d(CE_20xx) denotes weekly change in mean Consensus survey expectations at the 20xx horizon. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table 4.4.3

Granger causality tests for mean inflation expectations with implied inflation-indexed swap rates

Pairwise Granger Causality Tests
Sample: 6/22/2009 7/11/2010; Lags: 2

Null Hypothesis:	Obs	F-Statistic	Probability
IS_1 does not Granger Cause MEAN2010_ALL	48	5.61898	0.00679
MEAN2010_ALL does not Granger Cause IS_1		0.21526	0.80719
IS_2 does not Granger Cause MEAN2010_ALL	51	4.24050	0.02041**
MEAN2010_ALL does not Granger Cause IS_2		1.13576	0.33002
IS_10 does not Granger Cause MEAN2010_ALL	51	0.43099	0.65246
MEAN2010_ALL does not Granger Cause IS_10		4.48498	0.01662**
IS_1 does not Granger Cause MEAN2011_ALL	48	1.05424	0.35729
MEAN2011_ALL does not Granger Cause IS_1		1.49399	0.23589
IS_2 does not Granger Cause MEAN2011_ALL	51	1.25666	0.29419
MEAN2011_ALL does not Granger Cause IS_2		2.05690	0.13945
IS_10 does not Granger Cause MEAN2011_ALL	51	1.69655	0.19458
MEAN2011_ALL does not Granger Cause IS_10		0.87576	0.42338
IS_1 does not Granger Cause MEAN2019_ALL	48	0.22475	0.79965
MEAN2019_ALL does not Granger Cause IS_1		1.54900	0.22408
IS_2 does not Granger Cause MEAN2019_ALL	51	0.74636	0.47974
MEAN2019_ALL does not Granger Cause IS_2		0.23103	0.79463
IS_10 does not Granger Cause MEAN2019_ALL	51	0.73266	0.48615
MEAN2019_ALL does not Granger Cause IS_10		1.54722	0.22371
IS_2 does not Granger Cause IS_1	48	1.94810	0.15492
IS_1 does not Granger Cause IS_2		0.33137	0.71976
IS_10 does not Granger Cause IS_1	48	0.33190	0.71938
IS_1 does not Granger Cause IS_10		3.58488	0.03631**
IS_10 does not Granger Cause IS_2	51	0.02528	0.97505
IS_2 does not Granger Cause IS_10		1.37799	0.26229

Note: Mean20xx_ALL denotes mean DNB survey expectations at the 20xx horizon; IS_x denotes inflation rates implied by inflation-indexed swaps x years ahead. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table 4.4.4

Granger causality tests for changes in mean inflation expectations and implied inflation-indexed swap rates

Pairwise Granger Causality Tests Sample: 6/22/2009 7/11/2010; Lags: 2Null Hypothesis:	Obs	F-Statistic	Probability
D(IS_1) does not Granger Cause D(MEAN2010_ALL)	46	0.88702	0.41964
D(MEAN2010_ALL) does not Granger Cause D(IS_1)		0.10456	0.90096
D(IS_2) does not Granger Cause D(MEAN2010_ALL)	50	0.65697	0.52332
D(MEAN2010_ALL) does not Granger Cause D(IS_2)		0.61525	0.54499
D(IS_10) does not Granger Cause D(MEAN2010_ALL)	50	0.55122	0.58009
D(MEAN2010_ALL) does not Granger Cause D(IS_10)		0.26479	0.76856
D(IS_1) does not Granger Cause D(MEAN2011_ALL)	46	2.12023	0.13297
D(MEAN2011_ALL) does not Granger Cause D(IS_1)		1.39443	0.25949
D(IS_2) does not Granger Cause D(MEAN2011_ALL)	50	1.53178	0.22721
D(MEAN2011_ALL) does not Granger Cause D(IS_2)		2.75678	0.07423*
D(IS_10) does not Granger Cause D(MEAN2011_ALL)	50	4.52885	0.01614**
D(MEAN2011_ALL) does not Granger Cause D(IS_10)		0.83065	0.44234
D(IS_1) does not Granger Cause D(MEAN2019_ALL)	46	0.59871	0.55425
D(MEAN2019_ALL) does not Granger Cause D(IS_1)		1.19196	0.31393
D(IS_2) does not Granger Cause D(MEAN2019_ALL)	50	0.37245	0.69115
D(MEAN2019_ALL) does not Granger Cause D(IS_2)		0.37485	0.68952
D(IS_10) does not Granger Cause D(MEAN2019_ALL)	50	0.66821	0.51764
D(MEAN2019_ALL) does not Granger Cause D(IS_10)		2.65338	0.08141*
D(IS_2) does not Granger Cause D(IS_1)	46	2.61771	0.08513*
D(IS_1) does not Granger Cause D(IS_2)		0.12563	0.88228
D(IS_10) does not Granger Cause D(IS_1)	46	0.29504	0.74607
D(IS_1) does not Granger Cause D(IS_10)		1.32756	0.27628
D(IS_10) does not Granger Cause D(IS_2)	50	0.58723	0.56007
D(IS_2) does not Granger Cause D(IS_10)		0.55693	0.57686

Note: d(Mean20xx_ALL) denotes weekly changes in mean DNB survey expectations at the 20xx horizon; d(IS_x) denotes weekly changes in inflation rates implied by inflation-indexed swaps x years ahead. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table 4.4.5

Granger causality tests for mean inflation expectations with breakeven inflation rates implied by government bonds

Pairwise Granger Causality Tests
Sample: 6/22/2009 7/11/2010
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Probability
RBEI_2 does not Granger Cause MEAN2010_ALL	51	2.60422	0.08484*
MEAN2010_ALL does not Granger Cause RBEI_2		0.70850	0.49768
RBEI_10 does not Granger Cause MEAN2010_ALL	51	0.25328	0.77733
MEAN2010_ALL does not Granger Cause RBEI_10		6.89825	0.00240***
RBEI_2 does not Granger Cause MEAN2011_ALL	51	6.59010	0.00304***
MEAN2011_ALL does not Granger Cause RBEI_2		0.17192	0.84258
RBEI_10 does not Granger Cause MEAN2011_ALL	51	1.35717	0.26750
MEAN2011_ALL does not Granger Cause RBEI_10		0.40346	0.67035
RBEI_2 does not Granger Cause MEAN2019_ALL	51	0.79003	0.45989
MEAN2019_ALL does not Granger Cause RBEI_2		0.97552	0.38466
RBEI_10 does not Granger Cause MEAN2019_ALL	51	0.63876	0.53257
MEAN2019_ALL does not Granger Cause RBEI_10		0.87585	0.42334
RBEI_10 does not Granger Cause RBEI_2	51	0.44824	0.64151
RBEI_2 does not Granger Cause RBEI_10		0.79225	0.45890

Note: Mean20xx_ALL denotes mean DNB survey expectations at the 20xx horizon; RBEI_x denotes breakeven inflation rates implied by government bonds x years ahead. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table 4.4.6

Granger causality tests for changes in mean inflation expectations and breakeven inflation rates implied by government bonds

Pairwise Granger Causality Tests
Sample: 6/22/2009 7/11/2010
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Probability
D(RBEI_2) does not Granger Cause D(MEAN2010_ALL)	50	0.03748	0.96325
D(MEAN2010_ALL) does not Granger Cause D(RBEI_2)		0.47155	0.62709
D(RBEI_10) does not Granger Cause D(MEAN2010_ALL)	50	0.44299	0.64489
D(MEAN2010_ALL) does not Granger Cause D(RBEI_10)		2.59444	0.08582*
D(RBEI_2) does not Granger Cause D(MEAN2011_ALL)	50	5.08052	0.01025**
D(MEAN2011_ALL) does not Granger Cause D(RBEI_2)		0.32952	0.72099
D(RBEI_10) does not Granger Cause D(MEAN2011_ALL)	50	1.99442	0.14794
D(MEAN2011_ALL) does not Granger Cause D(RBEI_10)		0.60221	0.55195
D(RBEI_2) does not Granger Cause D(MEAN2019_ALL)	50	0.22491	0.79948
D(MEAN2019_ALL) does not Granger Cause D(RBEI_2)		0.16493	0.84847
D(RBEI_10) does not Granger Cause D(MEAN2019_ALL)	50	0.89503	0.41574
D(MEAN2019_ALL) does not Granger Cause D(RBEI_10)		1.42920	0.25016
D(RBEI_10) does not Granger Cause D(RBEI_2)	50	0.82371	0.44531
D(RBEI_2) does not Granger Cause D(RBEI_10)		0.74317	0.48135

Note: d(Mean20xx_ALL) denotes weekly changes in mean DNB survey expectations at the 20xx horizon; d(RBEI_x) denotes weekly changes in breakeven inflation rates implied by government bonds x years ahead. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table 4.6.1(a)

Correlation between group inflation expectation means, 2010 horizon

Specification: $\overline{\pi}_t^{g_1,2010} = c + \alpha_1 \overline{\pi}_t^{g_2,2010} + \varepsilon_t$

g_2 \ g_1	ACA	STU	DNB
ACA	1		
STU	0.56**	1	
DNB	0.78**	0.48**	1

Note: Correlation coefficients estimated by OLS. ** and * denote significance at the 1% and 5% levels, resp. Groups are academics (ACA), students (STU) and DNB staff (DNB).

Table 4.6.1(b)

Correlation between detrended group inflation expectation means, 2010 horizon

Specification: $\overline{\pi}_t^{*g_1,2010} = c + \alpha_1 \overline{\pi}_t^{*g_2,2010} + \varepsilon_t$

g_2 \ g_1	ACA	STU	DNB
ACA	1		
STU	0.34*	1	
DNB	0.40**	0.13	1

Note: Correlation coefficients estimated by OLS. ** and * denote significance at the 1% and 5% levels, resp. Groups are academics (ACA), students (STU) and DNB staff (DNB). $\overline{\pi}^*$ denotes an inflation expectation mean detrended by its linear trend (estimated by OLS).

Table 4.6.2

Correlation between group inflation expectation means, 2011 horizon

Specification: $\overline{\pi}_t^{g_1,2011} = c + \alpha_1 \overline{\pi}_t^{g_2,2011} + \varepsilon_t$

g_2 \ g_1	ACA	STU	DNB
ACA	1		
STU	0.01	1	
DNB	0.08	0.04	1

Note: Correlation coefficients estimated by OLS. ** and * denote significance at the 1% and 5% levels, resp. Groups are academics (ACA), students (STU) and DNB staff (DNB).

Table 4.6.3

Correlation between group inflation expectation means, 2019 horizon

Specification: $\overline{\pi}_t^{g_1,2019} = c + \alpha_1 \overline{\pi}_t^{g_2,2019} + \varepsilon_t$

g_2 \ g_1	ACA	STU	DNB
ACA	1		
STU	0.13	1	
DNB	0.04	0.23	1

Note: Correlation coefficients estimated by OLS. ** and * denote significance at the 1% and 5% levels, resp. Groups are academics (ACA), students (STU) and DNB staff (DNB).

Table 4.6.4

Pairwise Granger causality tests on group inflation expectation means, 2010 horizon

↓*does not cause* →	ACA	STU	DNB
ACA	—	0.085*	0.242
STU	0.062*	—	0.433
DNB	0.026**	0.255	—

Note: p values of pairwise Granger causality tests (2 lags). ***, ** and * denote significance at the 1%, 5% and 10% levels, resp. Groups are academics (ACA), students (STU) and DNB staff (DNB).

Table 4.6.5

Pairwise Granger causality tests on group inflation expectation means, 2011 horizon

↓*does not cause* →	ACA	STU	DNB
ACA	—	0.212	0.228
STU	0.495	—	0.491
DNB	0.023**	0.476	—

Note: p values of pairwise Granger causality tests (2 lags). ***, ** and * denote significance at the 1%, 5% and 10% levels, resp. Groups are academics (ACA), students (STU) and DNB staff (DNB).

Table 4.6.6

Pairwise Granger causality tests on group inflation expectation means, 2019 horizon

↓*does not cause* →	ACA	STU	DNB
ACA	—	0.098*	0.693
STU	0.726	—	0.528
DNB	0.532	0.007***	—

Note: p values of pairwise Granger causality tests (2 lags). ***, ** and * denote significance at the 1%, 5% and 10% levels, resp. Groups are academics (ACA), students (STU) and DNB staff (DNB).

Table 4.6.7

Impact of 2010 and 2011 group inflation expectation means on 2019 expectations means

Specification: $\overline{\pi}_t^{g,2019} = c + \alpha_1 \overline{\pi}_t^{g,2010} + \alpha_1 \overline{\pi}_t^{g,2011} + \alpha_1 \overline{\pi}_{t-1}^{g,2019} + \varepsilon_t$

	Estimated coefficients:					Diagnostics (*p* values):		
Group (*g*)	*c*	$\overline{\pi}_t^{g,2010}$	$\overline{\pi}_t^{g,2011}$	$\overline{\pi}_{t-1}^{g,2019}$	R^2	B-G	White	Ramsey
ACA	1.81**	0.04	0.21	—	0.08	*0.70*	*0.80*	*0.008***
STU	1.16**	-0.06	0.31	0.27*	0.16	*0.98*	*0.03**	*0.97*
DNB	1.41**	0.28**	0.02	0.20	0.45	*0.44*	*0.09*	*0.72*

Note: Coefficients estimated by OLS. ** and * denote significance at the 1% and 5% levels, resp. Groups are academics (ACA), students (STU) and DNB staff (DNB). Diagnostic tests are Breusch-Godfrey, 2 lags (B-G); White heteroskedasticity test, no cross terms (White); Ramsey RESET test, 1 fitted term (Ramsey).

Table 4.6.8

Inflation prediction rules by group and horizon

Specification: $\overline{\pi}_t^{g,h} = c + \alpha_1 \pi_t + \alpha_2 CE_t^h + \alpha_3 CDS_t^{EA} + \alpha_4 CDS_t^{GR} + \alpha_5 \overline{\pi}_{t-1}^{g,h} + \alpha_6 \overline{\pi}_{t-2}^{g,h} + \varepsilon_t$

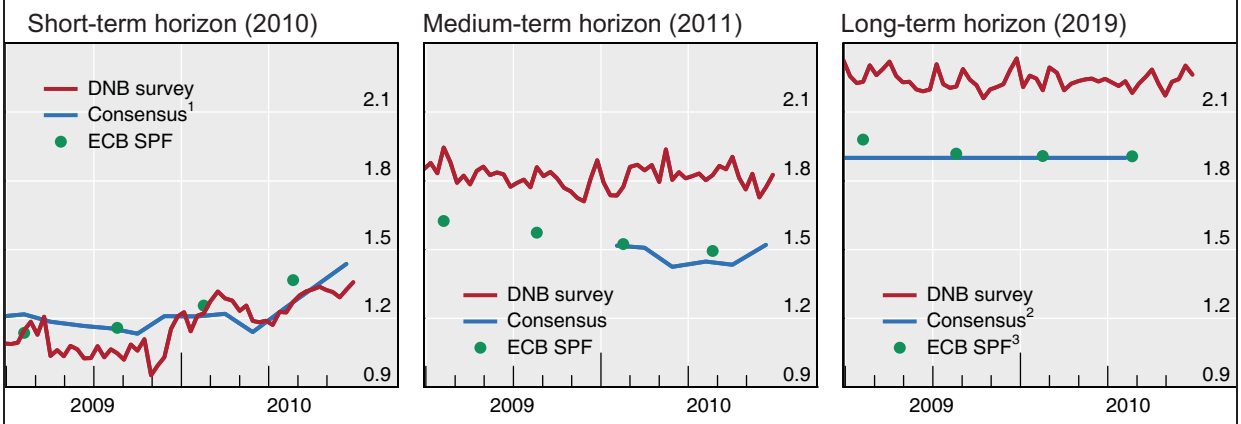
		Estimated coefficients:								Diagnostics (*p* values):		
g	*H*	*c*	π_t	CE_t^h	CDS_t^{EA}	CDS_t^{GR}	$\overline{\pi}_{t-1}^{g,h}$	$\overline{\pi}_{t-2}^{g,h}$	R^2	B-G	White	Ramsey
ACA	2010	0.68**	0.05*	—	—	0.047*	—	0.41**	0.84	*0.21*	*0.63*	*0.09*
STU	2010	0.52**	0.09**	—	—	—	0.48**	—	0.56	*0.12*	*0.07*	*0.41*
DNB	2010	0.87**	0.03*	0.14	—	0.059**	—	—	0.83	*0.22*	*0.25*	*0.82*
ACA	2011	2.17**	-0.05	—	—	0.061*	—	—	0.12	*0.26*	*0.25*	*0.45*
STU	2011	1.19**	0.03	—	—	—	0.49**	-0.21	0.27	*0.12*	*0.97*	*0.10*
DNB	2011	1.18**	—	—	—	—	0.28*	—	0.09	*0.13*	*0.001***	*0.57*
ACA	2019	2.57**	-0.03	—	—	0.047*	—	-0.13	0.16	*0.36*	*0.08*	*0.047**
STU	2019	2.25**	-0.05*	—	—	—	—	—	0.10	*0.19*	*0.57*	*0.15*
DNB	2019	2.16**	—	—	—	0.029**	—	—	0.33	*0.32*	*0.19*	*0.85*

Note: Coefficients estimated by OLS. ** and * denote significance at the 1% and 5% levels, resp. Groups are academics (ACA), students (STU) and DNB staff (DNB). Diagnostic tests are Breusch-Godfrey, 2 lags (B-G); White heteroskedasticity test, no cross terms (White); Ramsey RESET test, 1 fitted term (Ramsey). For the regressors, *CE* stands for Consensus Economics, *CDS* for Credit Default Swap (*EA* denoting Euro area and *GR* Greece), π is the most recent inflation number (flash or actual), and $\overline{\pi}$ is an inflation expectation mean.

Figure 4.1.1

Mean of individual forecasts

In percent



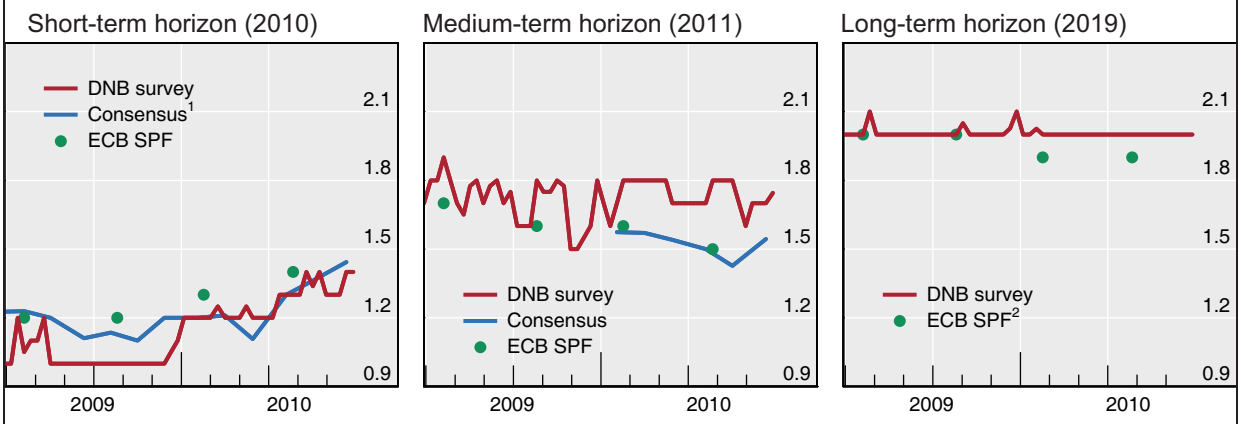
[1] First observation is from June 8 2009 Consensus Forecasts issue. [2] First observation is from April 14 2009 Consensus Forecasts issue. Forecasted period is 2015–2019 in year 2009 and 2016-2020 in year 2010. [3] Five years ahead.

Sources: © Consensus Economics; ECB, Survey of Professional Forecasters.

Figure 4.1.2

Median of individual forecasts

In percent



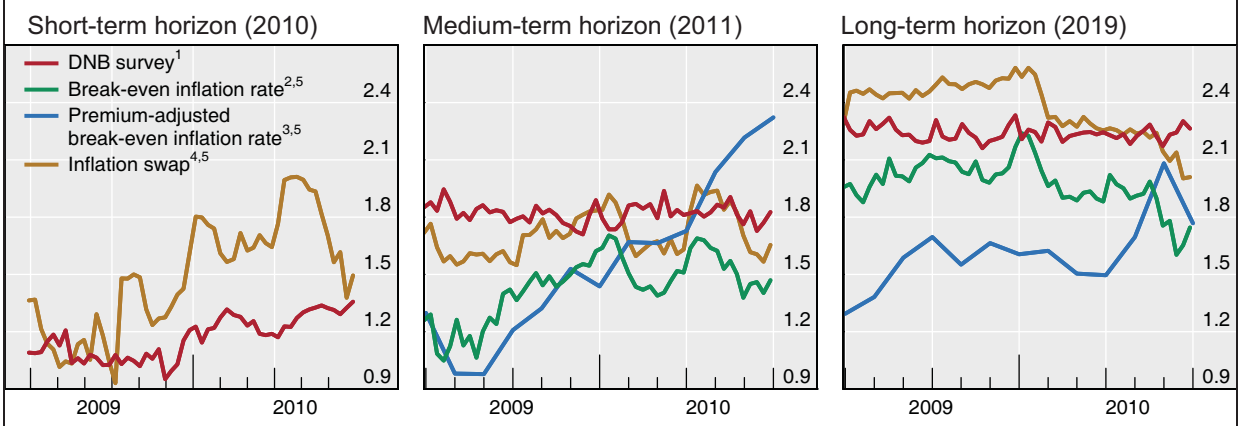
[1] First observation is from June 8 2009 Consensus Forecasts issue. [2] Five years ahead.

Sources: © Consensus Economics; ECB, Survey of Professional Forecasters.

Figure 4.1.3

Mean forecasts and implied market expectations

In percent



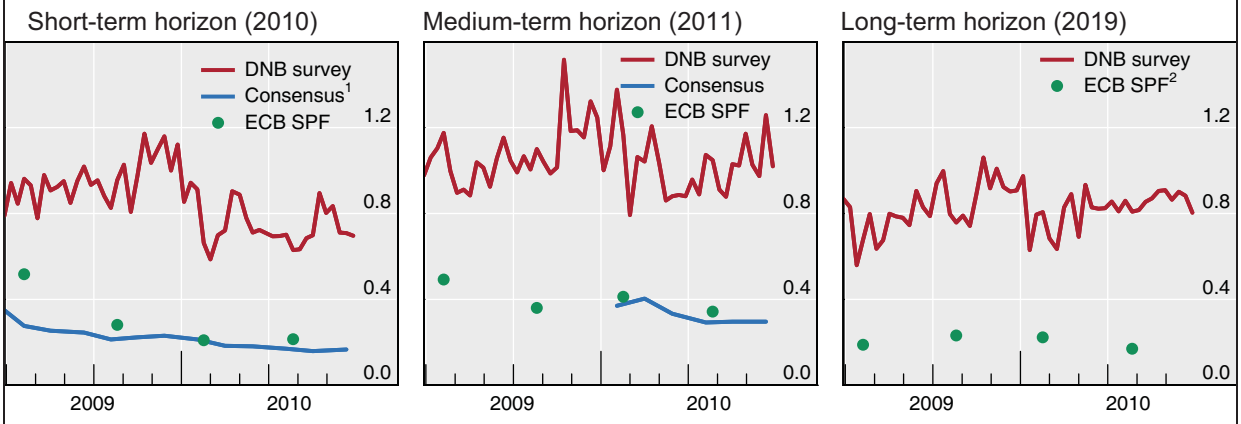
[1] Survey mean expectations of inflation, as reported in the DNB survey. [2] All break-even inflation rates are based on zero coupon real and nominal rates calculated using the Nelson-Siegel-Svensson method on nominal and index-linked government bond prices; end-of-month data. [3] Break-even inflation rate less the estimated 10-year inflation risk premium. [4] Zero coupon fixed rate leg necessary to build a par swap against a leg on zero coupon CPI appreciation. [5] Market anticipation 1, 2 and 10 years ahead of the observation time.

Sources: Bloomberg; ECB; Federal Reserve Bank of Philadelphia; BIS calculations.

Figure 4.1.4

Standard deviation of individual forecasts

In percentage points



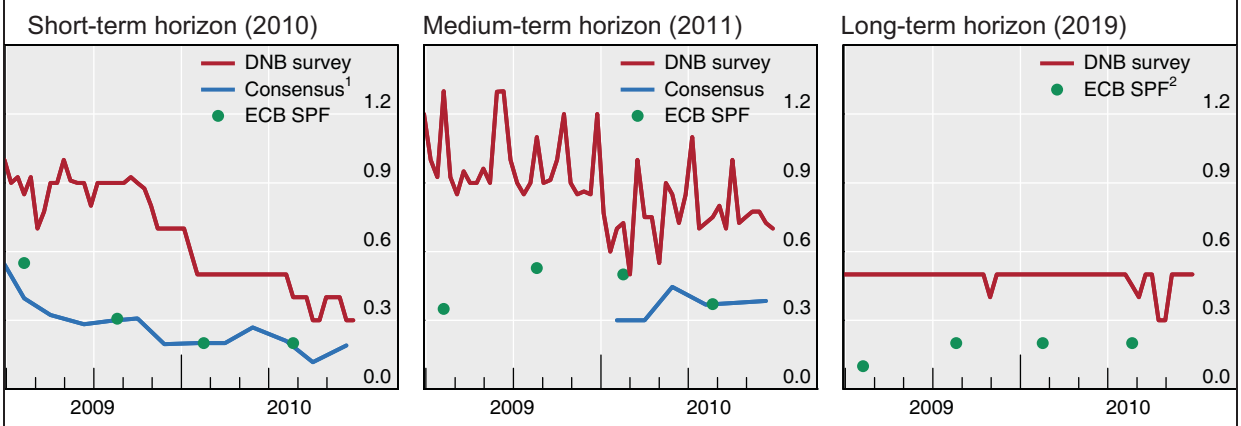
[1] First observation is from June 8 2009 Consensus Forecasts issue. [2] Five years ahead.

Sources: © Consensus Economics; ECB, Survey of Professional Forecasters.

Figure 4.1.5

Interquartile range of individual forecasts

In percentage points

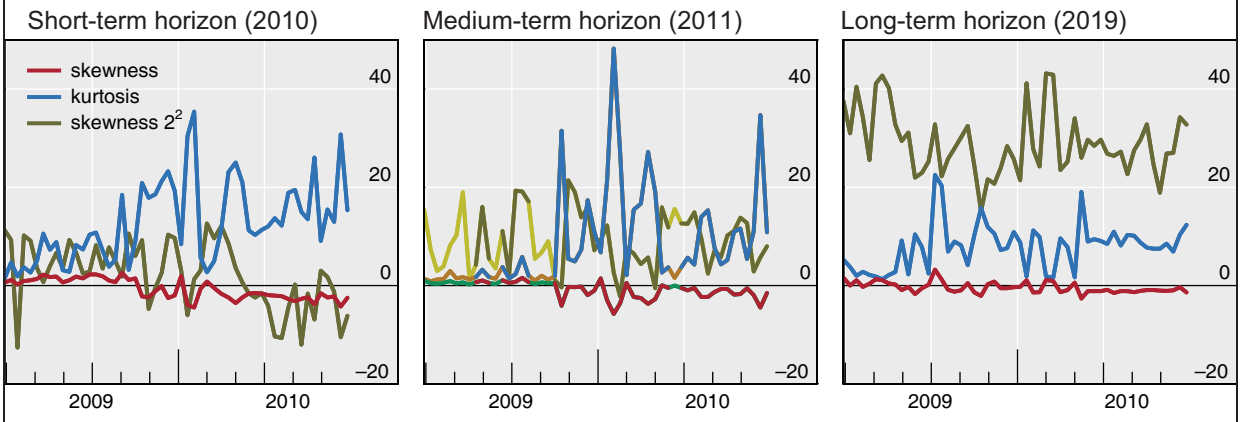


[1] First observation is from June 8 2009 Consensus Forecasts issue. [2] Five years ahead.

Sources: © Consensus Economics; ECB, Survey of Professional Forecasters.

Figure 4.1.6

Skewness and excess kurtosis of individual forecasts[1]



[1] Green, beige and olive colors represents periods where 1% Jarque-Bera test suggests normal distributions. [2] Skewness measure based on the formula: (mean-median)/standard deviation.

Figure 4.1.7

Skewness and excess kurtosis based on percentiles of individual forecasts

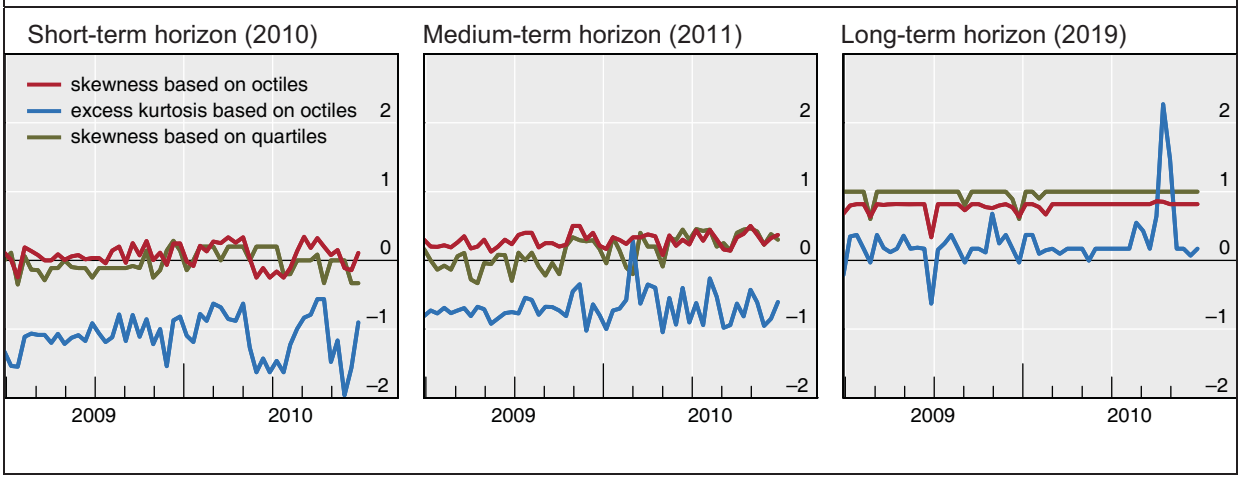
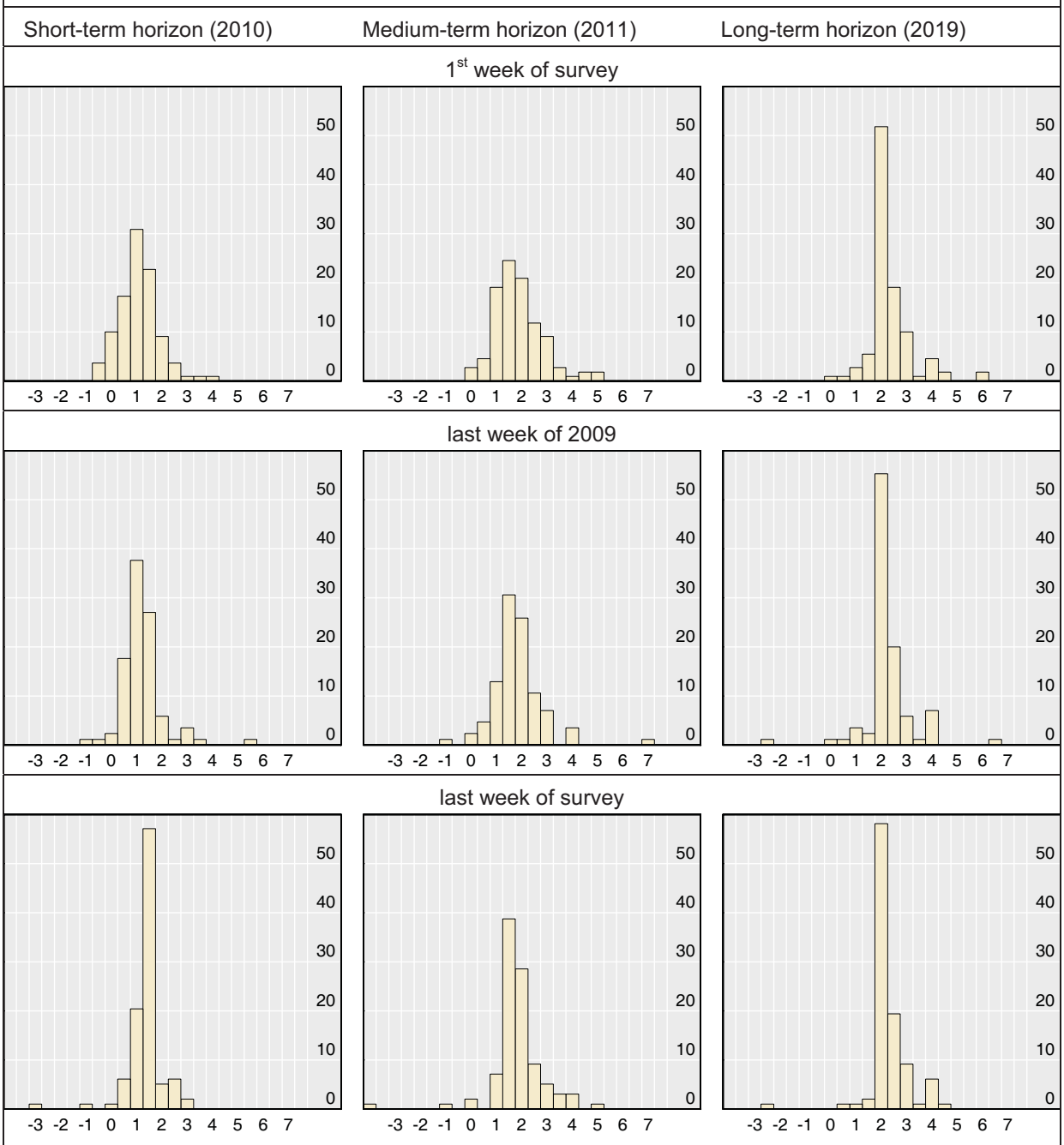


Figure 4.1.8

Survey distributions[1]

In percentage of respondents

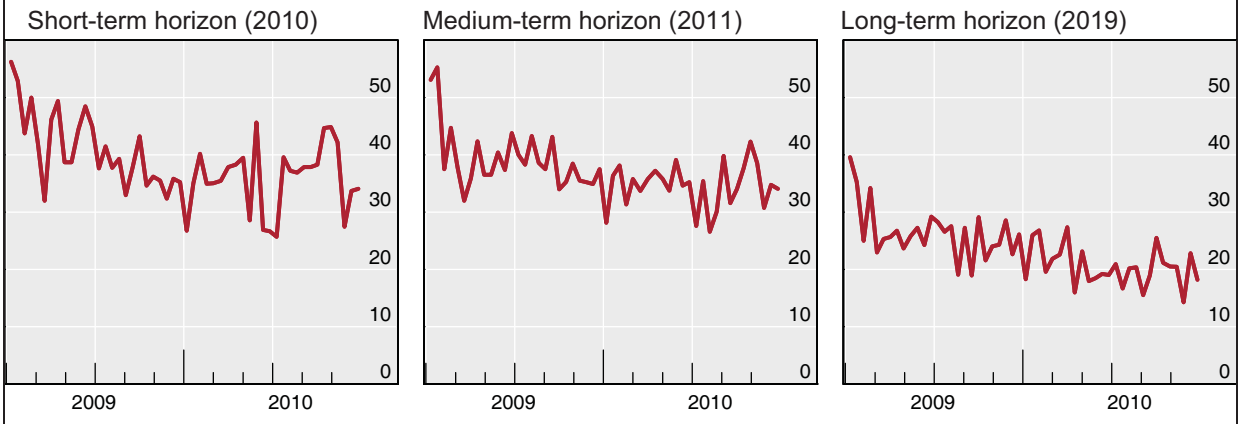


[1] Non-missing responses considered.

Figure 4.1.9

Proportion of changes in inflation expectations per week[1]

In percentage of respondents

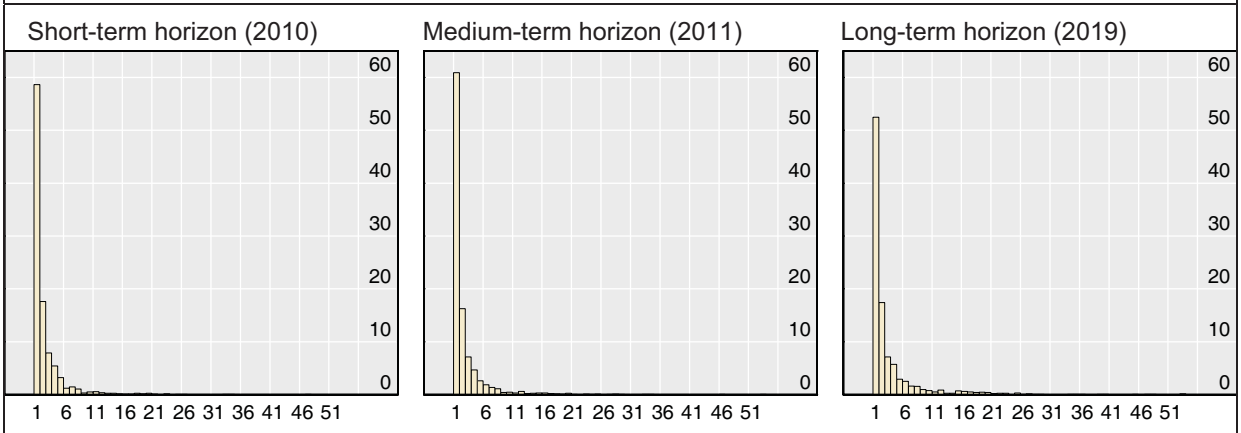


[1] A change in inflation expectation is considered if responses are given and differ for two consecutive weeks

Figure 4.1.10

Duration of spells when expectations are unchanged[1]

In percentage of total number of spells

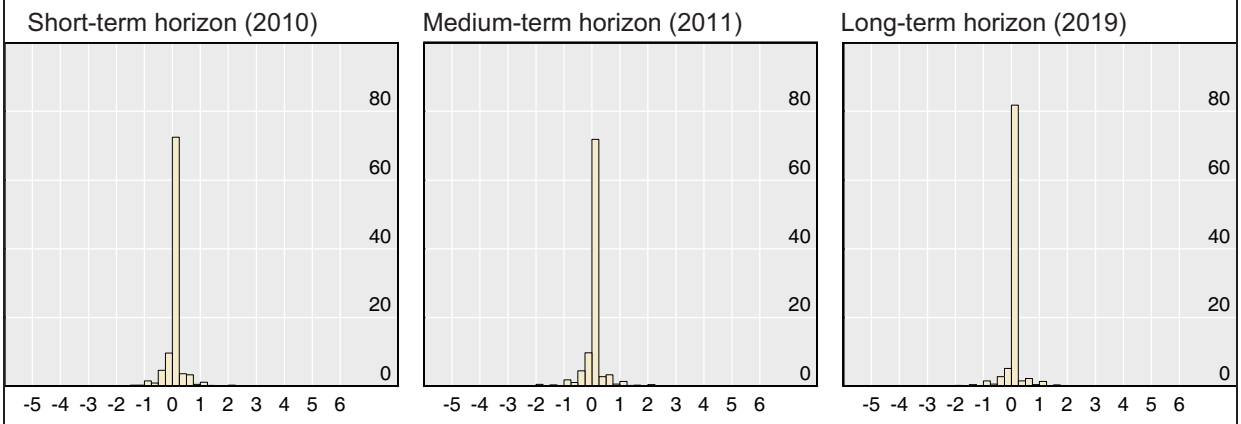


[1] A spell of inflation expectation is considered if a minimum of two consecutive responses are given.

Figure 4.1.11

Distributions of weekly changes in inflation expectations[1]

In percentage of respondents

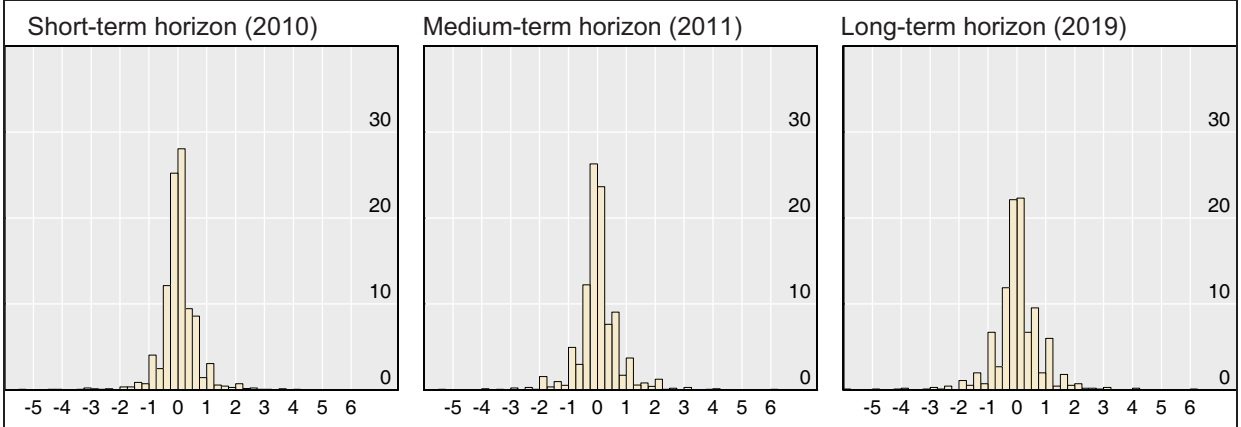


[1] Non-missing responses considered.

Figure 4.1.12

Distributions of non-zero weekly changes in inflation expectations[1]

In percentage of respondents

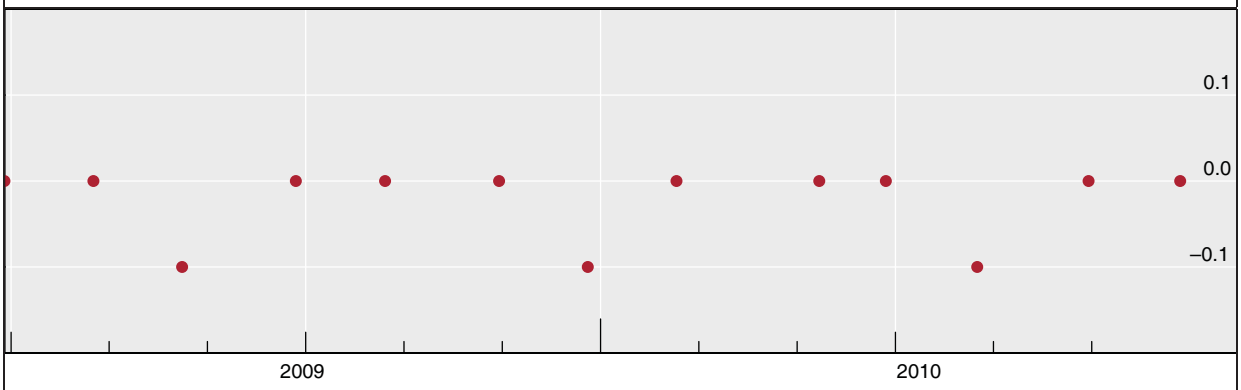


[1] Non-missing responses considered; excluding unchanged responses.

Figure 4.2.1

Surprise in euro area HICP data releases[1]

In percentage points



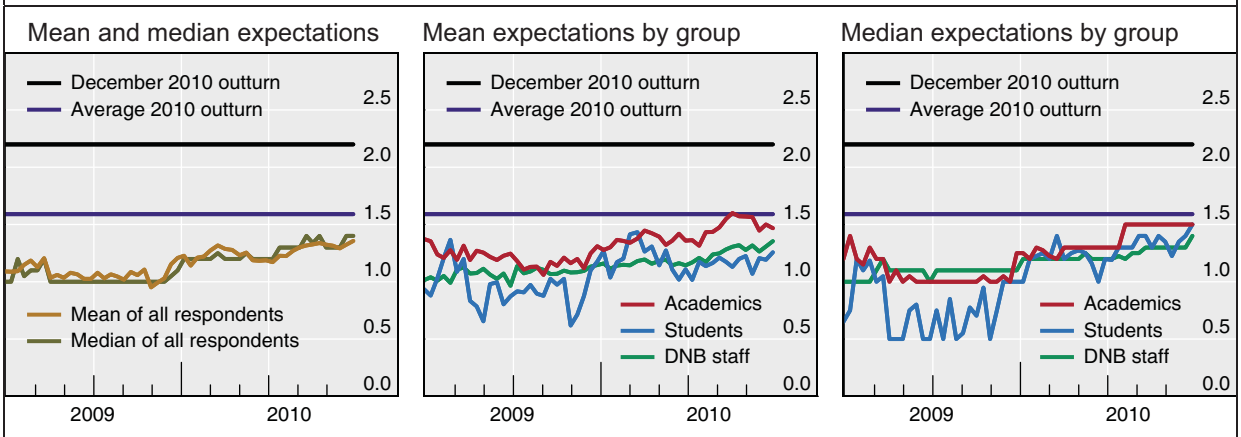
[1] Based on Bloomberg surveys

Sources: Bloomberg.

Figure 4.5.1

Survey expectations for 2010 and outturns

In percent



Source: Eurostat.

Figure 4.6.1

Mean of individual forecasts by groups

In percent

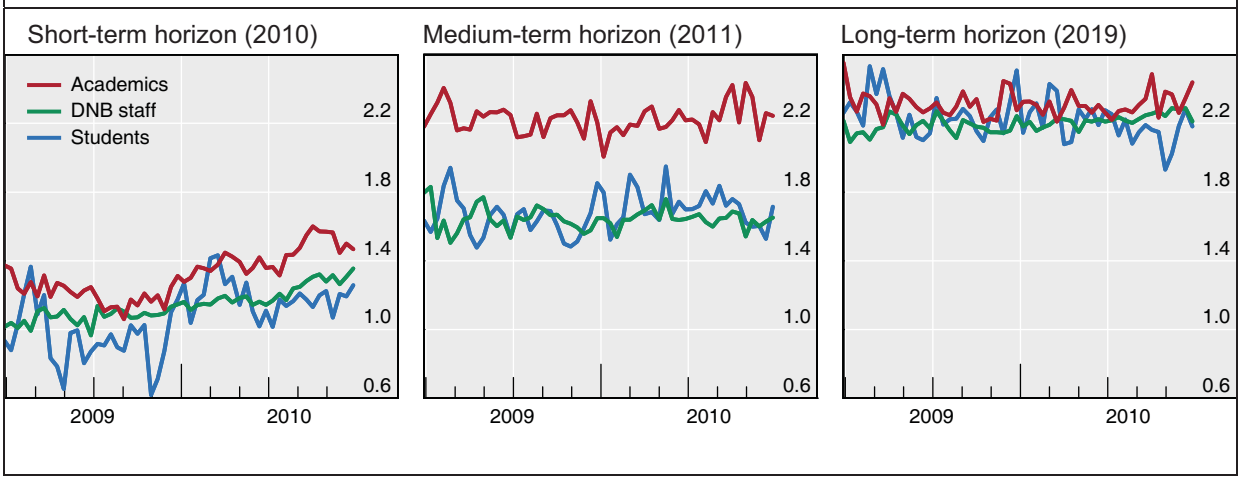
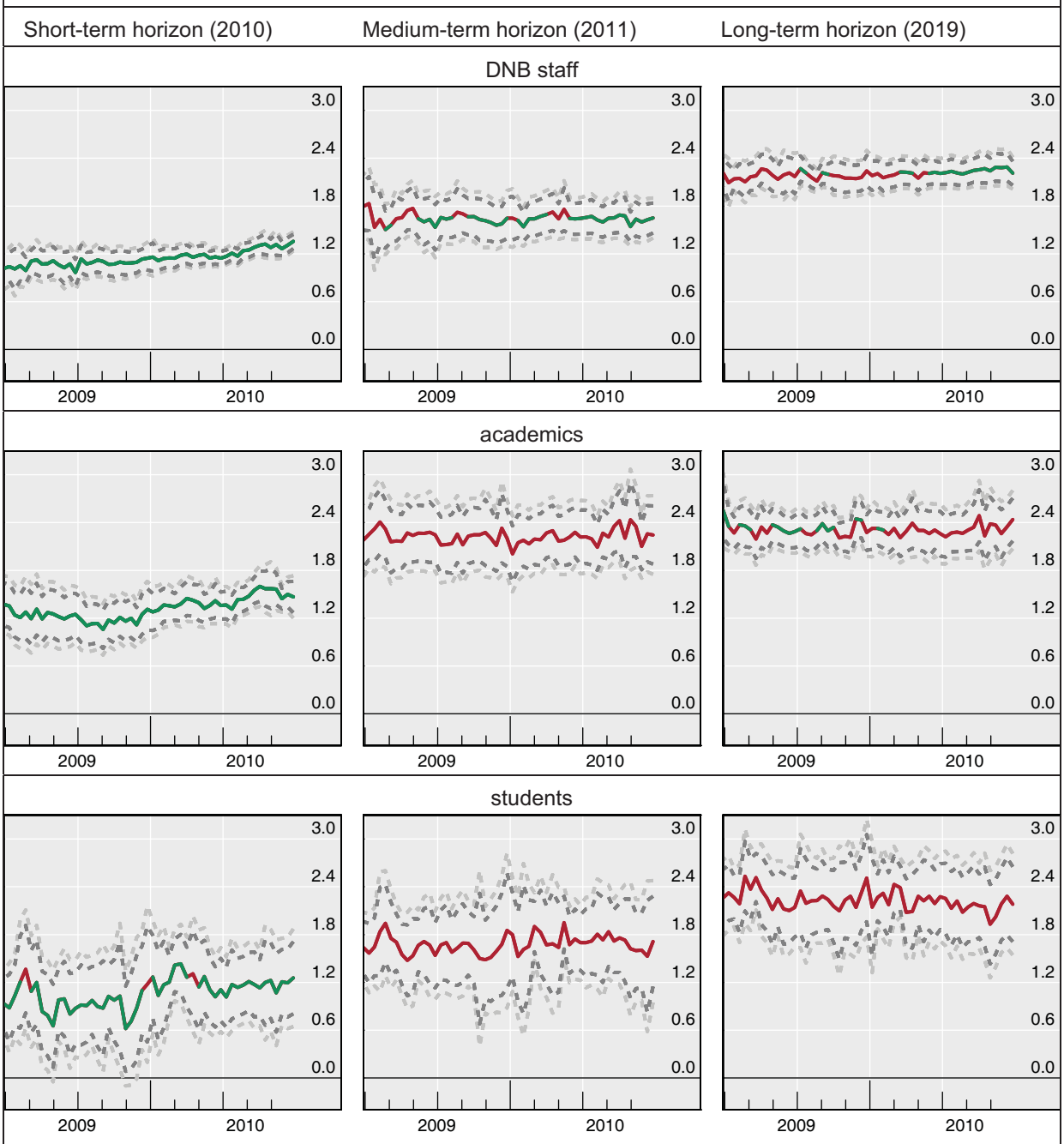


Figure 4.6.2

Mean of individual forecasts by groups

In percent



[1] Green colour represents periods where 1% t-test suggests that mean forecast is different from 2%. Dark and light dashed lines show 95% and 99% confidence intervals, respectively.

Appendix I: Definitions of robust and standard higher moments

This appendix presents definitions of the robust and standard higher moments used in the paper, drawing on Moessner et al. (2011). The interquartile range (IQR) of a probability distribution is defined as

$$IQR = Q_{0.75} - Q_{0.25}\,, \qquad \text{(A1)}$$

where $Q_{0.75}$ and $Q_{0.25}$ are the 75th and 25th percentiles, respectively.

The standard skewness measure is defined as the normalised third central moment

$$Skew = E[(x-\mu)^3/\sigma^3], \qquad \text{(A2)}$$

where μ and σ are the mean and standard deviation of x. E(·) is the expectations operator. Hinkley (1975) suggested a class of robust skewness measures of the following form:

$$Skew_R^p = \frac{\left(Q_{1-p} - Q_{0.5}\right) - \left(Q_{0.5} - Q_p\right)}{Q_{1-p} - Q_p} \qquad \text{(A3)}$$

where Q_p is the p-th quantile, $p \in (0,1)$, and $Q_{0.5}$ is the median. For p=0.25, the quartile-based skewness is given by

$$Skew_R^{0.25} = \frac{\left(Q_{0.75} - Q_{0.5}\right) - \left(Q_{0.5} - Q_{0.25}\right)}{Q_{0.75} - Q_{0.25}} \qquad \text{(A4)}$$

For p=1/8, the octile-based skewness is defined analogously.

The standard excess kurtosis measure is defined as the normalized fourth central moment minus 3 (which is the value of the kurtosis for the standard normal distribution),

$$Kurt = E[(x-\mu)^4/\sigma^4] - 3 \qquad \text{(A5)}$$

Moors (1988) proposed a robust, octile-based measure of excess kurtosis as

$$Kurt_R^{1/8} = \frac{\left(Q_{7/8} - Q_{5/8}\right) - \left(Q_{3/8} - Q_{1/8}\right)}{Q_{6/8} - Q_{2/8}} - 1.23 \qquad \text{(A6)}$$

The value of 1.23 corresponds to the Moors coefficient of kurtosis for the standard normal distribution.

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