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Inflation, deflation, and uncertainty: What drives euro area option-implied inflation expectations and are they still anchored in the sovereign debt crisis?

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Non-technical summary

Research Question

Inflation expectations are important for gauging the effectiveness and credibility of monetary policy. Concentrating on the period of the sovereign debt crisis we look at the drivers and the anchoring of inflation expectations derived from inflation option data for the euro area.

Contribution

We use a new data set on options on the euro area harmonized index of consumer prices to derive probability distributions of inflation expectations including uncertainty and asymmetry of market participants beliefs about the inflation outlook. For analyzing the changing effects of monetary policy announcements and macro news over the sample period from 2009 to 2013 we use a time varying event study framework. A third contribution is to compare option implied and statistical density functions to gain insight into deflation risk.

Results

Inflation expectations show a decreasing mean but growing uncertainty especially since the intensification of the sovereign debt crisis in mid-2011. Around the same time the influence of monetary policy announcements on inflation expectations diminished. Tail events such as deflation although still contained became more probable. The impact of macroeconomic news to explain inflation probabilities overall decreased and shifted towards countries more affected by the crisis. Concerning the anchoring of inflation expectations the paper provides a twofold result: The mean and low sensitivity to actual news speak for anchored inflation expectations whereas the growing uncertainty reveals market participants concerns about possible extreme inflation or deflation outcomes in the future.

Nichttechnische Zusammenfassung

Fragestellung

Inflationserwartungen sind ein wichtiger Indikator, um Glaubwürdigkeit und Effektivität der Geldpolitik einzuschätzen. Vor dem Hintergrund der jüngsten Staatsschuldenkrise stellen wir uns die Frage, welche Faktoren die Inflationserwartungen im Euro-Raum treiben und ob sie weiterhin fest verankert sind.

Beitrag

Ein neuer Datensatz von Optionen auf den europäischen Verbraucherpreisindex erlaubt es, Wahrscheinlichkeitsverteilungen für Inflationserwartungen abzuleiten. Damit lassen sich auch Unsicherheit und Divergenzen in den Reaktionen (Asymmetrien) der Marktteilnehmer über zukünftige Inflationsszenarien abbilden. Die sich in der Krise verändernde Rolle von geldpolitischen Ankündigungen und makroökonomischen Überraschungen kann mit einer zeitvariablen Methode erfasst werden. Als dritte Neuerung wird ein Vergleich zwischen Dichtefunktionen aus Optionen und Dichtefunktionen ohne Annahme der Risikoneutralität angeboten. Dieser erlaubt, Schlüsse über Deflationsrisiken zu ziehen.

Ergebnisse

Über den Krisenzeitraum sanken die Inflationserwartungen der Marktteilnehmer deutlich. Gleichzeitig waren sie sich stärker uneins über zukünftige Inflationsszenarien, die Unsicherheit der Inflationserwartungen nahm zu. Der Einfluss von geldpolitischen Ankündigungen verringerte sich, der Effekt von makroökonomischen Überraschungen ebenso. Letztere verlagerten sich außerdem auf das stärker von der Krise betroffene Italien. Die Wahrscheinlichkeit einer zukünftigen Deflation wurde höher eingeschätzt, sie ist zudem mit Indikatoren für Heterogenität im Euro-Raum wie Renditeeunterschieden von Staatsanleihen positiv korreliert. Der Mittelwert und die geringe Reaktion langfristiger Inflationserwartungen sprechen für weiterhin fest verankerte Inflationserwartungen. Gleichzeitig wird aber auch eine zunehmende Unsicherheit über den zukünftigen Verlauf der Inflationsentwicklung festgestellt.

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Abstract

We tackle two questions in this paper: In the sovereign debt crisis, what moves the euro area inflation outlook and has the firm anchoring of medium to long-term inflation expectations been touched? Deriving densities from a new data set on options on the euro area harmonized index of consumer prices provides us with the full distribution of inflation expectations. The daily data set allows us to analyze effects of monetary policy announcements and macro news in a time varying event study framework despite the short sample period from 2009 to 2013. Due to renewed fears of deflation we compare option-implied and statistical density functions to gain insight into deflation risk. Inflation expectations show a decreasing mean but growing uncertainty especially since the intensification of the sovereign debt crisis in mid-2011. Around the same time the influence of monetary policy announcements on inflation expectations diminished. Tail events such as deflation although still contained became more probable. The impact of macroeconomic news to explain inflation probabilities overall decreased and shifted towards countries more affected by the crisis. Concerning the anchoring of inflation expectations the paper provides a twofold result: The mean and low sensitivity to actual news speak for anchored inflation expectations whereas the growing uncertainty reveals market participants concerns about possible extreme inflation or deflation outcomes in the future.

Keywords: Inflation expectations, Deflation, Options, Monetary policy, Financial crisis

JEL classification: C58, E31, E44, G13

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1 Introduction

Inflation expectations are important for gauging the effectiveness and credibility of monetary policy. The anchoring of inflation expectations does not only include the containment of the mean or level of expectations but also low uncertainty about future realizations of inflation rates, and only marginal reactions of long-term inflation expectations to news. The rationale for the first anchoring definition to contain inflation expectations within a certain range is straightforward. Secondly, a high variation of inflation expectations covers the risk of sudden expectation swings towards extreme outcomes. Then, if long term inflation expectations are way above target, people will have an inherent distrust in the central bank to keep overall inflation in control and will eventually try to link their long run income streams to actual inflation rates to circumvent real income depressions. Ultimately this could end in an inflation spiral with negative effects on the allocation of capital and goods and on overall growth. The same could apply to deflationary outcomes. Thirdly, a mute reaction of long-term inflation expectations on macroeconomic news can be seen as an indicator of a firm belief of market participants in the central bank to effectively maintain price stability in the long run.

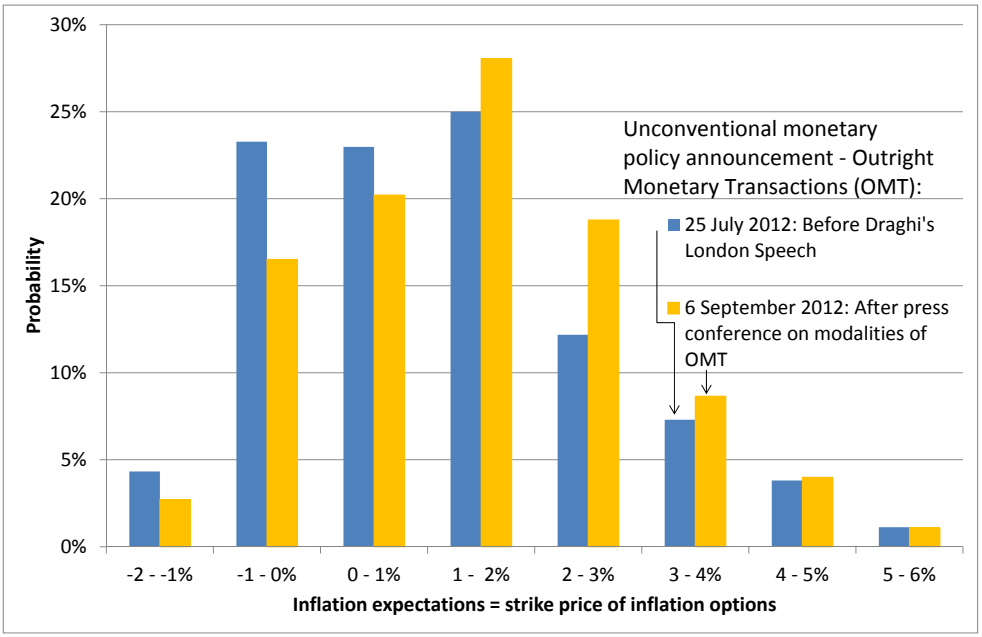

Figure 1: Reaction of option-implied probability distribution of expected inflation rates for the five year horizon on an unconventional monetary policy announcement.

We will cover especially the latter two aspects of anchoring, uncertainty and reaction to news by first deriving risk neutral implied probability density functions from a new data set on options on euro area inflation rates. Full distributions allow us to observe different zones of inflation expectations, ie inflation, deflation, extreme inflation and extreme deflation. In addition we can look at variance and skewness as measures of uncertainty and asymmetry of market participants expectations about future realizations of inflation rates. Figure 1 shows the histogram of the option-implied probability distribution of ex-

pected inflation rates over the next five years for a range of strike prices at two certain points in time. The probability that market participants attach to a certain future inflation rate span, eg from 0 to 1 %, determines the height of the corresponding bar. Any change in a bar signals a change in the distribution function of inflation expectations as well. For example the announcement of possible unlimited albeit conditional sovereign bond purchases of debt troubled euro area countries in concordance with the definition of the modalities of the purchase programme has increased the mean but foremost shifted the skewness of inflation expectations to the right in Summer 2012. Furthermore we will analyze reactions of inflation expectations on macroeconomic and monetary policy news during the last five years and on the change in reactions since the intensification of the sovereign debt crisis in a time varying event study framework. Due to the possibly devastating outcome in terms of economic growth a special focus will be on deflation risk.

Overall the mean of inflation expectations as measured by inflation options decreased over the last five years for all time horizons (see Figure 2). Yet, uncertainty about the future realization of inflation rates soared among market participants especially since the intensification of the sovereign debt crisis in mid-2011. Around the same time the influence of monetary policy announcements measured as high frequency changes in long-term interest rates diminished. We reconcile both developments with a surge in disagreement over the influence of monetary policy towards future inflation outcomes especially towards extreme outcomes such as deflation or high inflation rates. In concordance with that the probability of deflation to occur increased in 2011 albeit from a low level. Measures of heterogeneity within the euro area such as differences in bond yields or inflation rates among euro area member countries are identified as drivers of deflationary outcomes. With respect to macroeconomic news on inflation expectations the influence of surprises about countries more in the focus of the sovereign debt crisis like Italy increased.

The remainder of the paper is organized as follows. The next Section describes the data used and gives information on the inflation option market. The influence of macro news and monetary policy announcements on different inflation expectation zones, ie inflation, deflation, extreme inflation and extreme deflation, is explored in Section 3. We then analyze the anchoring of inflation expectations with respect to uncertainty of the inflation outlook and with respect to time varying effects of inflation to news in concordance with the intensification of the sovereign debt crisis. Deflation probabilities, adjustments for overestimating tail risk due to the risk neutrality assumption, and drivers of deflation risk are subsumed in Section 5. Section 6 features robustness checks and the last Section concludes.

2 Inflation options, monetary policy announcements, and macro news

Many monetary authorities routinely use information that is embedded in financial asset prices for better formulating and implementing monetary policy. Especially derivative markets provide a rich source of information for gauging market sentiment. Due to their forward looking nature forwards and option prices mirror market perceptions about underlying asset prices in the future. Information encapsulated in forwards can be derived

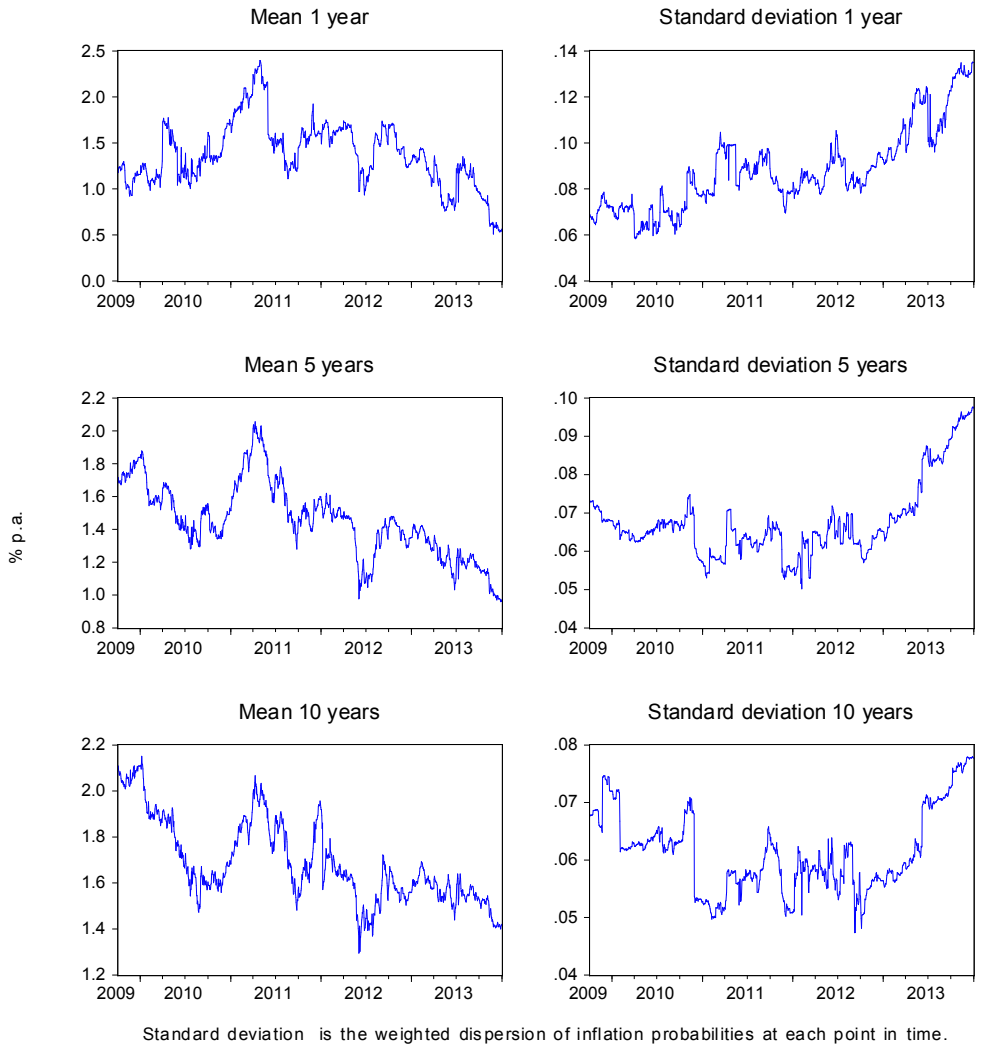

Figure 2: Mean and standard deviation of risk neutral densities for inflation expectations derived from inflation options over the one, five, and ten year horizons.

from cash market instruments, option prices do reveal genuinely new information about underlying price processes.

Yields of inflation-indexed bonds cover - by subtracting them from nominal yields of bonds of comparable quality and maturity - a broad measure of inflation compensation. Secondly, the fixed leg of inflations swaps gives an assessment of the level of inflation expectations of market participants as well. See eg Schulz and Stapf (2014) for a detailed description of both markets and their interrelation. Yet, both measures are not able to show the level of uncertainty since distribution functions of expected inflation rates cannot be recovered from this types of instruments. Some surveys show the dispersion among individual respondents. The Survey of Professional Forecasters (SPF) by the ECB shows in addition the distribution of probabilities of different future inflation rates and can therefore be used to replicate aggregate uncertainty measures (Bowles, Friz, Genre, Kenny, Meyler, and Rautannen (2007)). However their low frequency - quarterly for the

SPF - makes it difficult to analyze the influence of news on a timely basis.

We use European call and put options on the euro area harmonized consumer price ex tobacco (HICPxT), derive implied densities, and look at the distribution of inflation expectations on a daily basis. The HICP covers a broad range of final consumer expenditure for all types of households. It therefore aims at giving a timely and relevant picture of inflation. It is calculated as Laspeyres-type price index and measures the prices of a fixed expenditure pattern. Excluding tobacco as an administered price and use the HICPxT dates back to the fist issue of an inflation-linked government bond of an euro area country in France in 1998. It has become the standard reference index for all inflation linked market instruments in the euro area. We explore how market participants believe inflation rates could evolve over time by using options with different time horizons. Having an interest in gauging the influence of economic developments and monetary policy decisions we develop a macro news and monetary policy surprise data set for three big European countries and the Eurosystem's common monetary policy respectively. We assess reactions of inflation expectations on these data in a static and a time varying event study framework. To better assess the tail risk of deflation we compare option-implied and statistical distributions derived from forecasts of inflation rates. The combination of euro area option-implied inflation expectations with time varying event study regressions featuring monetary policy and macro announcements and limiting the overestimation of option-implied distributions with statistical distributions are the contributions of this paper to the literature.

The empirical literature on inflation-linked bonds and swaps and on their relation to the macroeconomy is huge. Event study regressions relating inflation expectations to macro news have been conducted recently by Gurkaynak, Levin, and Swanson (2010), Beechey, Johannsen, and Levin (2011), Galati, Pelhekke, and Zhou (2011), Haubrich, Pennacchi, and Ritchken (2011), Hofmann and Zhou (2013), and Autrup and Grothe (2014). For inflation options the empirical literature is far more limited. This is because they are a relatively new instrument and data does not date back to before 2009. The papers most closely related to our's are Kitsul and Wright (2013) and Fleckenstein, Longstaff, and Lustig (2013). Both link inflation options to macroeconomic or financial risk developments, yet for US data. Smith (2012) estimates probability density functions for inflation options on UK retail price indices but does not analyze economic drivers.

2.1 Inflation options

An inflation call option (cap) is a contract that gives the holder the right to get compensation payments if the predetermined inflation rate is below the realized inflation rate at a certain date in the future. It involves no obligation if the realized rate falls below the predetermined rate. The option is called an inflation floor if the contract triggers compensation payment for a future inflation rate that is below the predetermined rate. The predetermined rate is known as the strike or exercise price and the date at which the option expires is known as the maturity date. The contingent pay outs of the options are positively correlated with the price of the underlying asset for caps and negatively for floors. In exchange for the contingent future payments the buyer pays the seller a price upfront, the option premium which is the price of the option and is quoted in basis points. Imagine you have bought an inflation cap with a strike price of an annualized

inflation rate of 2%, a notional amount of €100, and a maturity of one year. At maturity the realized inflation rate is 3%. The payout of the option is then €1.

For maturities above one year payment will depend on the option being a zero coupon or a year on year option. Zero coupon options exhibit a single payment at maturity based on cumulative inflation from inception. For year on year options the payment is based on the difference between the year on year inflation rate and the strike price of the option. They generally have annual pay dates. Densities for zero coupon inflation options are easier to calculate and are used throughout the paper. The realized inflation rate is the HICPxT and it is lagged by three months in order to be known at the day of expiration of the option. The price of the underlying asset ie the inflation rate over the maturity of the option is - differently from other options such as stock options - not observable daily. The price of delivery of the realized inflation rate over the maturity of the option on the inflation swap market is therefore taken as a proxy. This is the so called fixed leg of an inflation swap contract over the same maturity horizon and it is traded daily. In sum to hedge the amount of €100 against an increase of the inflation rate above 2% for the next ten years and a compensation payment at the end of the maturity date cost €1,11 at end-September 2013 (€100*111 basis points/100 = €1,11).

While inflation options have been around since the beginning of the new millenium, trading did not pick up until the inception of the financial crisis. Dominated by interbank trading the completely over the counter market reached transactions volumes of over US$ bn 100 in 2011 (Whittal (2012)). While trading takes place mostly in options hedging against extreme outcomes, ie in the tails of the inflation rate distribution, arbitrage ensures the timely adjustment of prices in between. Protection sellers backing banks trading are mutual funds and insurances with the aim to secure real cash flows (Kerkhof (2005)). In addition an inflation cap can be used to limit the uncertain payoff of the payer of an inflation swap. On the investing side caps and floors can be used to build up on leverage on a HICPxT view. According to the SEC filings PIMCO[1] has written several inflation floors.

The over the counter trading makes it difficult to judge the overall liquidity of the market. Aggregated trading volumes are based on estimates of large traders, bid-ask spreads and other measures of liquidity are rarely available. Nevertheless some authors estimate the euro area inflation options market as being the most liquid among US, UK, and euro markets (Smith (2012) and Kanter (2013)). We checked for liquidity by calculating put call parity and by comparing the evolution of option-implied inflation expectations with proven measures of inflation expectations such as the fixed leg of inflation swaps for different time horizons. Put call parity showed no arbitrage violations for at the money options. An example for the put call parity for the inflation option data can be seen in Table A-1 in the Appendix. Put call parity stems from the idea that portfolios replicating the same cash flows should be priced equally to prevent arbitrage opportunities. For European zero coupon inflation options where the underlying inflation swap requires no up front cash investment the standard put call parity (see eg Hull (2006)) melts down to the price of an inflation cap minus that of a floor quoted as percentage of the notional of the option equals the pay outs of the fixed leg of an inflation swap (Kanter (2013)). This holds given the options are at the money options ie their strike price equals that of the actual inflation swap of the same maturity. If compared with inflation swaps the mean of option-implied

[1]Pacific Investment Management Company LLLC with one of the world largest fixed income funds.

inflation expectations develop very similar (see Figure A-1 in the Appendix). Whereas the level of inflation expectations derived from options is somewhat compressed due to the risk neutrality assumption (see Section 5 for a detailed description) decreases and increases run nearly parallel for both kind of inflation measures. We judged information out of inflation options data as being meaningful in describing market participants aggregated beliefs about future inflation developments consequently. That notwithstanding liquidity shortages especially in times of extreme crisis can influence prices of derivative securities as well. However since derivatives such as swaps and options do not involve the exchange of a notional we expect them to be less influenced compared to securities like inflation-linked bonds. One advantage of inflation options compared to standard financial options is that they are traded at constant maturities. Contracts are quoted on a daily basis for whole year tenors as are inflation swap contracts. Standard financial options in contrast feature mostly just four expiry dates per year and must be interpolated across adjacent time horizons to avoid the problem of decreasing time to maturity.

We use end-of-day indicative quotes of zero coupon inflation caps with strike prices of 1, 2, 3, 4, 5, and 6% and floors with exercise prices of -2, -1, 0, 1, and 2% both with strike prices with half percentage points in between respectively. No reliable information is available which contracts trade more and which less, so we take all contracts available into account in our estimation. The maturity of the options ranges from 1 to 30 years with intervals of 3, 5, 7, 10, 12, 15 and 20 years in between. Zero coupon option data is available since October 2009 and is graciously supplied by BGC partners. We use maturities of 1, 3, 5, and 10 year horizons. Our data sample ends in December 2013. Inflation swap quotes and EONIA interest rate swaps on the respective maturities are taken from Bloomberg. EONIA swaps exchange daily flexible interest payments as given by the Euro Over Night Index Average (EONIA) against fixed payments for the maturity of the contract. EONIA swaps do neither contain a country-specific default risk such as government bonds and to a much lesser amount counterparty risk as do unsecured money market rates such as the Euribor.

2.2 Deriving risk neutral densities

European call options on the same asset with the same time to maturity but with different strike prices can be combined to mimic other state-contingent claims, that is assets whose returns are dependent of the state of the economy at some time in the future. The prices of such state-contingent claims are driven by investors' assessments of the probabilities of these particular states occurring in the future. In this respect we can derive the probability a risk neutral representative agent puts to a certain inflation rate to occur at the maturity of the option from the price of a combination of inflation options. An important example of a state-contingent claim is an Arrow-Debreu security that pays one at a future time if the underlying asset takes a particular value (or state) at that time and zero otherwise. The prices of Arrow-Debreu securities at each possible state are directly proportional to the risk neutral probabilities of each of these states occurring. Such a security even though not directly traded can be replicated by a suitable combination of European call options known as a butterfly spread. A butterfly spread centred on a certain state S consists of a short position of two options with strike price K and a long position of one option with strike price $K - \delta$ and $K + \delta$ respectively, where δ is the step size between

adjacent calls. Breeden and Litzenberger (1978) showed that if the underlying price at maturity has a continuous probability distribution then the state price at maturity is determined by the second partial derivative of the call option pricing function with respect to the exercise price. When applied across the continuum of states this second derivative is directly proportional to the risk-neutral probability density function of the respective states.[2] Pricing options in a standard Black-Scholes framework requires some assumptions to hold. Short selling must be allowed, transaction costs do not apply and money can be borrowed at the risk-free interest rate. Pricing will be formulated in the absence of arbitrage. The price of an European call option C is then given by

$$C = e^{-rT} \int_{S_T=K}^{\infty} (S_T - K) g(S_T) d_T \tag{1}$$

with r as the risk free rate, K as the exercise price, T as the maturity date of the option, S_T as the underlying asset price and $g(S_T)$ as the risk neutral density function of S_T. In the absence of arbitrage C is convex and monotonic decreasing in exercise prices. The second partial derivative with respect to the strike price is then

$$\frac{\partial c^2}{\partial K^2} = e^{-rT} g(K) \tag{2}$$

where

$$g(K) = e^{-rT} \frac{C_1 + C_3 - 2C_2}{\delta^2} \tag{3}$$

with C_1 has the strike price $K - \delta$, C_3 with $K + \delta$, and C_2 with K, provided δ is small.

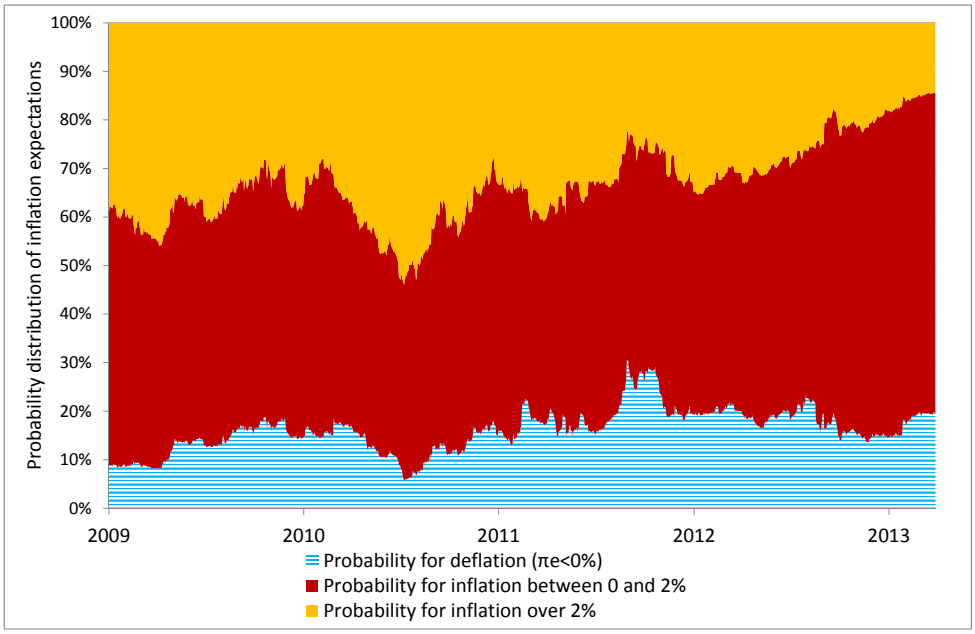

Figure 3: Evolution of probability distribution of inflation expectations for the five year horizon.

[2]See eg Bahra (1997) for a more general description of deriving probability density functions from options.

The histogram of the implied probability density function for a five year horizon at two certain points in time can be seen in Figure 1. To better compare the evolution of the distribution of probabilities of different inflation outcomes over time we clustered the probabilities according to strike price intervals in large groups. These clusters comprise normal inflation with strike prices between 0% and 2%, inflation with strike prices above 2%, deflation with strike prices below 0%, extreme inflation with exercise prices above 4%, and extreme deflation with exercise prices below -1%. We restrict our probabilities by the level of the lowest floor and the highest cap for the clustered expectations and the histograms in the next two sections. Nevertheless probabilities in the highest cap and the lowest floor strike price ranges are far below 1% for most maturities. The evolution of the first three clusters of inflation expectations for the five year horizon over the sample is shown in Figure 3.

Whereas for the clustering into different inflation or deflation expectation zones or the histogram we do not need to interpolate between adjacent strike prices. Yet to derive a full probability density function we need to recover the functional form from the set of option prices or interpolate between strike prices. The latter is usually done by fitting a cubic spline across the call prices for different strike prices or across the volatility smile which is obtained by non-linear transformation from call prices (Bliss and Panigirtzoglou (2002)). Another way is to assume a specific functional form of the probability density function and recover its parameter by minimizing the distance between function-implied and observed option prices (Bahra (1997) and Melick and Thomas (1997)). Pros and cons of different methods to extract probability density functions have been extensively discussed (see eg Clews, Panigirtzoglou, and Proudman (2000) and Jackwerth (2004)). We use as functional form the mixture of two lognormals which is parsimonious because it requires only five parameters to fit and can account for asymmetric responses to positive and negative shocks and allows for high probabilities of extreme events to occur (Craig, Glatzer, Keller, and Scheicher (2003)). Owing to put call parity we can derive probabilities on calls and puts solely on days were no trading of one or the other option takes place. In addition fitting a functional form does not involve extrapolating the fitted spline in the tails because the tails are given by the distributional assumption. Yet, information in the tails is valuable for the behavior of expectations in crisis periods. The disadvantage of the method is that it can generate density functions characterized by sharp spikes (Clews et al. (2000)).

The fitted call prices are minimized in a two step procedure with respect to the parameters of the double lognormal (see eg Bahra (1997) for a detailed description). The probability density function has the form

$$g(S_T) = \theta L(\alpha_1, \beta_1) + (1-\theta)L(\alpha_2, \beta_2), \tag{4}$$

with L as the lognormal density function with parameters α and β. The fitted call prices are given by

$$\hat{C}(S, K, T) = e^{-rT} \int_{S_T=K}^{\infty} (S_T - K)[\theta L(\alpha_1, \beta_1) + (1-\theta)L(\alpha_2, \beta_2) dS_T]. \tag{5}$$

The two step procedure comprises first a grid search where root mean square errors (RMSE) for θs from 0 to 1 in stepsizes of 0,01 are calculated. Starting with the θ with the

lowest RMSE α and β are minimized in both directions. Resulting probability density functions for inflation options with different time horizons at End-December 2013 can be seen in Figure 4. Density functions become steeper with less time to maturity since observations get closer to the mean with expiry approaching. In terms of option pricing the implied volatility decreases with less time to maturity. Density functions show a high but decreasing probability in time to maturity to end up in a deflationary scenario. whereas the high probability in general is overstated due to the risk neutrality assumption the decrease of the probability over the time horizons is due to the realized inflation rate at End-December 2013 was very much below average rates. Options with long horizons mirror the influence of actual inflation rates to a lesser extent compared to short-lived options and are therefore less tilted towards actual inflation outcomes.

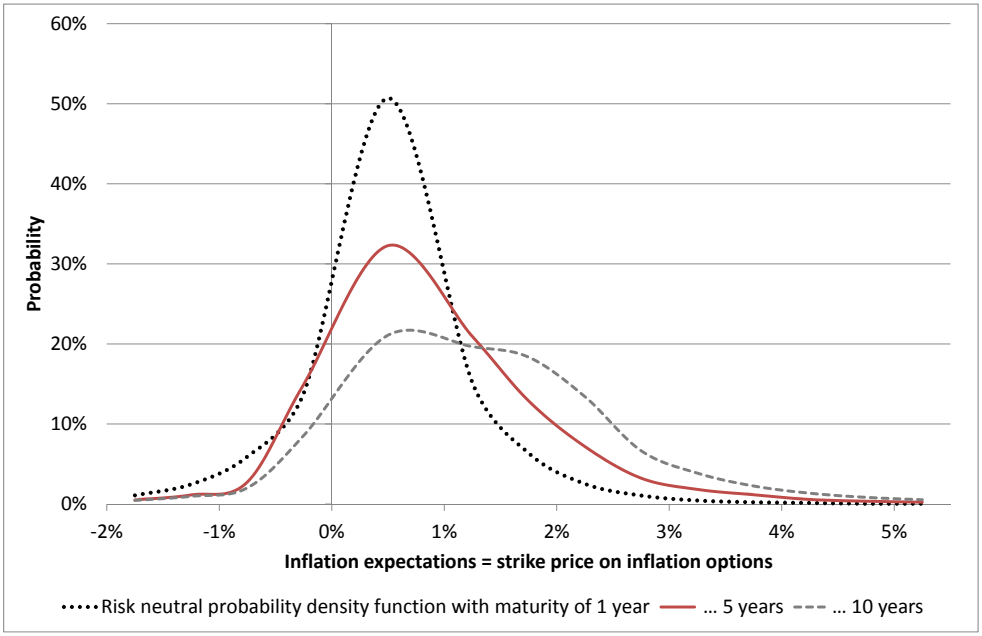

Figure 4: Option-implied probability density functions of inflation expectations for one, five, and ten year horizons.

2.3 Data on macro and monetary policy surprises

Inflation expectations should be driven by the broad macroeconomic development prospects of the underlying economy and the overall stance of monetary policy. Since inflation expectations are measured with daily financial market data it is viable to trace changes in short time intervals. To assess whether the effect on the change in the inflation outlook is directly related to the macro or monetary policy event the information content of the respective event must be identified clearly. In the economy and especially on financial markets, participants constantly form expectations about important events influencing market prices. The newness or surprise of the event can therefore be gauged by subtracting the actual outcome of the macro data or monetary policy decision from perceptions of the potential outcome that have been formed before. In order to assess the latter we use for macro indicators the survey conducted among participants by the trading and

information system Bloomberg which is updated up to the day before the announcement of the indicator. The surprise is calculated as realization minus survey value of the respective macro variable. In this respect our macro news data does not display absolute positive or negative values of macro variables. A positive surprise rather depicts a better than expected realization of the macro variable which can be eg a negative GDP number but less negative than expected.

Following Galati et al. (2011) and Hofmann and Zhou (2013) we use macro data for the three biggest euro area countries: Germany, France and Italy. We suppose they have more influence on inflation expectations since these three countries have a large weight in the HICP, too. We decided against using euro area aggregates since most of the individual country data is known beforehand. Hence the announcement of euro area aggregates only contains news about a sample of smaller countries which have not been published before the aggregate data. A cross check with euro area aggregates showed a lower number of significant coefficients accordingly. We use monthly announcements of HICP, PPI, industrial production, business climate or confidence, and purchasing manager indices for manufacturing and services on all three countries. Disclosures of the unemployment rate for Germany and France are employed. Quarterly news on GDP for France and Italy and on the current account for Germany do complete our data set. We ended up with 23 time series for macro news. The inclusion of further macroeconomic variables on the respective countries is restricted by availability of surveys on the series in the time dimension. As a robustness check we included macro news on US data (see Section 6). All data is taken from Bloomberg. We control for monetary policy news by estimating effects simultaneously therefore single announcement effects might not be overlain by other news. Since surprises on a variety of macro announcements can be differently large in terms of value we standardize news by the standard deviation and subtract the average daily changes over the whole period of the respective time series.

For monetary policy decisions there is no standard survey information apart from surveys on interest rate decisions eg from Reuters. However, during the financial crisis a bunch of unconventional monetary policy measures have been implemented including asset purchase programmes, collateral framework modifications, forward guidance etc. In order to numerically assess the effects of these policies we follow the literature (Wright (2012) and Neely (2010)) and take the change in long-term interest rates of German bonds and the change in a GDP-weighted average of other euro area members bond yields on the day of the monetary policy announcement as indicator. By containing the time window to the respective day of the announcement we hope to capture mostly effects of the monetary policy decisions. The length of the optimal window to capture announcement effects is subject to debate. Studies use windows ranging from one hour to two days. We expect financial markets to quickly react to relevant news. By using a GDP-weighted average of euro area members bond yields prevents us from applying intra-daily data. The monetary policy indicator is therefore estimated in a one-day window. Estimations with a two-days window did not changed the results qualitatively (see Section 6). Monetary policy surprises are calculated at the respective dates (one-day window) of the announcement of interest rate decisions and of unconventional measures in press conferences following Governing Council meetings. Unconventional measures comprise forward guidance, asset purchase announcements, extensions of the full allotment fixed rate tender procedure, adjustments of the collateral framework and swap lines with foreign central banks. All

announcements are published on the ECB's web site. Furthermore our monetary announcement data set comprises press releases, ad-hoc communications of the ECB such as the first early repayment of funds raised on the three year LTRO on January 25, 2013, a restricted number of important speeches such as Draghi's London speech on July 26, 2012, and seminal market news such as the inclusion of purchases of Italian and Spanish government bonds in the SMP on August 8, 2011. Daily changes in the ten year German government bond yield rate as well as in the GDP-weighted average of other euro area ten year government Benchmark rates are taken from Reuters. The rate changes are standardized with average daily movements over the whole time period. The surprise date sample period runs from October 2009 to end December 2013 and features 76 monetary policy news. A more comprehensive description of all data used can be found in the Appendix in Table A-2.

3 Drivers of inflation and deflation expectations

Do monetary policy decisions move financial conditions for the real economy and drive the inflation outlook? Are inflation expectations reacting to macroeconomic developments?

A quick cross check on the first question is to look at the difference in reactions of long-term bond yields on days of monetary policy announcements (called event days) compared to days with no announcement (called non event days) in Table 1. The standard deviation of long-term rate changes is higher on event days compared to non event days for German bond yields and GDP-weighted other euro area yields. Overall the sample period comprises a time of decreasing long-term rates and therefore has the notion of a further monetary easing. However on event days the German bond yields increased on average by two basis points. This can be interpreted as either relief from former safe haven flows due to a monetary policy supported decrease in financial stress that induced investors to return to more risky assets. Or it can be seen as an increase in risk bearing due to a higher exposure to euro area sovereign default risk on German government debt in concordance with the implementation of unconventional monetary policy measures.

A quick cross check concerning the second question on the relation of inflation expectations and the broader economy is to look at financial series representing developments in other markets. In concordance with the literature about inflation formation we looked at daily changes in crude oil prices, in a share price index, and in the Euro-US-Dollar exchange rate. Single time series regressions in log differences (all time series are non stationary according to standard augmented Dickey-Fuller tests) show significant positive correlations with Brent oil prices, with the broad stock market index Eurostoxx, and with an appreciation of the Euro against the Dollar (see upper part of Table A-3 in the Appendix). Price increases in oil and shares are negatively correlated with deflation probabilities. Interestingly the influence of the contemporaneous financial market data is not confined to short horizons of inflation expectations. It extends well up to maturities of ten years. For oil prices this would indicate that the actual price is the best predictor for future oil prices - random walk property - and therefore has an influence even on distant-future inflation expectations. Yet, the influence is decreasing with time to maturity. Share prices are inherently forward looking indicators as they present discounted future dividend payments. Increasing share prices might be seen as an indicator of future growth which gives the link to inflation probabilities by a mounting price pressure in the

	One-day yield changes on ...	
	GDP-weighted average of other euro area ten year government bonds	Ten year German bonds
On all days (1106 days)		
Mean	-0.0006	-0.0013
Standard deviation	0.0619	0.0494
On days of monetary policy events: event days (76 days)		
Mean	-0.0022	0.0151
Standard deviation	0.0818	0.0562
On days of no monetary policy events: non event days (1030 days)		
Mean	0.0005	-0.0024
Standard deviation	0.0602	0.0487

Table 1: Standard deviation and mean of yield changes on event days and non event days from October 5, 2009 to December 31, 2013.

future. Wealth effects on consumption in relation with growing share prices might play a role although possibly to a lesser extent in the more bank based euro area. A decreasing inflation probability with a depreciation of the Euro against the Dollar is in contrast with the standard argument of imported inflation via imported goods prices. Yet, since both currency areas cannot be identified as very open economies the spillovers of exchange rate fluctuations on inflation expectations rely possibly more on signals of economic growth mirrored in exchange rate fluctuations than on imported goods prices (see Section 6 for an analysis of US macro news on inflation expectations). Overall adjusted R-squares for the log difference regressions are low (ranging from 0.01 to 0.12) suggesting that non-stationarity properties explain some part of the development of inflation probabilities and there is room for further influence factors which do not drive share prices and oil prices to the same extent as inflation expectations.

For estimating long-term influences of macroeconomic developments and of monetary policy on the formation of inflation expectations the inflation option data sample is far too short. In a seminal paper Andersen, Bollerslev, Diebold, and Vega (2003) showed nevertheless that in a short window around macroeconomic news announcements there is a systematic influence of macroeconomic surprises on financial variables. We follow this approach to relate high frequency changes in risk neutral densities to the surprise component of an array of macro variables as well as to the unexpected component of monetary policy announcements.

Event study regressions relate the change in inflation expectations to the surprise components of an announcement over all days where there is at least one announcement. If there is no other announcement at that day the surprise component is zero for all other news. This formulation accommodates the possibility of multiple announcements on a

single day.

$$\Delta p_{\pi^e,t} = \sum_{j=1}^{J} \beta_j s_{j,t} + \gamma_n m_{n,t} + \epsilon_t \tag{6}$$

with $\Delta p_{\pi^e,t}$ as the change in the inflation (deflation, extreme inflation, extreme deflation) probability at day t, β_j as the coefficient of the surprise s_j of the macro variable j and γ_n as the coefficient of the announcement m_n of the monetary policy variable n which is either the ten year German Bund yield change or the GDP-weighted average of other euro area ten year government bond yield changes. ϵ_t is an error term. Estimating the impact of macro news and monetary policy announcements in a single regression ensures that the influence of either surprise is controlled by the effect of all other news. This is, if there is no multicollinearity among regressors which lead to inflated variances. Pairwise correlation coefficients and variance inflation factors show levels well below 0,1 and slightly above 1 respectively indicating that multicollinearity is not an issue with our event study regressions.

Looking at the event study regressions we see an impact of standardized macro announcements foremost on the short horizon of inflation probabilities. Nevertheless, even for probabilities over the next three, five and ten years some macro surprises have a significant impact (see left part of Table A-4 in the Appendix). Nearly all of the signs on the significant coefficients are in line with an economic intuition of growth and the inflation outlook, eg positive surprises drive inflation and negative ones curb deflation expectations. This means a higher than expected unemployment rate should drive inflation expectations down and a higher than expected industrial production or purchasing manager index should increase inflation expectations in line with standard demand and capacity utilization arguments. For some coefficients the interpretation might be ambiguous. A better than expected current account number signal an increase in competitiveness and therefore bolder future growth expectation and more inflation pressure to come. Yet, in the sovereign debt crisis improvements in the current account might be associated with a deterioration of imports, decreasing demand and lower actual inflation rates and therefore can feature a negative coefficient with short-term inflation expectations. This explains the negative coefficient on three year inflation expectations with the German current account in the sovereign debt crisis. German business climate features positive coefficients with short-run inflation expectations and negative ones with log-term expectations. Maybe market participants think of second order effect in terms of monetary policy tightenings in the long-run if business perspectives are very promising. All other macro news show consistent coefficients over all time horizons and sample periods. Mostly it is German ifo business climate, purchasing manager indices, and current account that drives inflation expectations. Around the same influence level show Italian industrial production and French producer prices as well as Italian producer prices and real GDP. To a somewhat lesser extent Italian purchasing manager indices, French consumer prices and GDP, and German unemployment have a significant influence. Astonishingly the unemployment rate in France and Italian business confidence have the highest number of significant coefficients for all macro surprises. It is either the labor market developments of the second biggest euro area economy or the growth prospects of the private industry in Italy that worries market participants with respect to inflation expectations. Or it is a

common underlying factor that drives all three series.

Monetary policy surprises show mostly significant reactions on the one to three year horizon (see column 2 in Table A-5 in the Appendix). This can be subsumed under the medium-term monetary policy horizon verified by the eurosystem for example in inflation projections over this and the next two years (ECB (2013a)). Monetary policy news tend to drive inflation and extreme inflation outlooks but are somewhat less significant when it comes to fighting deflation expectations. This is in line with theoretical deliberations relating deflation to a liquidity trap where economic growth cannot be fostered with further monetary easing (Schmitt-Grohé and Uribe (2013)). The biggest impact of monetary policy surprises is on the probability of inflation to exceed two percentage points where a monetary policy tightening this is an increase in government bond yields lowers the inflation probability.

Inflation expectations for short, medium, and long term horizons are influenced by actual oil prices and share prices as indicators of future activity of the economy. Macroeconomic surprises on business climate and business outlook variables in the three major euro area economies drive inflation expectations of all horizons. Price and labor market news show correlations with inflation expectations yet mostly up to medium horizons. Monetary policy announcements impact the inflation outlook mostly for one and three year horizons and show more significant coefficients with inflation compared to deflation expectations.

4 Changing influence of macro news and monetary policy during the debt crisis and uncertainty

As explained above inflation anchoring can have different dimensions. A mute reaction of long-term expectations to news might indicate confidence of market participants in the central banks ability to counter short-term deviations from price level stability in the long run (see eg Clarida, Gali, and Gertler (2000)). Erosion of confidence might be measured differently by the dispersion of market participants beliefs of future inflation rates. A mute reaction on news can be driven by either no reaction or by offsetting reactions. Since we do not have data on individual reaction functions a growing standard deviation of inflation expectations might be an indicator of diverging reactions of market participants on the same news.

As a first approximation to analyze diverging reaction functions and an increase in the standard deviation of inflation expectations we estimate the event study regressions with monetary policy news and macro surprises in split samples. Standard break point tests suggests autumn 2011 as a break point. Most of the test statistics of the Chow break point test did not reject the null of a break at End-July 2011. Bai-Perron multiple break point tests of sequentially determined breaks suggested one to two break dates for regressions including all macro announcements. The break dates varied between February 2011 and October 2012. For regressions just featuring monetary policy announcements test statistics indicated mostly one brake date on July 2011 at the 5% significance level. The results did not change qualitatively when using non-standardized regressors. Obviously the reaction function of inflation expectations on monetary policy announcements changes just once - in July 2011, whereas the reaction function on the 23 macro news

showed more time variation. In line with the economic rationale of the renewed blaze in the sovereign debt crisis we split the sample in two sub samples running from October 2009 to July 2011 and from August 2011 to December 2013 respectively.

The results for monetary policy announcements are straightforward (see the last two columns of Table A-5 in the Appendix). Whereas most coefficients for the first two-year sample are significant they become insignificant for the extreme crisis samples from mid-2011 onwards. Especially if looking at the German government bond yield as an indicator, monetary policy did have a systematic impact on inflation and deflation probabilities for all time horizons up to 2011. To a somewhat lesser extent this holds for regressions with EMU bond yields as an indicator. Obviously with the high time of the sovereign debt crisis starting in mid-2011 inflation expectations became disentangled from monetary policy news with the exception of the very short horizon over the next year. Yet, interpreting the growing standard deviation of inflation probabilities as diverging reaction functions of market participants bends the result of no influence of monetary policy to one of disagreement on the influence of monetary policy towards future inflation outcomes. If there is no consensus about a monetary policy decision bringing future inflation rates up or down, the reaction of inflation expectations on monetary policy news can very well be quite mute.

For the event study regressions with macro surprises and sample splits no such clear cut change in the results emerge. Whereas the number of significant coefficients for German and French macro news decreased after mid-2011, it slightly increased for Italy. This might be related to the growing alertness on macroeconomic developments in Italy in relation to its debt servicing capacity during the ongoing sovereign debt crisis.

4.1 Time varying event study regressions with flexible least squares

Event study regressions usually feature static coefficients for the respective sample period. Although one can introduce a dynamic element by splitting the sample, event study regressions generally do not cover moving coefficients over time. We therefore apply Flexible Least Squares (FLS) as an approach for estimating time-varying parameter models. FLS was first proposed by Kalaba and Tesfatsion (1988). The model to be estimated is

$$y_t = x_t'\beta_t + u_t \tag{7}$$

where y_t is a vector of data and x_t a matrix of regressors. As in the Kalman filter approach, the time-varying coefficients are assumed to follow an autoregressive process. In contrast to the Kalman filter, FLS does not impose implicit distributional priors on model discrepancy terms but rather apply an explicit smoothness prior. Since the surprise time series feature a large number of zeros and only occasional positive or negative values we felt not comfortable with applying implicit distributional assumptions on dynamic discrepancy terms.[3]

Kalaba and Tesfatsion (1989) define two types of errors for each possible sequence of estimated coefficients $\beta = (\beta_1, \cdots, \beta_T)$. They call them the dynamic and the measurement discrepancy term. Whereas the measurement error terms reflect the difference between

[3]The relationship between FLS and the Kalman filter is explored in Darvas and Varga (2012).

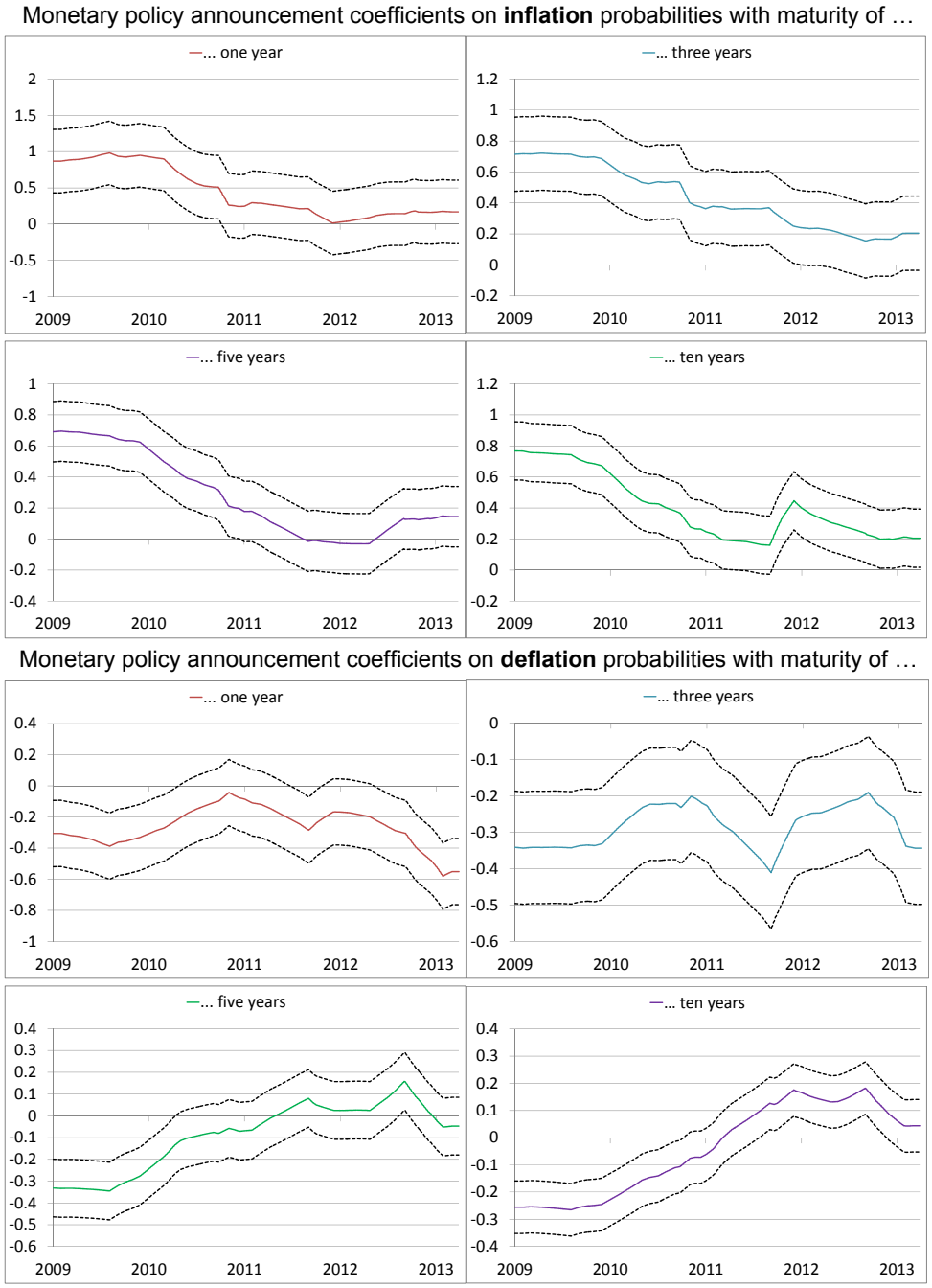

Figure 5: Time varying coefficients of inflation expectations on monetary policy announcements for different time horizons.

actually observed and theoretically predicted outcomes, the dynamic discrepancy terms show the time variation in successive coefficient vectors relative to a null of constancy. $r_M^2(\beta)$ is the sum of squared residuals of the "measurement equation"

$$r_M^2(\beta) = \sum_{t=1}^{T} u_t^2 \tag{8}$$

and $r_D^2(\beta)$ is the "sum of squared residual dynamic errors".

$$r_D^2(\beta) = \sum_{t=2}^{T} (\beta_t - \beta_{t-1})' (\beta_t - \beta_{t-1}) \tag{9}$$

(8) and (9) define the so called residual possibility set, which is the set of all possible combinations of $r_M^2(\beta)$ and $r_D^2(\beta)$. Generalizing the goodness-of-fit criterion of ordinary least squares, for each possible sequence of coefficients an incompatibility cost can be asigned

$$C(\beta, \mu) = (1 - \mu) r_M^2(\beta) + \mu r_D^2(\beta), \tag{10}$$

which is a weighted average of both types of costs. The relative weight is determined by μ which is given. The flexible least squares estimator

$$\hat{\beta}_t^{FLS} = \min C(\beta, \mu) \tag{11}$$

minimizes the incompatibility cost subject to both errors. If μ is close to zero, the smoothness of the sequence of coefficients over time is not relevant. In that case, this sequence is quite erratic. The OLS solution can be obtained by setting μ rather large, assigning an extremely large role to smooth estimates, i.e. $r_M^2(\beta)$ dominates $r_D^2(\beta)$.

Time varying coefficients for the impact of monetary policy announcements on inflation expectations decreased during most of the years 2010 to 2012 down to the point where they are not longer statistically significant from zero (see Figure 5, upper four graphs, confidence bands are constructed using two standard deviations around the estimated coefficients). Coefficients on inflation ceased to be significant in 2011. They rebounded somewhat for horizons of one and five years but still remained insignificant towards the end of the sample. The diminished response to monetary policy surprises towards inflation expectations on the part of the market participants might be reflected in the wording of the ECB's press conferences following the Governing Council's decisions. In these the role of the ECB in fighting "financial market tensions" and "heightened uncertainty weighing on confidence and sentiment" were stressed (see eg the transcripts of the press conferences on 8 December 2011 and on 2 August 2012 available at: www.ecb.eurpa.eu/press/pressconf/). The impression might emerge that decisions were not as decisively directed at maintaining price level stability as they have been before the intensification of the sovereign debt crisis.

For deflation expectations the evolution of regression coefficients is less even over maturities (see Figure 5, lower four graphs). At shorter horizons expansionary monetary policy news had a negative impact on deflation probabilities, ie moved inflation expectations up. That downward movements accelerated in 2013 when inflation rates fell below 2% throughout the year. Coefficients stayed significant over nearly the whole sample period. Yet, longer maturities responded with positive coefficients. Though these positive responses are not statistically different from zero, they indicate that monetary policy announcements did not help to contain market participants expectations for deflationary outcomes over medium to long-term horizons. The introduction of "prolonged periods of low inflation" in the wording of the ECB's press conferences in 2013 coincided with a change in the response of deflation probabilities towards monetary policy surprises (see eg transcript of the press conference on 7 November 2013).

4.2 Higher moments of probability density functions

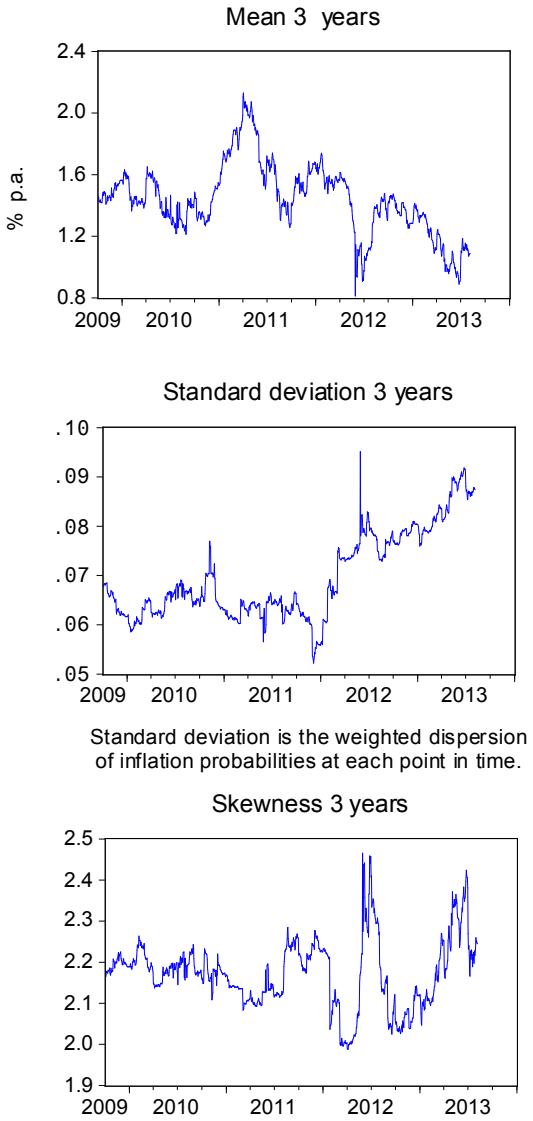

Figure 6: Higher moments of probability density functions for inflation expectations for the three year horizon.

The advantage of having full distributions of inflation expectations is to explore higher moments as indicators of uncertainty and of asymmetry of market participants beliefs. Looking at the mean, standard deviation, and skewness of inflation probabilities one can detect a decreasing mean, an increasing standard deviation, and a volatile skewness (see Figure 6 for the three year horizon and Figure 2 for other horizons). Before attributing the decreasing mean to a monetary policy having become more and more credible it might be advisable to check with the second definition of anchoring of inflation expectations, ie uncertainty. Otherwise the decreasing mean might be attributable to lower growth prospects in the euro area which might be manifested by the ongoing sovereign debt crisis. The rising standard deviation of inflation expectations since mid-2011 might speak for diverging expectations to more extreme outcomes. This is in line with survey data on

inflation expectations where participants do put more weights on the tails of the overall distribution (Andrade, Ghysels, and Idier (2012)). This in turn hints at a growing unease of market participants about the way central banks are able to deal with the increasing challenges coming from a low growth environment with an extremely loose monetary policy.

Nevertheless, skewness is still shifted to the right speaking for relatively low deflation probabilities and a firm anchoring of inflation expectations in positive grounds. Although at times of extreme crisis, eg at end-2011 and mid-2012, and at the end of the sample the inflation probabilities have become more skewed towards lower inflation values (see for a more thorough discussion of deflation issues Section 5). The evolution of higher moments over the course of time hints to a change in the underlying reaction function of market participants on news with probable relevance for future inflation rates. A nearly 50% higher standard deviation of inflation expectations might be induced by agents reacting to incoming news in a more dispersed way especially in relation to the probability of extreme inflation outcomes. Looking at the impact of macro news on higher moments the picture emerges of a mean partly driven by German surprises, a standard deviation that rather shows the influence of Italian data announcements and a skewness that is evenly affected by news for all three countries (see left part of Table A-6 in the Appendix). Again monetary policy announcements are far more influential on forming average expectations, uncertainty and asymmetry of the future distribution of inflation within the first half of the sample (see middle part of Table A-6 in the Appendix). Significance on future levels, standard deviations and skewness of inflation rates vanishes after mid-2011 (see right part of Table A-6 in the Appendix).

Time varying event study regressions showed no increase in the reaction of inflation expectations to news, more so for monetary policy announcements than for macro variables. Yet the rising standard deviation of inflation expectations for all horizons since mid-2001 might hint at a growing divergence of market participants beliefs about the way central bank actions influence future inflation rates. A diverging reaction function might not be a concern itself but might cover the risk of sudden swings towards extreme outcomes. This in turn might disanchor the mean and increase the reaction of inflation expectations to actual news.

5 Deflation risk

The full distribution of possible future inflation outcomes comprises deflation scenarios as well. Inflation expectations derived from inflation swaps or break-even inflation rates from index-linked bonds give deflationary outcomes very little room. Euro area inflation swaps over the one year horizon just showed a negative mean in autumn 2008 after the collapse of Lehman brothers for around one month. Survey data on inflation expectations allow for deflation probabilities but the ECB's Survey of Professional Forecasters (SPF) figures are considerably small, ranging under 2% for deflation in the euro area to occur within the next one, two, and five years (ECB (2013b)). For the US estimates of the deflation protection option embedded in inflation-linked bonds also give low values of deflation probabilities for most of the time except the extreme crisis period in 2008 (Christensen, Lopez, and Rudebusch (2012)). The SPF conducted by the Fed Philadelphia featured deflation probabilities for the next year under 1% recently (Fed (2013)).

5.1 Risk aversion and statistical probability density functions

The option-implied risk neutral density functions give far more room for deflation scenarios with probabilities between 10% to 20% (see Figure 3 and Figure A-2 in the Appendix). This is clearly driven by the risk neutrality assumption. A risk neutral investor weighs a possible loss around the mean equally to one in the tails of the distribution. Yet, one unit of loss in an extreme outcome can be more harmful for investors compared to one unit of loss around the mean scenario. Therefore risk averse investors tend to penalize losses in extreme outcomes with higher risk premia. The price level stability target within the euro area is defined as inflation being below but close to 2%. Hence deflation and inflation rates above 4% can be considered tail events for inflation.

Risk neutral probability density functions do not ascribe a risk premium to tail events which extremely affects market participants wealth and consumption possibilities. In this respect the price of the inflation floor protecting against deflationary outcomes is far "too high" for a risk neutral investor. This "too high" price translates into "too high" probabilities for extreme events to occur. Fleckenstein et al. (2013) suggest to derive a risk premium from inflation swaps in an arbitrage-free affine term structure framework and to adjust the probability density function by this risk premium. For US data this resulted in a ratio of three to one of risk neutral probability to objective probability functions for tail events.

Another approach to gain insight into the risk aversion of market participants is to compare risk neutral option-implied distributions with statistical distributions derived from mean and variance forecasts of a model not assuming risk neutrality (Tarashev, Tsatsaronis, and Karampatos (2003) and Gai and Vause (2006)). Inflation is not a financial market variable, forecasting with General Autoregressive Conditional Heteroskedasticity (GARCH) models like in the literature on options on financial market instruments might not be adequate. Faust and Wright (2013) in their overview article on inflation forecasting state that good inflation forecasts must account for a slowly time varying local mean and must include subjective information from surveys. As a device to capture these features they suggest to use long-term survey forecasts as trend level of inflation τ_t. Note, that the model is based on monthly data since inflation figures are not available on a daily basis. They define the inflation gap g_t as

$$g_t = \pi_t - \tau_t \tag{12}$$

with π_t as annualized inflation rate and assume g_t is stationary and τ_t follows a random walk. Using their autoregression in a gap forecast model we estimate

$$g_t = \rho_0 + \sum_{j=1}^{p} \rho_j g_{t-j} + \epsilon_t \tag{13}$$

iterate this forward to g_T and add τ_T back to the gap forecast to get the implied inflation forecast. T the maximum forecast horizon, here comparable to the maturity of the options used to derive option-implied densities and p is the lag length of the gaps included in the forecast. Subtracting the risk neutral implied density function from the statistical density function for a certain range of strike prices far away from the mean gives then a measure that can be interpreted as risk aversion with respect to the tail outcome.

5.2 Comparing risk neutral and statistical deflation expectations

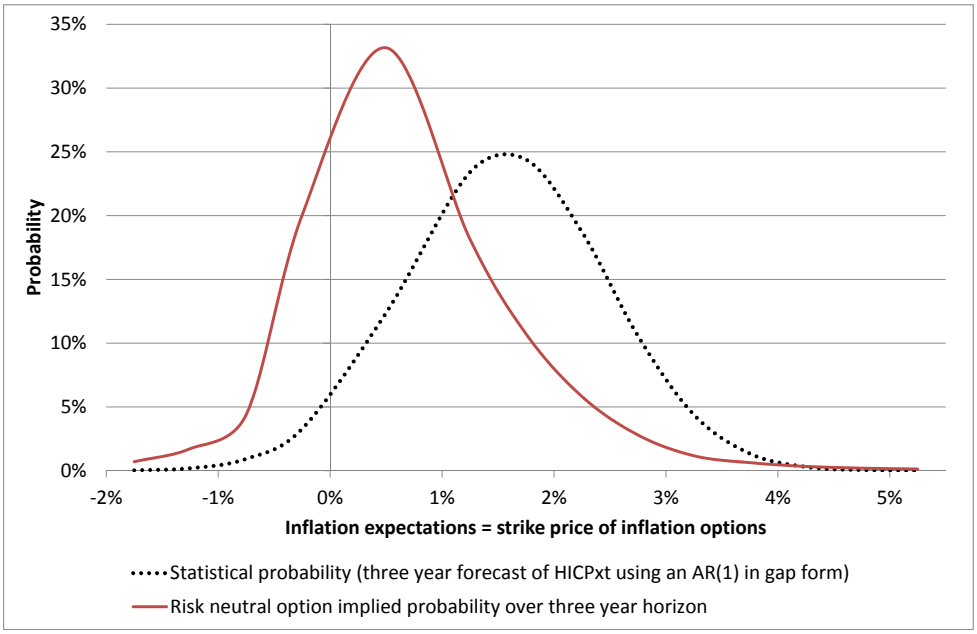

Figure 7: Comparison of option-implied and statistical probability density functions of inflation expectations as of December 31, 2013.

We estimate an AR(1) for the gap between realised HICPxt inflation and six to ten year inflation forecasts from surveys from Consensus Economics for the euro area from 1996[4] to 2013 and calculate the implied distribution of inflation from three years forecasts of the mean and variance and call that a statistical distribution. A comparison of the risk neutral option-implied and the statistical probability (see Figure 7) reveals the higher ascription of deflation risks for the risk neutral estimation. For the statistical distribution the probability of ending in a deflation scenario is far more contained. In order not to make the higher tail outcome of the option-implied density an artefact of our statistical inflation forecast we checked for an alternative forecast method with financial market data and did not find diverging results (see Section 6).

Despite the severe negative outcomes that are associated with deflationary scenarios in the last century no compelling forecasts or drivers for deflation risks have been firmly identified. Fleckenstein et al. (2013) have regressed economic and financial risk variables on deflation probabilities from options for the US. We replicate their regressions with euro area data and find that deflation probabilities are only loosely related to financial market risk such as the implied volatility of options on the BUND future and of options on the German stock market index or liquidity measures such as the KfW-Bund spread (see Table A-7 in the Appendix). That notwithstanding deflation probabilities are significantly negatively correlated with financial market and commodity prices such as share price in-

[4]Data for the euro area HICPxT dates only back to 1995. From 1995 to 1998 Eurostat uses a GDP-weighted aggregation of national CPIs of future euro area member countries.

dices and oil prices, respectively (see upper part of Table A-3 in the Appendix). More interestingly, measures of dispersion within the euro area seem to explain movements in deflation probabilities better. On a daily frequency the GDP-weighted spread of other euro area government bond rates to German government bond yields is a significant driver of deflation expectations over the one, three, five, and ten year horizons (see lower part of Table A-3 in the Appendix). For monthly data the dispersion of euro area inflation rates measured as the standard deviation of monthly CPI flash estimates of the different euro area countries has a significant coefficient with deflation and extreme deflation expectations of three and five years. This would imply that heterogeneity of actual inflation rates either mirrors or supports economic distortions that can result in deflationary scenarios.

Looking only at the deflation part with our event study regressions the big picture of fading influence of monetary policy news on inflation probabilities does not change very much. However for the GDP-weighted EMU bond yield we can detect some significant coefficients in the second half of our sample during the intensified sovereign debt crisis. For deflation and extreme deflation at the one year horizon monetary policy announcements seemed to have taken some deflationary pressure from market participants expectations.

To sum up, deflation risk coming from risk neutral densities overstates risk-adjusted deflation expectations greatly. The correlation of deflation expectations with financial market risk variables in the euro area is low. More significant are variables representing heterogeneous developments in the euro area such as government bond yield differences or the dispersion of inflation rates. Whereas monetary policy news lost influence on deflation probabilities overall since mid-2011, they kept an impact on deflation and extreme deflation expectations over the short horizon.

6 Robustness checks

The results of the paper can be challenged in several respects. Have we omitted important drivers of inflation expectations in our even study regressions? Is the result of the decreasing influence of monetary policy announcements subject to the choice of the window length for the indicators long-term bond yields? Is the result of less weight in the tails of the statistical density function unique to the use of the respective inflation forecasting model?

As mentioned in the data section the use of macro variables in the event study regression is constrained by the availability of surveys to extract the newness or surprise of the respective realization of the variable. We enlarged the regressions with data on euro area aggregates and on US macro variables to capture influences other than from the biggest three euro area members. Using euro area aggregate surprises does not enhance the fit of the event study regressions. As a robustness check we estimated the effect of euro area business confidence, HICP, producer price indices, industrial production, purchasing manager indices and real GDP on inflation and deflation expectations. We found low coefficients of determinations ($r^2 \leq 0.01$) and only a marginal number of significant coefficients for business confidence and producer price indices.

Literature on inflation and inflation expectations (Neely and Rapach (2011) and Netsunajev and Winkelmann (2014)) suggest that developments in the euro area might be driven by news from the US. Whereas the common argument for spillovers are trade and

exchange rate relations, variables like non farm payroll numbers, who served as nominal anchor for the forward guidance period in the US, might signal changes in monetary policy stance and therefore serve as a catalyst for reaction of euro area inflation expectations. That notwithstanding influences of seven US macro news (CPI, GDP, industrial production, non farm payrolls, prices from ISM business surveys, purchasing manager indices on manufacturing and services) do not dominate influences of own news on euro area inflation expectations. A substantial number of significant coefficients show only news on non farm payrolls. CPI surprises and prices from ISM business surveys are less influential. The number of significant coefficients on US macro variables does not change over the course of the time speaking for a stable if any relationship among US news and euro area inflation expectations.

Using a two days-window for assessing the effect of monetary policy announcements on long-term interest rates does not change the results in the event study regressions qualitatively. Number and values of significant coefficients are mostly very close to estimations with a one-day window. Yet, coefficients on monetary policy news are somewhat higher with the first time period, ie before the intensification of the sovereign debt crisis. This speaks for monetary policy announcements have taken some time to be fully incorporated in inflation expectations.

Given the brevity of our data sample on options and the length of the forecasting horizon evaluating the forecasting performance is not a sensible exercise. In addition inflation options feature a low frequent macroeconomic variable as underlying which is in contrast to options written on financial time series. Apparently it is difficult to match the evolution of daily financial market data with monthly macroeconomic data. We therefore repeat the forecasting exercise with zero coupon inflation swaps with maturity of three years. In order not to increase the number of one-step ahead forecasts to much for a daily time series we derive the distribution of inflation expectations from 12 month ahead forecasts of the mean and conditional variances of an EGARCH(1,1) model.[5] The statistical distribution exhibits in turn far lower deflation probabilities compared to the risk neutral option-implied distribution (see Figure A-3 in the Appendix).[6]

Summing up, the decreasing influence of monetary policy announcements and the effect of macro news on inflation expectation is not driven by the selection of the window

[5]Using an EGARCH model to forecast conditional variances has the advantage of capturing the leverage effect that shocks in disturbances have exponential effects on the conditional variance and asymmetric responses to positive and negative shocks which might be akin to financial market options. The specification of an EGARCH(1,1) model for inflation expectations, IE_t at time t, is given as

$$IE_t = c + AR(1) + \epsilon_t \tag{14}$$

for the mean equation with c as constant, $AR(1)$ as a first order autoregressive term, ϵ_t as an error term, and

$$ln(\sigma^2) = \omega + \alpha \left| \frac{\epsilon_{t-1}}{\sigma_{t-1}} \right| + \beta ln(\sigma^2) + \gamma \frac{\epsilon_{t-1}}{\sigma_{t-1}} \tag{15}$$

for the conditional variance equation. ω is a constant, α describes the news about volatility from the previous period, ie the ARCH term, and β last periods forecast variance, ie the GARCH term. Finally γ depicts the leverage effect. If γ is below zero then negative shocks will have a far bigger impact on the conditional variance compared to positive shocks and vice versa.

[6]All regression and estimation results for the robustness checks are available from the authors upon request.

length or by the choice to include only news from the three biggest euro area member countries. The feature of risk-neutral densities to overestimate tail events is not based upon the use of the forecast model for the statistical distribution of inflation.

7 Conclusion

Inflation expectations for the euro area as measured through inflation option data show a decreasing mean over the last five years. Yet, uncertainty about the future realization of inflation rates soared among market participants especially since the intensification of the sovereign debt crisis in mid-2011. Around the same time the influence of monetary policy announcements measured as high frequency changes in long-term interest rates diminished. We reconcile both developments with a surge in disagreement over the influence of monetary policy towards future inflation outcomes especially towards extreme outcomes such as deflation or high inflation rates. In concordance with that the probability of deflation to occur increased in 2011 albeit from a low level. Measures of heterogeneity among euro area member countries such as differences in bond yields or inflation rates are identified as drivers of deflationary outcomes. With respect to macroeconomic news on inflation expectations the influence of news about countries more in the focus of the sovereign debt crisis like Italy increased.

Regarding the anchoring of inflation expectations during the sovereign debt crisis time varying event study regressions showed no increase in the reaction of inflation expectations to news, more so for monetary policy announcements than for macro variables. Yet, the rising standard deviation of inflation expectations for all horizons since mid-2011 might hint at a growing divergence of market participants beliefs about the way central bank actions influence future inflation rates. A diverging reaction function might not be a concern itself but might cover the risk of sudden swings towards extreme outcomes. This in turn might disanchor the mean and increase the reaction of inflation expectations to actual news.

The shortness of the inflation option data sample limits the application of methods and research questions considerably. Once the time series evolve questions like forecasting performance of inflation options alone or in comparison to survey data and other inflation forecasting models might be tested. Once the inflation options become more widely traded and listed on electronic trading platforms or even stock exchanges, liquidity will improve and could be judged in-depth. In addition a comparison of option-implied densities for the euro area, the UK and the US, and their interrelation might be explored in further research.

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8 Appendix

Tenor	Inflation swap rate % p.a.	Price of caps in % of notional ATM*	ATM* +50 bps	ATM* +100bps	Price of floors in % of notional ATM*	ATM* -50 bps	ATM* -100bps
1y	1.24	0.3	0.1	0.1	0.3	0.2	0.1
3y	1.33	1.2	0.7	0.4	1.2	0.6	0.3
5y	1.50	2.1	1.3	0.8	2.1	1.0	0.6
7y	1.63	3.3	2.1	1.3	3.3	1.7	1.0
10y	1.87	4.9	3.2	2.1	4.9	2.7	1.4

* At The Money options = ATM

Table A-1: Put call parity for various inflation caps and floors as of September 23, 2013.

Data on inflation options

Zero coupon inflation options

	strike price	ticker
Caps	1.00%	EUIZC11 CPIC Curncy
	1.50%	EUIZCB1 CPIC Curncy
	2.00%	EUIZC21 CPIC Curncy
	2.50%	EUIZCE1 CPIC Curncy
	3.00%	EUIZC31 CPIC Curncy
	3.50%	EUIZCH1 CPIC Curncy
	4.00%	EUIZC41 CPIC Curncy
	4.50%	EUIZCL1 CPIC Curncy
	5.00%	EUIZC51 CPIC Curncy
	5.50%	EUIZCI1 CPIC Curncy
	6.00%	EUIZC61 CPIC Curncy
Floors	-2.00%	EUIZFO1 CPIC Curncy
	-1.50%	EUIZFI1 CPIC Curncy
	-1.00%	EUIZFZ1 CPIC Curncy
	-0.50%	EUIZFX1 CPIC Curncy
	0.00%	EUIZF01 CPIC Curncy
	0.50%	EUIZFV1 CPIC Curncy
	1.00%	EUIZF11 CPIC Curncy
	1.50%	EUIZFB1 CPIC Curncy
	2.00%	EUIZF21 CPIC Curncy
	2.50%	EUIZFE1 CPIC Curncy
	3.00%	EUIZF31 CPIC Curncy
	3.50%	EUIZFH1 CPIC Curncy

Source: BGC Partners

Eonia swaps with maturities

1 year	EUSWE1 Curncy
3 year	EUSWE3 Curncy
5 year	EUSWE5 Curncy
10 year	EUSWE10 Curncy

Zero-coupon inflation swaps with maturities

1 year	EUSWI1 Curncy
3 year	EUSWI3 Curncy
5 year	EUSWI5 Curncy
10 year	EUSWI10 Curncy

Source: Bloomberg

Data on macro news

Actual releases and BN median survey

DE Current Account	GRCAEU Index
DE HICP	GRCP2HMM Index
DE ifo Business Climate	GRIFPBUS Index
DE Industrial Production	GRIPIMOM Index
DE PPI	GRPFIMOM Index
DE PMI Manufacturing	PMITMGE Index
DE PMI Services	PMITSGE Index
DE Unemployment Rate	GRUEPR Index
FR GDP	FRGEGDPQ Index
FR CPI	FRCPEECM Index
FR Business Confidence	INSESYNT Index
FR Industrial production	FPIPMOM Index
FR PPI	FRPIMOM Index
FR PMI Manufacturing	PMITMFR Index
FR PMI Services	PMITSFR Index
FR Unemployment Rate	FRUEREU Index
IT Real GDP	ITPIRLQS Index
IT HICP	ITCPEM Index
IT Business Confidence	ITBCI Index
IT Industrial Production	ITPRSANM Index
IT PPI	ITPNIMOM Index
IT PMI Manufacturing	PMITMIT Index
IT PMI Services	PMITSIT Index

Data on macro news (continued)

US Non-Farm Payroll	NFP TCH Index
US CPI	CPI CHNG Index
US Industrial Production	IP CHNG Index
US Prices Paid (ISM Business Report)	NAPMPRIC Index
US GDP	GDP CQOQ Index
US PMI Manufacturing	NAPMPMI Index
US Consumer Confidence	CONCCONF Index

Source: Bloomberg

Data on monetary policy announcements

Announcment dates according to:
Press conferences of the ECB
http://www.ecb.europa.eu/press/pressconf/2013/html/index.en.html

Press releases of the ECB on monetary policy
with effect for the whole euro aea
(excluding statements on eligibility of national sovereign bonds
and statements on publications and political statements)
http://www.ecb.europa.eu/press/pr/activities/mopo/html/index.en.html

Interest rates, financial variables and financial risk factor

Interest rate 10 year German bond yield
Interest rate GDP-weighted EMU average 10 year yield excl.Germany

HICPxt non seasonally adjusted, non working day adjusted,
for euro area in changing composition

CPI flash estimates

EMU	ECCPEMUY Index
Austria	ATCPYY10 Index
Belgium	BECPYOY Index
Cyprus	CYCPEHYY Index
Germany	GRCP20YY Index
Estonia	ESCPLYOY Index
Spain	SPCPEUYY Index
Finland	FICP2YOY Index
France	FRCPEECY Index
Greeece	GKCPIUHY Index
Ireland	IECPEUIY Index
Italy	ITCPNICY Index
Malta	MTCPEHYY Index
Netherlands	NECPEURY Index
Slovenia	SVCPYOY Index
Slowakia	SLCPLYOY Index

Crude oil / Brent / Market place London / US-$ per Barrel
DOW JONES EURO STOXX SXXE 31.12.1991=100
Euro USD reference rate as published by the ECB, 1 Euro = … USD
Gold price in London/ Daily afternoon fixing/ 1 ounce fine gold = ... EUR
EURO - BUND CONTINUOUS CALL
Option BUND-Future: 3M implied volatility constant maturity
VDAX-NEW DAX VOLATILTY INDEX - PRICE INDEX
KfW-Bund spread = difference between generic KfW bond yields
and German Bund yields of matching maturities.

Sources :Bloomberg, Bundesbank, Eurostat,
ECB, and Thomson Reuters.

Table A-2: Data description.

Regressions of inflation probabilities on financial variables°)			
Explaining variable	Brent oil price	Eurostoxx	€/US-$ exchange rate
Inflation probability over …			
… 1 year	0.26***/0.03	0.86***/0.02	0.24***/0.01
… 3 years	0.14***/0.03	0.64***/0.04	0.21***/0.02
… 5 years	0.12***/0.04	0.72***/0.08	0.17***/0.03
…. 10 years	0.11***/0.01	0.68***/0.07	0.18***/0.03
Extreme inflation probability over …			
… 1 year	0.06**/0.01	0.02*/0.01	0.01*/0.01
… 3 years	0.06***/0.01	0.04***/0.02	0.01***/0.01
… 5 years	0.07***/0.01	0.04***/0.01	0.01*/0.01
…. 10 years	0.11***/0.01	0.05***/0.02	0.01**/0.01
Deflation probability over …			
… 1 year	-0.11***/0.03	-0.34***/0.01	-0.15***/0.02
… 3 years	-0.11***/0.05	-0.44***/0.04	-0.14***/0.03
… 5 years	0.10***/0.06	-0.44**/0.07	-0.13**/0.03
…. 10 years	-0.05***/0.03	-0.32***/0.07	-0.10***/0.04
Extreme deflation probability over …			
… 1 year	-0.02***/0.02	-0.09***/0.01	-0.05***/0.02
… 3 years	-0.02***/0.05	-0.09***/0.05	-0.02***/0.03
… 5 years	-0.03***/0.04	-0.10***/0.04	-0.02***/0.02
…. 10 years	-0.01**/0.01	-0.04***/0.01	-

Regressions of inflation probabilities on heterogeneity variables°)		
Explaining variable	EWU-Bund spread	Dipersion of inflation rates#)
Inflation probability over …		
… 1 year	-0.39***/0.03	
… 3 years	-0.29**/0.01	
… 5 years	-0.21***/0.01	
…. 10 years	-0.17**/0.01	
Extreme inflation probability over …		
… 1 year		
… 3 years	-0.02**/0.01	
… 5 years	-0.01**/0.01	
…. 10 years	-0.01**/0.01	
Deflation probability over …		
… 1 year	0.15**/0.01	0.67*/0.05
… 3 years	0.16***/0.01	0.81**/0.09
… 5 years	0.13***/0.01	0.71**/0.08
…. 10 years	0.11**/0.01	0.38**/0.04
Extreme deflation probability over …		
… 1 year	0.04**/0.01	
… 3 years	0.03***/0.01	0.18*/0.12
… 5 years	0.02**/0.01	0.21**/0.09
…. 10 years		

Estimation equation: $\Delta P_{\pi^e t} = \beta Xt + \varepsilon t$, with Xt = oil prices, Eurostoxx, exchange rate, EMU Bund spread, and dispersion of inflation rates.

*, **, *** 10, 5, 1% significance level (HAC consistent t-stat)/ adjusted r^2. Blanks indicate no significant coefficient.

°) Estimation in log differences. #) Monthly regressions.

Table A-3: Inflation probabilities explained by financial variables and measures of heterogeneity.

Regression of inflation probabilities on macroeconomic news°)												
Time	**Whole sample: 2009-2013**				**10/2009-7/2011**				**8/2011-12/2013**			
Explained variables	Inflation probability over …				Inflation probability over …				Inflation probability over …			
Explaining variables:	… 1 year	… 3 years	… 5 years	…. 10 years	… 1 year	… 3 years	… 5 years	…. 10 years	… 1 year	… 3 years	… 5 years	…. 10 years
DE_CURRENT_ACCOUNT	0.10**								0.11*	-0.04*		
DE_HICP												
DE_IFO_BUSINESS_CLIMATE	0.10**		-0.05**		0.15***						-0.05*	
DE_INDUSTRIAL_PRODUCTION												
DE_PPI												
DE_UNEMPLOYMENT_RATE												
DE_PMI_MANUFACTURING					0.82*							
DE_PMI_SERVICES			-0.05**			-0.06*	-0.09***					
FR_BUSINESS_CONFIDENCE												
FR_CPI						0.05*	0.06**					
FR_GDP												
FR_INDUSTRIAL_PRODUCTION												
FR_PPI						-0.18**	-0.13**					
FR_UNEMPLOYMENT_RATE	-0.29**	-0.08*	-0.06*		-0.28**	-0.07*	-0.07*					
FR_PMI_MANUFACTURING												
FR_PMI_SERVICES												
IT_BUSINESS_CONFIDENCE				0.04*		0.05*	0.05***	0.06***				
IT_HICP									0.07*	0.06***		
IT_INDUSTRIAL_PRODUCTION									0.04**	0.04*	0.05**	0.05*
IT_PPI												
IT_REAL_GDP							0.04**					
IT_PMI_MANUFACTURING												
IT_PMI_SERVICES												
Adjusted r^2	0.05	0.01	0.01	0.01	0.16	0.08	0.08	0.08	0.01	0.01	0.01	0.02
Time	**Whole sample: 2009-2013**				**10/2009-7/2011**				**8/2011-12/2013**			
Explained variables	Deflation probability over …				Deflation probability over …				Deflation probability over …			
Explaining variables:	… 1 year	… 3 years	… 5 years	…. 10 years	… 1 year	… 3 years	… 5 years	…. 10 years	… 1 year	… 3 years	… 5 years	…. 10 years
DE_CURRENT_ACCOUNT										0.03*		
DE_HICP		-0.03*								-0.03*		
DE_IFO_BUSINESS_CLIMATE					-0.04*							
DE_INDUSTRIAL_PRODUCTION				-0.03*								-0.05**
DE_PPI												
DE_UNEMPLOYMENT_RATE												
DE_PMI_MANUFACTURING	-0.08*				-0.09*							
DE_PMI_SERVICES						0.05**	0.06***	0.06***				
FR_BUSINESS_CONFIDENCE												
FR_CPI									-0.03***			
FR_GDP					-0.02*							
FR_INDUSTRIAL_PRODUCTION												
FR_PPI						0.12***	0.12**					
FR_UNEMPLOYMENT_RATE	0.04*				0.05***	0.03**	0.02*	0.02*				-0.06**
FR_PMI_MANUFACTURING												
FR_PMI_SERVICES												
IT_BUSINESS_CONFIDENCE			-0.02**	-0.02**		-0.03**	-0.02***	-0.02***				
IT_HICP									-0.18**			
IT_INDUSTRIAL_PRODUCTION									-0.04***	-0.03*		
IT_PPI	-0.04**	-0.04**								-0.06**		
IT_REAL_GDP					-0.02*							
IT_PMI_MANUFACTURING				-0.02*								
IT_PMI_SERVICES												
Adjusted r^2	0.02	0.01	0.01	0.02	0.03	0.08	0.09	0.11	0.06	0.02	0.01	0.03

Regression of inflation probabilities on macroeconomic news°) (continued)												
Time	**Whole sample: 2009-2013**				**10/2009-7/2011**				**8/2011-12/2013**			
Explained variables	Extreme inflation probability over …				Extreme inflation probability over …				Extreme inflation probability over …			
Explaining variables:	… 1 year	… 3 years	… 5 years	…. 10 years	… 1 year	… 3 years	… 5 years	…. 10 years	… 1 year	… 3 years	… 5 years	…. 10 years
DE_CURRENT_ACCOUNT	0.10*				0.01**							
DE_HICP												
DE_IFO_BUSINESS_CLIMATE	0.07*				0.01**							
DE_INDUSTRIAL_PRODUCTION												
DE_PPI												
DE_UNEMPLOYMENT_RATE									-0.02*			
DE_PMI_MANUFACTURING					0.02*							
DE_PMI_SERVICES												
FR_BUSINESS_CONFIDENCE									0.01*			
FR_CPI												
FR_GDP	0.05**				0.01***							
FR_INDUSTRIAL_PRODUCTION					0.01*							
FR_PPI												
FR_UNEMPLOYMENT_RATE	-0.11**	-0.01*			-0.01**							
FR_PMI_MANUFACTURING												
FR_PMI_SERVICES												-0.01*
IT_BUSINESS_CONFIDENCE				0.03*			0.02*	0.01**				
IT_HICP										0.01*		
IT_INDUSTRIAL_PRODUCTION			0.01*								0.02*	0.01*
IT_PPI												
IT_REAL_GDP							0.01***	0.01*				
IT_PMI_MANUFACTURING								-0.01*				
IT_PMI_SERVICES												
Adjusted r^2	0.01	0.01	0.01	0.01	0.06	0.04	0.02	0.05	0.03	0.03	0.04	0.02
Time	**Whole sample: 2009-2013**				**10/2009-7/2011**				**8/2011-12/2013**			
Explained variables	Extreme deflation probability over …				Extreme deflation probability over …				Extreme deflation probability over …			
Explaining variables:	… 1 year	… 3 years	… 5 years	…. 10 years	… 1 year	… 3 years	… 5 years	…. 10 years	… 1 year	… 3 years	… 5 years	…. 10 years
DE_CURRENT_ACCOUNT										0.03**		
DE_HICP		-0.07**										
DE_IFO_BUSINESS_CLIMATE												
DE_INDUSTRIAL_PRODUCTION												
DE_PPI												
DE_UNEMPLOYMENT_RATE			0.04*						0.01*		0.01*	
DE_PMI_MANUFACTURING												
DE_PMI_SERVICES								0.01**				
FR_BUSINESS_CONFIDENCE												
FR_CPI		-0.01*										
FR_GDP									0.01**			
FR_INDUSTRIAL_PRODUCTION												
FR_PPI		0.01**				0.03***	0.02***					
FR_UNEMPLOYMENT_RATE	0.01*				0.01**	0.01*	0.06*	0.04**				-0.05*
FR_PMI_MANUFACTURING												
FR_PMI_SERVICES												
IT_BUSINESS_CONFIDENCE		-0.01*	-0.04**			-0.03*	-0.04***	-0.02***				
IT_HICP				-0.01*								
IT_INDUSTRIAL_PRODUCTION									-0.01**	-0.01*		-0.01**
IT_PPI		-0.01*							-0.01**	-0.02**		
IT_REAL_GDP					-0.01*		-0.02*					
IT_PMI_MANUFACTURING			0.01*	0.01*								0.01*
IT_PMI_SERVICES			-0.01**									
Adjusted r^2												

Estimation equation:

$$\Delta P_{\pi^e,t} = \sum_{j=1}^{J} \beta_j s_{j,t} + \gamma_n m_{n,t} + \varepsilon_t \quad \text{, with j = 1,…, 23: macro news for Germany, France, and Italy.}$$

*, **, *** 10, 5, 1% significance level (HAC consistent t-stat). Blanks indicate no significant coefficient. °) Controlled with monetary policy announcements.

Table A-4: Event study regressions of inflation probabilities on macro news.

Regression of inflation probabilities on monetary policy announcements°)			
	Whole sample	***Sample split***	
Time	**2009-2013**	**10/2009-7/2011**	**8/2011-12/2013**
Observations	1108	475	632
Explaining variable: changes in German Bund yields on event days			
Inflation probability over …			
… 1 year		0.71***/0.16	
… 3 years	0.38***/0.01	0.69***/0.08	
… 5 years	0.28*/0.01	0.65***/0.08	
…. 10 years	0.41**/0.02	0.75***/0.08	
Extreme inflation probability over …			
… 1 year		0.04**/0.06	
… 3 years	0.03**/0.01	0.05***/0.04	
… 5 years		0.04***/0.02	
…. 10 years	0.04*/0.01	0.06***/0.05	
Deflation probability over …			
… 1 year	-0.22*/0.02	-0.31***/0.03	
… 3 years	-0.24***/0.01	-0.26***/0.08	
… 5 years		-0.25***/0.09	
…. 10 years		-0.28***/0.11	
Extreme deflation probability over …			
… 1 year	-0.05*/0.01	-0.09***/0.02	
… 3 years	-0.04**/0.01	-0.05***/0.06	
… 5 years			
…. 10 years		-0.06**/0.02	
Explaining variable: changes in GDP-weighted other EMU member states bond yields			
Inflation probability over …			
… 1 year		-0.82**/0.16	
… 3 years		-0.75***/0.08	
… 5 years		-0.72***/0.07	
…. 10 years		-0.69***/0.06	
Extreme inflation probability over …			
… 1 year			
… 3 years		-0.07***/0.04	
… 5 years		-0.04*/0.02	
…. 10 years		-0.06***/0.04	
Deflation probability over …			
… 1 year		0.32**/0.04	-0.25*/0.07
… 3 years		0.25**/0.07	
… 5 years		0.33***/0.09	
…. 10 years		0.25***/0.11	
Extreme deflation probability over …			
… 1 year		0.11***/0.02	-0.05**/0.02
… 3 years			
… 5 years			
…. 10 years			

Estimation equation:

$$\Delta P_{\pi^e,t} = \sum_{j=1}^{J} \beta_j s_{j,t} + \gamma_n m_{n,t} + \varepsilon_t$$, with n = 1, 2: ten year German Bund yield, and GDP-weighted average of other euro area ten year government bond yields.

*, **, *** 10, 5, 1% significance level (HAC consistent t-stat)/ adjusted r^2. Blanks indicate no significant coefficient. °) Controlled with 23 time series of macroeconomic news.

Table A-5: Event study regressions of inflation probabilities on monetary policy announcements.

Regressions of higher moments of inflation probabilities on monetary announcements and macro news												
Time	**Whole sample: 2009-2013**				**10/2009-7/2011**				**8/2011-12/2013**			
	Explained variables **Mean** of inflation probability over …				**Mean** of inflation probability over …				**Mean** of inflation probability over …			
Explaining variables:	… 1 year	… 3 years	… 5 years	…. 10 years	… 1 year	… 3 years	… 5 years	…. 10 years	… 1 year	… 3 years	… 5 years	…. 10 years
Monetary policy news on German Bunds				1.11**	2.39***	2.01***	1.84***	2.12***				
DE_CURRENT_ACCOUNT	0.25**	1.26***	0.78*									
DE_HICP												
DE_IFO_BUSINESS_CLIMATE	0.25**				0.42***							
DE_INDUSTRIAL_PRODUCTION									-0.31*			
DE_PPI												
DE_UNEMPLOYMENT_RATE												
DE_PMI_MANUFACTURING					1.80**							
DE_PMI_SERVICES			-0.14*				-0.24***	-0.16*				
FR_BUSINESS_CONFIDENCE												
FR_CPI									0.19**			
FR_GDP												
FR_INDUSTRIAL_PRODUCTION												
FR_PPI							-0.47***	-0.23**				
FR_UNEMPLOYMENT_RATE					-0.55*	-0.58**						
FR_PMI_MANUFACTURING												
FR_PMI_SERVICES												
IT_BUSINESS_CONFIDENCE			0.12**	0.13***		0.17*	0.15***	0.18***				
IT_HICP												
IT_INDUSTRIAL_PRODUCTION								0.12**			0.18*	0.16*
IT_PPI												
IT_REAL_GDP					0.16*	0.10**	0.14***	0.13***			-0.13**	
IT_PMI_MANUFACTURING												
IT_PMI_SERVICES												
Adjusted r^2	0.03	0.01	0.01	0.01	0.13	0.08	0.09	0.10	0.01	0.01	0.01	0.01
Time	**Whole sample: 2009-2013**				**10/2009-7/2011**				**8/2011-12/2013**			
	Explained variables **Standarddeviation** of inflation probability over …				**Standarddeviation** of inflation probability over …				**Standarddeviation** of inflation probability over …			
Explaining variables:	… 1 year	… 3 years	… 5 years	…. 10 years	… 1 year	… 3 years	… 5 years	…. 10 years	… 1 year	… 3 years	… 5 years	…. 10 years
Monetary policy news on German Bunds		-0.23***			-0.51***	-0.41***						
DE_CURRENT_ACCOUNT	-0.14**				-0.13*				-0.18*			
DE_HICP										-0.03***		
DE_IFO_BUSINESS_CLIMATE					-0.17*							
DE_INDUSTRIAL_PRODUCTION											0.06*	
DE_PPI												
DE_UNEMPLOYMENT_RATE											-0.05*	
DE_PMI_MANUFACTURING												
DE_PMI_SERVICES												
FR_BUSINESS_CONFIDENCE												
FR_CPI												
FR_GDP					-0.11*							
FR_INDUSTRIAL_PRODUCTION		0.05**				0.05*	0.05*	0.03**		0.07*		
FR_PPI												
FR_UNEMPLOYMENT_RATE	0.15**				0.12**							
FR_PMI_MANUFACTURING												
FR_PMI_SERVICES				0.04*								0.03*
IT_BUSINESS_CONFIDENCE			-0.02**	-0.03**			-0.03*	-0.03*				
IT_HICP		-0.03*										
IT_INDUSTRIAL_PRODUCTION							-0.05*			-0.07**		
IT_PPI								-0.03**				
IT_REAL_GDP						-0.03*	-0.03**				0.03*	
IT_PMI_MANUFACTURING												
IT_PMI_SERVICES			0.05*	0.05*				0.09*				
Adjusted r^2	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.05	0.01	0.01	0.01	0.02
Time	**Whole sample: 2009-2013**				**10/2009-7/2011**				**8/2011-12/2013**			
	Explained variables **Skewness** of inflation probability over …				**Skewness** of inflation probability over …				**Skewness** of inflation probability over …			
Explaining variables:	… 1 year	… 3 years	… 5 years	…. 10 years	… 1 year	… 3 years	… 5 years	…. 10 years	… 1 year	… 3 years	… 5 years	…. 10 years
Monetary policy news on German Bunds		-4.31*			-6.58***		-6.68***	-7.91***				
DE_CURRENT_ACCOUNT												
DE_HICP		-0.76**								-0.95*		
DE_IFO_BUSINESS_CLIMATE												
DE_INDUSTRIAL_PRODUCTION				-0.98*								-1.54**
DE_PPI												
DE_UNEMPLOYMENT_RATE												
DE_PMI_MANUFACTURING												
DE_PMI_SERVICES			0.74*	0.89*			1.63**	2.24**				
FR_BUSINESS_CONFIDENCE	0.96*											
FR_CPI									-1.46**			
FR_GDP												
FR_INDUSTRIAL_PRODUCTION					-1.63***	-0.36*						
FR_PPI	1.91**						3.11**		1.20*			
FR_UNEMPLOYMENT_RATE						2.41**						-1.84***
FR_PMI_MANUFACTURING												
FR_PMI_SERVICES												
IT_BUSINESS_CONFIDENCE			-0.53**	-0.44**		-0.73*	-0.69***	-0.67***				
IT_HICP												-0.51*
IT_INDUSTRIAL_PRODUCTION												
IT_PPI												
IT_REAL_GDP					-0.84**						0.43*	
IT_PMI_MANUFACTURING												
IT_PMI_SERVICES								-0.94*				
Adjusted r^2	0.01	0.01	0.01	0.01	0.02	0.05	0.09	0.01	0.01	0.01	0.01	0.01

Estimation equation:

$$\Delta HMP_{\pi^e,t} = \sum_{j=1}^{J} \beta_j s_{j,t} + \gamma_n m_{n,t} + \varepsilon_t \text{ , with } HMP = 1, 2, 3\text{: mean, standard deviation, and skewness of probability distribution of inflation expectations.}$$

*, **, *** 10, 5, 1% significance level (HAC consistent t-stat). Blanks indicate no significant coefficient.

Table A-6: Event study regressions of higher moments of inflation probabilities on monetary policy and macro news.

Regressions of inflation probabilities on financial risk factors°			
Explaining variable	Implied volatility of BUND future	VDAX	KfW-BUND spread
Inflation probability over …			
… 1 year			-0.36**/0.02
… 3 years			-0.29**/0.03
… 5 years	-1.47*/0.04		-0.19*/0.03
…. 10 years		-0.41*/0.01	
Extreme inflation probability over …			
… 1 year			
… 3 years			
… 5 years			
…. 10 years		-0.08*/ 0.01	-0.04*/0.01
Deflation probability over …			
… 1 year		0.47*/0.02	
… 3 years			0.23*/0.03
… 5 years	1,25*/0.04		
…. 10 years			
Extreme deflation probability over …			
… 1 year			
… 3 years			
… 5 years			
…. 10 years		0.10**/0.01	

Estimation equation: $\Delta P_{\pi^e t} = \beta Xt + \varepsilon t$ with Xt = implied volatility, VDAX, and KfW-Bund spread.

*, **, *** 10, 5, 1% significance level (HAC consistent t-stat)/ adjusted r^2. Blanks indicate no significant coefficient. °) Estimation in log differences.

Table A-7: Inflation probabilities explained by financial risk variables.

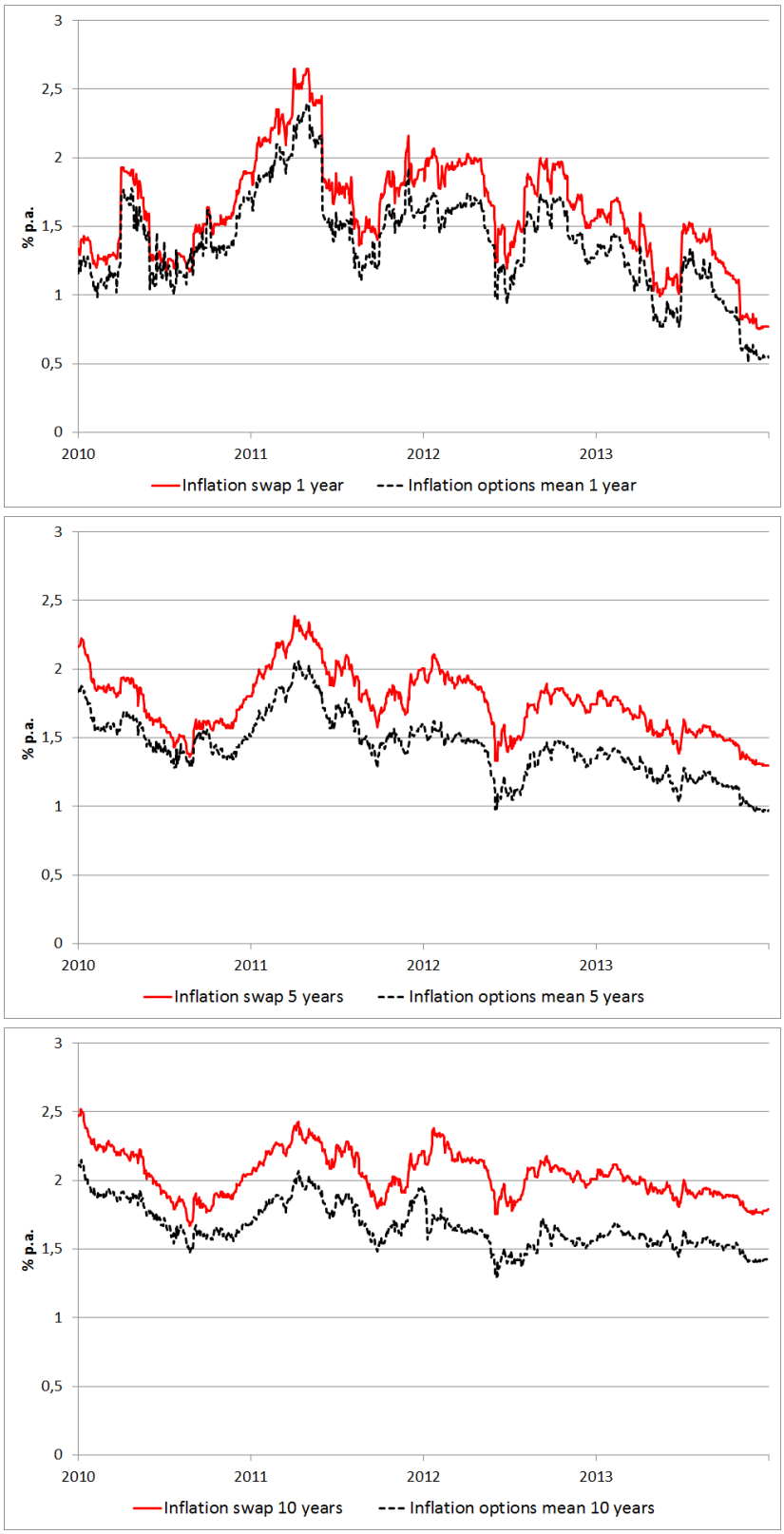

Figure A-1: Comparison of option-implied mean of inflation expectations and the fixed leg of inflation swaps for one, five, and ten year horizons.

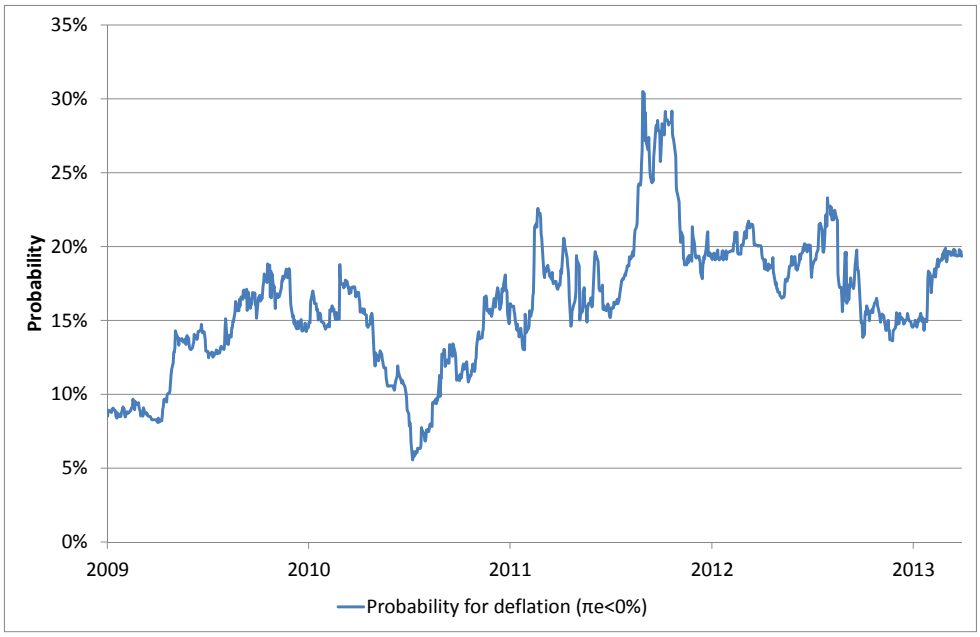

Figure A-2: Risk neutral probability for deflation for a five year horizon.

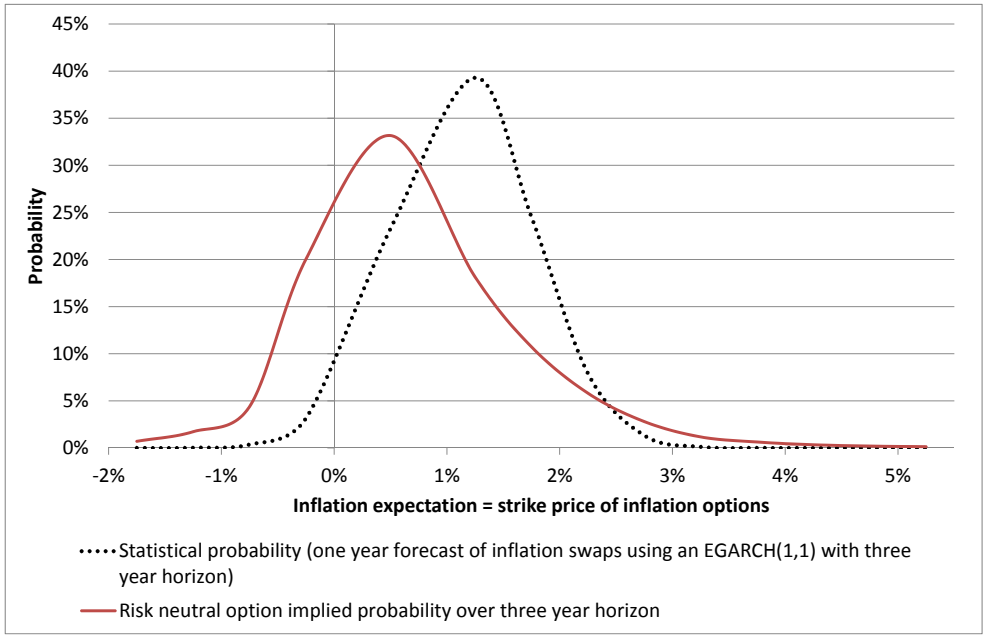

Figure A-3: Comparison of option-implied and statistical probability density forecasts for inflation expectations as of December 31, 2013.