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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Abstract

We tackle two questions in this paper: In the sovereign debt crisis, what moves euro area inflation outlook and has the firm anchoring of medium to long-term inflation expectations been touched? We try to answer these questions by looking at option-implied probability density functions of future inflation. Deriving densities from a new data set on options on the euro area harmonised index of consumer prices (without tobacco) provides us with the full distribution of inflation expectations including uncertainty and asymmetry of market participants beliefs about the inflation outlook. The daily data set allows us to analyse 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 all horizons of 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. For judging the anchoring of inflation expectations the new data set provides somewhat contradictory results. The mean and low reactivity 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.

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Keywords: inflation expectations, deflation, options, monetary policy, financial crisis.

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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 realisations of inflation rates, and only marginal reaction of 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 the overall price level 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 control the overall price level and to implement the right measures to maintain price stability in the long run.

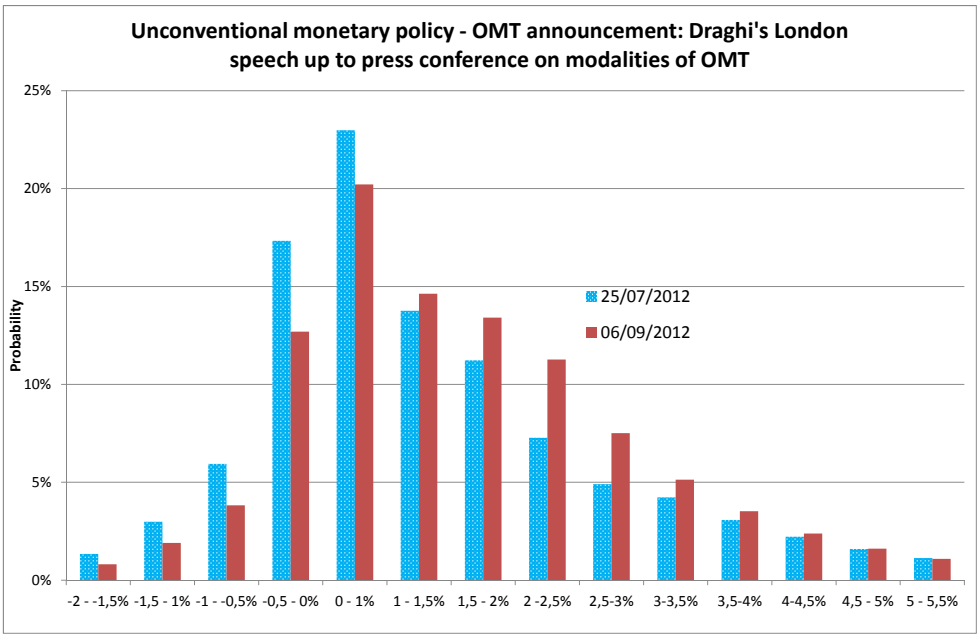

Figure 1: Probability distribution of expected inflation rates over the next five years.

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 realisations of inflation rates. 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 2013 (see figure 1). Furthermore we will analyse 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. Yet, uncertainty about the future realisation 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 measured by macroeconomic surprises the influence of news 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 analyse 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. 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 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 (2013) 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 (Bowles, Friz, Genre, Kenny, Meyler, and Rautannen (2007)) shows in addition the distribution of probabilities of different future inflation rates and can therefore be used to replicate aggregate uncertainty measures. However their low frequency - quarterly for the SPF - makes it difficult to analyse the influence of news on a timely basis.

We use European call and put options on the euro area harmonised consumer price ex tobacco (HICPxT) derive implied densities and look at the distribution of inflation expectations on a daily basis. We furthermore 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 recently conducted 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 Wright and Kitsul (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 analyse economic drivers.

2.1 Inflation options

An inflation call option is a contract that gives the holder the right to get compensation payments if the predetermined inflation rate is above the inflation rate at a certain date in the future (cap). It involves no obligation if the realised 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 payouts 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 annualised inflation rate of 2%, a notional amount of €100, and a maturity of one year. At maturity the realised 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 realised 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 i.e. the inflation rate over the maturity of the option is - differently from other options such as stock options - not daily observable. The price of delivery of the realised 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 costed €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 crises. 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 HICP view. According to the SEC filings PIMCO[1] has written several inflation floors.

The entirely 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)). No reliable information is available which contracts trade more and which less, so we take all contracts available into account in our estimation. Arbitrage anomalies, such as single strike prices leading to negative probabilities when put into the continuum of strike prices and extracting option-implied densities, occur only in a negligible number of cases in our data set. We therefore considered them as outliers. Occasional checks for put call parity for at the money options showed no violations. 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 payouts 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. An example for the put call parity for the inflation option data can be seen in the appendix in table A-1. We judged information out of inflation options data as being meaningful in describing market participants aggregated beliefs about future inflation levels consequentially. 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 do 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. 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

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

and EONIA interest rate swaps on the respective maturities are taken from Bloomberg well. EONIA swaps exchange daily flexible interest payments as given by the Euro OverNight Index Average against fixed payments for the maturity of the contract. EONIA swaps do neither contain a country-specific default risk such as government bonds nor a counterparty risk as do unsecured money market rates such as Euribor or swaps on 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 return 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

$$C = e^{-rT} \int_{S_T=K}^{\infty} (S_T - K) g(S_T) d_T \tag{2.1}$$

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

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

with respect to the strike price is then

$$\frac{\partial c^2}{\partial K^2} = e^{-rT} g(K) \tag{2.2}$$

where

$$g(K) = e^{-rT} \frac{C_1 + C_3 - 2C_2}{\delta^2} \tag{2.3}$$

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

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 price above 4%, and extreme deflation with exercise price 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 one percent for most maturities. The evolution of the first three clusters of inflation expectations over the next five years over the sample are shown in figure 2.

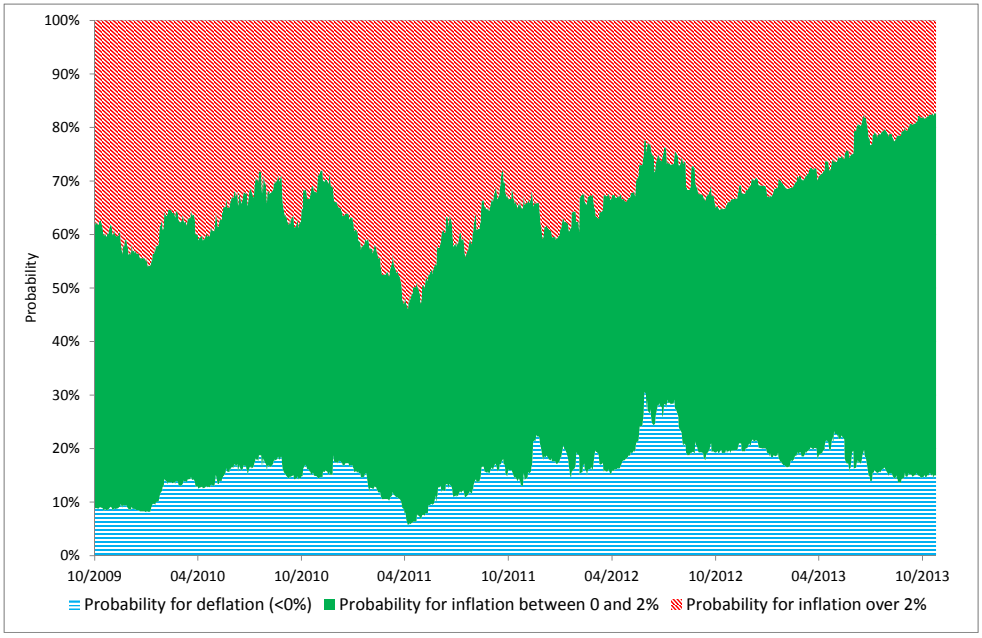

Figure 2: Evolution of probability distribution of expected inflation rates over the next five years.

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 it's parameter by minimising 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)). Since the focus of this paper is on relating inflation expectations to monetary policy and macro news and not the exact pricing of inflation options we decided for a standard estimation technique. We use the mixture of two lognormals a functional form 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)). It's disadvantage is that it can generate density functions characterised by sharp spikes (Clews et al. (2000)).

The fitted call prices are minimised 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

$$g(S_T) = \theta L(\alpha_1, \beta_1) + (1-\theta)L(\alpha_2, \beta_2), \tag{2.4}$$

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

$$\hat{C}(S, K, T) = e^{-rT} \int_{S_T=K}^{\infty} (S_T - K)[\theta L(\alpha_1, \beta_1) + (1-\theta)L(\alpha_2, \beta_2) dS_T]. \tag{2.5}$$

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 minimised in both directions. Resulting probability density functions for inflation options with a three year horizon can be seen in figure 6.

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 of the currency union. 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. 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 the surprise effect is measured as the change in long-term interest rates of German bonds and as the change in a GDP-weighted average of other euro area members bond yields. 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 (Wright (2012)) to two days (Neely (2010)). We control for relevant macro and 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 standardise news by the standard deviation and subtract the average daily changes over the whole period of the respective time series.

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 small sample of mostly minor 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. All data is taken from Bloomberg.

Monetary policy surprises are calculated at the respective dates of the announcement of interest rate decisions and of unconventional measures in press conferences following Governing Council meetings, press releases and a restricted number of important speeches. Unconventional measures comprises 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. 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 as indicators of

monetary policy surprises. Again the rates are standardised 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 save 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 price series representing developments in other markets. In concordance with the literature about inflation formation we looked at daily changes in crude oil prices and in a share price index. 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 and with the broad stock market index EuroSTOXX (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 also to a lesser extent. 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 growing activity which gives the link to inflation probabilities by a mounting price pressure in the 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. Overall adjusted r-squares for the log difference regressions are

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

Table 1: Standard deviation and mean of yield changes on event days and non event days.

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.

$$\Delta p_{I,t} = \sum_{j=1}^{J} \beta_j s_{j,t} + \sum_{n=1}^{N} \gamma_n m_{n,t} + \epsilon_t \tag{3.6}$$

with $\Delta p_{I,t}$ 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, γ_n as the coefficient

of the announcement m_n of the monetary policy variable n, and ϵ_t as 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 1 respectively indicating that multicollinearity is not an issues with our event study regressions.

The dispersion of the standardised news on German, French and Italian real economy data in figure 3 shows somewhat astonishingly no cyclical movement, having in mind the cyclical up- and downswings of the euro area economy during that time. In addition one can not see an overweight of negative surprises which would have been in concordance with a decrease in inflation expectations over the respective period as depicted in figure 5.

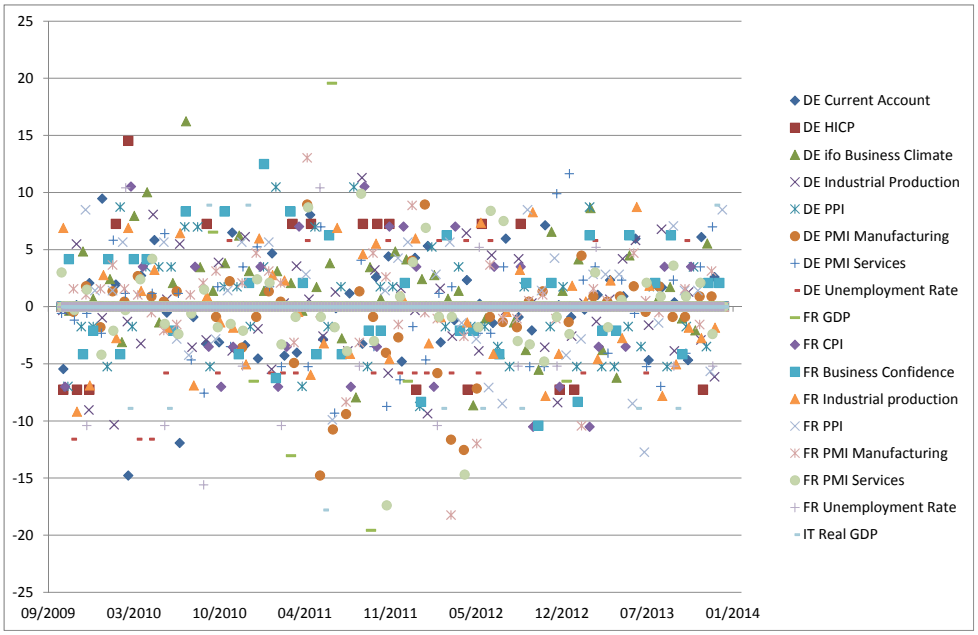

Figure 3: Dispersion of macro surprises.

Looking at the event study regressions we see an impact of standardised 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 an 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. 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.

As mentioned in the data section 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 0.01) and only a marginal number of significant coefficients for business confidence and producer price indices.

Monetary policy surprises calculated as the change in the long term rates 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 euro system 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 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 believe 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 reaction of market participants on the same news.

As a first approximation to analyse 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 (Chow break point test and Bai-Perron multiple break point test of sequentially determined breaks) mostly suggests autumn 2011 as a break point for regressions including monetary policy announcements. 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 last column 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

$$y_t = x_t'\beta_t + u_t \tag{4.7}$$

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.[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 actual 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"

$$r_M^2(\beta) = \sum_{t=1}^{T} u_t^2 \tag{4.8}$$

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

$$r_D^2(\beta) = \sum_{t=2}^{T} (\beta_t - \beta_{t-1})'(\beta_t - \beta_{t-1}) \tag{4.9}$$

(4.8) and (4.9) 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

$$C(\beta, \mu) = (1-\mu) r_M^2(\beta) + \mu r_D^2(\beta) \tag{4.10}$$

can be assigned, 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

$$\hat{\beta}_t^{FLS} = \min C(\beta, \mu) \tag{4.11}$$

minimizes these costs. 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 a 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 4, upper graph).[4] Coefficients on

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

[4]Setting the weights to the measurement and dynamic error term prevent us from calculating standard confidence bands. We followed Luetkepohl (1993) and calculated average coefficients and standard deviations for sample splits (see table A-7 in the appendix).

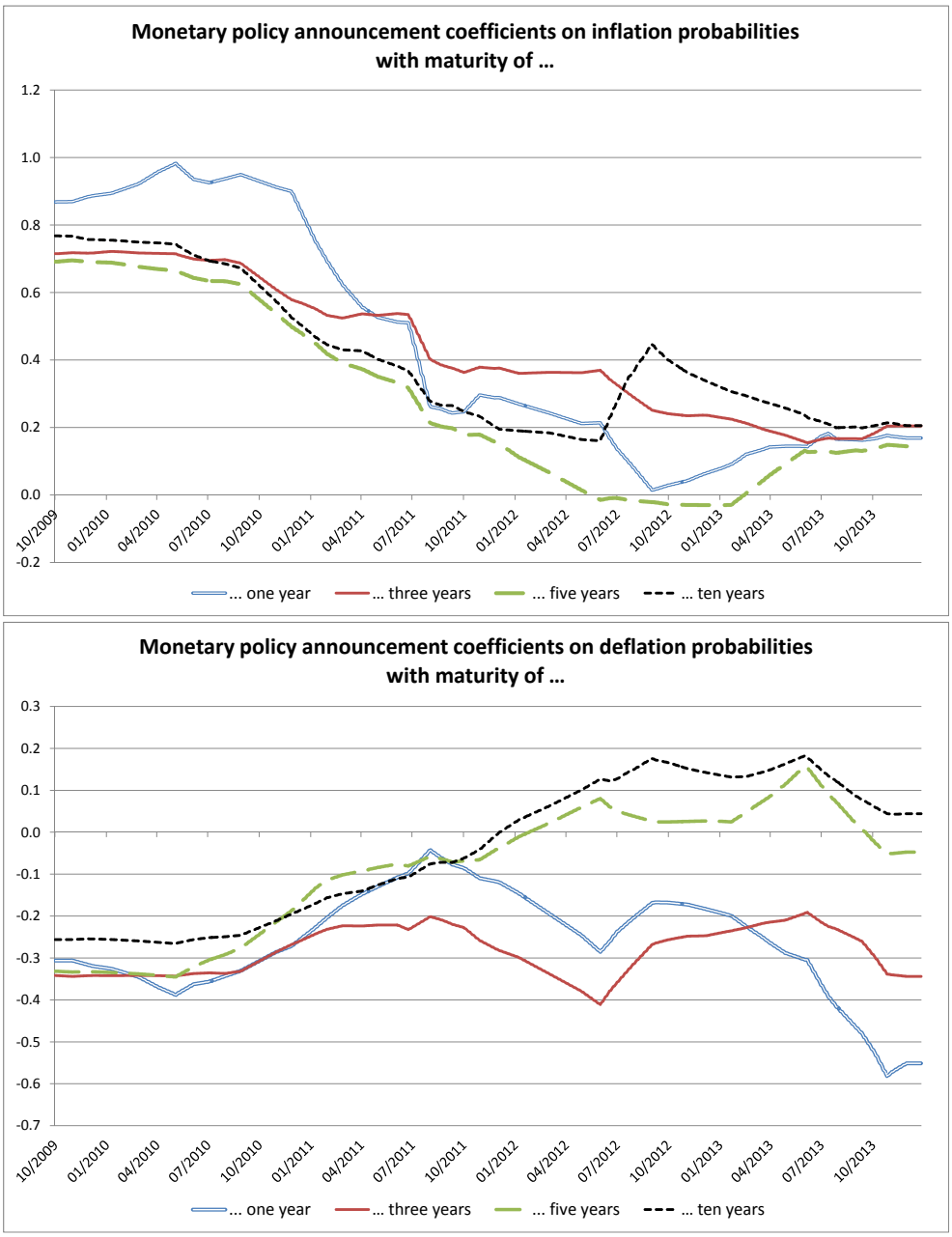

Figure 4: Time varying coefficients of monetary policy announcements.

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 taken in line with the price level stability goal but not in order to achieve it.

For deflation expectations the evolution of regression coefficients is less even over maturities (see figure 4, lower graph). At shorter horizons expansionary monetary policy news had a negative impact on deflation probabilities, ie moved inflation expectations down. That downward movements accelerated in 2013 when inflation rates fell below two percentage points throughout the year. Coefficients stayed significant over 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

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 5 for the three year horizon and figure A-1 in the appendix 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 crises. 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

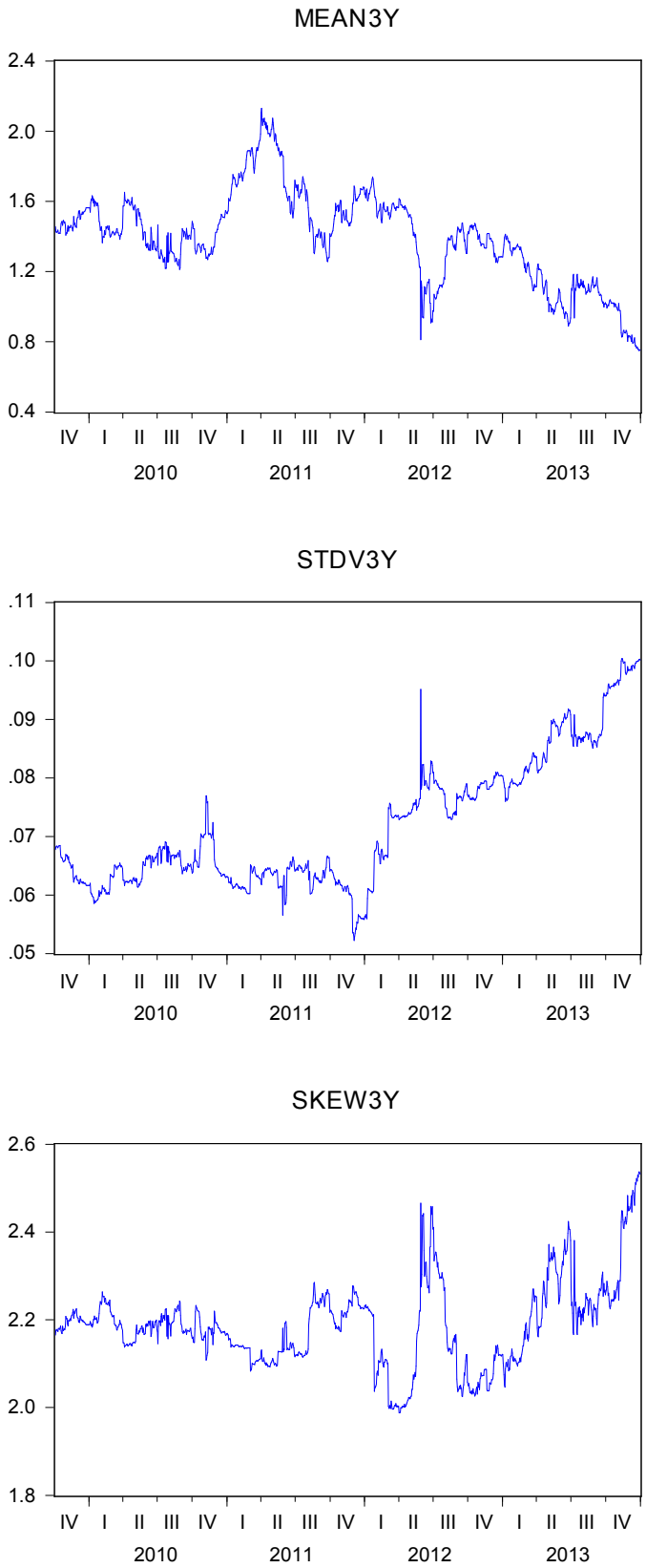

Figure 5: Higher moments of probability density functions for three year horizons.

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.

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 banks 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 a 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 two percentage point 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 one percentage point 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 the lower part in figure 2 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 over 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. In order not to overestimate the probabilities of tail events the risk neutral density function must be corrected consequentially. 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 this features they suggest to use long-term survey forecasts as trend level of inflation τ_t. They define the inflation gap g_t as

$$g_t = \pi_t - \tau_t \tag{5.12}$$

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

$$g_{t+h} = \rho_0 + \sum_{j=1}^{p} \rho_j g_{t-j} + \epsilon_{t+h} \tag{5.13}$$

iterate this forward to g_{T+h} and add τ_T back to the gap forecast to get the implied inflation forecast. h is the step size of the forecast, here one month, and 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

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[5] 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 6, upper part) 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.

Given the brevity of our data sample on options and the length of the forecasting horizon an evaluation of 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.[6] The statistical distribution exhibits in turn far lower deflation probabilities compared to the risk neutral option implied distribution (see figure 6, lower part).

Despite the severe negative outcomes that are associated with deflation 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-8 in the appendix). That notwithstanding

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

[6]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

$$IE_t = c + AR(1) + \epsilon_t \tag{5.14}$$

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

$$ln(\sigma^2) = \omega + \alpha \left| \frac{\epsilon_{t-1}}{\sigma_{t-1}} \right| + \beta ln(\sigma^2) + \gamma \frac{\epsilon_{t-1}}{\sigma_{t-1}} \tag{5.15}$$

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

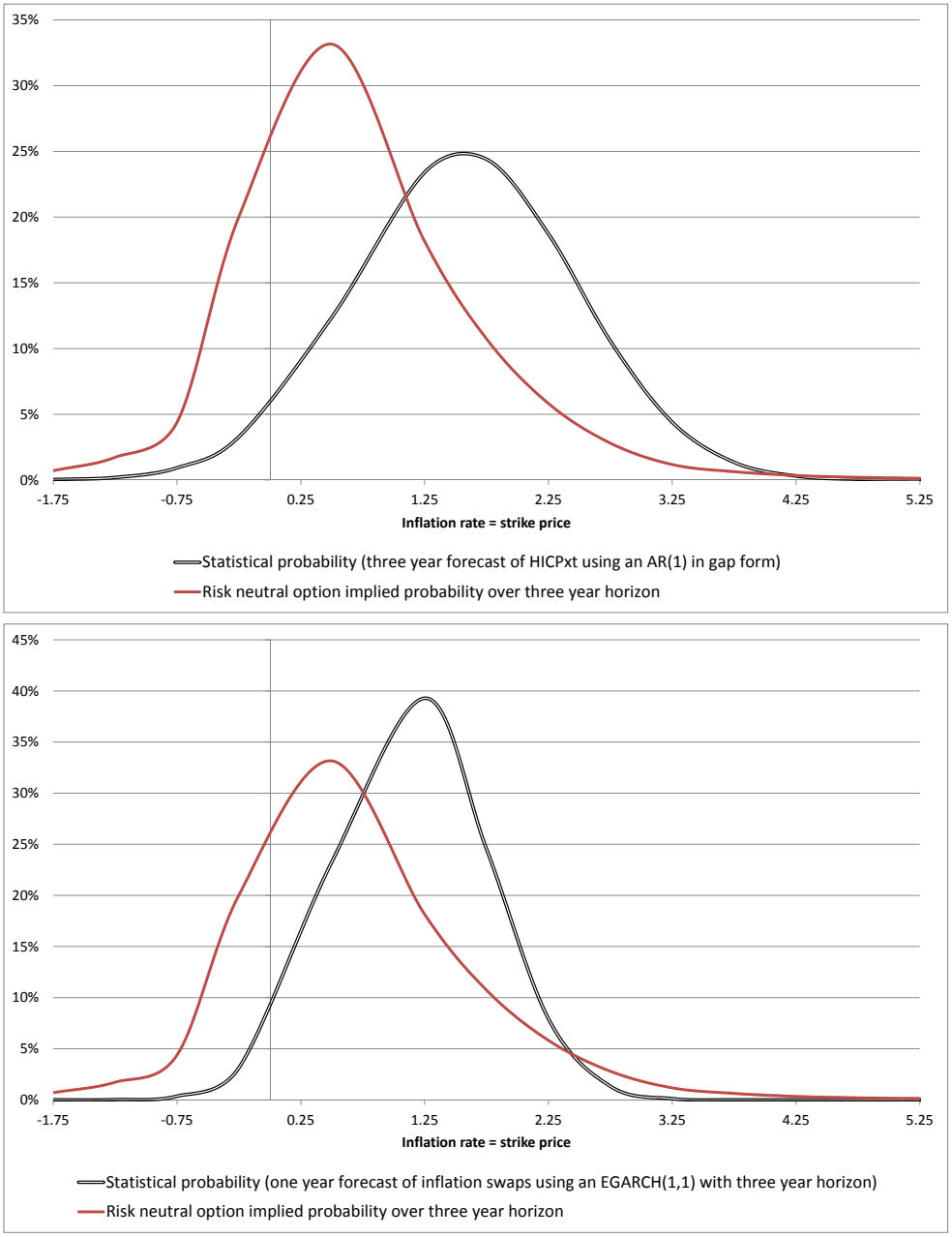

Figure 6: Comparison of inflation and deflation probabilities derived from options and statistical forecasts as of 31.12.2013.

deflation probabilities are significantly negatively correlated with financial market and commodity prices such as share price indices 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-1 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.

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 over the short horizon.

6 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 realisation 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 measured by macroeconomic surprises 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-2001 might hint at a growing divergence of market participants beliefs about the way central banks 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. 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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7 Appendix

	ATM* HICPxt	Caps in % of notional			Floors in % of notional		
	swap rate	ATM	ATM	ATM	ATM	ATM	ATM
Tenor	%		+50 bps	+100bps		-50 bps	-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: Pricing as of September 23, 2013 of various HICPxT caps and floors in the market.

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

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 raters, 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

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, and Thomson Reuters.

Table A-2: Data description.

Inflation probabilities and financial variables°)		
Explaining variable	Brent oil price	Eurostoxx
Inflation probability over …		
… 1 year	0.26***/0.03	0.86***/0.02
… 3 years	0.14***/0.03	0.64***/0.04
… 5 years	0.12***/0.04	0.72***/0.08
…. 10 years	0.11***/0.01	0.68***/0.07
Extreme inflation probability over …		
… 1 year	0.06**/0.01	0.02*/0.01
… 3 years	0.06***/0.01	0.04***/0.02
… 5 years	0.07***/0.01	0.04***/0.01
…. 10 years	0.11***/0.01	0.05***/0.02
Deflation probability over …		
… 1 year	-0.11***/0.03	-0.34***/0.01
… 3 years	-0.11***/0.05	-0.44***/0.04
… 5 years	0.10***/0.06	-0.44**/0.07
…. 10 years	-0.05***/0.03	-0.32***/0.07
Extreme deflation probability over …		
… 1 year	-0.02***/0.02	-0.09***/0.01
… 3 years	-0.02***/0.05	-0.09***/0.05
… 5 years	-0.03***/0.04	-0.10***/0.04
…. 10 years	-0.01**/0.01	-0.04***/0.01
Inflation probabilities and 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	-	-

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

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

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

Inflation probabilities and 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												
DE_PMI_SERVICES			-0.05**		0.82*	-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												

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												

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												

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**									

*, **, *** 10, 5, 1% significance level (HAC consistent t-stat)

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

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

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

°) Controlled with 23 time series of macroeconomic news.

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

Higher moments of inflation probabilities and effects of monetary announcements and macroeconomic 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												
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											-0.05*	
DE_UNEMPLOYMENT_RATE												
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*				
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*				

*, **, *** 10, 5, 1% significance level (HAC consistent t-stat)

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

Average coefficients and standard deviation* of time varying regressions		
	Sample split	
Time	**10/2009-7/2011**	**8/2011-12/2013**
Observations	475	632
Explainig variable: changes in German bond yields on event days		
Inflation probability over …		
… 1 year	0.81 (0.18)	0.17 (0.08)
… 3 years	0.63 (0.08)	0.27 (0.08)
… 5 years	0.55 (0.14)	0.07 (0.08)
…. 10 years	0.60 (0.15)	0.25 (0.07)
Deflation probability over …		
… 1 year	-0.27 (0.09)	-0.25 (0.14)
… 3 years	-0.29 (0.05)	-0.28 (0.06)
… 5 years	-0.23 (0.11)	0.02 (0.06)
…. 10 years	-0.21 (0.06)	0.09 (0.07)

* Standard deviations in paranthesis.

Table A-7: Average coefficients and standard deviations of time varying regressions.

Inflation probabilities and 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	-

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

°) Estimation in log differences.

Table A-8: Inflation probabilities explained by financial risk variables.

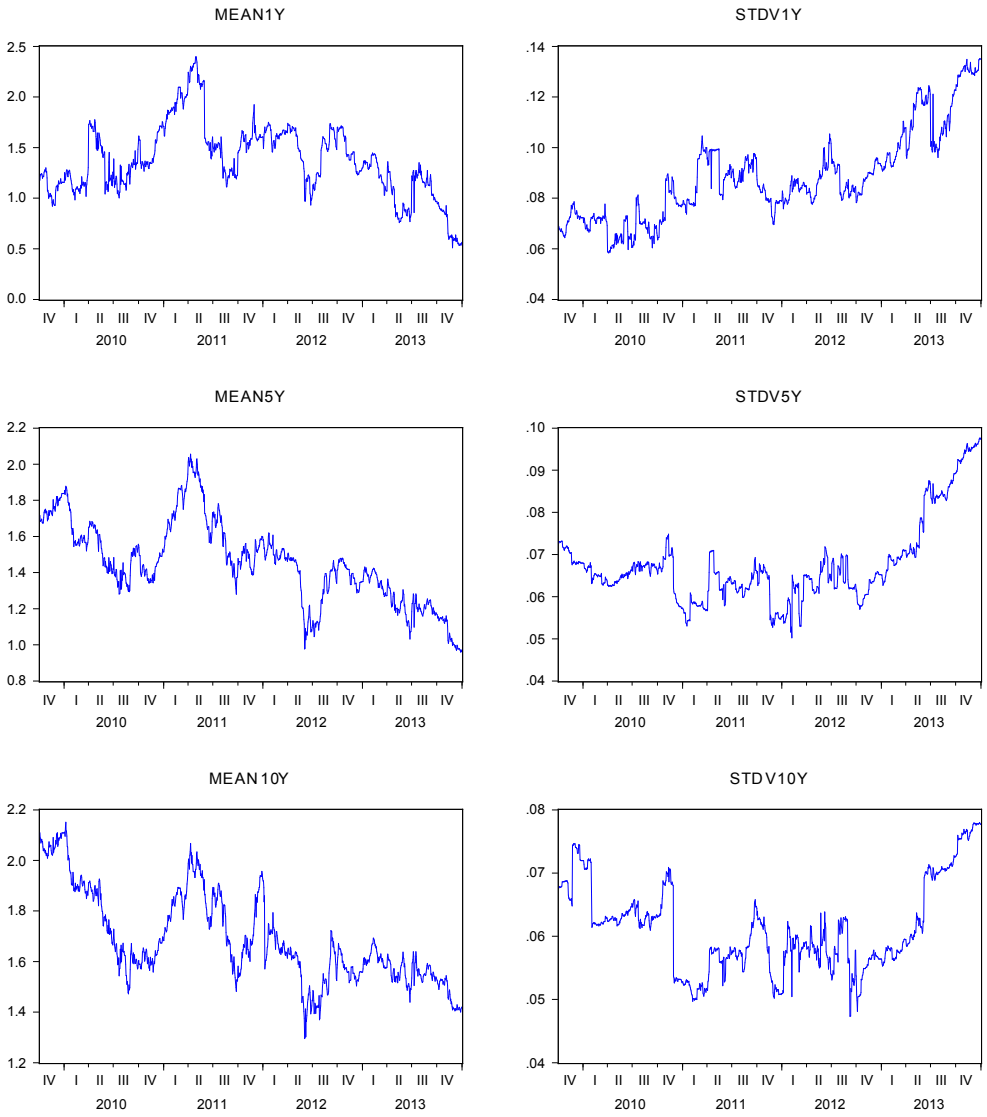

Figure A-1: Mean and standard deviation of risk neutral densities for one, five, and ten year horizon.

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