Discussion Paper

Inflation anchoring in the euro area

Christian Speck

Non-technical summary

Research Question

The low inflation rates in the euro area between 2013 and 2015 raise the question of whether euro-area inflation is still credibly anchored to the Eurosystem's medium-term target of below, but close to, 2%. If inflation is firmly anchored to the Eurosystem target, this means that the current economic situation will have no impact on long-run inflation expectations as short-run fluctuations will peter out over time.

Contribution

This research paper examines the impact of surprises stemming from the release of macroeconomic data - such as inflation rates or business climate indices - on market-based inflation expectations from inflation swaps in a novel time-varying event study setting. This new method enables us to analyze inflation anchoring over shorter horizons, too. The period of low inflation from 2013 to 2015 will be incorporated for the first time in order to investigate the economic causes of the decline in longer-term, market-based inflation expectations.

Results

Inflation expectations responded more readily to macroeconomic news following the outbreak of the financial crisis than prior to it. This primarily concerns shorter forecast horizons, whereas medium-term expectations normally respond little to macroeconomic news and may still be considered firmly anchored. For the first time, short periods in which medium-term inflation expectations respond significantly can be identified using the new time-varying event study method. First, in 2009, a surprisingly strong recession led to a sharp decline in the inflation rate, which is taking longer than usual to return to its target. Second, in February 2015, higher than expected inflation led to a rise in medium-term inflation expectations toward the inflation target. In both cases, macroeconomic news elicits no response from inflation expectations looking further ahead. The response of medium-term inflation expectations is therefore a sign of a protracted phase of inflation adjustment towards the Eurosystem's inflation target and should not be interpreted as a de-anchoring of inflation dynamics or a credibility problem on the part of the Eurosystem.

Nichttechnische Zusammenfassung

Fragestellung

In Anbetracht der niedrigen Inflationsraten im Euro-Raum von 2013 bis 2015 steht die Frage im Raum, ob die Inflation im Euro-Raum noch glaubwürdig am Ziel des Eurosystems von Inflationsraten von unter, aber nahe 2% über die mittlere Frist verankert ist. Wenn die Inflation fest am Ziel des Eurosystems verankert ist, hat der gegenwärtige Zustand der Wirtschaft keinen Einfluss auf langfristige Inflationserwartungen, weil kurzfristige Schwankungen mit der Zeit auslaufen.

Beitrag

Dieses Forschungspapier untersucht mit Hilfe einer neuen, nichtlinearen Ereignisstudienmethodik den Einfluss von Überraschungen bei der Veröffentlichung makroökonomischer Daten – wie Inflationsraten oder Geschäftsklimaindizes – auf marktbasierte Inflationserwartungen aus Inflationsswaps. Mit Hilfe der neuen Methodik ist es möglich, auch über nur kurze Beobachtungszeiträume die Verankerung zu untersuchen. Erstmals wird die Periode der Niedriginflation von 2013 bis 2015 einbezogen, um ökonomische Ursachen des Rückgangs der längerfristigen, marktbasierten Inflationserwartungen zu untersuchen.

Ergebnisse

Die Reaktion der Inflationserwartungen auf makroökonomische Neuigkeiten ist nach Ausbruch der Finanzkrise größer als zuvor. Dies betrifft vor allem kurze Prognosehorizonte, wohingegen mittelfristige Erwartungen zumeist keine signifikante Reaktion auf makroökonomische Neuigkeiten zeigen und weiterhin als fest verankert angesehen werden können. Mit der neuen zeitvariablen Ereignisstudienmethodik lassen sich erstmals kurze Perioden signifikanter Reaktion mittelfristiger Inflationserwartungen identifizieren: Zum einen führte 2009 eine überraschend starke Rezession zu einem starken Rückgang der Inflationsrate, deren Rückkehr zum Ziel länger dauerte als gewöhnlich. Zudem führten im Februar 2015 überraschend hohe Inflationsveröffentlichungen zu einem Anstieg der mittelfristigen Inflationserwartungen in Richtung des Inflationsziels. In beiden Fällen zeigten weiter in die Zukunft gerichtete Inflationserwartungen keine Reaktion auf makroökonomische Neuigkeiten. Die Reaktion mittelfristiger Erwartungen ist deshalb ein Zeichen einer längeren Anpassungsphase der Inflation an das Inflationsziel des Eurosystems und sollte nicht als Inflationsentankerung oder als Glaubwürdigkeitsproblem des Eurosystems interpretiert werden.

Inflation Anchoring in the Euro Area

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Abstract

Did the decline in inflation rates from 2012 to 2015 and the low levels of market-based inflation expectations lead to de-anchored inflation dynamics in the euro area? This paper is the first time-varying event study to investigate the reaction of inflation-linked swap (ILS) rates – a market-based measure of inflation expectations – to macroeconomic surprises in the euro area. Compared to the pre-crisis period, surprises have a much stronger effect on spot ILS rates during the crisis. Medium-term forward ILS rates remain insensitive to news most of the time, which implies inflation anchoring. Only short periods of sensitivity on the part of medium-term forward ILS rates are identified at times of low inflation or recession. The sensitivity is lower over more distant forecast horizons such that medium-term sensitivity represents an inflation adjustment process and provides no evidence for a de-anchoring of inflation expectations or a loss of credibility for the Eurosystem's policy target.

Keywords: Inflation Anchoring, Inflation Expectations, Inflation-Linked Swaps, Event Study, Central Banking

JEL classification: E31, E44, G12, G14.

1   Introduction

Inflation rates in the euro area dropped from 3% in early 2012 to negative rates in 2015 (see π_{EA} in Fig. 1) and realized inflation was lower than previously expected in many macroeconomic projections. The long record of inflation rates below the Eurosystem's target of "inflation rates below, but close to, 2% over the medium term"[1] could represent a challenge to the target's credibility. The decrease in realized inflation in the euro area is accompanied by a decline of inflation-linked swap (ILS) rates, a financial market indicator of expected inflation.[2] Short-term ILS spot rates usually move in a similar manner to the realized inflation rate – see, for example, the green two-year spot rate ILS^{2Y} in Fig. 1. These fluctuations reflect the business cycle and external shocks such as fluctuations in commodity prices or exchange rates. They are no concern for the credibility of the medium-term oriented monetary policy target. However, not only have short-term inflation expectations dropped, but inflation expectations over more distant horizons have also declined. The medium-term inflation expectations contained in the five-year forward inflation rate starting in five years – which "is the metric that we [the ECB] usually use for defining medium term inflation"[3] – dropped below the 2% target in summer 2014 (see the blue $ILS^{5Y \to 10Y}$ in Fig. 1). Therefore, low medium-term inflation expectations may signal doubts about the "anchoring" of inflation dynamics at the Eurosystem's target. De-anchored inflation expectations indicate doubts about the effectiveness of the Eurosystem's policy measures and, ultimately, the credibility of its monetary policy target. Consequently, the Eurosystem's expanded asset purchase programme was implemented because it is expected to "decisively underpin the firm anchoring of medium to long-term inflation expectations."[4]

This paper tests the hypothesis of anchored euro-area inflation expectations in a novel time-varying event study setting. The high frequency of the ILS data allows for a daily reconciliation of macroeconomic news releases – the events – with changes in market-based inflation expectations. Since changes in ILS rates have no effect on the macroeconomic releases on the announcement day, causality runs from macroeconomic news to ILS quotes. Following the law of iterated expectations, far-ahead forward inflation rates are supposed to be unaffected by the current economic conditions if the central bank's inflation target is credibly anchored (at 2%) because shocks at the business cycle frequency will have dissipated over distant horizons.[5] Therefore, the anchoring hypothesis in the event study framework can be tested by examining the sensitivity of medium-term forward ILS rates to news about the current macroeconomic situation.

My event study builds on the nonlinear methodology of Swanson and Williams (2014),

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[1]Details of the Eurosystem's price stability definition can be found on the ECB webpage: https://www.ecb.europa.eu/mopo/strategy/pricestab/html/index.en.html

[2]When entering into an inflation swap, the inflation-linked swap (ILS) rate is the inflation rate that can be locked in for a certain time in the future in exchange for uncertain future inflation rates.

[3]Mario Draghi, August 22, 2014, Jackson Hole. https://www.ecb.europa.eu/press/key/date/2014/html/sp140822.en.html

[4]Mario Draghi, January 22, 2015, Introductory statement to the press conference. https://www.ecb.europa.eu/press/pressconf/2015/html/is150122.en.html

[5]The law of iterated expectations implies that today's expectation of tomorrow's far-ahead expectation of a variable should be equal to tomorrow's far-ahead expectation of the variable if far-ahead expectations are anchored.

Figure 1: **Euro Area Inflation and Inflation-Linked Swap Rates**

Realized inflation rate π_{EA} measured by the 12-month log change in the euro-area HICP and inflation-linked swap (ILS) rates in percentage points per annum. The year labels on the x-axis refer to January 1. Sample: April 21, 2004 to October 15, 2015.
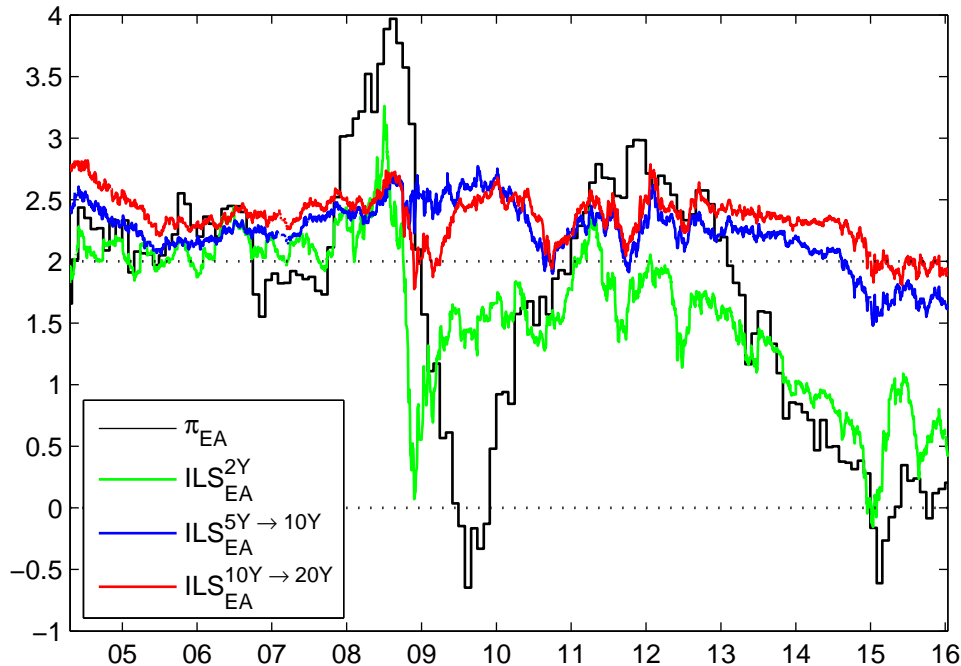
which makes it possible to investigate inflation anchoring on a much finer time grid than conventional event study approaches. However, a study of inflation anchoring requires the *joint* estimation of short and long ILS maturities. During periods of inflation anchoring, like the pre-crisis period in the euro area, no release of macroeconomic data has a systematic impact on medium-term forward ILS rates. In turn, medium-term forward ILS rates cannot be used in the pre-crisis period to identify relevant macro releases; instead, they have to be combined with news-sensitive short-maturity ILS spot rates in the estimation. Therefore, I extend the method of Swanson and Williams (2014) to include a joint estimation of multiple maturities in order to study inflation anchoring.

The level of market-based expectations, like that of ILS rates, is not a pure measure of inflation expectations but rather is affected by premia for liquidity and inflation risk. Changes in the inflation risk premium signal changes in investors' fear surrounding inflation dynamics which is informative for policymakers. By contrast, liquidity risk is uninformative when investigating inflation anchoring and central bank credibility, since it is related to technical market conditions. In the event study setting, it is not the level of risk premia that matters but rather the systematic impact of macroeconomic news surprises on the change of the risk premium. Since macroeconomic surprises are supposed to have a greater impact on inflation risk than on liquidity risk, an event study focuses on the policy-relevant components of ILS rates.

My event study is the first to use ILS data from the low inflation period from 2013 up to October 2015 including the Eurosystem's expanded asset purchase program that started in early 2015. I find unprecedently high levels of spot ILS rate sensitivity to macroeconomic

news during the crisis. Using the new time-varying method, I identify short episodes in which the five-year forward ILS rate starting in five years systematically reacts to news about the current economic situation. The first period was in 2009 at the peak of the economic downturn, when negative news about the real economic situation caused a decline in medium-term forward ILS rates, but not unexpectedly low inflation. The second period runs from February to September 2015, when positive inflation surprises pushed inflation expectations toward the inflation target. In fall 2015, there was no significant reaction of medium-term forward ILS rates in line with firm inflation anchoring.

While no reaction of the five-year forward inflation rate starting in five years to a news shock signals inflation anchoring, a reaction such as that in 2009 or 2015 does not necessarily imply an inflation process that is de-anchored from the Eurosystem's target. First, if low inflation leads to a credibility problem, there should be learning from inflation news about the new, lower inflation target. The sensitivity in 2009 was caused by negative surprises about the real economy, which provides no evidence for a change in the market perception of the Eurosystem's target. Second, only surprises that push inflation away from its target signal de-anchoring. In February 2015, the sensitivity of medium-term ILS rates to inflation releases represented an increase in the ILS rates toward the target following positive inflation surprises. Finally, the reaction of the five-year forward ILS rates starting in five years might also reflect a strong shock that is expected to take longer than normal to recover from and will affect expectations five years from now. In this case, the reaction to news should be less pronounced for more distant forecast horizons. It is only if inflation expectations over all horizons react to macroeconomic surprises including the most distant ones, that the reaction of medium-term inflation expectations is a sign of de-anchoring of the target. In fact, I find a stronger reaction of short-term expectations to news compared to longer-term expectations, and the one-year forward inflation rate starting nine years from now shows insignificant sensitivity to macro surprises, both in 2009 and 2015.

Thus, in the low inflation period, market participants did not learn from (negative) inflation surprises about a (lower) Eurosystem inflation target. Market participants rather assumed, that the recovery of the real economy in 2009 would take longer and the persistence of low inflation in 2015 would be greater than in normal times. Therefore, while the increased sensitivity of the medium-term forward inflation rate reflects a changing perception of the adjustment process from unusually low to normal inflation rates, the Eurosystem's inflation target can still be regarded as credibly anchored.

The remainder of the paper is structured as follows. After a review of the literature in section 2 and a description of the data in section 3, a conventional time-constant analysis in section 4 identifies relevant factors for the new time-varying approach. The results of the time-varying event study are in section 5, including the distinction between target de-anchoring versus inflation persistence, a study of the determinants of elevated sensitivity and the role of announcement surprises in the revision of survey forecasts. Section 6 concludes this paper.

2 Related Literature

Existing event studies on the anchoring of inflation dynamics in the euro area – such as Autrup and Grothe (2014), Galati, Poelhekke, and Zhoua (2011), Coffinet and Frappa

(2008), ECB (2012), and Beechey, Johannsen, and Levin (2011) – cover data up to 2012.[6] They agree that medium-term inflation expectations in the euro area are firmly anchored prior to the crisis, irrespective of the model specification, and find no clear evidence for de-anchoring during the crisis. Given the Eurosystem's quantitative inflation target, the insensitivity of medium-term forward inflation rates in the euro area is interpreted as an indicator of a credible implementation of an inflation target, and of the Eurosystem's determination and ability to meet its target. By contrast, the medium-term forward ILS rates in the US, reacted to macro surprises both prior to the financial crisis and afterwards.[7] The comparison of the US, with the dual mandate of the Federal Reserve System, to countries with inflation-targeting central banks provides evidence for the crucial role of the monetary policy regime in the sensitivity of ILS rates and inflation anchoring: Gürkaynak, Levin, and Swanson (2010) compare US, UK and Swedish data to distinguish different monetary policy regimes. They conclude that the source of the responsiveness in the US and in early UK data is a missing or a flexible inflation target. This finding is substantiated by De Pooter, Robitaille, Walker, and Zdinak (2014) and Gürkaynak, Levin, Marder, and Swanson (2007), who report a sensitivity of medium-term market-based inflation expectations in the US to macroeconomic news but find anchored inflation expectations in inflation-targeting countries Brazil, Canada, Chile, and Mexico.

An alternative way to use high-frequency, market-based expectations to analyse the anchoring of inflation is the "spillover" or "pass-through" from short-term expectations to long-term expectations. In this approach, the dependent variable is a medium-term or long-term forward ILS rate as in the event study. The explanatory variable that represents the current economic situation are short-term, market-based inflation expectations (ILS).[8] Similar to the event study approach, the monetary policy regime seems to play an important role: Jochmann, Koop, and Potter (2010) find a significant spillover in the US. This result is confirmed by Gefang, Koop, and Potter (2012) for the US but in the UK there is evidence for anchored inflation expectations. For the euro area, Lemke and Strohsal (2013) find well-anchored inflation expectations in a sample that includes data up to March 2012. The advantage of the spillover approach compared to an event study is that it does not require a specific data release with an announcement survey. Thereby the effect of (un)conventional monetary policy announcements can be directly investigated. However, risk premia are a more relevant issue for the spillover approach compared to the event study. Risk premia not only affect the dependent variable (medium-term forward ILS rates) but also the explanatory variable (short-term ILS rates). If a change in the risk premium affects all horizons, interpreting a spillover from short-term ILS rates to medium-term forward ILS rates as a de-anchoring of expectations might be misleading.[9]

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[6]Miccoli and Neri (2015) use data up to December 2014, but do not investigate maturities beyond the five-year spot rate. Therefore they cannot address anchoring of inflation expectations.

[7]See Bauer (2014) for a recent study. Nautz and Strohsal (2015) test for multiple breakpoints in US market-based inflation expectations' reaction to macroeconomic news in the sample 2004 to mid 2014 and find one breakpoint in July 2009. They use this breakpoint to split the sample for a conventional event study analysis and find a stronger reaction after the breakpoint.

[8]The term "dependent" or "explanatory" variable in the pass-through approach should not be understood as a single equation setting; instead, it refers to the tests in which the dependence of long-term expectations on short-term expectations is investigated. For example Lemke and Strohsal (2013) use a bivariate VAR with market-based expectations to derive an implicit inflation target level for the euro area to test whether there is a significant effect of short-term on long-term expectations.

[9]I am not aware of any investigation of this problem in the inflation expectation spillover literature.

In the event study approach, only changes in risk premia caused by the surprise stemming from macroeconomic conditions have an impact on the interpretation, but all risk premia affect the spillover methodology, including liquidity risk.

Another strand of the literature uses survey data to study inflation anchoring. The advantage of survey data is its independence from risk premia and a longer history that comes at the cost of lower frequencies and the inability to establish causal relations between realized inflation and expectations as in the event study apporach. Kozicki and Tinsley (2012) develop a model for the US that uses short-term and long-term survey expectations in addition to realized inflation in an internally consistent way to estimate inflation dynamics. Other authors do not impose internal consistency of inflation expectations and realized inflation but rather use an econometric approach to relate the forecasts of different horizons, e.g. Mehrotra and Yetman (2014) and Yetman (2015) use a Weibull decay function. In both approaches, the model-implied limit of the expected inflation is interpreted as the inflation target. Demertzis, Marcellino, and Viegi (2009) estimate implicit time-varying inflation targets from realized inflation and long-term Consensus inflation forecasts – including data up to 2008 – for different countries. They find well-anchored inflation expectations in the euro area at levels in line with the Eurosystem's target. Cruijsen and Demertzis (2011) concentrate on the relationship between long-term inflation expectations with realized inflation for the aggregate euro area and member countries using data up to 2009 in vector autoregressive models. They interpret their finding of independent long-term expectations from realized inflation as an anchoring of inflation expectations. A problem related to survey-based approaches is that the long-term survey expectations can be above the model-implied inflation target, which creates an implausible hump in the expectation term structure.[10] This might imply either a misspecification of the dynamic inflation model or a mismeasurement contained in long-term expectations caused by the slow adjustment of long-term survey outlooks.[11]

Given that each method has pros and cons, they are complementary components in a thorough analysis of inflation anchoring. Overall, the existing literature provides overwhelming evidence for anchored inflation expectations in the euro area prior to the crisis and during the first years of the financial crisis, irrespective of the method used. However, there is scarce research on inflation anchoring during the low inflation period from 2013 onwards.

An example of the joint dependence of dependent and explanatory variable on the risk premium can be found in Hanson and Stein (2015): They find a surprising impact of changes in the two-year nominal Treasury bond yield – as a proxy for monetary policy surprises – on the long-term real forward rate. A detailed analysis shows that it is the risk premium in the two-year nominal yield that accounts for this reaction such that they conclude that – according to theory – monetary policy cannot impact long-term real forward rates.

[10] See Mehrotra and Yetman (2014) for the euro area, or Demertzis et al. (2009) for Sweden. The problem is particularly relevant if realized inflation or short-term expectations are low compared to long-term expectations.

[11] About 4 out of 5 forecasters participating in the ECB's Survey of Professional Forecasters panel update long-term inflation expectations only annually, whereas short-term forecasts are updated monthly by 3 out of 4 survey participants. See ECB (2014, Chart 5).

3 Data

3.1 Inflation Swap Data

Euro-area spot inflation-linked swap (ILS) rates are from Reuters. The quotes are closing prices that are collected at 17:00 CET starting from April 22, 2004 on a daily frequency until January 13, 2016. Mid quotes ILS_t^n are calculated from bid and ask quotes and are transformed into log rates. Maturities n from one to 30 years are available with annual spacing up to ten years and five-year spacing from ten to 30 years.

The implied forward inflation rate between year n and m, denoted $ILS_t^{n \to m}$, is a linear combination of the (logarithmic) spot rates:

$$ILS_t^{n \to m} = \frac{m}{m-n}ILS_t^m - \frac{n}{m-n}ILS_t^n \tag{1}$$

Figure 2 displays the average spot ILS term structure (solid lines in graphs), the usual 5Y-5Y-forward inflation swap rate $ILS^{5Y \to 10Y}$ and the ten-year forward rate starting in ten years $ILS^{10Y \to 20Y}$ and starting in 20 years $ILS^{20Y \to 30Y}$ (forwards are dashed horizontal lines). The term structure of spot ILS rates is upward sloping. Prior to the crisis, ILS rates were, on average, above the 2% threshold – even for short horizons. During the crisis, the ILS rate curve shifted downwards; most pronounced for short maturities. On average, the 5Y-5Y-forward ILS rate has not changed much since the onset of the financial crisis. The volatility of daily ILS rate changes is downward sloping such that long-term ILS rates move less than short-term ILS rates. Forward rate volatility is usually above the average spot rate volatility: If there are measurement errors or mispricing in one of the spot rates, both enter the forward and lead to a higher forward volatility.[12] Prior to the crisis, the volatility of the forwards was clearly above the average spot volatility, whereas this is not the case after the onset of the crisis. This might be an indication that, after the onset of the crisis, fundamental factors played a larger role in forward ILS volatility compared to measurement error.

For the estimation, maturities from two to ten years are used. Due to the indexation lag of three months, the high impact of seasonality on short maturities and the resulting high volatility, the one-year ILS rate is excluded.[13] ILS rates with maturities in excess of ten years are more subject to risk premia than the maturities considered for estimation. At the end of 2008 when the banking crisis was at its peak, the forward between ten and 20 years was considerably below $ILS^{5Y \to 10Y}$ (see Fig. 1). This implies a huge hump in the ILS rate curve, which is hard to interpret from the perspective of inflation expectations.[14] The forward between 20 and 30 years is much more volatile compared to the five-year forward inflation rate five years ahead. Therefore, ten years is the maximum maturity

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[12]For one-year forwards starting in n years, this effect is even more pronounced, e.g. the volatility of $\Delta ILS_t^{9 \to 10}$ exceeds 5 bp in both subsamples.

[13]The indexation lag is necessary because realized inflation is quoted at a monthly frequency. Therefore it is not possible to determine the exact inflation at the time the swap expires, e.g. realized inflation of a 1Y-spot ILS starting on April 5, 2014 cannot be determined at its expiration on April 5, 2015. Therefore inflation indexation is lagged by three months such that a price index can be interpolated on a daily basis, e.g. from January 5, 2014 to January 5, 2015 for the example above.

[14]A variance ratio analysis in Appendix A provides evidence for a deterioration of the data quality of $ILS^{10Y \to 20Y}$ during the financial crisis.

Figure 2: **Data Description**

Panel A contains the spot term structure as a solid line. The 5Y-5Y-forward inflation rate is the dashed, horizontal line.
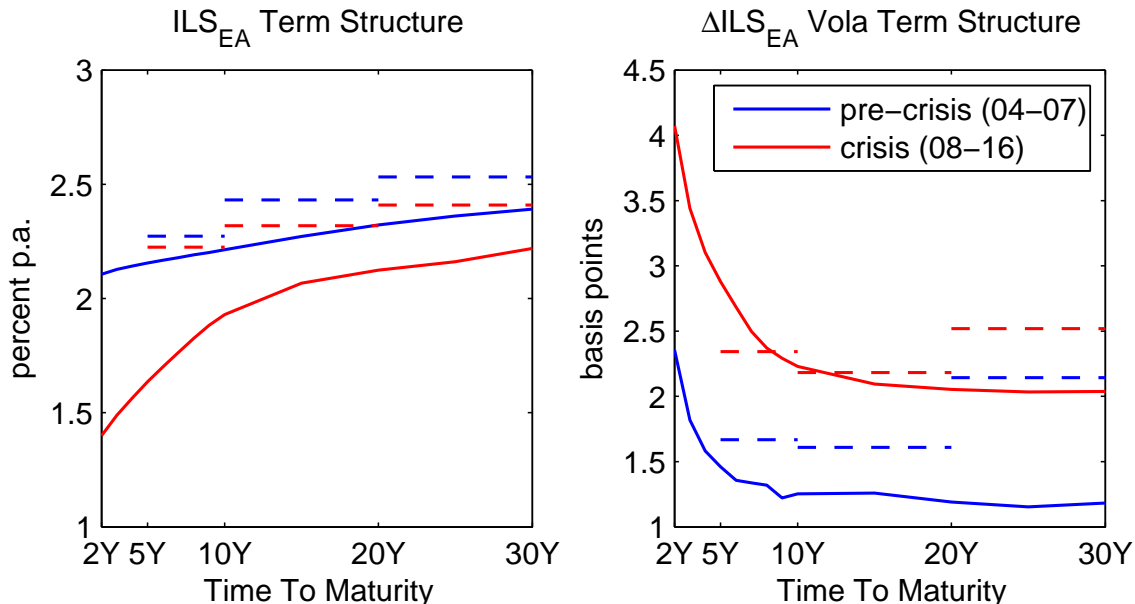
considered for estimation.

3.2   Macro Announcement Data

Bloomberg announcement surveys are published with an intraday time-stamp for each release. In the case of euro-area inflation swaps, announcements after 17:00 CET have no price impact on the announcement day and are assigned to the next business day. For each macro announcement, Bloomberg publishes the median forecast M_t, the high forecast H_t, the low forecast L_t, the dispersion of forecasts D_t and the number of forecasters N_t. The actual release A_t (as first reported) is from Bloomberg as well. The dispersion D_t of opinions among the survey participants can lead to a different reaction for a given median surprise $(A_t - M_t)$. If there is a large level of consensus among the participants before an announcement, a given surprise is supposed to have a larger effect on prices compared to a situation in which there is large disagreement among analysts. The dispersion measure is a unique feature of the Bloomberg survey and I define the surprise measure as:

$$S_t \;\; = \;\; \frac{A_t - M_t}{D_t} \tag{2}$$

If dispersion is zero, the surprise S_t is set to zero if the actual value corresponds to the survey median $(A_t - M_t = 0)$.[15] For the selected variables, there is no announcement

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[15]Bloomberg data provide a "Surprise" measure that is likewise calculated by $\frac{A_t - M_t}{D_t}$ only if there is pre-announcement disagreement $(D_t \neq 0)$ and contains a missing observation in case of complete pre-announcement agreement $(D_t = 0)$. Therefore, the Bloomberg "Surprise" misses unsurprising events and has fewer observations than my surprise measure S_t.

in which a surprise ($A_t - M_t \neq 0$) occurs with complete pre-announcement agreement ($D_t = 0$).

In the euro area, both announcements for aggregate euro-area (EA) data and announcements of member countries' data can be used. Member country data are often published prior to aggregate euro-area data. The shorter publication lag of national data makes them a valuable source of information. I use data from Germany (DE), France (FR), Italy (IT) and Spain (ES) that make up more than three quarters of euro area's household expenditures that determine the country weights for the HICP. There are hundreds of macroeconomic data releases for the euro area and its member countries. For some variables, there are announcements of preliminary and final data.[16] The information content of final announcements turns out to be negligible: There is a large fraction of final data announcements without surprise and zero dispersion. Therefore, only preliminary announcements are used. Announcements of final data releases are only considered if no preliminary data announcements are available, e.g. for French inflation.

Price indicators are consumer price inflation announcements.[17] Preliminary inflation rate estimates for Germany, Spain, Italy and the euro area are usually published during the last days of the reporting period (e.g. EA preliminary inflation on September 30, 2014 for September). The final data for the euro area are published in the middle of the following month (e.g. October 16, 2014 for September) a few days after national data are published (e.g. October 14 and 15, 2014 for September). As INSEE does not publish a flash estimate for French inflation, I use the final release. Figure 3 contains the inflation surprises. In 2009, 2013 and 2014, the decrease in the inflation rate was largely accompanied by negative surprises, while strong positive surprises were observed in February 2015. Aggregate euro-area surprises are zero more often than national data since country-specific data releases reduce uncertainty about the aggregate outcome.

Indicators for the real economy are survey-based confidence indices of the corporate sector. At the end of each month, sentiment indices are published and provide the most timely information about the situation of the real economy.[18] I use the industry confidence index for the whole euro area and national confidence indices from Germany, France and Italy.[19] Usually, French corporate sentiment data is released first, followed by German, Italian and aggregate euro-area data. French and German confidence indicators are often published prior to the preliminary inflation data and are therefore of special relevance, whereas Italian and aggregate euro-area confidence indicators are usually not published before inflation data is released. Furthermore, GDP and industrial production for the

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[16] "Preliminary" refers to the first publication of a datapoint. The Bloomberg labels for these announcements is "flash", "preliminary" and "advanced".

[17] For member country inflation, I use the harmonized definition of the price index. For Germany, I use the national price level definition up to December 2005, because surveys are not available before March 2005 on a regular basis and Bloomberg surveys on German HICP have fewer respondents than the national definition in the early sample. All inflation rates are expressed as yield-over-year (YoY).

[18] In the European Union, harmonized surveys are conducted at the national level and aggregated by the European Commission. The sentiment index questionnaires are returned in the first weeks of a month by the participants. A few days before the end of month, national partners send their results to the European Commission, which aggregates national data into an aggregate indicator that is published on the last working day of a month.

[19] The confidence indices of the corporate sector are the "ifo business climate index" for Germany, "Manufacturing Confidence" for France and "Business Confidence" for Italy. There are no Bloomberg surveys for Spanish business confidence.

Figure 3: **Inflation Surprise Data**

Surprises of inflation. × indicates an inflation surprise that drives inflation away from target. + indicates all other surprises, including zero surprises. Green areas below a surprise indicate that a release is not contained in the high-low range of analysts' forecasts. Dates on the x-axis refer to January 1.

Figure 4: **Corporate Sentiment Surprise Data**

Surprises of corporate sentiment indices in index points. + indicates surprises, including zero surprises. Green areas below a surprise indicates a release is not contained in the high-low range of analysts' forecasts. Dates on the x-axis refer to January 1.
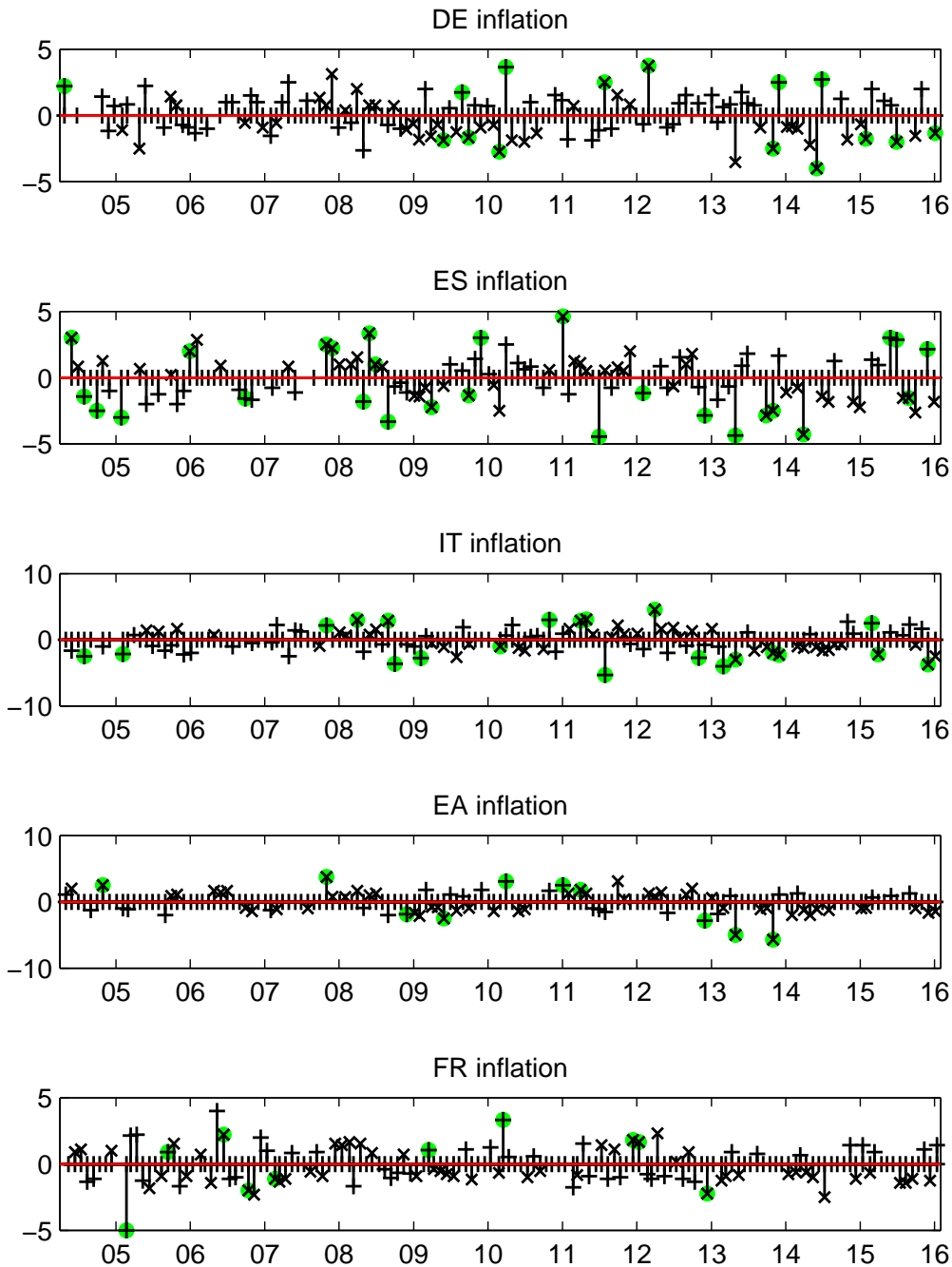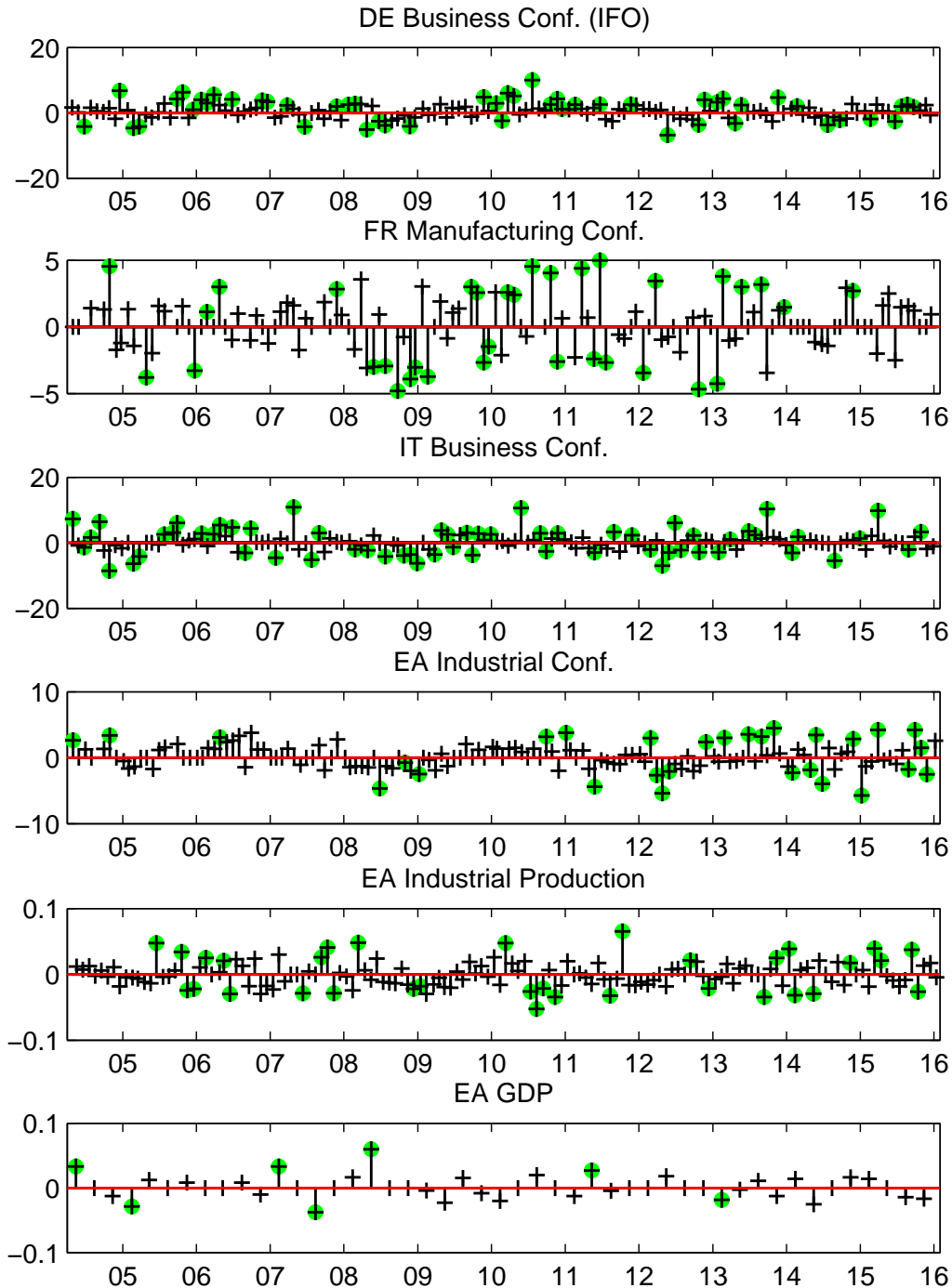
whole euro area are considered indicators for the real economy and are published with a publication lag of several weeks. Both measures are published after the next month's sentiment indices become available. Figure 4 reveals negative surprises in the great recession of 2008 and 2009 but no clear tendency in the low inflation period from 2013 onwards.

No monetary policy announcement surprises are included. Bloomberg surveys the ECB main refinancing rate but there are only a few surprises for the median, very little dispersion and often complete agreement among more than 60 forecasters. Using the change in the money market instruments as a surprise measure for monetary policy decisions following the idea of Kuttner (2001) contains more variation compared to surveys but induces other problems discussed by Thornton (2014).[20] In addition, I do not consider qualitative information about unconventional monetary policy decisions. In the pre-crisis period, there was no unconventional monetary policy. Therefore, a comparison of the pre-crisis and crisis period is not possible. Furthermore, Thornton (2013) finds qualitative information about unconventional monetary policy surprises to be badly identified from other news released at the same time. However, the macro announcements are indirect measures of conventional and unconventional monetary policy because, for example lower inflation or growth increases the probability of a more expansionary monetary policy.

4 Factor Identification

Medium-term inflation expectations are anchored in the literature prior to the low inflation period that starts in 2013. During that time, medium-term forward ILS rates do not respond to any macroeconomic data release and therefore cannot be used for variable selection: It is not possible to separate data releases that are completely irrelevant to inflation expectations from other data releases that are potentially relevant as soon as inflation expectations become de-anchored. Therefore, the selection of surprise variables cannot be made based on medium-term forward ILS regressions. However longer-term *spot* ILS rates were found to be responsive to macro announcement surprises even before the crisis in the existing literature. A reaction of a longer-term *spot* ILS rate is either caused by a change in the short-term spot ILS rate or by a change in a medium-term forward ILS rate.

In order to identify the important surprise factors for the time-varying analysis in the next section, I estimate conventional time-constant models separately for the pre-crisis period (2004 to 2007) and for the crisis period (from 2008 onwards). According to the efficient market hypothesis, changes in inflation-linked swap rate ΔILS_t^n with a maturity n should only react to surprising news S_t but not to the level of the current macroeconomic situation:

$$\Delta ILS_t^n = \alpha^n + \beta^n S_t + \varepsilon_t^n \tag{3}$$

The estimation is carried out jointly for all maturities from two to ten years with OLS. Standard errors are corrected for heteroskedasticity using the method of White (1980). Given the β^n-estimates of the spot curve, the sensitivity of a forward between year n and

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[20]One problem consists of the risk premia contained even in short-term interest rates that proxy monetary policy; see for example the dicussion of Hanson and Stein (2015) contained in footnote 9.

m can be tested using a conventional Wald test:

$$H_0: \qquad \beta^{n \to m} = \frac{m}{m-n}\beta^m - \frac{n}{m-n}\beta^n = 0 \qquad (4)$$

Figure 5 contains the results of a multivariate regression for two subsamples: The pre-crisis period from April 2004 to December 2007 is depicted in blue and the crisis period from January 2008 onwards is depicted in red. The last datapoint is January 13, 2016 when French inflation of December 2015 is published. The upper left panel contains the R^2 in percent, while the other panels contain the parameters with the name of the macro announcement in the panel title. The maturity of the ILS is depicted on the x-axis. Solid lines refer to the spot ILS term structure. The dashed horizontal lines between year five and ten refer to the 5Y-5Y forward ILS rate parameters $\beta^{5Y \to 10Y}$. A coefficient significantly different from zero at the 1%, 5% or 10% level is indicated by $*$, $\times$ and $+$ respectively.

The estimation results from the unrestricted spot rate β^n from equation (3) in Figure 5 show a smooth parameter pattern across maturities. The inflation and corporate confidence index releases have an effect on a large set of maturities of *spot* ILS rates at least in one of the subsamples. The impact is usually larger in absolute terms for short maturities than for longer maturities and R^2 decreases as maturity increases. This is in line with the phasing-out of a short-term shock on long-term expectations.

Inflation surprises increase spot ILS rates in both subsamples. In the crisis period, all inflation announcements have a positive impact. Pre-crisis, only the parameters of EA aggregate inflation and French inflation are significantly positive for the whole maturity spectrum. The reaction of German inflation is only significantly different from zero for short horizons in the pre-crisis sample, but has a significant impact on the whole spot ILS curve during the crisis. By contrast, Spanish and Italian inflation surprises have a minor impact on spot ILS rates in the pre-crisis period. Spanish inflation turns into an important driver of ILS rates in the crisis period.

There is a more pronounced difference between the pre-crisis period and the crisis period for the business confidence indices compared to inflation surprises. Pre-crisis, only German ifo surprises affect spot ILS rates. With the exception of French manufacturing confidence, the surprise impact is larger in the crisis period than before. Italian industry confidence data releases are only significant after the onset of the crisis for the two-year spot ILS rate. Euro-area industry confidence has a counterintuitive negative sign. This probably reflects an interrelation with inflation surprises because, in the case of only three releases, EA industry confidence is not released on a day with an inflation release in DE, ES, IT or EA. Therefore, euro-area industry confidence is not included in the next section's time-varying analysis. Industrial Production is irrelevant in both subperiods. Euro-area GDP has a significantly positive impact on some spot ILS rates prior to the crisis but there is no clear maturity pattern. During the crisis, there is no significant impact of GDP surprises on ILS rates. Given the unclear change in the parameter pattern of GDP and IP in Figure 5 and their rather long publication lag, I do not include GDP and IP in the time varying investigation contained in the next section.

Overall, spot ILS rates are more sensitive after 2008 and indicators of the real economy seem to play a larger role in inflation expectations during that period. Furthermore data from Italy and Spain did not play a major role in the pre-crisis period. After the onset

Figure 5: **Unrestricted Split Sample Regression** β^n

Results for the pre-crisis period in blue and for the crisis period in red. The upper left panel contains the R^2 in percent, the other panels the parameters β^n and $\beta^{n\to m}$. Sentiment coefficients are multiplied by 100. The maturity is indicated on the x-axis. Solid lines refer to spot ILS rates. The dashed horizontal line represents the parameter of the 5Y-5Y-forward ILS rate. A coefficient significantly different from zero at the 1%, 5% or 10% level is indicated by $*$, $\times$ and $+$ respectively.
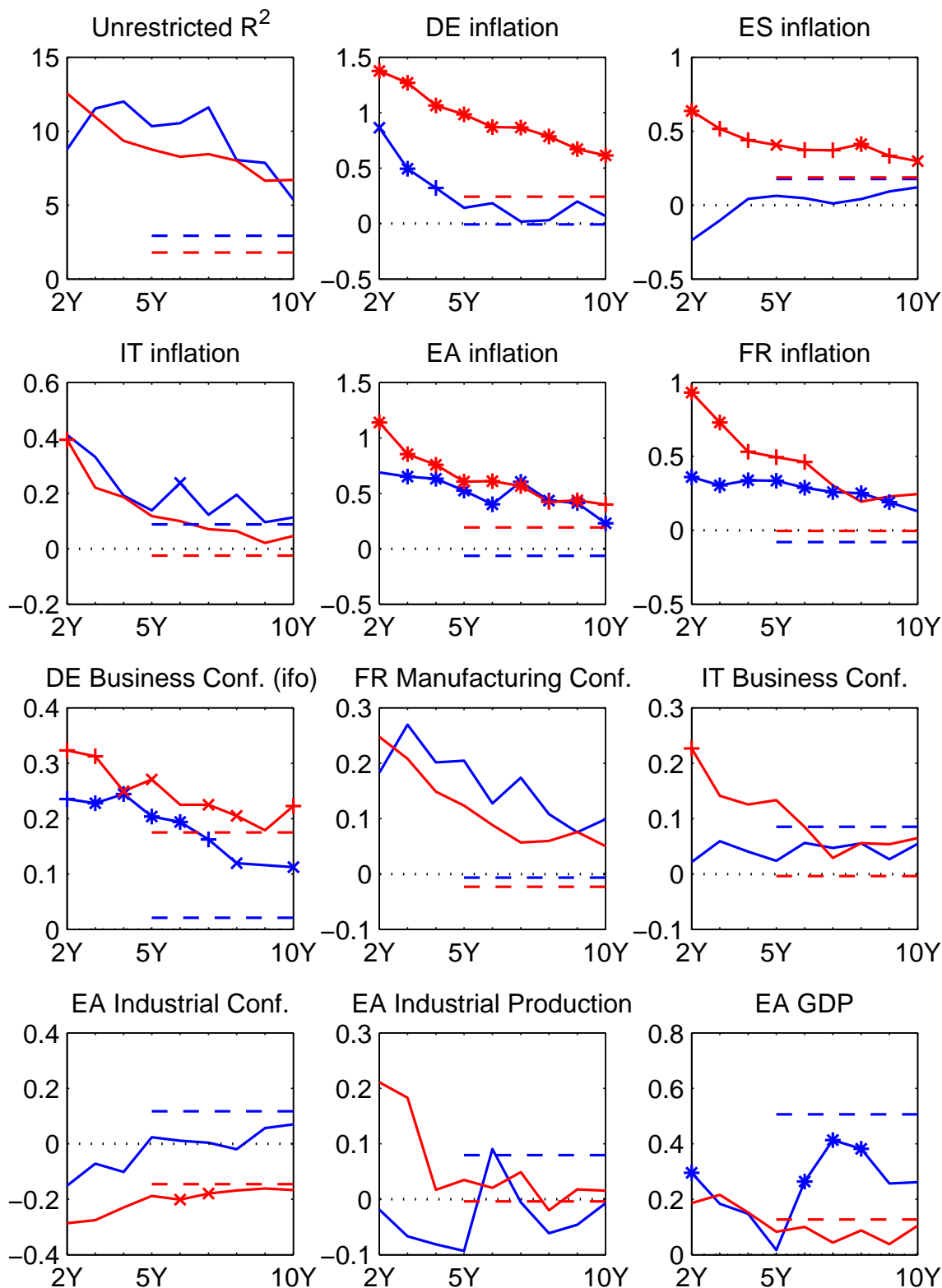
of the sovereign debt crisis, they turned into a significant driver of market-based inflation expectations. This indicates an increased importance of the southern countries for the economic dynamics of the euro area as a whole.

The medium-term 5Y-5Y-forward ILS rate (dashed, horizontal lines in Fig. 5) is insignificantly affected by all announcements and its R^2 is lower than for any spot rate. Medium-term inflation expectations are insensitive to the current state of the business cycle and can be regarded as firmly anchored in the euro area, a result similar to the existing literature. However the "crisis period" is not a homogeneous period and the *average* non-responsiveness of medium-term market-based expectations in Figure 5 does not rule out possible de-anchoring in shorter periods like the recent past. The analysis of the sensitivity on a finer time grid is the topic of the next section.

The set of five inflation announcements and three business confidence indices selected for the time-varying study in the next section is quite restrictive compared to other studies. However, inflation announcements are not only macroeconomic events – inflation itself is the underlying of the financial market contract. Therefore, the announcement of euro-area inflation takes away all uncertainty about the current value of the underlying – a unique feature in an event study. Only the business confidence indicators that are published prior to inflation data carry some information about inflation. Other standard economic indicators like GDP, IP, PPI inflation or unemployment have little impact on the ILS term structure, probably due to their long publication lag.[21] While adding arbitrary macro releases with insignificant impact on ILS rates poses no major problem in a conventional event study, this is not the case in the nonlinear framework introduced in the next section. Insignificant macro variables increase the error bands in the time-varying analysis and lead, by construction, to more anchoring. So both the special properties of the inflation market and the econometric method call for a parsimonious set of explanatory variables.

5 Time-Varying Inflation Anchoring

5.1 Methodology and Main Results

A sample split with subsample-specific β_t^n requires a long time-series of data for a re-estimation of the vector β_t^n. The approach of Swanson and Williams (2014) alleviates the sample size problem by imposing a nonlinear structure:

$$\Delta ILS_t^n = \alpha^n + \delta_t^n \cdot (\beta S_t) + \varepsilon_t^n$$

The structural impact vector β of K announcements is identical for all maturities n and fixed over time – i.e. the elements in β capture the different impact of a surprise in German inflation compared to a surprise in the Italian business confidence. The scalar δ_t^n represents the time variation of the ILS rate reaction for each maturity and is used to investigate the degree of anchoring of medium-term inflation expectations over time.

The multiplicative setting $\delta_t^n \beta$ of Swanson and Williams (2014) for a time-varying estimation has the advantage that multiple announcements can be used in each month to

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[21] Appendix B contains a discussion of a few announcements used in the literature that are not included in my analysis. Appendix C illustrates the impact of macroeconomic announcements from the US on euro-area ILS rates and elaborates why they are not considered in this paper.

estimate the time-varying scalar δ_t^n for a given β. The larger sample size makes it possible to investigate the time variation for a much finer time grid than would be the case using sample splits.

Swanson and Williams (2014) estimate δ_t^n separately for each maturity. This approach is not possible for the 5Y-5Y forward ILS rate because it is irresponsive to macro news if inflation expectations are anchored.[22] For the estimation of the time-varying model in a joint approach, I use the two-year spot rate ILS_t^{2Y}, the three-year forward inflation rate starting in two years $ILS_t^{2Y \to 5Y}$ and the five-year forward inflation rate starting in five years $ILS_t^{5Y \to 10Y}$ to span the whole maturity spectrum up to ten years.[23]

The estimation of δ_t^n is carried out in a two-step procedure: In the first step, the relative sensitivity β is estimated for all maturities and points in time. To capture potential time variation, dummy variables $dummy_\tau^n$ are specified that are specific to maturity n and time:

$$
\begin{pmatrix} \Delta ILS_t^{2Y} \\ \Delta ILS_t^{2Y \to 5Y} \\ \Delta ILS_t^{5Y \to 10Y} \end{pmatrix} = \begin{pmatrix} \alpha_\tau^{2Y} \\ \alpha_\tau^{2Y \to 5Y} \\ \alpha_\tau^{5Y \to 10Y} \end{pmatrix} + \begin{pmatrix} \bar{\delta}_\tau^{2Y} \cdot dummy_\tau^{2Y} \\ \bar{\delta}_\tau^{2Y \to 5Y} \cdot dummy_\tau^{2Y \to 5Y} \\ \bar{\delta}_\tau^{5Y \to 10Y} \cdot dummy_\tau^{5Y \to 10Y} \end{pmatrix} \beta S_t
$$
$$
+ \begin{pmatrix} \varepsilon_t^{2Y} \\ \varepsilon_t^{2Y \to 5Y} \\ \varepsilon_t^{5Y \to 10Y} \end{pmatrix} \quad (5)
$$

The pre-crisis period up to and including September 2007 data releases ($\tau = 1$) is the benchmark period in which the restriction $\bar{\delta}_1^{2Y} = 1$ identifies the scale of β. Therefore, all dummy parameters $\bar{\delta}_\tau^n$ are expressed relative to the reaction of the two-year spot ILS rates in the benchmark period (βS_t). The estimation is carried out with nonlinear least squares. Standard errors from outer product estimates are corrected for heteroskedasticity.[24]

The dummy length is set to nine months such that 40 announcement days with about 70 data releases are used to estimate each dummy parameter $\bar{\delta}_\tau^n$. The estimation results of β are robust to the choice of dummy length.[25] By contrast, the dummy length is crucial for $\bar{\delta}_\tau^n$: Fine spacing leads to large standard errors due to a low number of announcements, whereas sparse spacing entails the risk of missing time variation.[26]

The dummies' boundaries do not correspond to calendar month ends but rather refer to reporting months: The date of the French inflation release in the middle of the following calendar month – being the last release of a reporting month – is the breakpoint of the dummy. French inflation is usually published before the first data release of the next reporting month (French or German corporate sentiment) such that we have grouped all releases of a reporting month. The last dummy covers data starting from April 2015 and

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[22]Swanson and Williams (2014) test whether nominal interest rates are "anchored" at the zero lower bound. In their framework, the hypothesis $\delta_t^n = 0$ indicates a binding zero lower bound. Since the zero lower bound is not binding in the pre-crisis period, a maturity-specific analysis is possible.

[23]An alternative is the usage of spot rates in an indirect test of the forward rate response, similar to equation (4). The Wald tests in a high-dimensional parameter space cause numerical problems when the variance of the implicit forward parameter is determined.

[24]The implementation of the following nonlinear estimation and related tests is based on the Matlab code of Swanson and Williams (2014) published on the AER webpage. The code is extended to include the case of a joint estimation of multiple maturities.

[25]See Appendix D for a plot of $\hat{\beta}$ for different dummy lengths.

[26]A plot of the estimates for the dummy length of nine months is contained in Appendix E.

Table 1: **First Step Estimation Results**

The left panel contains the structural reaction parameter vector β with heteroskedasticity-consistent standard errors in brackets. Sentiment coefficients and standard errors are multiplied by 100. In the last row is the p-value in percent of a GMM J-test for overidentifying restrictions, that is rejected if the elements of β are time-varying.

DE inflation	0.768	***	(0.097)
ES inflation	0.165	**	(0.074)
IT inflation	0.098	**	(0.048)
EA inflation	0.323	**	(0.141)
FR inflation	0.324	***	(0.127)
DE Business Conf. (ifo)	0.203	***	(0.069)
FR Manufacturing Conf.	0.078		(0.067)
IT Business Conf.	0.008		(0.029)
H0: β time-constant	p(J=0) = 50.89%		

ends on January 13, 2016, when French inflation for December 2015 was published.

Table 1 contains the estimates of the structural reaction parameter vector $\hat{\beta}$. Given the results of the split-sample analysis, the signs and their significance levels are hardly surprising. The impact of inflation in France and Germany significantly differ from zero at the 1% level, while the impact of Spanish, Italian, and euro-area inflation significantly differ at the 5% level. Business confidence indices do not differ from zero at any conventional significance level except for German Business Confidence (ifo). A GMM J-test for overidentifying restrictions of the nonlinear model structure suggests that a time-varying β is not required. Thus, the multiplicative model structure is not rejected by the data.

In the second step, the time variation is investigated on a monthly frequency.[27] The estimated $\hat{\beta}$ from the first step in Table 1 is taken as given. The term $(\hat{\beta}S_t)$ acts as a compound surprise. Given $(\hat{\beta}S_t)$, a monthly rolling regression with all surprises during the preceding nine months is used to estimate δ_t^n:

$$\Delta ILS_t^n = \alpha_t^n + \delta_t^n \cdot (\hat{\beta}S_t) + \varepsilon_t^n \tag{6}$$

Figure 6 contains the estimated value (blue) and 95% confidence bands from the second step. The green error bands are adjusted for the first-step estimation error in $\hat{\beta}$, whereas the grey error bands are unadjusted.[28] The vertical red-dotted lines indicate the boundaries of the dummies in the first step.

For the two-year spot ILS rate in the first panel of Figure 6, we observe an increase in δ_t^{2Y} with the onset of the crisis in 2008. The first peak is in 2009 with an elevated level of estimation uncertainty. During the disinflation starting in 2013, the sensitivity of the two-year spot ILS rate increases again, but stays well below the levels attained in 2009. Despite declining inflation in mid-2014, the sensitivity δ_t^{2Y} reduced and was only marginally significant. Finally, starting in February 2015, we observe a significant reaction of ILS^{2Y}.

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[27] Again, a "month" refers to a reporting month that ends with the publication of French inflation in the middle of the following calendar month.

[28] The adjustment follows Swanson and Williams (2014) to ensure that, if the rolling window corresponds to a dummy, the standard deviation of δ^n corresponds to the standard deviation of the dummy. Therefore, the adjustment can only be determined from 2007 onwards. During the benchmark period, the rolling window never coincides with a dummy.

Figure 6: **Estimation Result of the Time-Varying δ_t^n**

Estimates of δ_t^n and 95% confidence intervals based on heteroskedasticity-adjusted standard errors. Vertical red-dotted lines indicate the end of the first-step dummies with a length of nine months on the day French inflation is released. Year labels on the x-axis indicate January 1. The vertical red-dotted lines indicate the boundaries of the dummies in the first step.
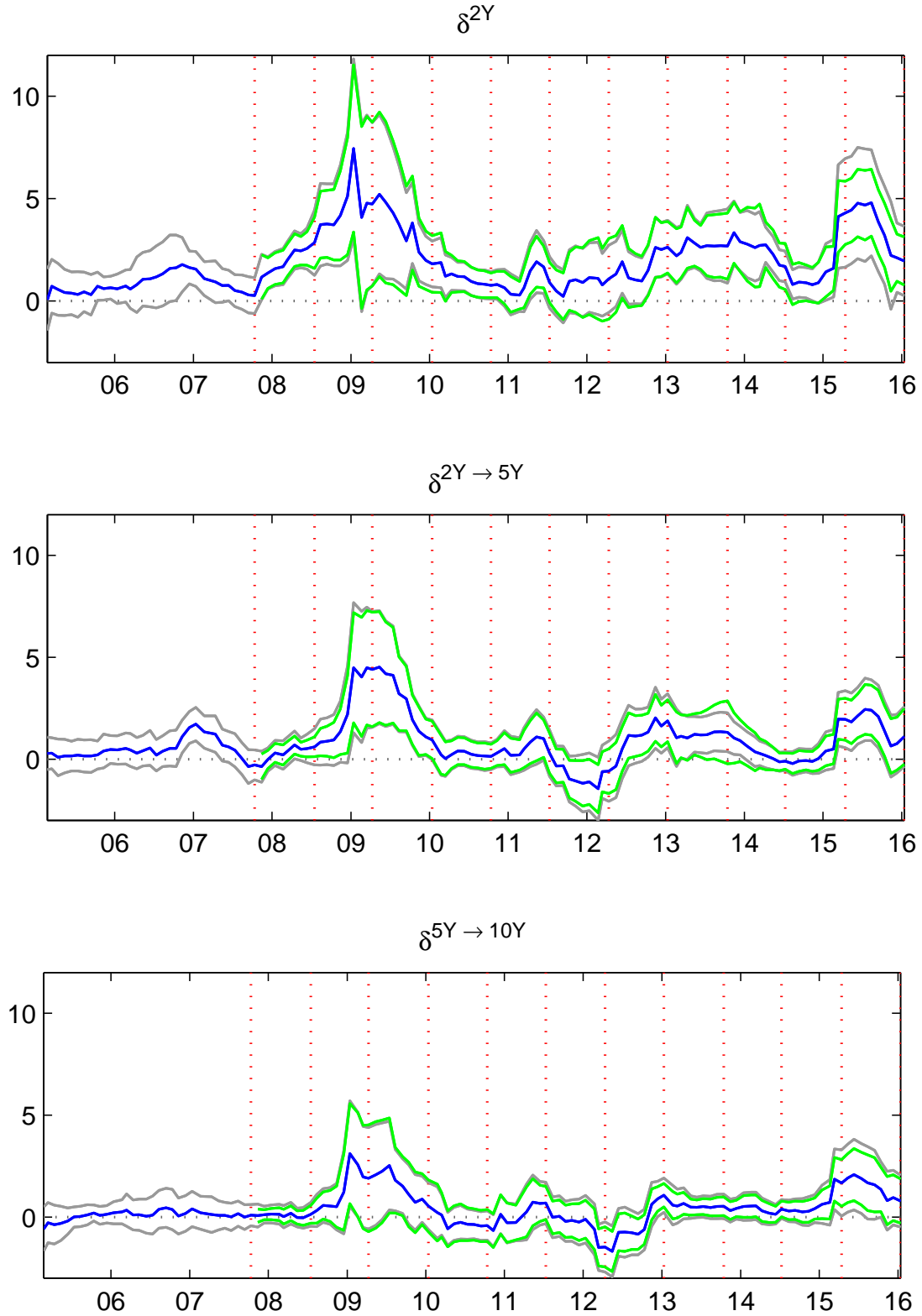

δ^{2Y}

$\delta^{2Y \to 5Y}$

$\delta^{5Y \to 10Y}$

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Figure 7: **Time-Varying δ_t^n without February 2015**

Estimates of δ_t^n and 95% confidence intervals based on heteroskedasticity-adjusted standard errors. Releases of inflation in February 2015 are not included in the estimation. The green error bands are adjusted for the first-step error in $\hat{\beta}$, whereas the grey error bands are unadjusted. Vertical red-dotted lines represent the end of the first-step dummies with a length of nine months on the day French inflation is released. Year labels on the x-axis indicate January 1.

$\delta^{5Y \to 10Y}$
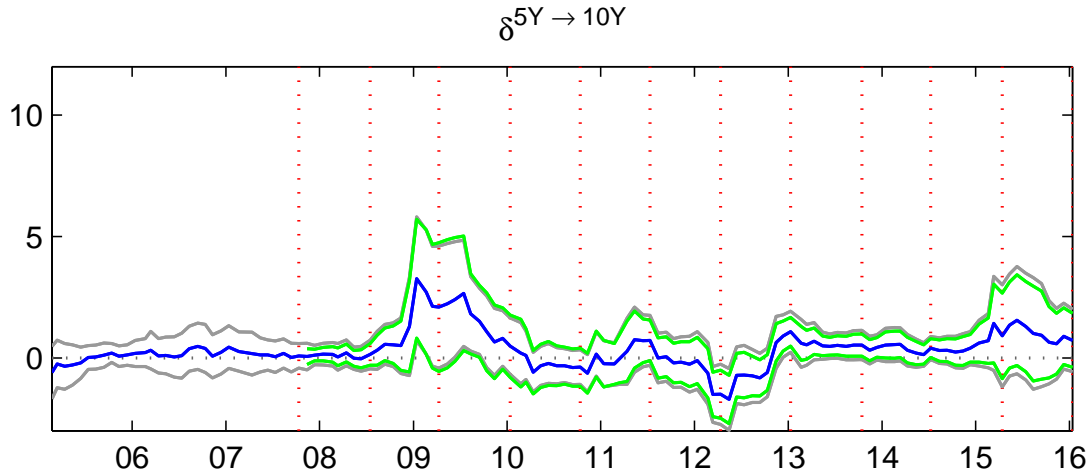
Over more distant horizons, the reaction is dampened. For the forward ILS rates between two and five years ($\delta_t^{2Y \to 5Y}$) in the middle panel, we observe extended periods of significant reaction. The reaction of the five-year forward inflation rate in five years ($\delta_t^{5Y \to 10Y}$) in the lower panel is insignificanly different from zero most of the time. However, there are two short episodes in which there is an elevated level of medium-term ILS reaction that remain undetected in the conventional split-sample analysis: In 2009 and from February to September 2015 $\delta_t^{5Y \to 10Y}$ is significantly positive at the 5% significance level if the corrected error bands (green) are considered.

Following the conventional definition, the short periods of medium-term forward ILS rate sensitivity to macroeconomic news imply de-anchoring of inflation expectations. However, there are many potential causes for a sensitivity of the ILS rate at a five-year horizon, not exclusively a loss of credibility in the Eurosystem's target. The remainder is therefore devoted to an in-depth analysis of the sources of the sensitivity and the indicator quality of the 5Y-5Y-forward ILS in order to derive reliable policy implications.

5.2 De-Anchoring or Re-Anchoring in 2015?

The backward-looking nature of the rolling regressions to determine $\delta^{5Y \to 10Y}$ in Figure 6 allows for two interpretations of the significant values of $\delta^{5Y \to 10Y}$ from February to September 2015. It may either reflect positive inflation surprises in February 2015 when ILS rates increased, or a decline in ILS rates caused predominantly negative inflation surprises for most of 2014 and January 2015. Since the policy implication of the interpretations is very different, I skip the five positive inflation surprises in February 2015 to eliminate the effect of the ILS rate movements towards the target and re-estimate the model.

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Figure 8: **Separated Model: Time-Varying $\delta_\pi^{5Y\to10Y}$ and $\delta_{sent}^{5Y\to10Y}$**

Estimates of δ_t^n and 95% confidence intervals based on heteroskedasticity-adjusted standard errors. The green error bands are adjusted for the first-step error in $\hat{\beta}$ whereas the grey error bands are unadjusted. Vertical red-dotted lines represent the end of the first-step dummies with a length of 12 months on the day French inflation is released. Year labels on the x-axis indicate January 1.
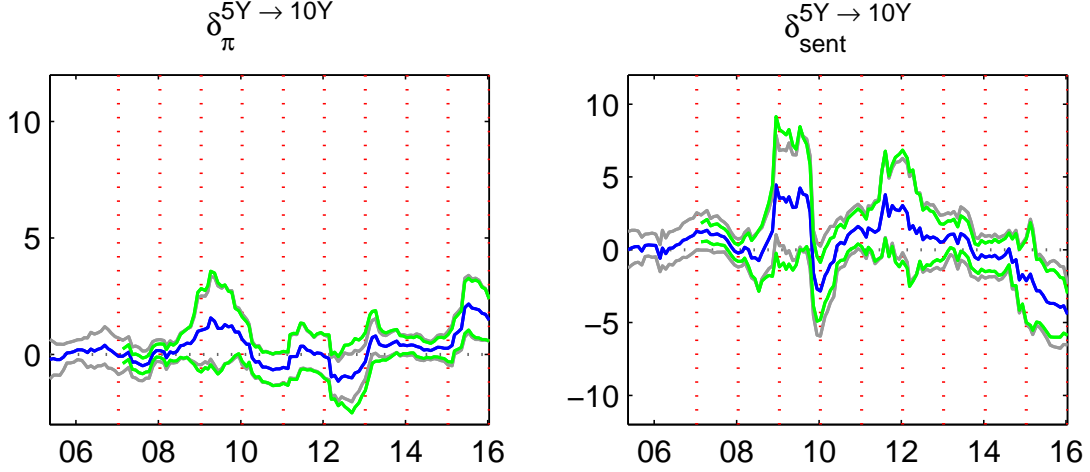
The time-varying sensitivity $\delta_t^{5Y\to10Y}$ of the re-estimated model in Figure 7 represents a measure of de-anchoring from the target. Without the February announcements, we still observe an increase of $\delta^{5Y\to10Y}$ in early 2015, but in contrast to figure 6, it is smaller and insignificantly different from zero. Therefore, the negative surprises do not account for the reaction in Figure 6, i.e. the decline of ILS rates in 2014 cannot be explained by macro surprises. The event study does not provide evidence for agents learning from low inflation rates about a lower inflation target of the Eurosystem during the low inflation period from 2013 onwards. The significant reaction rather reflects ILS rate movements *towards* the target from below caused by positive surprises in February 2015 at the realized inflation's turning point.

5.3 Inflation Persistence and Target De-Anchoring

The sensitivity of medium-term inflation expectations is not necessarily an indication of a de-anchored inflation target or incredible monetary policy for two reasons.

First, inflation and corporate sentiment indicator surprises are mixed to estimate δ_t^n, but the specific news group that drives the medium-term ILS reaction is informative as well. Surprisingly low inflation realizations driving medium-term forward ILS rates can either signal learning about the monetary policy target or about the increase in inflation persistence. Surprises about the real economic situation are not a signal of quantitative inflation target adjustment but of the persistence of the business cycle. In order to separate the impact of inflation and sentiment news, group-specific dummies are used in the first step:

$$\Delta ILS_t^n = \alpha_\tau^n + \bar{\delta}_{\pi,\tau}^n dummy_{\pi,\tau}^n(\beta^\pi S_t^\pi) + \bar{\delta}_{sent,\tau}^n dummy_{sent,\tau}^n(\beta^{sent} S_t^{sent}) + \varepsilon_t^n \qquad (7)$$

Figure 9: **Time-Varying δ_t^n for $ILS^{9Y \to 10Y}$**

Estimates of δ_t^n and 95% confidence intervals based on heteroskedasticity-adjusted standard errors. An adjustment for the first-step estimation error is not possible because $ILS^{9Y \to 10Y}$ is not included in the first-step estimation. Vertical red-dotted lines represent the end of the first-step dummies with a length of nine months on the day French inflation is released. Year labels on the x-axis indicate January $1st$.
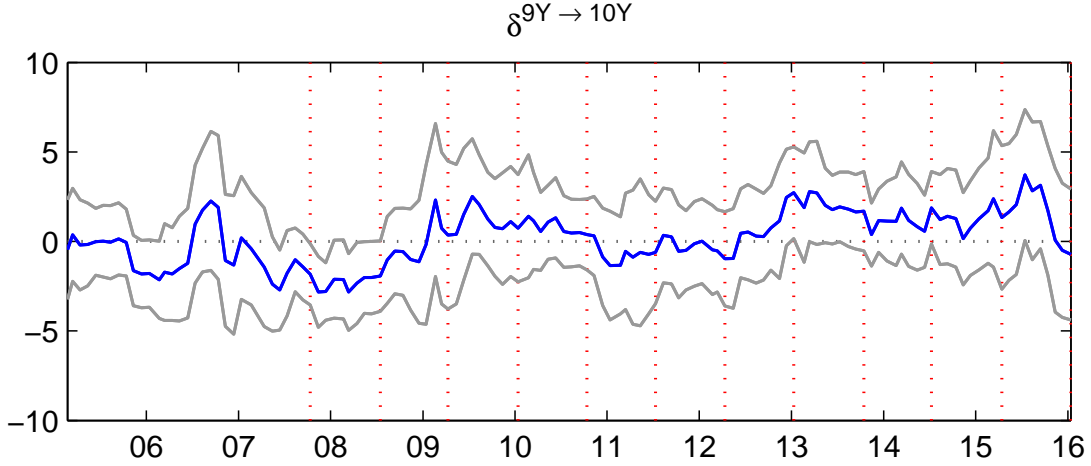
The number of announcements to estimate the group-specifc dummies is only five and three per month. In order to compensate for the reduction of the sample size for each group, the dummy length is increased to 12 months. All data – including the inflation releases in February 2015 – are included in the estimation. The estimates of the structural inflation impact $\hat{\beta}^\pi$ and the structural sentiment indicator impact $\hat{\beta}^{sent}$ are used to construct a composite inflation surprise $(\hat{\beta}^\pi S_t^\pi)$ and a composite sentiment surprise $(\hat{\beta}^{sent} S_t^{sent})$. In the second step, group-specific scalars $\delta_{\pi,t}^n$ and $\delta_{sent,t}^n$ describe the impact of inflation and sentiment indicators over time:

$$\Delta ILS_t^n = \alpha_t^n + \delta_{\pi,t}^n \cdot (\hat{\beta}^\pi S_t^\pi) + \delta_{sent,t}^n \cdot (\hat{\beta}^{sent} S_t^{sent}) + \varepsilon_t^n \tag{8}$$

Standard errors of $\delta_{x,t}^n$ are corrected for the first-step error in $\hat{\beta}^\pi$ and $\hat{\beta}^{sent}$. The estimates for the 5Y-5Y-forward horizon $\delta_{\pi,t}^{5Y \to 10Y}$ and $\delta_{sent,t}^{5Y \to 10Y}$ of this separated model are depicted in Figure 8. There is an evident difference between the elevated reaction level in 2009 and 2015. In 2009, surprises about the real economic situation played the dominant role when sentiment was worse than previously expected. Whether low potential growth and spare capacities can be solved by expansionary monetary policy or whether such developments are beyond the scope of monetary policy is open to discussion. In contrast, the recent period of significant medium-term forward ILS rate reaction from February to September 2015 is not caused by real economic news but by positive inflation surprises.[29]

Increased inflation persistence is the second reason why a reaction of the medium-term 5Y-5Y-forward ILS rate to macroeconomic surprises is not necessarily a sign of a

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[29]In contrast to $\delta_t^{5Y \to 10Y}$ in Figure 6, $\delta_\pi^{5Y \to 10Y}$ in Figure 8 is significant from zero at the 5% level in October 2015. This is caused by the longer 12-month rolling window that includes the February data releases. If the rolling window is shortened to exclude February data releases, the reaction parameter $\delta_\pi^{5Y \to 10Y}$ is insignificantly different from zero.

de-anchored inflation target. More than seven years have passed since the onset of the subprime crisis in the US and more than five years since the first restructuring of Greek debt in 2010. Some southern countries of the euro area did not reach pre-crisis levels of economic activity by the end of 2015. The economic recovery might take longer in a downturn caused by a financial crisis than in a usual business cycle downturn.[30] Given the long duration of the current crisis, market participants' perceived persistence of shocks may have increased compared to the pre-crisis level. Even if the inflation target is firmly anchored at 2%, it may take five years or longer until inflation reaches target levels. Thus, the reaction of a forward rate starting in five years might reflect slow recovery as well. The hypothesis of a slow recovery can be tested by using a more distant forecast horizon than the usual 5Y-5Y forward ILS rate. Figure 9 contains the time-varying sensitivity of the one-year forward inflation rate starting in nine years $\delta_t^{9Y \to 10Y}$ determined from $(\hat{\beta}S_t)$ of the original specification (6) with eight news releases and a dummy length of nine months. This forward ILS rate contains expectations about the inflation rate over one year starting nine years from now. In 2009, the hypothesis of zero impact on $ILS^{9Y \to 10Y}$ cannot be rejected at the 5% level. In 2015, we do not observe a significant sensititvity $\delta_t^{9Y \to 10Y}$. However, the estimated values of $\delta_t^{9Y \to 10Y}$ are more erratic and the error bands are wider than for $\delta_t^{5Y \to 10Y}$.

Inflation surprises did not lead to systematic changes for expectations over very distant horizons, i.e. market participants did not learn from inflation surprises about a different inflation target. Therefore, the sensitivity of the medium-term 5Y-5Y-forward ILS rate reflects a longer adjustment period and is no sign of a de-anchored inflation target in the current situation of low inflation rates.[31]

5.4 What Drives Time-Varying Sensitivity?

The time variation of the sensitivity δ_t^n in equation (6) is instructive for the interpretation of the results. If the deviation from normal inflation is large, it takes longer to come back to normal levels and (market-based) expectations are supposed to be affected stronger by macro news. Therefore, the realized inflation rate is supposed to be an important driver of the sensitivity of market-based inflation expectations. Both especially low and high inflation rates should lead to a high sensitivity, such that a nonlinear approach is required.

Another potential driver of sensitivity is perceived uncertainty. At times of high uncertainty about the current situation and the future path of the economy, information revealed by data releases is particularly valuable to investors. In those uncertain times, a stronger reaction to a given surprise is plausible.

In the following, inflation π_t is the level of the realized aggregate euro-area inflation and uncertainty is measured by the mean-adjusted three-month option-implied volatility of the Bund Future σ^{Bund}. The dependent variable δ_t^n is taken from the benchmark model (6) and the estimation is carried out with nonlinear least squares:

$$\delta_t^n = \alpha^n + \kappa^n |\bar{\pi}^n - \pi_t| + \gamma^n \sigma_t^{Bund} + \varepsilon_t \qquad (9)$$

[30]See for example Reinhart and Rogoff (2009).
[31]Using Consensus forecasts instead of market-based inflation expectations, Ehrmann (2014) also provides evidence for a longer recovery from persistently low inflation rates.

Table 2: **Drivers of Sensitivity** δ^n

Explanation of the time-varying sensitivity δ^n using realized inflation π_{EA} and the three-month option-implied volatility of the Bund Future σ^{Bund}. Bund Future and inflation are quoted in percent per annum. δ^n is taken from the benchmark model with eight announcements of inflation and sentiment indicators. Nonlinear least square optimization of equation (9) with heteroskedasticity-adjusted standard errors in brackets. R^2 in percent.

	δ^{2Y}	$\delta^{2Y \to 5Y}$	$\delta^{5Y \to 10Y}$
α^n	0.933	0.032	-0.303
	(0.114)	(0.128)	(0.082)
$\bar{\pi}^n$	2.517	2.983	2.718
	(0.138)	(0.192)	(0.121)
κ^n	0.968	0.587	0.576
	(0.115)	(0.106)	(0.062)
γ^n	0.331	0.203	0.119
	(0.095)	(0.081)	(0.043)
R^2	80.89	52.27	53.55

The parameter $\bar{\pi}^n$ is the implicit inflation rate at which there is a normal sensitivity. It should be close to the offical inflation target. κ^n determines the change in δ_t^n for a deviation of inflation from the implicit target $\bar{\pi}^n$. It should be lower for more distant forecast horizons if persistence is the reason for a reaction over a specific horizon. γ^n measures the impact of uncertainty on the reaction parameter δ_t^n and should be positive.

The results in Table 2 are broadly in line with the above-mentioned hypotheses except for the the implicit inflation target $\bar{\pi}^n$, which is significantly above 2% for all maturities. Positive κ^n implies that low inflation rates lead to higher sensitivities. Furthermore, a deviation of π_t from its implicit target $\bar{\pi}^n$ leads to a stronger change in the case of short maturities than for more distant horizons. While the effect of the uncertainty is highest for short-term expectations, Bund volatility has no significant impact five years ahead.

The smaller parameter values κ^n and γ^n for more distant forecast horizons are also reflected in a decaying pattern of R^2. Furthermore, the explanatory power of realized inflation for δ_t^n in Table 2 is higher than the explanatory power of short-term ILS^{2Y} (not displayed). This supports the hypothesis that high δ_0^n reflect a longer adjustment period following low realized inflation because short-term ILS^{2Y} contain the first two years of adjustment.

5.5 Survey Expectation Revisions

Surprising news about the economic situation should not only change market-based expectations but should also lead to revisions of survey-based expectations. In the following, I test whether the surprises S_t identified in the event study are drivers of changes in survey expectations from the ECB's Survey of Professional Forecasters (SPF). If surprises that are identified from market-based expectations are important for survey-based expectations, we can be sure to capture general dynamics of inflation expectations rather than idiosyncratic movements of inflation swap markets. A close relation of market-based and survey-based inflation expectations is quite likely because more than 40% of the SPF forecasters use financial market indicators when they form their expectations for the

Figure 10: **Survey of Professional Forecasters Inflation Expectations**

Realized inflation of the euro area π_{EA} and survey-based inflation expectations from the ECB's Survey of Professional Forecasters (SPF). "12M" and "24M" indicate the fixed 12- and 24-month forecast horizon of the SPF questionnaire. "5Ys" refers to the longest forecast horizon of the SPF with a forecast horizon of between 57 and 66 months. Last observation is Q4 2015 released in October 2015.
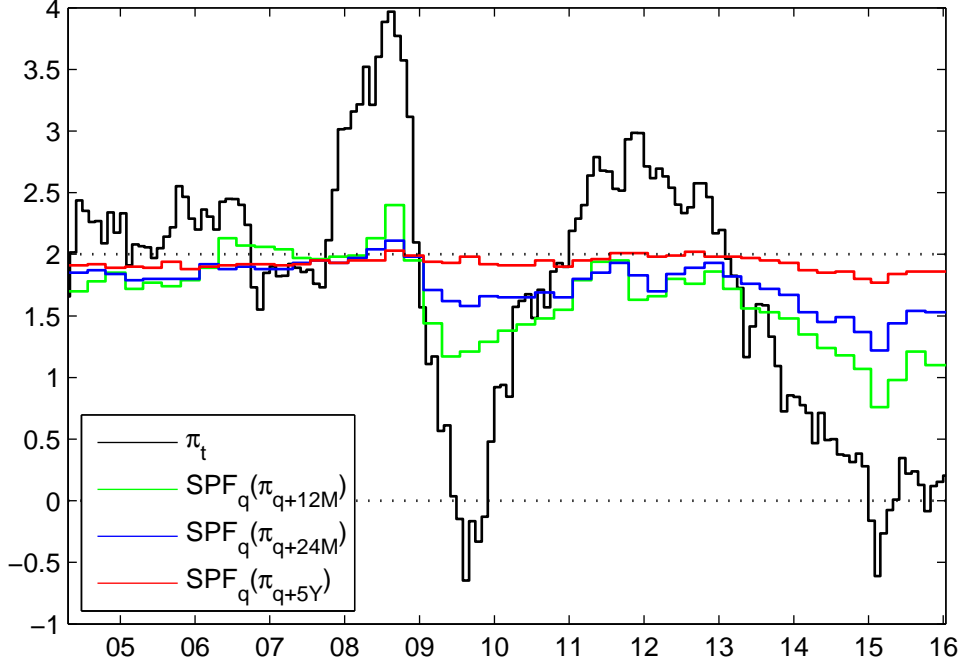
SPF.[32]

The SPF is available on a quarterly frequency. Its forecast horizon covers up to five years and is therefore shorter than the benchmark indicator of market-based inflation expectations $ILS^{5Y\rightarrow10Y}$.[33] The SPF time series in Figure 10 exhibit less time variation compared to market-based inflation expectations in Figure 1, maybe due to the premia for inflation and liquidity risk contained in ILS. Expectations for short forecast horizons are low (high) when realized inflation is low (high) which is in line with a gradual adjustment process of inflation. In 2015, the expected inflation rate one and two years from now are at historically low levels. The SPF expectations at the 5 year horizon are close to, but below two percent. When realized inflation declined from 3 % in 2012 to negative territory in early 2015 the SPF expectations at the five year horizon declined by not more than 0.3 percentage points. When inflation recovered in the first half of 2015, the five year SPF expectation increased as well but remains below 2%.

Due to the quarterly SPF frequency, it is not possible to match changes in survey expectations to surprises on a daily basis. It is necessary to determine the aggregate surprise of a quarter. The aggregate surprise of a quarter AS_q is defined as the sum of all surprises S_t that occures during a quarter weighted by the estimated value of their

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[32]See ECB (2014, Chart 8).

[33]The horizons of the expected inflation from the SPF correspond approximately to ILS^{1Y}, $ILS^{1Y\rightarrow2Y}$ and $ILS^{4Y\rightarrow5Y}$. Time-varying δ_t^n for the those maturities are contained in Appendix F.

Table 3: **Aggregate Surprise and SPF Revisions**

Impact of aggregate surprises AS_q during a quarter (definition from equation 10) on the change in the SPF forecasts. "12M" and "24M" indicate the fixed 12- and 24-month forecast horizon of the SPF questionnaire. "5Y" refers to the longest forecast horizon of the SPF with a forecast horizon of between 54 and 66 months. OLS estimation. Heteroskedasticity-adjusted standard errors in brackets. R^2 in percent.

| | **A:** Survey-Based Expectations | | | **B:** Market-Based Expectations | | |
	$SPF_q(\pi_{q+12M})$	$SPF_q(\pi_{q+24M})$	$SPF_q(\pi_{q+5Y})$	ILS_q^{1Y}	$ILS_q^{1Y\rightarrow 2Y}$	$ILS_q^{4Y\rightarrow 5Y}$
constant	-0.015	-0.008	-0.001	-0.034	-0.033	-0.025
	(0.022)	*(0.013)*	*(0.005)*	*(0.082)*	*(0.037)*	*(0.031)*
AS_q	2.700	1.021	0.075	6.138	3.023	1.800
	(0.755)	*(0.434)*	*(0.176)*	*(2.816)*	*(1.260)*	*(1.042)*
R^2	22.54	11.18	0.42	9.76	11.58	6.36

structural impact from the event study $\hat{\beta}$:

$$AS_q = \sum_{t=q-1}^{q} \hat{\beta} S_t \tag{10}$$

All macroeconomic data releases up to the deadline to reply to the SPF questionnaire can impact the SPF forecasts. The end of a quarter is set to the day of the deadline to reply.[34] There are fewer than 50 quarterly observations for the sample starting in 2004. This is about the same number of announcement days that is used in the nine month rolling window in section 5.1. Given the small sample, I run a time-constant regression of aggregate announcement surprises on the change in SPF inflation forecasts at the forecast horizon $n = 12M, 24M, 5Y$:

$$\Delta SPF_q(\pi_{q+n}) = \gamma_0^n + \gamma_1^n AS_q + \varepsilon_q^n \tag{11}$$

The results in Table 3 (Panel A) show a significant impact of the aggregate announcement surprises on the revisions of short-term inflation forecasts, similar to Bauer (2014) for US data.[35] The parameter value and R^2 decays for longer forecast horizons. This is in line with an adjustment of the short-term outlook to current shocks that fade over time. The expected inflation in five years from the SPF is not affected by the aggregate surprise measure, providing no evidence for de-anchored survey expectations over the whole sample. While this is in line with the split-sample analysis in section 4, the short periods of sensitive medium-term ILS rate sensitivity in Figure 6 are uncovered in the analysis of the quarterly SPF data. This finding might be caused by the time-invariant methodology used for the SPF data or by the fact that macro announcements affect the risk premia of ILS rates that are not contained in the SPF data.

The role of risk premia is corroborated by the analysis in panel B, where the quarterly change in SPF expectations in the time-constant equation (11) is replaced by the quarterly change of the ILS rate with horizons that match best the SPF horizons. We observe a decaying pattern for longer forecast horizons well in line with the SPF results and time-

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[34]The dates are published on the ECB webpage:
http://www.ecb.europa.eu/stats/prices/indic/forecast/html/index.en.html
[35]Bauer (2014) uses an unrestricted approach to investigate the effect of aggregate surprises.

varying analyses. At the one-year horizon, the market-based ILS^{1Y} contains a strong idiosyncratic variation from seasonalities and the indexation lag. Its coefficient is only significant at the 5% level and its R^2 is less than half the R^2 of the one-year SPF. At the two-year horizon, the explanatory power for the $ILS^{1Y \to 2Y}$ is close to its SPF counterpart and the coefficients of the SPF and ILS both differ significantly from zero at the 1% level. The most pronounced difference between ILS and SPF expectations is over the five-year horizon: The market-based expected inflation over a five-year horizon is significantly affected by the aggregate surprise at the 10% confidence level and its R^2 is larger than 6%, whereas the SPF revisions are not affected by aggregate surprises and R^2 is close to zero. It seems that inflation surprises affect expected inflation and risk premium for unexpectedly high inflation in the same direction such that the reaction of market-based ILS expectations exceeds the reaction of SPF expectations.

Overall, the sensitivity of the short-term SPF expectations to the aggregate surprises identified from the ILS rates provides evidence that in these surprises, we capture some general dynamics of inflation expectations rather than idiosyncratic movements of inflation swap markets.

6 Conclusion

The extension of the time-varying methodology of Swanson and Williams (2014) to market-based inflation expectations reveals that a sensitivity of the medium-term 5Y-5Y-forward inflation rate is not a unique feature of the US resulting from to the dual mandate of the Fed. It also occurs in the euro area in times of a recession or a period of persistently low inflation rates.

However, this sensitivity should not be interpreted mechanically as a signal of inflation dynamics that are de-anchored from the Eurosystem's inflation target and is therefore not necessarily a threat to the credibility of monetary policy in the euro area. In the past, it rather reflected a longer-than-normal adjustment process from (low) inflation levels to the target that is transferred to inflation-linked swap rates of longer maturities – including the five-year forward inflation rate starting in five years. Market-based inflation expectations over more distant horizons are not affected by macro news and euro area inflation can still be regarded as firmly anchored at the Eurosystem's target.

This study delivers no explanation for the pronounced reduction in the 5Y-5Y-forward inflation-linked swap rate we observed from mid-2014 to January 2015. But the analysis shows that it was *not* unexpectedly low inflation or unexpected developments in the real economy in the euro area. Determinants of inflation expectations, inflation risk or liquidity risk that are not related to macroeconomic developments probably account for the decline in medium-term forward inflation-linked swap rate. However, term structure models are required for a better understanding of the determinants of ILS rates, which is beyond the scope of this event study.

A ILS Rates, Risk Premia and Inflation Expectations

Inflation-linked swap rates contain expectations surrounding not only future inflation but also inflation risk and liquidity premia. According to the law of iterated expectations, long-run (inflation) expectations tomorrow should correspond to long-run (inflation) expectations today. If medium-term ILS rates correspond to pure inflation expectations, the differenced forward ILS series should be unpredictable.[36] Unpredictable changes imply that the variance over a longer m-day change is equal to m times the one-day change and the variance ratio $VR(m)$ is equal to one

$$VR(m) \;=\; \frac{var\left(\sum_{i=1}^{m} ILS_{t+1-i}^{n} - ILS_{t-i}^{n}\right)}{m \cdot var\left(ILS_{t+1}^{n} - ILS_{t}^{n}\right)} \tag{12}$$

Table 4 contains the variance ratio and p-value of the hypothesis $VR(m) = 1$ for the 5Y-5Y-forward ILS rate and for the 10Y-10Y-forward ILS rate.

Pre-crisis, the variance ratio of both ILS rates is below one, which indicates a mean reversion behavior. Changes are corrected in the following periods. The longer the horizon, the closer $VR(m)$ is to one, providing evidence that $ILS^{10Y \to 20Y}$ is a superior long-term indicator of inflation expectations compared to $ILS^{5Y \to 10Y}$ (furthermore its volatility is lower, see Fig. 2). However, neither ILS forward is a martingale, meaning that neither is a wholly accurate indicator of pure inflation expectations.

With the onset of the crisis, the variance ratios increase and exceed one for the short m of $ILS^{5Y \to 10Y}$. This mean-diverging behavior implies that a positive shock on a forward ILS rate is not corrected but rather followed by another shock in the same direction. Since this behavior is more pronounced for $ILS^{10Y \to 20Y}$, this behavior is likely to be caused by worse liquidity and higher inflation risk compensation than prior to the crisis. $ILS^{10Y \to 20Y}$ are therefore not a suitable indicator for inflation expectations in the crisis. The five-year forward inflation rate starting in five years $ILS^{5Y \to 10Y}$ is the preferred indicator for the analyses in this paper.

Table 4: **Variance Ratio Tests**

	$ILS^{5Y \to 10Y}$				$ILS^{10Y \to 20Y}$			
	pre-crisis		crisis		pre-crisis		crisis	
std	1.71		2.38		1.65		2.21	
m	VR(m)	p-val	VR(m)	p-val	VR(m)	p-val	VR(m)	p-val
5	0.69	0.00	1.21	0.42	0.78	0.14	1.34	0.00
10	0.57	0.03	1.13	23.93	0.71	0.94	1.32	0.50
20	0.42	0.10	0.90	53.24	0.59	1.21	1.27	8.31
60	0.42	6.04	0.78	40.36	0.54	12.79	1.40	12.71

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[36]Here, I neglect the time-to-maturity effect of one day.

B Euro-Area Announcement Selection

Producer Price Index (PPI) surprises are not used in this study in contrast to many other event studies. Prior to the crisis, PPI surprises significantly increased ILS rates in the euro area over long horizons. With the onset of the crisis, the impact changes sign and there is a negative reaction of market-implied expected information to unexpectedly high PPI inflation.[37] However, the number of survey participants before 2008 used to be between 20 and 30 but decreased to ten to 15 participants. The decrease in participants was accompanied by an increase in dispersion. Furthermore, PPI data is published after the final CPI data in all euro-area member countries.[38] EA PPI is often published after the next month's preliminary EA HICP release. The change in behavior after the onset of the financial crisis might therefore be explained by the low information content of the PPI announcements due to their long publication lag and the reduced coverage by economic analysts. It is therefore omitted from the analysis.

Consumer Confidence Indices and related Bloomberg surveys have been available for the whole European Union since 2004. In the case of Germany (GfK) and France, the Bloomberg surveys did not start untill 2006. As for the Italian consumer confidence index, there are only a small number of participants in the Bloomberg survey. The impact of the aggregate consumer confidence index is tiny in a univariate analysis. This is maybe related to the fact that euro-area consumer confidence (like the index for EA industry confidence) is usually not published before inflation data are released. As a result, consumer confidence indices are omitted from the analysis.

Economic Sentiment Index (ESI) for the whole European Union combines information from the consumer and corporate sector surveys and does not change the economic implications of my analysis compared to the EA industrial confidence. It is published at the same time as the EA industrial confidence index after inflation data are released and therefore shares the industrial confidence index's problem of multicollinearity with inflation releases.

German ZEW Index surveys the real economic outlook of financial market experts and is not part of the harmonized surveys in the European Union. The current situation has a significant coefficient in a univariate analysis of medium-term forward ILS rates in the pre-crisis period. However, no coefficient is significant in a multivariate analysis and there is no clear pattern of the coefficients for different maturities. The ZEW Index is therefore not considered in the analysis.

Unemployment in the euro area and EA inflation announcements seem to be multicollinear. EA unemployment is published many weeks after the end of the reporting period.[39] Despite this long publication lag and the fact that labor market information

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[37]This result is similar to Autrup and Grothe (2014, p.15)

[38]This is different in the US, where the PPI is the first price index that is released (see App. C).

[39]Unemployment data from member countries are published in a very timely manner compared to GDP or IP data, e.g. German unemployment data are published around the end of the reporting period. However, national unemployment data provide no explanation for ILS rate changes in my sample.

from member countries is available prior to the EA aggregate without having an impact on ILS rate changes, EA unemployment has a highly significant and *positive* impact on $ILS^{5Y \to 10Y}$ in a univariate setting prior to the crisis (there is no clear pattern in the spot rates). In a multivariate setting, there is a positive impact of unemployment on spot ILS rates with a decreasing magnitude for longer maturities. Such a positive reaction – which is also observed in Autrup and Grothe (2014) – implies higher inflation expectations if unemployment is larger than expected, which is hard to reconcile with economic theory. However, 59 out of 135 unemployment announcements occure on the same date as EA inflation releases, and those two announcement series are significantly positively correlated if they are published at the same day. Due to the large publication lag of unemployment and the irrelevance of national unemployment data releases, which become available in a more timely manner but are insignificant, I do not take the euro-area unemployment announcements into consideration. In light of this, the significance levels of EA inflation releases in the pre-crisis period increase, supporting the multicollinearity hypothesis.

C Interrelation with the US Economy

A number of studies investigate euro-area ILS rates in an event study and use US macro announcements to model international linkages. Figure 11 contains the results of the unrestricted estimation of equation (3) with a selection of US macro announcements in addition to the usual euro-area announcements. No announcement has a significant impact on the 5Y-5Y-forward ILS rate before or after the onset of the crisis, but the effect on the spot ILS curve changes.

In the US, PPI is published prior to CPI and provides the most timely information about inflation. The core CPI and core PPI have a significantly positive impact in the pre-crisis period.[40] During the financial crisis, the price level changes in the US turn out to be irrelevant. The impact of US inflation surprises on euro-area ILS rates has *declined* since the onset of the crisis.

Sentiment indicators from the US were hardly ever significant pre-crisis and if so mostly negatively like the University of Michigan Survey. After the onset of the crisis, it turns out that they exert a significantly positive influence on the ILS rates of the euro area. This is similar to the behavior of the sentiment indicators in the euro area, whose relevance with respect to market-based inflation expectations increased after the onset of the crisis. US Nonfarm Payrolls (NFP) behave in a similar manner to the sentiment indices, whereas GDP has a significantly positive influence pre-crisis but a significantly negative impact afterwards. The impact of US real economic indicator surprises on euro-area ILS rates has *increased* since the onset of the crisis.

Overall, the real and inflation indicators show no homogeneous change in shape from the pre-crisis period to the crisis period. For the time-varying analysis following the method used in section 5.1, a single δ_{US}^n is not instructive because it fails to capture the different time-varying tendencies of inflation and real economic indicators. The estimation of US-specific sub-groups is problematic due to the low number of (inflation) releases: It requires long dummy periods, which are not conductive to the investigation of (recent) time-varying behavior. Therefore no US data are included.

[40]Core indices turn out to contain more information than headline indices.

Figure 11: **US Announcements: Unrestricted Regression** β^n

Results for the pre-crisis period in blue and for the crisis period in red. The upper left panel contains the R^2, the other panels the parameters β^n and $\beta^{n\to m}$. Sentiment coefficients are multiplied by 100, US NFP by 100 000. The maturity is indicated on the x-axis. Solid lines refer to spot ILS rates. The dashed horizontal line represents the parameter of the 5Y-5Y-forward ILS rate. A coefficient significantly different from zero at the 1%, 5% or 10% level is indicated by $*$, $\times$ and $+$ respectively.
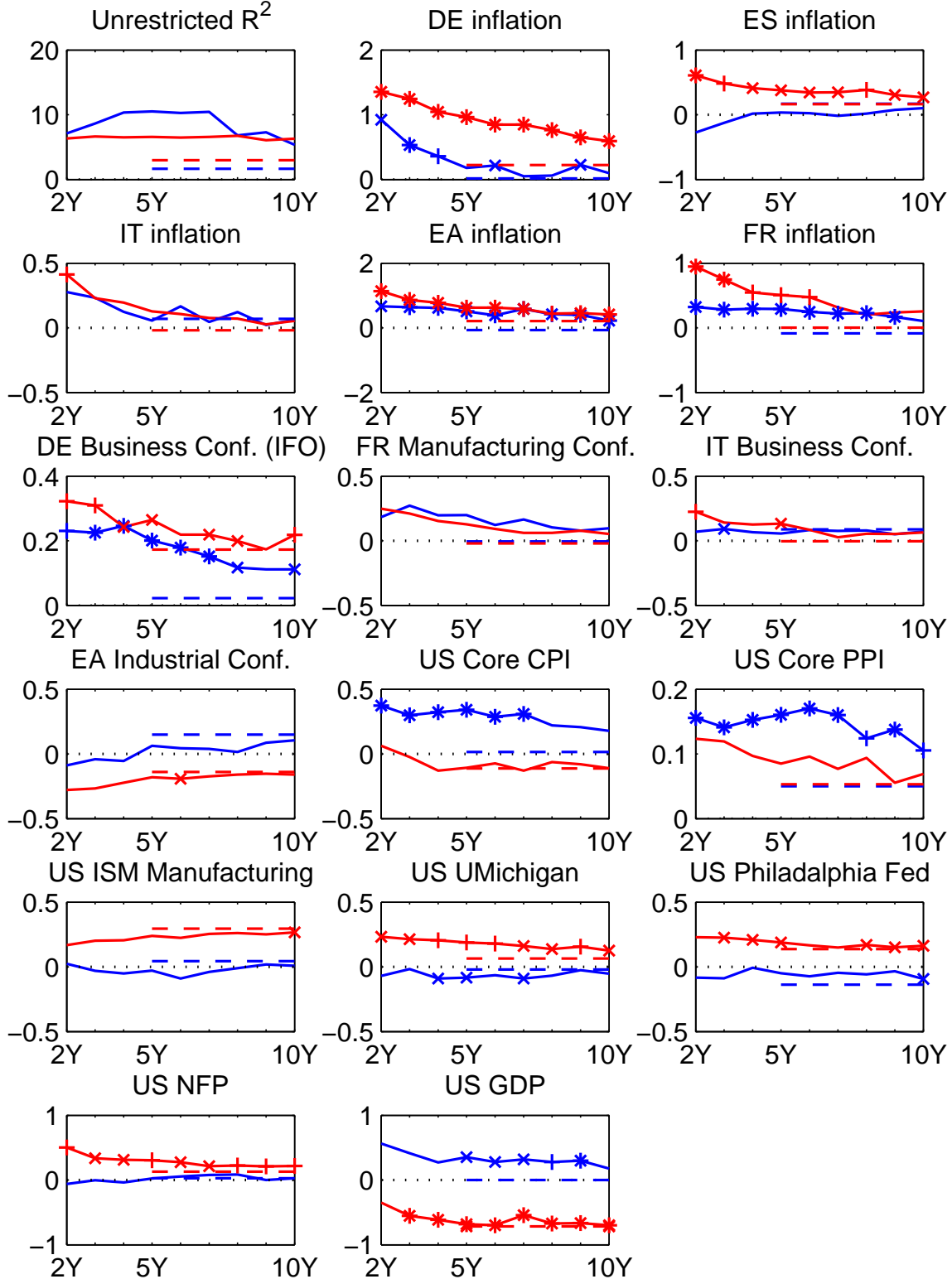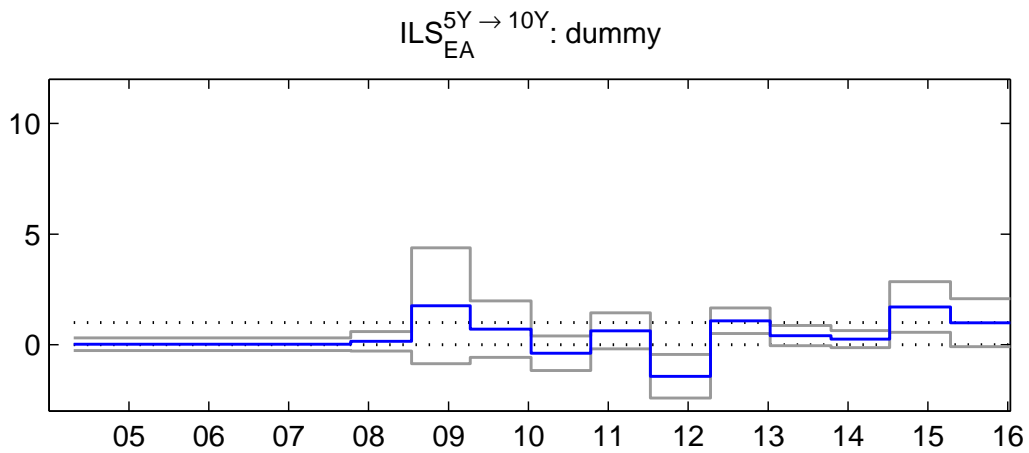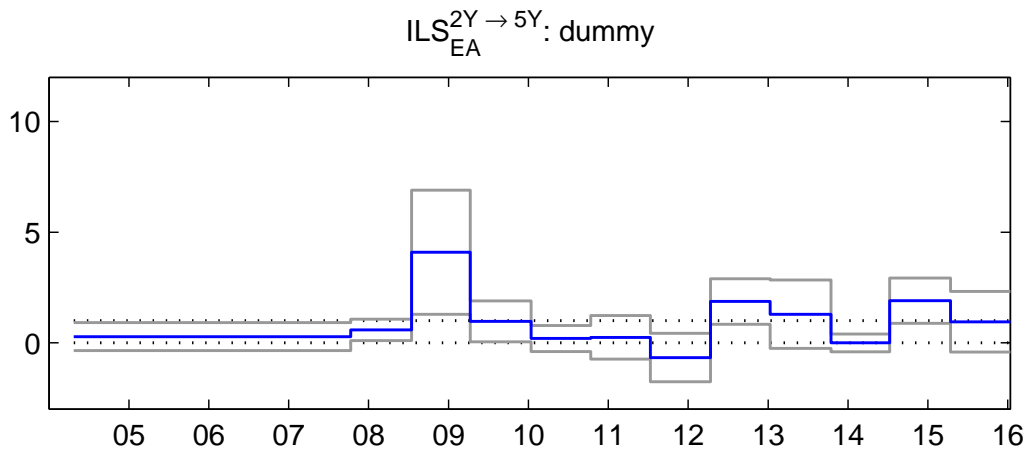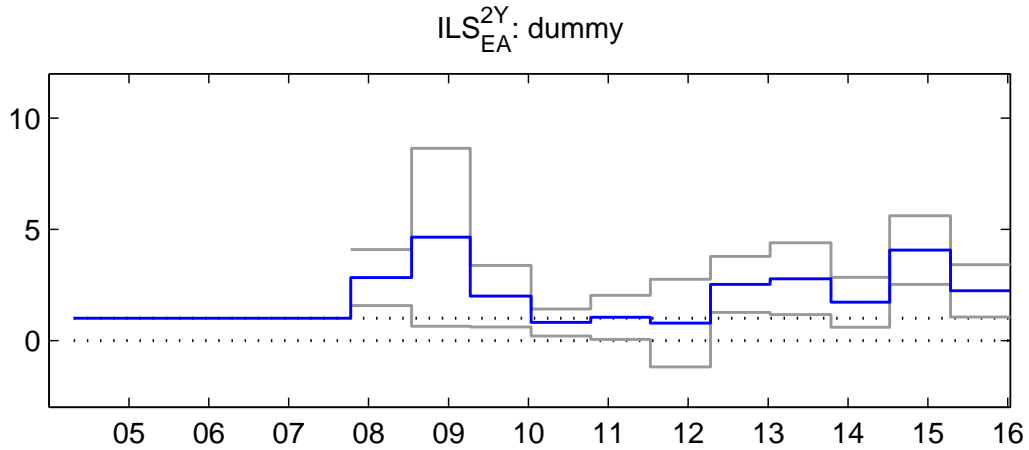
D Structural Impact Vector $\hat{\beta}$ and Dummy Length

Estimates of the structural impact parameter vector $\hat{\beta}$ from equation (5) and 95% error bands for different lengths of the dummy length. The length of the dummy is indicated on the x axis in months.
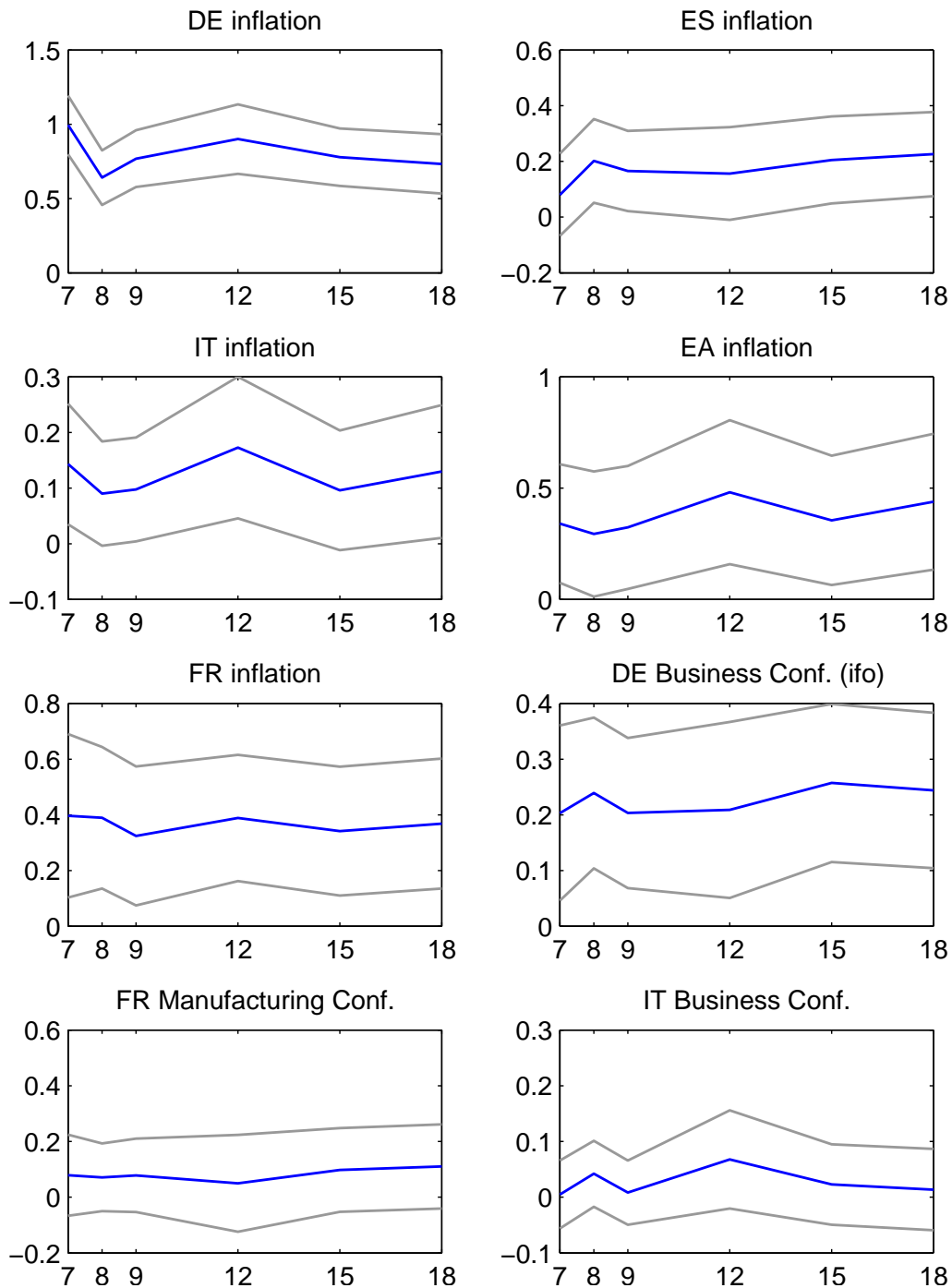
E   First-Stage Dummy Parameter Plot

Estimates of $\bar{\delta}_\tau^n$ from equation (5) and 95% error bands. No error band for the two-year spot ILS rate in the pre-crisis period since this dummy coefficient $\bar{\delta}_1^{2Y}$ is not estimated but rather fixed at 1 to identify β and $\bar{\delta}_\tau^n$.

ILS_{EA}^{2Y}: dummy

$ILS_{EA}^{2Y \rightarrow 5Y}$: dummy

$ILS_{EA}^{5Y \rightarrow 10Y}$: dummy

F   Time-Varying δ_t^n for Matched SPF Maturities

Estimates of δ_t^n from equation (6) and 95% confidence intervals based on heteroscedasticity-adjusted standard errors. An adjustment for the first-step estimation error are not possible because the data are not included in the first-step estimation. Vertical red-dotted lines indicate the end of the first-step dummies with a length of nine months on the day French inflation is released. Year labels on the x-axis indicate January 1.
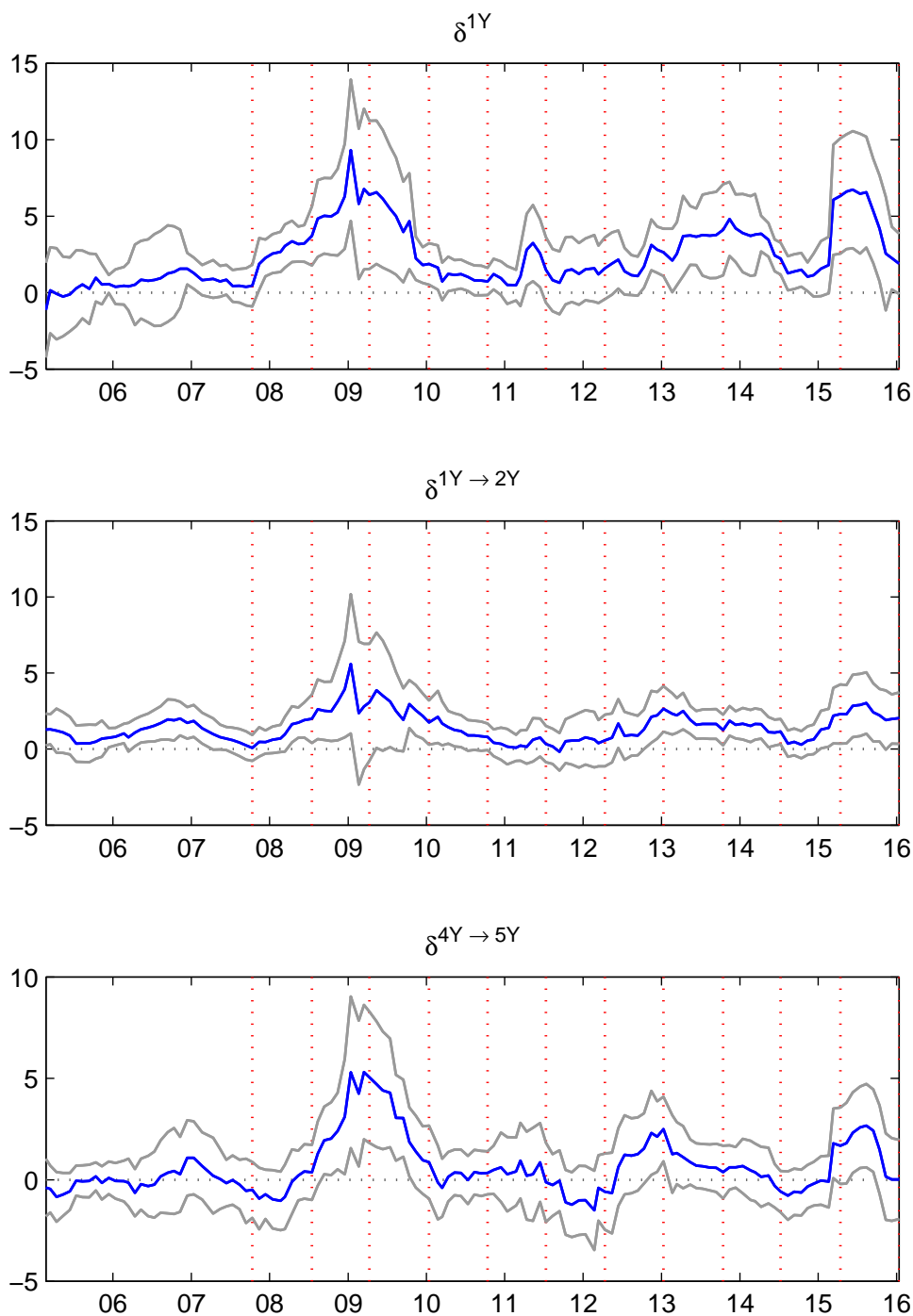
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