The Impact of Forward Guidance on Inflation Expectations: Evidence from the ECB

Marc de la Barrera
Juraj Falath
Dorian Henricot
Jean-Alexandre Vaglio

December 2017

Barcelona GSE Working Paper Series

Working Paper nº 1010

The Impact of Forward Guidance on Inflation Expectations: Evidence from the ECB*

Marc de la Barrera[a], Juraj Falath[b], Dorian Henricot[c], Jean-Alexandre Vaglio[d]

[a]Barcelona Graduate School of Economics, Universitat Pompeu Fabra
[b]Barcelona Graduate School of Economics, Ministry of Finance of the Slovak Republic
[a]Barcelona Graduate School of Economics, Banque de France
[a]Barcelona Graduate School of Economics, Université Panthéon-Assas

This paper empirically investigates the impact of forward guidance announcements on inflation expectations in the Eurozone. We identify forward guidance shocks as changes in the 2-year nominal ECB yield on specific announcement days to measure changes in daily inflation swaps of different maturities. In the process, we also separately identify the effect of quantitative easing and interest rate change announcement shocks. We find that forward guidance was successful in reviving inflation expectations across maturities. Analyzing the transmission channels of forward guidance, we find evidence that both a reanchoring channel and a portfolio effect might have been at play.

JEL Codes: E31, E52, E65.

1 Introduction

The recent financial crisis and its aftermath saw inflation expectations progressively drop in the eurozone. They bottomed in 2015 with 10-year forward inflation expectations down to 1%. In the vicinity of the zero-lower bound (ZLB)[1], the European Central Bank (ECB) had to resort to

*The authors would like to thank Donghai Zhang for his numerous suggestions and invaluable advice. We also express our gratitude to Geert Mesters and Jordi Gali for their feedback on our project. The views presented here are solely those of the authors and do not necessarily represent those of the institutions we are part of. The usual disclaimer applies.

[1]The ECB hit the zero percent rate on the deposit facility in July 2012, and on the Main Refinancing Operations rate in March 2016.

extraordinary measures to stimulate inflation (Figure 1). The two main unconventional policies used by the ECB are arguably i) forward guidance, which was first officially used during the press conference of July 4, 2013 and ii) Quantitative Easing (QE), with the full-scale asset purchase programme starting in January 22, 2015[2]. This paper focuses on the impact of forward guidance in the euro area.

The basic mechanisms at play with forward guidance at the ZLB have long been theoretically established with foundational work by Krugman (1998), Eggertsson & Woodford (2003) and Reifschneider & Williams (2000). By providing transparency on the path of future policy rates, or on future deviations from the policy rule, forward guidance shapes agents' expectations (see Table 1 for examples of such announcements). In an economy with forward looking agents, this in turn affects current variables. Historically, the Bank of New Zealand was the first to implement forward guidance by publishing its projection of the future path of the policy rate as early as 1997[3]. When developed economies started hitting the ZLB in the midst of the Great Recession, an increasing number of central banks began to resort to it.

However, despite its immediate impact on the interest rate path, forward guidance does not necessarily have an expansionary effect. As stressed by Campbell et al. (2012), we will "distinguish between Odyssean forward guidance, which publicly commits the [ECB] to a future action, and Delphic forward guidance, which merely forecasts macroeconomic performance and likely monetary policy actions". In the former case, the central bank commits to future deviation from its policy function to meet its objective. Doing so, it stimulates real interest rates in the short term, yet not in the long run when inflation expectations adjust to higher recovery prospects. In the latter case, real interest rates are impacted at all horizons and mirror nominal interest rates. Indeed, inflation expectations do not take-off in the long run given the more pessimistic economic outlook. Hence, the impact of forward guidance on inflation expectations is ambiguous.

[2]More details on the timeline of ECB actions during the crisis in Appendix A.

[3]In addition to New Zealand, the central banks in Norway, Sweden, the Czech Republic and Israel currently publish interest rate forecasts. In addition, the Federal Reserve publishes the individual interest rate forecasts of the members of the Federal Open Market Committee (FOMC).

Literature review and contribution

Measuring forward guidance is difficult for a number of reasons. First, at least in the case of the qualitative forward guidance used in the Eurozone, forward guidance is a news shock and not an actual interest rate change. As such, one cannot measure the accomodation intended by the ECB, but only the interpretation financial markets make of it. Hubert & Labondance (2017) use an event study on two selected dates to assess whether forward guidance was effective in moving interest rates. However, such an approach could be misleading in that all announcements potentially convey very different news. Hence, we will follow most of the literature in measuring forward guidance through price changes of short-term interest rate futures. Forward guidance indeed qualifies as such when it impacts the path of future interest rates, as opposed to current interest rates. Consequently, forward guidance should impact interest rate futures, and leave current interest rates unaffected. We will indeed verify that EONIA does not significantly move around forward guidance announcements.

Second, forward guidance is difficult to disentangle from other monetary policy announcements. Announcements are often bundled and the ECB may release in the same speech some QE and some forward guidance news. Besides, inaction from the Central Bank may also constitute a news shock in itself. Third, we can only measure the impact of the unanticipated change in monetary policy since agents are forward looking. Last, one needs to account for the endogeneity of monetary policy. A monetary policy shock can reflect both an exogenous policy decision to influence macroeconomic variables, or an endogenous reaction to fundamentals.

To address the last three difficulties, Gürkaynak et al. (2005) were pioneers in the use of high frequency factor models to identify forward guidance by looking at the movement of selected asset prices in a short window around announcements. They showed that two dimensions were necessary to explain the comovements in asset prices, and argued that this second dimension could be the forward guidance component of announcements. The narrow window allows to assume that the only macroeconomic news in this timeframe are the monetary policy announcements, which overcomes the reverse causality concern aforementioned. In the wake of the financial crisis, Swanson (2017) extended the method to account for the implementation of QE, and suggested announcements bore information along three dimensions.

Another way to identify forward guidance is to perform high frequency regressions on announce-

ment days when the forward guidance component has been identified as the only one at play. This method has been privileged by Hubert & Labondance (2017). As already mentioned, this can be difficult since inaction is also action in the field of monetary policy. However, looking at press releases prior to announcements, major QE and target rate changes were expected in the immediate foremath of the meetings. The advantage of this method is that it does not require the statistical specifications of a factor model.

The next step is to regress the macroeconomic variables of interest on such measures of forward guidance shocks. We focus on inflation expectations. Two types of data are commonly used for such practices. High frequency data such as Treasury Inflation Protected Securities (TIPS) or inflation swaps were used by Hanson & Stein (2015) and Nakamura & Steinsson (2013). On their side, Campbell et al. (2012) resorted to low-frequency survey data. We deemed high-frequency data were more relevant to avoid interference with other macroeconomic news. Doing so, our paper is actually the first to measure the effectiveness of forward guidance in reviving inflation expectations. Although Nakamura & Steinsson (2013) and Hanson & Stein (2015) did measure movements in high-frequency inflation data, they did not disentangle the different components of monetary policy and used federal funds rate futures changes indifferently on all announcement dates. Doing so, they could have implicitly captured the forward guidance effect of QE announcements. Our study is also one of the first empirical measures of the effectiveness of forward guidance in the Eurozone.

Our study suggests forward guidance was effective in reviving inflation expectations at all horizons, pointing to an Odyssean interpretation of ECB monetary policy. We find that a forward guidance-driven 1 point increase in 2-year nominal ECB yield translated in a 33 bps decrease in inflation expectations five years ahead. This it at odds with the findings of Hanson & Stein (2015) in the US, who found a positive correlation between monetary policy shocks and inflation expectations five years ahead, pointing to a Delphic impact of monetary policy. Although not statistically significant, Campbell et al. (2012) also found a positive correlation in the US over the 2007-11 period. Our results are consistent with the measures performed by Nakamura & Steinsson (2013), who found that a 1 point shock in monetary policy translated in a 21 bps decrease in inflation expectations five years ahead.

On the theoretical side, standard approaches have typically been charged of over-predicting

the effects of forward guidance. Del Negro et al. (2012) referred to this as the "forward guidance puzzle". A number of theoretical studies have then struggled to find an appropriate theoretical explanation. For instance, Wiederholt (2015) and Kiley (2014) claimed that imperfect information could account for this puzzle. McKay et al. (2016) showed that heterogeneous beliefs with borrowing constraints could also play a role. Gabaix (2017) overcomes this puzzle through the lens of bounded rationality, suggesting that agents are myopic about the present and the future state of the economy, which makes forward guidance less powerful. Woodford (2012) and Andrade et al. (2015b) then proved that the puzzle could be attributed to heterogeneous interpretations of the interest rate path announced.

We empirically assess the relevance of the four different transmission channels that we identified in the literature. Nakamura & Steinsson (2013) emphasize the existence of an information channel which would explain why forward guidance can be Delphic. Gali (2017) builds a framework for assessing the external channel of forward guidance. Hanson & Stein (2015) highlight the existence of a portfolio effect on yield oriented investors. Last, Andrade et al. (2015a) showed the existence of a reanchoring channel whereby forward guidance would contribute to reduce the credibility gap of the Central Bank. These two latter channels stand out in that they would be expected to stimulate real interest rates well into the term structure. We will measure forward guidance with our methodology against future real interest rates, and show that these channels are the most relevant in accounting for the effects of forward guidance.

The paper is organized as follows. In Section 2, we describe the data set and our classification of ECB meetings. In Section 3, we present our identification strategy and our econometric approach. In Section 4, we document that forward guidance shocks did succeed in reviving inflation expectations. We also comment on the relative impact of other types of announcements, perform some robustness tests, and extend our approach to a country-level analysis. In Section 5, we discuss transmission channels. Section 6 concludes.

2 Data

We gathered daily data using Thomson Reuters Datastream, covering 3191 observations from January 7, 2005 to March 31, 2017 for the Eurozone and 2023 observations from July 1, 2009 to March 31, 2017 for our country-level data, covering Germany, France, Spain, and Italy.

2.1 Financial data

Inflation-linked swaps

As our identification strategy requires daily data, we have to focus on market-based inflation expectations instead of lower frequency survey-based measures. To that end, we chose to use zero coupon inflation-linked swaps (ILS) sourced by ICAP. This choice is motivated by a number of reasons : i) an ILS is a contract involving the exchange of a fixed payment for realized inflation over a defined horizon and this fixed swap rate hence provides a direct reading of the market's expectation on inflation outlook; ii) this market has rapidly grown for the euro area and became liquid enough to be more resilient to seasonality and liquidity disturbances than break-even inflation rates and index-linked bonds; iii) they are available for a wide array of maturities (from 1 year to 30 years) for the Eurozone as well as for the main economies (Germany, France, Italy, Spain). After reviewing various market updates on the liquidity and volumes traded for each maturity, we decided to focus our analysis on the 1-year, 2-year, 5-year, 10-year and 20-year maturities.

Monetary policy shocks

In order to measure forward guidance shocks, we follow the approach presented in Hanson & Stein (2015) to measure monetary policy news. Indeed, the monetary policy announcement is likely to bring significant information about the expected path of rates and not so much about an actual change in the current MRO rate. This can be captured by using the change in the 2-year nominal ECB yield which can be interpreted as a weighted average of short-term interest rates in the upcoming two years[4]. This synthetic index has the advantage of being constructed on high-quality (AAA) government bond yields and hence less sensitive to market disturbances, providing a less

[4]Hanson & Stein (2015) used changes in 2-year nominal Treasury yields to measure news shocks. Their results are robust to using other related variables that capture expected medium-term path of interest rate changes.

noisy interpretation of markets' reaction. This assumption is tested in the extension of our results to country-level data using the domestic bond yields as monetary policy shocks.

Real interest rates

While the focus of our study is inflation expectations, the monetary channels we discuss also require to look at real interest rates. To do so, we gathered Overnight Index Swap data for the EONIA (also from ICAP) at 1-year, 2-year, 5-year and 10-year maturities. We compute the difference with the ILS data we have at the same maturities to get the implied forward real interest rates, as done in Box 3 of the *ECB Economic Bulletin* (2015).

Control variables

We use daily data to identify the impact of forward guidance with the underlying assumption that on these dates there are no macro-news of larger impact. Therefore, we use for sole control the daily change in oil prices, as measured by the WTI index. As shown in Rodriguez & Yoldas (2016), it is the main driver of inflation expectations in the Eurozone in the recent past.

2.2 ECB meetings breakdown

Qualitative approach

We have analyzed and categorized all monetary policy decision meetings of the ECB since 2005. Until December 2014, the Governing Council was meeting on the first Thursday of each month. Since then, it changed to meet every six weeks. Therefore, we cover a total of 139 meetings in our data set. For each meeting, the monetary policy decisions are released at 13:45 CET and followed by the press conference at 14:30 CET, so we assume markets have time to incorporate the news before closure. Our daily identification strategy on monetary policy announcement is also strengthened by the fact that all other decisions taken by the Governing Council are only released the Friday after the meeting, at 15:00 CET. To keep our framework consistent, we chose to exclude all speeches and communications made by Governing Council members outside of the official monetary policy decision meetings. For instance, we exclude the famous "Whatever it takes" speech of President

Draghi on July 26, 2012 at UKTI's Global Investment conference, as well as his August 22, 2014 statement hinting at the possibility of QE during the central bankers meeting in Jackson Hole.

To disentangle forward guidance from other information shocks during ECB announcements, we categorize each meeting in the following way: i) from January 2005 to June 2013, all meetings excluding those during which a change in the MRO target rate is announced are referred to as conventional (Conv)[5]; ii) starting July 4, 2013, the ECB implemented forward guidance, hence all meetings after this date and excluding those announcing MRO target rate changes and QE announcements are qualified as forward guidance (FG); iii) meetings when changes in MRO target rate are announced are identified as interest rate change (IR); iv) finally, all QE announcements (e.g., introduction, extension) are classified as Quantitative Easing (QE)[6]. This classification of ECB meetings is summed up in Table 2. Figure 2 shows a visual representation of this classification. Since a thorough identification requires that there is no overlapping across these four categories, we made the following assumption: the latest changes in the MRO target rate that were decided along with QE announcements are treated in the QE dummy as they were considered secondary with respect to QE announcements. We will verify this assumption in the results section. This classification does not overcome the challenge that inaction may also constitute a news shock. The absence of QE announcement or of MRO target rate change may in itself surprise the market. Although we did not completely overcome this, our press review of the period covered suggests that major QE announcements and MRO target rate changes were mostly expected in the immediate foremath of announcements.

[5]Until July 2008, the ECB set a minimum bid rate for Main Refinancing Operations which were held at variable rates. Since then, there are no longer MRO tenders and the ECB sets the fixed rate. Throughout the paper, we alternatively refer to MRO target rate change and interest rate announcement.

[6]We consider quantitative easing to encompass the expanded asset purchase program started in January 2015. Thereby, we exclude of our scope the successive LTRO/ TLTRO, the SMP, and other instruments leveraged over the past years.

Quantitative approach

To confirm this qualitative breakdown of a pre- and post-forward guidance era in the eurozone, we carry out the following regression:

$$\begin{aligned}\Delta\pi_{t,m} = \beta_0 + \beta_1 All_t + \beta_2 \Delta y_t + \beta_3 U_t + \beta_4 All_t * \Delta y_t + \beta_5 All_t * U_t + \beta_6 \Delta y_t * U_t + \\ \beta_7 All_t * \Delta y_t * IR_t + \beta_8 All_t * \Delta y_t * U_t + \beta_9 All_t * \Delta y_t * IR_t * U_t + \epsilon_t\end{aligned} \tag{1}$$

$\Delta\pi_{t,m}$ stands for the 1-day change in inflation-linked swap at maturity m. Our monetary policy news shock is Δy_t, the 1-day change in 2-year nominal ECB yield. All_t is a dummy variable equal to one at each monetary policy meeting of the ECB. IR_t is a dummy variable to account for ECB meetings during which the target interest rate was changed. U_t is a dummy variable equal to one on all days after a break date between the pre- and post-forward guidance era, as previously described. We particularly examine the magnitude of the β_8 coefficient, depending on the break date chosen. We run our regression with five different break up dates evenly spaced in time: three meetings with interest rate changes evenly spaced in time from 2007 to 2011, then July 2013 when the ECB officialized its use of forward guidance, and January 2015 when the ECB started its QE program. We clearly see in Table 3 that the estimate for β_8 jumps using a break up date in 2013 or 2015. This suggests that financial markets have been accounting for more information from these meetings.

To investigate this in more details, we focus on these two dates and examine the estimates of β_8 for break up dates at the meetings immediately before and after, as in the Table 4. The strong increase in β_8 estimates using July 2013 as our turning point confirms our initial intuition. Conversely, the coefficient estimate does not move using January 2015 as break up date, suggesting that QE was already anticipated then.

3 Empirical methodology

3.1 Baseline regression

We estimate the following equation:

$$\Delta\pi_{t,m} = \beta_0 + (\beta_1 FG_t + \beta_2 QE_t + \beta_3 IR_t + \beta_4 Conv_t) * \Delta y_t + \beta_5 All_t + \beta_6 \Delta y_t + \beta_7 X_t + \epsilon_t \tag{2}$$

As done in the previous section, $\Delta\pi_{t,m}$ stands for the 1-day change in ILS at maturity m. The four dummies for the different types of ECB announcements described in Section 2.2 are multiplied by the monetary policy news shock Δy_t, still the daily change in the 2-year nominal ECB yield. We also add a dummy All_t covering all the ECB meetings of the sample we cover. X_t is the vector of control variables. Here, we control for oil price changes which have been identified to be the main driver of inflation expectations in the eurozone (Rodriguez & Yoldas (2016)). Finally, ϵ_t designates the error term, which requires a specific approach discussed in the next subsection. Our main parameter of interest will be β_1, but our identification strategy will also allow us to comment on the other parameters.

3.2 Identification strategy

Our identification strategy rests upon four important assumptions. First, QE and MRO target rate changes only impact the 2-year ECB nominal yields in the announcements identified in Section 2.2. However, the absence of change may also constitute a news shock if a change was expected. Therefore, our first assumption is that over the period we cover, the effect of the absence of QE announcement or MRO target rate change never dominated forward guidance. This means that we assume that no changes in QE or MRO target rate were expected in the immediate foremath of our forward guidance announcements.

Second, we assume that there is a change in the nature of the news shocks before and after our break date of July 2013. Although any ECB speech by nature contains some forward guidance component, we verified in Section 2.2. that there was a change in the way markets reacted to monetary policy shocks after this date. Therefore, we assume forward guidance shocks only start after this date, while prior to it announcements are considered as conventional. This break also corresponds to the moment when ECB officially implemented forward guidance. Morover, the period we selected corresponds to a time when interest rates were at the zero-lower bound, hence announcements did not affect the target rate, and only the path of interest rates.

This brings us to our third assumption. The changes in 2-year ECB nominal yields accurately reflect forward guidance shocks. We insist that we focus exclusively on measuring the impact of the change of the path of interest rates, in opposition to current interest rates. In this perspective,

2-year ECB nominal yields can be seen as an average of future short-term interest rates over the upcoming two years. We also verify that these announcements did not impact short-term interest rates, as measured by EONIA. In Table 5 we substitute EONIA rates to 2-year nominal yield as monetary policy news schock in our baseline regression. We find that on announcement days, forward guidance shocks did not move at all EONIA rates. We also confirm that in general (outside announcement days), EONIA rates and the 2-year ECB nominal yield are correlated. This suggests that the forward guidance shock we measure only affects the path of interest rate and confirms the relevance of our assumption.

Lastly, as pointed at by Hanson & Stein (2015) and Gürkaynak et al. (2005), our analysis could suffer from an omitted variable bias, with movements on these announcement days driven by macroeconomic factors and news exogenous to monetary policy. Both papers show that using intraday data with a tight window around the announcement, and using daily data to compute the monetary policy shock display the same results, indicating that monetary policy announcements seem to be the strongest drivers of sovereign yields on these days. Our daily changes in the 2-year nominal ECB yields are hence good proxies for monetary policy surprises.

We expect our estimates of the forward guidance and conventional impact to be relatively unbiased as the announcements in the scope are announcements during which only one type of shock occurred. In contrast, estimates of the other two monetary policies should be more liberal as they can also incorporate a forward guidance effect. In addition, QE announcements themselves constitute a form of forward guidance as they indicate that monetary conditions will remain accommodative as long as the program is operational (Hubert & Labondance (2017)). Besides, on several occasions QE announcements came with interest rate change announcements. In these cases, we fully identified the impact to the effect of QE announcement. To a lesser extent, the effect of MRO target rate change might also be slightly liberal since the rates were lowered on three occasions since the introduction of forward guidance in 2013. In those cases, we fully identified the impact to the effect of a target rate change. Again, these comments hold true only to the extent that market participants did not expect other announcements to be made on those dates - in which case the effect of the absence of such announcement could be dominating.

3.3 Error specification

In order to obtain relevant statistical validation of our results, we start our analysis with a simple OLS regression, compute estimated errors, and look for autoregressive, moving average, and heteroskedasticity effects (Appendix B displays the following results). We compute PACF of estimated residuals (Figure 5) and find a small order 1 component which suggests there are limited autoregressive effects in our residuals. This is not surprising since our dependent variable is already a first difference of ILS. We compute ACF of estimated residuals (Figure 6) and find small order 1 and 2 components which suggests there are limited moving average effects in our residuals. However, we expect heteroskedasticity to be present in our model because, as emphasized by Galati et al. (2011), inflation expectation measures in the Eurozone became much more volatile during the recent crisis. Periods of forward guidance are then expected to be periods of higher volatility in comparison to previous periods. To check for the presence of heteroskedasticity, we plot the first difference of ILS, which is our main dependent variable. Figure 4 depicts the development of this difference for 5-year inflation swaps. Additionally, we plot the development of 2-week rolling average of conditional volatility of our time series. This can be taken as a smoothed measure of volatility and the plot confirms our expectations. We then test formally for the presence of heteroskedasticity. The standard solution we chose to allow for autocorrelation, moving average, and heteroskedasticity in the error terms is to use the standard error estimators developed by Newey & West (1987). Another approach could have been the use of an ARCH model, with lag one, as in Hubert & Labondance (2017), which we compute in our robustness section.

4 Results

4.1 Overview

The results of our baseline regression are presented in Table 6[7]. The results are also normalized by the standard deviation of monetary policy shocks in Table 7. These results suggest that forward guidance as measured by changes in the 2-year nominal ECB yields did have a significant impact on inflation expectations at all horizons. In the following sections, we will explore in detail our results

[7]Where interaction dummies coefficients are denoted as *FG, QE, IR, CONV*. Our monetary surprise Δy is *ECB 2y* and ILS daily changes are written by maturity as *IS 1y, IS 2y, 5y, 10y, 20y*

for each type of monetary policy shock.

4.2 Forward guidance

Forward guidance succeeded in reviving inflation at all maturities with an impact ranging from 45bps increase per point decrease in nominal yields at 1-year maturity, to 23bps increase twenty years ahead. In other words, when a forward guidance statement translates in a one point decrease in nominal yields, it strengthens inflation expectations by 23bps twenty years ahead. It reaches 33bps increase for a one point nominal yield drop five years ahead. If we normalize, a one standard deviation monetary policy shock translates in a 9bps increase in inflation expectations five years ahead (see Table 7). As a benchmark, we separately run our regression using only an interaction dummy on all meetings to see how markets react to ECB announcements in general. We find that the average impact of a one point increase in nominal yields on announcement dates on inflation expectations stands at +14bps five years ahead (Table 8). Monetary policy shocks over the period are thus positively correlated to the change in inflation expectations, while they are negatively correlated on the dates when forward guidance information was released. This indeed suggests that specific economic forces where at play on forward guidance announcement days.

We complement our study with an event study à la Hubert & Labondance (2017) to explore what was the average forward guidance shock during the time frame. The coefficients found are null and not significant (Table 9). This is not surprising since the measure focuses here on forward guidance shocks which can happen in both directions depending on what expectations agents had formed prior to announcements, even in a general period of accommodating announcements. The surprises being of random direction and amplitude, their effects are averaged out which confirms our approach of measuring forward guidance shocks as a move in nominal yields.

Finally, we wonder whether markets anticipated shocks prior to announcements. Indeed, the ECB has adopted the "quiet period principle" whereby the members of the Executive Board cannot give any information that could influence the expectations about forthcoming monetary policy decisions, starting seven days prior to any meeting. Looking at the inflation trends around press conferences with QE announcements, it does seem like markets incorporate additional information in the run up to announcements (Figure 3). This could reflect information leakage, or rumours

spreading. Inflation expectations tend to increase 5 days before the announcement. To test this assumption, we regress the five-day change in inflation expectations on the five-day change in nominal yields. The results are of high statistical significance, and of higher magnitude than the daily regression. This could indicate some interference with other macro news occurring over the five day. However, this also supports the claim that markets anticipated shocks prior to announcements and that the impact of forward guidance is in fact higher than what is suggested in the baseline regression. On the other hand, the coefficient of QE is no longer significant, suggesting a higher volatility of its impact on inflation expectations. This could indicate that other macro-news could dominate in this time frame. Further analysis would be required to be more conclusive.

4.3 Quantitative easing announcements

We then look at the impact of quantitative easing announcements, a different work than identifying the effect of QE itself. QE announcements succeeded in reviving inflation at all maturities with a non monotonic impact at the different horizons. The impact of a one point decrease in nominal yields peaks at 79bps increase in inflation expectations five years ahead. This seems in line with the conclusions of Swanson (2017) who finds that the impact of forward guidance dominates in the short term, while that of QE takes over in the medium to long term.

4.4 Interest rate announcements

The impact of interest rate change is of small amplitude and not significant. Since this instrument is used by the ECB not only under exceptional times, we wonder whether this insignificance is consistent over time, or whether there are different phases of monetary policy that we average through regression (2), generating the insignificance. In order to verify this hypothesis, we break our dataset into three distinct periods: until the end of the financial crisis (2005-09); until President Draghi's 'Whatever it takes' speech (2009-12); since the speech and throughout implementation of unconventional monetary policy (2012-17), as presented in Table 11. Over 2005-09, the sign of the coefficient is positive and the market seems to have a Delphic interpretation of interest rate changes. Over 2009-12 on the other hand, the shocks are of the expected sign. The results are stronger, significant in the short term, and dampen across the term structure. This could relate to

the action of a standard forward guidance channel whereby clarity in future interest path decreases nominal short-term interest rate expectations. Finally, since 2012, we find this instrument has had little to no impact on inflation expectations, confirming the switch to unconventional monetary policy and the ineffectiveness of conventional levers at the ZLB. Overall, except for the impact of interest rate changes in the short term over 2009-2012, the results are never significant. It could just be due to a lack of data points. We also observe distinct phases in the implementation of this monetary policy which we average out in the baseline regression.

4.5 Others

To conclude on our results, we say a few words about the other coefficients identified. Conventional monetary policy shocks seem to have the expected sign but are of a magnitude of only 6bps change per point change in nominal yields and are not significant. Second, a change of nominal yield on any announcement day is positively correlated with inflation expectations. This is in line with standard economic theory since inflation expectations typically adjust to interest rate changes by the neutrality of money assumption. Finally, our coefficient on oil price change is highly significant at all horizons with the expected inflationary effect.

4.6 Comparison to the literature

We investigate whether our results are consistent with the literature. The difficulty lies in the fact that to the best of our knowledge no direct measure of the impact of forward guidance on inflation expectations has been performed. The closest studies have been the one Hanson & Stein (2015), Nakamura & Steinsson (2013), and Campbell et al. (2012) which we now compare ourselves to.

Nakamura & Steinsson (2013) find that that a one point monetary policy shock as measured by changes in one year Treasury yields generated a -21bps impact on inflation expectations five years ahead. This measure is biased upwards with respect to ours since we measure one point changes in 2-year nominal yields. Therefore, this measure seems comparable in magnitude to our estimate.

However, Hanson & Stein (2015) find that a one point monetary policy shock as measured by changes in 2-year nominal Treasury yields translates in a $+19$bps for inflation five years ahead. This is directly comparable to our measure of -33bps and we note that the coefficients are of opposite

signs. A plausible explanations are that these authors did not disentangle forward guidance from other types of monetary policy shocks. Besides, they run their measure on the US market while we focused on the Eurozone. We believe forward guidance could have been more efficient in the Eurozone for two reasons: (i) Forward guidance was used in the US in the early stages of the crisis when its full extent and duration were not yet well accounted for. Therefore it could have been interpreted as a release of negative macro-news; (ii) Forward guidance was used in the Eurozone when inflation expectations in the long run started to fall in the midst of the sovereign debt crisis, a situation which was never reached in the US. Last, Campbell et al. (2012) find that a one point change in their measure of the path factor of monetary policy impacted inflation expectations by 23bps three quarters ahead (although not statistically significant). This becomes more difficult to compare since the path factor is an aggregate measure of various asset prices. However, one could generally agree that this measure is biased upwards versus ours since the asset prices in the path factor have horizons lower than a year. This is to be compared to our estimate of -45bps one year ahead. This figure seems lower in magnitude than our estimate, but of the same sign.

4.7 Robustness

The results are robust to a number of alternative regressions. First, we check for another econometric model, as discussed in our methodological section, using an ARCH model with one lag. We find that our results still hold (Table 12). Second, instead of the daily change ($\Delta\pi_t = \pi_t - \pi_{t-1}$) in ILS, we compute a 2-day change ($\Delta\pi_t = \pi_{t+1} - \pi_{t-1}$). This is to cope with the argument of Hanson & Stein (2015) who pointed out that markets may take up to two days to adjust after a monetary policy announcement. As expected, the estimates increase, especially in the case of QE announcements, but our interpretation and relative impacts remain unchanged[8] (Table 13). Finally, to account for the heterogeneity of countries' respective ILS response to monetary policy announcements, we perform a panel data analysis over the time period available across the data we have for Germany, France, Italy and Spain (July 2009 – March 2017). To remain consistent with the error specification concerns we have, we run linear regressions with fixed effects and AR(1) disturbances. We use the 2-year nominal ECB yield as monetary policy shock, and then replace it with the change in countries'

[8]Since we keep 1-day change in 2-year ECB yield as interaction regressor.

respective 2-year nominal yields. Using the same monetary policy shocks yields results that are very similar to what we found in our baseline analysis (Table 14). However, using the countries' respective 2-year nominal yields decrease the absolute level of estimates since they average different patterns across countries (Table 15). We will come back to these country-level measures in the next section. The results of these four robustness tests are summarized in Table 16 for the 5-year ILS.

4.8 Extensions

We now turn to the country-level analysis to investigate whether our interpretation for the euro area data is also valid in the four main economies of the monetary union. Table 17 presents the results for the 5-year ILS for each country, using the 2-year nominal ECB yield as a monetary surprise shock. We see that estimates are very similar despite slight differences in the significance levels. Table 18 presents the estimates when we apply a different monetary surprise to each country, using their respective 2-year nominal sovereign bond yields. The forward guidance impact for France and Germany is very similar, while it is now close to zero for Spain and Italy. This difference very likely reflects the European sovereign debt crisis and higher risk profile of sovereign bonds in Spain and Italy that distorts their prices, make them more volatile and hence much less precise as monetary policy shock measures. We indeed find a variance of around 7% for the daily change of Spanish and Italian 2-year nominal yields on forward guidance announcement days, while the 2-year nominal ECB, French and German yields have a variance in the 2-3% range. There were in particular large discrepancies in 2013 for Spain and Italy, as the European debt crisis was unwinding. Conversely, we also remark that QE announcements had a stronger impact in Spain and Italy on inflation expectations five years ahead (resp. -62bps and -63bps), than in France and Germany (resp. -41bps and -39bps), in line with De Santis (2016) who found that countries with riskier debt profiles (Portugal, Italy and Spain) benefited the most from QE announcements.

5 Theoretical interpretation

5.1 The channels of forward guidance

We now explore mechanics of forward guidance to understand which channels might have been at play in the eurozone. As we have seen with the distinction between Odyssean and Delphic forward guidance, it does not necessarily have an expansionary effect. Historically, forward guidance was coined to name what became referred to as Odyssean forward guidance. For instance, Katagiri (2016) still follows this restrictive definition of forward guidance. Strictly speaking, Odyssean forward guidance however conceals a commitment consistency issue (Campbell et al. (2012)). To illustrate this, suppose that the central bank commits now to maintain low interest rates for an extended period of time to revive inflation expectations. In the future, when inflation finally picks up, the central bank will have an incentive to deviate and increase its interest rates. This explains why the central bank's credibility is key, but also why strictly constraining forward guidance can be undesirable. For this reason, some have claimed that no Odyssean forward guidance has been really implemented to date (Moessner et al. (2015)). We will stick to forward guidance as outlined by Andrade et al. (2015b) which defines forward guidance through its interpretation by market participants: forward guidance will be considered Odyssean when agents translate it into higher long-term inflation expectations, and Delphic if not.

We identified in the literature four channels through which forward guidance will shape inflation expectations (Table 19). These can be either Odyssean or Delphic. As highlighted by Hanson & Stein (2015), forward guidance can reduce the term premium through a portfolio effect on yield-oriented investors. Through this mechanism, since forward guidance reduces short-term interest rates, investors rebalance their portfolio towards longer term assets thus increasing their price without changing the interest path. Therefore, this portfolio rebalancing translates into a lower term premium. This effect would be consistent with a lasting impact on real interest rates through the term structure. Another transmission channel is the external channel explored by Gali (2017). Its effects are not fully understood, but qualitatively it is expected that the external channel would leave the interest rates unchanged while stimulating inflation through currency devaluation. Forward guidance can also act directly through what Andrade et al. (2015a) dub a reanchoring channel. It

then transmits through a reduction of the disagreement between ECB and agents over the future path of inflation. This is consistent with an increase of inflation expectations at all horizons. Among Delphic channels, Nakamura & Steinsson (2013) point at the existence of an information channel due to the existence of an information asymmetry between ECB and economic agents. Forward guidance would then reveal ECB's stance on the future of the economy, which would depress inflation expectations at all horizons in the case of an accomodative shock.

5.2 Interpretation

The negative impact of forward guidance on inflation expectations that we estimated is consistent with an Odyssean interpretation. When there is an accomodative forward guidance shock, inflation expectations revive at all horizons. If it were Delphic, inflation expectations would remain depressed at all horizons despite the shock to interest rate expectations. We regress real interest rate futures on forward guidance shocks, and find that forward guidance accomodative shocks had an accomodative impact throughout the term structure (Table 20). In other words, changes in the 2-year nominal yield did impact real rates at 1-year and 10-year maturities. This is *a priori* at odds with the long-term neutrality of money since monetary policy should not impact real rates at these horizons. This is however consistent both with the reanchoring channel of Andrade et al. (2015a), as well as with the portfolio effect of Hanson & Stein (2015). The fact that the impact on real rates increases through the term structure also suggests that a term premium effect was at play.

6 Conclusion

Forward guidance shocks have a strong impact on inflation expectations with a one point decrease in 2-year nominal ECB yields pushing inflation expectations 33bps upwards five years ahead, with high significance. In Campbell's terminology (Campbell et al. (2012)), market participants' interpretation was Odyssean. Our findings are overall aligned with those of Nakamura & Steinsson (2013). In contrast, Hanson & Stein (2015) and Campbell et al. (2012) suggested a larger Delphic channel was at play in the US. Given that the ECB implemented forward guidance at a time of heightened uncertainty and while long-term inflation expectations were dropping, there are reasons to believe it could have been more efficient in the Eurozone than in the US. We also document

that QE announcements were more effective in amplitude than forward guidance announcements. Finally, we regress daily real interest rates on forward guidance shocks and find that real rates are positively impacted with an increasing impact through the term structure. Therefore, we suggest that a reanchoring channel à la Andrade et al. (2015a) and a portfolio effect à la Hanson & Stein (2015) may explain the bulk of the transmission of forward guidance.

References

Andrade, P., Breckenfelder, J., De Fiore, F., Karadi, P. & Tristani, O. (2015a), 'The ECB's asset purchase programme: an early assessment', *ECB Working Paper* (1956).

Andrade, P., Gaballo, G., Mengus, E. & Mojon, B. (2015b), 'Forward guidance and heterogenous beliefs', *Banque de France Working paper* (WP-573).

Campbell, J., Evans, C., Fisher, J. & Justiniano, A. (2012), 'Macroeconomic Effects of Federal Reserve Forward Guidance', *Brookings Papers on Economic Activity* **43**(1), 1–80.

De Santis, R. (2016), 'Impact of the asset purchase programme on euro area government bond yields using market news', *ECB Working Paper* (1939).

Del Negro, M., Giannoni, M. & Patterson, C. (2012), 'The forward guidance puzzle', *FRB of New York Staff Report* (574).

ECB Economic Bulletin (2015), *ECB Monthly bulletin* (July 2015).

Eggertsson, G. & Woodford, M. (2003), 'Optimal monetary policy in a liquidity trap', *NBER Working Paper* (w9968).

Gabaix, X. (2017), 'A behavioral new keynesian model', *NBER Working Paper* (22954).

Galati, G., Poelhekke, S. & Zhoua, C. (2011), 'Did the crisis affect inflation expectations?', *International Journal of Central Banking* **7**(1), 167–207.

Gali, J. (2017), 'Forward guidance and the exchange rate', *CREI Working Paper* (Rev. May 2017).

Gürkaynak, R., Sack, B. & Swanson, E. (2005), 'Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements', *International Journal of Central Banking* **1**(1), 55–93.

Hanson, S. & Stein, J. (2015), 'Monetary policy and long-term real rates', *Journal of Financial Economics* **115**(3), 429–448.

Hubert, P. & Labondance, F. (2017), 'The effect of ecb forward guidance on the term structure of interest rates', *International Journal of Central Banking* (Forthcoming).

Katagiri, M. (2016), 'Forward Guidance as a Monetary Policy Rule', *Bank of Japan Working Paper Series* **16**(6).

Kiley, M. (2014), 'The Response of Equity Prices to Movements in Long-Term Interest Rates Associated with Monetary Policy Statements: Before and After the Zero Lower Bound', *Journal of Money, Credit and Banking* **46**(5), 1057–1071.

Krugman, P. (1998), 'It's baaack: Japan's slump and the return of the liquidity trap', *Brookings Papers on Economic Activity* **29**.

McKay, A., Nakamura, E. & Steinsson, J. (2016), 'The power of forward guidance revisited', **106**(10), 3133–3158.

Moessner, R., Jansen, D.-J. & de Haan, J. (2015), 'Communication about future policy rates in theory and practice: A Survey', *DNB Working Paper* (475).

Nakamura, E. & Steinsson, J. (2013), 'High frequency identification of monetary non-neutrality: The information effect', *NBER Working Paper* (w19260).

Newey, W. & West, K. (1987), 'A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix', *Econometrica* **55**(3), 703–708.

Reifschneider, D. & Williams, J. (2000), 'Three lessons for monetary policy in a low-inflation era', *Journal of Money, Credit and Banking* **32**, 936–66.

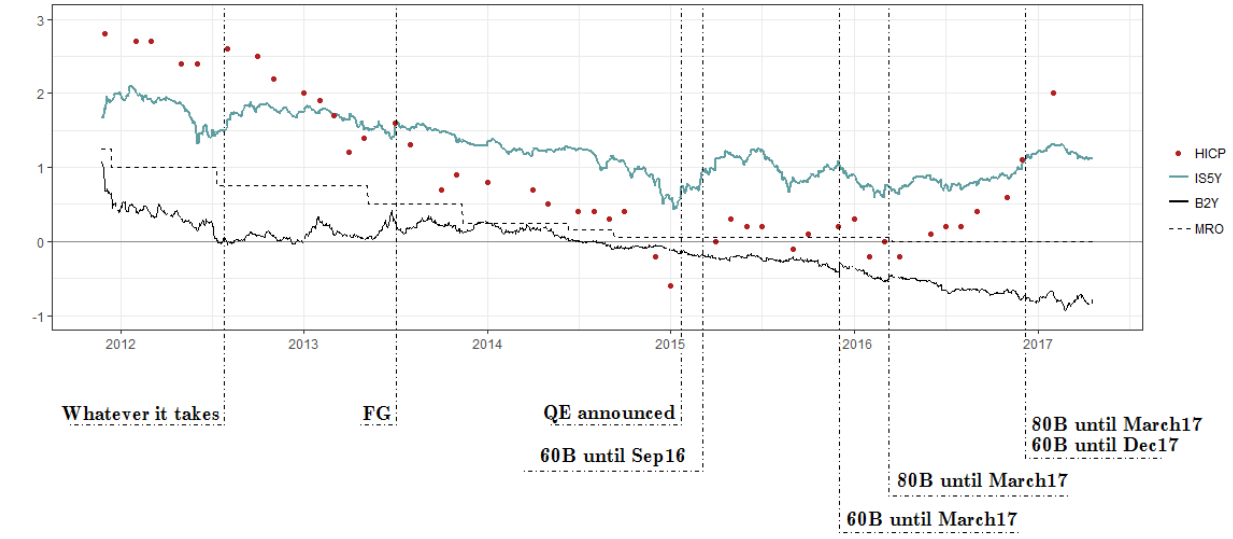
Rodriguez, M. & Yoldas, E. (2016), 'Drivers of inflation compensation: Evidence from inflation swaps in advanced economies', *IFDP Notes 2016-12-30* (Federal Reserve Board).

Swanson, E. (2017), 'Measuring the effects of federal reserve forward guidance and asset purchases on financial markets', *NBER Working Paper* (w23311).

Wiederholt, M. (2015), 'Empirical properties of inflation expectations and the zero lower bound', *Goethe University Frankfurt* (Rev. October 2015).

Woodford, M. (2012), 'Methods of policy accommodation at the interest-rate lower bound', *The Changing Policy Landscape* pp. 185–288.

Figures



*"Whatever it takes" refers to the famous speech of President Draghi on July 26, 2012 at UKTI's Global Investment conference. FG refers to forward guidance official introduction by the ECB.

Figure 1: Timeline of ECB monetary policy over 2012-17

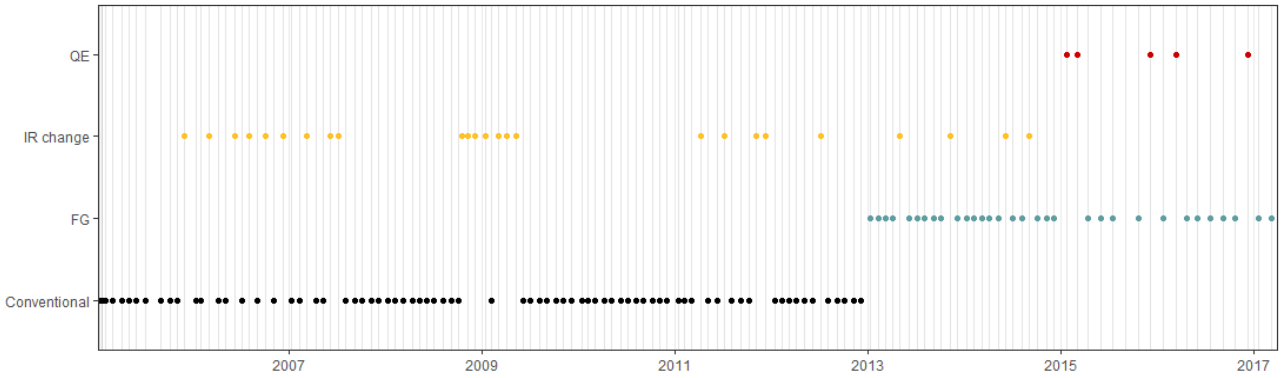


Figure 2: ECB 139 meetings, breakdown by Communication

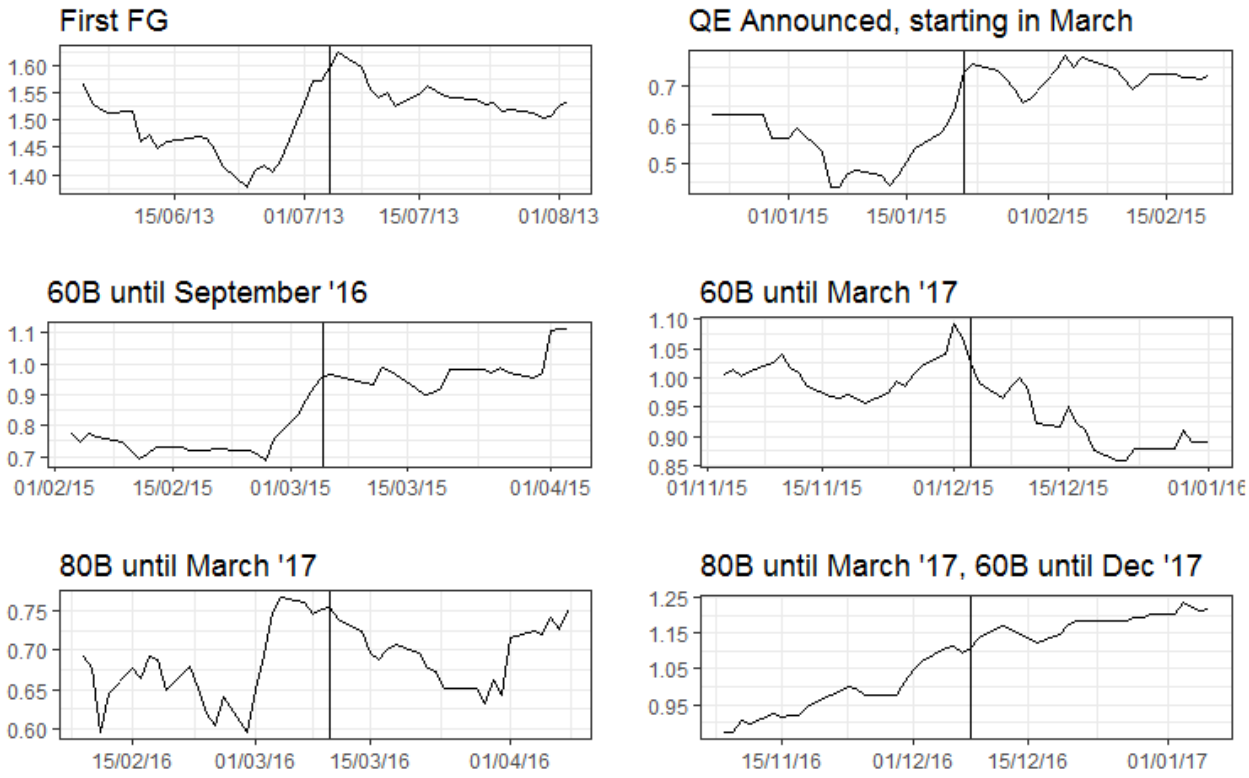


Figure 3: Trends of inflation expectations around press conferences

Tables

	Qualitative	Threshold-based
Time-contingent	"The GC continues to expect the key ECB interest rates to remain at present or lower levels for an extended period of time" - ECB July 2013 "Policy accomodation can be maintained for a considerable period" - Fed 2003	"The target overnight rate can be expected to remain at its current level until the end of the second quarter of 2010" - Bank of Canada April 2009
State-contingent	"[committed to a near-zero interest rate policy] until deflationary concerns would be dispelled" - Bank of Japan April 1999	"The Committee anticipates that its 0 to 1/4 percent target range for the federal funds rate will be appropriate at least as long as the unemployment rate remains above 6-1/2 percent" - Fed 2012

Table 1: Classification of forward guidance types

ECB 139 Meetings, breakdown by Communication			
Communication type	# of meetings	First date	Description
Forward Guidance (FG)	32	04/07/2013	All meetings after July 4, 2013 with no QE or IR
Quantitative Easing (QE)	5	22/01/2015	All meetings with a QE announcement
Interest Rate change (IR)	25	01/12/2005	All meetings with an interest rate change with no QE or FG
Conventional (CONV)	77	13/01/2005	All meetings after January 13, 2005 with no FG, QE or IR

Table 2: Characterization of ECB meetings over 2005-17

	IS 1y	IS 2y	IS 5y	IS 10y	IS 20y
β_8					
08/03/2007	-0.04	0.12	0.05	-0.07	0.01
15/01/2009	0.21	0.09	-0.06	-0.13	-0.12
07/04/2011	-0.08	-0.08	-0.17	-0.15	-0.14
04/07/2013	-0.53***	-0.61***	-0.61***	-0.50***	-0.51***
22/01/2015	-0.50***	-0.60***	-0.78***	-0.69***	-0.72***

Table 3: Evolution of β_8 over time

	IS 1y	IS 2y	IS 5y	IS 10y	IS 20y
β_8					
06/06/2013	-0.37**	-0.48***	-0.51***	-0.42***	-0.42***
04/07/2013	-0.53***	-0.61***	-0.61***	-0.50***	-0.51***
01/08/2013	-0.53***	-0.56***	-0.62***	-0.51***	-0.52***
04/12/2014	-0.49**	-0.60***	-0.78***	-0.69***	-0.72***
22/01/2015	-0.50**	-0.60***	-0.78***	-0.69***	-0.72***
05/03/2015	-0.45**	-0.53***	-0.65***	-0.57***	-0.60***

Table 4: Evolution of β_8 around key meetings

	IS 1y	IS 2y	IS 5y	IS 10y	IS 20y
FG	0.00	-0.01	0.00	0.00	0.00
QE	0.03	0.01	0.00	-0.01	-0.03
IR	-0.00	-0.01	-0.00	0.00	0.00
CONV	0.00	-0.00	-0.00	-0.00	-0.00
ECB 2y	0.19***	0.15***	0.13***	0.10***	0.09***
Oil	0.30***	0.25***	0.17***	0.13***	0.12***
All	0.00	0.00	0.00	0.00*	0.00
_cons	-0.00	-0.00	-0.00	-0.00	-0.00
N	3191	3191	3191	3191	3191

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Results of EONIA surprise regression

	IS 1y	IS 2y	IS 5y	IS 10y	IS 20y
FG	-0.45***	-0.44***	-0.33**	-0.27***	-0.23**
QE	-0.58***	-0.59***	-0.79***	-0.66***	-0.70***
IR	-0.11	-0.12	-0.02	0.11	0.12
CONV	-0.08	-0.05	-0.06	-0.07	-0.07
ECB 2y	0.20***	0.16***	0.14***	0.11***	0.09***
Oil	0.30***	0.25***	0.17***	0.13***	0.12***
All	0.00	0.00	0.00	0.00**	0.00**
_cons	-0.00	-0.00	-0.00	-0.00	-0.00
N	3191	3191	3191	3191	3191

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Results of baseline regression

	IS 1y	IS 2y	IS 5y	IS 10y	IS 20y
One-standard-deviation shock					
FG	-12.9	-12.6	-9.4	-7.7	-6.6
QE	-16.6	-16.9	-22.6	-18.9	-20
IR	-3.1	-3.4	-0.6	3.1	3.4
CONV	-2.3	-1.4	-1.7	-2.0	-2.0

Results are in basis points and normalised by the 2-year ECB standard deviation

Table 7: Results of baseline regression expressed in standard deviation shocks

	IS 1y	IS 2y	IS 5y	IS 10y	IS 20y
All surprise	-0.14*	-0.11*	-0.11**	-0.09**	-0.09**
ECB2y	0.20***	0.16***	0.14***	0.11***	0.10***
Oil	0.30***	0.25***	0.17***	0.13***	0.12***
_cons	-0.00	-0.00	-0.00	-0.00	-0.00
N	3191	3191	3191	3191	3191

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Results of the benchmark regression

	IS 1y	IS 2y	IS 5y	IS 10y	IS 20y
FG	-0.01*	-0.01	0.00	-0.00	0.00
QE	0.01	0.01	0.02	0.02	0.02
IR	-0.01	-0.01	-0.00	0.01	0.00
CONV	-0.06	-0.04	-0.06	-0.07	-0.07*
ECB 2y	0.19***	0.15***	0.13***	0.11***	0.09***
Oil	0.30***	0.25***	0.17***	0.13***	0.12***
All	0.01	0.00	0.00	0.00	0.00
_cons	-0.00	-0.00	-0.00	-0.00	-0.00
N	3191	3191	3191	3191	3191

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Results of event study regression

	IS 1y	IS 2y	IS 5y	IS 10y	IS 20y
FG	-1.93***	-1.33***	-0.95***	-0.67***	-0.59***
QE	0.13	-0.59	-0.70	-0.59	-0.86
IR	1.16	0.43	0.02	0.05	0.11
CONV	-0.30	-0.29	-0.22	-0.15	-0.04
ECB 2y	0.07	0.10	0.09	0.07*	0.06*
Oil	0.75***	0.59***	0.40***	0.26***	0.22***
All	-0.00	0.01	0.01**	0.01**	0.01**
_cons	-0.00	-0.00	-0.00*	-0.00**	-0.00*
N	3191	3191	3191	3191	3191

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10: Results of 5-day change regression

	IS 1y	IS 2y	IS 5y	IS 10y	IS 20y
2005-2009					
IR	**0.71**	**0.34**	**0.18**	**0.05**	**-0.00**
CONV	-0.26**	-0.18**	-0.11	-0.05	-0.05
ECB 2y	0.29***	0.21***	0.16***	0.11***	0.09***
Oil	0.18*	0.12	0.06	0.03	0.04
All	0.00	-0.00	-0.00	0.00	0.00
_cons	-0.00	-0.00	-0.00	-0.00	-0.00
2009-2012					
IR	**-0.52****	**-0.36****	**-0.13**	**0.15**	**0.20**
CONV	0.09	0.07	-0.03	-0.08*	-0.08*
ECB 2y	0.15***	0.13***	0.12***	0.11***	0.10***
Oil	0.22**	0.24***	0.19***	0.15***	0.14***
All	0.00	0.00	0.00	0.00	0.00
2012-2017					
IR	**-0.01**	**-0.09**	**0.02**	**0.00**	**-0.01**
FG	-0.28	-0.39**	-0.36***	-0.31***	-0.29**
QE	-0.50**	-0.60***	-0.87***	-0.73***	-0.78***
CONV	0.00	0.00	0.00	0.00	0.00
ECB 2y	0.05	0.12*	0.16***	0.15***	0.14***
Oil	0.54***	0.43***	0.29***	0.21***	0.19***
All	-0.00	0.00	0.01	0.01*	0.01*
_cons	-0.00	-0.00	-0.00	-0.00	-0.00

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 11: Results of split sample regression

	IS 1y	IS 2y	IS 5y	IS 10y	IS 20y
Mean equation					
FG	-0.49	-0.48*	-0.37***	-0.29***	-0.25***
QE	-0.61	-0.65*	-0.77***	-0.76***	-0.88***
IR	-0.03	0.05	0.07	0.07	0.08
CONV	-0.11	-0.04	-0.09**	-0.07**	-0.09**
ECB 2y	0.22***	0.16***	0.14***	0.11***	0.10***
Oil	0.29***	0.28***	0.16***	0.10***	0.10***
All	0.00	-0.00	0.00	0.00*	0.00**
_cons	-0.00	0.00	-0.00	-0.00**	-0.00***
Var equation					
L.arch	0.19***	0.44***	0.49***	0.40***	0.36***
_cons	0.00***	0.00***	0.00***	0.00***	0.00***
N	3191	3191	3191	3191	3191

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 12: Results of ARCH(1) regression

	IS 1y	IS 2y	IS 5y	IS 10y	IS 20y
FG	-0.68***	-0.65***	-0.51***	-0.36**	-0.33**
QE	-1.04***	-0.96***	-1.21***	-1.04***	-1.14***
IR	-0.17	-0.27	0.03	0.15	0.13
CONV	0.19	0.15	0.11	0.05	0.03
ECB 2y	0.25***	0.21***	0.17***	0.13***	0.12***
Oil	0.61***	0.51***	0.33***	0.24***	0.21***
All	-0.00	-0.00	0.00	0.00**	0.00**
_cons	-0.00	-0.00	-0.00	-0.00	-0.00
N	3191	3191	3191	3191	3191

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 13: Results of Hanson-Stein type regression of 2-day changes in ILS and yields

	IS 1y	IS 2y	IS 5y	IS 10y	IS 20y
FG	-0.46**	-0.42***	-0.32***	-0.27***	-0.25***
QE	-0.63**	-0.66***	-0.81***	-0.69***	-0.73***
IR	-0.45	-0.30	0.00	0.04	0.10
CONV	-0.07	-0.03	-0.11**	-0.12***	-0.10**
ECB 2y	0.14***	0.14***	0.12***	0.11***	0.10***
Oil	0.51***	0.43***	0.31***	0.22***	0.20***
All	0.01**	0.01***	0.01***	0.01***	0.01***
_cons	-0.00	-0.00	-0.00	-0.00*	-0.00
N	8092	8092	8092	8092	8092

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 14: Results of panel data regression on ECB yields

	IS 1y	IS 2y	IS 5y	IS 10y	IS 20y
FG	-0.20*	-0.19**	-0.14***	-0.12***	-0.11**
QE	-0.50**	-0.50***	-0.54***	-0.44***	-0.49***
IR	0.02	-0.00	-0.02	-0.02	-0.05*
CONV	-0.07	-0.07*	-0.05**	-0.03	-0.02
ECB 2y	0.13***	0.13***	0.11***	0.10***	0.09***
Oil	0.52***	0.43***	0.30***	0.22***	0.20***
All	0.01**	0.01***	0.01***	0.01***	0.00***
_cons	-0.00	-0.00	-0.00	-0.00*	-0.00
N	8092	8092	8092	8092	8092

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 15: Results of panel data regression on domestic bond yields

	Newey-West	ARCH(1)	Two-day change	Panel	Panel (domestic)
Mean equation					
FG	-0.33***	-0.37***	-0.51***	-0.32***	-0.14***
QE	-0.79***	-0.78***	-1.21***	-0.83***	-0.55***
IR	0.02	0.07	0.03	-0.00	-0.02
CONV	-0.06	-0.09*	0.11	-0.11**	-0.05**
ECB 2y	0.14***	0.14***	0.17***	0.12***	0.11**
Oil	0.17***	0.16***	0.33***	0.31***	0.31***
All	0.00	0.00	0.00	0.01***	0.01***
_cons	-0.00	-0.00	-0.00	-0.00	-0.00*
Var equation					
L.arch	-	0.50***	-	-	-
_cons	-	0.00***	-	-	-
N	3191	3191	3191	3191	3191

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 16: Robustness checks for the coefficient β_1 of equation (2)

	Euro	France	Germany	Spain	Italy
FG	-0.33**	-0.32**	-0.27**	-0.35***	-0.36***
QE	-0.79***	-0.80***	-0.79***	-0.83*	-0.81***
IR	-0.02	-0.05	-0.02	-0.10	-0.05
CONV	-0.06	-0.09*	-0.03	-0.31*	-0.07
ECB 2y	0.14***	0.13***	0.09**	0.15***	0.13***
Oil	0.17***	0.18***	0.28***	0.20***	0.26***
All	0.00	0.00	0.00*	0.01	0.01*
_cons	-0.00	0.00	-0.00	-0.00	-0.00***

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 17: Results of country regression for the 5-year ILS on ECB yields

	Euro	France	Germany	Spain	Italy
FG	-0.33**	-0.22	-0.31**	-0.06	-0.07
QE	-0.79***	-0.41***	-0.39***	-0.62***	-0.63***
IR	-0.02	0.11	0.16	-0.01	0.03
CONV	-0.06	-0.01	0.01	-0.04	-0.01
DOM 2y	0.14***	0.06***	0.10*	-0.03***	-0.05***
Oil	0.17***	0.19***	0.27***	0.23***	0.27***
All	0.00	0.00*	0.01**	0.01	0.00
_cons	-0.00	0.00	-0.00	-0.00**	-0.00***

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 18: Results of country regression for the 5-year ILS on domestic bond yields

	Nominal LM int. rates		Inflation expectations		Real LM int. rates	
	ST	LT	ST	LT	ST	LT
Portfolio effect	−	−	+	+	−	−
Reanchoring channel	0	0	+	+	−	−
Information channel	−	−	−	−	0	0
External channel	0	0	+	0	−	0

Legend: ST: short term < 2 years horizon ; LT: long term > 5 years horizon; SM: short maturity ; LM: long maturity; +: positive impact; −: negative impact ; 0: neutral impact.
Note the difference between the long-term maturity of the interest rates we are interested in (which drive consumption and investment decisions) from the horizon (ST or LT) at which we look at future rates

Table 19: Main transmission channels and qualitative impact of an expansionary forward guidance shock

	RI 1y	RI 2y	RI 5y	RI 20y
FG	0.55***	0.56***	0.99***	0.76***
QE	0.95***	0.95***	1.54***	1.29***
IR	0.52	0.55*	0.44**	0.27**
CONV	0.61***	0.58***	0.23**	-0.02
ECB 2y	0.24***	0.46***	0.51***	0.44***
Oil	-0.23***	-0.13**	-0.01	0.10**
All	0.00	0.00	0.00	0.00
_cons	-0.00	-0.00	-0.00	-0.00
N	3033	3033	3033	3033

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 20: Results of regression on real interest rates

Appendix A: The ECB timeline of actions during the crisis

This appendix details ECB action around the zero-lower bound (2012-17), the definition and evolution of the key interest rates it sets (2008-17), and the turning points in ECB forward guidance over 2013-17.

Date	ECB action
05/07/12	ECB sets the interest rate on the deposit facility at zero percent, with effect from July 11, 2012.
16/07/12	Draghi pledges to do "whatever it takes to preserve the euro", amid the European sovereign debt crisis.
04/07/13	ECB introduces forward guidance for the first time in a press conference: "The Governing Council expects the key ECB interest rates to remain at present or lower levels for an extended period of time".
10/06/14	ECB announces the first TLTROs (Targeted Long-Term Refinancing Operations) program with financing facilities of maturities of up to four years, to improve bank lending to the euro area non-financial private sector.
22/01/15	ECB announces an expanded asset purchase program (QE). The combined monthly purchases of public and private sector securities will amount to 60B until the end of September 2016.
05/13/15	ECB specifies the details of the QE and declares operations will start on March 9, 2015.
03/12/15	ECB extends QE until the end of March 2017.
10/03/16	ECB increases the QE purchases to 80B until the end of March 2017, or beyond, if necessary. The MRO rate reaches the ZLB and a new TLTROs program is announced.
08/12/16	ECB announced another extension of QE. It will purchase 80B until end of March 2017, and 60B until end of December 2017, or beyond, if necessary.

Table 21: Main ECB actions during the crisis

Date	Announcement
04/07/13	"The Governing Council expects the key ECB interest rates to remain at present or lower levels for an extended period of time."
05/09/13	"The Governing Council confirms that it expects the key ECB interest rates to remain at present or lower levels for an extended period of time."
09/01/14	"We firmly reiterate our forward guidance that we continue to expect the key ECB interest rates to remain at present or lower levels for an extended period of time."
04/09/14	"In particular, [the unconventional measures] will support our forward guidance on the key ECB interest rates and reflect the fact that there are significant and increasing differences in the monetary policy cycle between major advanced economies."
22/01/15	"In line with our forward guidance, we decided to keep the key ECB interest rates unchanged."
21/01/16	"Based on our regular economic and monetary analyses, and after the recalibration of our monetary policy measures last month, we decided to keep the key ECB interest rates unchanged and we expect them to remain at present or lower levels for an extended period of time."
10/03/16	"The Governing Council expects the key ECB interest rates to remain at present or lower levels for an extended period of time, and well past the horizon of our net asset purchases."

Table 22: Main changes in ECB forward guidance over 2013-17

Appendix B: Error specification

This appendix provides support for our choice of ARCH(1) as a baseline regression.

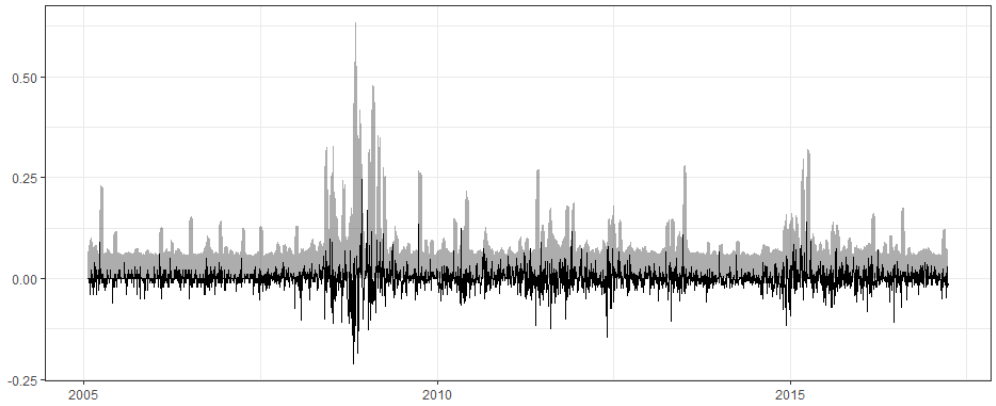


Figure 4: First difference of 5-year inflation swap (black) vs 2-week rolling average of the conditional variance (shaded)

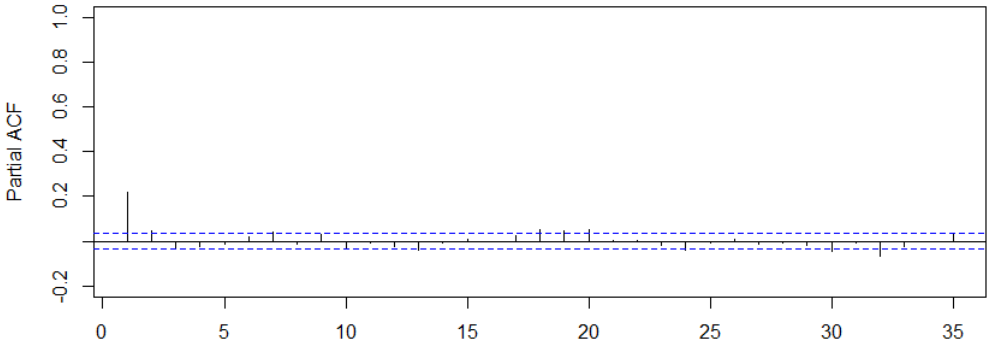


Figure 5: Partial autocorrelation function of the residuals of OLS on regression (1) using 5-year change in inflation swaps.

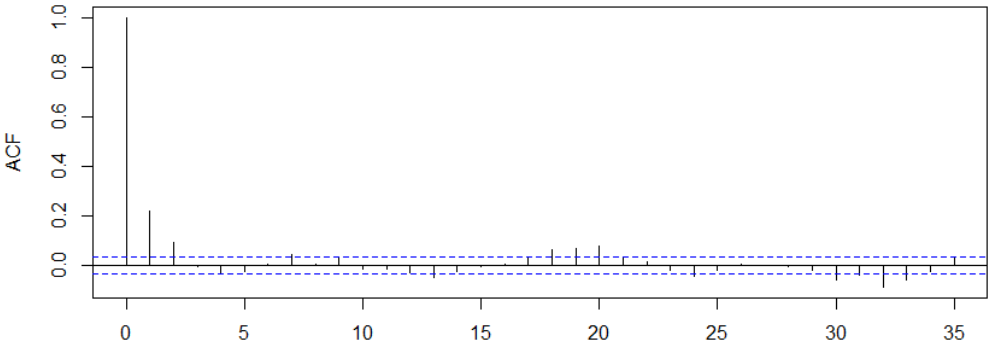


Figure 6: Autocorrelation function of the residuals of OLS on regression (1) using 5-year change in inflation swaps.