The Effect of ECB Forward Guidance on the Term Structure of Interest Rates*

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Abstract
This paper investigates the instantaneous and dynamic effects of ECB forward guidance announcements on the term structure of interest rates. We estimate the static and dynamic impacts of forward guidance on Overnight Indexed Swaps (OIS) rates using a high-frequency methodology and an ARCH model, complemented with local projections. We find that ECB forward guidance announcements have lowered the term structure of private short-term interest rates at most maturities, even after controlling for the macroeconomic information published by the ECB. The effect is stronger on longer maturities and persistent.

Keywords: Central bank communication, Short-term interest rates, Yield curve, OIS.

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1. Introduction

After the European Central Bank (ECB) cut the main refinancing operations rate towards its effective lower bound (ELB) in 2010, forward guidance became one of the only tools available to provide monetary accommodation (Eggertson and Woodford, 2003), together with liquidity provisions and asset purchases. "*The Governing Council expects the key interest rates to remain at present or lower levels for an extended period of time*." With this statement pronounced on 4 July 2013 after the meeting of ECB Board of Governors, Mario Draghi adopted a new communication strategy. On 9 January 2014, Mario Draghi reinforced the use of this communication policy: "*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*". This paper aims to investigate the impact of these forward guidance announcements on the yield curve. Because long-term interest rates – a key determinant of investment and consumption decisions – depend on expected short-term interest rates plus a term premium, Overnight Indexed Swaps (OIS) are a natural candidate for measuring the effect of forward guidance. Indeed, the OIS curve represents a combination of short-term interest rate expectations and term premiums. We therefore estimate the effect of ECB forward guidance on daily changes in OIS rates at maturities from 1 month to 10 years ahead. We use a high-frequency identification and an autoregressive conditional heteroscedasticity (ARCH) model, estimated both in a static fashion and with local projections *à la* Jordà (2005) for measuring dynamic effects.

Central banks have enhanced transparency of their actions and communication to the public over the last decades in order to better signal future policy decisions, shape private expectations and optimise their policy outcomes (see e.g. Geraats, 2002; Woodford, 2005; King, Lu and Pasten, 2008, Reis, 2013). The question of whether central bank communication has had a positive impact on financial markets or helped predict policy decisions has given rise to an abundant literature surveyed by Blinder et al. (2008). However, the question of its transmission mechanism and why central bank communication affects private beliefs remains a much more open question. Gürkaynak, Sack and Swanson (2005a) showed the importance of information about the future policy path embedded in Federal Open Market Committee (FOMC) statements that affect financial markets. One possibility is that central bank communication reveal signals to private agents about policymakers' views about the current and future state of the economy. This paper explores the other possibility that such communications reveal policymakers' reaction functions (their objectives and planned responses to different states of the world) and includes forward guidance and the commitment to deviate from a given rule.

Two types of forward guidance policy have been used by central banks so far. The FOMC adopted time-contingent commitment from December 2008 to December 2012. After that it was replaced by a state-contingent commitment conditional on the evolution of the labour market. The Bank of England also introduced state-contingent forward guidance conditional on unemployment in August 2013. Similarly, the Bank of Japan used state-contingent forward guidance conditional on inflation between October 2010 and March 2013. The Bank of Canada implemented time-contingent forward guidance between April 2009 and April 2010, while the Swedish Riksbank during two periods between April 2009 and July 2010 and between February 2013 and December 2014. Finally, the ECB implemented time-contingent forward guidance without referring to an end date or a precise period of time.

But an announcement that interest rates will remain low is ambiguous: it may reflect an anticipation of bad economic fundamentals or an anticipation of a more accommodative monetary policy.[1] Campbell et al. (2012) introduced the distinction between Delphic and Odyssean forward guidance, where the former describes communication about future macroeconomic fundamentals and the latter consists of statements that bind policymakers to future courses of action. They suggest for the US that the market participants' interpretation of the FOMC's announcements is Delphic. Campbell et al. (2016) show that responses of private expectations to movements in policy rates on FOMC announcement days can also be attributed in part to Delphic forward guidance. But Odyssean forward guidance remains a possibility as a large fraction of the variability of futures rates on announcement days remains unexplained. For the Euro area case, Andrade and Ferroni (2016) find that the ECB communication was Delphic since 2002 but has been interpreted as a signal about future monetary policy (the Odyssean type) over the most recent period. Bletzinger and Wieland (2016) analyse whether the ECB forward guidance follows the outcome of a policy rule so is about transparency, or deviates from it, so signals an accommodative policy stance. In addition, Andrade, Gaballo, Mengus and Mojon (2015) find that forward guidance reduces the dispersion of professional forecasts for interest rates but has no effect on their dispersion for output or inflation. In contrast, our paper focuses on the effect of forward guidance on the level of the yield curve.

The empirical evidence about how forward guidance policies impact the macroeconomy is rather homogenous.[2] Gertler and Karadi (2015), Bundick and Smith (2016), Ben Zeev, Gunn, and Khan (2015) and D'Amico and King (2016) find that real activity and prices decline after a positive forward guidance shock. Gertler and Karadi (2015) find that the response of long-term interest rates cannot be explained by the expected path of short rates, which should be the main channel through which forward guidance operates. The transmission channels of forward guidance and in particular the horizons at which it would lower the yield curve are much less documented. The objective of this paper is then to quantify the effect of forward guidance at various maturities of the term structure of OIS rates.[3]

Because private-sector decisions depend on the entire path of expected future short-term interest rates and term premiums, this paper investigates the effect of ECB forward guidance announcements on the term structure of OIS rates at maturities from 1 month to 10 years ahead. We use the same high-frequency event-study methodology as the literature on the

[1] This is possible only in a framework where private agents and the central bank have different information sets, so the central bank has some private information to reveal to the public (see e.g. Baeriswyl and Cornand (2010), Hubert and Maule (2016) and Melosi (2017) for analysis of situations where monetary policy decisions signal central bank's information to the private sector). If private agents and the central bank have a similar information set, forward guidance can only be a pure commitment mechanism: a promise by the central bank to keep future policy rates lower than its policy rule suggests.

[2] These communication policies have also given rise to an abundant theoretical literature. Carlstrom, Fuerst, and Paustian (2015), Del Negro, Giannoni and Patterson (2015), McKay, Nakamura, and Steinsson (2015) and Kiley (2016) focus on optimal monetary policy under Odyssean guidance and its macroeconomic effects. Bassetto (2015) studies the cheap talk problems resulting from forward guidance policies. Gavin et al. (2014) show that the accommodative effect of forward guidance is offset by the underlying central bank predictions of near-term economic growth, while Gaballo (2016) documents that imperfect information reduces the efficiency of forward guidance. Boneva, Harrison and Waldron (2015) analyse the benefits of threshold-based forward guidance to stimulate the economy, as an insurance against the asymmetric effects of shocks and a credible announcement.

[3] This paper is related to the literature on the value of publishing interest rate projections, a form of forward guidance, and on the predictability of future policy decisions. Rudebush and Williams (2008), Andersson and Hofmann (2009), Moessner and Nelson (2008), Svensson (2015), Mirkov and Natvik (2016) have assessed the effects of the publication of central bank interest rate projections. Moessner (2015), Raskin (2013), Filardo and Hofmann (2014) and Kool and Thornton (2014) have assessed the effects of different types of guidance about the future policy path. Jansen and De Haan (2009), Hayo and Neuenkirch (2010), Middeldorp (2011), Sturm and De Haan (2011) have analyzed how other forms of central bank communication may help predict future policy decisions.

impact of macroeconomic news and policy announcements on financial market variables (see e.g. Gürkaynak, Sack and Swanson, 2005b, or Swanson and Williams, 2014). We control for the effect of monetary decisions taken the same day as forward guidance announcements, especially communication policies about the future policy path. To do so, we use two measures of monetary shocks. The first one is based on Kuttner (2001) high frequency methodology and the second is computed from the Krippner (2013, 2014) shadow rate that encompasses various monetary dimensions (conventional and unconventional instruments and communication) in interest rate space. As common with financial variables and because of evidence of "volatility clustering", we use an ARCH model developed by Engle (1982) to properly account for the presence of heteroscedasticity. Finally, we estimate the dynamic effects using the local projections method of Jordà (2005).

We find that ECB forward guidance announcements have lowered the full term structure of private short-term interest rates. The result is stronger on longer maturities and is persistent. The result is robust to different estimation models (GARCH, TARCH and OLS), to different estimation windows, and to controlling for the inclusion of ECB and private macroeconomic forecasts in the empirical specification. The latter test suggests that the effect of these announcements is more about the stance of future policy than about revealing macroeconomic information. This is consistent with the sign of the effect of forward guidance announcement: while the statement is about keeping interest rates at "*present or lower levels*", the effect on OIS rates is strongly negative.

The rest of the paper is organized as follows. Section 2 describes the data, section 3 the empirical strategy, section 4 the estimates. Section 5 concludes.

2. Data

Our dependent variables are the different maturities of the OIS rate, from 1-month to 10-year forward. The OIS rate being the average EONIA (for Euro OverNight Index Average) expected at a given maturity, these instruments are a combination of expectations of future short-term interest rates plus a term premium. OIS allow financial institutions to swap the interest rates they are paying without having to refinance or change the terms of loans they have taken from other financial institutions. Typically, when two financial institutions create an OIS, one of the institutions is swapping a floating interest rate and the other institution is swapping a fixed short-term interest rate at a given maturity. The transaction involves only marginal counterparty risk since the principal amount is not exchanged between the parties.[4] Under absence of arbitrage, OIS rates would reflect risk-adjusted financial market participants' expectations of the average policy rate over the horizon corresponding to the maturity of the swap (see Bauer and Rudebusch, 2014, or Christensen and Rudebusch, 2012). Our dataset, collected from Datastream, has a daily frequency across the term structure and spans from August 2005 to June 2015.

Following the literature on the impact of macroeconomic news and policy announcements on financial market variables, we use a dummy variable, labelled FG_t, taking the value of one to single out dates of ECB forward guidance announcements. No other non-standard policy measures were announced on those days, so the dummy variable only captures forward

[4] OIS rates are then free of default or liquidity risks, but they may still incorporate a so-called term premium (see Piazzesi and Swanson, 2008).

guidance announcements and does not capture other non-standard policy announcements.[5] The variable FG_t captures two heterogeneous events with potentially different information contents. In a second step, we decompose the forward guidance announcements into two dummy variables to disentangle the effect of each event. In addition, one may consider that the announcement of the ECB Quantitative Easing (QE) programme, known as the Public Sector Purchase Programme (PSPP), on 22 January 2015 constitutes a sort of forward guidance, since the policy rate is assumed to remain low during the period of asset purchases. The announcement of this programme works as time-contingent forward guidance and may also be taken into consideration.[6] In a third step, we consider a FG_QE_t variable that includes the QE announcement as an additional forward guidance event.

Because monetary policy decisions are taken the same day as forward guidance announcements, our analysis requires controlling for the effect of monetary shocks. We use two complementary measures of monetary shocks. Kuttner (2001) proposes a high frequency methodology to identify monetary policy shocks. For a monetary policy event on day d of the month m, the monetary shock can be derived from the variation in the rate implied by current-month fed funds futures contracts on that day. The price of the future being computed as the average monthly rate, the change in the futures rate must be augmented by a factor related to the number of days in the month affected by the change:

$$MP_{kutt,t} = \frac{D}{D-d}\left(f^0_{m,d} - f^0_{m,d-1}\right) \quad (1)$$

$MP_{kutt,t}$ is the unexpected policy decision constituting the monetary shock, $f^0_{m,d}$ is the current-month futures rate and D is the number of days in the month and d the day of the decision.

One issue with the Kuttner measure is that it focuses on futures contracts relating to the interest rate only. Monetary policy, however, has taken many different dimensions over the last years and we ought to consider shocks to unconventional instruments and communication policies (about the future policy path, for instance) in addition to shocks to the conventional instrument. One way to measure these different dimensions of monetary policy is to use shadow rates as proposed by Krippner (2013, 2014) and Wu and Xia (2016) that translate these various dimensions into a single variable expressed in interest rate space.[7] The Krippner shadow short rate (SSR) series is estimated at the daily frequency so the concept of Kuttner's high frequency event-study identification of monetary surprises can be applied to the daily variation in SSR_t on the policy announcement day:

$$MP_{kripp,t} = SSR_t - SSR_{t-1} \quad (2)$$

Because shadow rate measures are not calendar-based instruments like fed funds futures, there is no need for an adjustment for the remaining number of days. These Krippner shocks rely on the financial market participants' interpretation of the overall monetary news disclosed that day. This includes private reactions to central bank conventional or unconventional decisions, and central bank communication (about the state of the economy or the likely future policy path) released at the same time. Because these Krippner shocks encompass most of the dimensions of monetary policy, they may also capture some of the private reaction to forward guidance conveyed the same day.[8]

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[5] The one of July 4th 2013 is available at: www.ecb.europa.eu/press/pressconf/2013/html/is130704.en.html and the one of January 9th 2014 at www.ecb.europa.eu/press/pressconf/2014/html/is140109.en.html.

[6] Altavilla et al. (2015) evaluate the effect of the ECB asset purchase program announcement on asset prices.

[7] Wu and Xia's series is available at the monthly frequency only. Both shadow rates have a correlation of 0.91.

[8] Another way to measure monetary shocks has been proposed by Gürkaynak, Sack and Swanson (2005) and their distinction between a "target factor" and a "path factor". Such measures are also provided by Nakamura and

In addition, we use different macroeconomic and financial variables as control variables. Our dataset includes daily returns of the Eurostoxx50, which could potentially correlate with changes in OIS rates. In the same vein, commodity prices, financial stress or private sentiment might also explain changes in our dependent variables.[9] We thus include in our specification changes in WTI oil prices; a variable capturing financial stress in the euro area, the level of the Composite Indicator of Systemic Stress (CISS) interpolated from weekly to daily frequency; and changes in private sentiment measured by the Economic Sentiment Indicator (ESI) of the European Commission.[10]

3. Empirical Methodology

We use a high-frequency methodology to estimate the effects of forward guidance, which focuses on movements in OIS rates in a narrow window around ECB meetings. This approach was initiated by Cook and Hahn (1989), Kuttner (2001), and Cochrane and Piazzesi (2002). The key assumption is that the reaction of OIS rates that are continually affected by various factors can be specifically attributed to monetary policy news on the day of the policy announcement. Said differently, there is no other macroeconomic news during that window. Since the yield curve adjusts in real-time to macro news, movements in OIS rates during the window of a policy announcement only reflect the effect of news about monetary policy. This is crucial for identification since it strips out the endogenous variation in OIS rates associated with other shocks than monetary news.

We focus our empirical analysis on a narrow window (from the close of business the day before to close of business the day of the announcement) around ECB policy announcements. We control for the policy decision implemented the same day using Kuttner shocks. However, the Kuttner shocks capture only the interest rate dimension of monetary policy. On these days, policymakers do not only provide the decision about the interest rate but also provide decisions about unconventional policies, publish statements about the rationale for their decisions, and disclose their view about the current and future state of the economy, which would be informative of the future likely policy path. Our analysis therefore requires controlling for all announcements other than those related to forward guidance. Using a series of monetary shocks identified from a shadow rate that captures all dimensions of monetary policy enables us to capture the effects of unconventional policies and of other communications on the term structure of interest rates, and so to single out the effect specific to pure forward guidance announcements. Estimating the effect of forward guidance when controlling for Krippner shocks (that react to forward guidance announcements and could potentially capture part of the effect of forward guidance) should provide more conservative estimates than the baseline specification. The specification estimated with Kuttner shocks would provide a more precise estimate of the effect of forward guidance than the one with Krippner shocks but might suffer from an omitted variable bias (i.e. unconventional policies for instance).

Steinsson (2016). They measure, for the US, shocks to the monetary policy news contained in FOMC announcements and so captures policy communication in general and "forward guidance" more specifically.

[9] Because these variables may also react to forward guidance, they could lead us to underestimate the effect of forward guidance announcements. However, this bias goes against the hypothesis that FG_t do affect OIS rates. Moreover, as a robustness test, we allow the coefficients of these controls to vary on announcement days.

[10] Weekly and monthly data are constant-interpolated to daily frequency to respect the information structure. The assumption is that the information set at date *t* includes the last data figure published, whereas a linear interpolation would assume that agents already know the next data figure to be published. This interpolation does not provide an original data point at the day of the forward guidance announcement. However, these controls may explain OIS rates over the sample, so their omission may bias the measure of the effect of forward guidance announcements.

There are two other issues that we need to overcome. First, as is common with financial variables, the variance of our dependent variables changes over time. We therefore use an ARCH model to address this "volatility clustering". Second, because of potential heteroscedasticity and auto-correlation of the residuals, we compute robust standard errors using the Huber-White-sandwich (HAC) estimator. The ARCH model is estimated with maximum likelihood at the daily frequency (so on 2575 observations) and the estimated equations are the following:

$$\Delta r^E_{t,m} = \beta_0 + \beta_1 \, FG_t + \beta_2 \, MP_{j,t} + \beta_3 \, C_t + \epsilon_t \, , \, \epsilon_t \sim (0, \sigma_t^2) \tag{3}$$

$$\sigma_t^2 = \gamma_0 + \sum_{i=1}^{p} \gamma_i \, \epsilon_{t-i}^2 \tag{4}$$

where $\Delta r^E_{t,m}$ is the change between t and $t-1$ in euro area OIS rates for a given maturity m, FG_t is the ECB forward guidance dummy, and $MP_{j,t}$ is the monetary shock (j being either Kuttner or Krippner shocks). C_t is a vector of controls including the CISS, Eurostoxx50 daily returns, oil price daily variations and the ESI index. The number of lags p in the variance equation is determined by their significance and set to one.[11] We are particularly interested in the β_1 coefficient. This should be interpreted as the effect of ECB forward guidance on OIS rates controlling for other monetary announcements, as well as other financial developments captured by the C_t vector that might have potentially occurred on the same days.

4. The Effects of Forward Guidance

4.1. Baseline estimates

We assess the impact of ECB forward guidance on OIS rates at the horizons of 1, 3, 6 and 9-months, and 1, 2, 3, 5 and 10-years. Our estimation sample starts in August 2005 so we have 2575 observations for each maturity. Table 1 shows the baseline estimates using alternatively Kuttner and Krippner shocks as measures for monetary shocks.[12]

In the panel A of Table 1, we control for Kuttner monetary shocks. The β_1 coefficient associated with forward guidance announcements is negative and significant for the 9-month and 1, 2 and 3-year maturities. When controlling for Krippner shocks (panel B of Table 1), the β_1 coefficient associated with forward guidance announcements remains negative and significant at the 1, 6 and 9-month and 1, 2, 3 and to 5-year horizons. Both estimated parameters have the same magnitude. We note that the effect of the FG_t dummy is slightly stronger when controlling for Kuttner shocks, as expected. The peak effect is on the longest maturities, forward guidance announcements decreasing OIS rates by around 4 and 5 basis points at the 3 and 5-year horizons. Andrade and Ferroni (2016) find that, in the case of the ECB, Delphic forward guidance is at work at short horizons whereas Odyssean forward guidance gets more important at medium term. This suggests that the effect evidenced here on medium-run horizons may be interpreted as a signal about the future policy stance, i.e. the Odyssean forward guidance.[13]

The β_2 coefficient associated with Kuttner and Krippner shocks is positive and significant for all maturities indicating that a restrictive monetary shock increases OIS rates. The β_2 coefficient associated with Kuttner shocks (panel A) is positive and significant, but smaller and less

[11] We assess the sensitivity of the results to this choice in the robustness section.

[12] For sake of clarity, parameters of the control variables are not shown in Table 1 but in Table A in the Appendix.

[13] A complementary possibility for explaining the effect of forward guidance announcements is that it may transmit to private agents through another channel of monetary policy –the risk-taking channel– and may affect the risk aversion of market participants and so the term premium embedded in OIS rates.

significant than for Krippner shocks (panel B). These results are consistent with the fact that interest rate variations are not the unique instrument used by the ECB over the sample period. In that respect, Krippner shocks provide a more relevant measure of the ECB monetary stance because they encompass unconventional policies and communication, including the likely future policy path. It suggests that forward guidance announcements have had a negative effect beyond the usual communication about potential future intentions.[14]

For each of the two panels of Table 1 (using Kuttner or Krippner shocks), we show estimates of alternative specifications when differentiating the effects of the two announcements of forward guidance. The results suggest that the first announcement has driven most of the effects induced by forward guidance on the OIS rates. The effect of the second forward guidance announcement is also negative and significant, but is smaller especially at the longer horizons. Because the announcement of the QE programme on 22 January 2015 may be interpreted as a signal that policy rates would remain low until its end, it may be considered as another way for the ECB to reiterate and extend the forward guidance policy. For each of the two panels of Table 1, we provide estimates for a specification that uses the *FG_QE* dummy in equation (3). The negative and significant effect on OIS rates is confirmed.

4.2. Alternative estimates

In this subsection, we estimate alternative specifications to assess the robustness of the baseline estimates. These specifications consider Krippner shocks as monetary shocks in order to provide conservative estimates of the effects of forward guidance. Because forward guidance announcements may be interpreted as a signal about the economic outlook (Delphic forward guidance), we assess whether controlling for the central bank macroeconomic information set modifies the baseline results. The ECB/Eurosystem staff macroeconomic projections for the euro area are produced quarterly since June 2004. They are published in March, June, September and December and are presented as ranges for annual percentage changes in inflation and real GDP. We also control for the private agents' macroeconomic information set. The ECB's Survey of Professional Forecasters (SPF) is a quarterly survey of expectations of inflation, real GDP growth and unemployment in the euro area. Participants are experts affiliated with financial or non-financial institutions. SPF inflation forecasts are produced in February, May, August and November. Because Krippner shocks are based on financial market participants' reactions to policy announcements, they may capture some of the reaction to forward guidance, so we test the effect of removing them. We also estimate equation (3) when allowing the coefficients associated to the control variables in the daily ARCH specification to vary on statements days compared to non-statement days. We go on to test whether including changes in the monthly changes in the Wu and Xia (2016)'s shadow rate modifies estimates of the effect of forward guidance announcements. This shadow rate measure is only available at a monthly frequency, however, so it cannot be used to estimate monetary shocks in a high-frequency event-study fashion. Nevertheless, it might still contain some information about the policy stance that would affect the effect of forward guidance. Finally, we examine whether including a measure of FOMC monetary shocks, identified with the Krippner's shadow rate for the US, affects our estimation. Estimates provided in Table B in the appendix confirm in all cases that the effect of forward guidance announcements is negative and significant. As expected, the point estimate is stronger when not controlling for monetary shocks. Interestingly, the effect of forward guidance announcements is unchanged when controlling for ECB projections and SPF forecasts, suggesting that the effect at work is mainly Odyssean.

[14] Table A in the Appendix shows the estimated parameters of the control variables and of the variance equation.

We perform a second series of robustness tests related to the econometric specifications tested. We test an alternative ARCH specification with two and four lags in the variance equation or alternative estimation methods such as GARCH and TARCH models. GARCH models enable to take into account the variance of lagged residuals in the variance equation. Threshold ARCH enables to take into account the asymmetric nature of positive and negative innovations: positive and negative shocks have a different effect on volatility. On financial markets, downward movements ("bad news") are followed by higher market volatility than upward movements ("good news"). We also estimate equation (3) with Ordinary Least Squares (OLS) and HAC-corrected robust standard errors both on all days and on statement days only (so on 115 observations). Finally, we increase the window over which we assess the response of changes in OIS rates (between *t-1* to *t* in the baseline case) to *t+1*, *t+2* and *t+3*.[15] Table C in the Appendix provides estimates of the effect of forward guidance for all these cases and confirms that the baseline results are robust and do not depend on the type of estimation performed. Interestingly, estimations on wider windows show that the negative effect of forward guidance announcements tends to reinforce and shift to longer maturities.

4.3. Dynamic estimates

We also investigate how persistent is the contemporaneous effect of forward guidance announcements. More specifically, we test the null hypothesis that the effect of forward guidance is offset during the following days.[16] We use the local projections method of Jordà (2005), which suggests estimating a set of h regressions representing the impulse response of the dependent variable at the horizon h to a given variable at time t.[17]

We assess the dynamic effects of ECB forward guidance announcements on the following 25 business days, so we estimate 25 different regressions of the ARCH model represented by equations (3)-(4), each of them measuring the effect of forward guidance announcements at date t on daily changes in OIS rates h days later (h going from 1 to 25). Equations (5)-(6) show how the initial ARCH model is specified for a given horizon h:

$$\Delta r^{E}_{t+h,m} = \beta_{0,h} + \beta_{1,h}\, FG_t + \beta_{2,h}\, MP_{j,t} + \beta_{3,h}\, C_t + \epsilon_{t+h}\,,\ \epsilon_{t+h} \sim (0,\sigma^2_{t+h}) \quad (5)$$

$$\sigma^2_{t+h} = \gamma_{0,h} + \sum_{i=1}^{p} \gamma_{i,h}\, \epsilon^2_{t+h-i} \quad (6)$$

Figure 1 is made of six panels for 9-month and 1, 2, 3, 5 and 10-year OIS rates.[18] Each of these panels plots the responses of $\Delta r^{E}_{t+h,m}$ over the following 25 business days to forward guidance announcements. Said differently, each panel plots the $\beta_{1,h}$ coefficient from the 25 regressions. Estimates show that the effect of forward guidance announcements on maturities until 1 year is very small but we cannot reject the hypothesis that the effect is offset during the following days. For maturities between 2 and 10 years, the pattern is different and suggests that the effect is persistent. We observe that the negative effect measured on the day of the announcement is not offset during the 25 following days. There is no significant positive effect on the following days that would offset the contemporaneous negative effect. The cumulated local projection effect also suggests that the impact of forward guidance is not offset and even tends to increase

[15] This goes against the very objective of high-frequency studies isolating an event from others and should reduce the precision of the estimation

[16] Because signals can be noisy or costly to process or because of learning mechanisms, it might be that the initial reaction is different from the true reaction after some days.

[17] Impulse response functions obtained from VARs may be imposing excessive restrictions on the endogenous dynamics, so estimates derived from more flexible approaches might be preferable. Another advantage is the robustness of local projections to model misspecification to estimate dynamic responses to exogenous shocks.

[18] Results for other maturities are available from the authors upon request.

over time.[19] In addition, the effect of forward guidance announcement appears to be stronger for longer-term maturities, consistent with the outcome of wider estimation windows presented in the subsection 4.2.

5. Conclusion

This paper estimates the effect of ECB forward guidance announcements on the term structure of short-term interest rates using a high-frequency event-study methodology and an ARCH model, complemented with local projections. We find that forward guidance announcements reduce OIS rates at most maturities. This result is stronger for longer maturities and persistent. Furthermore, controlling for ECB and private macroeconomic information sets in the empirical specification does not alter the negative effect of ECB forward guidance announcement on the term structure of interest rates. This suggests that the effect of these announcements is more about the stance of future ECB monetary policy than about signalling ECB's views about the macroeconomic outlook.

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[19] The cumulated local projections are provided without confidence bands since they come from different estimations and their standard-errors from different variance-covariance matrices, and are thus indicative only.

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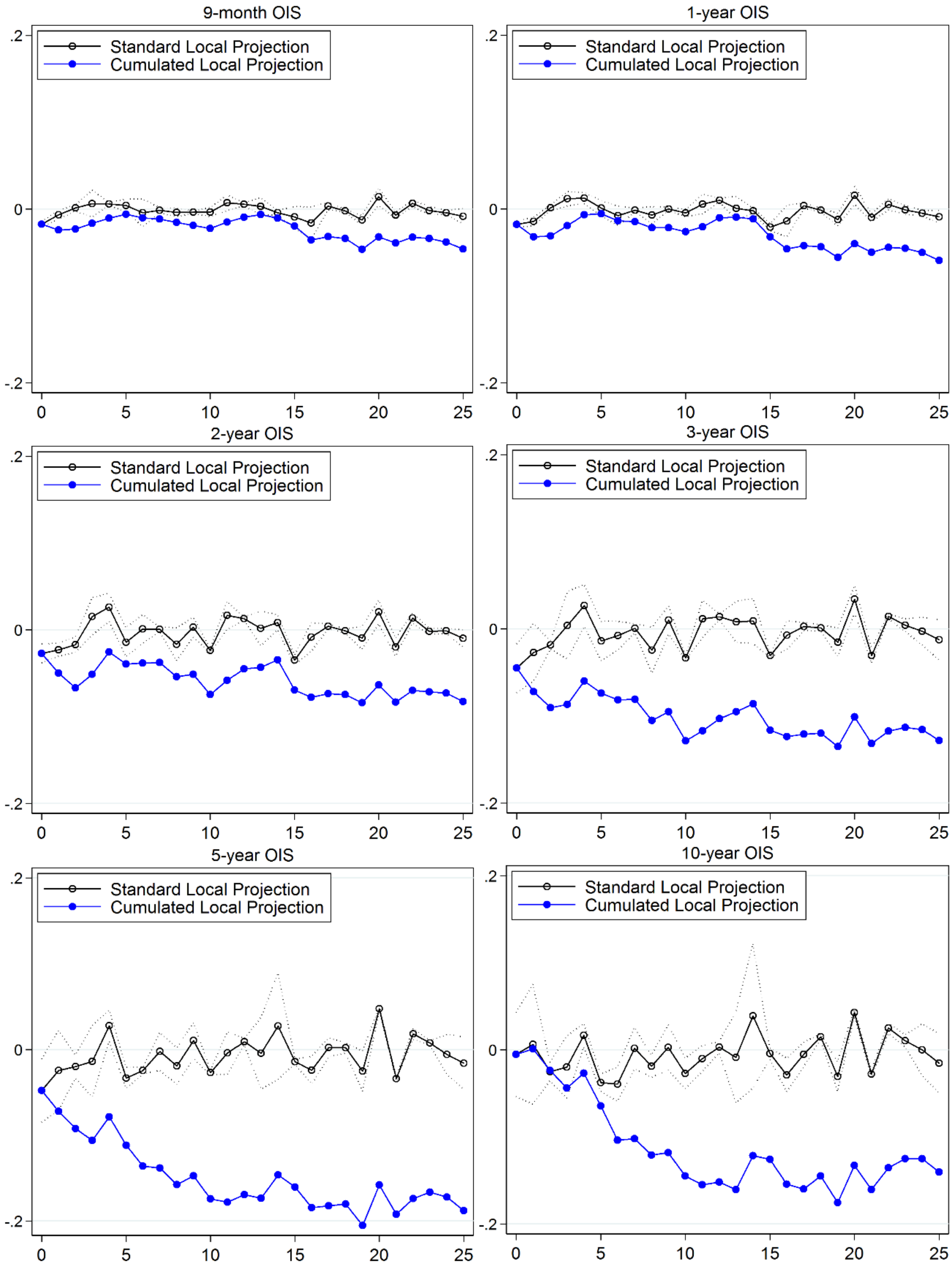
Table 1: Baseline estimates

	(1) oieur1m	(2) oieur3m	(3) oieur6m	(4) oieur9m	(5) oieur1y	(6) oieur2y	(7) oieur3y	(8) oieur5y	(9) oieur10y
Panel A - Baseline specification using Kuttner shocks									
FG	-0.004	-0.002	-0.011	-0.019**	-0.021**	-0.033**	-0.050**	-0.054	-0.009
	[0.00]	[0.00]	[0.01]	[0.01]	[0.01]	[0.02]	[0.03]	[0.03]	[0.03]
Kuttner_shock	0.284***	0.450***	0.517***	0.545***	0.557***	0.478***	0.312***	0.172	0.038
	[0.09]	[0.07]	[0.11]	[0.14]	[0.17]	[0.17]	[0.11]	[0.11]	[0.10]
Using alternative indicators of FG									
Decomposing FG announcements									
FG_04/07/2013	-0.009***	-0.004*	-0.024***	-0.032***	-0.034***	-0.057***	-0.085***	-0.090***	-0.045***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
FG_09/01/2014	0.001	0.001	0.002***	-0.006***	-0.006***	-0.003***	-0.004***	0	0.012***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Including the QE announcement as a FG event									
FG_QE	-0.004	0.001	-0.002	-0.007	-0.011	-0.022	-0.038*	-0.047**	-0.005
	[0.00]	[0.00]	[0.01]	[0.01]	[0.01]	[0.01]	[0.02]	[0.02]	[0.04]
Panel B - Baseline specification using Krippner shocks									
FG	-0.004***	-0.002	-0.009***	-0.017***	-0.018***	-0.027***	-0.045***	-0.048**	-0.005
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.02]	[0.02]	[0.03]
Krippner_shock	0.352**	0.751***	1.145***	1.149***	1.350***	1.686***	1.427***	1.421***	1.126***
	[0.16]	[0.20]	[0.26]	[0.20]	[0.36]	[0.45]	[0.27]	[0.34]	[0.23]
Using alternative indicators of FG									
Decomposing FG announcements									
FG_04/07/2013	-0.007	0.002	-0.012**	-0.021***	-0.020***	-0.035***	-0.065***	-0.069***	-0.027***
	[0.00]	[0.00]	[0.01]	[0.00]	[0.01]	[0.01]	[0.01]	[0.01]	[0.00]
FG_09/01/2014	-0.002	-0.005***	-0.007***	-0.014***	-0.015***	-0.015***	-0.014***	-0.011***	0.004
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Including the QE announcement as a FG event									
FG_QE	-0.008**	0.000	-0.006**	-0.013***	-0.016***	-0.024***	-0.038***	-0.043***	-0.003
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.02]	[0.04]

Note: Heteroscedasticity-robust standard errors in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Each column corresponds to equations (3) and (4) estimated for a different horizon. The specification shown in Panel A includes Kuttner shocks (computed using equation (1)) as monetary shocks in equation (3) whereas the specification of Panel B uses Krippner shocks (computed using equation (2)) in equation (3). Only the key parameters are shown in this table for sake of parsimony. Parameters of control variables and of the variance equation are shown in Table A in the Appendix. The bottom part of both panels shows estimates of alternative specifications of equation (3) in which (i) the FG_t dummy is decomposed in two dummies for each forward guidance event, and (ii) the QE announcement is included as a third forward guidance announcement.

Figure 1: Local projection estimates



Note: Impulse responses to forward guidance announcements, over the following 25 business days, estimated with equations (5)-(6) for each horizon using local projections with 90 per cent confidence intervals and the cumulated effect of estimates. The cumulated local projections are provided without confidence bands since they come from different estimations and their standard-errors from different variance-covariance matrices. These cumulated local projections are indicative only.

APPENDIX

Table A: Full specification of baseline estimates

	(1) oieur1m	(2) oieur3m	(3) oieur6m	(4) oieur9m	(5) oieur1y	(6) oieur2y	(7) oieur3y	(8) oieur5y	(9) oieur10y
Using Kuttner shocks									
	Mean equation								
FG	-0.004	-0.002	-0.011	-0.019**	-0.021**	-0.033**	-0.050**	-0.054*	-0.009
	[0.00]	[0.00]	[0.01]	[0.01]	[0.01]	[0.02]	[0.03]	[0.03]	[0.03]
Kuttner_shock	0.284***	0.450***	0.517***	0.545***	0.557***	0.478***	0.312***	0.172	0.038
	[0.09]	[0.07]	[0.11]	[0.14]	[0.17]	[0.17]	[0.11]	[0.11]	[0.10]
CISS	-0.001	-0.003***	-0.001	0.000	-0.002	-0.002*	-0.002*	-0.001	0.001
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Eurostoxx50	0.001	0.001*	0.005***	0.004***	0.008***	0.011***	0.015***	0.016***	0.016***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Oil	0.001	0.002***	0.002*	0.002	0.001	0.001	0.001	0.001	0.001
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
ESI	0.001**	0.003***	0.002*	0.002***	0.002**	0.001	0.001	0.001	0.002
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Constant	0.000	0.000	0.001	0.001	0.000	-0.001	-0.001*	-0.001	-0.001
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
	Variance equation								
arch(1)	1.237***	1.000***	0.825***	0.745***	0.465***	0.387***	0.246***	0.192***	0.180***
	[0.27]	[0.27]	[0.20]	[0.21]	[0.12]	[0.09]	[0.05]	[0.04]	[0.04]
constant	0.000***	0.000***	0.000***	0.000***	0.000***	0.001***	0.001***	0.001***	0.001***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
N	2575	2575	2575	2575	2575	2575	2575	2575	2575
Using Krippner shocks									
	Mean equation								
FG	-0.004***	-0.002	-0.009***	-0.017***	-0.018***	-0.027***	-0.045***	-0.048**	-0.005
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.02]	[0.02]	[0.03]
Krippner_shock	0.352**	0.751***	1.145***	1.149***	1.350***	1.686***	1.427***	1.421***	1.126***
	[0.16]	[0.20]	[0.26]	[0.20]	[0.36]	[0.45]	[0.27]	[0.34]	[0.23]
CISS	-0.001	-0.003***	-0.002	0.00	-0.002	-0.002	-0.002	-0.001	0.001
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Eurostoxx50	0.000	0.001	0.005***	0.004***	0.007***	0.010***	0.014***	0.015***	0.016***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Oil	0.001	0.002**	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
ESI	0.001**	0.002***	0.001	0.002***	0.002**	0.001	0.001	0.001	0.001
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Constant	0.00	-0.001	0.000	0.001	0.00	-0.001	-0.001	-0.001	-0.001
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
	Variance equation								
arch(1)	1.141***	0.908***	0.689***	0.767***	0.453***	0.370***	0.246***	0.182***	0.164***
	[0.26]	[0.25]	[0.14]	[0.19]	[0.09]	[0.08]	[0.05]	[0.05]	[0.04]
constant	0.000***	0.000***	0.000***	0.000***	0.000***	0.001***	0.001***	0.001***	0.001***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
N	2575	2575	2575	2575	2575	2575	2575	2575	2575

Note: Heteroscedasticity-robust standard errors in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Each column corresponds to equations (3) and (4) estimated for a different horizon. The specification shown in the upper panel includes Kuttner shocks (computed using equation (1)) as monetary shocks in equation (3) whereas the specification of the bottom panel uses Krippner shocks (computed using equation (2)) in equation (3).

Table B: Alternative estimates: controls

	(1) oieur1m	(2) oieur3m	(3) oieur6m	(4) oieur9m	(5) oieur1y	(6) oieur2y	(7) oieur3y	(8) oieur5y	(9) oieur10y
Including ECB projections and SPF forecasts									
FG	-0.004***	-0.002	-0.009***	-0.017***	-0.018***	-0.027***	-0.044***	-0.045**	0.001
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.02]	[0.02]	[0.04]
Including changes in ECB projections and SPF forecasts									
FG	-0.004***	-0.002	-0.009***	-0.017***	-0.016***	-0.026***	-0.045***	-0.047**	-0.006
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.02]	[0.02]	[0.03]
Removing monetary shocks									
FG	-0.006	-0.005	-0.014	-0.023*	-0.025**	-0.036*	-0.052*	-0.055*	-0.009
	[0.00]	[0.00]	[0.01]	[0.01]	[0.01]	[0.02]	[0.03]	[0.03]	[0.03]
Allowing coeffients of controls to vary on statement days									
FG	-0.006**	0.000	-0.008*	-0.020***	-0.015**	-0.019***	-0.043***	-0.044**	-0.017
	[0.00]	[0.00]	[0.00]	[0.01]	[0.01]	[0.01]	[0.01]	[0.02]	[0.03]
Including the Wu&Xia shadow rate									
FG	0.002	0.002	-0.003	-0.013***	-0.013***	-0.031***	-0.043**	-0.050**	-0.003
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.02]	[0.02]	[0.03]
Including US Krippner shocks									
FG	-0.005**	-0.002	-0.010***	-0.018***	-0.018***	-0.027***	-0.045***	-0.048**	-0.005
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.02]	[0.02]	[0.03]

Note: Heteroscedasticity-robust standard errors in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Each column corresponds to equations (3) and (4) estimated for a different horizon. The specifications estimated in this table uses Krippner shocks as monetary shocks (computed using equation (2)) in equation (3), except the third panel for which no monetary shock is included in equation (3).

Table C: Alternative estimates: specifications

	(1) oieur1m	(2) oieur3m	(3) oieur6m	(4) oieur9m	(5) oieur1y	(6) oieur2y	(7) oieur3y	(8) oieur5y	(9) oieur10y
ARCH(2)									
FG	-0.005	-0.001	-0.009***	-0.017***	-0.017***	-0.023***	-0.037***	-0.041**	-0.004
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.01]	[0.02]	[0.02]
ARCH(4)									
FG	-0.012***	-0.001	-0.009**	-0.017***	-0.016***	-0.023***	-0.036**	-0.038*	-0.005
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.02]	[0.02]	[0.02]
GARCH(1,1)									
FG	-0.011***	-0.004*	-0.013***	-0.020***	-0.018***	-0.020**	-0.030**	-0.025*	-0.004
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.01]	[0.01]	[0.01]
TARCH(1,1)									
FG	-0.004***	-0.001	-0.009***	-0.017***	-0.017***	-0.027***	-0.046***	-0.047**	-0.005
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.02]	[0.02]	[0.03]
OLS									
FG	-0.007*	-0.004***	-0.011***	-0.020***	-0.019***	-0.027***	-0.039**	-0.040*	-0.013
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.02]	[0.02]	[0.01]
OLS on statement days (115 observations)									
FG	-0.004	0.003	-0.005	-0.014**	-0.012*	-0.017**	-0.037**	-0.036**	-0.020*
	[0.00]	[0.01]	[0.00]	[0.01]	[0.01]	[0.01]	[0.02]	[0.02]	[0.01]
Δr^E between t+1 and t-1									
FG	-0.003	-0.006**	-0.011**	-0.023***	-0.031***	-0.046***	-0.042***	-0.032*	0.012
	[0.01]	[0.00]	[0.00]	[0.01]	[0.00]	[0.01]	[0.01]	[0.02]	[0.03]
Δr^E between t+2 and t-1									
FG	-0.009**	-0.006***	-0.010**	-0.022***	-0.028***	-0.051***	-0.075***	-0.065***	-0.03
	[0.00]	[0.00]	[0.00]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.03]
Δr^E between t+3 and t-1									
FG	0.003	-0.001	-0.002	-0.011	-0.015	-0.031	-0.067**	-0.089***	-0.043***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.02]	[0.03]	[0.01]	[0.01]

Note: Heteroscedasticity-robust standard errors in brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Each column corresponds to equations (3) and (4) estimated for a different horizon. The specifications estimated in this table uses Krippner shocks as monetary shocks (computed using equation (2)) in equation (3).