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Delphic and Odyssean Monetary Policy Shocks: Evidence from the Euro Area

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Abstract:
What drives the strong reaction of financial markets to central bank communication on the days of policy decisions? We highlight the role of two factors that we identify from high-frequency monetary surprises: news on future macroeconomic conditions (Delphic shocks) and news on future monetary policy shocks (Odyssean shocks). These two shocks move the yield curve in the same direction but have opposite effects on financial conditions and macroeconomic expectations. A drop in future interest rates that is associated with a negative Delphic (Odyssean) shock is perceived as being contractionary (expansionary). These offsetting effects can explain why central bank communication leads to a strong reaction of the yield curve together with a weak reaction by inflation expectations or stock prices. The two shocks also have different impacts on macroeconomic outcomes, such that central bankers cannot infer the degree of stimulus they provide by looking at the mere reaction of the yield curve. However, changes in their communication policy can influence the way markets predominantly understand communication about future interest rates.

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Keywords: central bank communication, yield curve, monetary policy surprises, signaling, forward guidance

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1 Introduction

For many academics and central bankers, the potency of monetary policy decisions does not stem from their direct impact on current short-term rates but from their influence on expectations about future interest rates and, hence, on the whole yield curve. Long-term rates are indeed deemed to have a greater impact than short-term rates on firms' and households' decisions. This view has led central bankers to increasingly rely on communication in order to improve the transmission of their policy rate decisions (Woodford 2005, Bernanke 2013). It is also at the core of the forward guidance policies that are advocated when the conventional nominal rate is constrained by its effective lower bond (Krugman 1998, Eggertsson and Woodford 2003, Woodford 2012).

Consistent with this view, a large literature shows that the yield curve reacts strongly—and far ahead—to central bank communication on the days of policy decisions (Gürkaynak, Sack and Swanson 2005b). However, how markets understand these announcements is not clear. For example, Bernanke and Kuttner (2005) show that unexpected increases in short-term interest rates on the days of policy meetings have a negative impact on stock prices. Nakamura and Steinsson (2018) show that, by contrast, news about future interest rates has little impact on market-based inflation expectations and that it correlates positively with the private sector's GDP growth forecasts. While the former evidence is consistent with markets viewing these surprises as future monetary policy shocks, the latter is not.

In this paper, we emphasize that central bank communication on future interest rates sends two types of signals: news about the future state and news about the central bank's future stance. We develop a methodology that allows us to separately identify two shocks from a single monetary policy surprise observed on the day of a policy decision: a "Delphic" shock—that is, news about the macroeconomic state to which the central bank will react given its usual policy rule—and an "Odyssean" shock—that is, news about future deviations from the central bank policy rule given a future macroeconomic state.[1]

We show that the coexistence of these two components in central bank communication can explain why announcements about future interest rates leads to a strong reaction by the yield curve together with a weak reaction by inflation expectations and stock prices. The intuition is that the two shocks move the yield curve in the same direction but have offsetting effects on these asset prices. Take expected inflation for instance: A communication that signals lower future interest rates can reveal, *at the same time*, bad news about future macroeconomic outcomes—which will lower the expected price pressures—and the good news of a more accommodative

[1] The "Delphic" versus "Odyssean" terminology was introduced by Campbell, Evans, Fisher and Justiniano (2012). Delphic shocks correspond to the central bank's oracles on the macroeconomic outlook. Odyssean shocks correspond to the central bank tying its hands to the mast to commit to future deviations from its usual reaction function.

monetary policy, as the central bank signals it will deviate from its usual reaction function in the future—which will increase expected inflation.

We also document that these two shocks have different impacts on not only financial conditions but also macroeconomic expectations and outcomes. A negative Odyssean shock implies a decrease in future interest rates together with an increase in stock prices, an increase in the private sector's forecasts for GDP and inflation, and an increase in activity and prices. A negative Delphic shock also brings a decrease in future expected interest rates. But, by contrast, it goes with an increase in stock prices, an increase in the private sector's forecasts for GDP and inflation, as well as an increase in prices.

Our results suggest that a central bank cannot infer the degree of stimulus it provides by looking at the mere reaction of the yield curve to its decisions. In this regard, our methodology can be helpful because it allows us to isolate what, in the reaction of the yield curve, are understood as future monetary policy shocks. A related issue is whether and how a central bank can control its communication to financial markets in order to deliver the degree of accommodation it desires. We do not identify a clear driver of Delphic and Odyssean shocks. They are not predictable based on information available before the policy announcement. Moreover, Delphic shocks are not driven by the release of central bank staff forecasts. However, we also illustrate that changes in central bank communication policy—such as the move to explicit forward guidance—modifies what markets predominantly infer from the announcements on the days of policy decisions.

We work with euro-area data. This is an interesting case study, as the communication of the European Central Bank (ECB) on the days of a Governing Council meeting explicitly brings more information than the mere policy decision. Indeed, a policy statement is released first, followed by a press conference of about one hour. We identify surprises in expected future interest rates that result only from ECB communication by looking at the intraday variations in interest rate swap contracts observed in a tight window around the press release and press conference. We consider the reaction of swap contracts of maturities between one month and two years. As in Gürkaynak, Sack and Swanson (2005a), we show that the bulk of the variations in these contracts can be summarized by two factors: a "Target" factor that reflects surprises about the current policy rate and a "Path" factor that conveys news on the path of future interest rates that are independent of the news affecting the current rate.

The reaction of asset prices to the Target factor is broadly consistent with the typical effects expected from a monetary policy shock. In particular, an unexpected drop in the current target rates lowers future interest rates for as long as three years, increases inflation expectations for as long as three years, and increases stock prices. The reaction to the Path factor, however, is much more puzzling. An unexpected lower path of future interest rates lowers expected future interest rates, even for horizons as far ahead as 10 years. However, it also leads to lower expected inflation and has no significant impact on stock market prices. In sum, this is inconsistent with expectations of future monetary policy shocks.

We then identify Delphic and Odyssean shocks in the Path factor. More specifically, we combine interest rate swaps with market-based measures of inflation expectations derived from Inflation Linked Swaps contracts (ILS). We impose sign restrictions so that a Delphic (Odyssean) shock generates a positive (negative) correlation between the reaction of future interest rates and the reaction of medium-term inflation expectations. The time series of shocks we obtain is broadly consistent with a narrative description of the latest episodes of the ECB monetary policy announcements. Moreover, the three factors—Target, Delphic, and Odyssean—together account for a large share of the variations in both interest rates and inflation swaps.

These two shocks have very different impacts on financial conditions. Delphic shocks have effects on the path of future interest rates and on inflation expectations that are comparable, such that the path of expected real rates remains almost constant. By contrast, Odyssean shocks that move the path of future interest rates downward have a negative impact on expected nominal interest rates and a positive impact on inflation expectations. These impacts are roughly the same for maturities of interest rates and inflation swaps ranging from one to ten years. Stock market prices decrease in response to a negative Delphic shock, and they increase in response to a negative Odyssean shock. Moreover, after a negative Delphic shock, corporate borrowing rates decrease by less than the average reaction of risk-free rates, signaling an increase in credit risk. By contrast, they decrease on average more than risk-free rates after a negative Odyssean shock, implying a decrease in credit risk. Overall, these reactions are consistent with Delphic shocks conveying news about the macroeconomic outlook and Odyssean shocks conveying news about future monetary policy shocks.

We also assess how the two types of shocks affect macroeconomic expectations and realizations. First, we document that market reaction to these shocks persists beyond the business days immediately following the monetary policy press conference. Second, we show that they affect the private sector's forecasts of GDP growth and inflation as measured in the Consensus Forecasts survey. Delphic shocks are positively correlated with private forecasts of output and inflation, and Odyssean shocks are negatively correlated with both. These results are again consistent with the structural interpretation of the two shocks. Third, we estimate the dynamic propagation of Delphic and Odyssean shocks on realized output and prices by using high-frequency monetary policy surprises as exogenous shocks in a VAR, as in Gertler and Karadi (2015). Our estimation strategy relies on instrumenting the reduced-form VAR residuals with our high-frequency observable measures of exogenous monetary policy shocks as in Mertens and Ravn (2013) and Stock and Watson (2012). An unexpected decline in the path of future interest rates generates a drop in prices, which suggests a strong signaling effect of central bank communication. By contrast, consistent with expectations of future accommodation, a negative Odyssean shock generates a drop in the slope of the yield curve and an increase in realized output and prices.

Finally, we explore how a central bank can affect Delphic and Odyssean shocks. The surprise about the current interest rate (captured by the Target factor) partly reveals macroeconomic information that is incorporated in staff forecasts. However, this is not the case for surprises about future interest rates that are independent of the current decision. So, Delphic shocks are not correlated with superior information that the central bank incorporates in its forecasts. This does not necessarily imply that markets' reaction to specific communication on future rates is a reaction to uninformative central bank signals. The central bank can communicate private information that is not included in staff forecasts. A typical example is when it communicates its balance of risk assessment, which is frequently revised, even when staff forecasts are not (in particular at meetings where no staff forecasts are released).

We also document that surprises to the path of future rates were predominantly associated with perceived Delphic shocks during the pre-2012 period. Conversely, Odyssean shocks became prevalent in the post-2012 period, during which policy rates went to zero (in July 2012) and the Governing Council started giving explicit guidance on future rates (in July 2013). This period corresponds to a time when the ECB dropped its practice of making no pre-commitment to future rates. We provide some evidence that the relative importance of Delphic shocks declines when ECB presidents use less "no pre-commit" type of wording during their press conferences. So, changes in communication policy affect the way markets understand communication about future interest rates.

The rest of this paper is organized as follows. Section 1.1 reviews the related literature. Section 2 presents some basic properties of monetary policy surprises in the euro area, in particular some puzzling impacts on financial markets. Section 3 details how we separately identify Delphic and Odyssean shocks from news on the expected path of future interest rates, and it discusses their impact on financial conditions. Section 4 investigates the transmission of the two different shocks to macroeconomic variables. Section 5 investigates what drives Delphic shocks. Section 6 documents how communication regimes change the way markets predominantly understand what central bankers say. Section 7 provides concluding remarks.

1.1 Related Literature

Our paper is linked to works that use high-frequency data on future interest rates observed in a narrow window around monetary policy announcements to identify exogenous monetary policy surprises and analyze their effect on financial markets.[2] This approach was pioneered by Kuttner (2001) and Cochrane and Piazzesi (2002). Bernanke and Kuttner (2005) show that the reaction of stock markets to surprises in the current policy rate is consistent with what is expected from a monetary policy shock.[3] This is also the case if one looks at the cross-section reaction of stocks for firms with different price (Weber 2015) or information (Özdagli 2018) rigidities. Gürkaynak et al. (2005a) emphasize that the Path factor, that is, surprises that affect the expected path of future short-term rates but are independent of news on the current interest rates, is an important driver of the yield curve reaction to monetary policy announcements.[4] They also document that US stock prices barely reacted to these Path surprises over the 1990-2004 sample. We obtain similar results for the euro area over the 2004-2016 sample and show that this comes from the offsetting effects of Delphic and Odyssean shocks.

Earlier studies find evidence that central bank communication about current and future rates conveyed information on future macroeconomic conditions by looking at the reaction of private sector expectations as measured in survey forecasts (Romer and Romer 2000, Campbell et al. 2012, Andrade, Gaballo, Mengus and Mojon 2015). Several recent studies provide evidence that information about future states can be found even in intraday monetary policy surprises. Ramey (2016) shows that high-frequency surprises are predictable based on past available information, and Miranda-Agrippino and Ricco (2017) show they correlate with central bank staff forecasts. Gürkaynak et al. (2005b) and Nakamura and Steinsson (2018) show that some properties of market reaction to high-frequency data are consistent with the signaling channel of monetary policy (Ellingsen and Söderstom 2001, Melosi 2017, Tang 2015). Gürkaynak, Kısacıkoğlu and Wright (2018) emphasize that markets extract several dimensions from macroeconomic news such as monetary policy announcements. We explicitly decompose high-frequency surprises into information about the macroeconomic outlook (Delphic) and information about future monetary policy shocks (Odyssean) and show that the information component is quite substantial.

We also find evidence of predictability for intraday euro-area monetary surprises. However, our methodology allows us to show that the predictability of intraday surprises and their correlation with the staff forecasts result only from surprises about the current rate (the Target factor). In contrast, surprises specific to future rates (the Path factor) are not predictable based on past information and do not correlate with staff forecasts.[5]

Several recent papers propose alternative ways to construct high-frequency monetary pol-

[2] This is just one out of several dimensions in which central bank communication matters. See Blinder, Ehrmann, de Haan, Fratzscher and Jansen (2008) for a general survey.

[3] Paul (forthcoming) shows this remains valid for the more recent period with some variation over time.

[4] See also Brand, Buncic and Turunen (2010), Jardet and Monks (2014), Leombroni, Vendolin, Venter and Whelan (2017) and Altavilla, Brugnolini, Gürkaynak, Motto and Ragusa (2019) for similar results in the euro area.

[5] Hubert and Labondance (2018) find that ECB forward guidance announcements lowered the yield curve, even after they control for the macroeconomic information published by the ECB.

icy shocks that are purged from the information conveyed by central bank communication. In particular, Campbell, Fisher, Justiniano and Melosi (2017) and Miranda-Agrippino and Ricco (2017) control for the information revealed in survey and staff forecasts in high-frequency monetary policy surprises.[6] Jarociński and Karadi (2018)—developed independently of us—also introduce (different) sign and zero restrictions to disentangle a pure monetary policy shock from an information shock: They identify a monetary policy shock purged of information effects as an interest rate hike accompanied by a decline in stock market price.[7] This identifying scheme does not a priori exclude a central bank's response to supply side information shocks. Imposing sign restrictions on market-based inflation expectations as we do is not prone to this limit under standard monetary policy rules. Another important difference between the Jarociński and Karadi (2018) study and ours is that the authors focus on signalling in the three month short-term rate. We emphasize that central bank communication can affect macroeconomic expectations over long horizons, which is consistent with the work of Gürkaynak et al. (2005b), Nakamura and Steinsson (2018), and Eusepi, Giannoni and Preston (2018).

Finally, our work contributes to the literature assessing the effectiveness of using central bank communication as a non-conventional instrument through forward guidance policies. Swanson and Williams (2014) show that FOMC announcements of non-conventional policies have a strong impact on the yield curve. Swanson (2018) develops a methodology for separating the effect of forward guidance from the effect of large scale asset purchase (LSAP) announcements in intraday variations of the US yield curve at the time of FOMC meetings. He shows that both have been effective at easing US financial conditions despite the zero lower bound (ZLB) constraint. Consistent with the analysis of forward guidance policy provided in Andrade et al. (2015), our evidence underlines that announcements of future low rates at the ZLB should be predominantly understood as Odysssean shocks if they are to be expansionary, and that they could be counterproductive if predominantly understood as Delphic shocks. We find evidence that the ECB announcements became predominantly understood as Odyssean when explicit forward guidance policy was implemented relative to the period without forward guidance policies. This is consistent with the evidence in Swanson (2018) for the US.[8]

Del Negro, Giannoni and Patterson (2012) show that standard New Keynesian dynamic stochastic general equilibrium (DSGE) models predict incredibly strong positive impacts of forward guidance policies on future inflation and activity, a result that has been dubbed the forward guidance puzzle. The authors' exercise implicitly assumes that the yield curve reaction to for-

[6]See also Lakdawala (2017). D'Amico and King (2015) rely on survey data together with exclusion and sign restrictions in a VAR model of quarterly data.

[7]See also Cieslak and Schrimpf (2018), who combine stock prices together with short- and long-term interest rates to separately identify surprises pertaining to monetary policy, information on output growth, and risk premium.

[8]See also Lunsford (2019) for related US evidence during the 2003-2006 period, a time when the FOMC first gave forward guidance on interest rates.

ward guidance announcements results only from future monetary policy—Odyssean—shocks. We emphasize that it is important to control for the Delphic component of forward guidance in that exercise. Our work also shows that the empirical impact of purely Odyssean shocks on output and prices is not excessively strong. This is consistent with recent models in which the impact of forward guidance is mitigated compared with its impact in the basic New Keynesian setup due to incomplete markets (McKay, Nakamura and Steinsson 2016), imperfect information and higher-order beliefs (Angeletos and Lian 2018), bounded rationality (Gabaix 2016), or bounded rationality combined with incomplete markets (Farhi and Werning forthcoming).

2 Financial market reaction to monetary policy surprises

We use intraday data to identify surprises about current and future short-term interest rates generated by central bank communication on the days of a policy decision. We split these surprises into two dimensions: a component related to the surprise in the current interest rate decision and a component related to surprises about future actions on interest rates. These two types of surprises account for the vast majority of movements in the interest rates with maturity between one month and two years. Surprises about the current decision dominate for maturities of less than six months, and their impact on asset prices is broadly consistent with the effect associated with a monetary policy shock. By contrast, surprises about expected future actions account for most of the variations in maturities of between six months and two years, and their effect is inconsistent with the one associated with a standard monetary policy shock.

2.1 Surprises in current and future monetary policy decisions

We rely on intraday data to identify the reaction of future short-term rates to the ECB Governing Council's monetary policy decisions. More specifically, we use minute-by-minute mid-quote observations of euro-area overnight indexed swap (OIS) contracts from the Thomson-Reuters Tick History database to compute changes in forward rates when such decisions are publicly released. We look at contracts with maturities of between one month and two years.

The ECB communicates its decisions in the following way. A monetary policy decision statement is released at 1:45pm Central European Time (CET). The statement release is followed by a press conference with the ECB's president that begins at about 2:30pm CET and lasts for about one hour.[9] We assume that the change in forward rates observed during this period identifies the effect of news released by ECB communication on current and future interest rates. Accordingly, we compute the difference in OIS forward rates using five-minute averages

[9]The conference opens with the ECB president reading an introductory statement that lasts about 15 minutes and contains the reasons for the monetary policy decisions, including staff forecasts. This is followed by a Q&A session with the press.

before the start and after the end of an identification window around the ECB interest rate announcement and press conference that starts at 1:35pm and ends at 3:50pm CET. We consider nine forward rates associated with horizons of between one month and two years. Our sample covers 169 scheduled Governing Council meetings from January 2002 through January 2016.[10]

The range of horizons considered provides information on how markets update their beliefs about future short-term interest rates both in the short and medium run. This is potentially a rich set of information. To summarize it, we follow the methodology of Gürkaynak et al. (2005a). We standardize the variations of the selected forward OIS rates and extract their first two principal components. We then apply some identifying constraints to give these factors some structural interpretation. Namely, we rotate them so that the first factor affects every forward rate considered, whereas the second factor contributes to the variation in every forward rate but the current-month one. As in Gürkaynak et al. (2005a), we label the first a "Target" factor. It corresponds to the conventional monetary surprise in the current policy rate (hence to the target interbank market rate). Because monetary policy decisions are persistent, this surprise also affects expected future rates. As we document below, it looks like an innovation in the level of the yield curve. We label the second factor a "Path" factor. It conveys surprises about future short-term rates that are independent of current policy action, typically communication about central bank future intentions.[11]

A salient feature of these two factors is that they account for almost the whole of the variation in forward rates during ECB communication on the days of Governing Council meetings. This is illustrated in Table 1 below. While the Target factor accounts for more than half of the variation in short-term maturities, the Path factor contributes to the bulk of the variance for maturities beyond six months. Moreover, as reported in Appendix A, these two factors based on intraday surprises also account for a substantial fraction of monthly variations in the yield curve.

These results are not specific to the euro area. As a matter of fact they are strikingly similar to the ones reported by Gürkaynak et al. (2005a) in their study of US monetary policy surprises. Except for maturities shorter than six months, central bank communication about future interest rates is the main driver of the yield curve on the days of the monetary policy decisions.[12]

[10]We exclude the 1999-2002 period to avoid outliers induced by liquidity issues regarding euro-area OIS contracts at the time.

[11]We normalize the Target factor loadings on the current OIS rates and the Path factor loading on the one-year-ahead future to unity, which is slightly different from Gürkaynak et al. (2005a) but has no impact on the variance decomposition and statistical significance.

[12]Considering a third factor becomes important when one wants to describe the long end of the yield curve, typically between 2 and 10 years. That third factor can be associated with the effect of large asset purchases (Swanson 2018).

Table 1: Contributions of the Path and Target factors to intraday changes in the yield curve

Forward rates	Target	Path
EONIA current	85	0
EONIA next	66	17
EURIBOR 3M in 3M	42	49
EURIBOR 3M in 6M	25	67
EURIBOR 3M in 9M	16	76
EURIBOR 3M in 12M	15	78
EURIBOR 3M in 15M	8	80
EURIBOR 3M in 18M	11	57
EURIBOR 3M in 21M	2	64

This table reports the share of the total variance of interest rate forward rates derived from OIS contracts observed during ECB communication on the days of Governing Council meetings that is explained by the Target and Path factors. "EONIA current" corresponds to the unexpected change in the EONIA rate that will prevail until the next Governing Council meeting. "EONIA next" corresponds to the unexpected change in the EONIA rate that will prevail between the following two Governing Council meetings. The sample includes the scheduled Governing Council meetings that took place from January 2002 through January 2016. The variance is computed as the R^2 of the regression of the change in each swap contract on either the Target factor or the Path factor.

2.2 Market reaction to central bank communication

We assess how markets react to ECB communication on Governing Council meeting days by running the following regression:

$$\Delta x = \alpha + \beta \text{Target} + \gamma \text{Path} + \epsilon,$$

where Δx is the change in various asset prices, Target and Path are the two factors describing the intraday reaction of the short- to medium-term yield curve to monetary policy decisions described in the previous section, and ϵ is an error term.

As emphasized in Gürkaynak et al. (2005a), an interesting feature of this specification is that it allows us to separately identify the impact of the surprise on current policy rate decisions from the independent effect of future policy decisions that markets extract from central bank communication. As previous work does, we investigate the reaction of the yield curve and of the stock price index. We also consider the reaction of market-based measures of expected inflation that has not been documented so far.

More precisely, we consider the following set of financial data: daily measures of nominal OIS spot rates with maturities of 1 month to 10 years;[13] daily marked-based inflation expectations using the Inflation Linked Swaps (ILS) with horizons of 1 year to 10 years;[14] daily variations in

[13]We obtain comparable results when using euro-area average sovereign yields instead.

[14]An alternative is to use the break-even inflation rate, which is calculated as the yield spread between nominal

real interest rates that are derived by taking the difference between OIS rates and ILS rates of corresponding maturity; daily and intraday observations of the reference log stock price index for the euro area, Eurostoxx50; and daily bond yields for euro-area non-financial corporations and banks from Gilchrist and Mojon (2017). These rates correspond to the effective yields on the zero-coupon euro-denominated bonds issued by banks and by non-financial corporations in the euro area.

The Target (Path) factor is normalized so that it generates a 1% increase in the one-month (one-year) OIS. Table 2 reports the coefficient estimates together with the associated adjusted R^2.[15]

The response of financial markets to the Target factor is broadly consistent with what is expected from a standard monetary policy shock. Monetary policy decisions are persistent, and so a higher-than-expected interest rate today implies higher nominal rates tomorrow and hence transmits to rates of longer maturities. This impact is not significant for maturities of more than three years. An unexpected tightening lowers expected inflation two to three years ahead, which is consistent with the estimated reaction to monetary shocks obtained from typical VAR studies. As a consequence, this unexpected tightening implies a hump-shaped and persistent increase in real rates. Lower rates have a negative impact on the intraday reaction of stock prices, even though this impact is not statistically significant. This is consistent with the evidence in Bernanke and Kuttner (2005) and with higher expected real rates being associated with lower expected dividends and higher discount rates. Finally, corporate yields do not significantly increase in reaction to an unexpected tightening such that the difference with the risk-free rate declines. This is inconsistent with the intended effects of a monetary policy shock, which should increase credit spreads.

By contrast, markets' reaction to the Path factor is puzzling. Its impact on the yield curve is stronger and more persistent than the impact of the Target factor. This is consistent with the fact that monetary policy communication sends signals about future interest rates even far ahead. It is possible that markets extract signals about the long-term inflation objective from the communication of the central bank (Ellingsen and Söderstom 2001, Gürkaynak et al. 2005b). In that case, a higher interest rate would be associated with lower expected inflation. However, the reaction of inflation is positively correlated with the Path factor. As a consequence, unexpected signals of future tightenings lead to persistent increases in real rates. Yet, the reaction of stock

and inflation-linked bonds. However, these contracts are country-specific, which makes them unsuitable for computing expected inflation for the whole euro area. Moreover, the euro ILS market is much more liquid than the market for inflation-linked bonds. A drawback is that these ILS rates are available only from 2004 onward.

[15] We consider the variation in a 2-day window around the ECB monetary policy press conference as a baseline. Tables 10 and 11 in Appendix B compare the results obtained when regressing the 1-day or the 2-day variations in Spot ILS rates on the Target and Path factors. Coefficient estimates are comparable in the two specifications. Yet, adjusted R^2's are larger with 2-day variations.

Table 2: Market reaction to ECB communication on the days of Governing Council meetings

Δx	Target	Path	Adj R^2
Interest Rates			
OIS 1m	0.78***	-0.03	0.34
OIS 1y	0.89***	0.84***	0.46
OIS 2y	0.87***	1.16***	0.44
OIS 3y	0.58**	1.13***	0.48
OIS 5y	0.37	0.93***	0.38
OIS 10y	-0.09	0.50***	0.11
Inflation			
ILS 1y	0.23	0.43***	0.07
ILS 2y	-0.41*	0.34***	0.07
ILS 3y	-0.53***	0.33***	0.12
ILS 5y	-0.08	0.24***	0.09
ILS 10y	0.12	0.17***	0.06
Real Rates			
OIS 1y	0.59*	0.37**	0.07
OIS 2y	1.20***	0.76***	0.37
OIS 3y	1.08***	0.79***	0.36
OIS 5y	0.42*	0.69***	0.27
OIS 10y	-0.23	0.33***	0.05
Stock prices			
EuroStoxx50	-5.06	0.19	0.02
Corporate bonds			
NFC	0.22	0.77***	0.25
Banks	0.13	0.70***	0.30

Regression estimating the impact of intraday Target and Path surprises on 2-day variations of various assets observed after Governing Council's decisions, except stock prices for which the variation is intraday. Real rates are computed as the difference between the nominal interest rates and the inflation rates of equivalent maturity. *, ** and *** indicate statistical significance at 10%, 5%, and 1% respectively. The "Target" ("Path") factor is normalized so that it generates a 1% increase in the one-month (one-year) OIS rates.

prices is very small (about 2.5 times smaller than their reaction to the Target factor) and positive, which is inconsistent with expectations of future tightenings. Finally, corporate yields increase with the Path factor, but less than the average reaction of nominal rates, so that credit spreads decline after a positive surprise on future short-term rates.

3 Delphic and Odyssean components in central bank communication

The previous section provides evidence that the major driver of the yield curve reaction to central bank communication is related to signals about future short-term rates and that these are inconsistent with signals about future monetary policy shocks. So what are markets reacting to? In this section we show that they react to two different dimensions in the Path factor: information about the future state of the economy and information about the future monetary policy stance given the expected future state. We also show that these two components have very different impacts on financial conditions, such that identifying each is crucial to assessing the impact of central bank communication on financial markets.

Consistent with previous work emphasizing the signaling effect of monetary policy (Romer and Romer 2000, Ellingsen and Söderstom 2001, Melosi 2017, Nakamura and Steinsson 2018), we assume that central bank decisions reveal information about both the future state of the economy and the central bank's future intentions given the state. Like Andrade et al. (2015), we focus on the information the central bank reveals through communication about future short-term interest rates. Using the terminology of Campbell et al. (2012), we assume that the Path factor can be decomposed into:

$$\text{Path} = \sigma \text{Delphic} + \varsigma \text{Odyssean} + \varepsilon,$$

where Delphic and Odyssean are two orthogonal shocks affecting future interest rates but not the current one, and ε is a noise that affects future interest rates.

3.1 Identification

In a narrow window around monetary policy announcements, it is reasonable to assume that there is no extrinsic variation in economic fundamentals (other than monetary policy shocks). So, in a model with perfect information, all the variation in the slope of the term structure of nominal interest rates is attributable to future policy decisions given the outlook, hence to an Odyssean shock. A positive (negative) intraday monetary policy surprise would mean more tightening (accommodation) given the outlook. This should thus lead markets to revise their inflation expectations downward (upward). In other words, Odyssean shocks generate a *negative* correlation between the Path factor and market-based inflation expectations.

With imperfect information, the private sector might revise its estimates of the fundamentals based on the monetary authority's communication during the press conference. We can even think of an extreme case where the variation in the slope of the term structure of nominal interest rates is solely attributable to private central bank information about the future outlook, hence to a Delphic shock. A positive (negative) intraday monetary policy surprise would correspond to a better (worse) economic outlook, to which the central bank is expected to adjust given its reaction function. This should thus lead markets to revise their inflation expectations upward (downward). In other words, Delphic shocks generate a *positive* correlation between the Path factor and market-based inflation expectations.

We use these sign restrictions to separately identify the Delphic and Odyssean shocks in the Path factor. More precisely, we postulate that the intraday variations in the OIS and ILS rates can be described by the following three-factor model:

$$Y = F\Lambda' + e,$$

where Y is a $T \times k$ matrix pooling together the high-frequency variations in the OIS and ILS rates for the k maturities observed around the T Governing Council meetings in our sample, F is a $T \times 3$ matrix of factors, Λ is a $k \times 3$ matrix of loadings, and e is an error term. We then rotate the factors to get a structural factor model

$$Y = (FH)(\Lambda H)' + e,$$

where (ΛH) satisfies identifying assumptions. Specifically, let us assume, without loss of generality, that the first three columns in the Y matrix are made of the intraday variations in the current-month OIS, the intraday variations in the one-year ahead OIS, and the two-day variations in the five-year ILS, followed by the remaining OIS and ILS rates. Our identification is achieved assuming that ΛH has the following structure:

$$\begin{pmatrix} \Delta OIS_{1M,t} \\ \Delta OIS_{1Y,t} \\ \Delta ILS_{5Y,t} \\ \vdots \\ * \end{pmatrix} = \begin{pmatrix} * & 0 & 0 \\ * & + & + \\ * & + & - \\ \vdots & \vdots & \vdots \\ * & * & * \end{pmatrix} \begin{pmatrix} \text{Target}_t \\ \text{Delphic}_t \\ \text{Odyssean}_t \end{pmatrix} + e_t.$$

This set of restrictions implies that the second and the third factors do not influence the current-month OIS, while the first one has an impact. This is akin to the split between a Target and a Path factor. To distinguish between the Delphic and Odyssean components, we further assume that the second factor has a positive impact on the one-year OIS futures contract and on the five-year ILS, and that the third factor has a positive impact on the one-year OIS futures contract and a negative impact on the five-year ILS. The second factor can be interpreted as a Delphic forward guidance shock and the third factor as an Odyssean forward guidance shock. Further details can be found in Appendix C.

3.2 Estimated shocks and illustrating examples

Figure 2 depicts the Target (black line in the top panel) and Path (black line in the central panel) factors obtained when using only information on OIS as well as the Delphic and Odyssean factors obtained using both OIS and ILS. The Target (Path, Delphic, and Odyssean) factor is normalized so that it generates a 1% increase in the one-month (one-year) OIS spot rate. The top panel shows the Target factor obtained when using only OIS or both OIS and ILS: That factor stays relatively similar under the two identifications. The central panel compares the Path factor with the Delphic shocks in monetary policy communication. Although there are clear co-movements between the two, the differences are also substantial. The correlation between the Path factor and the Delphic factor is 0.70. Finally the bottom panel reports the estimated Odyssean shocks and highlights several episodes in which realized shocks were larger than the standard deviations (in absolute values). The correlation between the Path and the Odyssean factors is 0.46.

In particular, some recent outliers are:

07/2013 *Odyssean factor* −4.8 *basis points.* President Draghi announced for the first time forward guidance. According to his introductory statement, "[The Governing Council] expects the key ECB interest rate to remain at present or lower levels for an extended period of time."

01/2015 *Odyssean factor* −4.9 *basis points.* President Draghi announced the QE package. He stated, "First, [the Governing Council] decided to launch an expanded asset purchase programme, encompassing the existing purchase programmes for asset-backed securities and covered bonds. Under this expanded programme, the combined monthly purchases of public and private sector securities will amount to Euro 60 billion. They are intended to be carried out until end-September 2016 and will in any case be conducted until we see a sustained adjustment in the path of inflation which is consistent with our aim of achieving inflation rates below, but close to, 2% over the medium term."

10/2015 *Odyssean factor* −6.3 *basis points.* President Draghi signals that the QE package could be expanded. "In this context, the degree of monetary policy accommodation will need to be re-examined at our December monetary policy meeting, when the new Eurosystem staff macroeconomic projections will be available. The Governing Council is willing and able to act by using all the instruments available within its mandate if warranted in order to maintain an appropriate degree of monetary accommodation. In particular, the Governing Council recalls that the asset purchase programme provides sufficient flexibility in terms of adjusting its size, composition and duration."

12/2015 *Odyssean factor* +10 *basis points.* President Draghi announced two monetary measures: (1) a 10 basis point cut in the deposit facility rate (from −0.2% to −0.3%) and (2) an extension of the horizon of the asset purchase program until at least March 2017 (instead of September 2016). The Odyssean number seems inconsistent with the announcement about monetary accommodation. However, market participants were expecting a more aggressive move. According to the transcripts of the monetary policy press conference, questions about the weakness of monetary policy actions were raised by the press conference participants. For example, one participant said, "And my second question is, it seems like what you've done is a little bit on the low end of the range of what the financial markets had expected, in terms of your stimulus package today. It seems like the initial reaction in the financial markets bears this point. Why didn't you do more, given how much you've warned about the risks of low inflation? Why didn't you raise the monthly purchase amount? Why didn't you cut the deposit rate more?" Similarly another participant said, "You've just explained your reasoning, but nevertheless, financial markets appear to be disappointed. So what is the reason there? Do you think that something went wrong in your communication in the run-up to the decision? Did you perhaps overestimate your ability to convince fellow policy-makers to decide something even more aggressive? Or do financial markets not understand yet how powerful these measures actually are?"

Our measure of Odyssean shocks is thus able to identify a number of recent key events that appear relevant from a narrative viewpoint. Interestingly, these shocks do not appear as (relative) outliers if one looks at the mere Path factor. It also seems that the Delphic shocks are more important in the central part of our sample and less so in the recent episodes. This could be consistent with a change in ECB communication, in particular to include more explicit forward guidance policy in the period when interest rates were low. Section 6 provides further investigation of this assumption.

3.3 Impact on financial markets

We assess how markets react to the information released via ECB communication on the days of a Governing Council meeting by running the following regression:

$$\Delta x = \alpha + \beta \text{Target} + \delta \text{Delphic} + \kappa \text{Odyssean} + \upsilon,$$

where Δx is the change in various asset prices (we consider the same four class of asset prices than in the previous section); Target, Delphic, and Odyssean are the three factors describing the intraday reaction of the short- to medium-term yield curve to monetary policy decisions described in the previous section; and υ is an error term. Table 3 reports the results. There are several things worth highlighting.

First, the Target, Delphic, and Odyssean factors provide a better fit for the variations in different segments of the yield curve compared with the one obtained using only the Target

Table 3: Delphic / Odyssean communication

Δx	Target	Delphic	Odyss.	Adj R^2
Nominal Rates				
OIS 1m	0.58***	0.10	-0.08	0.13
OIS 1y	1.23***	1.23***	0.38**	0.59
OIS 2y	1.57***	1.60***	0.49**	0.59
OIS 3y	1.45***	1.54***	0.51**	0.54
OIS 5y	0.90***	1.42***	0.49**	0.46
OIS 10y	0.18	0.88***	0.01	0.17
Inflation				
ILS 1y	-0.33	1.56***	-0.35	0.46
ILS 2y	-1.08***	1.52***	-0.66***	0.85
ILS 3y	-0.99***	1.32***	-0.63***	0.92
ILS 5y	-0.08	0.87***	-0.83***	0.86
ILS 10y	0.33***	0.61***	-0.96***	0.88
Real Rates				
OIS 1y	1.56***	-0.33*	0.73**	0.18
OIS 2y	2.65***	0.08	1.14***	0.52
OIS 3y	2.44***	0.21	1.13***	0.45
OIS 5y	0.97***	0.56***	1.32***	0.31
OIS 10y	-0.17	0.28*	0.97***	0.11
Stock prices				
EuroStoxx50	-4.01	1.62	-13.95***	0.24
Borrowing rates				
NFC	0.51**	0.85***	0.75***	0.31
Banks	0.54**	0.68***	0.94***	0.31

Regression estimating the impact of intraday Target, Delphic, and Odyssean surprises on 2-day variations in various assets observed after Governing Council's decisions, except stock prices for which the variation is intraday. The variation in the real rates is computed as the difference between the nominal interest rates and the inflation rates of equivalent maturity. *, ** and *** indicate statistical significance at 10%, 5%, and 1% respectively. The Target (Delphic, Odyssean) factor is normalized so that it generates a 1% increase in the one-month (one-year) OIS rates.

and Path factors. The R^2 adjusted for the larger number of explanatory variables increases by about 10 percentage points (with some heterogeneity across maturities). Noticeably, these three factors account for the bulk of the variations in the spot ILS rates observed right after Governing Council meetings with figures above 85% for maturities of 2 to 10 years.

Second, real rates react differently to Delphic and Odyssean shocks. As expected, a Delphic (Odyssean) shock driving up future interest rates is associated with higher (lower) price expectations for a wide range of maturities. Note that this result is not fully obtained by construction, as the identifying sign restrictions apply only to the five-year maturity spot ILS rate. A positive Delphic shock is associated with first a drop in real rates and then an increase in real rates, consistent with gradualism in the central bank reaction function. By contrast, a positive Odyssean shock is associated with an increase in real rates of every maturity, consistent with an expected future tightening given the outlook due to, for example, a change in the preference of the Governing Council regarding the long-term inflation target (Ellingsen and Söderstom 2001).

Third, both Delphic and Odyssean shocks affect stock prices with opposite signs. The lack of reaction of stock prices to the Path factor is thus due to the fact that the two effects offset each other. These different effects are also consistent with the different natures of the two shocks. A positive Delphic shock signals a better macroeconomic outlook, to which stock markets react positively. A positive Odyssean shock signals tighter future monetary policy given the outlook, to which stock market react negatively.

Fourth, positive Delphic and Odyssean shocks exert upward pressures on the cost of marketable debt for non-financial corporations and banks. However, the reaction of corporate bond yields to a positive Delphic shock is lower than the average reaction of the riskless (OIS) yield curve to the same shock. Conversely, the reaction of corporate bond yields to a positive Delphic shock is lower than the average reaction of the riskless (OIS) yield curve to the same shock. In other words, corporate spreads decline (increase) after a positive Delphic (Odyssean) shock. A positive Delphic shock conveys looser financing conditions due to good news about the macroeconomic outlook. A positive Odyssean shock signals tighter financing conditions stemming from more restrictive monetary policy.[16]

4 Impact of delphic and odyssean shocks beyond the initial reaction

In this section, we document that the impact of Delphic and Odyssean shocks on financial conditions lasts beyond the days right after central bank announcements. We then analyze the reaction of macroeconomic expectations and outcomes to central bank communication on future interest rates and to its Delphic and Odyssean components.

[16] In unreported results, we find evidence that Delphic shocks correlate negatively with sovereign spreads of euro-area countries that were under stress during the sovereign crisis, while Odyssean shocks correlate negatively with these spreads. This impact on euro-area fragmentation is reminiscent of the evidence in Leombroni et al. (2017).

4.1 Persistence after initial impact

To get a sense of the persistence of the effects of Delphic and Odyssean shocks on daily financial variables, we follow Jordà (2005) and run a series of daily local projection regressions of the form:

$$x_{t+h} = a_h + b_h(L)x_t + c_h \text{Factor}_t + \epsilon_{t+h}^{(h)},$$

where each forecast horizon h is associated with a different regression; x denotes the daily financial variable of interest; t indexes business days; Factor $= \{$Target, Delphic, Odyssean$\}$ denotes the factors underlying the intraday monetary policy surprises as estimated earlier in the paper (and is set equal to zero on non-ECB announcement days); $\epsilon^{(h)}$ is a forecast error term; and $a_h, b_h(L)$, and c_h are parameters that may vary across regressions h.[17]

We find that a_h and b_h are essentially always close to zero and one, respectively. Of course, for longer horizons, there will also be a greater amount of non-monetary-policy news that impacts swaps, so the residuals and standard errors surrounding the coefficient estimates will tend to be larger. Figure 3 plots the results of these regressions for the two-year, the two-year in two-year, and the five-year in five-year ILS; the non-financial corporation borrowing rates; and the (log of) stock market prices. The solid blue line in each panel plots the point estimates of c_h as a function of the horizon h, and gray areas correspond to the Newey-West ± 1.96-standard-error bands around those point estimates, allowing for $h - 1$ lags of autocorrelation.

The effects of Target shocks are transitory and disappear after a few days, whereas Delphic and Odyssean shocks have effects that last at least a month, which is well beyond the business days immediately following the monetary policy announcements at the press conference. Interestingly, while we impose signs restrictions on only the contemporaneous correlation between nominal and inflation rates, we find that the signs of the impact of Delphic and Odyssean shocks associated with the two-day variations also hold at different horizons.

4.2 Impact on macroeconomic expectations

Table 4 reports the regressions estimating the monthly variations of GDP and inflation expectations from Consensus Economics on various factors (and a constant). In particular, we consider the following specifications:

$$\Delta\overline{E} = \alpha + \beta \text{Target} + \gamma \text{Path} + \varepsilon$$

and

$$\Delta\overline{E} = \alpha + \beta \text{Target} + \delta \text{Delphic} + \kappa \text{Odyssean} + \nu,$$

[17] Altavilla, Giannone and Modugno (2017) and Hanson, Lucca and Wright (2017) provide thorough assessments of the persistence of the impact monetary policy decisions have on the yield curve.

Table 4: Central bank communication and macroeconomic expectations

	Target	Path	Adj R^2	Target	Delphic	Odyss.	Adj R^2
Δ GDP growth forecasts							
current calendar year	-0.47	0.12	-0.01	-0.40	0.75*	-0.25	-0.00
next calendar year	-1.37*	0.38	0.04	-1.52**	0.73	-0.60	0.05
Δ CPI inflation forecasts							
current calendar year	0.28	-0.07	-0.01	0.27	0.13	-0.75*	0.00
next calendar year	-0.71	-0.13	0.03	-0.83	0.10	-0.57*	0.04

Regression estimating the monthly variation in the Consensus Forecasts (median across individual forecasts) on the factors. OLS estimates and statistical significance, 1(5 and 10) % indicated with $***$ ($**$ and $*$) with robust SE.

where $\Delta\overline{E}$ is the change in the median expectation of euro-area GDP growth and HICP inflation observed in the Consensus Economics surveys conducted before and after the Governing Council meeting.[18]

Although they are small components of the total change, Delphic and Odyssean shocks contribute to the revision in macroeconomic forecasts with the expected signs. The effects are not always statistically significant. However, this might be due to the small size of our sample. When we look at the individual responses in panel regressions with fixed or random effects, point estimates are similar to those obtained with the median respondent, and coefficients are all statistically significant (see Table 12 in Appendix D).

These regressions focus on only contemporaneous impact effects. In the next section, we offer a quantitative estimate of the dynamic propagation of Odyssean and Path shocks on output and prices and on survey expectations about output growth and inflation.

4.3 Impact on macroeconomic outcomes

A popular way to measure the dynamic transmission of a macroeconomic shock in general and a monetary policy shock in particular is to use VAR models (see Ramey 2016 for an overview). VAR models assume that the joint comovements of the macroeconomic variables can be described by linear lag structure of order p, which takes the following form:

$$y_t = \Phi_0 + \Phi_1 y_{t-1} + ...\Phi_p y_{t-1} + e_t \quad e_t \sim N(0, \Sigma),$$

where y_t is a vector that contains the observable variables, and ϵ_t is a vector of a normal zero mean identically distributed and serially uncorrelated shocks with $\Sigma = E(\epsilon_t \epsilon_t')$. Note that

[18] Fourteen dates for which the monthly revision in the Consensus Forecasts preceded the Governing Council meeting were dropped from our sample.

$\Phi_0, \Phi_1, ..., \Phi_p$ are matrices of appropriate dimensions describing the dynamics of the system. We can rewrite the VAR in a companion form—that is, $y_t = x_t'\Phi + e_t$, where $x_t = [y_{t-1}', ..., y_{t-p}', 1]'$, with Φ being the companion form matrix—and estimate the parameters of interest either with classical estimators or by using a Bayesian approach. Under the assumption of normal distribution of the residuals, the reduced-form VAR is compatible with several structural representations in which reduced-form shocks can be expressed as linear combination of structural uncorrelated innovation; that is,

$$e_t = \Omega \nu_t,$$

where $\Omega\Omega' = \Sigma$, $E(\nu_t \nu_t') = I_n$. Since it is likely the data are flat along the Ω matrix dimension, additional restrictions are needed to identify the structural shocks.

Following Mertens and Ravn (2013) and Stock and Watson (2012), we map the reduced-form VAR residuals with the structural shock of interest by *instrumenting* the VAR residuals (observable) with a measurable proxy for the structural shock (unobservable). In our context, the proxy for monetary policy shocks is given by either the Path factor or the Odyssean shocks extracted from the high-frequency data as discussed in previous sections. Gertler and Karadi (2015) apply this methodology to study the transmission of FOMC announcements on prices, output and the credit spread using a small-scale VAR estimated with classical inference. Similarly, Miranda-Agrippino (2015) use this framework to measure the transmission of orthogonal monetary policy surprises in the United Kingdom. The novelty of this paper is that we isolate the effect of the Odyssean component of monetary policy announcements and then measure its impact.

The basic idea of the structural VAR with an external instrument is that the monetary policy shock in the structural VAR is identified as the predicted value in the population regression of the instrument on the reduced-form VAR residuals. For this result to hold, the instrument needs to be valid; that is, it needs to be relevant (correlated with the unobserved monetary policy shock of the VAR) and exogenous (uncorrelated with the other shocks). This approach allows us to recover the first column of the rotation matrix Ω and thus to recover impulse responses and the transmission mechanism. More formally, let m_t be the time series proxy for the unobserved structural shock. Assume, without loss of generality, that the proxy is linked to the first shock as follows

$$\begin{aligned} E(\nu_t m_t) &= [\rho, 0, ..., 0]', \\ E(\Omega \nu_t m_t) &= \Omega[\rho, 0, ..., 0]', \\ E(e_t m_t) &= \rho[\Omega_{11}, \Omega_{2:N,1}']'. \end{aligned}$$

Assuming that the first reduced-form shock is related to the observed proxy, we can partition the two sets of relationships and obtain

$$E(e_{2,t}m_t)E(e_{1,t}m_t)^{-1} = \Omega_{11}^{-1}\Omega_{2:N,1},$$

where the second equation can be estimated using the sample analog, since m_t is observable, e_t is observable conditional on Φ and Σ, and they are both stationary. This restriction, coupled with the fact that $\Omega\Omega' = \Sigma$, gives rise to a set of equations that, up to a sign normalization, uniquely pin down the first column of the rotation matrix.

The econometric approach works as follows. We first run the VAR ordinary least square (OLS) regression to obtain Φ and Σ. We next isolate the variation in the reduced-form residual of the policy indicator that is attributable to the proxy. We then regress the remaining reduced-form residuals on the fitted value of the first regression. To obtain the confidence bands around the impulse response, we follow Mertens and Ravn (2013) and run a wild bootstrap of the VAR residuals.

The VAR includes six variables: the difference between the one-year and the three-month forward EONIA derived from OIS rates, which is a measure of the slope of the term structure of rates; the seasonally adjusted (log) industrial production index (excluding construction); the (log) HICP excluding energy and food prices; and the Gilchrist and Mojon (2017) credit spread. We also include survey measures of expectations, namely the Consensus Forecasts for next year's GDP growth and next year's inflation rate. The data series are observed at monthly frequencies and span the period from January 2002 through January 2016.

Figure 4 reports the estimated impulse responses to a shock to the Path of future interest rates, with no distinction between Delphic and Odyssean shocks (left panel) and the response to an Odyssean shock (right panel). Both announcements are normalized to generate an increase in expected short-term rates given the current short-term rate. In other words, the shock induces a larger spread between the short-term rates expected one year and three months ahead, hence a steepening of the slope of the yield curve. A positive shock to the Path increases prices, lowers credit spreads, and increases the private sector's output and inflation forecasts. This is consistent with an important signaling or information component in this Path shock. In contrast, a positive Odyssean shock lowers output and prices, increases the credit spread, and lowers the private sector's output and inflation forecasts. This is consistent with the intended effects of future monetary policy shocks. The cumulated impact of a shock that increases forward rates in one year by 20 basis points is of about 25 basis points on core inflation after two years. It also increases IPI by a cumulated 2.5%.Those effects are comparable to the effect of a standard monetary policy shock of the same magnitude. This suggests that there is no forward guidance puzzle in the data.

5 The information content of delphic shocks

In this section, we assess the predictability of the intraday monetary policy surprises for the euro area based on past information and on central bank private information.

5.1 Are euro-area intraday monetary policy surprises predictable?

One simple way to test the predictability is to project the Path and Target factors onto a rich set of variables intended to capture the information set common to the central bank and the agents. More precisely, let F_t be the vector containing the Target and Path factors at time t, and let X_t be a vector collecting a number of macroeconomic and financial variables. We define the following system:

$$X_t = \Lambda \mathbf{f}_t + u_t,$$
$$F_{t+1} = \mathbf{f}_t' B + e_{t+1},$$

where $\mathbf{f}_t$ are some factors summarizing the information content of X_t, the set of observables whose realizations are known before the announcement; e_t and u_t are independent identically distributed (i.i.d.) shocks; and B is the matrix that loads the factors onto the monetary policy surprises. If B is statistically significant, then monetary policy surprises can be predicted by using past common information.

We include a total of about 40 variables in X_t that are related to macro data, financial variables, and surveys.[19] The test is run in various steps. We first extract the first principal component, which explains about 70 percent of the volatility of the entire data set. Factors are extracted on a rolling basis in order to avoid including the information available after the announcement. In a second step, we regress either the Path or the Target factor on the lagged macro factors and look at the F and t statistics to test for statistical significance.

Table 5 reports the individual p-values of the coefficients of the regression of the Path and Target factors on lagged macroeconomic, financial, and surveys factors or only lagged financial factors. The last row reports the F-test of the joint statistical significance. Overall, the publicly available information seems to explain very little of the interest rate variations in a narrow window around the monetary policy press conference. If anything, one macro factor appears to be statistically influential in explaining the Target factor.[20] However, monetary policy announcements about future monetary policy actions (Path factor) are not predictable using past information.

[19] The selection of variables is pretty standard for the euro area and mimics the choices in Banbura and Modugno (2014). More details on selection and transformation of variables are reported in the appendix; see table 13.

[20] Factor 5 can be associated with measures of inflation. Table 14 in the appendix reports the regression estimating f_5 on each observable variable in the factor model, $f_{5,t} = \alpha_0 + \alpha_0 X_{j,t} + e_t$. Individual regressions are ranked with respect to the R^2. Core and headline HICP inflation explain one-fourth of the variation in the $f_{5,t}$.

Table 5: Predictability of HF monetary policy surprises.

Factors in set of 40 variables	Target	Path
f_1	0.28	0.40
f_2	0.14	0.34
f_3	0.09*	0.39
f_4	0.30	0.39
f_5	0.02***	0.29
f_6	0.27	0.38
f_7	0.22	0.21
f_8	0.39	0.31
c	0.39	0.36
F test	1.498	0.393

P-values of the regression of the Path and Target factors on macroeconomic and financial lagged factors. Last row reports the F statistics.

5.2 Do delphic shocks convey private information released in staff forecasts?

Some authors argue that the central bank can process more information relative to the private sector. Agents might then close the information gap during the press conference and revise their expectations about the future. If this is the case, then variations in expected interest rates do not reflect exogenous monetary policy shocks; rather they are the result of adjustments to information sets. If we had an empirical measure of information asymmetry, we could clean the monetary policy surprises extracted from interest rate futures variations from the adjustments in private and central bank information sets.

The problem is that it is not easy to measure information sets. Miranda-Agrippino and Ricco (2017) propose removing the component of the interest rate variations that are predictable based on the central bank forecasts and forecast revisions and use the residual as a proxy for the monetary policy shock. Along the lines of their analysis of the US monetary policy, we estimate the following regressions:

$$\text{Factor} = \alpha + \theta' \text{PR}^{\text{ECB}} + \omega,$$

where $\text{Factor} = \{\text{Target}, \text{Path}, \text{Odyssean}, \text{Delphic}\}$, and PR^{ECB} is a vector that contains ECB staff projections of GDP growth and CPI inflation for the current and next calendar years or their revisions compared with the previous quarter.

The major complication with this approach is the sample size reduction, as the Eurosystem projections are conducted only quarterly and released during the press conferences of the March, June, September, and December Governing Council meetings. We thus limit our sample to monetary policy surprises that are associated with such releases of the staff macroeconomic projections. This reduces our sample size from 135 to 46 for Delphic and Odyssean factors and from 169 to 55 for Target and Path factors. Note that since we are removing two-thirds of the observations, the new series for the estimated factors might not be centered at zero and with zero autocorrelation.

We run two separate regressions with either the Eurosystem projections or forecast revisions (see table 6). The OLS estimates, statistical significance, adjusted R^2 results, and F-test results are reported. Standard errors are computed with robust covariance estimates for ordinary least squares. Monetary policy Target surprises are explained by the Eurosystem projections of inflation for the current year and next year; the sign for the next year is puzzling. Nothing else is statistically significant (except for constants), and the measures of fit are low.[21]

Our takeaway is consistent with the results on the predictability of monetary policy surprises. We find that the Target responds to the factor 5 in table 5. And factor 5 is associated with measures of inflation. Therefore, it is not surprising to see that the Target responds to the Eurosystem forecasts of inflation. In any case, we do not think that there is enough evidence to conclude that the Path, the Odyssean, or the Delphic factor responds to Eurosystem forecasts and forecast revisions.

6 Changing communication near the effective lower bound

We document that the ECB's communication changed when the euro area entered a regime in which interest rates were very close to the effective lower bound (ELB). Starting in July 2012, excess liquidity combined with a rate on the deposit facility of the Eurosystem set at zero drove the interbank market rates close to zero. These rates even entered negative territory starting in June 2014, when the deposit facility rate was set to $-.10\%$. We label this a "near-ELB" regime.

As we document in this section, during that period, the ECB managed to have a larger impact on the risk-free yield curve through its communication on future interest rates. Moreover, while the ECB's communication was mostly understood as Delphic before the near-ELB regime, it became predominantly interpreted as Odyssean afterward. Still, the Delphic component remained present. This change in communication can be related to explicit policy decisions, such as offering explicit forward guidance about future rates, which was adopted in July 2013.

6.1 ECB gave more forward guidance

The first striking difference between the two regimes is the relative contribution of each identified factor in explaining the volatility of the OIS futures at various maturities. This is illustrated

[21] Campbell et al. (2017) emphasize that the private sector's and the central bank's information sets might not be the same before the press conference and construct a measure of information discrepancy. In Appendix 5.2 we provide evidence that the asymmetry between staff and private sector forecasts does not correlate with the Path factor.

Table 6: Monetary policy surprises and Eurosystem staff projections and forecast revisions.

	Target	Path	Delphic	Odyss.
Projections				
INF current year	0.01**	-0.02	0.01	-0.00
INF next year	-0.02**	0.04	-0.01	-0.01
GDP current year	0.00	0.00	0.01	0.00
GDP next year	-0.00	-0.02	-0.01	0.00
const	0.02	0.00	0.04	0.02
Adj R2	0.06	-0.03	-0.04	-0.07
F test	1.91	0.55	0.59	0.31
Revisions of projections				
INF current year	0.01	0.03	0.01	0.00
INF next year	-0.02	-0.01	-0.02	-0.00
GDP current year	-0.00	-0.01	0.00	-0.00
GDP next year	0.00	0.01	-0.01	0.00
const	0.00	0.02*	0.01**	0.01
Adj R2	-0.04	-0.05	-0.03	-0.09
F test	0.48	0.36	0.63	0.09
Sample size	56	56	46	46

This table provides estimates for various regressions of the different factors in the intraday monetary policy surprises on the Eurosystem staff projections and revisions released with the monetary policy decisions. OLS estimates and statistical significance, 1 (5 and 10)% indicated with $***$ ($**$ and $*$) with robust SE. Top panel ECB forecasts, bottom panel ECB forecast revisions.

in Table 7. For convenience, the first two columns report the fractions of the variance of each interest rate futures contract rate that are due to the Target and the Path factors over the whole sample period of January 2002 through January 2016. The next columns report the same for the 2002-2012 and 2012-2016 subsamples. The Path factor explains 55% of the variance in the three-month Euribor 1.5 years ahead in the pre-ZLB regime. This contribution jumps to 75% in the near-ZLB period.[22]

Table 7: Contribution of the Path and Target factors to intraday changes in the yield curve

	Whole sample		**Pre-ZLB**		**Near-ZLB**	
Forward rates	Target	Path	Target	Path	Target	Path
EONIA current	85	0	84	0	93	0
EONIA next	66	17	66	17	67	19
EURIBOR 3M in 3M	42	49	44	49	28	58
EURIBOR 3M in 6M	25	67	26	67	15	73
EURIBOR 3M in 9M	16	76	16	76	9	80
EURIBOR 3M in 12M	15	78	15	78	8	81
EURIBOR 3M in 15M	8	80	8	79	5	88
EURIBOR 3M in 18M	11	57	12	55	7	75
EURIBOR 3M in 21M	2	64	2	62	0	83

This table reports the variance of interest rate forward rates derived from OIS contracts observed during ECB communication on the days of Governing Council meetings that are explained by the Target and Path factors. "EONIA current" corresponds to the unexpected change in the EONIA rate that will prevail until the next Governing Council meeting. "EONIA next" corresponds to the unexpected change in the EONIA rate that will prevail between the following two Governing Council meetings. The sample includes the unscheduled Governing Council meetings that took place from January 2002 through January 2016. The "pre-ZLB" sample runs from January 2002 through January 2012. The "near-ZLB" sample runs from February 2012 through January 2016. The variance is computed as the R^2 of the regression of each futures contract on the Target or Path factor.

6.2 ECB communication became predominantly interpreted as Odyssean

We run the regression used in previous sections, namely

$$\Delta x = \alpha + \beta \text{Target} + \gamma \text{Path} + \epsilon,$$

over the pre-ELB and near-ELB sub-samples.

Table 8 provides the results. Over the pre-ELB regime, the Path factor had a positive impact on both market-based inflation expectations derived from ILS contracts and stock prices (although non-significant for stock prices). In comparison, the Path factor had a negative impact on both market-based inflation expectations derived from ILS contracts and stock prices over the

[22]Carvalho, Hsu and Nechio (2016) obtain comparable results for US yields including for longer maturities.

Table 8: Changes in markets interpretation of ECB communication

	ILS 2Y	ILS 5Y	ILS 10Y	ILS 15Y	EuroStoxx50
Whole sample					
Target	-0.41*	-0.08	0.12	0.05	-5.06
Path	0.34***	0.24***	0.17***	0.13**	-0.19
Adj R^2	0.07	0.09	0.06	0.04	0.02
Pre-ELB					
Target	-0.37	-0.02	0.18	0.11	-3.42
Path	0.38***	0.28***	0.20***	0.17***	0.94
Adj R^2	0.09	0.14	0.12	0.09	0.02
Near-ELB					
Target	-0.64	-0.73**	-0.83***	-0.58**	-29.95***
Path	-0.64***	-0.69***	-0.63***	-0.81***	-11.96***
Adj R^2	0.24	0.27	0.51	0.55	0.36

Response of the two-day change in ILS spot rates of various maturities and in the intraday change in EuroStoxx50 to the Target and Path factor extracted from OIS reaction to ECB communication on the days of Governing Council meetings. Estimates are provided for the entire July 2004-January 2012 sample, the pre-ELB July 2004-June 2012 sample and the near-ELB July 2012-January 2016 sample. The Target (Path) factor is normalized so that it generates a 1% increase in the one-month (year) OIS futures. One, two, and three asterisks indicate statistical significance at 10%, 5%, and 1%, respectively.

near-ELB regime. This is consistent with ECB communication being predominantly interpreted as Delphic before the euro area reached very low levels of interest rates and then Odyssean when interest rates were at or below zero and forward guidance policies were more actively used to promise future accommodation. These time variations in the response of inflation expectations to the Path factor are also observed with rolling estimates or local kernel estimators instead of considering arbitrary subsamples (see Appendix E).

We provide further evidence that the relative share of Delphic to Odyssean shocks evolves with ECB communication. More precisely, we count the number of times that the negation of the term "pre-committ*" was used during the monetary policy press conference. ECB communication put a strong emphasis on the absence of pre-commitment until it started to give forward guidance on interest rates. We therefore count the number of times ECB presidents used the following terms during press conferences: "never pre-commit," "no pre-commit*," "not pre-commit*." We then average that number for each year in the sample and compare it with the average of the ratio between the squared Delphic and Odyssean shocks for the same year. Figure 1 below illustrates that there is a strong positive correlation between the two series (the correlation is 0.85): Delphic shocks became relatively less important when the ECB used much less of this type of wording in its communication.

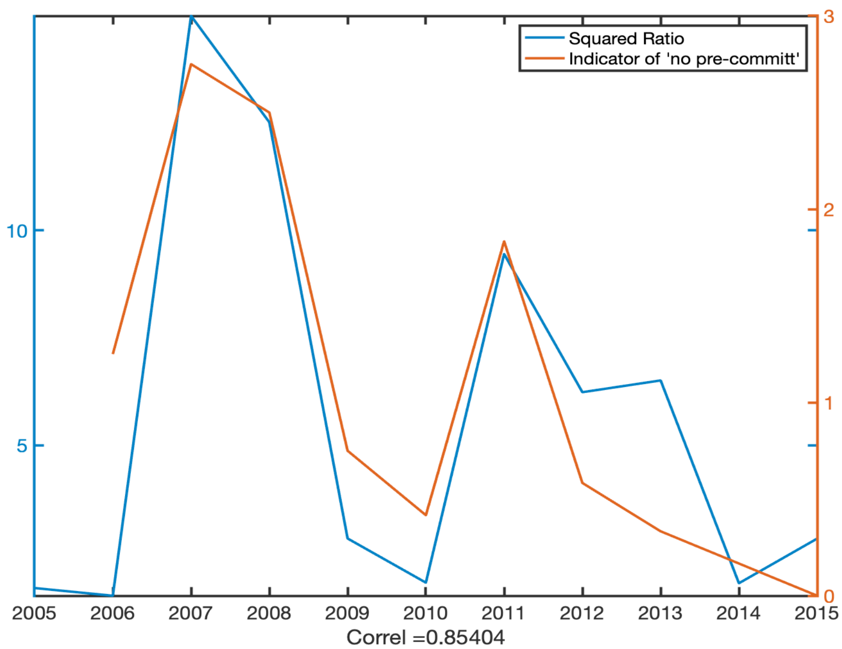

Figure 1: Number of times that the negation of the term “pre-commit*” is used during the monetary policy press conference and ratio of squared Delphic and Odyssean shocks, yearly average.

7 Conclusion

We emphasize the importance of Delphic and Odyssean shocks to understand how central bank communication about future interest rates affects financial conditions. We develop an approach to separately identify these shocks from intraday monetary policy surprises and measure their dynamic impact on financial conditions as well as on macroeconomic expectations and realizations in the euro area. We show that there is a substantial information effect in financial markets' reaction to central bank communication on the days of Governing Council meetings. However, that information is not redundant with new central bank assessments revealed in the release of macro staff forecasts. Markets also partly interpret news on future interest rates as a signal that the central bank will deviate from its normal-time reaction function in the future. These results emphasize that monetary authorities should not look at just the reaction of the yield curve to assess the degree of accommodation/tightening they provide. Our methodology offers a way to extract the pure expected monetary policy shocks in the reaction of the yield curve. Another implication of our results is that monetary authorities affect the relative weight of Delphic versus Odyssean shocks that markets extract from central bank communication. The evidence that Odyssean shocks became prevalent during the time when the ECB implemented explicit forward guidance policies and dropped the term "never pre-commit" from its communication also underlines that central banks can have some control over how markets understand those communications. Understanding better how central banks can influence the way their communication affects financial markets—either via language (Hansen and McMahon 2016) or by stating conditions for future actions (Ehrmann, Gaballo, Hoffmann and Strasser 2018)—is left for further research.

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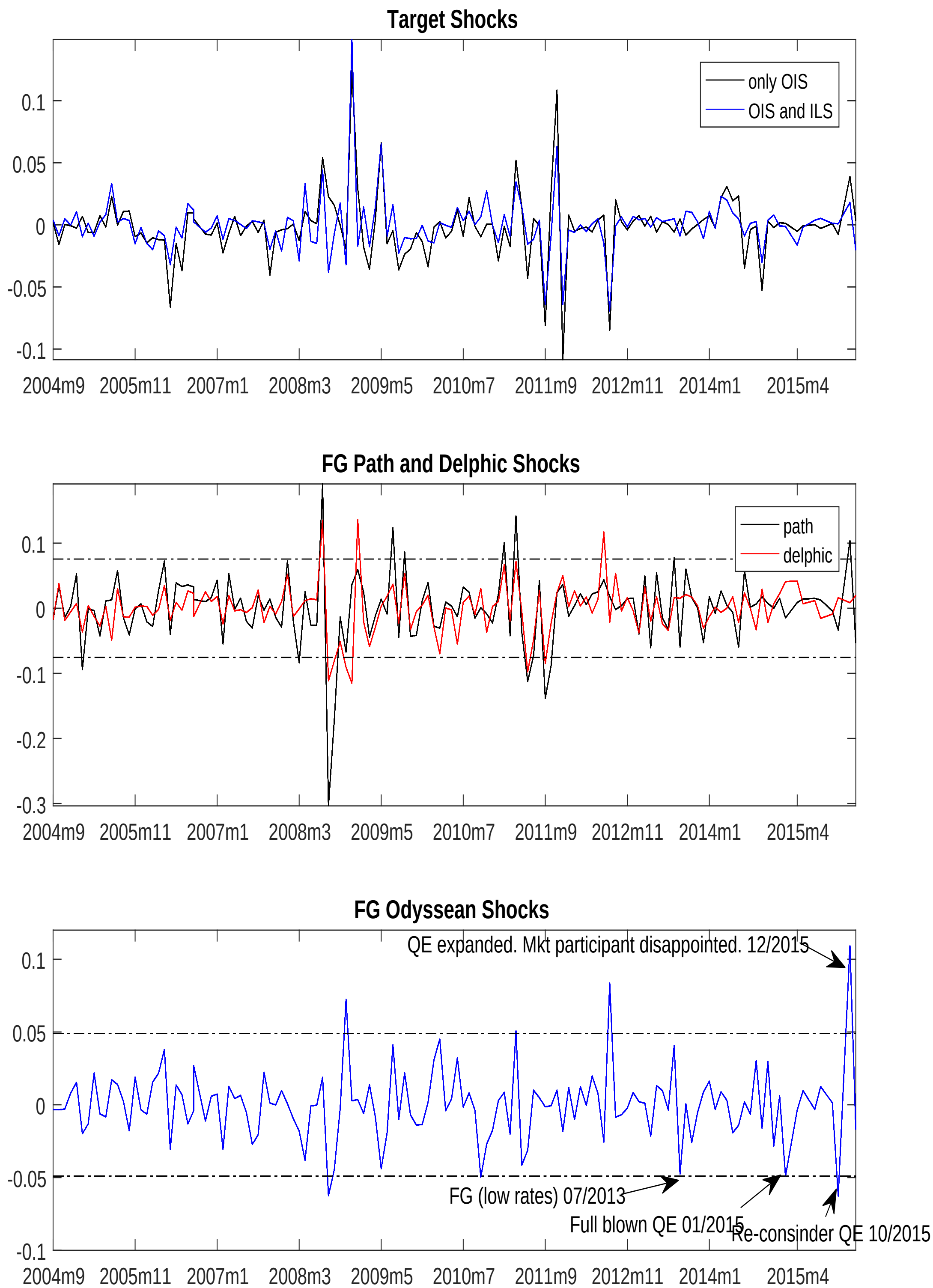


Figure 2: Target, Path, and Delphic and Odyssean forward guidance (FG) shocks in percentage units.

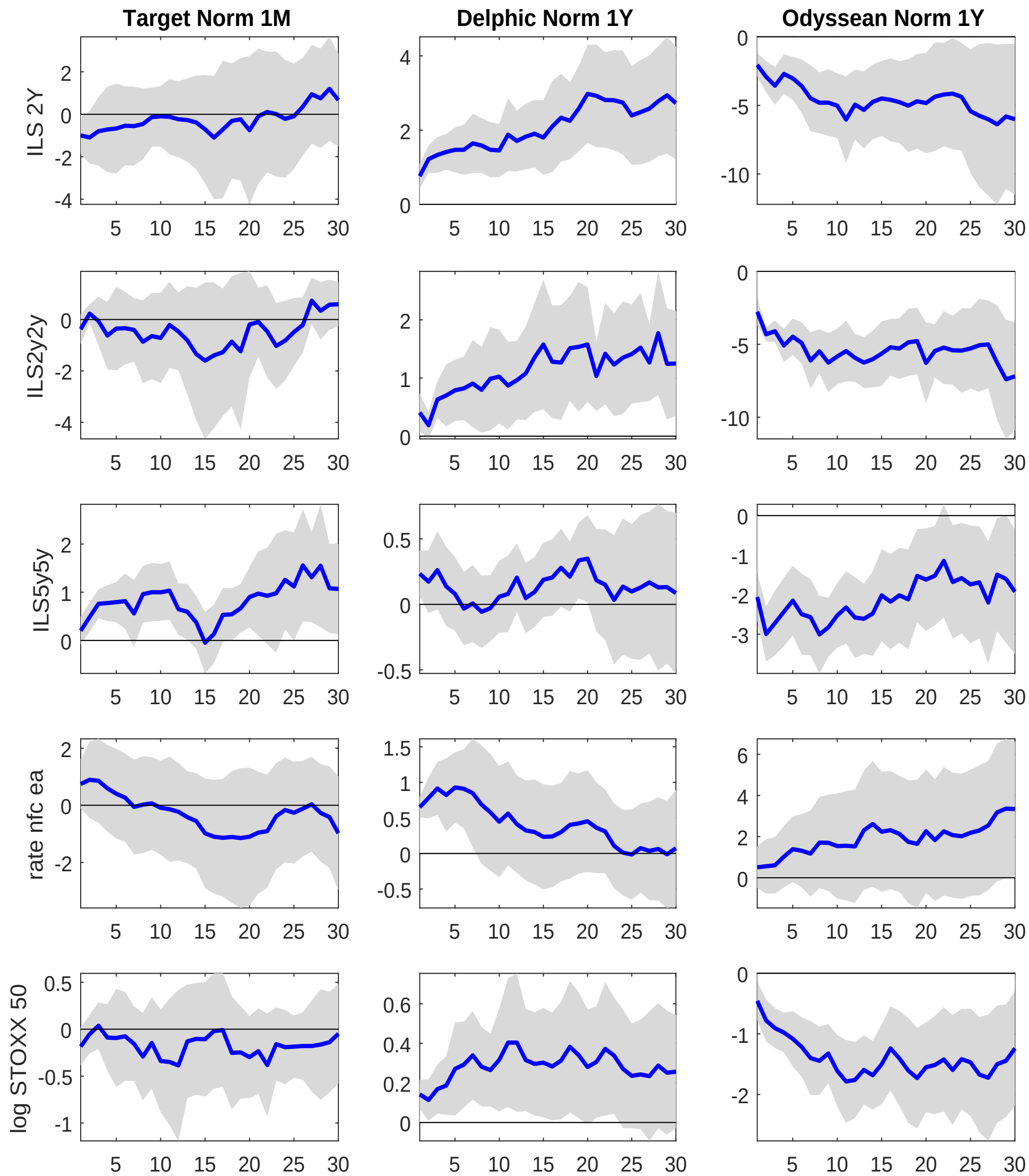
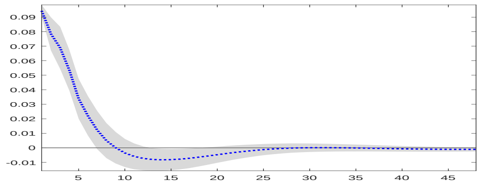
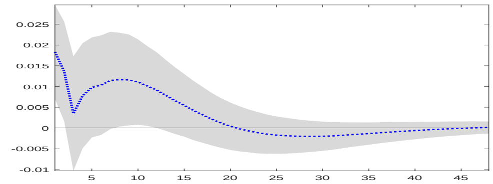


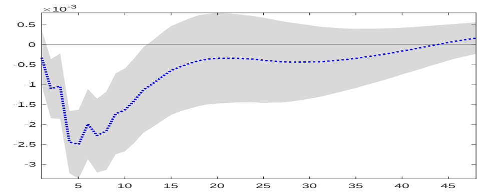
Figure 3: Persistence of monetary policy surprises. Impact of monetary policy surprises on two years, the two years in two years, and the five years in five years ILS; the non-financial corporation borrowing rates; and the (log of) stock market prices x days after the monetary policy announcement.



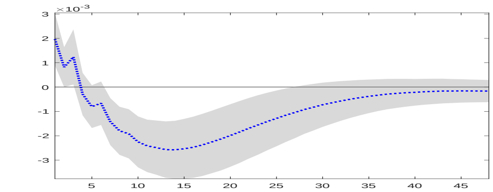
(a) Path to rates slope



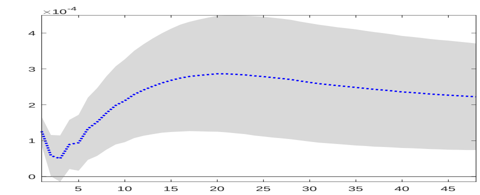
(b) Odyssean to rates slope



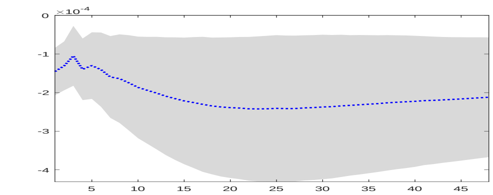
(c) Path to IP



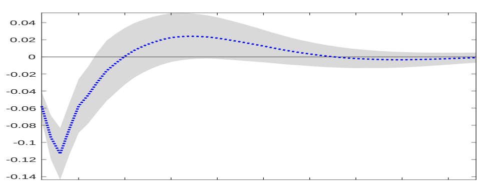
(d) Odyssean to IP



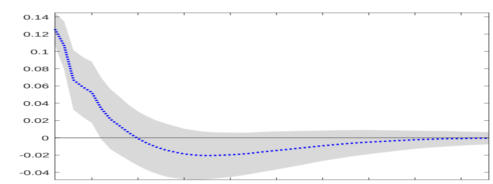
(e) Path to CORE



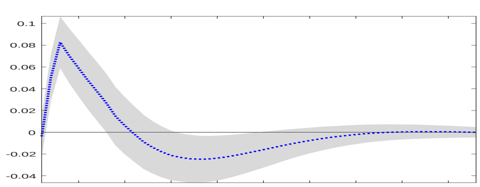
(f) Odyssean to CORE



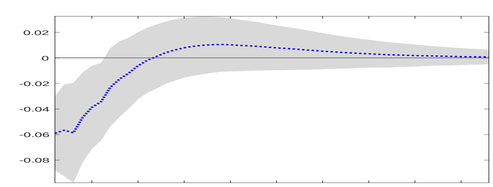
(g) Path to Credit Spread



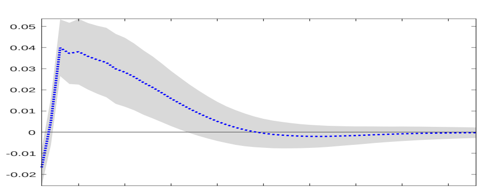
(h) Odyssean to Credit Spread



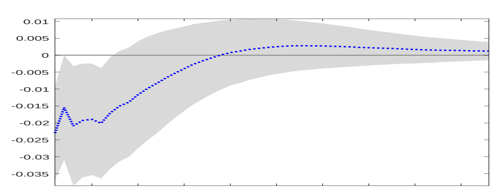
(i) Path to expected output growth



(j) Odyssean to expected output growth



(k) Path to expected inflation



(l) Odyssean to expected inflation

Figure 4: Impulse responses of expectations, prices, and output to the Odyssean monetary policy announcement and to a generic monetary policy announcement. The gray bands are 68% confidence sets.

A Intraday monetary policy surprises and monthly variations in the yield curve

While intraday monetary policy surprises explain a large portion of the volatility in intraday OIS futures, one may wonder how much these surprises contribute to the variation in interest rates at lower frequencies—say, monthly variations. To find out, we run the following regression of the monthly variations in (spot) EONIA swaps at various maturities on Target and Path factors (and a constant, though the results are not shown):

$$\Delta^m OIS = \alpha + \beta \text{Target} + \gamma \text{Path} + \epsilon.$$

Table 9 presents the results. The Path factor loads significantly in the monthly variation in (spot) EONIA swaps at various maturities. The share of the variance of monthly variations in EONIA swaps explained by the two factors is between 10% and 20% for maturities of one year to three years for the full sample. This share increases as much as about 40% in the second part of the sample. Similar patterns can be found for the average euro-area government bond rates and Euribor interest rates.

Table 9: Impact of intraday changes in the Path and Target factors on monthly variations in the yield curve

OIS rates	Target	Path	Adj R^2
One month	0.44	0.31	0.01
Three months	0.34	0.48**	0.02
Six months	0.36	0.75***	0.06
One year	0.42	1.17***	0.11
Two years	0.62	1.48***	0.15
Three years	-0.18	1.69***	0.21
Five years	-0.44	1.44***	0.16
Ten years	-1.09*	0.92***	0.07

Regression estimating the monthly variation of EONIA swaps at the different maturities explained by the (intraday) Target and Path factors. One (two, three) star indicates the statistical significance at 1% (5%, 10%) computed with robust standard errors.

B 1-day vs 2-day reaction of ILS to HF monetary policy surprises

	ILS 1Y	ILS 2Y	ILS 3Y	ILS 4Y	ILS 5Y	ILS 6Y	ILS 7Y	ILS 8Y	ILS 9Y	ILS 10Y	ILS 12Y	ILS 15Y
Target	0.23	-0.41	-0.53	-0.24	-0.08	0.04	-0.14	-0.06	-0.01	0.12	0.07	0.05
Path	0.43***	0.34***	0.33***	0.19**	0.24***	0.26***	0.18***	0.18***	0.16**	0.17***	0.23***	0.13**
Adj R^2	0.07	0.07	0.12	0.05	0.09	0.11	0.06	0.06	0.05	0.06	0.11	0.04
Target	0.31	-0.37	-0.49	-0.19	-0.02	0.10	-0.08	0.00	0.05	0.18	0.13	0.11
Path	0.48***	0.38***	0.37***	0.23***	0.28***	0.30***	0.22***	0.21***	0.20***	0.20***	0.27***	0.17***
Adj R^2	0.09	0.09	0.14	0.07	0.14	0.18	0.09	0.10	0.09	0.12	0.18	0.09
Target	-0.73	-0.64	-0.64*	-0.62**	-0.73**	-0.78***	-0.86***	-0.84***	-0.72***	-0.83***	-0.66***	-0.58**
Path	-0.83***	-0.64***	-0.76***	-0.83***	-0.69***	-0.73***	-0.68***	-0.63***	-0.65***	-0.63***	-0.70***	-0.81***
Adj R^2	0.29	0.24	0.28	0.29	0.27	0.36	0.39	0.43	0.46	0.51	0.51	0.55

Table 10: Regression estimating responses of the revision (two-day) of market-based inflation expectations (spot rates) to Target and Path factors, full sample and subsamples.

	ILS 1Y	ILS 2Y	ILS 3Y	ILS 4Y	ILS 5Y	ILS 6Y	ILS 7Y	ILS 8Y	ILS 9Y	ILS 10Y	ILS 12Y	ILS 15Y
Target	0.39	-0.38	-0.56*	-0.39	-0.22	-0.08	-0.15	-0.11	-0.13	-0.04	-0.17	-0.11
Path	-0.43	0.15	0.18**	0.11	0.11	0.13**	0.09*	0.12**	0.10	0.11*	0.10*	0.06
Adj R^2	0.07	0.04	0.11	0.06	0.05	0.03	0.02	0.03	0.02	0.03	0.03	0.00
Target	0.43	-0.37	-0.56*	-0.38	-0.20	-0.05	-0.13	-0.09	-0.11	-0.00	-0.14	-0.09
Path	-0.43	0.16	0.20***	0.13	0.13	0.16**	0.11*	0.14**	0.12*	0.13*	0.12**	0.08
Adj R^2	0.07	0.04	0.12	0.06	0.06	0.05	0.04	0.05	0.03	0.05	0.03	0.01
Target	-0.61	-0.32*	-0.15	-0.25	-0.34	-0.36*	-0.35*	-0.30	-0.34*	-0.54**	-0.45**	-0.21
Path	-0.31	-0.28*	-0.42**	-0.39**	-0.37	-0.44*	-0.43**	-0.41*	-0.36*	-0.30	-0.36*	-0.43*
Adj R^2	0.07	0.01	0.09	0.09	0.07	0.16	0.20	0.14	0.12	0.14	0.19	0.16

Table 11: Regression estimating responses of the revision (one-day) of market-based inflation expectations (spot rates) to Target and Path factors, full sample and subsamples.

C Identification with zero and sign restrictions

Let X be a $T \times k$ matrix containing the OIS and ILS variations. We assume that the data are generated by the following factor structure:

$$X = F\Lambda' + e,$$

where F is a $T \times 3$ matrix containing the unobserved factors, Λ is a $k \times 3$ matrix of factor loadings, and e is a matrix of i.i.d. normal shocks of appropriate dimensions. We extract factors and loadings using principal component analysis (PCA). We rotate the factor using an orthonormal matrix H (that is $HH' = H'H = I$) so that

$$Z = FH.$$

Substituting the latter equation into the factor model we obtain

$$X = Z(\Lambda H)' + e.$$

Without loss of generality, assume that the ordering of the variables in the X matrix is the following: current-month OIS, one-year ahead OIS, five-year ILS, and then all the remaining variables. Our identification is achieved assuming that ΛH has the following structure:

$$\Lambda H = \begin{pmatrix} * & 0 & 0 \\ * & + & + \\ * & + & - \\ \vdots & \vdots & \vdots \\ * & * & * \end{pmatrix},$$

where an asterisk indicates a number. Imposing the zero and sign restrictions on ΛH is equivalent to imposing the zero and sign restrictions on $\Lambda_{3:3}H$, which is the top 3×3 submatrix of ΛH. In order to obtain the desired rotation, we proceed in two steps. We first obtain the Cholseky decomposition of $\Lambda_{3:3}\widetilde{H}$, that is,

$$\Lambda_{3:3}\widetilde{H} = \begin{pmatrix} * & 0 & 0 \\ * & * & 0 \\ * & * & * \end{pmatrix}$$

and recover $\widetilde{H}$ by

$$\widetilde{H} = \Lambda_{3:3}^{-1} chol(\Lambda_{3:3}\Lambda_{3:3}'),$$

given that $\Lambda_{3:3}\Lambda_{3:3}' = \Lambda_{3:3}\widetilde{H}\widetilde{H}'\Lambda_{3:3}'$. We then rotate the $\widetilde{H}$ matrix using the Givens rotation such that the structure of ΛH is preserved. More formally,

$$\widetilde{H}Q(\theta) = H,$$

where

$$Q = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{pmatrix}.$$

This rotation will leave unchanged the first row and column of $\Lambda_{3:3}\widetilde{H}$, thus preserving the zero restrictions. We consider a grid of values for θ ranging from 0 to π with a 0.05 step. For each of these values we keep the rotation if the signs in $\Lambda\widetilde{H}Q(\theta)$ are satisfied. We then consider the average of the accepted rotations, $H_m = \Lambda_{3:3}^{-1} 1/J \sum_j^J \Lambda_{3:3}\widetilde{H}Q(\theta^{(j)})$.

Table 12: Central bank communication and macroeconomic expectations

	Target	Path	Adj R^2	Target	Delphic	Odyss.	Adj R^2
Δ GDP growth forecasts							
current calendar year	-0.41***	0.18***	-0.01	-0.41**	0.73***	-0.17	0.01
next calendar year	-1.73***	0.34***	0.04	-1.65***	0.29	-0.52***	0.02
Δ CPI inflation forecasts							
current calendar year	0.35***	-0.16***	-0.01	0.31***	0.13**	-0.48***	-0.01
next calendar year	-0.72***	-0.11**	-0.00	-0.75***	0.17*	-0.51***	0.00

Regression estimating the monthly variation in the Consensus Forecasts individual forecasts on the factors. Fixed effect estimates and statistical significance, 1(5 and 10) % indicated with $***$ ($**$ and $*$) with robust SE.

D Impact on macroeconomic expectations: further evidence using a panel of professional forecasters

Table 12 reports the regressions estimating the monthly variations of GDP and inflation forecasts of individual institutions surveyed by Consensus Economics on the estimated high-frequency surprises, controlling for individual fixed effects. Namely it reports estimates of

$$\Delta E_i = \alpha_i + \beta \text{Target} + \gamma \text{Path} + \varepsilon_i$$

and

$$\Delta E_i = \alpha_i + \beta \text{Target} + \delta \text{Delphic} + \kappa \text{Odyssean} + \nu_i,$$

where ΔE_i is the change in expectations of either euro-area GDP growth or HICP inflation at the end of the current or next year for individual i in the panel of Consensus Economics. We consider the surveys that are conducted before and after a Governing Council meeting.[23]

The effects of the Delphic and Odyssean shocks on forecast revisions are of the same order as what is obtained when looking at a regression with the median forecasts instead of the individual ones. This is consistent with the nature of these two shocks. A key difference with the regression using the median revision is that the effects are also statistically significant thanks to the larger number of observations we get with individual data.

E Time variation in the response of ILS to the Path factor

To gauge more evidence on the possible time variation in the impact of the Target and Path factors on inflation expectations, we conduct two complementary exercises where we do not arbitrarily select the subsamples. The first exercise is based on a rolling window regression

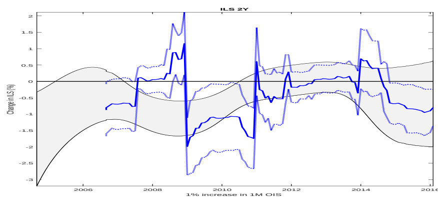
[23] Fourteen dates for which the monthly revision in the Consensus Forecasts preceded a Governing Council meeting were dropped from our sample.

and the second on a local kernel regression, which has the advantage of smoothing the abrupt time variation of the rolling window estimates. The local kernel regression is a form of rolling regression with a different data-weighting scheme. More formally, for each $\tau = 1, .., T$, we minimize the following residual sum squares:

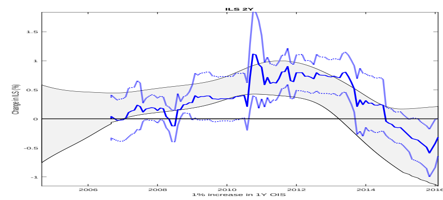
$$\sum_{t=1}^{T} K_f(\frac{t-\tau}{h})(ILS_{j,t} - \eta_t' B_\tau),$$

where $K_f(.)$ is the Gaussian kernel function and h is the bandwidths, and where η_t collects the Path and Target factors (and a constant). Data points far from τ will have small weights, yet are nonzero as in the rolling window.[24] Figure 5 reports the rolling sample estimates of the impact of the Target factor (left panels) and Path factor (right panels) on market-based inflation expectations. In particular, the blue solid and dashed lines plot the OLS estimates of regressing the financial instrument on the Target factor and the Path factor along with the 90% confidence bands in a 24-month window. The gray areas report the same information using a local linear kernel estimator. The impact of the Target factor tends to be relatively stable over the rolling windows, fluctuating between negative or nonsignificant values. The impact of the Path factor instead displays slowly moving time variation, switching from positive to negative values.While in the central part of our sample the ECB communication had a Delphic component, the last part of the sample is dominated by the Odyssean forward guidance.

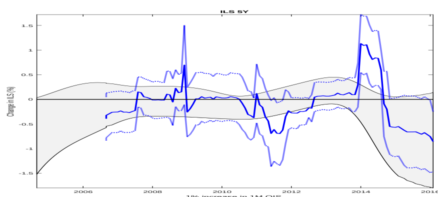
[24]We use the optimal bandwidth as suggested by Bowman and Azzalini (1997). Since the weighting scheme is known, standard weighted least square methods can be used to estimate the parameters, B_τ.



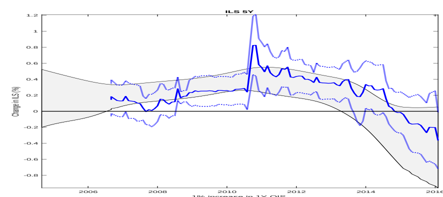
(a) Target on 2Y ILS



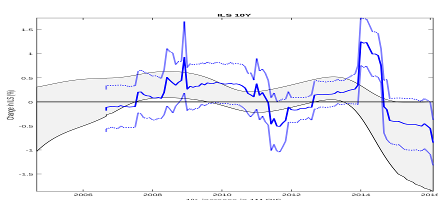
(b) Path on 2Y ILS



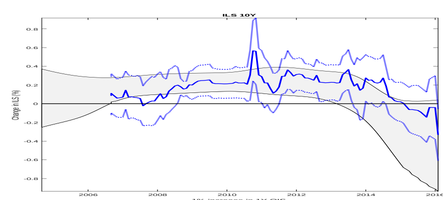
(c) Target on 5Y ILS



(d) Path on 5Y ILS



(e) Target on 10Y ILS



(f) Path on 10Y ILS

Figure 5: Impact of the Path factor on the ILS over rolling windows or with a local kernel estimator

F Information set considered in predictability test

Variables	Transf
ECB Nominal effective exch. Rate	1
UK pound sterling/Euro, 2:15 pm (C.E.T.)	1
Japanese yen/Euro, 2:15 pm (C.E.T.)	1
US dollar/Euro, 2:15 pm (C.E.T.)	1
Total Turnover Index, Manifacturing	2
ECB Commodity Price index Euro denominated	2
Standardised unemployment, Rate,	1
Car registration, New passenger car;	2
Total Turnover Index, Retail trade including fuel	2
New orders, total, MANUFACTURING, FOR NEW ORDERS	2
Industrial Production Index, Total Industry (excluding construction)	2
Industrial Production Index, Total Industry excluding construction and MIG Energy	2
Brent crude oil 1-month Forward	2
Equity index - Dow Jones Eurostoxx 50 index - Index	2
Rate - Eonia rate - Euro	1
Rate - 1-year Euribor (Euro interbank offered rate) - Euro	1
Rate - 3-month Euribor (Euro interbank offered rate) - Euro	1
Equity index - Standard and Poor 500 - Index	2
Exchange rate, ECB real effective exchange rate CPI deflated	2
Loans, total maturity, all currencies combined	2
Monetary aggregate M3, all currencies combined	2
HICP - Overall index - Index	2
HICP - All-items excluding energy and unprocessed food - Index	2
Standardised unemployment, Total (all ages), Male - Percentage	1
Consumer Survey - Consumer Confidence Indicator - Percentage	2
Economic Sentiment Indicator - Percentage	2
Industrial Production Index, Consumer goods industry - Index	2
Industrial Production Index, MIG Durable Consumer Goods Industry - Index	2
Industrial Production Index, MIG Energy - Index	2
Industrial Production Index, Total Industry - Index	2
Industrial Production Index, MIG Intermediate Goods Industry - Index	2
United States - CONSUMER PRICES, ALL ITEMS	2
United States - Employment	1
United States - 10-Year Treasury Constant Maturity Rate	1
United States - Manufacturing ISM Report on Business	2
United States - Real Retail and Food Services Sales	2
United States - Three months treasury bill	1
United States - Unemployment rate	1

Table 13: List of variables included in X_t to test the predictability of monetary policy surprises. Transformations: 1 = first difference, 2 = growth rate

G Further evidence on predictability of euro-area monetary policy surprises

G.1 autocorrelation

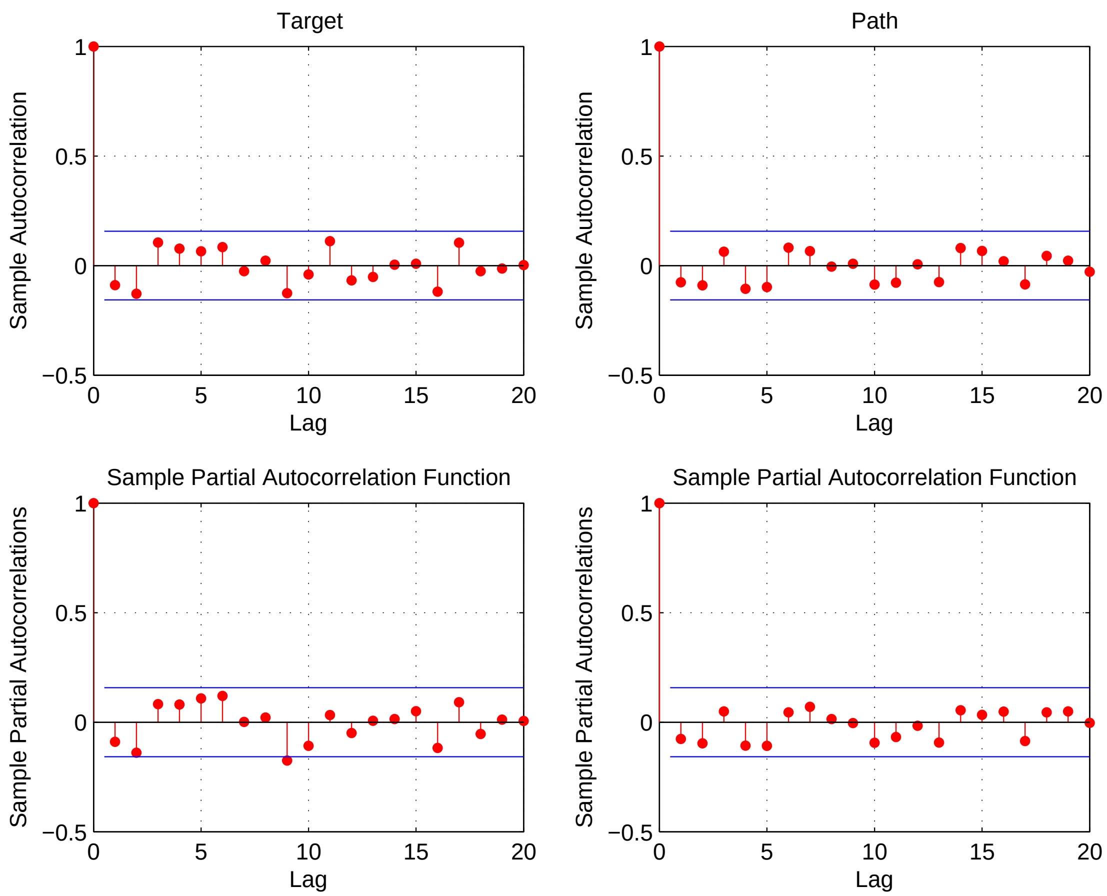


Figure 6: Autocorrelation and partial autocorrelation function for the Path and the Target factors. Blue bands indicate statistical significance.

G.2 WHAT INFORMATION IS CONVEYED BY THE TARGET FACTOR?

	R^2	OLS Coeff
CORE	0.29	1.82
HICP	0.27	1.99
TURNOVERRET	0.07	0.04
ESI	0.06	-0.22
DJ50	0.05	-0.07
SP500	0.05	-0.09
IPIEN	0.05	-0.05
CCI	0.04	-0.21***
NAPM	0.04	-0.08
UNRATEPER	0.02	0.17*
EONIA	0.01	1.24*
IPINOCOSTR	0.01	-0.18
M3	0.01	-0.38***
IPIINTER	0.01	-0.01
IPINOCOSTREN	0.01	-0.14
TURNOVERMAN	0.01	0.02
UNRATE	0.01	1.84***
UKEUROSPOT	0.01	8.27
GS10	0.01	-0.68
PCOMM	0.01	-0.04*
1YEURIBOR	0.01	-0.76***
UNRATEUS	0.01	0.71***
BRENT	0.01	0.01
CE16OV	0.01	-0.47***
TB3MS	0.00	-0.55***
3MEURIBOR	0.00	-0.51
CPIUS	0.00	0.20
NEWORDER	0.00	-0.03***
CARREG	0.00	-0.00
DOLEUROSPOT	0.00	-1.53*
REXRATE	0.00	-0.03
YENEUROSPOT	0.00	0.01
RRSFS	0.00	0.04
IPICONS	0.00	-0.00**
IPITOT	0.00	0.00
LOANS	0.00	-0.03
IPIDUR	0.00	0.00

Table 14: Regression estimating f_5 on each observable variable in the factor model; that is, $f_{5,t} = \alpha_0 + \alpha_0 X_{j,t} + e_t$. OLS estimates and statistical significance, 1(5 and 10) % indicated with $***$ ($**$ and $*$) with robust SE.

G.3 INFORMATION ASYMMETRY

Campbell et al. (2017) use the difference between the Blue Chip forecasts and the Greenbook forecasts as an observable proxy for information asymmetry. They interpret this difference as the amount of Delphic forward guidance contained in the monetary policy announcements. We follow Campbell et al. (2017) and construct an observable proxy for the euro area. We consider inflation and real GDP forecasts obtained from the Survey of Professional Forecasters as a measure of private-sector forecasts and from the Eurosystem staff projections for the euro area as a measure of central bank forecasts.[25] Tables 15 and 16 report the available figures at quarterly frequency.

We define the difference between the Eurosystem and SPF forecasts for the current year and the next year as a measure of information discrepancy. We have in total four time series. We then regress the Target and Path factors on these gaps, contemporaneously and lagged

$$\begin{aligned}\eta_t^j =& \beta_0 + \beta_1(HICP_{t-k}^{SPF} - HICP_{t-k}^{ECB}) + \beta_2(HICP(+1)_{t-k}^{SPF} - HICP(+1)_{t-k}^{ECB}) \\ &+ \beta_3(GDP_{t-k}^{SPF} - GDP_{t-k}^{ECB}) + \beta_4(GDP(+1)_{t-k}^{SPF} - GDP(+1)_{t-k}^{ECB}) + v_t\end{aligned}$$

for $j = t, p$ and $k = 0, 1$ and where (+1) () indicates the next (current) year forecasts. We report the results in Table 17.

The regression results are poor. The R^2 results are low, and either singularly or jointly we fail to reject the singularity of coefficients. And even for $k = 0$, the Path factor is not explained by the discrepancy between central bank and private sector forecasts.

[25] Tables can be downloaded from the ECB webpage. See https://www.ecb.europa.eu/mopo/strategy/ecana/html/table.en.html and http://www.ecb.europa.eu/stats/prices/indic/forecast/html/table_hist_hicp.en.html.

Table 15: Eurosystem staff projections for the euro area, inflation and real GDP.

	HICP		Real GDP	
	Current Y	Next Y	Current Y	Next Y
March 2002	1.8	1.6	1.0	2.5
June 2002	2.3	1.9	1.2	2.6
September 2002	2.2	1.8	0.8	2.1
December 2002	2.2	1.8	0.8	1.6
March 2003	2.0	1.5	1.0	2.0
June 2003	2.0	1.3	0.7	1.6
September 2003	2.1	1.5	0.4	1.5
December 2003	2.1	1.8	0.4	1.6
March 2004	1.7	1.5	1.5	2.4
June 2004	2.1	1.7	1.7	2.2
September 2004	0.2	1.3	1.6	1.7
December 2004	2.2	2.0	1.8	1.9
March 2005	1.9	1.6	1.6	2.1
June 2005	2.0	1.5	1.4	2.0
September 2005	2.2	1.9	1.3	1.8
December 2005	2.2	2.1	1.4	1.9
March 2006	2.2	2.2	2.1	2.0
June 2006	2.3	2.2	2.1	1.8
September 2006	2.4	2.4	2.5	2.1
December 2006	2.2	2.0	2.7	2.2
March 2007	1.8	2.0	2.5	2.4
June 2007	2.0	2.0	2.6	2.3
September 2007	2.0	2.0	2.5	2.3
December 2007	2.1	2.5	2.6	2.0
March 2008	2.9	2.1	1.7	1.8
June 2008	3.4	2.4	1.8	1.5
September 2008	3.5	2.6	1.4	1.2
December 2008	3.3	1.4	1.0	-0.5
March 2009	0.4	1.0	-2.7	0.0
June 2009	0.3	1.0	-4.6	-0.3
September 2009	0.4	1.2	-4.1	0.2
December 2009	0.3	1.3	-4.0	0.8
March 2010	1.2	1.5	0.8	1.5
June 2010	1.5	1.6	1.0	1.2
September 2010	1.6	1.7	1.6	1.4
December 2010	1.6	1.8	1.7	1.4
March 2011	2.3	1.7	1.7	1.8
June 2011	2.6	1.7	1.9	1.7
September 2011	2.6	1.7	1.6	1.3
December 2011	2.7	2.0	1.6	0.3
March 2012	2.4	1.6	-0.1	1.1
June 2012	2.4	1.6	-0.1	1.0
September 2012	2.5	1.9	-0.4	0.5
December 2012	2.5	1.6	-0.5	-0.3
March 2013	1.6	1.3	-0.5	1.0
June 2013	1.4	1.3	-0.6	1.1
September 2013	1.5	1.3	-0.4	1.0
December 2013	1.4	1.1	-0.4	1.1
March 2014	1.0	1.3	1.2	1.5
June 2014	0.7	1.1	1.0	1.7
September 2014	0.6	1.1	0.9	1.6
December 2014	0.5	0.7	0.8	1.0
March 2015	0.0	1.5	1.5	1.9
June 2015	0.3	1.5	1.5	1.9
September 2015	0.1	1.1	1.4	1.7
December 2015	0.1	1.0	1.5	1.7
March 2016	0.1	1.3	1.4	1.7
June 2016	0.2	1.3	1.6	1.7

Table 16: SPF projections for the euro area, inflation and real GDP.

	HICP		Real GDP	
	Current Y	Next Y	Current Y	Next Y
2002 Q1	1.7	1.8	1.3	2.6
2002 Q2	2.1	1.9	1.4	2.7
2002 Q3	2.1	1.8	1.2	2.5
2002 Q4	2.2	1.8	0.8	1.8
2003 Q1	1.8	1.8	1.4	2.3
2003 Q2	2.0	1.7	1.0	2.1
2003 Q3	1.9	1.5	0.7	1.7
2003 Q4	2.0	1.6	0.5	1.7
2004 Q1	1.8	1.7	1.8	2.2
2004 Q2	1.8	1.8	1.6	2.1
2004 Q3	2.1	1.9	1.8	2.1
2004 Q4	2.1	1.9	1.9	2.0
2005 Q1	1.9	1.8	1.8	2.1
2005 Q2	1.9	1.8	1.6	2.0
2005 Q3	2.1	1.8	1.4	1.8
2005 Q4	2.2	2.0	1.3	1.7
2006 Q1	2.0	2.0	2.0	1.9
2006 Q2	2.1	2.1	2.1	1.9
2006 Q3	2.3	2.1	2.2	1.8
2006 Q4	2.2	2.1	2.6	2.0
2007 Q1	2.0	1.9	2.1	2.1
2007 Q2	1.9	1.9	2.5	2.3
2007 Q3	2.0	2.0	2.7	2.3
2007 Q4	2.0	2.0	2.6	2.1
2008 Q1	2.5	2.0	1.8	2.0
2008 Q2	3.0	2.2	1.6	1.6
2008 Q3	3.6	2.6	1.6	1.3
2008 Q4	3.4	2.2	1.2	0.3
2009 Q1	0.9	1.6	-1.0	0.6
2009 Q2	0.5	1.3	-3.0	0.2
2009 Q3	0.4	1.1	-4.0	0.3
2009 Q4	0.3	1.2	-3.0	1.0
2010 Q1	1.3	1.5	1.2	1.6
2010 Q2	1.4	1.5	1.1	1.5
2010 Q3	1.4	1.5	1.1	1.4
2010 Q4	1.5	1.5	1.6	1.5
2011 Q1	1.9	1.8	1.6	1.7
2011 Q2	2.5	1.9	1.7	1.7
2011 Q3	2.6	2.0	1.9	1.6
2011 Q4	2.6	1.8	1.6	0.8
2012 Q1	1.9	1.7	-0.0	1.1
2012 Q2	2.3	1.8	-0.0	1.0
2012 Q3	2.3	1.7	-0.0	0.6
2012 Q4	2.5	1.9	-0.0	0.3
2013 Q1	1.8	1.8	-0.0	1.1
2013 Q2	1.7	1.6	-0.0	1.0
2013 Q3	1.5	1.5	-0.0	0.9
2013 Q4	1.4	1.5	-0.0	1.0
2014 Q1	1.1	1.4	1.0	1.5
2014 Q2	0.9	1.3	1.1	1.5
2014 Q3	0.7	1.2	1.0	1.5
2014 Q4	0.5	1.0	0.8	1.2
2015 Q1	0.3	1.1	1.1	1.5
2015 Q2	0.1	1.2	1.4	1.7
2015 Q3	0.2	1.3	1.4	1.8
2015 Q4	0.1	1.0	1.5	1.7
2016 Q1	0.7	1.4	1.7	1.8
2016 Q2	0.3	1.3	1.5	1.6

Table 17: Monetary policy surprises and information gaps

	Const	HICP	HICP(+1)	RGDP	RGDP(+1)	F test	R2
Lagged ($k = 1$)							
Target	0.38	0.40	0.38	0.36	0.27	0.70	0.05
Path	0.20	0.39	0.31	0.39	0.40	0.22	0.02
Contemporaneous ($k = 0$)							
Target	0.37	0.03	0.04	0.19	0.32	2.29	0.15
Path	0.06	0.37	0.35	0.28	0.19	0.57	0.04

Information gaps are derived by taking the difference between the SFP and the ECB current or next year forecasts of real GDP and HICP.