Were the ECB announcements Odyessean or Delphic?*

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PRELIMINARY AND INCOMPLETE

Abstract

In this paper, we study the impact of the ECB announcements on interest rates, stock prices and market-based inflation expectations. Using high-frequency data, we find that the impact of the ECB announcements on stock market prices and inflation expectations has changed during the last fifteen years. In particular, while in the central part of our sample the ECB announcements were read as signals about the economic conditions (i.e. *Delphic* component), in the latest episodes the ECB communication has been interpreted as a commitment device on future monetary policy actions (i.e. *Odyssean* component). We propose an approach to separately identify the Delphic and Odyssean component of the ECB monetary policy announcements and we measure their dynamic impact on the economy. We find that an announcement of future monetary policy accommodation interpreted as Odyssean increases the price level and boosts industrial production. The impact on quantity and prices are short-lived and relatively small in magnitude.

Keywords:Monetary Policy announcements, High Frequency data, VAR with instrumented proxy

JEL Classification: C10, E52, E32.

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1 Introduction

Central banks around the world have been steadily placing more attention on the communication of their monetary policy stance to the public. In particular, explicit guidance about the likely future path of the short term interest rate has been increasingly used as a monetary policy instruments. The main justification behind the use of forward guidance is grounded on the assumption that expectations about future interest rates affect todays economy. Since individuals base their decisions conditional on the expectations about future rates, by manipulating the expectations of future rates the central bank can affect the decision of the agents today. However, the direction and the magnitude of the impact is not uncontroversial.

Standard New Keynesian models suggest that the announcement of future monetary policy accommodation generates a boom today (Krugman (1999) and Eggertsson and Woodford (2003)). Departures from the complete market assumption might cause the impact of forward guidance to differ substantially from the benchmark NK model in terms of intensity and persistence (Levin et al. (2010), McKay et al. (2014), and Werning (2015)). Moreover, information imperfections might deliver macroeconomic outcomes that are at the opposite end to ones of the standard full information rational expectation benchmark. The idea in a nutshell is the following. When central banks announce future monetary policy accommodation, agents revise downwards their expectations about the futures short term nominal rates. However, in the presence of informational frictions they do not know how to interpret these announcements, as a bad signal (i.e. a worsening of economic conditions) or as a good signal (i.e. an ultra accommodative monetary policy stance). Using data from surveys and interest-rate futures, Campbell et al. (2012) found that the Fed announcements of monetary policy accommodation generated downward revisions of inflation expectations in US. They argue that these outcomes are most likely interpretable as the agents reading the signals of the Fed as conveying negative information about the prospects for the economy ("Delphic" forward guidance), rather than as commitments to future stimulative deviations from the historical policy rule ("Odyssean" forward guidance).

In this paper, we propose an approach to separately identify the Delphic and Odyssean forward guidance shocks. We build on the High Frequency (HF) literature on the identification of monetary policy shocks, pioneered by Cook and Hahn (1989), Kuttner (2001), and Cochrane and Piazzesi (2002). We assume that monetary policy shocks can be isolated from the interest rates variations in a narrow window around the ECB interest rate decision and monetary policy press conference. Following Gurkaynac et al (2005), we assume that forward guidance shocks only affects future interest rates and do not affect current rates.

To identify the Delphic and Odyssean component of forward guidance shocks we assume that they have different sign impact on the growth of the stock market prices. In particular, a forward guidance shocks has a Delphic nature if it raises future interest rates and generates a positive variation in stock market prices contemporaneously, whereas Odyssean when the announcement raises future interest rates and depresses stock market prices. Since the latter generates an identified set, we consider the average impact to construct observable proxies of the Delphic and Odyssean froward guidance shocks. We then offer a quantitative estimate of their dynamic propagation on output and prices using a Vector of Autoregression model. We identify the transmission mechanism by instrumenting the reduced form VAR residuals with our observable measures of Delphic and Odyssean froward guidance shocks as in Mertens and Ravn (2012) and Stock and Watson (2012).

Our findings read as follow. First, we show that the ECB announcements (the path factor in the identification scheme of Gurkaynac et al (2005)) had a time-varying impact on marked-based inflation expectations and on stock prices, displaying a Delphic nature in early samples and Odyssean one towards the end. A similar pattern is found for the impact on the stock market prices. Second, when we combine the information of market based inflation expectations and stock prices we find that Delphic and Odyessean shocks coexisted and both shocks had non trivial impact on expected interest rates, inflation linked swaps and stock prices. In particular, in absence of Delphic shocks the five year inflation expectations would have been higher than what we actually observed since 2009. Third, the ECB announcements of the Odyssean type did have a statistically significant impact on the economic activity and on prices. An announcement of monetary policy accommodation generating a decline in the one year Euribor depresses the harmonized consumer price level and boosts industrial production. The impact on quantity and prices are short-lived and relatively small in magnitude.

The paper is organized as follow. Section 2 presents a simple theoretical framework to characterize Odyssean and Delphic forward guidance shocks. Section 3 reports the estimated impact of monetary policy announcements on market based inflation expectations and stock prices. Section 4 presents the identification strategy to tease Odyssean and Delphic announcements apart. In section 5 we estimate their dynamic impact on prices and quantities. Section 6 concludes.

1.1 Related Literature

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2 Theoretical Background

To build intuitions about the effect of monetary policy announcements, it is instructive to consider the three equations textbook New Keynesian model (Woodford (2003)). The first equation of the NK model is the IS curve (derived from linearizing the Euler equation), which relates the current output gap with the expected output gapand the gap between the real rate and the natural interest rate, i.e.

$$x_t = x_{t,t+1} - 1/\sigma(i_t - \pi_{t,t+1} - r_t^n)$$

where x_t is the output gap and $x_{t,t+1}$ is the expected output gap. r_t^n is the real interest rate, i.e. the rate that would prevail if prices were fully flexible. Solving forward, we obtain an expression where the output gap is the sum of future deviation of the real interest rate from the natural rate of interest, i.e.

$$x_t = -1/\sigma \sum(i_{t+j,t} - \pi_{t+1+j,t} - r_{t+j,t}^n)$$

The second equation of the NK model is the Phillips Curve, linking current inflation with the future expected inflation and the output gap, i.e.

$$\pi_t = \beta\pi_{t,t+1} + \kappa x_t$$

where π_t and $\pi_{t,t+1}$ are current and expected inflation. Solving this equation forward we obtain that current inflation can be expressed as the discounted sum of current and expected output gaps, i.e.

$$\pi_t = \kappa \sum \beta^j x_{t+j,t}$$

We assume that the central bank follows a very simple rule such that the real interest rate tracks the natural real rate with some error:

$$r_t = i_t - \pi_{t+1,t} = r_t^n + e_{t,t-j}$$

Absent any monetary shocks, the real interest rate will perfectly track the natural real rate and both the output gap and inflation will be zero.

A monetary policy announcement of - say - a monetary policy accommodation takes the form of a future decline in the real intrest rate, i.e. the real interest rate will be lower for a single quarter N quarters in the future, but maintained at r_t^n elsewhere. That is

$$e_{t+N,t} < 0 \rightarrow r_{t+N,t+N-1} - r_{t+N,t+N-1}^n < 0$$

Given the IS curve dynamics, such announcement generates an increase in the current ouptut gap, $x_t > 0$, and by moving the IS forward, also the expected output gaps increase, $x_{t+j|t} > 0$. Through the the Phillips Curve also inflation today and tomorrow will increase. This result is known in as front-loading, see Mankiw and Reis (2002). Different parameter values might magnify or dampen these dynamics without affecting the sign. ($\downarrow \sigma$) magnifies the response of x_t to announcement shocks and ($\downarrow \theta \rightarrow \uparrow \kappa$) magnifies the response of π_t to x_t. Moreover, the farther away is the announcement the strongest the response because summing more expectation bits. Models with strong precautionary motives might dampen these expectation channels, see Kay et al (2015), without altering the contemporaneous signs impact on current and expected inflation.

Relaxing the assumptions about rational expectation and/or full information, might turn these results upside-down. Consider the case in which agents have imperfect information about the state of the economy, Ω_t, and they assume that the monetary authority controls the future nominal short rates with the following reaction function

$$i_{t+1|t} = f(\Omega_t) + e_{t+1|t}$$

Since agents do not observe Ω_t nor $e_{t+1|t}$, when the future short rates decline they are engaged into a filtering problem and they have to ascribe the decline in $i_{t+1|t}$ either to a worsening of the economic landscape ($\Omega_t \downarrow$) or to a positive signal of future monetary policy accommodation. In other words, is the decline in interest rate the result of a worsening of the current fundamentals or a credible announcement of a future positive demand shocks ?

Following Cambell et al (2012) definitions, the latter type of announcement has a Delphic component. With a Delphic announcement the public believes that the central bank has superior information about macroeconomic fundamentals and that monetary policy surprises arise from this informational advantage. For example, by announcing future monetary policy tightening, the market participants decipher the signal as improvement in the future macroeconomic conditions and revises the expectations upwards. The former type of announcement is instead defined as the Odyssean forward guidance when, by publicly committing to a future course of actions, the policymaker is able to provide additional monetary accommodation and lift expectations about the future.

Teasing these two component apart is crucial for a correct assessment of the impact of monetary policy announcements. In the next section, we provide evidence on the difficulty to empirically identify $e_{t+1|t}$ when measuring only the variation in $i_{t+1|t}$, even when measured in a narrow window around the monetary policy announcements.

3 Monetary Policy Shocks, Market Expectations and Stock Prices

In this section we assess empirically the ability of the ECB to communicate future policy intentions to the private sector. We do so by using high frequency data on market interest rates to measure unanticipated changes in interest rate futures associated with ECB statements. The construction of monetary policy surprises follows closely the works of Jardet and Monks (2013) for the Euro Area who draw insights from the analysis of Gurkaynak et al. (2005) for the US experience. We include in our dataset the ECB press conferences from January 2002 until January 2016. The key idea is to isolate the variations in the current and future market interest rates in a narrow window around the monetary policy decision and press conference. Two estimated factors, a target factor that moves the the current policy rate and a path factor that only moves expected future rates, account for most of these changes.

Purpose of this section is to quantify the impact of the path shocks on market based inflation expectations and stock market prices. We measure marked-based inflation expectation using the Inflation Linked Swaps (ILS) at different maturities which are available from Bloomberg at daily frequency. Both of these measures are computed as the difference in a one- or two-day window around the ECB press conference. We consider the Euro Stoxx 50 as a measure of the European stock market prices, and compute the (log) variation around the same narrow intra-day windowaround the ECB monetary policy decision and press conference.

Various results emerge, all pointing at a substantial instability over time of the impact of the path factor on interest rate futures, on market based inflation expectations and stock price variations. In particular, we find that the path factor tend to explain a larger portion of the volatility of OIS futures in the period that corresponds to the Draghi presidency of the ECB relative to the period where Trichet was the ECB President. We also find that during the Trichet presidency an unanticipated increase in the path factor triggers an upward revision in the forecast of inflation. During Draghi presidency, we find that most of these impacts change signs and the monetary policy forward guidance shock has an Odyssean component, meaning that a decline in the path factor triggers an increase in market-based inflation expectations and generates positive returns on stock prices. These time variation in the response of inflation expectation to forward guidance shocks are unchanged when instead of considering arbitrary subsamples we use rolling estimates or local kernel estimators.

3.1 The impact of the ECB announcements on interest rates

We consider the changes in the forward Overnight Index Swaps (OIS)[1] in a 30 minute window around the ECB's monthly interest rate announcements and conference press from January 2002 until January 2016. Forward OIS are commonly used to measure expectation of future path of EONIA and by having as a counterpart payment only the accrued interest rate payments they are less sensitive to fluctuations in the credit risk premia. The data are extracted from the Thomson Reuters Tick History application. The database consists of minute by minute mid-quote rates for OIS contracts of different maturities up to two years during the days of the ECB monetary policy announcements. We consider 8 maturities from the current month until 2 years ahead[2]. We calculate the difference of each OIS forward rate using 5-minute averages before the start and after the end of a window around the ECB interest rate announcement and press conference. We define this window as beginning at 13:35 and ending at 15:50. The time series cumulative variations of OIS futures are plotted in figure 8 top panel. A few comments are of order. OIS futures cumulative variations

[1] The overnight indexed swap (OIS) is an interest rate swap where the periodic floating payment is generally based on a return calculated from a daily compound interest investment. The reference for a daily compounded rate is an overnight rate (or overnight index rate) and for the euro area is the EONIA rate.

[2] For each maturity, mid-quotes figures are transformed into forwards using the following formula

$$r_{t_1,t_2} = \left(\frac{(1+r_2)^{d_2}}{(1+r_1)^{d_1}} \right)^{\frac{1}{d_2-d_1}} - 1$$

with short maturities, i.e. current month (0-30), next month (30-30) and next quarter (90-90), tend to be fairly stable along the full sample; particularly so towards the end of the sample where the zero lower bound was clearly binding. OIS futures cumulative variations with longer maturities, display downward sloping trends, with two large episodes of sudden decline at the end of 2008 and in the middle of 2011.

From the term structure of variations in OIS forward rates we extract the first two principal components that explain the larges portion of variation in the standardized dataset. The identification of the factors is performed by rotating the factors in such a way that the second factor (path) explains the variation in all OIS future contracts but the current month interest rate variation. In doing this, we are implicitly assuming that monetary policy announcements are likely to affect the expectations of short term rates over an horizon larger then the current month[3]. Both estimated and rotated factors have zero mean and zero autocorrelation and partial autocorrelation functions, and by construction they are orthogonal to each other (see figure 4). Figure 5 reports the cumulative path factor along with two observable measures that turned out to be correlated with the future monetary policy stance, i.e. the spread between the current month and the one-year hence OIS future and the excess liquidity. Gray areas represent periods of a sequence of negative shocks, interpretable as periods of monetary policy tightening. The top panel reports the estimated path factor and the spread between the OIS futures with one month and one-year hence maturities. The cumulated series tend to comove and the correlation coefficient between the path factor and the spread is significant of the order of 0.42.

One interesting exercise is to assess the relative contribution of each identified factor in explaining the volatility of the OIS futures at various maturities. The first two columns of table 1 reports the fractions of innovation variance of each interest rate futures contract rate that are due to the identified target factor and to the identified path factor aver the sample period of January 2002 until October 2015. The variance is computed as the R^2 of the regression of each future contract on the target or path factor respectively. The path factor accounts for no changes in the current month interest rate and it accounts for only 17 % of the variance in the interest rate expected for the next month. The target factor accounts for nearly all of the remaining variance from these two contracts. The path and the target factors each explain about 40-50 % of the variance in interest rates expected for the next quarter. Finally, the path factor dominates in explaining the volatility of OIS futures contract expected at maturities longer two quarters. The remaining columns of table 1 carry the same information using two different sub-sample periods. In particular, we consider the ECB announcements during the Trichet presidency, i.e. from January 2002 until October 2011, and the ECB announcements during the Draghi presidency, i.e. from November 2011 until January 2016. The two subsamples are chosen because characterized by very different

[3]We normalize the target factor loadings on the current OIS rates and the path factor loading the one-year-ahead future to unity. GSS and JM use a slightly different normalization. This normalization has no impact on the variance decomposition and statistical significance.

economic episodes. The large swings in oil prices preceding the Great Recession, the global financial turmoil of 2009, the Euro Area sovereign debt crisis, and the short term rates hitting the zero lower bound and a novel set of unconventional monetary policy tools implemented by the ECB. Moreover, one could also argue that the communication strategy of the ECB has adapted to this changing environment, moving form a 'no pre-commitment' attitude as it was the case during the Trichet presidency towards more forward looking statements and commitments. This is somehow reflected in column 4 and 6 of table 1 where the portion of variance explained by the path factor for OIS future contracts at long horizons larger during Draghi presidency. For example, the path factor explains 55 % of the volatility the one year and half ahead OIS future contracts during Trichet and 78% during Draghi.

3.2 The impact of ECB announcements on inflation expectations and stock prices

What are the effects of the ECB announcements on market-based inflation forecasts and on stock prices?

To answer this question, we gather the daily average figures on Inflation Linked Swaps (ILS) at various maturities as proxies for market-based inflation expectations. We consider the variation in a one- and two-day window around the ECB monetary policy press conference and decision. Figure 8 reports the cumulative changes of the ILS from June 2004 until January 2016. Except for the one year ILS which looks clearly an outlier, they share common features; they are aligned until the 2009, and since then they decoupled showing different behavior. In particular, short term maturities (2-5 years) display an inverse U-shaped patterns and long term maturities (8 to 12 years) have an increasing pattern (see figure 9).

How much of these variations are due to changes in the target and path factor? Table 2 reports the coefficient estimates of the regression of the one- or two-day variations of the inflation linked swaps on the path and the target factors for the full sample and for different subsamples. A number of interesting results are worth highlighting. First, only few coefficients loading the target factor are statistically significant, typically at short horizons. When significant, they have negative signs, meaning that an increase in the target factor generates a decline in the the 2 and 3 years ILS for the two-day window and from the two- to the five-year ILS for the one-day window, which is consistent with the announcement of a monetary policy tightening. Interestingly, these results hold for the full sample and the Trichet period, but not for the Draghi presidency. Second, the path factor which captures the announcements of future monetary policy is significant at any horizon. Third, the path factor has a positive impact on the Trichet period and negative during the Draghi subsample. This suggests that, while for the first subsample the ECB announcements are characterized by a strong Delphic attitude, our estimates for the second subsample indicate that response of market-based inflation expectations to monetary policy becomes negative and therefore the Delphic component found for the previous episodes vanishes. The sign found for the second subsample is consistent with an Odyssean form of forward guidance and in line with a number of public statements characterized by future commitments on the monetary policy stance[4]. More precisely, our estimates indicate that since November 2011 the ECB announcements generating a 1 percent reduction in the one-year OIS future were able to generate an increase in inflation swaps of roughly 60 basis points if we consider the variation between the ILS value on the day following the ECB announcement and the ILS value on the day before. On a similar ground, the impact of the path factor on stock market prices has been relatively unstable in the two subsamples. Table 3 reports the impact of the path and target factors on the percentage variation in the Euro Stoxx 50 during the ECB conference press. We clearly see significant differences among the two sub periods. In the full sample and during the Trichet presidency announcements about the likely course of the key policy interest rates did not generate statistical significant variation in the stock market prices. If wee focus our analysis on the Draghi presidency we observe that a one percent decline in the one year OIS future triggers a statistically significant 10% increase in the Euro stoxx 50.

To gauge more evidence on the possible time variation in the impact of the path factor on ILS and stock market prices we have conducted two complementary exercises where we do not arbitrarily select the subsamples. The first exercise is based on based on rolling window regression and the second on local kernel regression which has the advantage of smoothing the abrupt time variation of the rolling window estimates[5].

Figures 6 and 7 reports the rolling sample estimates of the impact of the path factor on the stock market prices and on market-based inflation expectations. In particular, the blue solid and dashed lines reports the mean estimates along with the 90% confidence bands of the impact of the path factor on the inflation linked swaps in a 24 month window. The gray areas report the same information using a local linear kernel estimator. Both approaches offer the similar reading of the impact of ECB announcements. While in the central part

[4]Since July 2013 the Governing Council of the ECB has been providing forward guidance on the future path of the ECB policy interest rate conditional on the outlook for price stability. Following its meeting on July 2013 the ECB communicated that it 'expects the key ECB interest rate to remain at the present or lower level for an extended period of time.' Announcements about the stance of monetary policy also includes the communication of large asset purchases programs and various form of Quantitative Easing (QE). For example, the announcement of public sector purchase program (PSPP) was disclosed during the January 2015 conference press and it was coupled with the announcements an indicative duration, i.e. 'until September 2016, and in any case until the Governing Council of the ECB sees 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'.

[5]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

$$\sum_{t=1}^{T} K_f(\frac{t-\tau}{h})(y_t - \mathbf{x}_t' B_\tau)$$

where $K_f(.)$ is the Gaussian kernel function and h is the bandwidth. Data points far form τ will have small weights, yet non zero as in the rolling window. We use the optimal bandwidth as suggested by Bowman and Azzalini (1997) pag 31. Since the weighting scheme is known, standard weighted least square methods can be used to estimate the parameters, B_τ.

of our sample the ECB communication had a strong Delphic component, last part of the sample is dominated by the Odyssean type of communication of the future monetary policy stance.

4 Identifying the Delphic and Odyssean component of ECB announcements

The results of the previous sections highlighted the fact that the path factor (i.e. the forward guidance shock) had varying impact on the Euro Area inflation expectations and stock market prices. One way to rationalize this time variation is to assume that the path factor is the combination of two distinct shocks, a Delphic and an Odyssean monetary policy surprise. When using only the information of the variations in the OIS future contracts, we are unable to tease these two shocks apart. However, if we introduce in the dataset also the measures of inflation expectations and stock prices, we can exploit the opposite signaling implications that Delphic and Odyssean shocks have as a device to tease these two shocks apart.

To this aim, we pool together variations in the OIS futures, in the ILS and in the percentage variations in the stock market prices, and extract three factors. We rotate the factors so that the second and the third factor do not influence the current month OIS. Moreover, we assume that the second factor has a positive impact on the one year OIS future and in the Euro Stoxx 50, and the third factor has a positive impact on the one year OIS future and negative on in the Euro Stoxx 50[6]. The second factor can be interpreted as a Delphic forward guidance shock and the third factor as an Odyssean forward guidance shock. Given that OIS and Ero Stock are observed at the same freqeuncy (intraday), we prefer to impose sign restrictions on those variables for our benchmark analysis. However, results are robust when imposing the signs restrictions to ILS instead of on stock market prices.

Figure 10 reports the cumulated Delphic path factor (red) and Odyssean path (blue) factor in the top panel and in the bottom panel cumulative variation in the five year ILS. Periods of downward sloping trend correspond to period where OIS futures at long maturity decline, which can be interpreted as periods of monetary policy accommodation. For the Delphic shock, we observe a period of tightening from the end of 2006 up until middle of 2008. Then, a sequence of sharp accommodating episodes resulting in a decline form the end of 2008 until the end of 2012. Since then, a gradual tightening again. The Odyssean forward guidance shock has displayed less clear-cut trends.

Given our identification strategy, periods characterized by diverging paths of Delphic and Odyssean shocks generate either an increase or a decrease of ILS, whereas periods of comovement between Delphic and Odyssean shocks have an ambiguous effect on ILS. There are two episodes of diverging paths identified as the shaded areas in figure 1: (1) from middle of 2007 until the middle of 2008 (Delphic increasing and Odyssean decreasing), (2) from the

[6] Details on the identification with zero and sign restrictions can be found in the appendix.

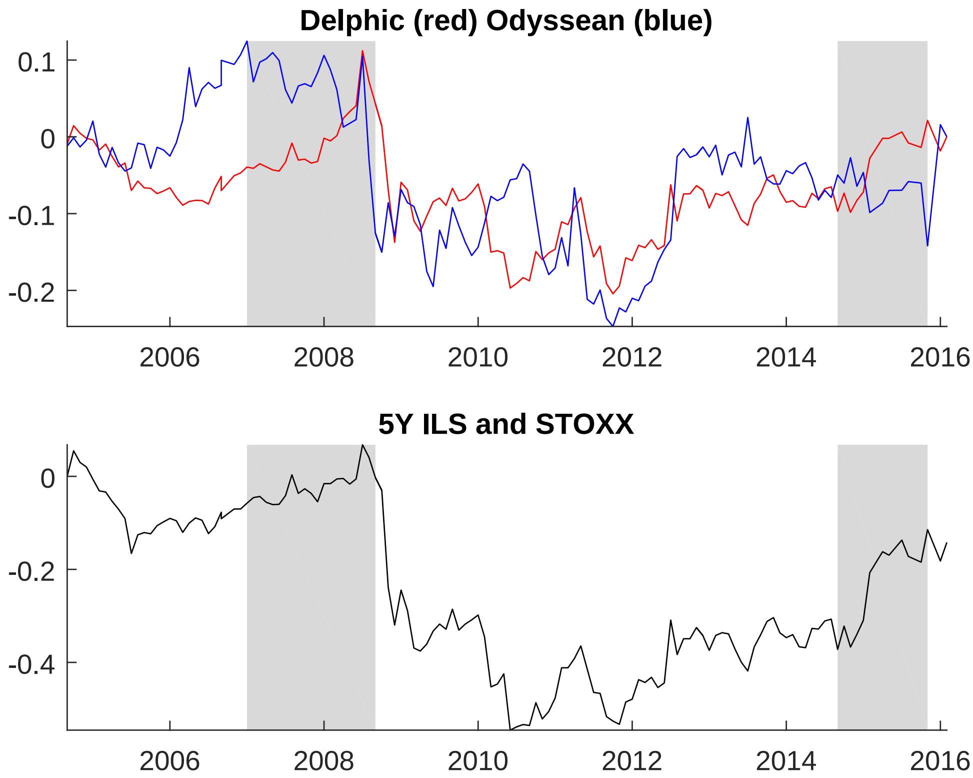

Figure 1: Delphic and Odyssean FG shocks and the 5 year ILS

middle of 2014 until end of 2015 (Delphic increasing and Odyssean mildly decreasing). Given the sign restrictions that we have imposed, both episodes generate an increase in ILS, which is what we observe in the the five-year ILS.

What would have happened to inflation expectations in absence of Odyssean shocks ? or in the absence of Delphic shocks ? In absence of Delphic shocks, inflation expectations would have been more stable and higher then what we have observed. In absence of Odyssean shocks, inflation expectations would have typically higher.

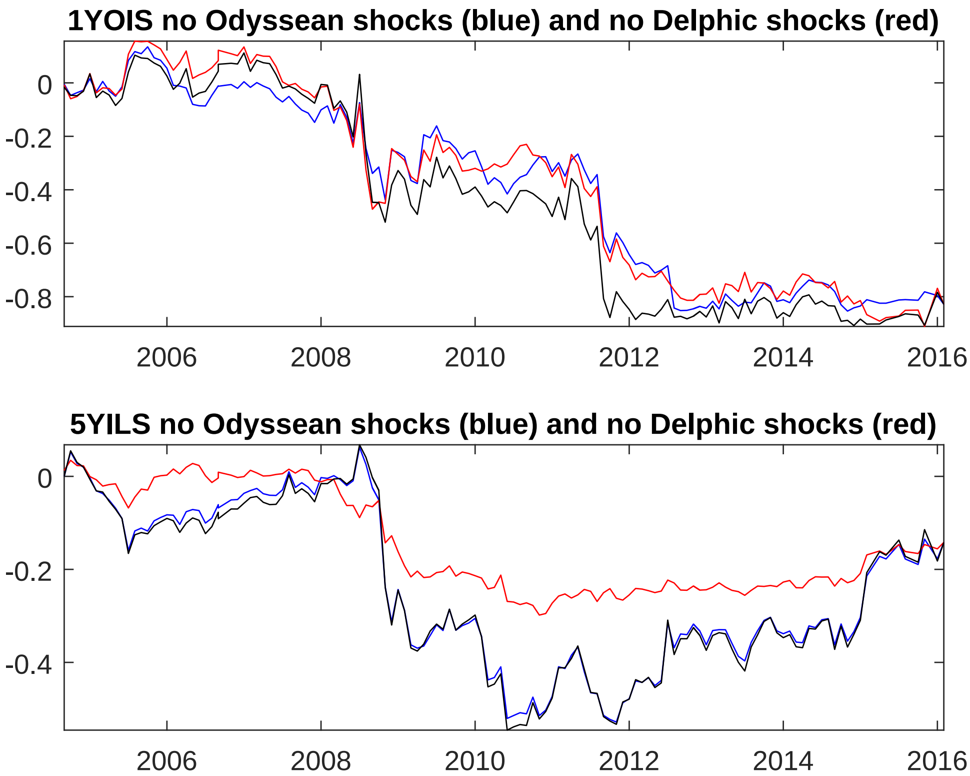

Figure 2: One year OIS and the 5 year ILS without Delphic (red) and Odyssean (blue) FG shocks. In back the original series.

5 The macroeconomic impact of the Delphic and Odyssean monetary policy surprises

We wish to quantify the dynamics impact of the identified measure of monetary policy surprises on macroeconomic variables. We consider six key macroeconomic variables at monthly frequency from January 2002 until January 2016, the one year Euribor, industrial production index (IPI), the consumption price index (HICP), a measure of non-volatile price index, i.e. the consumption price index excluding food and energy, the Gilchrist and Mojon (2013) corporate credit spread, and the real effective exchange rate. Prices and indexed are expressed in logs while rates and spread are raw. We assume that the joint co movements of these macroeconomic variables can be well approximated by a vector of autoregression of order p which take 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 normal zero mean i.i.d. shock with $\Sigma = E(\epsilon_t \epsilon_t')$. $\Phi_0, \Phi_1, ..., \Phi_p$ are matrices of appropriate dimensions describing the dynamics of the system. We can rewrite the VAR in a companion form , i.e. $y_t = x_t'\Phi + e_t$, where $x_t = [y_{t-1}', ..., y_{t-p}', 1]'$ and Φ is the companion form matrix, and estimate the paramaters of interests either with classical estimators or using a Bayesian approach.

The reduced form VAR is compatible with several structural representations where reduced form residual can be expressed as linear combination of structural uncorrelated innovation, i.e.

$$e_t = \Omega \nu_t$$

where $\Omega\Omega' = \Sigma$ and $E(\nu_t \nu_t') = I_n$. We assume that monetary policy surprises identified around the ECB press conferences are among the structural uncorrelated innovations that had contribute to drive the observed fluctuations.

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 of the structural shock (unobservable). In our context the proxy of monetary policy shock is given by the Odyssean and Delphic forward guidance shocks extracted form the high frequency data as discussed in previous sections. The basic idea of the structural VAR with external instrument is that the monetary policy shock in the structural VAR is identified as the 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 two stage regression allows to recover the the first column of the rotation matrix Ω, and thus to recover impulse responses and 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 partitioning the two set of relationship 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 is estimable 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 $\Omega\Omega' = \Sigma$ give rise to a set of equations that up to a sign normalization uniquely pin down the first column of the rotation matrix.

Our econmetric approach works as follows. We first run the VAR OLS regression to obtain Φ and Σ. We then 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. This two stage regression allows to recover the first column of the rotation matrix, and thus to recover impulse responses and transmission mechanism of the monetary policy surprises. To obtain the confidence bands around the impulse response we follow Mertens and Ravn (2012) and run a wild bootstrap of the VAR residuals.

Figures 3 report the estimated impulse responses of the Odyssean monetary policy announcement, the Delphic monetary policy announcement and a generic monetary policy announcement (i.e. the path factor as in Gurkaynac et al. (2005)). We find that an announcement of future monetary policy accommodation interpreted as Odyssean increases the price level and boosts industrial production. The impact on industrial production is short-lived and dies out immediately after. The impact on the price level is delayed reaching the maximum impact after 6 months. In terms of magnitude, an announcement that triggers an increase in the one year Euribor of 5 basis points generates a decline in the price level whose trough is located after 6 months at - 6 basis points. The Delphic components of monetary policy announcements does not have a statistically significant impact on price and quantities. If anything, a statistically significant impact on cope inflation.

6 Conclusions

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A 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, e is a matrix of iid normal shocks of appropriate dimension. We extract factors and loadings using PCA. We rotate the factor using an orthonormal matrix H (i.e. $HH' = H'H = I$) 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, 5 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 asterisk indicate 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 $\Lambda_{3:3}\widetilde{H}$, i.e.

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

and recover $\widetilde{H}$ by

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

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

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

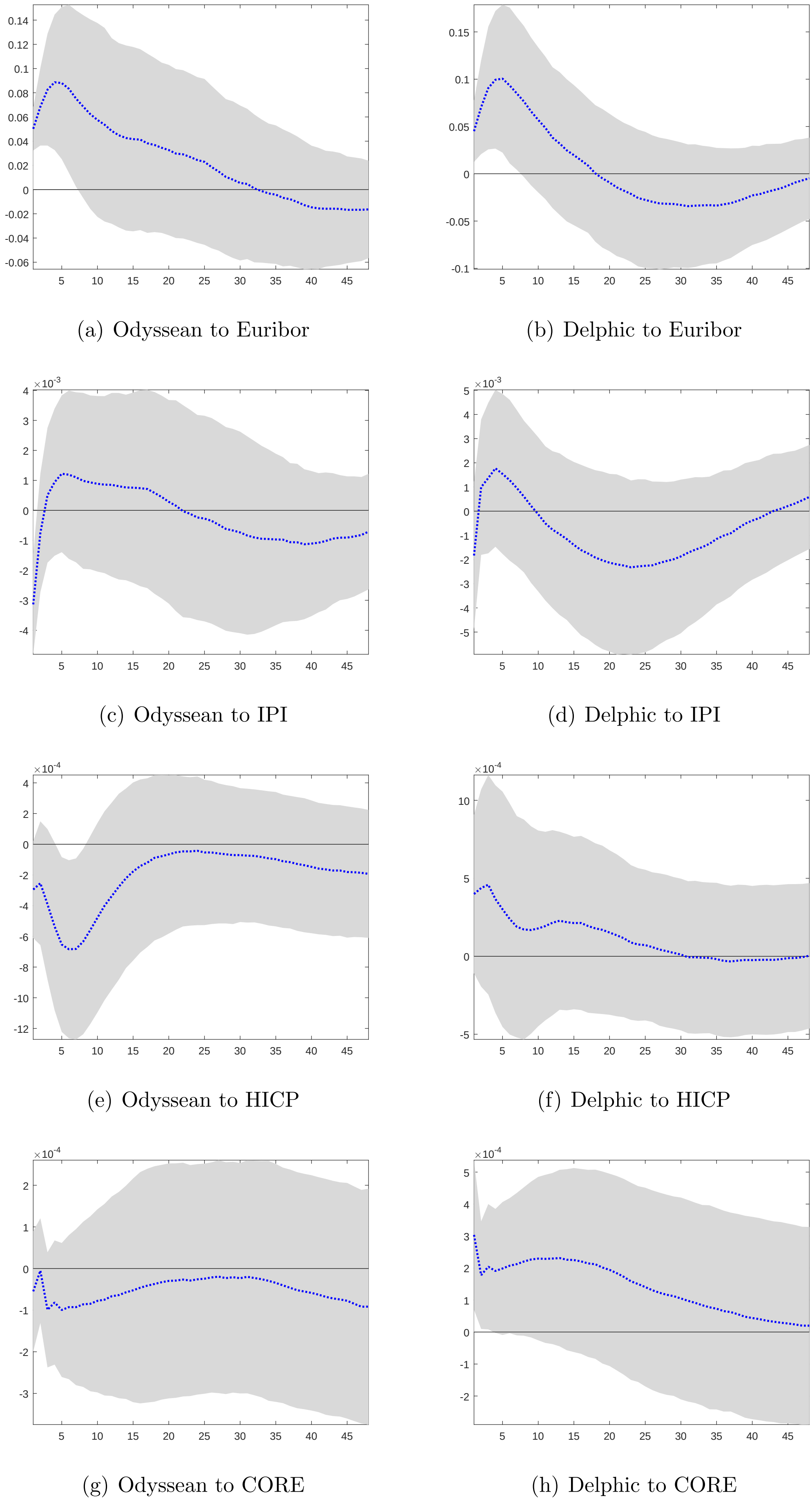
where

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

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 sign in $\Lambda\widetilde{H}Q(\theta)$ are satisfied. We then consider the average of the accepted rotations, $H_m = \Lambda_{3:3}^{-1} 1/J \sum_j^J \Lambda_{3:3}\widetilde{H}Q(\theta^{(j)})$.

	Variance Decomposition					
	Full		Trichet		Draghi	
	Target	Path	Target	Path	Target	Path
Current month (0-30)	85	0	84	0	93	0
Next month (30-30)	66	17	66	17	67	19
Next Quarter (90-90)	42	49	44	49	27	59
Two Quarter hence (180-90)	25	67	26	67	15	73
Three Quarter hence (270-90)	16	76	16	76	7	83
One year hence (360-90)	15	78	15	78	9	81
Five quarter hence (450-90)	8	80	8	79	5	88
One year and half hence (540-90)	11	57	12	55	7	75
630-90	2	64	2	62	0	84

Table 1: Decomposition of the Variance in Changes in OIS futures, full sample and Trichet and Draghi presidency.



(a) Odyssean to Euribor

(b) Delphic to Euribor

(c) Odyssean to IPI

(d) Delphic to IPI

(e) Odyssean to HICP

(f) Delphic to HICP

(g) Odyssean to CORE

(h) Delphic to CORE

Figure 3: Impulse responses of the Odyssean monetary policy announcement, the Delphic monetary policy announcement on one year Euribor, industrial production (IPI), consume price index (HICP) and Core.

		1Y	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y	10Y	12Y	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
Full Sample	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	0.29	-0.38	-0.49**	-0.19	-0.02	0.11	-0.08	0.00	0.05	0.19	0.13	0.11
Trichet	Path	0.49***	0.38***	0.37***	0.23***	0.27***	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	0.17	0.09	0.10	0.09	0.12	0.18	0.09
	Target	-0.64	-0.69	-0.85	-0.88	-0.85	-0.92*	-0.96*	-0.95**	-0.87**	-0.95**	-0.82**	-0.83**
Draghi	Path	-0.86**	-0.61*	-0.65*	-0.69**	-0.63*	-0.66**	-0.63**	-0.58**	-0.57**	-0.57**	-0.62***	-0.69***
	Adj R^2	0.30	0.24	0.27	0.29	0.27	0.37	0.40	0.44	0.46	0.51	0.51	0.52
	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
Full Sample	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***	-0.37**	-0.20*	-0.04	-0.12	-0.09	-0.11	0.00	-0.14	-0.09
Trichet	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	0.03	0.05	0.03	0.05	0.03	0.01
	Target	-0.36	-0.34	-0.38	-0.50	-0.47	-0.50	-0.50	-0.45	-0.47	-0.56	-0.52	-0.37
Draghi	Path	-0.42	-0.26	-0.30	-0.27	-0.31	-0.37	-0.36*	-0.34	-0.30	-0.28	-0.33*	-0.35*
	Adj R^2	0.08	0.02	0.07	0.09	0.08	0.17	0.20	0.14	0.13	0.16	0.21	0.15

Table 2: Regression Estimating Responses of the revision of ILS to Target and Path factors, full sample and subsamples. Two (one) day window upper (bottom) part.

		STOXX
Full Sample	Target	-5.06**
	Path	-0.19
	Adj R^2	0.02
Trichet	Target	-5.23**
	Path	1.06
	Adj R^2	0.05
Draghi	Target	-7.17
	Path	-10.78***
	Adj R^2	0.14

Table 3: Regression Estimating the STOXX % change to Target and Path factors, full sample and subsamples.

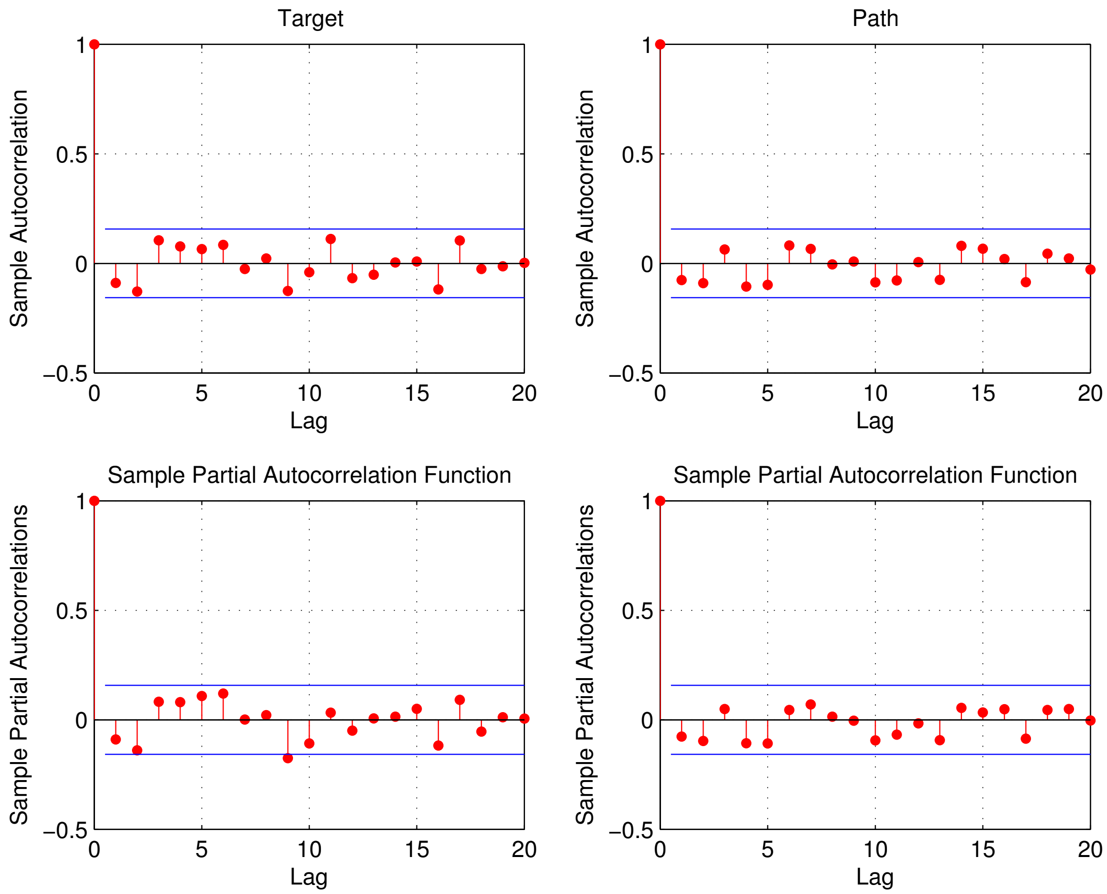
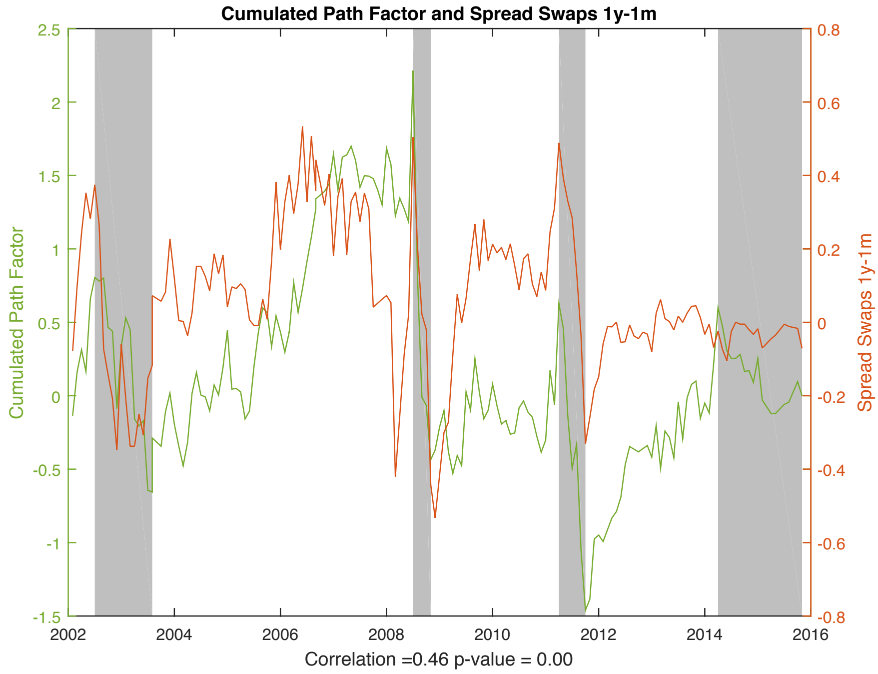


Figure 4: Autocorrelation and Partial Autocorrelation function for the path and the target factor. Blue bands indicate statistical significance.



(a) Cumulated Path Factor and Spread Swaps 1y-1m

(b) Cumulated Path Factor and Excess Liquidity

Figure 5: Plot of the path factor against different observable variables, Spread 1y-1m OIS swaps and the Excess liquidity. Gray areas identify periods of downward trends which are interpretable as monetary policy tightening.

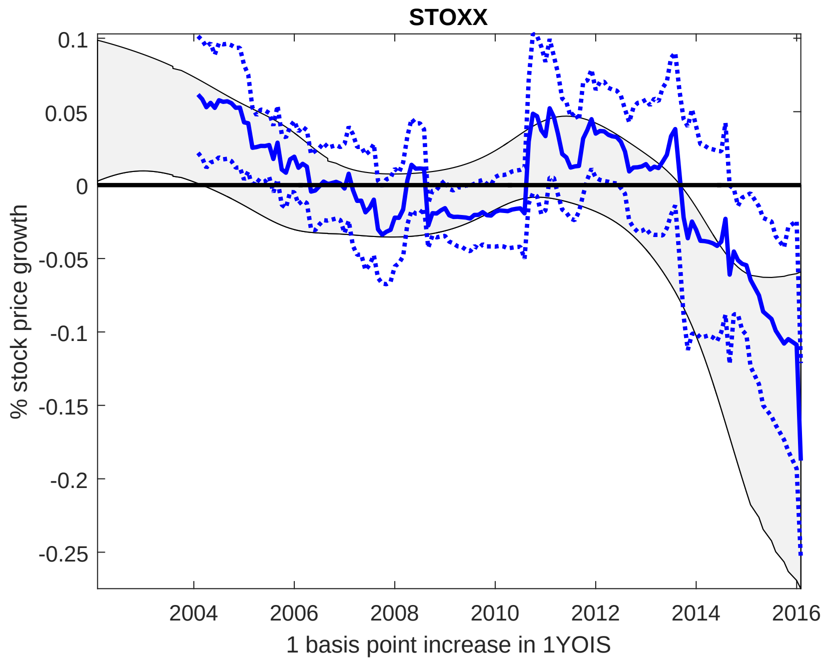
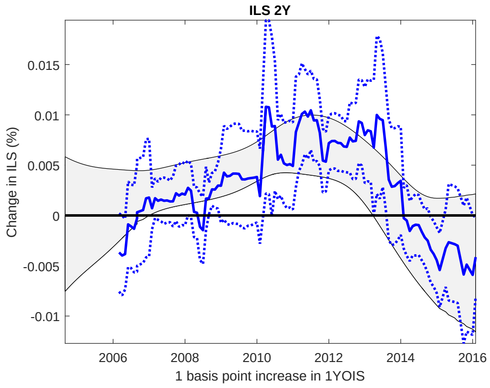
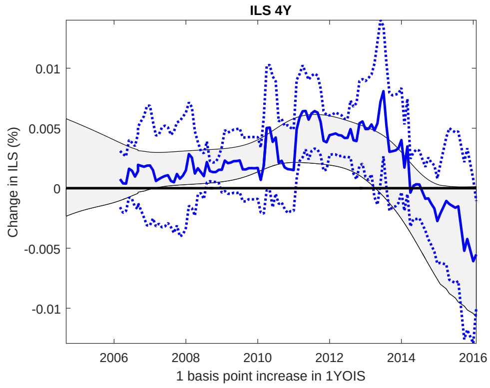


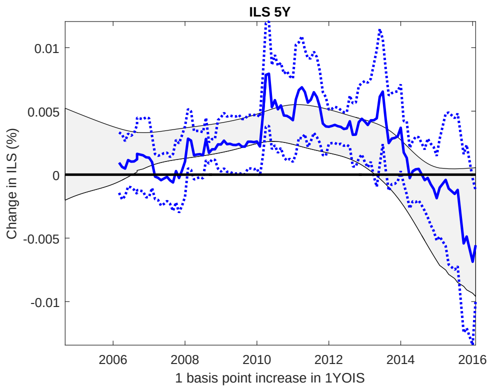
Figure 6: Impact of the path factor on the STOXX over rolling windows or with a local kernel estimator



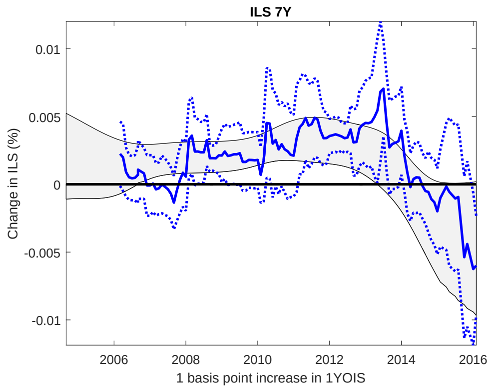
(a) 2 year



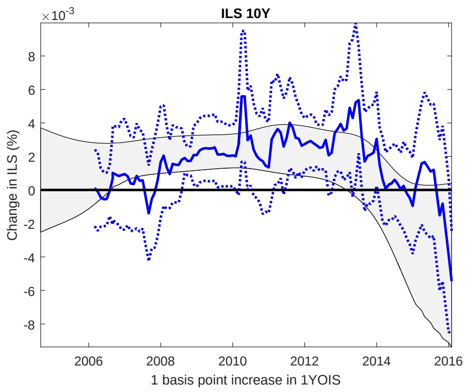
(b) 4 year



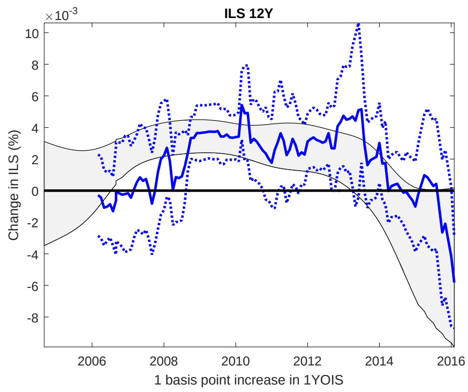
(c) 5 year



(d) 7 year

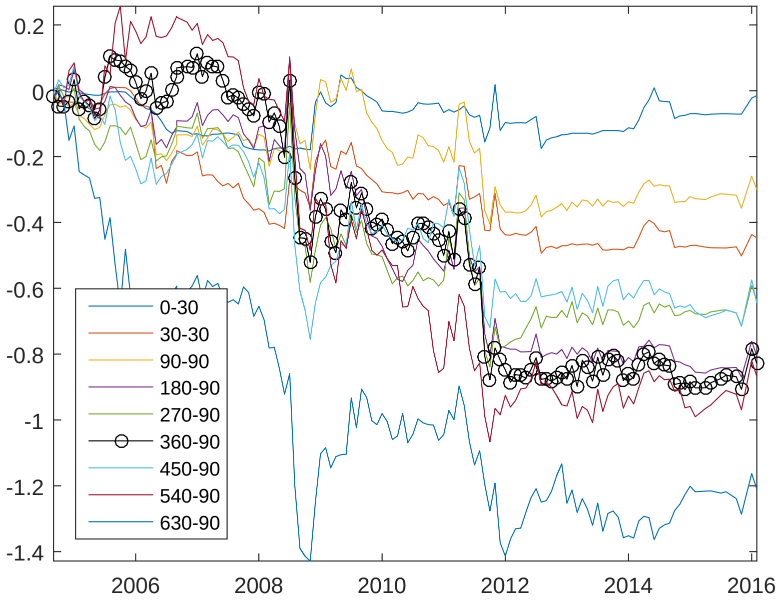


(e) 10 year

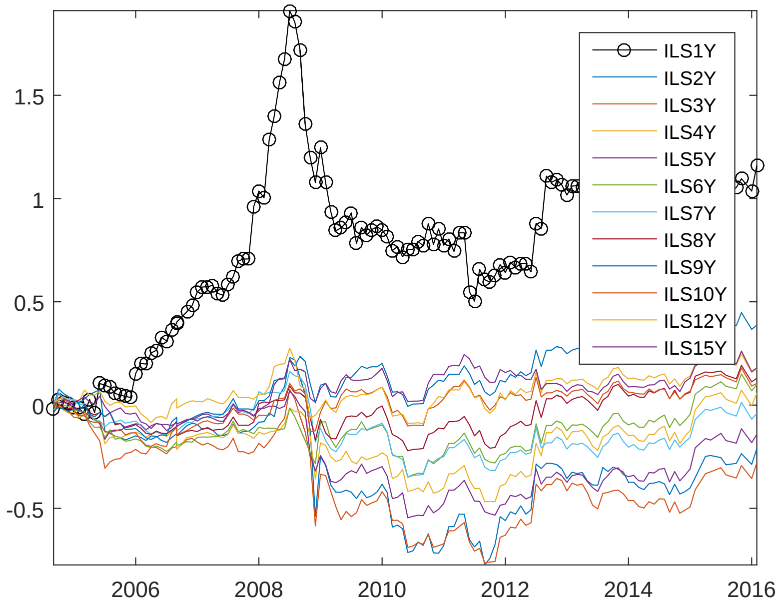


(f) 12 year

Figure 7: Impact of the path factor on the ILS over rolling windows or with a local kernel estimator



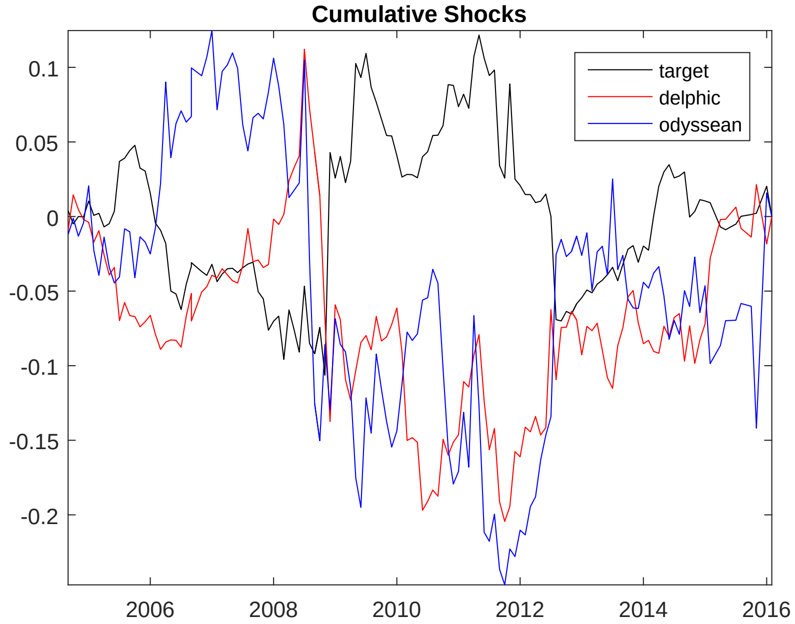
(a) Cumulated changes in OIS future during the ECB press conference



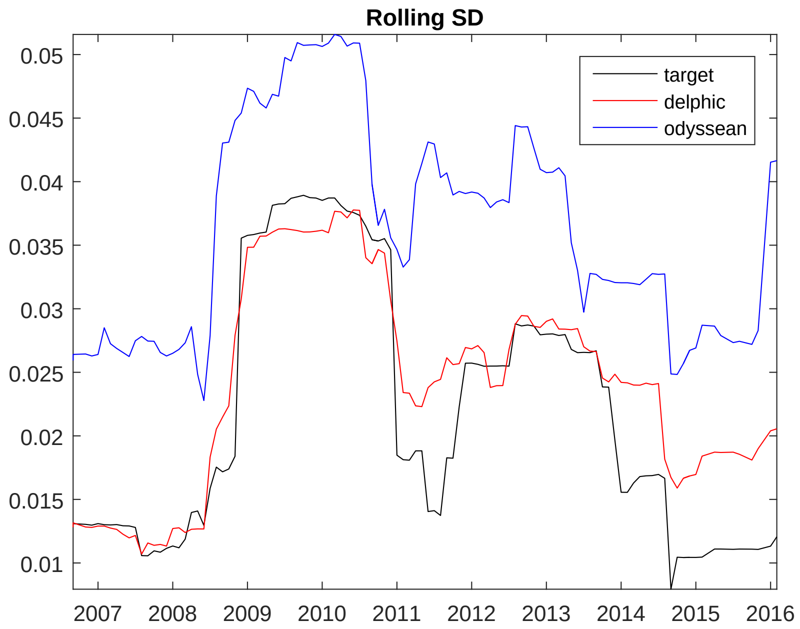
(b) Cumulated changes in Inflation Swaps during the ECB press conference

Figure 8: Plot of the cumulative changes in OIS and ILS around the ECB press conference.

Figure 9: Plot of the cumulative changes of ILS around the ECB press conference.



(a) Cumulated MP shocks



(b) Rolling SD of MP shocks

Figure 10: Plot of the cumulative Monetary Policy shocks (upper part) and the rolling standard deviation computed in a 2 years window (bottom). Black line represents the target factor, the red line the Delphic path factor and the blue line the Odyssean path factor. Dashed lines are obtained removing the 1 year inflation swaps from the database.