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Euro Area Monetary Policy Shocks: Impact on Financial Asset Prices during the Crisis?*

Caroline Jardet† and Allen Monks‡

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†Banque de France, Financial Research Division, 41-1391 RECFIN, 39 rue Croix des Petits-Champs, 75001 Paris, France. Email: caroline.jardet@banque-france.fr.

‡Central Bank of Ireland and Banque de France. Allen Monks is on secondment from the Central Bank of Ireland at the Banque de France, Financial Research Division. Email: allen.monks.external@banque-france.fr.

Abstract

We use high-frequency intraday interest rate data to measure euro area monetary policy shocks on the days of ECB interest rate announcements between 2002 and 2013. In line with Gürkaynak et al. (2005), we look at monetary policy shocks along two time dimensions: one related to the current level of short-term interest rates and a second related to expectations for the future path of these rates. We undertake regression analysis in order to determine the impact of monetary policy shocks on euro-denominated financial asset prices and confirm that shocks related to the future path of monetary policy are an important driver, particularly for longer-term bond yields. We find that this relationship has changed for certain asset classes since the onset of the crisis, notably the sovereign bonds of stressed euro area countries. These findings highlight the changed nature of the monetary policy transmission mechanism for some euro area countries during the sovereign debt crisis.

JEL Classification: E43, E52, E58, E61, E65.

Keywords: Monetary Policy, ECB, Transmission Mechanism, Financial Crisis.

Résumé

Dans cet article nous utilisons des données intra-journalières de taux d'intérêt pour mesurer la surprise de politique monétaire les jours d'annonces des décisions monétaires de la BCE entre 2002 et 2013. Dans la lignée des travaux de Gürkaynak et al. (2005) nous supposons que ces surprises incorporent deux dimensions: une surprise sur le niveau courant du taux court, et l'autre sur ses valeurs futures anticipées. Nos estimations montrent que cette dernière explique significativement les taux d'intérêt à long terme d'obligations souveraines de la Zone Euro. Néanmoins, cette relation s'est altérée pour certaines classes d'actif depuis le début de la crise financière, notamment pour les taux souverains des pays sous stress. Ces résultats illustrent la nature changeante du mécanisme de transmission de la politique monétaire depuis le début de la crise de la dette souveraine.

Classification JEL: E43, E52, E58, E61, E65.

Mots-clés: Politique Monétaire, BCE, Transmission de la Politique Monétaire, Crise Financière.

Non technical summary

This paper looks at euro area monetary policy shocks (i.e. the unanticipated component of ECB monetary policy announcements) and their impact on financial asset prices. We investigate various methods for measuring such shocks for the period 2002-2013. We place a particular emphasis on two time dimensions: one related to changes in the current level of short-term interest rates (*jump* shock); and a second related to changes in the expected future path of short-term interest rates (*path* shock). We confirm an important finding in the existing literature: the impact of monetary policy announcements on the money market interest rate curve cannot be summarised by one latent factor, at least one more is needed. This highlights the necessity of looking at monetary policy shocks along the two time dimensions listed above.

In addition to looking at the entire sample, we look at pre- and post-crisis subsamples. We find that two latent factors are required to explain movements in the money market curve for both periods. This finding may seem somewhat surprising during the post-crisis period, however, given the changes in the way that the ECB operationalised interest rate policy during this period as well as the various non-standard monetary policy measures that it adopted. Our findings suggest that such information is adequately summarised by the two factors listed above, in particular the *path* factor.

With regards to our analysis of the impact of these shocks on asset prices, we find that they explain a large proportion of the movement in euro area sovereign bond yields around the times of ECB monetary policy announcements. Looking at the pre- and post-crisis subsamples, we find that this is also the case for the sovereign bond yields of "core" euro area countries both before and after the onset of the financial market crisis in 2008. It is not the case, however, for the bond yields of "peripheral" euro area countries, with our measures only explaining a small amount of the movement in these yields in the post-crisis period. This indicates that these yields are reacting to other factors during this post-crisis period and highlights the changed nature of the euro area monetary policy transmission mechanism since the onset of the crisis.

1 Introduction

It is by now well established in the academic literature that central bank communication operates along two time dimensions: one related to the current level of short-term interest rates and another related to the expected future path of these rates.[1] Indeed, even before the recent adoption of forward guidance policies, central banks had become explicit about the role of expectations management in their monetary policy strategies.[2] It is also well established, in line with Kuttner (2001), that monetary policy announcements only matter to financial market participants when they deviate from expectations. While such deviations can be easily measured for the first component of central banks' communication (related to current short-term interest rates), it is less clear how changes to the second component (related to expectations for the future path of short-term rates) should be measured.

In this paper, we investigate different methods of measuring monetary policy shocks in the euro area along these two time dimensions, using data for the period 2002-2013. In line with Gürkaynak, Sack and Swanson (2005), we refer to these two components as a *jump* factor, corresponding to changes in the current level of short-term interest rates, and a *path* factor, corresponding to changes in the expected future path of short-term interest rates. Another methodology proposed by Gürkaynak (2005) includes a *timing* factor, which accounts for uncertainty related to the timing of announcements. We examine the impact of these shocks on euro-denominated financial asset prices and analyse whether the onset of the financial market and euro area sovereign debt crises gave rise to a change in these relationships, with a particular emphasis on euro area sovereign bond markets.

In order to undertake this analysis, we construct a new data set of high frequency intraday financial market data using the Thomson Reuters Tick His-

[1] As noted by Blinder et al. (2008): "the view that monetary policy is, at least in part, about managing expectations is by now standard fare both in academia and in central banking circles".

[2] For example, ECB (2008) states: "By using its ability to steer market interest rates at the shortest maturities close to the minimum bid rate in the Eurosystem's main refinancing operations and by communicating its strategy and policy intentions in a clear and transparent manner, the ECB can influence money market rates at longer maturities."

tory application. Our database comprises minute-by-minute mid-quote rates for OIS contracts of 16 different maturities (up to 2 years) on all days of ECB monetary policy announcements since January 2002. We use these data to construct forward OIS rates across the money market curve. Our data set also contains minute-by-minute data for the sovereign bond yields of the 4 largest euro area countries, the Eurostoxx 50 index, and the EUR-USD exchange rate. The use of such high frequency data permits an analysis of changes in interest rates and asset prices over very short time windows, allowing us to better isolate the impact of monetary policy announcements. Such data also allow us to pinpoint the short-term impact of specific statements and announcements such as, for example, the various non-standard monetary policy measures announced by the ECB since the onset of the financial market crisis.

These data allow us to undertake a systematic analysis of euro area monetary policy shocks during the period since the onset of the financial market crisis. Other studies, notably Brand, Buncic and Turunen (2010), undertake a similar analysis but do not include the post-2007 crisis period. We can, therefore, test for differences in the information content of monetary policy announcements before and after the crisis. We find that two factors continue to be sufficient during the post-crisis period in order to explain changes in the money market curve in a window around ECB interest rate announcements. This result is somewhat surprising, given that the ECB announced a number of non-standard measures over the course of the crisis, sometimes at the same time as interest rate announcements. In particular, announcements relating to the provision of liquidity (e.g., introduction and extension of the fixed-rate full allotment policy, introduction of additional liquidity-providing operations) impacted on expectations for the quantity of central bank reserves and, thus, the spread between policy rates and short-term money market rates. The results of our study indicate that such announcements are adequately captured by the *path* factor.

We employ two methodologies, based on Gürkaynak, Sack and Swanson (2005) and Gürkaynak (2005), in order to estimate monetary policy shock factors. We find that both sets of factors explain a large part of the variation of sovereign bond yields in a window around ECB monetary policy announcements. For example, regression specifications including the 2 factors measured using the first method explain 85% of the variation in French 2-year yields and 55% of the variation in French 10-year yields during our time windows for the period 2002-2013. Furthermore, the explanatory power of our *jump* and *path* factors remains quite consistent for French and German yields when we measure them separately for the periods before and after the crisis. However, this is not the case for the yields of Spain and Italy with, for example, our regression specification explaining 75% of the variation in Spanish 10-year yields in the period prior to the financial market crisis and just 6% thereafter. These results highlight the breakdown in the transmission mechanism of monetary policy for such countries during the euro area sovereign debt crisis.

The rest of the paper is organised as follows. Section 2 provides an overview of the existing literature in this area. In Section 3, we present details of our data set and of the methodologies used for constructing monetary policy shock measures before comparing the results of these methods. In Section 4, we present the results of our analysis on the impact on monetary policy shocks on euro-denominated financial asset prices. Section 5 concludes.

2 Literature Review

There are currently two dominant methods for identifying monetary policy shocks.[3] The first integrates such shocks into a vector autoregression (VAR) analysis by imposing timing and impact restrictions on the interaction between the central bank policy rate and other financial market or real economy variables (see, for example, Bernanke and Blinder (1992), Christiano, Eichenbaum, and Evans (1996), or Rudebusch (1998)). A second method relies on the use of high frequency data in order to measure the change in money market rates in a short window around monetary policy announcements (see Kuttner (2001), Hamilton (2008), and Campbell, Evans, Fisher, and Justiniano (2012)). The use of such high frequency data allows researchers to address two problems

[3] A third method employs content analysis on the text of central bank announcements in order to derive and codify the intended effect (see Berger et al., 2006, Jansen and De Haan, 2005, Gerlach, 2007, Rosa and Verga, 2006, Ehrmann and Fratzscher, 2007, and Rosa, 2008).

associated with estimating the impact of monetary policy shocks on financial asset prices. Firstly, simultaneity can arise if monetary policy shocks are in fact a response to changes in financial asset prices. Secondly, both monetary policy and financial asset prices could be reacting to another event, such as a data release or a re-pricing of risk by market participants, giving rise to omitted variable bias. Isolating the change in a short window encompassing the communication event reduces the risk of these two types of identification errors leading to biased estimates.

Our paper contributes to this second strand of the literature. A variant of this method places an emphasis on the ability of monetary policy announcements to change market expectations of future short-term rates. Gürkaynak et al. (2005) find that two factors are required to explain the common movement in a range of forward interest rates around a short window encompassing US Federal Reserve interest rate announcements. They rotate these two factors so that one relates to news about the current policy rate while the other relates to news about the future path of policy rates. Brand et al. (2010) undertake a similar analysis for ECB interest rate announcements and also find that two factors are needed in order to explain the common movement of forward interest rates around these announcements. An alternative method proposed by Gürkaynak (2005) uses a series of recursive regressions on Fed Funds futures contracts in order to separate unanticipated policy announcements into three factors: 1) the level of short-term rates; 2) the timing of interest rate announcements; and 3) the future path of interest rates. Brand et al. (2010) and Ehrmann and Fratzcher (2007) propose similar methods that exploit the separate timing of ECB interest rate announcements and press conferences.

The results of such research indicate that monetary policy shocks generally move financial asset prices in the intended direction, although there is less certainty on the magnitude of the change. Much of the literature focuses on the impact on the yield curve. Kuttner (2001) finds that the unanticipated component of Federal Reserve interest rate announcements has a significant impact across the yield curve but that this impact diminishes as maturity increases. In line with the findings of Gürkaynak et al. (2005) for the US, Brand et al. (2010) find that the forward-looking element of ECB communication has a substantial impact on long-term interest rates and that the importance of this component increases with maturity. Similarly, Rosa (2008) finds that the surprise component of Federal Reserve and ECB interest rate announcements have an impact across the respective yield curve and that this impact can be explained by both the interest rate announcement and the content of the accompanying statement. This study also finds that the response of the long-end of the yield curve is significantly larger in the US than in the euro area and that Federal Reserve announcements move euro yields across all maturities to a greater extent than ECB announcements move US dollar yields.

3 Measurement of Monetary Policy Shocks

In this section we describe the two methods that we use for extracting measures of monetary policy shocks.[4] The first is based on Gürkaynak, Sack and Swanson (2005) (GSS hereafter) and consists of a latent factor analysis and factor rotation using forward Overnight Index Swap (OIS) rates. The second is similar to a methodology described in Gürkaynak (2005) and consists of a series of recursive regressions on forward OIS rates. We compare the results of these two methodologies and discuss developments in euro area monetary policy shocks before and since the onset of the financial market crisis. We also look at the announcement effects of some of the non-standard monetary policy measures adopted by the ECB in recent years.

3.1 Data

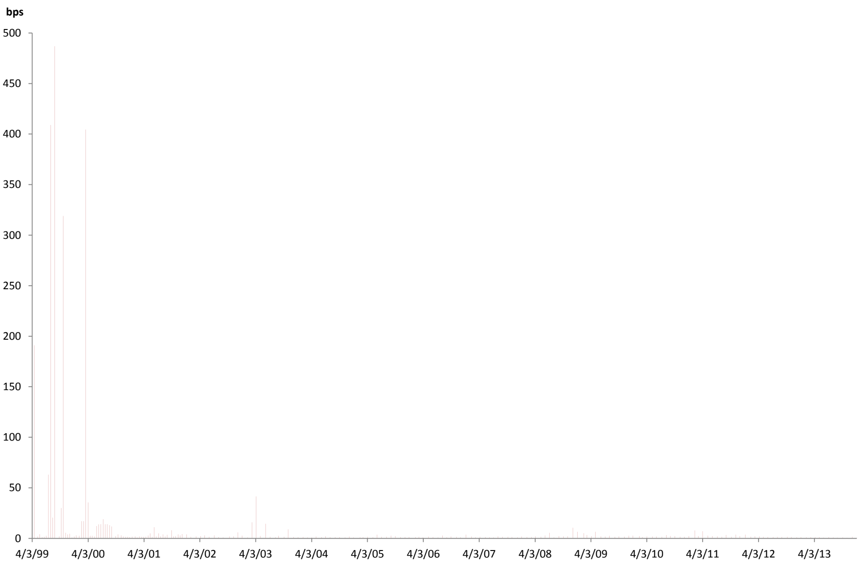
Our data set consists of the changes in forward OIS[5] rates in a window around the ECB's monthly interest rate announcements and press conferences. We

[4]We do not explore methods based on the sequencing of the ECB's interest rate announcements (i.e., a press release followed by a press conference), such as in Brand et al. (2010).

[5]An OIS contract is a fixed-for-floating interest rate swap with the floating leg tied to a daily interbank rate. In the case of euro OIS contracts, this interbank rate is the euro overnight index average (EONIA) rate. The EONIA rate is a weighted average of the interest rates on overnight unsecured transactions for a panel of banks. See Remolona and Wooldridge (2003) for an overview of the euro OIS market.

include the 144 scheduled[6] and 1 unscheduled[7] interest rate announcements between 2002 and 2013. We do not include ECB interest rate announcements during the period 1999 to 2002 due to a high level of volatility in our intraday OIS data during this period, likely reflecting a lack of market depth. This can be seen in Figure 1, which shows the largest minute-on-minute change in 12-month OIS rates for each scheduled ECB monetary policy announcement since March 1999.

Figure 1: Maximum Minute-on-Minute Change in 12-Month Intraday Data



Our OIS data include all monthly maturities up to 1 year and quarterly maturities between 1 and 2 years (16 series in total).[8] For each maturity, we

[6]The ECB's Governing Council generally meets twice monthly but only makes an interest rate announcement following the first meeting of the month, which typically takes place on the first Thursday of the month. A decision to not discuss the monetary policy stance at the mid-month meeting was announced by ECB President Duisenberg on 8 November 2001.

[7]The ECB announced a 50bps cut in its main refinancing rate on 8 October 2008. This was part of a joint interest rate announcement from a number of central banks.

[8]Our intraday OIS data come from the Thomson Reuters Tick History application, which contains historical high-frequency financial market data for a wide range of asset classes starting in 1996.

have minute-by-minute bid and ask quotes, which are compiled using quotes from a number of dealers on the market. These data require a seasonally-varying time adjustment from GMT to CET. Calculating mid-quote figures, we construct a number of monthly and quarterly forward OIS rates. These forward OIS rates are calculated using the following formula, based on a 360 annual day count convention:

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

where t_1 refers to the start of the forward rate, t_2 to the end of the forward rate, and d_1 and d_2 to the respective day counts.

Forward OIS rates are commonly used as a benchmark for gauging expectations of the future path of the EONIA rate. OIS contracts have a number of advantages over other money market rates for the calculation of such expectations. Notably, the low level of credit risk inherent in interest rate swap contracts, for which the only payment is the net accrued interest payment at the end of the contract, means that rates are not significantly affected by credit risk premia, even at longer maturities.

Given the ECB's stated aim of maintaining short-term money market rates close to its main refinancing rate, such forward rates also provide useful information on the future course of monetary policy. A number of studies document the close relationship between the EONIA rate and the ECB's main refinancing rate in the period prior to the adoption of the ECB's fixed-rate full allotment policy on 8 October 2008. For example, ECB (2008) shows that the spread between the two rates averaged 6bps between March 2004 and December 2007, with a standard deviation of 9bps. During this period, the ECB sought to provide banks with adequate liquidity so that short-term money market rates remained aligned with the main refinancing rate. The relationship between the EONIA rate and the main refinancing rate became more complex after the introduction of the fixed-rate full allotment policy in October 2008, with the spread between these two rates depending on factors such as the level of (excess) liquidity held by money market participants and the width of the ECB's standing facility corridor (see Hernandis and Torr, 2013, for a discussion).

It is common for market analysts to adjust forward OIS rates using the dates of forthcoming ECB reserve maintenance periods, thus allowing market participants to observe the average EONIA rate expected to prevail during each period. We make such an adjustment to the 1-month OIS rate and the 1-month forward OIS rate in one month's time in order that they correspond to the EONIA rates expected to prevail during the two maintenance periods following the Governing Council decision (see Appendix A for details on this calculation).[9] We then calculate the difference in each forward rate using 5-minute averages before the start and after the end of a window around the ECB's interest rate announcement and press conference. We define this window as beginning at 13:35 and ending at 15:50, allowing an approximately 10-minute margin on either side of the monetary policy announcement process.[10]

As changes in OIS rates during our window can also be affected by other events that occur within the window, we look at the timing of other economic data releases on ECB monetary policy announcement days. The only other significant release that systematically occurs during our time window is the US Initial Jobless Claims report, which is generally released by the US Department of Labor at 14:30 CET, i.e., at the same time as the beginning of the ECB's press conference.[11] We regress the changes in our OIS forward rates on

[9]This adjustment is only possible from March 2004, when the ECB changed the timing of its reserve maintenance periods so that they would always begin on the settlement date of the first liquidity-providing operation following the Governing Council interest rate decision. Prior to this, interest rate decisions could be taken during reserve maintenance periods, making it difficult to calculate market expectations for future changes to ECB policy rates (see ECB, 2003, for a discussion). We therefore do not adjust the 1-month OIS rate and the 1-month forward OIS rate prior to March 2004.

[10]The Governing Council's interest rate decision is announced in the form of a press release at 13:45 CET. The press conference begins at 14:30 CET and generally lasts for slightly longer than one hour. The press conference begins with an Introductory Statement, which is read by the President and subsequently released on the ECB's website. The remainder of the press conference takes the form of a questions and answers session. Press conferences were not held on a small number of the days included in our analysis; we do not adjust the length of our window on these days.

[11]Initial Jobless Claims figures were released on 136 of our 145 daily observations. We exclude two of these data points as the release was made at 13:30 CET, i.e., before the start of our time window. The release was made at 15:30 on 3 occasions during our sample. The Bank of England commonly makes a monetary policy announcement on the same day as the

the percentage deviation of the Initial Jobless Claims figure from the median expectation of this figure from a Bloomberg survey of market analysts. We find that this deviation has a statistically significant relationship with a number of our forward OIS rate series.[12] In order to remove the impact of the Initial Claims figures on our OIS forward rates, we replace the forward rates with the residual of the regression described above.

In order to verify that our monetary policy shock measures are not being driven by other events, we cross check dates of large monetary policy shocks with a list of data releases from Bloomberg. While we confirm that the US Initial Jobless Claims report is the only important data release to occur systematically during our window, we observe some other releases that may have affected our monetary policy shock measures on a limited number of days. For example, US GDP data were released on 31 July 2003 during our time window. As a robustness test, we re-estimate our factors excluding these days and re-run our regressions on asset prices (detailed in Section 4). We find that the exclusion of these days does not change our estimated coefficients and standard errors. We, therefore, do not exclude these observations from the results presented in Section 4.

3.2 Latent Factor Analysis and Factor Rotation

This approach is based on the methodology proposed in GSS (2005). We assume that monetary policy announcements are likely to affect expectations of short-term interest rates over an horizon longer than the current month. More formally, we assume that monetary policy announcements at date t influence changes in a set of forward OIS interest rates (adjusted for Initial Jobless Claims announcements) collected in the vector Y_t. The key issue is to determine how many latent factors, denoted by F_t, are sufficient to adequately capture the impact of these announcements on Y_t.

Let Y denote the $T \times n$ matrix with rows Y_t corresponding to Governing

ECB but this occurs before the start of our time window (at 13:00 CET).

[12]This result is quite interesting in itself, highlighting the impact of US data releases on expectations for euro short-term interest rates and, therefore, the ECB's monetary policy stance.

Council dates and columns corresponding to changes in a selection of forward OIS interest rates. Y can be written in the form:

$$Y = F\Lambda + \eta \tag{2}$$

where F is a $k \times T$ matrix of latent factors (with $k < n$), Λ is the matrix of factors loadings, and η is a $T \times n$ matrix of white noise residuals. In the following we consider $n = 7$ and $Y = (\Delta f_1^0, \Delta f_1^1, \Delta f_3^3, \Delta f_3^6, \Delta f_3^9, \Delta f_6^{12}, \Delta f_6^{18})$ where f_m^j denotes the m month j months ahead forward OIS rate, e.g., f_6^{12} represents the 6-month forward rate in 12 months time. Note that for f_1^0 and f_1^1 we use the date adjustment described in the previous section in order that they correspond to the EONIA rates expected to prevail during the two maintenance periods following the Governing Council.

As in GSS (2005) and Brand et al. (2010), we test the number of factors k using the matrix rank test of Cragg and Donalds (1997, see details in appendix).[13] The null hypothesis states that Y is described by k_0 factors against the alternative hypothesis that Y is described by $k > k_0$. This test is applied to three samples: the first covers the whole sample period, the second the "pre-crisis" period, and the third the "post-crisis" period. We define the pre- and post-crisis periods in function of the ECB's announcement of its fixed-rate full allotment policy on 8 October 2008, shortly after the bankruptcy of Lehman Brothers.

Table 1 reports the results of these tests. For the entire sample and the two sub samples, we cannot reject the hypothesis (at a 5% significance level) that 2 factors are needed in order to explain variation in our set of forwards OIS rates, although we robustly reject the hypothesis of more than two.

[13] As in Brand et al. (2010) preference is given to this test rather than the more recent test of Bai and Ng (2002) as the latter requires a much larger column dimension for Y.

Table 1: Test of the Number of Factors

	All Sample		Pre-Crisis		Post-Crisis	
$H_0 : k = k_0$	Wald statistic	p-value	Wald statistic	p-value	Wald statistic	p-value
0	56.60	0.00	51.00	0.00	85.69	0.00
1	33.67	0.00	26.84	0.02	36.73	0.00
2	7.40	0.49	10.67	0.22	8.40	0.39

Note: Test H_0: Number of factors $= k_0$ against the alternative hypothesis H_1: Number of factors $>k_0$ by measuring the minimum distance between $cov(Y)$ and the covariance matrices of all possible factor models (2) with k_0 factors. This distance, after normalisation, has a limiting χ^2 distribution with $(n-k_0)(n-k_0+1)/2-n$ degrees of freedom. See GSS(2005) for details.

The factor estimation is performed in two steps. First we estimate the unobserved factors F using the standard method of principal component analysis applied to the data matrix Y, after normalizing each column to have zero mean and unit variance. Based on the results of the tests on the number of factor, we retain the first two factors F_1 and F_2. These factors are orthogonal and explain a maximum fraction of the variance of Y. Second, as in GSS (2005) and Brand et al. (2010), we perform a rotation of the estimated factors in order to provide a more structural interpretation of these factors. Let Z_1 and Z_2 denote the two rotated factors. The rotation is performed in such a way that Z_1 and Z_2 remain orthogonal and that the second factor Z_2 has no impact on the first vector of Y_t (Δf_1^0), i.e, the EONIA rate expected to prevail during the maintenance period following the interest rate announcement.

The two rotated factors, calculated using data from the entire sample, are shown in Figures 2 and 3.

Figure 2: GSS Jump Factor

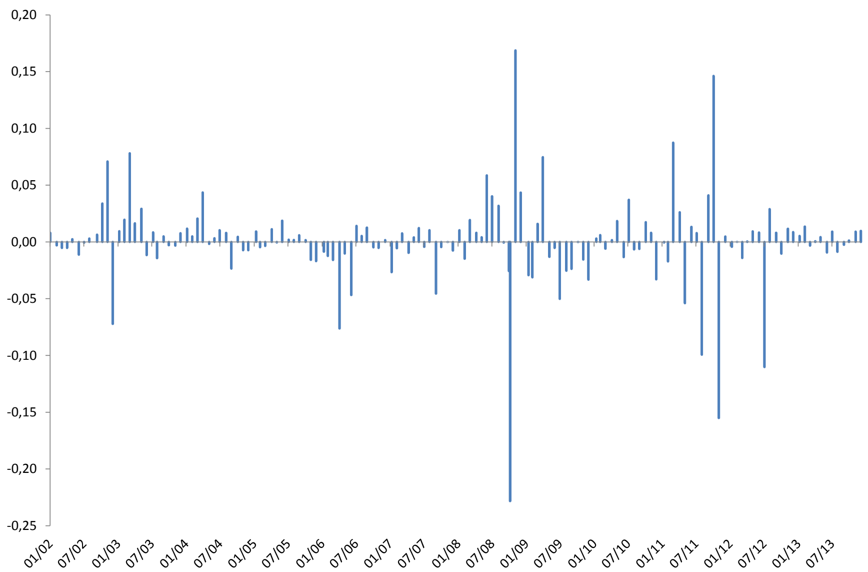
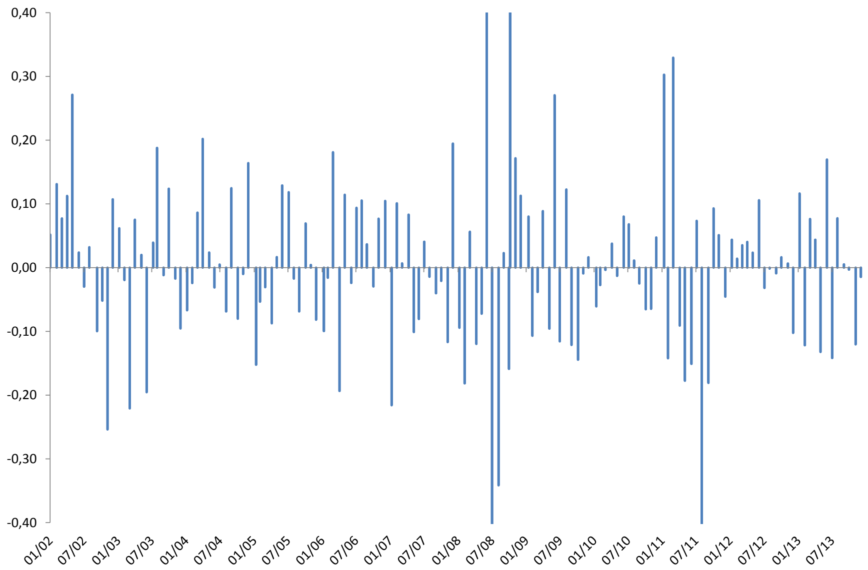


Figure 3: GSS Path Factor



3.3 Recursive Regressions

Our methodology for measuring monetary policy shocks using recursive regressions is based on Gürkaynak (2005).[14] We use the change in expectations of EONIA for the two maintenance periods following the interest rate announcement ($\Delta mp1$ and $\Delta mp2$) as well as a long-dated forward rate (Δf_6^{18}) in order to estimate three types of monetary policy shock: *jump*, *timing*, and *path*.

The *jump* shock is simply the change in expectations for the EONIA rate during the second maintenance period following the announcement:

$$jump_t = \Delta mp2_t$$

We use the change for the second and not the first maintenance period in order to account for the possibility that market participants expect a change

[14]There are two differences between our methodology and that described in Gürkaynak (2005). Firstly, in line with the language used in the previous section, we refer to *jump* and *path* factors, as opposed to *level* and *slope* factors. Secondly, we use a longer-dated forward rate in the estimation of our *path* factor.

in interest rates but are unsure whether this will be announced at the upcoming or the subsequent ECB Governing Council meeting. Such uncertainty related to the timing of expected change to interest rates could have an impact on very short-term monetary market rates. We account for this timing uncertainty by including a *timing* factor, which is the residual of the regression of the *jump* factor on $\Delta mp1$:

$$\Delta mp1_t = \alpha_1 jump_t + timing_t$$

Finally, the *path* factor is the residual of a regression of the *jump* factor on the change in the long-term forward rate:

$$\Delta f_6^{18} = \alpha_2 jump_t + path_t$$

The three shocks measured using this methodology are shown in Figures 4, 5 and 6.

Figure 4: Recursive Regressions: Jump Factor

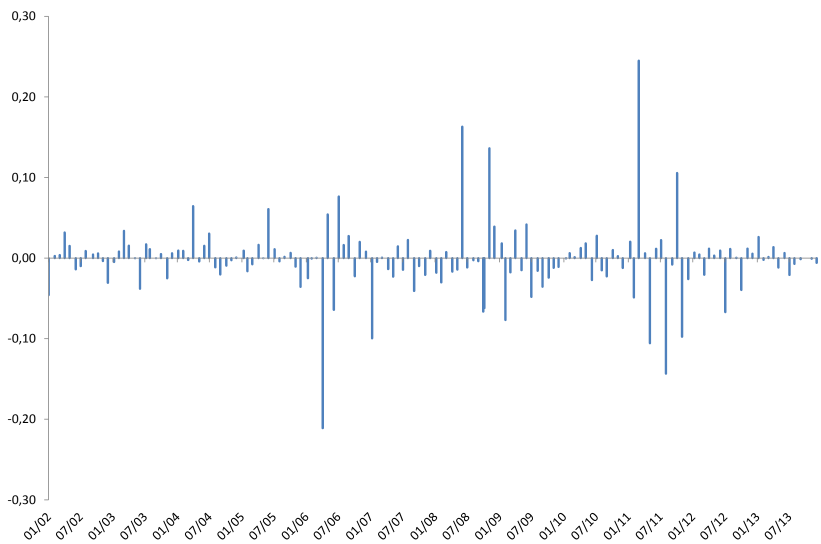
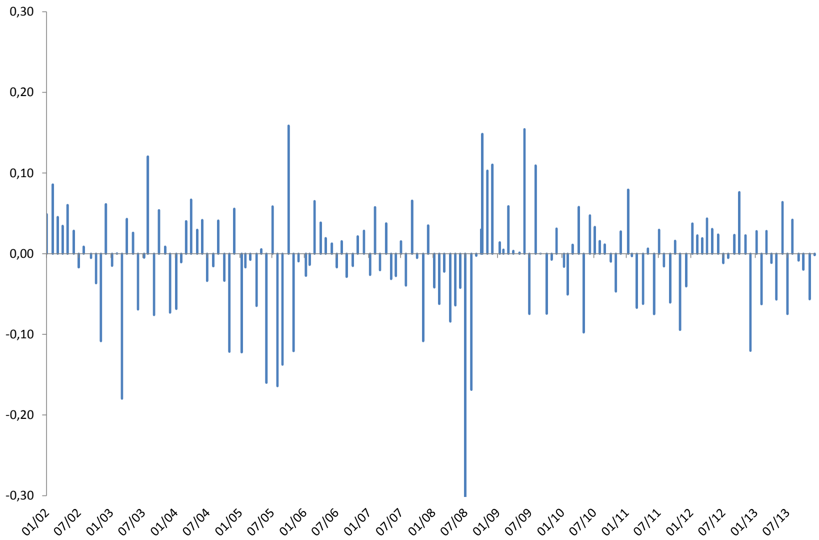


Figure 5: Recursive Regressions: Timing Factor

Figure 6: Recursive Regressions: Path Factor



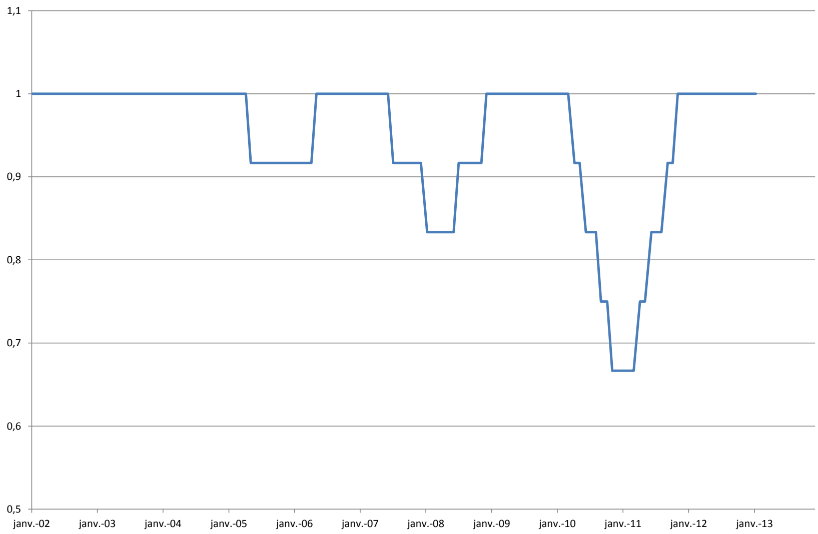
3.4 Discussion of Estimated Monetary Policy Shocks

Similar patterns can be observed in our two sets of factors. For example, both of the *jump* factors show two periods during which markets tended to be surprised by monetary policy announcements: firstly, during the months following the Lehman bankruptcy in September 2008 and, secondly, during 2011 when the ECB initially increased interest rates (April and July) and subsequently reduced them again (November and December). It is interesting to note that both of these episodes are in the post-crisis subsample, indicating that the onset of the crisis may have reduced the predictability of euro area monetary policy. This development can be observed more clearly by looking at the evolution of the ECB's *Hit Rate* over the full sample.[15] Using the *jump* factor from the recursive regressions as our measure of the (contemporaneous) monetary policy surprise, this rate equals 1 if the absolute value of the surprise is less than 10bps and 0 if not. Figure 7 shows the forward-looking 12-month moving average of this *Hit Rate*. This shows that ECB monetary policy decisions were largely anticipated by market participants prior to the crisis. A period of weak predictability arises in 2007/2008, due to two large surprises in June and November 2008. A period of still weaker predictability occurs between April 2010 and October 2011, with large monetary policy surprises on 4 occasions. This observed deterioration in the predictability of ECB monetary policy decisions since the onset of the crisis contrasts with the observation in a number of pre-crisis studies that euro area monetary policy decisions were becoming more predicable (see Blattner et al. (2008) and Brand et al. (2010)). However, as suggested by Winkelmann, Bibinger and Linzert (2014), the weakening of monetary policy predictability during these periods likely reflects a higher degree of uncertainty faced by policy makers in an environment of financial market stress.

Turning to the two measures of the *path* factors, both show some large shocks around the time of the Lehman Brother's bankrutcy but, otherwise, do not show any discernibly different pattern between the pre- and the post-crisis period. Indeed, these factors appears to be quite consistently large throughout

[15]See Blattner et al. 2008.

Figure 7: ECB Hit Values



the sample period, underlining the importance of this second element of euro area monetary policy announcements. In line with the conclusion of other studies and with the results of our Wald tests, the *timing* factor from the recursive regression analysis is generally not of a particularly large magnitude, although it also shows some instability during the two periods mentioned above.

3.5 Assessment of Non-Standard Measures

Our monetary policy shock measures allow us to gauge the announcement effect of the ECB's various non-standard monetary policy measures. It is important to note that our measures use shifts in the forward OIS curve in order to identify changes in the stance of monetary policy. However, certain non-standard monetary policy measures did not impact on these rates but instead sought to act directly on other market interest rates. For example, the ECB's Securities Markets Programme (SMP) targeted the sovereign yields of several euro area countries without seeking to change the overall stance of monetary policy. The impact of such initiatives cannot, therefore, be captured by our measures of monetary policy shocks.[16] In this section, we discuss the impact of two types of non-standard monetary policy measures that can be captured using our shocks: liquidity policies and forward guidance policies.

The first category of non-standard measures, liquidity policies, comprises a broad range of policies announced by the ECB over the course of the crisis, including the adoption and extension of the fixed-rate full allotment policy, the introduction of additional liquidity-providing operations, changes to the maturity of these operations, changes to the collateral framework, and the introduction of the additional credit claims (ACC) framework. These measures had a similar impact on the stance of monetary policy: changes to expectations of the future level of central bank reserves gave rise to changes in market participants' expectations of the spread between the EONIA rate and the ECB's main refinancing rate and, therefore, forward OIS rates.

A good example of such an impact can be seen on 4 August 2011. While the ECB did not announce any interest rate changes on this day, it announced several liquidity measures:

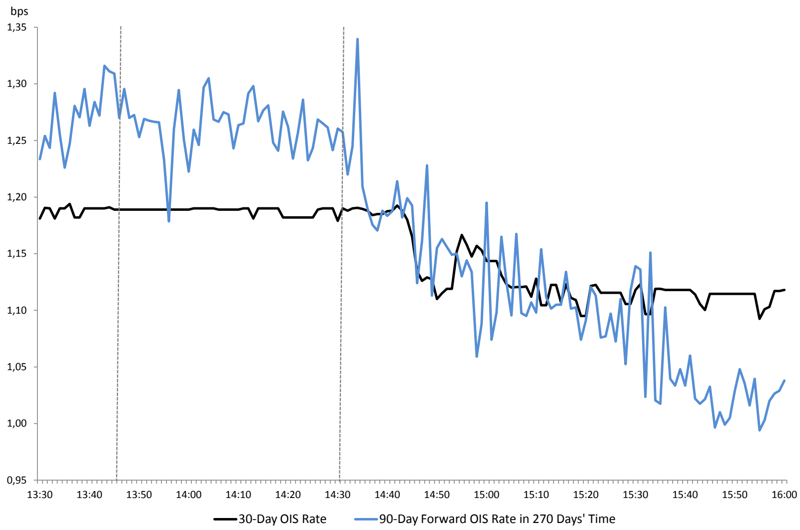
- A 6-month liquidity-providing operation to be held the following week;
- An extension of the fixed-rate full allotment policy for weekly operations until "at least until the end of the last quarter of 2011";
- A return to fixed-rate full allotment for liquidity-providing operations with a 3-month maturity.

Both of our GSS monetary policy shock factors show a relatively large negative shocks on this day: 10bps for the *jump* factor and 40bps for the *path* factor. Figure 8 shows intraday developments in the 30-day OIS rate and the 90-day forward OIS rate in 270 days time, both of which fell over the course of our window. It is noteworthy that while the 30-day OIS rate, covering the upcoming maintenance period, did not change in reaction to the press release (first vertical line), it fell over the course of the press conference.

[16] It is likely, however, that the announcement of these measure had an impact on the *path* factor through a signalling channel.

This means that information other than the level of ECB interest rates for this period caused the expected EONIA rate to fall. This most likely relates to the announcements about liquidity policies, which were released over the course of the press conference (second vertical line).[17] Figure 8 shows that longer-term forward OIS rates also fell on this day, reflecting changed expectations of liquidity conditions but also likely incorporating changed expectations for the ECB's future interest rate path. Interestingly, as shown in Figure 9, falls in forward EONIA rates were largest for the 3-month forward OIS rate in 12 months' time, suggesting that the additional easing from these liquidity measures were expected to start reversing after 15 months.

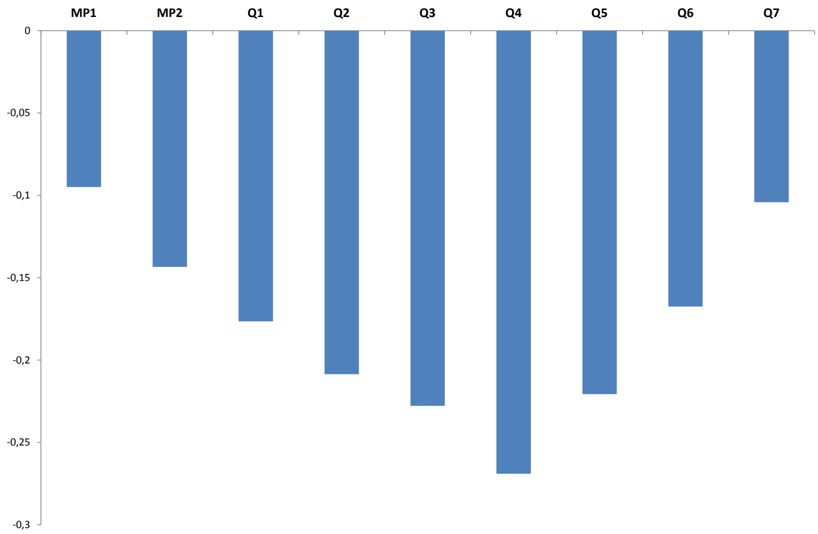
Figure 8: Forward OIS Rates: 4 August 2011



The second category of non-standard measures, forward guidance, seeks to directly influence economic agents' expectations for the future path of policy rates. The ECB adopted a forward guidance policy on 4 July 2013, with the

[17]The ECB also revealed over the course of the press conference that it had relaunched purchases of sovereign debt under the Securities Markets Programme (SMP). Uncertainty over whether these operations would be sterilised or not may have also contributed to changes in OIS rates over the course of our window.

Figure 9: Changes in Forward OIS Rates: 4 August 2011



inclusion of the following language in the President's opening statement at the press conference: "Looking ahead, our monetary policy stance will remain accommodative for as long as necessary. The Governing Council expects the key ECB interest rates to remain at present or lower levels for an extended period of time." On this day, our GSS measures show a small positive *jump* factor (Figure 10) and a large negative *path* factor (Figure 11), suggesting that the adoption of forward guidance did indeed lead to an easing of the policy stance. It is not possible to conclude, however, that this large *path* factor was due entirely to the ECB stating its expectation that rates would remain at low levels for an extended period of time. This is because the ECB simultaneously signalled the possibility of a further lowering of its policy rates. It is difficult to disentangle the two elements of this statement, limiting the usefulness of an event study analysis to assess this non-standard measure.

Figure 10: GSS Jump Factor: 4 July 2013

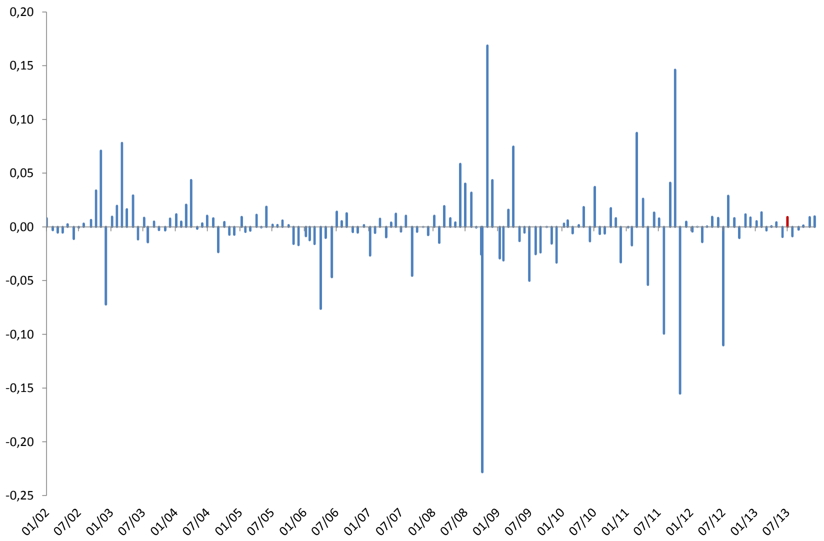
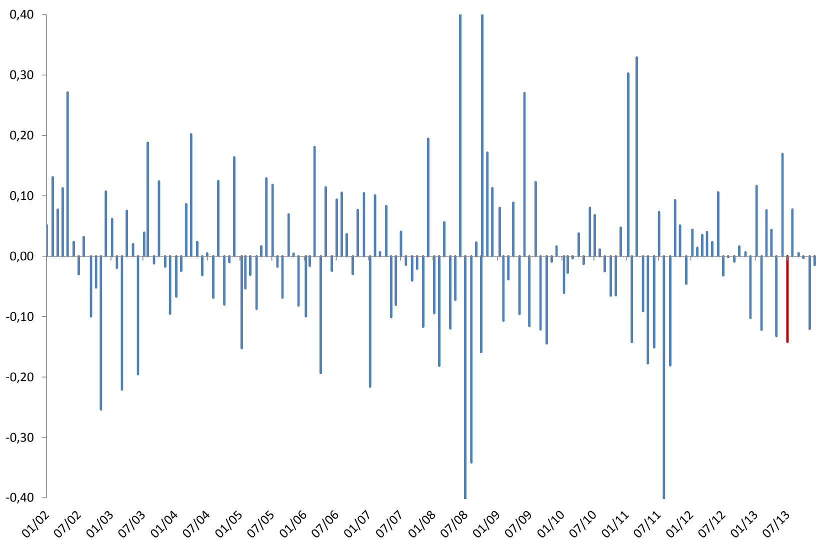


Figure 11: GSS Path Factor: 4 July 2013



4 Impact of Shocks on Asset Prices

In this section, we look at the relationship between our monetary policy shock measures (GSS and recursive regression methods) and various euro-denominated financial asset prices. We undertake this analysis using short and long-term sovereign bond rates, euro area equity prices, and the EUR-USD exchange rate. Such an analysis allows us to estimate elasticities for these asset prices vis-à-vis our monetary policy shocks. It also allows us to determine whether one set of factors is superior at explaining variation in assets price and whether prices reacted differently to monetary policy impulses before and since the onset of the financial market crisis.

4.1 Data

Our dataset of financial asset prices consists of minute-by-minute intraday data for Governing Council meeting days from the Reuters Tick History application.[18] The data cleaning process is quite similar to that undertaken for the OIS data, including the time adjustment, calculation of mid-quote figures, and differencing between 5-minute averages at the start and end of our time window. However, the raw data are tick-by-tick and not minute-by-minute, i.e., data points correspond to the appearance of a new quote from a dealer. This requires the calculation of minute-by-minute averages. Furthermore, there are several instances of missing data points at either end of the window for some series. We replace these missing data points with the average of the two adjacent quotes. In the limited number of cases where there are not two adjacent quotes, we leave the data point blank.

4.2 Sovereign Bonds

We estimate elasticities for changes in the 2-, 5- and 10-year sovereign bond yields of Germany, France, Spain and Italy over the course of our time window.

[18] We exclude observations for the ECB iterest rate announcement on 8 October 2008, i.e., an unscheduled 50bps interest rate cut made in concert with other major central banks. It is not possible to isolate the impact of the ECB announcement on asset prices on this day as several other central banks announced interest rate changes at the same time.

Each regression includes the "surprise" figure for Initial Jobless Claims and a constant term. In addition to regressions using factors estimated for the entire period, we undertake regressions using factors estimated on the pre-crisis and post-crisis sub periods. As our independent variables are constructed measures, we correct our coefficients and their standard errors using bootstrapping techniques.[19]

The results of these regressions are presented in Tables 2 to 4. Looking at the first column of results in Table 2 (German 2-year yields), we calculate that a 10bps positive *jump* (GSS) shock coupled with a 10bps postivie *path* (GSS) shock give rise to a cumulative increase of 7.5bps in the German 2-year yield (3.9bps + 3.6bps), assuming a zero Initial Jobless Claims "surprise". The same set of shocks give rise to a cumulative increase of 1.7bps in the German 10-year yield. As noted before, the *path* factor is scaled in such a way so that the 12-month forward has the same sensibility to both factors.

There are a number of observations to make on these results. Firstly, both sets of factors (in addition to the Initial Jobless Claims data) explain a large part of the variation in sovereign bond yields. For example, the GSS factors explain 93% of the variation in 2-year German bond yields and 67% of the variation in 10-year German bond yields for the "All Sample" period. Secondly, we observe that no one set of factors is consistently superior at explaining variation in yields. However, the *timing* factor from the recursive regressions is only significant in a small number of cases, reinforcing the results from the Wald tests, which indicate that only two factors are required. Thirdly, we observe that both sets of factors explain a progressively smaller part of variation in yields as maturity increases, indicating (as one would expect) that longer-term bond yields are less sensitive to monetary policy announcements.

[19]The standard errors of the coefficients presented in Tables 2 to 6 are corrected using bootstrap procedure. As a robustness check, we have also computed the standard errors by bootstrapping to capture the additional sampling error due to the fact that factors are estimated rather than directly observed. At each repetition, factors are re-estimated on a re-sampling of our observations (with replacement), also using 400 repetitions. These re-sampled observations are then used to estimate the financial asset price elasticities for each repetition. The magnitude of the estimated coefficients and standard errors are largely unchanged using this procedure and we do not report them. These results are available from the corresponding author on request.

At the same time, the magnitude of the *jump* coefficient becomes relatively smaller, compared to the *path* coefficient, as maturity increases. Indeed, the GSS *jump* factor is not statistically significant in the regressions on 10-year bond yields. These results support the conclusions in Gürkaynak et al. (2005) and Brand et al. (2010) that longer-term bond yields mainly react to changes in expectations of the future path of monetary policy.

It is noteworthy that the regression results based on the entire period show that our measures of monetary policy shocks explain a much lower proportion of the variation in Spanish and Italian yields across maturities, compared to German and French yields. An explanation for this can be found in the regression results for the pre-crisis and post-crisis periods (centre and right-hand panels). The magnitude of the coefficients and the R2s from each regression are largely similar across countries during the pre-crisis period, reflecting the generally high degree of common movement of these yields during this period. Reaction to the US Initial Jobless Claims report is also very similar, highlighting the strong impact of US data releases on expectations for the euro area monetary policy stance and, consequently, euro area sovereign yields. There is much higher heterogeneity in coefficients and R2s in the post-crisis period, however, with our monetary policy shock measures explaining a low proportion of the variation in bond yields for Spain and Italy. The R2s for France and Germany, in contrast, remain similar to the pre-crisis period. Furthermore, our monetary policy shock factors are not statistically significant in a number of the regressions using post-crisis period observations, particularly for the GSS factors. The *path* factor estimated using recursive regressions remain consistently statistically significant, however.

The smaller levels of explained variance for Italian and Spanish yields during the post-crisis period suggest that other events are driving changes in these yields during our time window. In order to determine what these events could be, we look at dates for which changes in Italian and Spanish yields were much larger or smaller than changes in German and French yields. This analysis suggests that two additional factors are important for Italian and Spanish yields during the post-crisis period. Firstly, during 2010 and 2012 there are several periods when the sovereign bond yields of these countries became very sensitive to news related to Eurosystem interventions in euro area sovereign bond markets. This appears to have begun even before the large increases in Spanish and Italian yield witnessed in 2011. For example, yields for those countries rose on 6 May 2010 following a statement by ECB President Trichet that the Governing Council had not discussed the possibility of purchasing Greek sovereign debt, despite widespread market expectations that such a measure would be announced. Unsurprisingly, Italian and Spanish yields became increasingly sensitive to such news around the time that the ECB extended its Securities Markets Program to include the sovereign bonds of those countries (August 2011) and during the months that the ECB released details of its Outright Monetary Transactions (August and September 2012). During the later part of the post-crisis period, Italian and Spanish bond yields became increasingly sensitive to changes in the monetary policy stance. For example, Spanish and Italian yields fell significantly on the day that the ECB announced its forward guidance policy, on 4 July 2013. This likely reflects a risk-taking channel of monetary policy whereby investors purchased riskier asset classes when they perceived that the ECB had further eased the bias of its monetary policy stance.

Table 2: Regression Results: 2-Year Sovereign Bonds

	All Sample				Pre-Crisis				Post-Crisis			
	DE	FR	ES	IT	DE	FR	ES	IT	DE	FR	ES	IT
GSS Factors												
Jump Factor	0.39***	0.51***	0.32**	0.10	0.47***	0.47***	0.61***	0.61***	0.40***	0.56***	0.35*	0.07
	(0.06)	(0.07)	(0.14)	(0.16)	(0.13)	(0.08)	(0.08)	(0.09)	(0.06)	(0.06)	(0.20)	(0.20)
Path Factor	0.36***	0.33***	0.29***	0.28***	0.23***	0.21***	0.21***	0.21***	0.35***	0.30***	0.19***	0.19**
	(0.01)	(0.02)	(0.03)	(0.04)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.06)	(0.10)
Initial Claims	-0.30***	-0.31***	-0.24***	-0.25***	-0.30***	-0.34***	-0.28***	-0.31***	-0.30***	-0.25***	-0.20*	-0.21
	(0.03)	(0.02)	(0.05)	(0.06)	(0.04)	(0.02)	(0.04)	(0.02)	(0.07)	(0.05)	(0.12)	(0.18)
N	142	139	144	144	81	77	82	82	61	62	62	62
r2	0.93	0.93	0.57	0.39	0.95	0.97	0.95	0.94	0.92	0.90	0.28	0.11
Recursive Regs												
Jump Factor	0.77***	0.79***	0.61***	0.45***	0.76***	0.74***	0.76***	0.75***	0.79***	0.88***	0.54***	0.24
	(0.07)	(0.05)	(0.09)	(0.13)	(0.12)	(0.09)	(0.08)	(0.10)	(0.06)	(0.05)	(0.16)	(0.25)
Timing Factor	0.03	0.16***	0.05	-0.07	0.16	0.15*	0.27***	0.29***	0.04	0.21***	0.15	0.04
	(0.08)	(0.05)	(0.15)	(0.18)	(0.11)	(0.08)	(0.09)	(0.09)	(0.10)	(0.07)	(0.24)	(0.35)
Path Factor	0.73***	0.65***	0.60***	0.66***	0.78***	0.72***	0.69***	0.69***	0.61***	0.50***	0.42***	0.62***
	(0.04)	(0.04)	(0.07)	(0.08)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.14)	(0.21)
Initial Claims	-0.30***	-0.31***	-0.24***	-0.26***	-0.33***	-0.37***	-0.31***	-0.34***	-0.25***	-0.21***	-0.19	-0.25
	(0.04)	(0.03)	(0.05)	(0.06)	(0.06)	(0.04)	(0.05)	(0.04)	(0.07)	(0.06)	(0.12)	(0.21)
N	142	139	144	144	81	77	82	82	61	62	62	62
r2	0.90	0.91	0.56	0.40	0.90	0.93	0.90	0.89	0.91	0.92	0.33	0.17

Bootstrapped standard errors in parentheses. Coefficient on the constant term is not reported.

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

Table 3: Regression Results: 5-Year Sovereign Bonds

	All Sample				Pre-Crisis				Post-Crisis			
	DE	FR	ES	IT	DE	FR	ES	IT	DE	FR	ES	IT
GSS Factors												
Jump Factor	0.18***	0.30***	0.05	0.04	0.26**	0.23**	0.24**	0.26**	0.13*	0.31***	0.12	0.10
	(0.06)	(0.08)	(0.12)	(0.17)	(0.11)	(0.10)	(0.12)	(0.11)	(0.08)	(0.10)	(0.14)	(0.25)
Path Factor	0.30***	0.30***	0.23***	0.24***	0.18***	0.18***	0.18***	0.18***	0.34***	0.32***	0.11*	0.13
	(0.01)	(0.01)	(0.03)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)	(0.03)	(0.04)	(0.06)	(0.10)
Initial Claims	-0.32***	-0.33***	-0.27***	-0.28***	-0.30***	-0.31***	-0.29***	-0.30***	-0.37***	-0.35***	-0.26**	-0.26
	(0.03)	(0.03)	(0.05)	(0.07)	(0.03)	(0.03)	(0.03)	(0.03)	(0.07)	(0.07)	(0.13)	(0.20)
N	144	140	144	144	82	79	82	82	62	61	62	62
r2	0.88	0.85	0.40	0.29	0.92	0.94	0.92	0.92	0.82	0.76	0.10	0.06
Recursive Regs												
Jump	0.55***	0.59***	0.35***	0.34***	0.56***	0.58***	0.56***	0.58***	0.54***	0.53***	0.21	0.17
	(0.04)	(0.05)	(0.09)	(0.12)	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)	(0.09)	(0.17)	(0.24)
Timing	-0.06	0.07	-0.06	-0.04	0.10	0.04	0.10	0.09	-0.11	0.19**	0.09	0.14
	(0.09)	(0.07)	(0.13)	(0.22)	(0.08)	(0.08)	(0.06)	(0.07)	(0.12)	(0.09)	(0.25)	(0.40)
Path	0.67***	0.66***	0.56***	0.60***	0.65***	0.65***	0.66***	0.65***	0.73***	0.71***	0.38***	0.50**
	(0.03)	(0.03)	(0.06)	(0.07)	(0.04)	(0.04)	(0.04)	(0.03)	(0.06)	(0.07)	(0.14)	(0.19)
Initial Claims	-0.33***	-0.32***	-0.27***	-0.28***	-0.33***	-0.33***	-0.31***	-0.33***	-0.35***	-0.34***	-0.29**	-0.32
	(0.03)	(0.03)	(0.06)	(0.07)	(0.03)	(0.04)	(0.03)	(0.04)	(0.06)	(0.07)	(0.15)	(0.21)
N	144	140	144	144	82	79	82	82	62	61	62	62
r2	0.88	0.88	0.43	0.32	0.92	0.93	0.93	0.92	0.85	0.83	0.15	0.11

Bootstrapped standard errors in parentheses. Coefficient on the constant term is not reported.

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

Table 4: Regression Results: 10-Year Sovereign Bonds

	All Sample				Pre-Crisis				Post-Crisis			
	DE	FR	ES	IT	DE	FR	ES	IT	DE	FR	ES	IT
GSS Factors												
Jump Factor	-0.01	0.09	-0.01	-0.03	0.01	0.23	-0.01	0.00	-0.04	0.04	0.05	0.02
	(0.05)	(0.08)	(0.10)	(0.15)	(0.10)	(0.22)	(0.10)	(0.10)	(0.08)	(0.09)	(0.14)	(0.18)
Path Factor	0.18***	0.16***	0.13***	0.12***	0.10***	0.10***	0.10***	0.09***	0.21***	0.17***	0.06	0.06
	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.03)	(0.06)	(0.06)
Initial Claims	-0.22***	-0.21***	-0.23***	-0.18***	-0.19***	-0.17***	-0.18***	-0.17***	-0.29***	-0.33***	-0.32**	-0.18
	(0.03)	(0.03)	(0.05)	(0.05)	(0.03)	(0.04)	(0.03)	(0.03)	(0.06)	(0.07)	(0.15)	(0.12)
N	144	144	144	144	82	82	82	82	62	62	62	62
r2	0.67	0.55	0.18	0.14	0.73	0.62	0.75	0.72	0.62	0.51	0.06	0.03
Recursive Regs												
Jump	0.26***	0.28***	0.16**	0.14	0.28***	0.35***	0.28***	0.27***	0.21***	0.20**	0.06	0.05
	(0.03)	(0.05)	(0.07)	(0.09)	(0.04)	(0.07)	(0.04)	(0.04)	(0.07)	(0.08)	(0.17)	(0.18)
Timing	-0.12	-0.01	-0.02	-0.04	-0.02	0.13	-0.05	-0.04	-0.15	0.02	0.13	0.09
	(0.08)	(0.09)	(0.13)	(0.18)	(0.08)	(0.21)	(0.08)	(0.08)	(0.11)	(0.11)	(0.29)	(0.30)
Path	0.42***	0.36***	0.35***	0.34***	0.39***	0.34***	0.38***	0.36***	0.49***	0.43***	0.28**	0.29**
	(0.04)	(0.05)	(0.05)	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)	(0.05)	(0.07)	(0.14)	(0.14)
Initial Claims	-0.23***	-0.22***	-0.23***	-0.18***	-0.21***	-0.18***	-0.20***	-0.19***	-0.28***	-0.35***	-0.36**	-0.22
	(0.03)	(0.03)	(0.05)	(0.05)	(0.03)	(0.04)	(0.03)	(0.03)	(0.07)	(0.06)	(0.17)	(0.15)
N	144	144	144	144	82	82	82	82	62	62	62	62
r2	0.69	0.59	0.21	0.17	0.75	0.66	0.78	0.75	0.65	0.59	0.10	0.06

Bootstrapped standard errors in parentheses. Coefficient on the constant term is not reported.

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

4.3 Equity Prices and Exchange Rates

We undertake a similar analysis on equity prices and exchange rates, using intraday data for the Eurostoxx 50 and the EUR-USD exchange rate. Regression results are presented in Tables 5 and 6. Focusing on the left-hand panel of Table 5 (All Sample), we see that none of our shock factors have a significant relationship with the percentage change of the Eurostoxx 50 index over the course of our window. However, we find that the GSS *jump* factor and the recursive regression *jump* and *timing* factors have an impact on equity prices during a shorter window (13:35 CET - 14:05 CET) around the ECB's press release at 13:45 CET, with the expected sign. For example, a 10bps negative *jump* factor (GSS) is associated with an increase of 40bps in the Eurostoxx 50 during this shorter window. In contrast, neither of the *path* factors have an impact during a second window surrounding the press conference (14:20 CET to 15:50 CET). These results indicate that the shock component of the ECB's press release is very quickly integrated into equity prices but that the impact is not persistent as prices subsequently react to other news, which we do not capture in our model. The speed of adjustment of equity prices with respect to *path* shocks may explain why we do not manage to capture the impact of this shock. These results largely hold when we split the sample into pre- and post-crisis subsamples. It in interesting to note that the Initial Jobless Claims announcement, which is generally made at the same time as the start of the Press Conference (14:30 CET) does not apear to have an impact on European equity prices. However, it is possible that our windows are too long to capture market reaction to this announcement.

Results of regressions using the percentage change in the EUR/USD exchange rate are shown in Table 6. Results for the entire sample show that both sets of factors explain around 25% of variation over our entire time window, with both the *jump* and *path* factors being statistically significant and of the expected sign. With regards to the GSS factors, a 10bps positive *jump* shock coupled with a 10bps positive *path* shock give rise to a cumulative 40bps appreciation of the euro. Looking at narrower time windows, it is interesting to note that the *jump* and *timing* factors are not statistically significant over the short

"Press Release" window and the R2s are very low. This would seem to indicate that the euro exchange rate does not react to the news contained in the ECB's Press Release until after the start of the Press Conference, possibly indicating that market participants wait to hear the ECB President's opening statement before making trading decisions. Again, these relationships are broadly similar both before and after the financial market crisis. The Initial Jobless Claims report does not appear to have a lasting impact on the EUR-USD exchange rate over the course of our windows.

Table 5: Regression Results: Equity Prices (Eurostoxx 50 Index)

	All Sample			Pre-Crisis			Post-Crisis		
	Full Window	Press Release	Press Conference	Full Window	Press Release	Press Conference	Full Window	Press Release	Press Conference
GSS Factors									
Jump Factor	-0.03	-0.04**		-0.09	-0.06***		-0.01	-0.04*	
	(0.03)	(0.02)		(0.06)	(0.02)		(0.03)	(0.02)	
Path Factor	0.00		-0.00	0.00		-0.00	0.00		0.01
	(0.01)		(0.00)	(0.00)		(0.00)	(0.01)		(0.01)
Initial Claims	-0.01		-0.01	-0.01		-0.02**	-0.00		0.00
	(0.01)		(0.01)	(0.01)		(0.01)	(0.02)		(0.02)
N	144	144	144	82	82	82	62	62	62
r2	0.02	0.19	0.01	0.10	0.19	0.06	0.01	0.21	0.01
Recursive Regs									
Level	-0.02	-0.02**		-0.02	0.00		-0.01	-0.03	
	(0.02)	(0.01)		(0.01)	(0.01)		(0.03)	(0.02)	
Timing	-0.02	-0.05***		-0.08	-0.07***		-0.01	-0.04	
	(0.03)	(0.02)		(0.05)	(0.02)		(0.04)	(0.03)	
Slope	0.00		-0.00	0.00		-0.01	-0.01		0.01
	(0.01)		(0.01)	(0.02)		(0.02)	(0.02)		(0.02)
Initial Claims	-0.01		-0.01	-0.01		-0.02**	-0.00		-0.00
	(0.01)		(0.01)	(0.01)		(0.01)	(0.02)		(0.02)
N	144	144	144	82	82	82	62	62	62
r2	0.02	0.23	0.01	0.10	0.26	0.05	0.01	0.23	0.00

Bootstrapped standard errors in parentheses. Coefficient on the constant term is not reported.

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

Table 6: Regression Results: EUR-USD Exchange Rate

	All Sample			Pre-Crisis			Post-Crisis		
	Full Window	Press Release	Press Conference	Full Window	Press Release	Press Conference	Full Window	Press Release	Press Conference
GSS Factors									
Jump Factor	0.03**	0.00		0.06**	-0.00		0.00	0.00	
	(0.01)	(0.01)		(0.02)	(0.01)		(0.02)	(0.01)	
Path Factor	0.01***		0.01***	0.01***		0.01***	0.02***		0.02***
	(0.00)		(0.00)	(0.00)		(0.00)	(0.01)		(0.00)
Initial Claims	0.00		0.00	0.01		0.01	-0.01		-0.01
	(0.01)		(0.01)	(0.01)		(0.01)	(0.01)		(0.01)
N	144	144	144	82	82	82	62	62	62
r2	0.25	0.00	0.28	0.24	0.00	0.22	0.37	0.00	0.48
Recursive Regs									
Level	0.04***	-0.00		0.04***	-0.00		0.03**	-0.00	
	(0.01)	(0.01)		(0.01)	(0.00)		(0.02)	(0.01)	
Timing	-0.00	0.00		0.02	-0.00		-0.01	0.01	
	(0.01)	(0.01)		(0.02)	(0.01)		(0.02)	(0.02)	
Slope	0.02***		0.02***	0.01		0.01	0.05***		0.04***
	(0.01)		(0.01)	(0.01)		(0.01)	(0.01)		(0.01)
Initial Claims	0.00		0.00	0.00		0.01	-0.01		-0.01
	(0.01)		(0.01)	(0.01)		(0.01)	(0.01)		(0.02)
N	144	144	144	82	82	82	62	62	62
r2	0.24	0.00	0.08	0.25	0.00	0.05	0.35	0.01	0.20

Bootstrapped standard errors in parentheses. Coefficient on the constant term is not reported.

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

5 Conclusions

In this paper, we have used high frequency financial market data in order to measure euro area monetary policy shocks and estimate their impact on financial asset prices in a short window around ECB monetary policy announcements. In doing so, we have emphasised the two time components of monetary policy shocks: one related to the current level of short-term interest rates (*jump* factor) and another related to the expected future path of short-term interest rates (*path* factor). We have investigated different methods for measuring monetary policy shocks along these two time dimensions. In doing so, we confirm the existing finding in the literature (Gürkaynak et al., 2005, Brand et al., 2010) that at least two factors are required to explain the movement in the money market curve in a short window around monetary policy announcements. Finally, we examine the elasticities of various financial asset prices to our monetary policy shock measures and confirm the finding that these measures explain a large part of the variation in such prices in a short window around monetary policy announcements.

In addition to testing the number of latent factors required to explain movements in the euro money market curve for the entire sample (2002-2013), we have undertaken the same test for the crisis period (starting with the adoption of the ECB's full-allotment policy in October 2008). We find that two factors continue to be sufficient to explain variation in the money market curve during this period. This finding is somewhat surprising, particularly in view of the range of non-standard monetary policy measures adopted by the ECB during this period. We therefore conclude that such additional information is captured by our forward-looking monetary policy shock, i.e., the *path* factor. Such a finding indicates that the methodologies proposed by Gürkaynak et al. (2005) and Gürkaynak (2005) provide powerful tools for summarising information communicated by central banks.

As part of our analysis of the elasticities of financial asset prices to our monetary policy shock measures, we have tested for changes in these elasticities between the pre- and post-crisis period (as defined above). For some of the asset classes examined (FX rates and equity values) we find no major changes in the relationships. This is also the case of sovereign bond yields of "core" euro area countries (Germany and France in this study). This is not the case for "stressed" euro area countries (Spain and Italy), with our monetary policy shock measures explaining a much lower degree of the variation in these yields in the post-crisis period compared to the pre-crisis period. We document how these yields became increasingly sensitive to other ECB policy announcements during this period, particularly those related to the purchase of sovereign bonds and other assets. In the later part of our sample, these yields appear to react more strongly to changes in the ECB's monetary policy stance, possibly highlighting the increased relevant of the risk-taking channel of monetary policy at the zero lower bound for interest rates. Such observations highlight the changed nature of the transmission of monetary policy in recent years and how this mechanism can be affected by sovereign stress.

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A Calculation of EONIA Expectations for Forthcoming ECB Maintenance Periods

Our data set includes market expectations of EONIA rates during the two maintenance periods following ECB interest rate announcements. These expectations are calculated using OIS rates and a count of the number of days in maintenance periods.[20] Given the close relationship between EONIA and the ECB's Main Refinancing Rate, changes in these expectations provide a more precise measure of short-term monetary policy shocks than unadjusted forward rates. Our methodology for constructing these expectations is similar to the one used in Gürkaynak et al. (2005).

The interest rate on an OIS contract at time t can be seen as a weighted-average of the daily EONIA rates expected over the course of that contract. If we assume that the EONIA rate is stable over the maturity of a maintenance period and that a 30-day OIS contract can cover a maximum of two maintenance periods[21], we can express the 30-day OIS rate prior to an ECB interest rate announcement as:

$$OIS(30)_{t-\Delta t} = \frac{d1}{30} r_0 + \frac{30 - d1}{30} E_{t-\Delta t}(r_1) + \rho 1_{t-\Delta t}$$

where $d1$ corresponds to the number of days remaining in the current maintenance period, r_0 is the current EONIA rate, r_1 is the EONIA rate expected to prevail in the next maintenance period, and $\rho 1$ is the risk premium present in the contract. Differencing this equation with the 30-day OIS rate at the end of the announcement window (time t)[22], we can define the change in r_1 ($MP1$) as:

$$MP1 = (OIS(30)_t - OIS(30)_{t-\Delta t}) \frac{30}{30 - d1}.$$

[20] We construct this day count using information published on the ECB's website.

[21] In our data set, 5 observations out of a total of 145 do not conform to this second assumption, i.e., the first maintenance period after the interest rate announcement is particularly short and a 30-day OIS contract covers three maintenance periods. We do not adjust our methodology to account for this, leading to a small bias in our calculated expectations on these days.

[22] We assume that the risk premium does not change over this period

A similar methodology is used to calculate the change in the EONIA rate expected to prevail during the second maintenance period following the interest rate announcement. The 30-day forward OIS rate in 30 day's time (f_m^1) before the interest-rate announcement can be expressed as a weighted average of the expected EONIA rate during the next two maintenance periods:

$$f^1_{m,t-\Delta t} = \frac{d2}{30}E_{t-\Delta t}(r_1) + \frac{30-d2}{30}E_{t-\Delta t}(r_2) + \rho 2_{t-\Delta t}$$

where $d2$ is the number of days that the forward rate covers during the first maintenance period, $E(r2)$ is the EONIA rate expected to prevail during the second maintenance period, and $\rho 2$ is the risk premium contained in the forward rate. Differencing the forward rates observed before and after the announcement (and assuming a constant risk premium), we can define the change in r_2 ($MP2$) as:

$$MP2_t = [(f^1_{m,t} - f^1_{m,t-\Delta t}) - \frac{d2}{30}MP1_t]\frac{30}{30-d2}.$$

B Factors rotation methodology

Let $F = [F_1 F_2]$ denote the first two principal components and $Z = [Z_1 Z_2]$ the two rotated factors. Following the notations used in GSS (2005), let the rotated factors Z be related to the initial factors F through the following relationship:

$$Z = FU \tag{3}$$

with

$$U = \begin{pmatrix} \alpha_1 & \beta_1 \\ \alpha_2 & \beta_2 \end{pmatrix} \tag{4}$$

The matrix U is identified by the following restrictions:

- Z_1 and Z_2 are orthogonal:

$$\alpha_1\beta_1 v_1 + \alpha_2\beta_2 v_2 = 0 \tag{5}$$

with $v_1 = E(F_1'F_1)$ and $v_2 = E(F_2'F_2)$

- Z_1 and Z_2 have unit variance:

$$\alpha_1^2 v_1 + \alpha_2^2 v_2 = 1 \tag{6}$$

$$\beta_1^2 v_1 + \beta_2^2 v_2 = 1 \tag{7}$$

- Z_2 does not influence $\Delta MP1$. Let denote γ_1 and γ_2 the loading of $\Delta MP1$ on F_1 and F_2, respectively. It follows that:

$$\gamma_2 \alpha_1 - \gamma_1 \alpha_2 = 0 \tag{8}$$

The system composed by restrictions (5), (6), (7) and (8) is solved to identify the matrix U.

Finally Z_1 and Z_2 are rescaled to Z_1^* and Z_2^* in such a way that Z_1^* moves one-for-one with $\Delta MP1$ and sensibilities of Δf_6^{12} to Z_2^* and Z_1^* are equal. More precisely, $Z_1^* = \xi_1 Z_1$ and $Z_2^* = \frac{\varsigma_2}{\varsigma_1} Z_2$ where ξ_1, ς_1 and ς_2 are coefficient estimates from the regression:

$$\begin{aligned} \Delta MP1 &= \xi_0 + \xi_1 Z_{1,t} + \varepsilon_{1,t} & (9) \\ \Delta f_6^{12} &= \varsigma_0 + \varsigma_1 Z_{1,t}^* + \varsigma_2 Z_{2,t} + \varepsilon_{t,2} & (10) \end{aligned}$$

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