

# THE IMPACT OF ECB MONETARY POLICY DECISIONS AND COMMUNICATION ON THE YIELD CURVE

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## Abstract

We use intraday changes in money market rates to construct indicators of news about monetary policy stemming separately from policy decisions and from official communication of the European Central Bank, and study their impact on the yield curve. We show that communication may lead to substantial revisions in expectations of monetary policy and, at the same time, exert a significant impact on interest rates at longer maturities. Thereby, the maturity response pattern to communication is hump-shaped, whereas that to policy decisions is downward-sloping. (JEL: E43, E58)

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## 1. Introduction

Recent advances in the theory of monetary policy emphasise that the success of monetary policy does not depend solely on the effective control of short-term interest rates, but also on the central bank's ability to shape market expectations of how interest rates and inflation are likely to evolve over time. Nowhere is this view as concisely summarised as in Woodford's widely quoted statement, "Not only do expectations about policy matter, but ...very little *else* matters" (Woodford 2003, p. 15).

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Over the last few decades increased emphasis on transparency and accountability has led central banks to more open and detailed communication, increasing the potential for communication to contribute to stabilising private sector expectations about the central bank's response to changes in the state of the economy. Central banks have gone to great lengths to explain their goals and make their decisions understood by the private sector. Communication has come to be recognised as an important requirement for monetary policy to be successful (see Blinder et al. 2008 for a survey). In turn, financial market participants have increasingly used central bank communication to revise their expectations about future short-term interest rates. In constructing indicators of monetary policy it has therefore become important to capture the information contained in central bank communication in addition to that contained in interest rate decisions.

The objective of this study is to use high frequency data on money market interest rates to construct multi-dimensional indicators of monetary policy news (capturing central bank communication and monetary policy decisions) and analyze their impact on the yield curve. Specifically, we decompose intraday changes in the euro area money market yield curve on European Central Bank (ECB) Governing Council meeting days into news related to the level (and timing) of the ECB policy interest rate and news related to the future path of monetary policy.

In constructing indicators of monetary policy news relating separately to monetary policy decision and communication we take advantage of the salient feature that the ECB announces and explains policy decisions on two different time instances within the same day. We find that news stemming from the communication of ECB monetary policy have a more substantial and longer-lasting impact on the euro area yield curve than news stemming from decisions on policy interest rates.

The contribution of our study is two-fold. First, the institutional feature that the ECB announces and explains policy decisions at two different points in time during the day allows us to construct direct measures of policy news that relate separately to the decision and to the communication dimensions. We compare these direct measures with previous indirect measures that are constructed using econometric techniques on time windows that contain both decision and communication news, as in the case of the Federal Reserve studied by Gürkaynak, Sack, and Swanson (2005) and Gürkaynak (2005). These studies show that intraday changes in federal fund futures on Federal Open Market Committee meeting days can be characterised by at least two factors—with one factor relating to the Federal Reserve's policy decisions and the other to communication about the future path of policy interest rates.

Second, we extend existing evidence of the financial market impact of the ECB's monetary policy decisions and communication in a number of dimensions. We provide first evidence of news about ECB monetary policy using multidimensional indicators, resulting in a richer description of news about monetary policy compared to studies that focus on single-factor indicators. A number of studies

have used single-factor indicators to study very short-term news about policy decisions (see Kuttner (2001) for an early contribution to this literature). These indicators are commonly based on information derived from (daily) changes in money market interest rates or surveys of financial market participants. For example, Perez-Quiros and Sicilia (2002) use daily changes in the 1-month EONIA swap rates, and Ehrmann and Fratzscher (2003) utilise the difference between mean expectations of the policy decision among ECB watchers from the Reuters poll one week before the decision and the actual policy outcome. Other European studies have used information from EURIBOR futures (Bernoth and von Hagen 2004; Wilhelmssen and Zaghini 2005).

We also provide first evidence of news stemming from ECB communication based on high frequency money market data. We treat intraday changes in money market yields around the time of the release of the Governing Council's interest rate decision and the press conference as containing all relevant information about changes in monetary policy. This approach can be justified by the absence of other relevant data releases during the narrow time window.

The use of money market data also allows us to identify the news component of ECB communication without relying on subjective indicators. Several authors have constructed indicators based on counting code words in the ECB Introductory Statement or the Monthly Bulletin editorial (Meyer 2004; Musard-Gies 2005; Rosa and Verga 2005; Gerlach 2007; Heinemann and Ullrich 2007). Using the indicator developed in Musard-Gies (2005), both Musard-Gies (2005) and Sebestyén and Sicilia (2005) find that the tone of ECB communication has an impact on both short- and long-term interest rates in the euro area. An alternative approach is taken by Ehrmann and Fratzscher (2005, 2007). They construct indicators of the tone in speeches and statements made by Governing Council members between Governing Council meetings. These indicators are then used to construct measures of dispersion about the views of the economic outlook and monetary policy, and to study the implications for the predictability of monetary policy. There are evident shortcomings to such approaches, however. The meaning of the subjective indicators may not coincide with how financial markets understand new information about monetary policy. By construction, subjective indicators cannot possibly reflect all the information that is used by financial markets when forming expectations about monetary policy. First, these indicators rely on the assumption that a central bank uses language and certain code words in a highly consistent manner. Second, these indicators confound information as to whether the tone detected in announcements is meant to explain a decision that had been taken, or to provide signals about an upcoming decision in the next meeting, or about policy actions at much longer horizons.<sup>1</sup>

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1. Our analysis captures the reactions of financial market participants to monetary policy announcements and communication as they are reflected in market prices. Information about the underlying thought processes that led market participants to react the way they did may be captured by alternative subjective indicators.

After constructing a set of multidimensional indicators of monetary policy news, we utilise these indicators to analyse the impact of monetary policy decisions and communication on the yield curve. A large literature on announcement effects using U.S. data documents a significant impact of policy decisions and macroeconomic data releases on long-term yields (Fleming and Remolona 1999; Piazzesi 2005). We focus on the impact of policy news on interest rates of different maturities. This aim differs from earlier studies of the euro area that have looked at the impact on volatility. For example, Sebestyén and Sicilia (2005) use daily data and an EGARCH model of volatility for a number of asset prices with different maturities and find that ECB communication results in increased market volatility. Using intraday data, Andersson, Hansen, and Sebestyén (2009) confirm that volatility in German bond markets increases within tight time windows around the ECB press conference.

Our results suggest that, according to the size and evolution of indicators of monetary policy news developed in this paper, market participants have recently been in a better position to anticipate the course of monetary policy than in the past. The results also suggest that ECB communication during the press conference may result in significant changes in market expectations of the path of monetary policy. Furthermore, our results support the use of indirect econometric methods to construct measures of news from central bank communication. Indeed, our indicators of news corresponding to ECB communication extracted with the different econometric methodologies give information that is consistent with the information obtained from a direct measurement on the communication window. Finally, with regard to the impact of monetary policy news on the yield curve, our results show that changes in expectations of the course of monetary policy triggered by ECB communication have a statistically significant and sizeable impact on medium- to long-term interest rates. At the same time, news about immediate policy decisions have an impact only at shorter maturities. Specifically, the maturity response pattern to communication is hump-shaped, whereas that to policy decisions is downward-sloping. These results are consistent with those obtained for the U.S. (Gürkaynak 2005; Gürkaynak, Sack, and Swanson 2005).

The remainder of the paper is structured as follows. In Section 2 we motivate different ways of constructing indicators of monetary policy news relating to different time horizons. To this end, we review in more detail how and when the ECB announces and explains its monetary policy decisions taken at its regular monthly rate-setting meeting and how money market interest rates tend to evolve on those days. In Section 3 we describe the various statistical methods adopted to construct indicators of monetary policy news. In Section 4 we discuss how the resulting indicators have evolved over time, and compare and validate them by explaining specific events. Based on these indicators, we provide an analysis of the impact of monetary policy news on the euro area yield curve in Section 5. We

conclude in Section 6. A data description and a number of methodological details are presented in the Appendices.

## 2. Institutional Features of ECB Decision Making and Communication

The Governing Council—the decision-making body of the ECB—meets regularly on a monthly basis to discuss monetary policy.<sup>2</sup> The release of monetary policy news on Governing Council meeting days has the following structure. Immediately after the Governing Council meeting, the ECB publishes its monetary policy decision at 13:45 Central European Time (CET). The publication consists of a short press release that states which interest rate decision was taken. Three quarters of an hour later, beginning at 14:30 (CET), the ECB holds a press conference where the President of the ECB explains this decision in detail. At the beginning of the press conference the President of the ECB reads an Introductory Statement that provides a comprehensive summary of the assessment of economic and monetary developments, followed by a short explanation of the decision taken by the Governing Council. This part of the press conference is usually over by about 14:45 (CET). After the Introductory Statement, the President is then available for about half an hour to answer questions that relate to considerations underlying the policy decision.

The clear separation of how the ECB releases information relating to monetary policy decisions and communication is a feature that allows us to use different time windows to construct indicators of monetary policy news. We consider three different time windows. The first time window, which we call the “long window” (from 13:35–15:50 CET), captures news relating to both monetary policy decisions and communication of the ECB. Statistical techniques are then applied to interest rate changes over this long window to separate news relating to interest rate decisions and communication. In addition to the “long window,” we consider two narrow time windows – a “decision window” (from 13:35–14:05 (CET)) and a “communication window” (from 14:20–15:50 (CET)). These narrow windows allow us to directly isolate the effects of monetary policy news on money market interest rates stemming separately from ECB policy decisions and ECB communication without needing to resort to statistical tools. As such, they provide a natural benchmark to which the statistically extracted indicators can be compared. Figure 1 shows a graphical representation of the three time windows that are used. The precise timings of when the policy decision is published and when the press conference begins are also shown in Figure 1.

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2. Since November 2001 the meetings are scheduled for the first Thursday of the month. Exceptions occur during the summer recess and around the turn of the year. Before November 2001, Governing Council meetings took place at fortnightly intervals: a press conference followed only after the first meeting of the month, however.

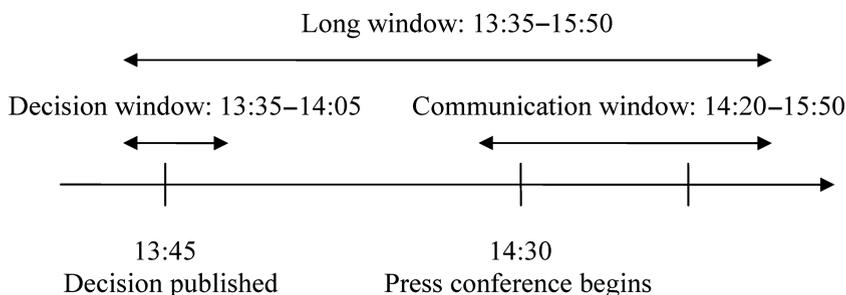


FIGURE 1. Graphical representation of the Long, Decision, and Communication windows.

It is instructive here to provide two illustrative episodes of how quickly money market interest rates react to monetary policy news from ECB decisions and communication, and how the constructed time windows capture such news. Figure 2 shows the minute-to-minute evolution from 13:35 to 15:50 (CET) of the 60-day money market interest rate on two specific instances.<sup>3</sup> The dashed line (RHS) in Figure 2 shows the evolution on 10 May 2001 when the ECB decided to lower its key policy interest rates by 25 basis points—a move that had not been anticipated by financial markets. Note that it took less than 10 minutes for money market interest rates to adjust to the announced change in key ECB interest rates. At the same time money market rates did not change in response to the explanation of the interest rate decision given subsequently by the ECB during the press conference starting at 14:30 (CET).

The solid line (LHS) in Figure 2 shows the evolution of the 60-day rate on 6 April 2006, when interest rates were mainly affected by communication. Although financial markets had attached a significant probability to an interest rate hike in May 2006, no immediate policy change was expected at the meeting on 6 April. As there was, in fact, no change in official interest rates on that day, they remained stable at the time of the publication of the ECB decision at 13:45 (CET). The first ten minutes of the press conference during which the President read out the Introductory Statement (14:32–14:42 (CET) on that occasion) did also not show any noticeable changes in money market interest rates. Yet following the start of the question and answer session, when the President stated that “the current suggestions regarding the high probability of an increase of rates in our next meeting do not correspond to the present sentiment of the Governing Council,” money market interest rates declined visibly. The 60-day rate dropped by about 8 basis points within the next 45 minutes and stabilised at a lower level roughly an hour after the press conference had started.

These two episodes illustrate the following important observations. First, they show that the adjustment in market interest rates takes place immediately

3. A description of the data is provided in Appendix A.

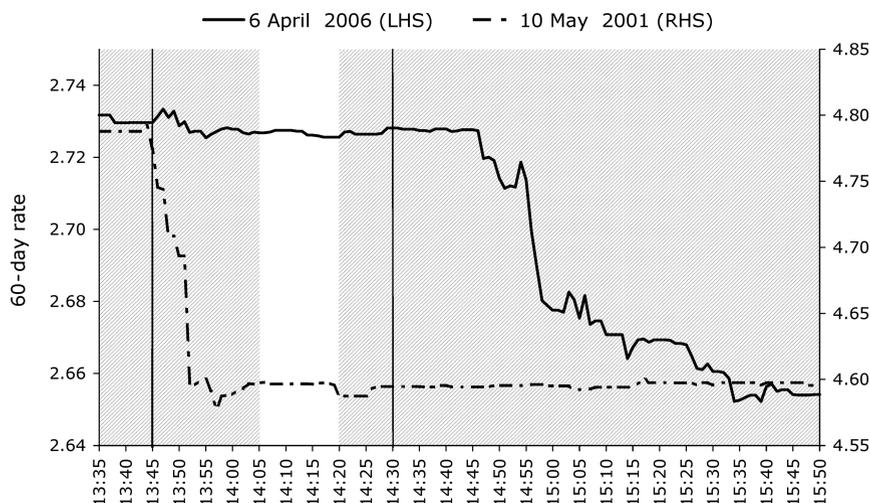


FIGURE 2. Intraday developments in the 60-day yield to maturity on 10 May 2001 and 6 April 2006. The vertical lines at 13:45 and 14:30 indicate the release of the monetary policy decision and the start of the press conference, respectively. The shaded areas indicate the Decision and the Communication windows.

after news about monetary policy become available. This observation is consistent with a number of empirical studies that find the euro area money market to be efficient in incorporating new information rapidly. (see Bernoth and von Hagen (2004), Hartmann, Manna, and Manzanares (2001), and Sebestyén (2006) for further evidence in different segments of the euro area money market). Second, the episodes show that our windows are wide enough to capture the time the market needs to absorb the news, yet they are narrow enough to prevent the indicators from becoming contaminated by other news releases on that day. The only other data that are released during the time span captured by our time windows are weekly initial unemployment claims for the U.S. at 14:30 (CET). This release coincides with the beginning of the ECB's press conference. In Section 3.4 we assess the potential difficulty in trying to isolate the effects of monetary policy news relating to ECB communication and U.S. initial unemployment claims.

### 3. Extracting News from the Money Market Yield Curve

We use high frequency changes in money market forward rates to extract indicators of monetary policy news. An exact description of the data used to construct the changes in the forward rates is given in Appendix A. In Appendix A we also briefly discuss how to filter out erroneous and outdated quotes and provide additional information regarding the liquidity of the market interest rates.

The sample period covers the regular Governing Council meeting days from 30 November 2000 through to 5 July 2007. The policy decision taken at the unscheduled Governing Council meeting on 17 September 2001 was excluded from the sample.

Three different methods are used to extract monetary policy news from changes in forward rates. These are discussed subsequently. To formalise the different approaches, let  $f_t^\tau$  denote the implied 10-day money market forward rate  $\tau$  days ahead, as extracted from the discount curve. Furthermore, let  $\Delta f_t^\tau$  denote the change in the implied forward rate over the time window under consideration. Changes in the forward rates 10, 30, and 150 days ahead are thereby labelled as  $\Delta f_t^{10}$ ,  $\Delta f_t^{30}$  and  $\Delta f_t^{150}$ . We identify high-frequency changes in forward rates 30 days ahead as news relating to monetary policy decisions. This is motivated by the fact that, since November 2001, the Governing Council has been meeting on a monthly basis to decide on policy interest rates. In this context, notice also that we do not explicitly decompose forward rate changes at high frequencies into changes in forward premia and expectations. At high frequencies, term premia are assumed to remain constant, so that they cancel out from the changes in forward rates (see also the discussion in Gürkaynak 2005, pp. 6–7).

### 3.1. Rotated Factors

A first method of extracting monetary policy indicators relating to different time horizons corresponds to the factor model approach as employed in Gürkaynak, Sack, and Swanson (2005). Let the factor model representation for  $Y$  be expressed in the following general form

$$Y = F\Omega' + \eta, \quad (1)$$

where  $Y$  is a  $T \times N$  matrix of data,  $F$  is a  $T \times k$  matrix of  $k$  unobserved factors with  $k < N$ ,  $\Omega'$  is a  $k \times N$  matrix of factor loadings, and  $\eta$  is a  $T \times N$  matrix of idiosyncratic disturbance terms. Matrix  $\Omega$  contains the eigenvectors of  $\text{Cov}(Y)$  and  $F$  is computed in the standard way as  $F = Y\Omega$ . The  $Y$  matrix was chosen to consist of  $\{\Delta f_t^{10}, \Delta f_t^{30}, \Delta f_t^{160}, \Delta f_t^{240}, \Delta f_t^{360}\}_{t=1}^T$ . The changes in the forward rates are those corresponding to the long time window (13:35–15:50 (CET)) and thus cover the policy announcement and the press conference.

We employ the reduced rank test of Cragg and Donald (1997) to determine the minimum number of factors that are necessary to sufficiently account for the variation in the data matrix  $Y$ .<sup>4</sup> We gave preference to this test, rather than to the more recently proposed tests by, for example, Bai and Ng (2002), as the

4. The computational details of this test are outlined in Gürkaynak, Sack, and Swanson (2005, pp. 87–88). We thank Eric Swanson for providing the Matlab code to perform this test.

column dimension of  $Y$  is fairly small. The asymptotic distribution of these more recent tests relies upon both the  $T$  and  $N$  dimension of the data matrix to go to infinity. The results of the reduced rank test are reported in the column under the “Long Window” heading in Table B.1 in Appendix B. From the results reported in Table B.1 it is evident that the null hypothesis that two factors are sufficient to account for most of the variation in  $Y$  cannot be rejected at the 1% level of significance.

Because the two factors that we extract from  $Y$  have no structural interpretation, we follow the approach in Gürkaynak, Sack, and Swanson (2005) and rotate the factors in such a way that the first one is labelled *jump* news and the second one, which is restricted so that it does not load into the short end of the forward rate curve, *path* news. That is, changes at the short end of the forward curve are identified as jump news, whereas changes at longer maturities that are not related to jump news are identified as path news. The computational details of this factor rotation are given in Appendix C. Note that, because the original (unrotated) factors obtained from principal component analysis are orthogonal by construction, the rotated factors are also orthogonal.

### 3.2. Recursive Regressions

The second approach to construct indicators of monetary policy news draws on a recursive regression decomposition proposed by Gürkaynak (2005). In addition to the jump and path factors, this decomposition also allows for a third news component, which is labelled *timing*. The rationale for this decomposition is as follows. Financial markets may anticipate a policy move of a certain size by a specific date. For example, an anticipated 50-basis-point cut in policy interest rates may have been anticipated by a certain date, but whether it is delivered fully on the first meeting within a month, or on the second meeting within a month, or in two consecutive 25-basis-point cuts might not be fully anticipated.

The three news factors are identified in the following recursive way. First, the change in the 30-day forward rate is defined to capture the jump component of monetary policy news, so that  $jump_t \equiv \Delta f_t^{30}$ . The timing component can then be obtained by filtering out the jump component from the changes in the 10-day forward rate. The path component is isolated by removing the jump and timing surprises from the changes in the forward rate 5 months ahead. This approach can be formalised by defining *timing* <sub>$t$</sub>  and *path* <sub>$t$</sub>  news as the residuals from the following recursive regressions:<sup>5</sup>

5. To evaluate the robustness of the choice of horizons, we have also performed the analysis using 20, 40 and 150 days instead. Both the jump and path news are unaffected by the use of these alternative horizons. These results are available from the authors upon request.

$$\Delta f_t^{10} = \alpha_0 + \alpha_1 \text{jump}_t + \text{timing}_t, \quad (2)$$

$$\Delta f_t^{150} = \gamma_0 + \gamma_1 \text{jump}_t + \gamma_2 \text{timing}_t + \text{path}_t. \quad (3)$$

As a result of the decomposition, the jump component corresponds to unanticipated changes in the policy interest rate, whereas the timing component relates to changes that may have been anticipated in terms of their magnitude, but not in terms of their timing. The path component captures the effect of changes in money market interest rates of longer-term maturities that are neither due to jump nor timing surprises. This recursive identification process is similar to that undertaken in the context of VAR models (see Gürkaynak 2005, pp. 14–15). Although, in principle, alternative identifying schemes also appear justifiable, for reasons of comparability with U.S. studies we decided to follow this particular scheme. The  $R^2$  of the regressions in equations (2) and (3) are 0.60 and 0.25, respectively, indicating that  $\Delta f_t^{10}$  is largely composed of jump news and  $\Delta f_t^{150}$  of path news.

The limited relevance of timing news across the sample is not surprising. Instances of unexpected interest rate changes at lower-than-monthly maturities have been rare and are constrained to the sample period prior to November 2001. Since November 2001 the Governing Council has met once a month to discuss interest rates.<sup>6</sup>

The regressions further suggest that for longer horizons it is important to clean out the impact of short-term news of monetary policy, as a quarter of the changes in forward rates at, for example, the 150-day horizon are still explained by changes at shorter horizons.

### 3.3. *Separate Decision and Communication Windows*

The third approach makes direct use of the salient feature that ECB interest rate decisions and the explanation of these decisions to the public are 45 minutes apart. Financial markets know the actual interest rate decision for already three quarters of an hour before the press conference begins. Any changes in forward rates during the press conference can, therefore, only be due to communication news and cannot contain news relating to the jump and/or timing components.

As a viable alternative approach, we thus segregate the measurement period into a decision and communication window. The first window, spanning from 13:35–14:05, is used to construct jump and timing news that relate to the interest

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6. In Section 4 we show that measured timing news are mostly of an insignificant size after November 2001. There is only one major exception related to the decoupling of money market interest rates from the ECB's minimum bid rate due to underbidding in the main refinancing operations. Changing the maturities to decompose timing and jump news at the monthly frequency would come at the cost that the timing news (which may have been more meaningful at fortnightly frequencies) observed in the pre-2001 period would be lost.

rate decision. That is, we define  $jump_t^D \equiv \Delta f_{t,D}^{30}$  and obtain  $timing_t^D$  again as the residual from the regression

$$\Delta f_{t,D}^{10} = \alpha_0^D + \alpha_1^D jump_t^D + timing_t^D, \quad (4)$$

where  $D$  indicates that this change occurs over the time span captured by the decision window. The  $R^2$  of this regression is 0.67. This provides additional confirmation that, also within the narrow decision window, the relevance of *timing* news is limited in our sample. The communication window, from 14:20–15:50, is used to get a direct measure of the path news. This is done by defining  $\Delta f_{t,C}^{150} \equiv path_t^C$ , where  $C$  indicates the change over the communication window.<sup>7</sup>

On 17 days within our sample period no press conference was held, and hence, in effect, no path news was measurable. These occasions fall into the pre-November 2001 period during which there were two scheduled Governing Council meetings a month, but with only one press conference after the first meeting of the month. As no official news was released during the communication window, we set news relating to the path component equal to zero on such days.

### 3.4. Initial Unemployment Claims

U.S. weekly initial unemployment claims are published on Thursdays at 14:30 (CET). This release coincides with the beginning of the press conference held by the ECB. It is, therefore, necessary to assess the possibility that weekly initial unemployment claims could influence the construction of our indicators of monetary policy news. For the recursive decomposition approaches outlined in Section 3.2 and Section 3.3, we thus included initial unemployment claims as a control variable in the regressions in equations (2), (3) and (4).<sup>8</sup> The coefficient

7. Again we test for the number of relevant factors using the reduced rank test on the communication window. The results are reported in the column under the ‘‘Communication Window’’ heading in Table B.1 in Appendix B. The null hypothesis that two factors are sufficient to account for most of the variation in  $Y$  cannot be rejected at the 1% level of significance. Correlation analysis of the two (unrotated) factors shows that the first factor, accounting for more than half of the variance, is closely related to both, the direct measure of communication (with a correlation coefficient of 0.88) and the two indirect measures of path news (with correlation coefficients of 0.51 and 0.68). This supports our view that most of the changes occurring during the communication window relate to communication about monetary policy relevant for the future path of interest rates. In contrast, the second factor is not correlated with any of the measures of monetary policy news. We therefore speculate that the second factor may reflect the remaining impact of other news, such as occasional releases of macroeconomic data, occurring during the communication time window. Neither factor is correlated with the first (unrotated) factor from the decision window, suggesting that the path news that we measure from the communication window are not contaminated by the possible impact of lingering decision news.

8. Due to different timing of moving to daylight saving in Europe and in the U.S. there exist three occasions when the U.S. initial unemployment claims data are released at 13:30 (CET) instead of 14:30 (CET). Because the release of the data on these three occasions occurs outside our considered time windows, we set the values on those occasions to zero.

estimates on initial unemployment claims were not only statistically insignificant, but also very small. We therefore decided to exclude this variable in the construction of the regression based surprise measures.

For the rotated factor approach outlined in Section 3.1 we assessed the impact of initial unemployment claims on the extracted surprises by regressing the rotated path and jump factors  $z_1$  and  $z_2$  on initial unemployment claims. This also resulted in statistically insignificant coefficients. To allow for the possibility of a non-linear impact of initial unemployment claims on the news components, we further inspected cross-plots of  $z_1$  and  $z_2$  against initial unemployment claims, with a super imposed non-parametric regression fit. We found no evidence of a non-linear relationship between the extracted surprises and initial unemployment claims. We therefore concluded that the construction of our monetary policy surprises was not contaminated by the release of initial unemployment claims in the U.S. on that day.

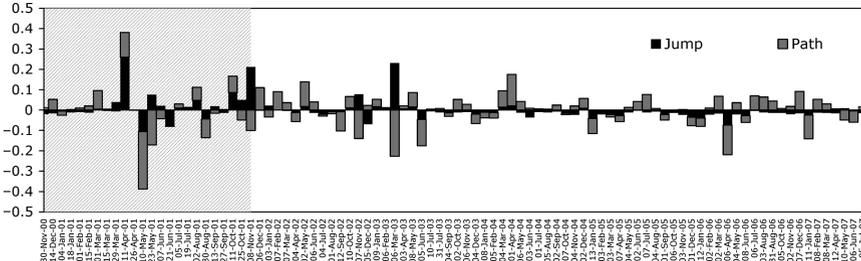
## 4. Evolution of Monetary Policy News Over Time

### 4.1. Main Results

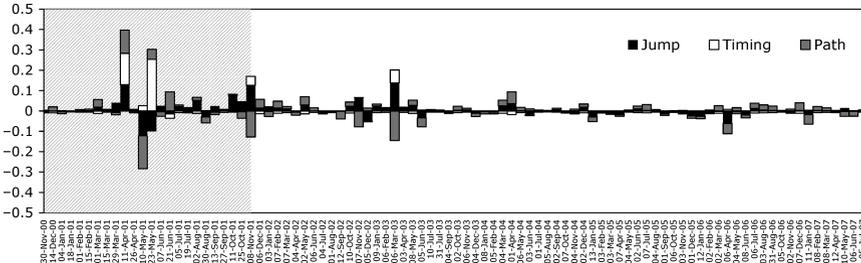
The resulting three sets of multi-dimensional indicators of monetary policy news are plotted in Figure 3. Panels (a), (b), and (c) in Figure 3 show the indicators obtained from the rotated factors, the recursive regressions, and the two narrow decision and communication windows, respectively. Positive entries denote, in percentage points, an unanticipated tightening of money market interest rates for each of the respective monetary policy surprises. These are jump and timing at the short end of the money market yield curve, and path relating to changes in expectations about the course of monetary policy several months out.

It is evident from Figure 3 that on average, the total size of monetary policy news appears to be relatively small. Across the methods the average of the absolute surprise component ranges between 1.4 and 2.8 basis points for jump and between 2.0 and 4.1 for path indicators. As expected, surprises related to timing are on average smaller (approximately 1 basis point). The size of the news indicators, in particular those related to monetary policy decisions, seems to have declined over the years, potentially reflecting improved short-term predictability of ECB interest rate decisions over time (see also Blattner et al. 2008). Indeed, the largest jump indicators are concentrated in the first two years of the sample period. Conversely, since the beginning of 2002, path news appears to have become relatively more important.

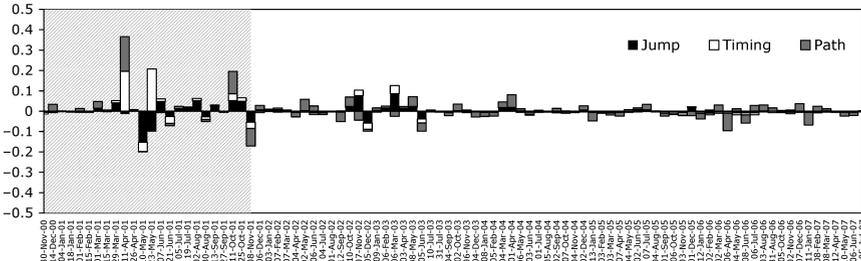
A comparison of the indicators across all methods shows a high degree of consistency. For example, the jump surprise from the rotated factor approach is strongly positively correlated with the jump news from the recursive regressions,



(a) Monetary policy news extracted from rotated factors.



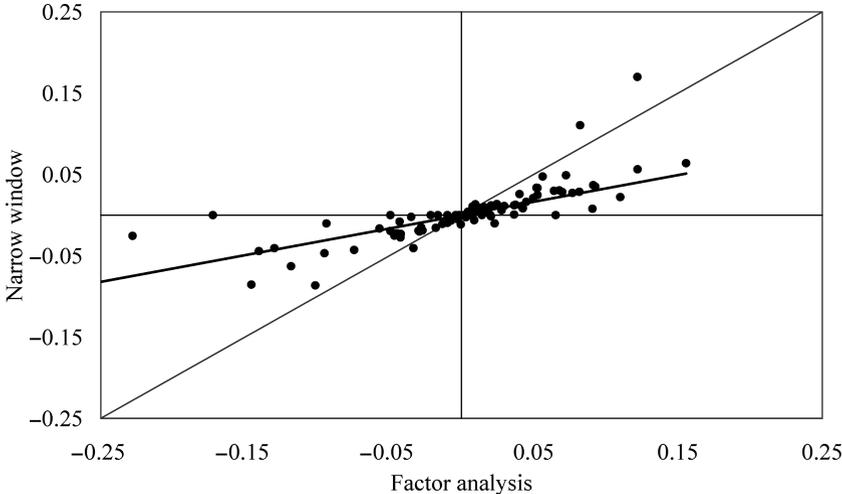
(b) Monetary policy news extracted from recursive regressions.



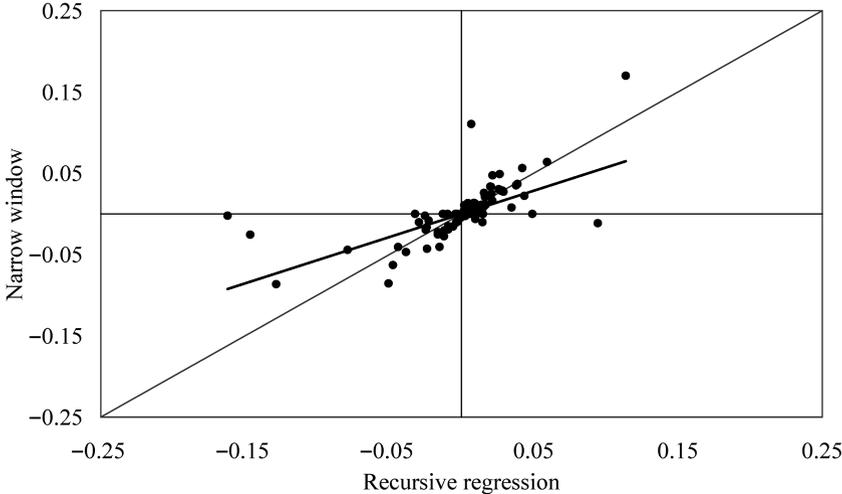
(c) Monetary policy news extracted from the partitioned decision and communication windows.

FIGURE 3. Extracted jump, timing, and path news of monetary policy. The shaded area marks the period between 30 November 2000 and 8 November 2001 during which Governing Council meetings took place at fortnightly intervals. The only exception is the 30 August 2001 meeting where there were four weeks between consecutive meetings.

with a correlation coefficient of 0.84. Path news extracted from the indirect statistical methods are closely related to the path measure constructed directly from the narrow communication window. This can be seen from Panels (a) and (b) in Figure 4, which show the direct path measure cross-plotted against path news computed from the factor model and the recursive regressions, respectively. The correlations corresponding to these cross-plots are 0.65 and 0.70. Also, for the majority of the 17 occasions when no official ECB press conference was held, and hence when path news from the communication window was set to zero,



(a) Path factor from factor analysis against communication window.



(b) Path factor from recursive regressions against communication window.

FIGURE 4. Crossplot of path news across methods.

path news extracted from the statistical methods was very small. Overall, the evidence suggests that the statistical methods for computing communication news of monetary policy are consistent with the direct path measure constructed from the communication window.

In order to verify that our surprise measures correspond to news about monetary policy, we have performed a robustness analysis and constructed indicators

from changes in forward rates over the same time windows on Thursdays when no Governing Council meetings took place. The surprises constructed on such non-Governing-Council meeting days are substantially smaller, yielding average absolute surprises ranging between 0.3 and 0.6 basis points for jump and 0.7 and 1.1 for path news, respectively. These results are indicative of our conjecture that movements in forward rates on Governing Council meeting days are largely due to news about monetary policy. Note that these results are also in line with the findings reported in Ehrmann and Fratzscher (2009), who study market reactions to ECB press conferences.

#### **4.2. *Interpreting Specific Events***

Our measures of monetary policy news are consistent with a narrative approach to specific episodes informed by knowledge about monetary policy and macro-economic circumstances. To illustrate this, we plot snapshots of the money market yield curve, over 1 to 150 days to maturity, on 10 May 2001, 1 April 2004, and 11 April 2001 in Panels (a) to (c) in Figure 5. The three time instances that we look at are 13:35, 14:05 (corresponding to before and after the announcement of the policy decision), and 15:50 (marking the end of the press conference).

Panel (a) of Figure 5 shows an example of an episode where the three different methodologies consistently bear out the same nature of news. The ECB cut official interest rates by 25 basis points on 10 May 2001, which had not been priced in by financial markets. The parallel downward shift in the money market curve following that decision is consistently identified as jump news by all three approaches. As is evident from Panel (a) of Figure 5, this adjustment took place within the time of the “decision window.” The money market curve did not move at all during the “communication window,” suggesting that market expectations regarding the path of monetary policy remained unaltered on the basis of information provided during the press conference.

Between June 2003 and November 2005 there were no changes in ECB policy interest rates. Although financial markets do not appear to have been surprised by the actual interest rate decisions as such during this period, our measures suggest that some re-adjustment of expectations about the future path of interest rates took place in response to ECB communication. For example, in spring 2004, macro-economic data indicating only modest growth in euro area economic activity and a number of shocks (including, among others, the March terrorist attacks in Madrid and excessive exchange rate volatility) led markets to attach a higher probability to interest rate cuts at some point, although no immediate change was expected at the Governing Council meeting of 1 April 2004. Policy interest rates did, in fact, remain unchanged at that meeting. But when the Introductory Statement to the press conference was read out, the remark that the current monetary policy stance remained in line with price stability triggered an upward shift in the money market

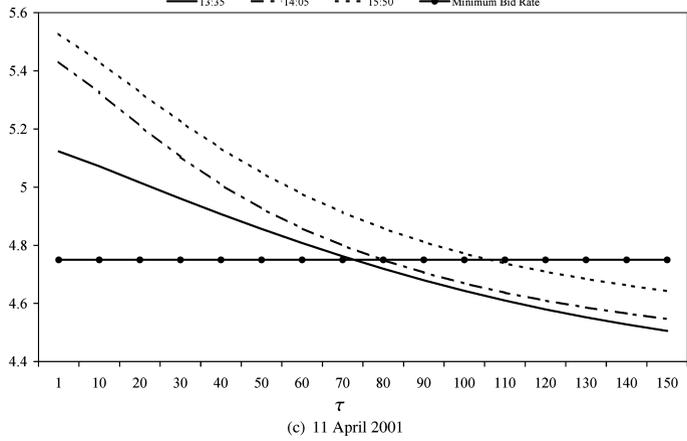
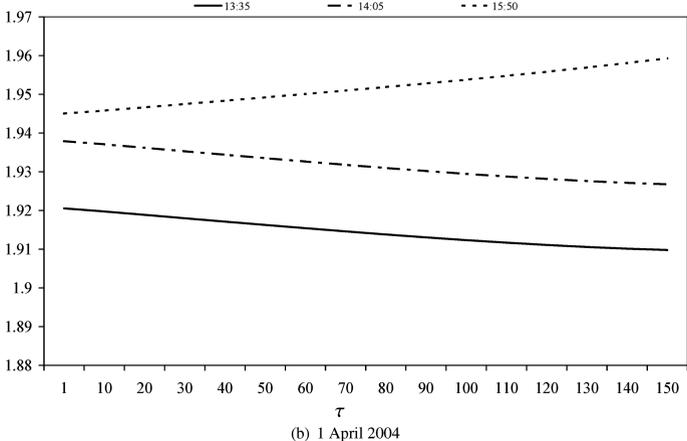
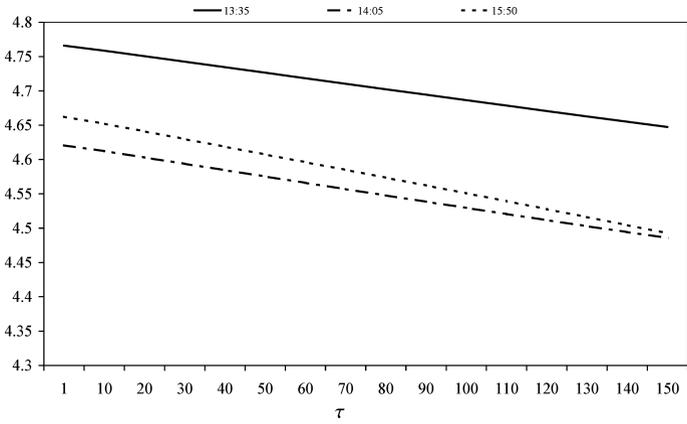


FIGURE 5. Money market rates as of 13:35, 14:05, 15:50 CET on various dates.

curve at longer maturities (see Panel (b) of Figure 5). This shift is consistently identified as positive path news across all three methods.

Although the indicators from the three different approaches provide overall consistent information about monetary policy news, a few occasions exist when they are not fully aligned. For instance, the period around early 2001, marking the beginning of a series of cuts in policy interest rates, was characterised by relatively large volatility in measured news. Although there was no cut in official interest rates on 11 April 2001, changes in money market interest rates nevertheless appear to suggest that financial markets had expected a cut in official interest rates. The tone of the ECB at the press conference was perceived by many as signalling a “wait and see” attitude, leading to an upward revision of expectations about future rates in monetary policy. On this particular instance, whereas the three different surprise measures correctly identify the changes in the money market curve as “tightening news,” they were associated with timing news from the recursive regression approach as well as from the separate time windows, and to jump news from the rotated factor approach.

This inconsistency in the surprise measures is due to the following. The episode in spring 2001 falls into a period during which the short-end of the money market yield curve was affected by underbidding in the ECB’s main refinancing operations. This is evident from Panel (c) of Figure 5, which shows the money market yield curve and the ECB’s minimum bid rate marked by the horizontal line at 4.75%. Money market interest rates of shorter maturities were largely detached from the level of the minimum bid rate. A similar episode occurred in March 2003. The impact of underbidding on money market interest rates varied across maturities. Because the indicators do not build on the same information set, but rather rely on yields of different maturities, the results are not entirely conclusive on these few occasions.

Overall, the quantitative description of changes in policy expectations from the constructed indicators match a judgmental assessment—informed by macroeconomic developments and the substance of ECB communication—of market developments. This supports the use of these indicators as a promising and coherent tool to analyse the response of assets prices to the different types of monetary policy news.

## **5. Impact of Monetary Policy News on Longer-Term Yields**

ECB Governing Council meeting days are widely regarded as special events by financial markets because of their ability to trigger comparatively strong reactions in bond and stock prices. For U.S. data, there exists a large literature on announcement effects which documents a significant impact of policy decisions and macroeconomic data releases on long-term yields. For example, on the basis of affine term-structure models, using high frequency data as in Fleming and

Remolona (1999) and Piazzesi (2005), the literature has identified a hump-shaped maturity response pattern in relation to macroeconomic news and a downward-sloping pattern in relation to monetary policy announcements. But this analysis has largely been restricted to modelling monetary policy in terms of changes in policy interest rates, neglecting information on monetary policy relating to longer horizons. Using the multi-dimensional indicators developed in the previous section, we analyse the impact of ECB monetary policy on longer-term yields. We also provide a comparison of our results to those obtained in Gürkaynak, Sack, and Swanson (2005) and Gürkaynak (2005) for the U.S.

To assess the impact of monetary policy on yields, we run the following sequence of regressions:

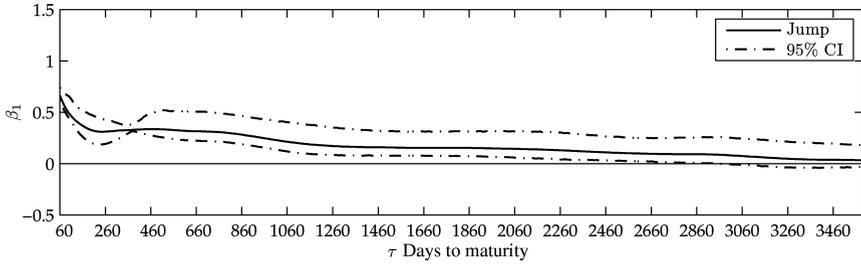
$$\Delta y_t^\tau = \boldsymbol{\beta}' \mathbf{I}_t + \varepsilon_t, \quad (5)$$

where  $\Delta y_t^\tau$  is the change in the  $\tau$  days ahead yield, for all  $\tau = 60, 70, 80, \dots, 3650$ , namely, over the long time window, including the decision and press conference. Including a constant,  $\mathbf{I}_t$  consists of the monetary policy indicators obtained from using the methods described in Section 3. As discussed previously, due to U.S. initial unemployment claims being released within this time window, we included initial unemployment claims ( $jobs_t$ ) as a control variable in  $\mathbf{I}_t$ .  $\mathbf{I}_t$  thus takes the form  $\mathbf{I}_t = (1, jump_t, timing_t, path_t, jobs_t)'$ .

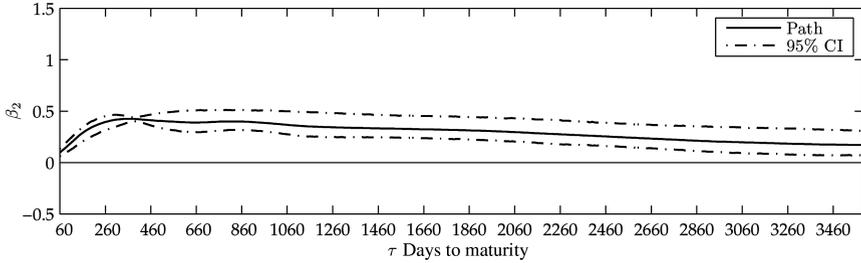
As shown earlier, the elements of  $\mathbf{I}_t$  are constructed variables. When computing standard errors of the estimate of  $\boldsymbol{\beta}$  it thus becomes important to account for the extra sample variation that arises from this construction. We compute the standard errors in two different ways. First, for the factor-based approach, we resort to re-sampling techniques. We use a non-parametric bootstrap to compute confidence bounds for  $\boldsymbol{\beta}$  in (5).<sup>9</sup> The results from regressing jump and path news on  $\Delta y_t^\tau$  for maturities  $\tau = 60, 70, 80, \dots, 3650$  with bootstrapped 95% confidence intervals are shown in Figure 6. Second, for the sequential regressions in equations (2), (3), and (5), we derive asymptotic confidence bands. Because the sequential regressions can be thought of as a sequential Method of Moments (MOM) estimation problem, it is possible to derive the correct asymptotic variance of  $\boldsymbol{\beta}$  analytically, taking account of the multiple estimation steps.<sup>10</sup> The derivation of this asymptotic variance is provided in Appendix D. Figure 7 shows the estimates of the effects

9. We employed two approaches in the non-parametric bootstrap. First, we treated the data as if they were iid. Second, we utilised a block bootstrap procedure to ensure that neighbouring news components were drawn together. This was done to preserve the structure of the components during certain volatile periods. Drawing blocks of size three leads to adequate re-sampling properties. However, there were no noticeable differences in the size of the standard errors (or the shape of the distribution) between the block bootstrap procedure and the standard iid one. We therefore decided to only report the results based on the iid draws. Bootstrapped 95% confidence intervals were computed as the 2.5% and 97.5% percentiles from 10,000 draws.

10. Note that for the factor-based model described, it is, in principle, also possible to write down a set of moment conditions for the estimation of the factors. However, it is not clear how the rotation of the factors impacts on the variance.



(a) Impact of the jump factor  $z_1$  on changes in yields with bootstrapped confidence bounds.



(b) Impact of the path factor  $z_2$  on changes in yields with bootstrapped confidence bounds.

FIGURE 6. Impact of news from the rotated factors from principal component analysis on yields at maturities  $\tau = 60, 70, 80, \dots, 3650$  (based on wide time window).

of jump, timing, and path news on  $\Delta y_t^\tau$  for maturities,  $\tau = 60, 70, 80, \dots, 3650$  together with 95% asymptotic confidence bounds. Last, the impact of monetary policy news on yield changes from the two narrow windows is presented in Figure 8, also with 95% asymptotic confidence bands.

We summarise the results of the impact of monetary policy surprises on the yield curve by reporting point estimates and regression  $R^2$  over a range of different maturities in Table 1. The maturities of the yields were chosen to correspond to those considered by Gürkaynak, Sack, and Swanson (2005) and Gürkaynak (2005) for the U.S. Their regression results are also reported in Table 1 to provide a comparison. In addition to the regression results we provide a variance decomposition which shows the contribution of each surprise component to the  $R^2$ . Because in a simple regression with one explanatory variable the  $R^2$  corresponds to the proportion of variance that is explained by the regressors, we can think of the individual squared correlations between the yield changes and the regressors as a decomposition of the  $R^2$ . This is possible here because the individual news components in the regressions are by construction orthogonal to each other.<sup>11</sup>

11. For the partitioned decision and communication windows, only the jump and timing components are orthogonal by construction. The correlation between path, and jump and timing components are respectively 0.11 and 0.12. The difference between the sum of the individual contributions to the  $R^2$  and the  $R^2$  is, as a consequence of this correlation, thus somewhat larger.

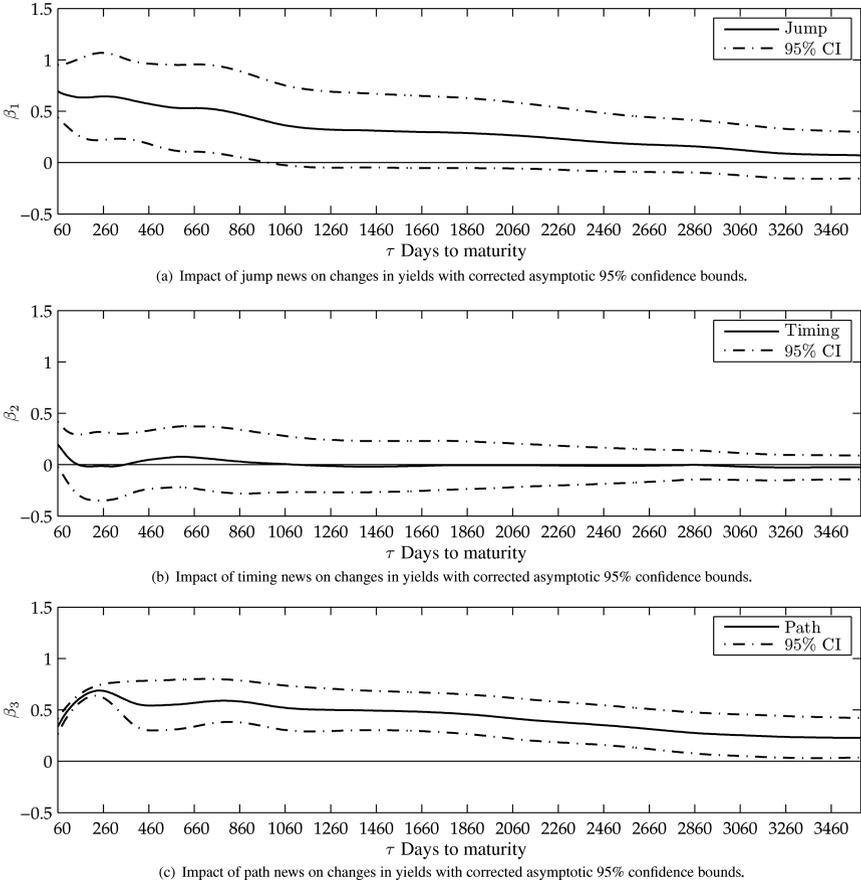


FIGURE 7. Impact of news from recursive regression analysis on yields of maturities  $\tau = 60, 70, 80, \dots, 3650$  (based on wide time window).

Notice from the results reported in Table 1 that the sum of the contributions to  $R^2$  do not exactly add up to the  $R^2$ . This is due to the initial unemployment claims variable  $jobs_t$  being included in the regressions which, although only very mildly correlated with the news components, is nevertheless not orthogonal by construction.<sup>12</sup>

The results reported in Table 1 show that overall the different dimensions of monetary policy news is crucial in distinguishing how monetary policy affects the yield curve across the maturity spectrum. Jump and path news have similar

12. The correlation between jobs and the individual news components extracted from the three approaches ranges between  $-0.05$  and  $0.14$ .

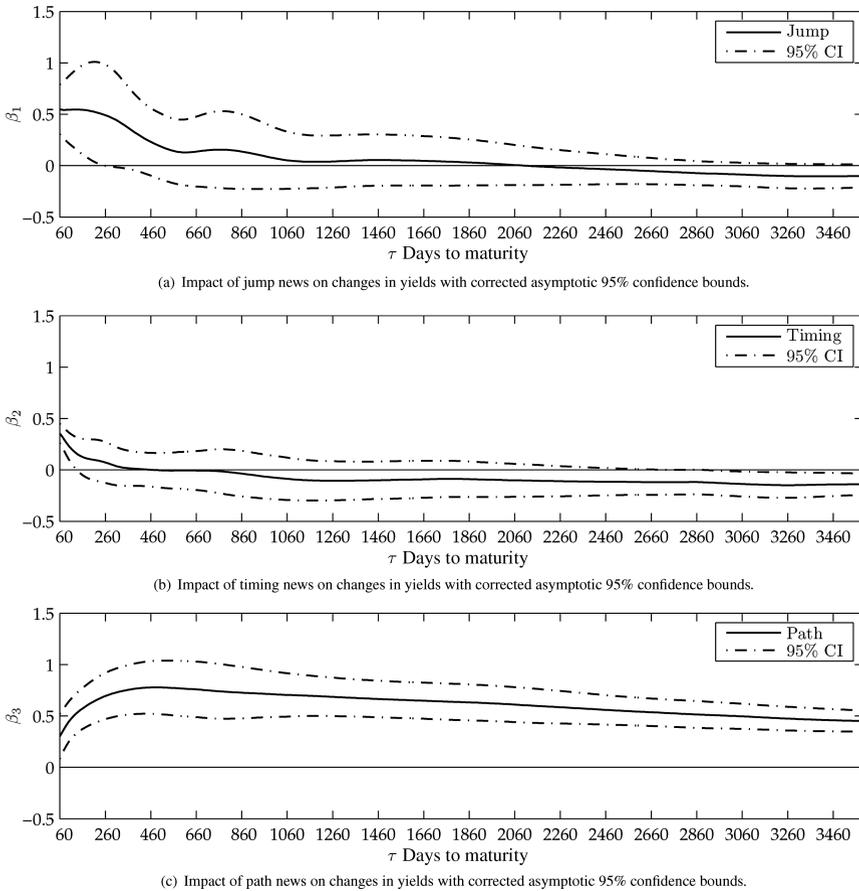


FIGURE 8. Impact of news from recursive regression analysis on yields of maturities  $\tau = 60, 70, 80, \dots, 3650$  (based on the the partitioned decision and communication windows).

impacts at shorter maturities and account for nearly all of the explained variance in the impact regressions (as shown by their contributions to the regression  $R^2$ ). Jump news tends to have an impact predominantly on short to medium-term maturities and exhibits a downward-sloping maturity response pattern. Timing news is mostly insignificant, except for the shortest maturities. Finally, irrespective of the method used to extract news about the future path of interest rates, path news has a statistically significant and sizeable impact across all maturities and exhibits a hump-shaped maturity response pattern. As these news mainly relate to ECB communication during the press conference, our results point to a significant role for central bank communication in shaping the impact of monetary policy on financial markets.

TABLE 1. Comparison of  $\beta$  estimates from US and Euro (EUR) data.

Maturity	Country	Factor Analysis				Recursive Regressions				Partitioned Windows					
		Jump	Path	Jobs	$R^2$	Jump	Timing	Path	Jobs	$R^2$	Jump	Timing	Path	Jobs	$R^2$
1/2 Year	US	-	-	-	-	<b>0.60</b>	<b>0.35</b>	<b>0.38</b>	-	0.81	-	-	-	-	-
180 Day	EUR	<b>0.34</b>	<b>0.32</b>	0.01	0.87	<b>0.65</b>	0.04	<b>0.54</b>	0.00	0.98	<b>0.55</b>	<b>0.18</b>	<b>0.50</b>	<b>-0.01</b>	0.71
Contribution to $R^2$		0.33	0.53	0.00		0.54	0.00	0.44	0.00		0.30	0.17	0.45	0.00	
2 Year	US	<b>0.48</b>	<b>0.41</b>	-	0.94	<b>0.64</b>	0.10	<b>0.96</b>	-	0.69	-	-	-	-	-
720 Day	EUR	<b>0.31</b>	<b>0.39</b>	-0.03	0.87	<b>0.53</b>	0.07	<b>0.57</b>	<b>-0.03</b>	0.70	0.14	-0.01	<b>0.76</b>	<b>-0.03</b>	0.57
Contribution to $R^2$		0.22	0.63	0.03		0.28	0.00	0.37	0.03		0.03	0.08	0.53	0.03	
5 Year	US	<b>0.28</b>	<b>0.37</b>	-	0.80	<b>0.40</b>	-0.01	<b>0.81</b>	-	0.45	-	-	-	-	-
1800 Day	EUR	<b>0.15</b>	<b>0.32</b>	-0.03	0.70	<b>0.29</b>	-0.01	<b>0.47</b>	<b>-0.03</b>	0.55	0.04	-0.09	<b>0.64</b>	<b>-0.03</b>	0.53
Contribution to $R^2$		0.08	0.59	0.05		0.13	0.00	0.37	0.05		0.01	0.04	0.48	0.05	
10 Year	US	<b>0.13</b>	<b>0.28</b>	-	0.74	<b>0.22</b>	0.02	<b>0.60</b>	-	0.32	-	-	-	-	-
3650 Day	EUR	0.03	<b>0.17</b>	-0.03	0.39	0.07	-0.03	<b>0.23</b>	<b>-0.03</b>	0.26	-0.10	-0.14	<b>0.45</b>	<b>-0.03</b>	0.47
Contribution to $R^2$		0.01	0.39	0.08		0.01	0.00	0.15	0.08		0.01	0.00	0.35	0.08	

Notes: Bold entries denote significance at the 5% level. Figures for the US entries are taken from Table 5 in Gürkaynak, Sack, and Swanson (2005) and Table 3 in Gürkaynak (2005). Contributions to  $R^2$  are the squared pairwise correlations between the yield changes and each individual regressor.

A comparison of the indicators across methods shows a high degree of consistency. This is especially the case for the factor-based approach, where there is a close methodological match between our study and the results obtained in Gürkaynak, Sack, and Swanson (2005). Yet, unlike in the U.S., the timing component turns out to be irrelevant.

In line with previous literature on announcement effects (e.g., Fleming and Remolona 1999; Gürkaynak, Sack, and Swanson 2005; and Gürkaynak 2005), the regressions in equation (5) involve yields to maturity on the left-hand side. Therefore, in addition to an independent impact of news, changes in yields at longer maturities might merely reflect changes in short-term interest rates at shorter maturities. Therefore, as a robustness check we compare our yield curve regressions with regressions on forward rates. Specifically, we run the sequence of regressions in equation (5) with  $\Delta y_t^\tau$  replaced by  $\Delta f_t^\tau$ —the implied forward rate changes—on the left-hand side of the equation. Although these regression coefficients, of course, exhibit some volatility across maturities, their qualitative pattern is consistent with that of the yield regressions reported above. In particular, path news affects directly forward rates of maturity up to 10 years ahead with a statistically significant positive sign. The forward rate regressions also show that jump news affects directly short term interest rates of maturity up to 2 years ahead, whereas timing news is largely irrelevant. The resulting sequence of parameter estimates and corresponding regression  $R^2$  are shown in Table 2.

## 6. Conclusions

We use high-frequency money market data on monetary policy days to construct multidimensional indicators of news about ECB monetary policy and study their impact on the euro area yield curve. Our analysis contributes in two ways to the existing literature on the financial market impact of monetary policy decisions and communication.

First, we exploit the institutional feature that the ECB announces and explains its monetary policy decisions on two different time instances during the day of interest-rate setting meetings. This allows us to validate existing econometric approaches of decomposing changes in the money market yield curve over a long time window (comprising decision and communication events) to indirectly construct indicators that capture the decision and the communication dimensions separately. Our results support the use of these indirect econometric methods in constructing measures of news from central bank communication. Indeed, the news indicators relating to ECB communication extracted from the different econometric methodologies give information that is highly consistent with the information from the direct approach.

Second, we take a more comprehensive approach to analysing the financial market impact of the ECB's policy decisions and communication than in the

TABLE 2. Forward rate regressions results.

Maturity	Factor Analysis				Recursive Regressions				Partitioned Windows					
	Jump	Path	Jobs	R <sup>2</sup>	Jump	Timing	Path	Jobs	R <sup>2</sup>	Jump	Timing	Path	Jobs	R <sup>2</sup>
180 Day	0.13	<b>0.57</b>	0.01	0.88	<b>0.55</b>	-0.29	<b>1.00</b>	0.00	0.99	<b>0.56</b>	-0.22	<b>0.50</b>	-0.00	0.62
720 Day	<b>0.25</b>	<b>0.47</b>	-0.03	0.71	<b>0.56</b>	-0.06	<b>0.75</b>	-0.04	0.66	<b>0.34</b>	-0.03	<b>0.76</b>	-0.04	0.35
1800 Day	<b>0.16</b>	<b>0.21</b>	-0.03	0.39	<b>0.21</b>	0.10	<b>0.28</b>	-0.04	0.26	0.10	-0.01	<b>0.64</b>	-0.03	0.34
3650 Day	-0.08	<b>0.08</b>	0.01	0.04	-0.06	-0.08	<b>0.19</b>	0.01	0.06	-0.01	-0.07	<b>0.45</b>	0.02	0.05

Notes: Bold entries denote significance at the 5% level.

current literature, which is primarily based on single-factor indicators and subjective measures of the tone of ECB statements. Our results suggest that market expectations of the path of monetary policy may change considerably during the ECB's press conference. Moreover, these changes have a sizeable impact on longer-term yields. While immediate policy decisions have a downward-sloping maturity response pattern, changes in expectations of monetary policy at longer horizons triggered by ECB communication have a hump-shaped maturity response pattern, with a more pronounced impact on longer-term yields. We find that the size of the impact on yields in the euro area is similar to that measured for the U.S. Our results show that news stemming from ECB communication matters more for long-term interest rates—crucial for the transmission of monetary policy—than news about actual monetary policy decisions.

### Appendix A: Data

We are grateful to Vincent Brousseau for providing the yield curve data used throughout this study. Yield curves have been constructed using Reuters real-time quotes of deposit rates (of maturity up to one week), overnight interest rate swaps (OIS, of maturity 1 week to 2 years), and swap rates (of maturity 1 to 10 years).<sup>13</sup> Figure A.1 shows how many quotes are available for each of these three instruments at various maturities (within the whole set of data available). The zero coupon yield curve has been constructed recursively using bootstrapping techniques and a Fama-Bliss type of interpolation scheme as described in Brousseau (2002, pp. 21–22).

Erroneous or outdated quotes have been filtered out using the algorithm described in Brousseau (2006, pp. 72–82). The algorithm fundamentally involves three steps: First, a “retroactive” filter is applied to remove isolated quotes that are markedly different from a majority of preceding and subsequent quotes. Second, a “simple” filter is used rejecting any data that imply the logarithm of their ratio over the previous mid price to be higher than 0.002. Last, a “dynamical” filter is employed consisting of the following steps: (1) Sorting the quotes of banks in chronological order; (2) Computing the best bid and the best ask for the  $n$  most recent banks; (3) Stopping when the best bid is equal to or bigger than the best ask price; (4) Eliminating quotes of bank  $n$ , as well as less recent ones; (5) Taking the best bid and best ask for the  $n - 1$  remaining banks.

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13. These interest rates are defined as follows: A deposit rate is the interest rate at which term deposits are offered by one bank to another. An overnight interest rate swap is an interest rate swap transaction, whereby one party agrees to receive or pay a fixed rate to another party, against paying or receiving a floating rate pegged to the EONIA (Euro Overnight Index Average). A swap rate is an interest rate swap transaction, whereby one party agrees to receive or pay a fixed rate to another party, against paying or receiving a floating rate pegged to three or six-month money market interest rates (EURIBOR – Euro Interbank Offered Rate).

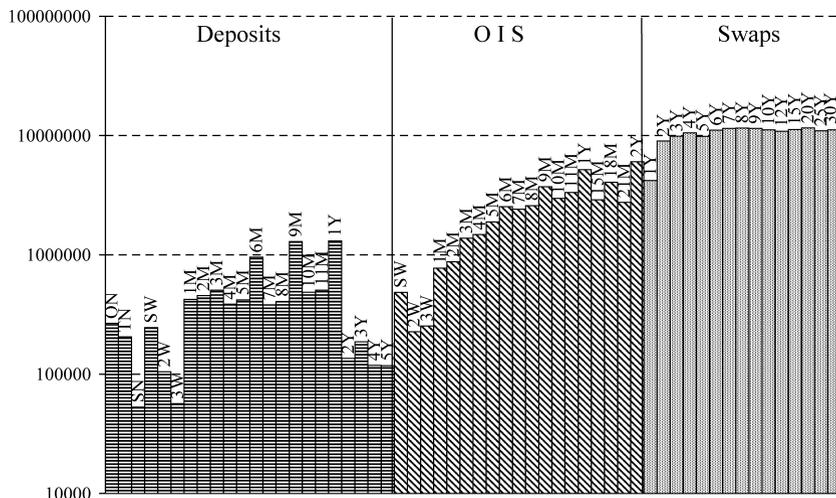


FIGURE A.1. The number of quotes contained in the database across the three instruments at various maturities.

Except for very few instances at the beginning of the sample, this procedure yields an extremely smooth yield curve (see also Brousseau and Sahel 2001). To this data set we last applied the B form of a smoothing spline, as described in James and Webber (2004, pp. 437–444). In the main body of the paper  $y_t^\tau$  refers to the yield to maturity  $\tau$  as given by the resulting zero-coupon curve. Forward rates of 10-day maturity  $\tau$  periods ahead  $f_t^\tau$  are derived from that zero-coupon curve.

### Appendix B: Factor Test

The factor test of Cragg and Donald (1997) tests the null hypothesis that  $Y$  was generated by  $h_0$  factors against the alternative hypothesis  $h > h_0$ . This test is performed on all three time windows that we consider. The results of the test are reported in Table B.1 below.

TABLE B.1. Cragg and Donald (1997) Factor test.

$h_0$	Long Window			Decision Window			Communication Window		
	test stat.	$\chi^2$ DF	$p$ -value	test stat.	$\chi^2$ DF	$p$ -value	test stat.	$\chi^2$ DF	$p$ -value
0	97.15	10	0.0000	40.27	10	0.0000	78.49	10	0.0000
1	36.04	5	0.0000	17.36	5	0.0039	21.92	5	0.0005
2	4.41	1	0.0357	5.34	1	0.0208	2.06	1	0.1516

Notes:  $Y$  consists of the 10, 30, 160, 240, and 360 day changes in forward rates around the considered policy windows. Note that a model with three factors can account for all the variation in the data, leading to singularity in the design matrix of the test. The largest  $h_0$  that we therefore considered was set at 2.

**Appendix C: Factor Rotation**

The notation in this section follows the one in Gürkaynak, Sack, and Swanson (2005, pp. 90–91). Let the rotated factors  $Z$  be related to the base set of factors  $F$  through the following relationship

$$Z = FU, \tag{C.1}$$

where

$$U = \begin{bmatrix} \alpha_1 & \beta_1 \\ \alpha_2 & \beta_2 \end{bmatrix}, \tag{C.2}$$

and  $U$  is an orthogonal matrix.  $U$  is identified by a number of restrictions. These are, unit length of the columns of  $U$ , orthogonality of the columns of  $Z = (z_1, z_2)$ , namely,  $E(z_1 z_2) = 0 = \alpha_1 \beta_1 + \alpha_2 \beta_2$ . We also need the restriction that  $z_2$  does not influence (or load into)  $\Delta f_t^{10}$ , so that  $\gamma_2 \alpha_1 - \gamma_1 \alpha_2 = 0$ , where  $\gamma_1$  and  $\gamma_2$  are entries (1, 1) and (2, 1) in the  $2 \times N$  matrix  $\Omega'$ , that is, the loadings of  $\Delta f_t^{10}$  on the two factors  $f_1$  and  $f_2$ . Also,  $z_1^*$  and  $z_2^*$  are re-scaled in such a way that  $z_1$  and  $z_2$  move one to one with  $\Delta f_t^{10}$  and  $\Delta f_t^{360}$ , respectively.

A preliminary set of unstandardised but rotated factors is then computed as

$$z_1^* = \alpha_1 f_1 + \alpha_2 f_2, \tag{C.3}$$

$$z_2^* = \beta_1 f_1 + \beta_2 f_2, \tag{C.4}$$

with

$$\alpha_1 = \frac{\gamma_1}{\gamma_1 + \gamma_2}$$

$$\alpha_2 = \frac{\gamma_2}{\gamma_1 + \gamma_2}$$

$$\beta_1 = \frac{-\alpha_2 \text{Var}(f_2)}{\alpha_1 \text{Var}(f_1) - \alpha_2 \text{Var}(f_2)}$$

$$\beta_2 = \frac{\alpha_1 \text{Var}(f_1)}{\alpha_1 \text{Var}(f_1) - \alpha_2 \text{Var}(f_2)}.$$

These are then standardised according to  $z_1 = \xi_1 z_1^*$  and  $z_2 = \frac{\zeta_2}{\zeta_1} z_2^*$  where  $\xi_1, \zeta_2$ , and  $\zeta_1$  are coefficient estimates from the regressions

$$\Delta f_t^{10} = \xi_0 + \xi_1 z_1^* + \varepsilon_{1,t}, \tag{C.5}$$

$$\Delta f_t^{360} = \zeta_0 + \zeta_1 z_1^* + \zeta_2 z_2^* + \varepsilon_{2,t}, \tag{C.6}$$

so that we finally obtain the rotated and standardised factors  $Z = (z_1, z_2)$ .

**Appendix D: Asymptotic Variance**

To illustrate the derivation of the asymptotic variance of  $\beta$  we adopt, for reasons of simplicity, the following notation. We define  $v_t$  and  $s_t$  as *timing<sub>t</sub>* and *path<sub>t</sub>* news respectively, and then use the following compact notation for equations (2) and (3):

$$\Delta f_t^{10} = \alpha' x_{1t} + v_t, \tag{D.1}$$

$$\Delta f_t^{150} = \gamma' x_{2t} + s_t. \tag{D.2}$$

Also,  $x_{1t}$  and  $x_{2t}$  are defined as  $x_{1t} = (1, \Delta f_t^{30})'$  and  $x_{2t} = (1, \Delta f_t^{30}, v_t)'$ , with  $\theta = (\alpha', \gamma)'$  being the set of first stage estimation parameters corresponding to  $x_{1t}$  and  $x_{2t}$ . Note that  $\Delta f_t^{30}$  was given the jump news label earlier. Writing equation (5) compactly as

$$\Delta y_t = \beta' x_{3t} + \varepsilon_t, \tag{D.3}$$

where  $x_{3t} = (1, \Delta f_t^{30}, v_t, s_t, jobs_t)'$  with 1 being a vector of constants and *jobs<sub>t</sub>* the control variable for U.S. initial unemployment claims data that are released during the same time interval. A consistent and asymptotically unbiased estimate of  $\beta$  using OLS can be obtained as long as the moment conditions implied by OLS are satisfied. We will assume that that is the case here. The problem, however, is to get the correct variance of  $\beta$ , which, in general, will not be  $E[x_{3t}x_{3t}']^{-1}Var[\varepsilon_t]$ , due to  $v_t$  and  $s_t$  being constructed variables, unless one can show that the expected value of the derivatives of the moment conditions of the last regression step in equation (D.3) is zero when taken with respect to the true parameter vector of the first regression steps.

The problem can be thought of as a standard sequential MOM estimation problem, as set out in Pagan (1984), Newey (1984), and Pagan (1986). The primary concern here is that  $\alpha$  and  $\gamma$  in equations (D.1) and (D.2), respectively, are unknown and are replaced by consistent estimates. Therefore, estimation of  $\beta$  in equation (D.3) is subject to additional sample variation. Given that these regressions can be formulated as a set of moment conditions which correspond to the first-order optimality conditions of OLS, we can think about deriving the asymptotic variance matrix of  $\beta$  within a MOM framework. Denoting by  $f_t$ ,  $g_t$ , and  $h_t$  the vectors of moment conditions for the regressions in equations (D.1), (D.2), and (D.3) respectively, it can be shown that the asymptotic variance matrix of  $\beta$  takes the form

$$\Sigma_\beta = Var(\beta) + H_\beta^{-1} H_\theta[\Psi] H_\theta' H_\beta^{-1}, \tag{D.4}$$

where  $H_\beta = E[\partial \mathbf{h}_t / \partial \beta']$ ,  $H_\theta = E[\partial \mathbf{h}_t / \partial \theta']$ ,  $\theta = (\alpha', \gamma')'$  and  $\Psi$  has the form

$$\Psi = \begin{bmatrix} \text{Var}(\alpha) & \text{Var}(\alpha)G' \\ G\text{Var}(\alpha) & \Sigma_\gamma \end{bmatrix} \tag{D.5}$$

where

$$G = \begin{bmatrix} \gamma^{(3)} & 0 \\ 0 & \gamma^{(3)} \\ 0 & 0 \end{bmatrix}, \tag{D.6}$$

and with

$$\Sigma_\gamma = \text{Var}(\alpha) + G\text{Var}(\alpha)G'.$$

$\text{Var}(t)$  for  $t = \alpha, \beta, \gamma$  is a Newey and West (1987) type heteroskedasticity and autocorrelation consistent (HAC) covariance matrix formed from the OLS regressions in equations (D.1) and (D.2) when ignoring the fact that we have constructed the variables. Letting  $\gamma^{(3)}$  denote the third element of  $\gamma$ , i.e., the coefficient on  $v_t$ , and using this notation henceforth to denote element entries, it can be shown that  $H_\theta$  takes the form

$$H_\theta = \begin{bmatrix} \vartheta & \vartheta E[\Delta f_t^{30}] & \beta^{(4)} & \beta^{(4)} E[\Delta f_t^{30}] & 0 \\ \vartheta E[\Delta f_t^{30}] & \vartheta E[(\Delta f_t^{30})^2] & \beta^{(4)} E[\Delta f_t^{30}] & \beta^{(4)} E[(\Delta f_t^{30})^2] & 0 \\ 0 & 0 & 0 & 0 & \beta^{(4)} E[v_t^2] \\ 0 & 0 & 0 & 0 & 0 \\ \vartheta E[jobs_t] & \vartheta E[jobs_t \Delta f_t^{30}] & \beta^{(4)} E[jobs_t] & \beta^{(4)} E[jobs_t \Delta f_t^{30}] & 0 \end{bmatrix} \tag{D.7}$$

with  $\vartheta = (\beta^{(3)} - \beta^{(4)}\gamma^{(3)})$  and one can recognise  $H_\beta = E[\partial \mathbf{h}_t / \partial \beta']$  to be the cross-product moment matrix of  $\mathbf{x}_{3t}$ .

For an easy way to derive the variance of  $\beta$  as in equation (D.4) consider the following set up. Let  $\phi = (\theta', \beta')'$  and  $\theta = (\alpha', \gamma')'$  where  $\alpha, \gamma$  and  $\beta$  are as defined above. For notational simplicity we will let  $X_t$  represent all the relevant data entries. Also, we will in general suppress the dependence of the moment conditions on the data and parameter vectors and hence write, for example,  $E[\mathbf{m}_t]$  instead of  $E[\mathbf{m}_t(X_t, \phi)]$ . The following partitioned vector of moment conditions can then be formed

$$E[\mathbf{m}_t] = E \begin{bmatrix} \mathbf{f}_t(X_t, \alpha) \\ \mathbf{g}_t(X_t, \theta) \\ \dots\dots\dots \\ \mathbf{h}_t(X_t, \phi) \end{bmatrix} = \mathbf{0}$$

where

$$f_t(X_t, \alpha) = (v_t, \Delta f_t^{30} v_t)', \tag{D.8}$$

$$g_t(X_t, \theta) = (s_t, \Delta f_t^{30} s_t, v_t s_t)', \tag{D.9}$$

$$h_t(X_t, \phi) = (\varepsilon_t, \Delta f_t^{30} \varepsilon_t, v_t \varepsilon_t, s_t \varepsilon_t, jobs_t \varepsilon_t)'. \tag{D.10}$$

From standard MOM theory we have that

$$\sqrt{T}(\hat{\phi} - \phi_0) \xrightarrow{d} \mathcal{N}(0, \Sigma_\phi),$$

where  $\Sigma_\phi = (M^{-1} \Omega M^{-1'})$  with  $M = \lim_{t \rightarrow \infty} T^{-1} E[\sum_{t=1}^T m_{\phi t}]$  and  $\Omega = \text{Var}(T^{-1/2} \sum_{t=1}^T m_t)$ . We will assume here that the moment conditions hold for all  $t$  so that  $T^{-1} E[\sum_{t=1}^T m_{\phi t}] = E[m_{\phi t}]$  which can then be written in the following partitioned form

$$E[m_{\phi t}] = E \begin{bmatrix} \frac{\partial f_t}{\partial \alpha'} & \frac{\partial f_t}{\partial \gamma'} & \vdots & \frac{\partial f_t}{\partial \beta'} \\ \frac{\partial g_t}{\partial \alpha'} & \frac{\partial g_t}{\partial \gamma'} & \vdots & \frac{\partial g_t}{\partial \beta'} \\ \dots & \dots & \dots & \dots \\ \frac{\partial h_t}{\partial \alpha'} & \frac{\partial h_t}{\partial \gamma'} & \vdots & \frac{\partial h_t}{\partial \beta'} \end{bmatrix} = E \begin{bmatrix} \frac{\partial f_t}{\partial \alpha'} & \mathbf{0} & \vdots & \mathbf{0} \\ \frac{\partial g_t}{\partial \alpha'} & \frac{\partial g_t}{\partial \gamma'} & \vdots & \mathbf{0} \\ \dots & \dots & \dots & \dots \\ \frac{\partial h_t}{\partial \alpha'} & \frac{\partial h_t}{\partial \gamma'} & \vdots & \frac{\partial h_t}{\partial \beta'} \end{bmatrix}$$

due to  $f_t$  being a function of  $\alpha$  only and  $g_t$  not being a function of  $\beta$ .  $\Omega = \text{Var}(T^{-1/2} \sum_{t=1}^T m_t)$  can be computed using a standard Newey and West (1987) HAC covariance matrix. We can also partition  $\Omega$  into

$$\Omega = \begin{bmatrix} \Omega_{ff} & \Omega_{fg} & \vdots & \Omega_{fh} \\ \Omega_{gf} & \Omega_{gg} & \vdots & \Omega_{gh} \\ \dots & \dots & \dots & \dots \\ \Omega_{hf} & \Omega_{hg} & \vdots & \Omega_{hh} \end{bmatrix}, \tag{D.11}$$

where, for example,  $\Omega_{fh} = \text{Var}(T^{-1/2} \sum_{t=1}^T (f_t h_t'))$ .

Given the nature of the sequential regressions, we also know that, by construction of the first regression steps,  $s_t$  and  $v_t$  are orthogonal to  $\varepsilon_t$  and are assumed to be uncorrelated over time as well, notably,  $E[s_t \varepsilon_{t-j}] = 0, \forall j > 1$ , we can set  $\Omega_{gf} = \Omega_{hf} = \Omega_{hg} = 0$ , so that equation (D.11) is effectively block diagonal, taking the form

$$\Omega = \begin{bmatrix} \Omega_{ff} & \mathbf{0} & \vdots & \mathbf{0} \\ \mathbf{0} & \Omega_{gg} & \vdots & \mathbf{0} \\ \dots & \dots & \dots & \dots \\ \mathbf{0} & \mathbf{0} & \vdots & \Omega_{hh} \end{bmatrix}.$$

From this partitioned set up, we can then follow Newey (1984) to find  $\Sigma_\beta$  to be of the form

$$\Sigma_\beta = H_\beta^{-1} \Omega_{hh} H_\beta^{-1'} + H_\beta^{-1} H_\theta [F_\theta^{-1} \tilde{\Omega}_{fg} F_\theta^{-1'}] H_\theta' H_\beta^{-1}, \tag{D.12}$$

where  $H_\beta = E[\partial h_t / \partial \beta']$  and  $H_\theta = E[\partial h_t / \partial \theta']$  are again, respectively, the cross-product moment matrix of  $x_{3,t}$  and as defined in equation (D.7), and  $F_\theta$  and  $\tilde{\Omega}_{fg}$  are, respectively

$$F_\theta = E \begin{bmatrix} \frac{\partial f_t}{\partial \alpha'} & \mathbf{0} \\ \frac{\partial g_t}{\partial \alpha'} & \frac{\partial g_t}{\partial \gamma'} \end{bmatrix} \tag{D.13}$$

and

$$\tilde{\Omega}_{fg} = \begin{bmatrix} \Omega_{ff} & \mathbf{0} \\ \mathbf{0} & \Omega_{gg} \end{bmatrix}. \tag{D.14}$$

Using the partitioned inverse of a matrix we have

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}^{-1} = \begin{bmatrix} P^{-1} & \vdots & -P^{-1}BD^{-1} \\ \dots\dots\dots & \cdot & \dots\dots\dots \\ -D^{-1}CP^{-1} & \vdots & D^{-1} + D^{-1}CP^{-1}BD^{-1} \end{bmatrix},$$

where  $P = A - BD^{-1}C$ . Because in our case  $B = \mathbf{0}$ , this then simplifies to  $P^{-1} = A^{-1}$  and

$$\begin{bmatrix} A & \mathbf{0} \\ C & D \end{bmatrix}^{-1} = \begin{bmatrix} A^{-1} & \vdots & \mathbf{0} \\ \dots\dots\dots & \cdot & \dots\dots \\ -D^{-1}CA^{-1} & \vdots & D^{-1} \end{bmatrix}. \tag{D.15}$$

Given the result in equation (D.15), the inverse of  $F_\theta$  is then formed as

$$F_\theta^{-1} = \begin{bmatrix} E \left[ \frac{\partial f_t}{\partial \alpha'} \right]^{-1} & \vdots & \mathbf{0} \\ \dots\dots\dots & \cdot & \dots\dots\dots \\ -E \left[ \frac{\partial g_t}{\partial \gamma'} \right]^{-1} & E \left[ \frac{\partial g_t}{\partial \alpha'} \right] E \left[ \frac{\partial f_t}{\partial \alpha'} \right]^{-1} & \vdots & E \left[ \frac{\partial g_t}{\partial \gamma'} \right]^{-1} \end{bmatrix}. \tag{D.16}$$

Finally, from equations (D.12), (D.14), and (D.16) we construct

$$\Sigma_\beta = H_\beta^{-1} \Omega_{hh} H_\beta^{-1'} + H_\beta^{-1} H_\theta [\Psi] H_\theta' H_\beta^{-1}$$

with  $\Psi$  as given in equation (D.5)

$$\Psi = \begin{bmatrix} \text{Var}(\boldsymbol{\alpha}) & \text{Var}(\boldsymbol{\alpha})G' \\ G\text{Var}(\boldsymbol{\alpha}) & \Sigma_{\boldsymbol{\gamma}} \end{bmatrix}.$$

To get this result, one needs to recognise that the two terms  $E[\partial \mathbf{f}_t / \partial \boldsymbol{\alpha}']^{-1} \Omega_{ff} E[\partial \mathbf{f}_t / \partial \boldsymbol{\alpha}']^{-1}$  and  $E[\partial \mathbf{g}_t / \partial \boldsymbol{\gamma}']^{-1} \Omega_{gg} E[\partial \mathbf{g}_t / \partial \boldsymbol{\gamma}']^{-1}$  are just  $\text{Var}(\boldsymbol{\alpha})$  and  $\text{Var}(\boldsymbol{\gamma})$ , namely, the standard HAC type covariance matrices of the estimates of  $\boldsymbol{\alpha}$  and  $\boldsymbol{\gamma}$  from the first and second step regressions, ignoring the fact that  $v_t$  is a constructed variable in the second regression step. Also,  $G$  is defined as

$$G = -E \left[ \frac{\partial \mathbf{g}_t}{\partial \boldsymbol{\gamma}'} \right]^{-1} E \left[ \frac{\partial \mathbf{g}_t}{\partial \boldsymbol{\alpha}'} \right],$$

which simplifies to equation (D.6) once these expectations are taken with respect to the true parameter vectors  $\boldsymbol{\gamma}$  and  $\boldsymbol{\alpha}$ .

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