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The Impact of ECB Monetary Policy Decisions and Communication on the Yield Curve

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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 ECB, 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, while that to policy decisions is downward sloping.

Keywords: money market rates, yield curve, ECB, central bank communication.
JEL Classification: E43, E58.

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).

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 length to explain their goals and make their decisions understood by the private sector and 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 rates to construct multi-dimensional indicators of monetary policy news (capturing central bank communication and monetary policy decisions) and analyse their impact on the yield curve. Specifically, we decompose intraday changes in the euro area money market yield curve on 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.

The contribution of our study is two-fold. First, the institutional feature that the ECB *announces* and *explains* policy decisions on 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 *et al.* (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, while 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 (see Bernoth and von Hagen, 2004; Wilhelmsen 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 (see Heinemann and Ullrich, 2005; Rosa and Verga, 2005; Gies, 2005; Meyer, 2004; Gerlach, 2004). Using the indicator developed in Gies (2005), both 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, 2007a). 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. However, there are evident shortcomings to such approaches. 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.[1]

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 US data documents a significant impact of policy decisions and macroeconomic data releases on long-term yields (see Fleming and Remolona, 1999, and 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 *et al.* (2006) 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 regards 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, while that to policy decisions is downward sloping. These results are consistent with those obtained for the US (see Gürkaynak, 2005; Gürkaynak *et al.*, 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 some 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 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, compare and validate them by explaining specific events. Based on these indicators, we provide an

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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.

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 Appendix.

2. Institutional features of the ECB

The Governing Council – the decision-making body of the ECB – meets regularly on a monthly basis to discuss monetary policy.[2] 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 interset 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 answers 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 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 to. 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.

It is instructive here to provide two illustrative episodes of how quickly money market 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 evo-

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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, however, a press conference followed only after the first meeting of the month.

lution from 13:35 to 15:50 (CET) of the 60 day rate on two specific instances.[3] 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 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. While financial markets had attached a significant probability of 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 rates. Yet, following the start of the questions and answers 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 rates declined visibly. The 60 day rate dropped by about 8 basis points within the next 45 minutes and stabilised at the lower level roughly an hour after the press conference had started.

These two episodes illustrate the following important observations. Firstly, they show that the adjustment in market rates takes place immediately after news about monetary policy becomes 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 *et al.*, 2001; Sebestyén, 2006, for further evidence in different segments of the euro area money market). Secondly, the episodes show that our windows are wide enough to capture the time the market needs to absorb the news, while 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 US at 14:30 (CET). This release coincides with the beginning of the ECB's press conference. Since there could, therefore, potentially exist a difficulty in trying to isolate the effects of monetary policy news relating to ECB communication and US initial unemployment claims, we provide an assessment of this possibility in Section 3.4.

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 discuss briefly the

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

algorithm employed to filter out erroneous and outdated quotes and provide additional information regarding the liquidity of the market 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 below. To formalise the different approaches, let f_t^τ denote the implied 10 day money market forward rate τ days ahead, as extracted from the discount curve. Furthermore, let Δf_t^τ 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 Δf_t^{10}, Δf_t^{30} and Δf_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, as at the high frequency changes that we consider the term premia are assumed to remain constant, leading to a cancelling out effect (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 *et al.* (2005). Let the factor model representation for Y be expressed in the following general form

$$Y = F\Omega' + \eta \tag{1}$$

where Y is a $T \times N$ matrix of data, F is a $T \times k$ matrix of k unobserved factors with $k < N$, Ω' is a $k \times N$ matrix of factor loadings and η is a $T \times N$ matrix of idiosyncratic disturbance terms. Matrix Ω contains the eigenvectors of $Cov\,(Y)$ and F is computed in the standard way as $F = Y\Omega$. The Y matrix was chosen to consist of $\{\Delta f_t^{10}, \Delta f_t^{90}, \Delta f_t^{180}, \Delta f_t^{720}, \Delta f_t^{1800}, \Delta f_t^{3600}\}_{t=1}^T$. 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.[4] We gave preference to this test, rather than to the more recently proposed tests by, for example, Bai and Ng (2002), as the 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

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[4]The computational details of this test are outlined in Gürkaynak *et al.* (2005, pp. 87-88). We thank Eric Swanson for providing the Matlab code to perform this test.

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 5% level of significance.

Since the two factors that we extract from Y have no structural interpretation, we follow the approach in Gürkaynak *et al.* (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 curve, *path* news. That is, changes at the short end of the forward curve are identified as jump news, while 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, since the original un-rotated factors obtained from principal component analysis are orthogonal by construction, the rotated factors are also orthogonal.

3.2. Recursive regressions

The second approach that we employ 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 rational 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 points 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. Firstly, 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 lastly by extracting the jump and timing surprises out of the changes in the forward rate 5 months ahead. This approach can be formalised by defining $timing_t$ and $path_t$ news as the residuals from the following recursive regressions:

$$\Delta f_t^{10} = \alpha_0 + \alpha_1 jump_t + timing_t, \tag{2}$$
$$\Delta f_t^{150} = \gamma_0 + \gamma_1 jump_t + \gamma_2 timing_t + path_t, \tag{3}$$

where, Δf_t^τ is again the change in the 10-day forward rate τ days ahead over the long time window.[5]

As a result of the decomposition, the jump component corresponds to unanticipated changes in the policy interest rate, while the timing component relates to changes that may

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[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.

have been anticipated in terms of its magnitude, but not in terms of its 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). While, in principle, alternative identifying schemes also appear justifiable, for reasons of comparability with US studies we decided to follow this particular scheme. The R^2 of the regressions in (2) and (3) are 0.60 and 0.25, respectively, indicating that Δf_t^{10} is largely comprised of jump news and Δf_t^{150} of path news.

As expected the relevance of *timing* news within our whole sample is limited. For institutional reasons instances of non-anticipated 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.[6] 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 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 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

$$\Delta f_{t,D}^{10} = \alpha_0^* + \alpha_1^* jump_t^D + timing_t^D \tag{4}$$

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.[7] The communication window, from 14:20-15:50, is used to get a direct measure

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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 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.

[7]This view is further supported by results of a reduced rank test performed on the decision window

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.[8]

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, with, however, only one press conference after the first meeting of the month. As no official news were released during the communication window, we set news relating to the path component equal to zero on such days.

3.4. Initial unemployment claims

US 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 (2), (3) and (4).[9] Yet the coefficient 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 un-

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reported in the column under the "Decisions Window" heading in Table B.1 in Appendix B. The null hypothesis that one factor is sufficient to account for most of the variation in Y cannot be rejected at the 5% level of significance.

[8]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 5% 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 0.85) and both indirect measures of path news (with correlation coefficients of 0.52 and 0.65). 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. Note that there exists no statistical evidence pointing to the need to allow for more than three factors in any of the time windows.

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

employment 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 US 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 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 with regards to 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 appear 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, with a correlation coefficient of 0.77. 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 0.61 and 0.65. 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 were set to zero, path news extracted from the statistical methods were 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 construct 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 (2007b) 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 macroeconomic 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. While 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 the Spring of 2004, macroeconomic data indicating only modest growth in euro area economic activity and a number of shocks (including, amongst 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. However, as 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 curve at longer maturities (see Panel (b) of Figure 5). This shift is consistently identified

as positive path news across all three methods.

While the indicators from the three different approaches provide overall consistent information about monetary policy news, there exist a few occasions where they were 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 rates nevertheless appear to suggest that financial markets had expected a cut in official 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, while 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 (red) horizontal line. Notice how money market 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. Since 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 judgemental 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 US 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. However, this analysis has largely been restricted to modelling monetary policy in terms of

13

changes in policy interest rates, neglecting information on monetary policy relating to longer horizons. In the following, 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 *et al.* (2005) and Gürkaynak (2005) for the US.

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

$$\Delta y_t^\tau = \boldsymbol{\beta}' \mathbf{I}_t + \varepsilon_t \tag{5}$$

where Δy_t^τ is the change in the τ days ahead yield, $\forall \, \tau = 60, 70, 80, \ldots, 3650$, viz, 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 US 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 from $\mathbf{I}_t = (1, jump_t, timing_t, path_t, jobs_t)'$.

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).[10] The results from regressing jump and path news on Δy_t^τ for maturities $\tau = 60, 70, 80, \ldots, 3650$ with bootstrapped 95% confidence intervals are shown in Figure 6. Second, for the sequential regressions in (2), (3) and (5), we derive asymptotic confidence bands. Since 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.[11] The derivation of this asymptotic variance is provided in Appendix D. Figure 7 below shows the estimates of the effects of jump, timing and path news on Δy_t^τ for maturities, $\tau = 60, 70, 80, \ldots, 3650$ together with 95% asymptotic confidence bounds. Lastly, 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

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[10]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 lead 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.

[11]Note that for the factor based model above, 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.

Gürkaynak *et al.* (2005) and Gürkaynak (2005) for the US. 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. Since 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.[12] 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) being included in the regressions which, although only very mildly correlated with the news components, is nevertheless not orthogonal by construction.[13]

The results reported in Table 1 show that overall the different dimension of monetary policy news are crucial in distinguishing how monetary policy affects the yield curve across the maturity spectrum. Jump and path news have similar 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 tend to have an impact predominantly on short to medium-term maturities and exhibit a downward-sloping maturity response pattern. Timing news are 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 have a statistically significant and sizeable impact across all maturities and exhibit a hump-shaped maturity response pattern. As these news mainly related 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.

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 *et al.* (2005). Yet, unlike in the US, the timing component turns out to be irrelevant.

In line with previous literature on announcement effects (e.g. Fleming and Remolona, 1999; Gürkaynak *et al.*, 2005; Gürkaynak, 2005), the regressions in (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 also simply reflect changes in expected short-term 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 (5) with Δy_t^τ replaced by Δf_t^τ – the implied forward rate changes – on

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[12]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.

[13]The correlation between Jobs and the individual news components extracted from the three approaches range from -0.05 to 0.14.

the left-hand side of the equation. While 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 impact directly on forward rates at future dates up to 10 years ahead with a statistically significant positive sign. The forward rate regressions also show that jump news impact directly on short term rates at future dates up to 2 years ahead, whereas timing news are 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 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 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 US. Our results show that news stemming from ECB communication matter more for long-term interest rates – crucial for the transmission of monetary policy – than news about actual monetary policy decisions.

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Appendix

A. Data

We are grateful to Vincent Brousseau for providing the yield curve data used throughout this study. The yield curve has 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).[14] 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).
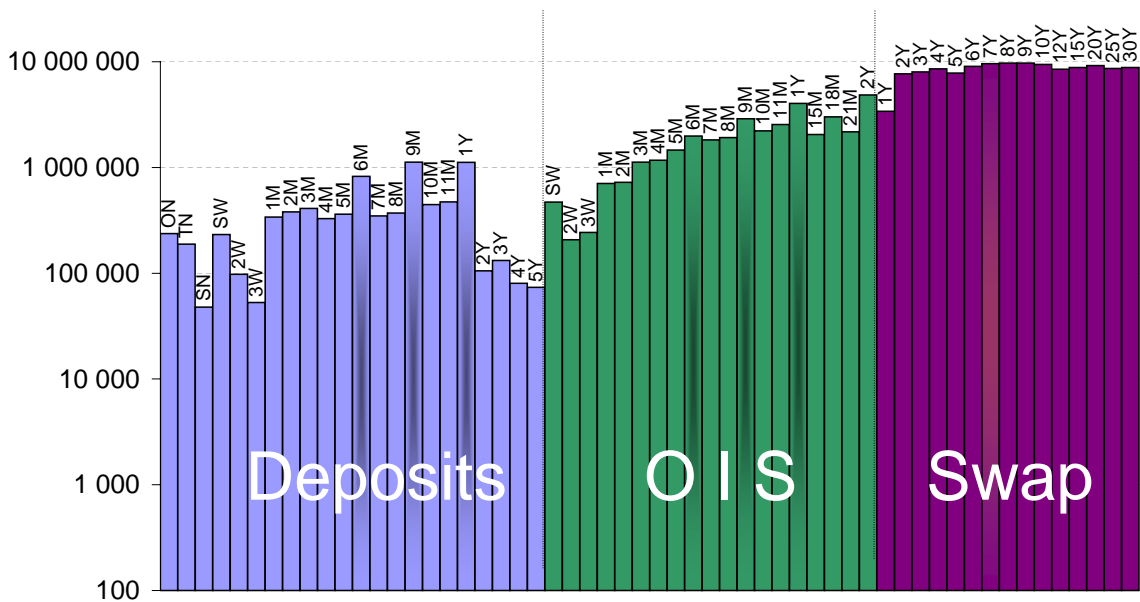

FIGURE A.1: The number of quotes contained in the database across the three instruments at various maturities.

Erroneous or outdated quotes have been filtered out using the algorithm described in Brousseau (2006, pp. 72-82). The algorithm involves three steps: Firstly, a 'retroactive' filter is applied to remove isolated quotes that are markedly different from a majority of preceding and subsequent quotes. Secondly, 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. Lastly, 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

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[14]These 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).

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.

Except for very few instances at the beginning of the sample, this procedure yields an extremely smooth yield curve (see also Brousseau and Sahel, 2002). To those observations we have 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^τ refers to the yield to maturity τ as given by the resulting zero-coupon curve. Forward rates of 10-day maturity τ periods ahead f_t^τ are derived from that zero-coupon curve.

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 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.	χ^2 DF	$p-$value	test stat.	χ^2 DF	$p-$value	test stat.	χ^2 DF	$p-$value
0	59.93	15	0.0000	32.68	15	0.0052	49.19	15	0.0000
1	19.33	9	0.0225	14.43	9	0.1077	20.62	9	0.0144
2	4.24	4	0.3749	6.24	4	0.1823	4.14	4	0.3869

Notes: Y consists of the current, 3 months, 6 months, 2 years, 5 years and 10 years changes in forward rates around the policy window. Note that a model with 3 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 considered, therefore, was up to 2.

C. Factor rotation

The notation in this section follows the one in Gürkaynak *et al.* (2005) on pages 90 to 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 $Z = (z_1, z_2)$, ie. $E(z_1 z_2) = 0 = \alpha_1 \beta_1 + \alpha_2 \beta_2$. We also need the restriction that z_2 does not influence (or load into)

Δf_t^{10}, so that $\gamma_2\alpha_1 - \gamma_1\alpha_2 = 0$, where γ_1 and γ_2 are entries $(1,1)$ and $(2,1)$ in the $2 \times N$ matrix Ω', viz, the loadings of Δf_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 Δf_t^{10} and Δf_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

$$\alpha_1 = \frac{\gamma_1}{\gamma_1 + \gamma_2}$$
$$\alpha_2 = \frac{\gamma_1}{\gamma_1 + \gamma_2}$$
$$\beta_1 = \frac{-\alpha_2 Var\,(f_2)}{\alpha_1 Var\,(f_1) - \alpha_2 Var\,(f_2)}$$
$$\beta_2 = \frac{\alpha_1 Var\,(f_1)}{\alpha_1 Var\,(f_1) - \alpha_2 Var\,(f_2)}$$

These are then standardised according to $z_1 = \xi_1 z_1^*$ and $z_2 = \frac{\zeta_2}{\zeta_1} z_2^*$ where ξ_1, ζ_2, and ζ_1 are coefficient estimates from the regressions

$$\Delta f_t^{10} = \xi_0 + \xi_1 z_1^* + \epsilon_{1,t} \tag{C.5}$$
$$\Delta f_t^{360} = \zeta_0 + \zeta_1 z_1^* + \zeta_2 z_2^* + \epsilon_{2,t} \tag{C.6}$$

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

D. Asymptotic variance

To illustrate the derivation of the asymptotic variance of β we adopt, for reasons of simplicity, the following notation. We define v_t and s_t as respectively $timing_t$ and $path_t$ news, and then use the following compact notation on 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 $x_{2t} ='$, with $\theta = (\alpha', \gamma')'$ being the set of first stage estimation parameters corresponding to x_{1t} and x_{2t}. Note that Δf_t^{30} was given the jump news label earlier. Writing (5) compactly as

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

where, for this case $I_t = x_{3t} = (1, \Delta f_t^{30}, v_t, s_t, j_t)'$ with 1 being a vector of constants and j_t the control variable for US jobless claims data being released during the same time interval. A consistent and asymptotically unbiased estimate of β using OLS as long as

22

the standard moment conditions of OLS are satisfied. We will assume that that is the case here. The problem, however, is to get the correct variance of β, which, in general, will not be $E\left[\mathbf{x}_{3t}\mathbf{x}'_{3t}\right]^{-1}Var\left[\varepsilon_t\right]$, 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 (D.3) is zero when taken with respect to the true parameter vector.

The problem can, in fact, 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 α and γ in (D.1) and (D.2), respectively, are unknown and are replaced by consistent estimates. Therefore, estimation of β in (D.3) is subject to additional sample variation. Using the assumption of exogenous regressor, implicit to OLS regressions, one can formulate a standard set of moment conditions and think about deriving the asymptotic variance matrix of β within a MOM framework. Denoting by $\mathbf{f}_t, \mathbf{g}_t$ and $\mathbf{h}_t$ 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 β takes the form

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

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

$$\Psi = \left[\begin{array}{cc} Var\left(\alpha\right) & Var\left(\alpha\right)G' \\ GVar\left(\alpha\right) & \Sigma_\gamma \end{array}\right] \tag{D.5}$$

where

$$G = \left[\begin{array}{cc} \gamma_{(3)} & 0 \\ 0 & \gamma_{(3)} \\ 0 & 0 \end{array}\right] \tag{D.6}$$

and with

$$\Sigma_\gamma = Var\left(\alpha\right) + GVar\left(\alpha\right)G'.$$

$Var\left(\iota\right)\ \forall\iota = \alpha, \beta$ and γ is a Newey and West (1987) type heteroskedasticity and autocorrelation consistent (HAC) covariance matrix formed from the OLS regressions in (D.1) to (D.2) when ignoring the fact that we have constructed variables. Letting $\gamma_{(3)}$ denote the third element of γ, ie., the coefficient on v_t, and using this notation henceforth to denote element entries, it can be shown that H_θ takes the form

$$H_\theta = \left[\begin{array}{cccccc} \vartheta & \vartheta E\left[\Delta f_t^{30}\right] & \beta_{(4)} & \beta_{(4)}E\left[\Delta f_t^{30}\right] & 0 \\ \vartheta E\left[\Delta f_t^{30}\right] & \vartheta E\left[\left(\Delta f_t^{30}\right)^2\right] & \beta_{(4)}E\left[\Delta f_t^{30}\right] & \beta_{(4)}E\left[\left(\Delta f_t^{30}\right)^2\right] & 0 \\ 0 & 0 & 0 & 0 & \beta_{(4)}E\left[v_t^2\right] \\ 0 & 0 & 0 & 0 & 0 \\ \vartheta E\left[j_t\right] & \vartheta E\left[j_t\Delta f_t^{30}\right] & \beta_{(4)}E\left[j_t\right] & \beta_{(4)}E\left[j_t\Delta f_t^{30}\right] & 0 \end{array}\right] \tag{D.7}$$

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

For an easy way to derive the variance of β as in (D.4) consider the following set up. Let $\boldsymbol{\phi} = (\boldsymbol{\theta}', \boldsymbol{\beta}')'$ and $\boldsymbol{\theta} = (\boldsymbol{\alpha}', \boldsymbol{\gamma}')'$ where $\boldsymbol{\alpha}, \boldsymbol{\gamma}$ and $\boldsymbol{\beta}$ 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 $E[\mathbf{m}_t(X_t, \boldsymbol{\phi})]$. The following partitioned vector of moment conditions can then be formed

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

where

$$\mathbf{f}_t(X_t, \boldsymbol{\alpha}) = \left(v_t, \Delta f_t^{30} v_t \right)' \tag{D.8}$$

$$\mathbf{g}_t(X_t, \boldsymbol{\theta}) = \left(s_t, \Delta f_t^{30} s_t, v_t s_t \right)' \tag{D.9}$$

$$\mathbf{h}_t(X_t, \boldsymbol{\phi}) = \left(\varepsilon_t, \Delta f_t^{30} \varepsilon_t, v_t \varepsilon_t, s_t \varepsilon_t, j_t \varepsilon_t \right)' \tag{D.10}$$

From standard MOM theory we have that

$$\sqrt{T}(\hat{\boldsymbol{\phi}} - \boldsymbol{\phi}_0) \xrightarrow{d} \mathcal{N}(0, \boldsymbol{\Sigma}_\phi)$$

where $\boldsymbol{\Sigma}_\phi = (M^{-1} \Omega M^{-1'})$ with $M = \lim_{t \to \infty} T^{-1} E\left[\sum_{t=1}^T \mathbf{m}_{\phi t} \right]$ and $\Omega = Var(T^{-1/2} \sum_{t=1}^T \mathbf{m}_t)$. We will assume here that the moment conditions hold for all t so that $T^{-1} E\left[\sum_{t=1}^T \mathbf{m}_{\phi t} \right] = E[\mathbf{m}_{\phi t}]$ which can then be written in the following partitioned form

$$E[\mathbf{m}_{\phi t}] = E \begin{bmatrix} \frac{\partial \mathbf{f}_t}{\partial \boldsymbol{\alpha}'} & \frac{\partial \mathbf{f}_t}{\partial \boldsymbol{\gamma}'} & \vdots & \frac{\partial \mathbf{f}_t}{\partial \boldsymbol{\beta}'} \\ \frac{\partial \mathbf{g}_t}{\partial \boldsymbol{\alpha}'} & \frac{\partial \mathbf{g}_t}{\partial \boldsymbol{\gamma}'} & & \frac{\partial \mathbf{g}_t}{\partial \boldsymbol{\beta}'} \\ \dots\dots\dots & & \cdot & \dots \\ \frac{\partial \mathbf{h}_t}{\partial \boldsymbol{\alpha}'} & \frac{\partial \mathbf{h}_t}{\partial \boldsymbol{\gamma}'} & \vdots & \frac{\partial \mathbf{h}_t}{\partial \boldsymbol{\beta}'} \end{bmatrix} = E \begin{bmatrix} \frac{\partial \mathbf{f}_t}{\partial \boldsymbol{\alpha}'} & \mathbf{0} & \vdots & \mathbf{0} \\ \frac{\partial \mathbf{g}_t}{\partial \boldsymbol{\alpha}'} & \frac{\partial \mathbf{g}_t}{\partial \boldsymbol{\gamma}'} & & \\ \dots\dots\dots & & \cdot & \dots \\ \frac{\partial \mathbf{h}_t}{\partial \boldsymbol{\alpha}'} & \frac{\partial \mathbf{h}_t}{\partial \boldsymbol{\gamma}'} & \vdots & \frac{\partial \mathbf{h}_t}{\partial \boldsymbol{\beta}'} \end{bmatrix}$$

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

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

where, for example, $\Omega_{fh} = Var\left(T^{-1/2} \sum_{t=1}^T (\mathbf{f}_t \mathbf{h}_t') \right)$.

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

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

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

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

where $H_\beta = E\left[\frac{\partial \mathbf{h}_t}{\partial \beta'}\right]$ and $H_\theta = E\left[\frac{\partial \mathbf{h}_t}{\partial \theta'}\right]$ are again respectively the cross-product moment matrix of $\mathbf{x}_{3,t}$ and as defined in (D.7), and F_θ and $\tilde{\Omega}_{fg}$ are respectively

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

and

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

Using the partitioned inverse of a matrix we have

$$
\begin{bmatrix} \mathbf{A} & \mathbf{B} \\ \mathbf{C} & \mathbf{D} \end{bmatrix}^{-1} = \begin{bmatrix} \mathbf{P}^{-1} & \vdots & -\mathbf{P}^{-1}\mathbf{B}\mathbf{D}^{-1} \\ \cdots\cdots\cdots & \cdot & \cdots\cdots\cdots\cdots\cdots \\ -\mathbf{D}^{-1}\mathbf{C}\mathbf{P}^{-1} & \vdots & \mathbf{D}^{-1}+\mathbf{D}^{-1}\mathbf{C}\mathbf{P}^{-1}\mathbf{B}\mathbf{D}^{-1} \end{bmatrix}
$$

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

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

Given the result in (D.15), the inverse of F_θ is then formed as

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

25

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

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

with Ψ as given in (D.5)

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

To get this result, one needs to recognise that the two terms $E\left[\frac{\partial \mathbf{f}_t}{\partial \boldsymbol{\alpha}'}\right]^{-1} \Omega_{ff} E\left[\frac{\partial \mathbf{f}_t}{\partial \boldsymbol{\alpha}'}\right]^{-1}$ and $E\left[\frac{\partial \mathbf{g}_t}{\partial \boldsymbol{\gamma}'}\right]^{-1} \Omega_{gg} E\left[\frac{\partial \mathbf{g}_t}{\partial \boldsymbol{\gamma}'}\right]^{-1}$ are just the standard HAC type covariance matrices of $\boldsymbol{\alpha}$ and $\boldsymbol{\gamma}$, denoted respectively by $Var\left(\boldsymbol{\alpha}\right)$ and $Var\left(\boldsymbol{\gamma}\right)$ from the first and second step regressions, ignoring the fact that ν_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 (D.6) once these expectations are taken with respect to the true parameter vectors $\boldsymbol{\gamma}$ and $\boldsymbol{\alpha}$.

Figures and Tables

Long window: 13:35-15:50

Decision window: 13:35-14:05   Communication window: 14:20-15:50

13:45   14:30
Decision published   Press conference begins
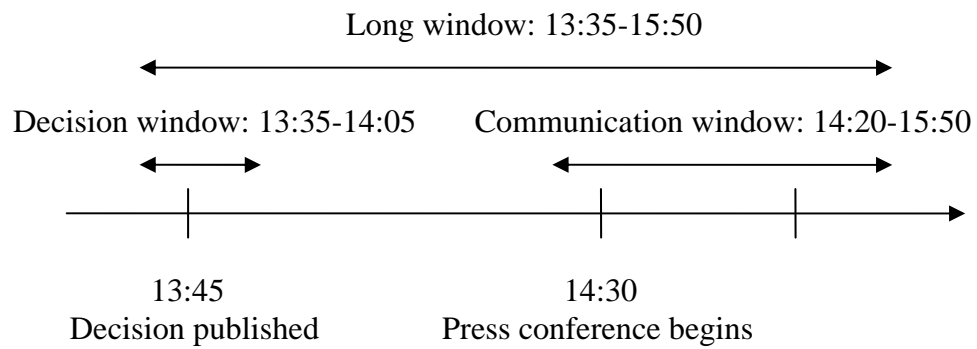
FIGURE 1: Graphical representation of the Long, Decision and Communication windows.
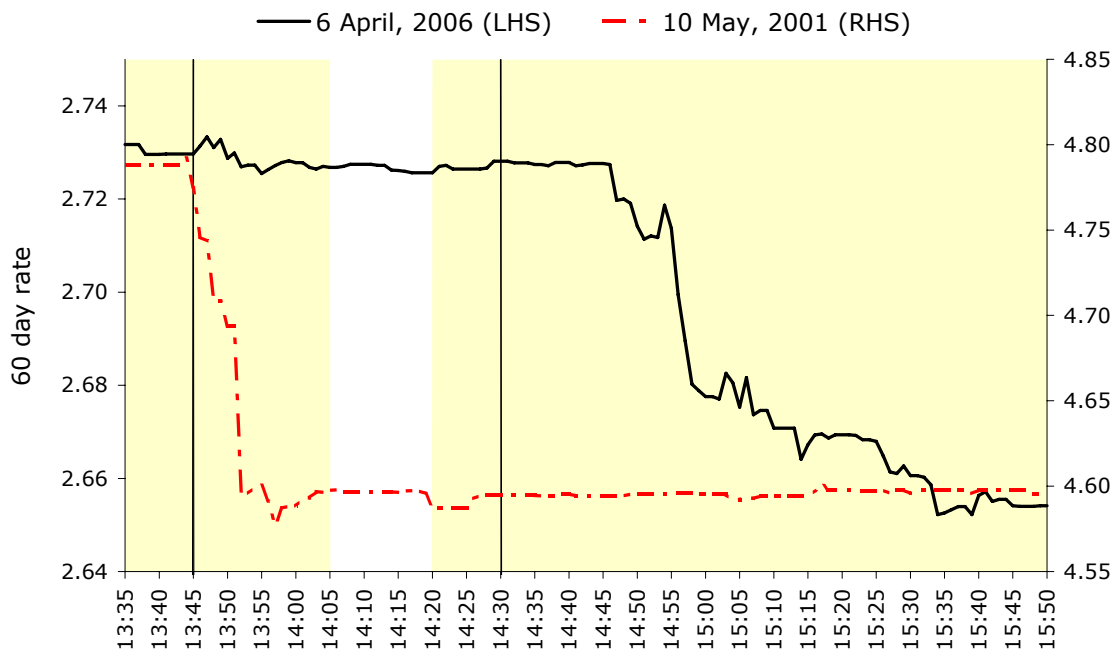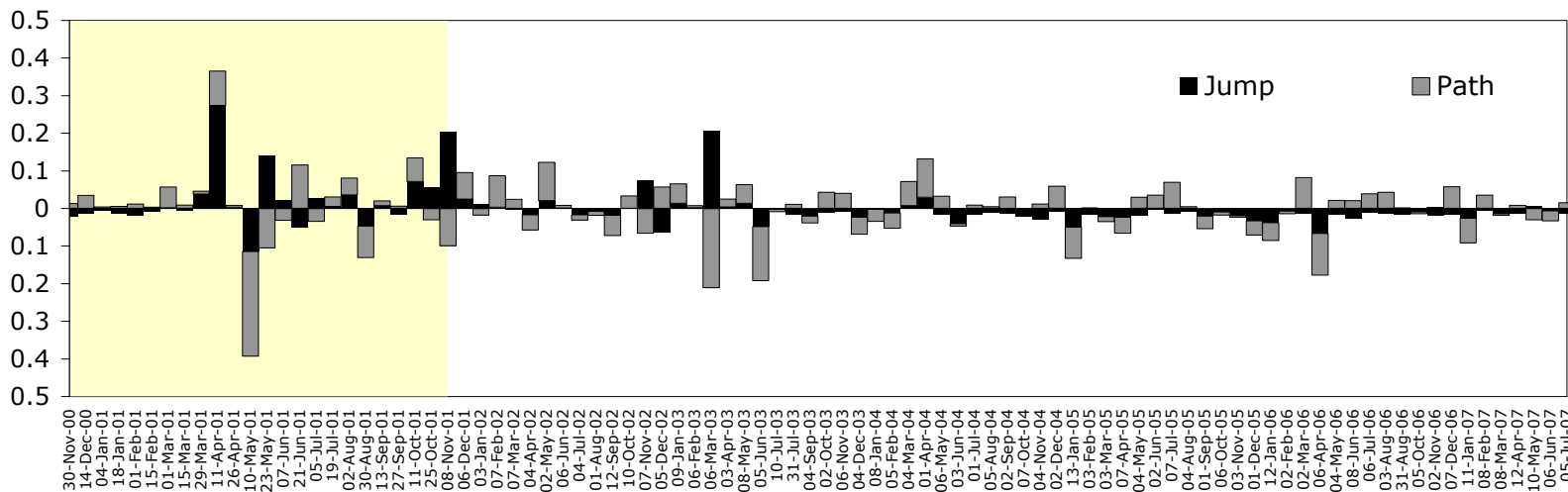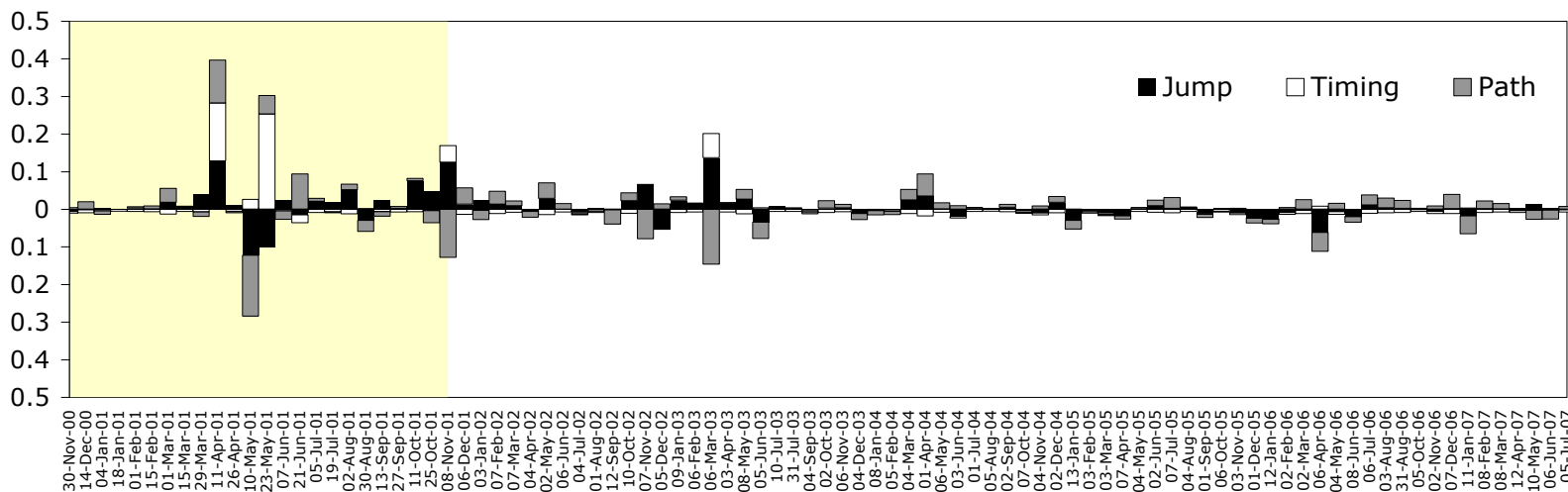
FIGURE 2: Intraday developments in the 60-day yield to maturity on 10 May 2001 and 6 April 2006. The vertical lines at 13:45 and 14:30 indicate the release of the monetary policy decision and the start of the press conference, respectively. The shaded areas indicate the Decision and the Communication windows.

(a) Monetary Policy News extracted from rotated factors.

(b) Monetary Policy News extracted from recursive regressions.
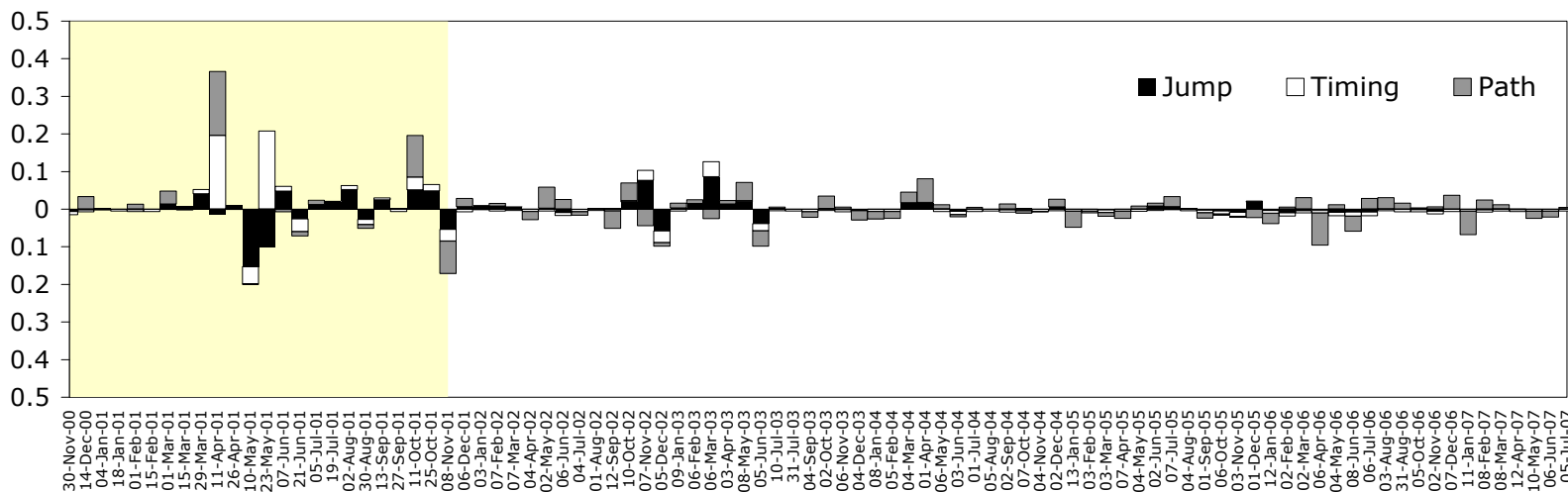
(c) Monetary Policy News extracted from the partitioned decision and communication windows.

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 4 weeks between consecutive meetings.
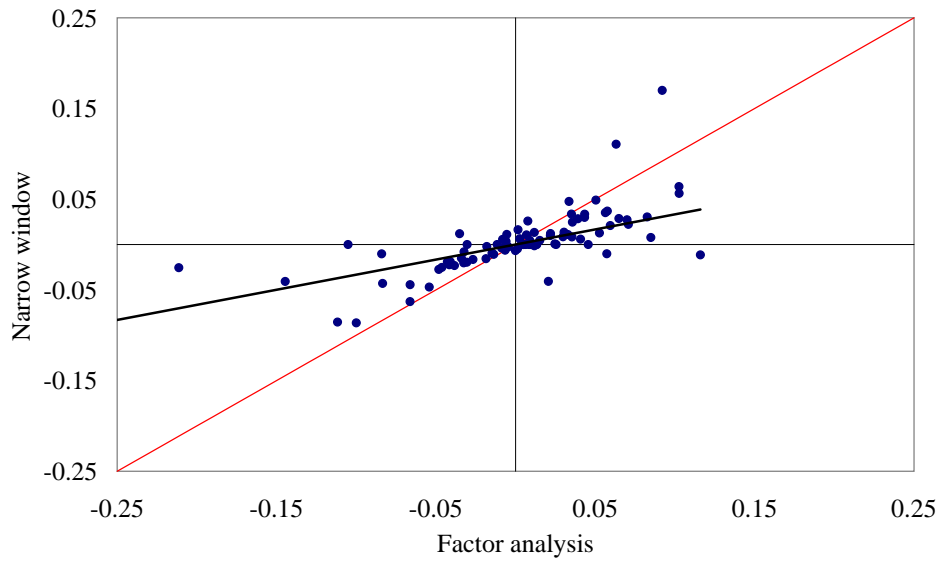
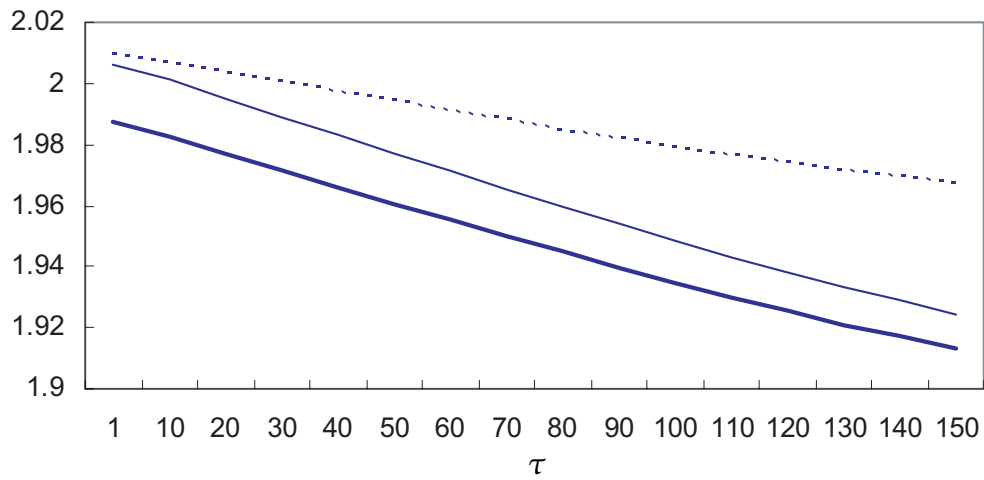(a) Path from factor analysis against communication window
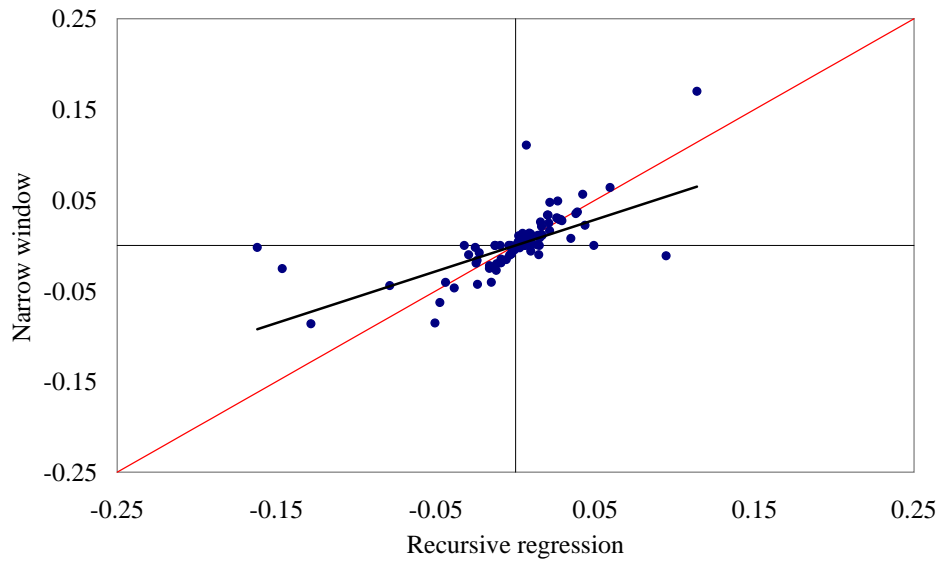
(b) Path from recursive regressions against communication window

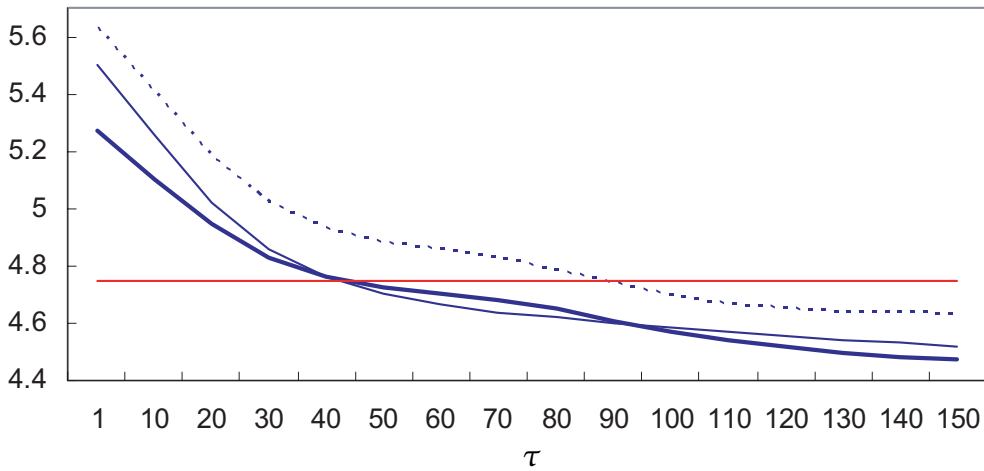**FIGURE 4:** Crossplot of path news across methods.
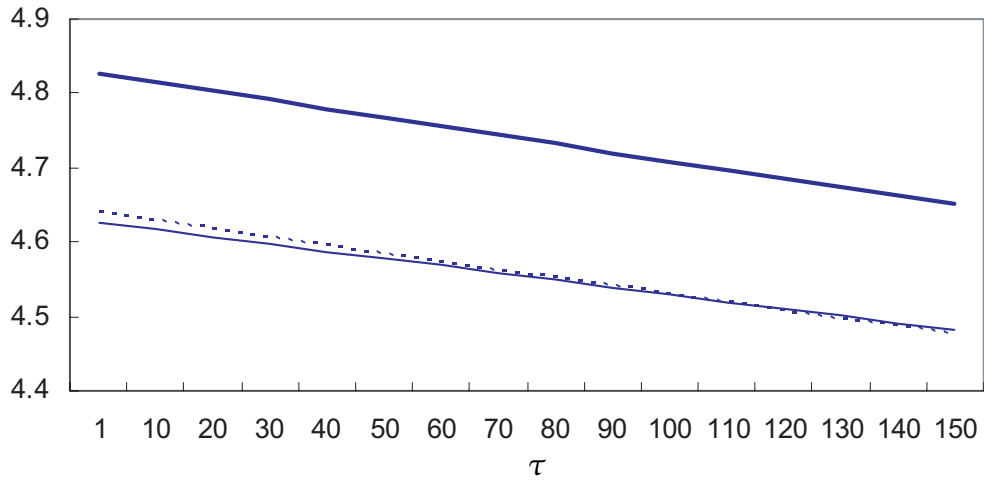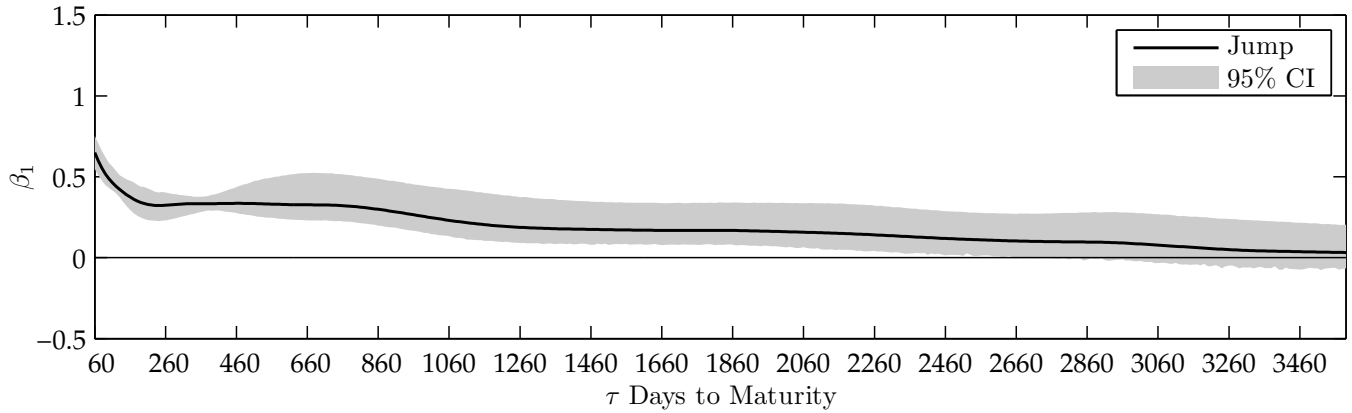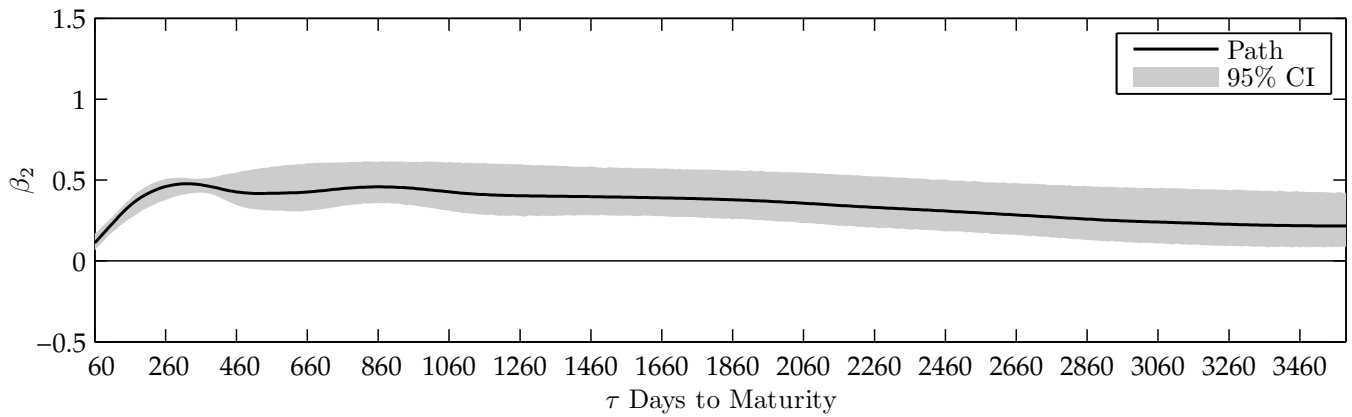
(a) 10 May 2001

(b) 1 April 2004

(c) 11 April 2001

FIGURE 5: Money market rates as of 13:35, 14:05, 15:50 hours on various dates.
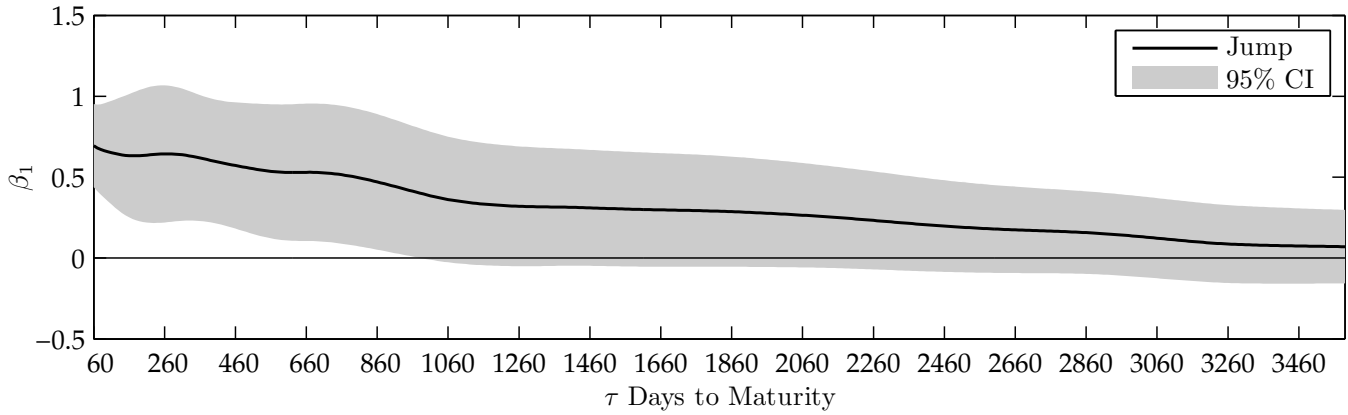
(a) Impact of the jump factor z_1 on changes in yields with bootstrapped confidence bounds
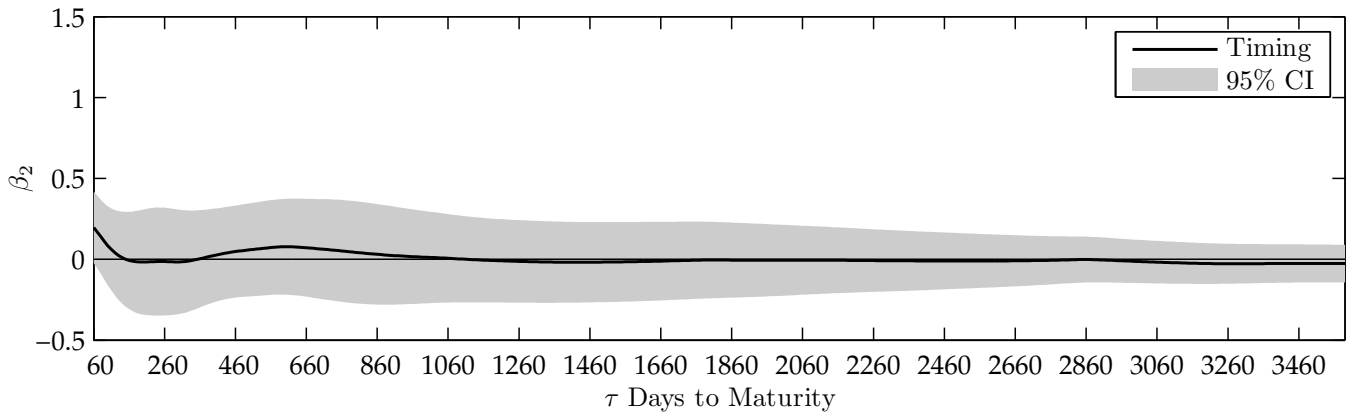

(b) Impact of the path factor z_2 on changes in yields with bootstrapped confidence bounds
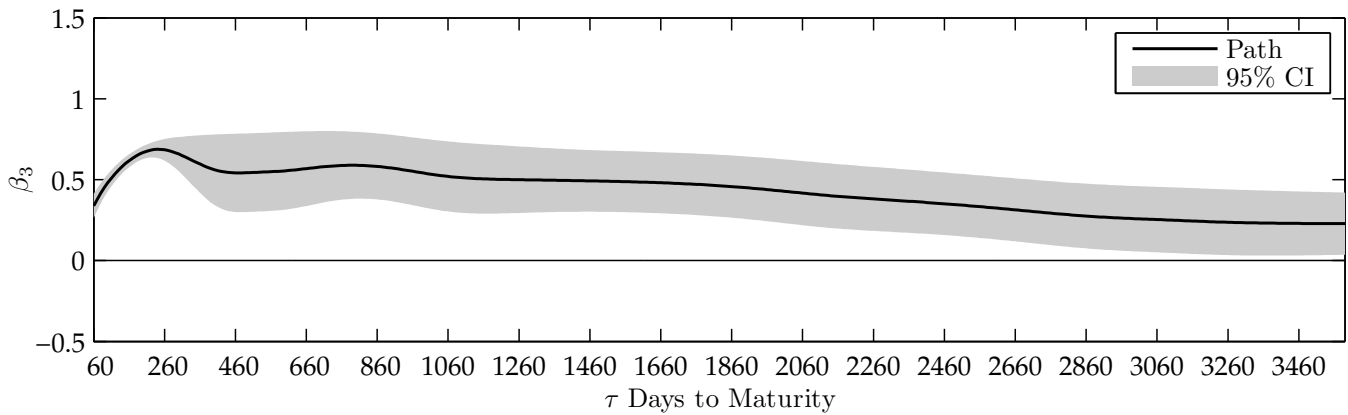
FIGURE 6: Impact of news from the rotated factors from principal component analysis on yields at maturities $\tau = 60, 70, 80, \ldots, 3650$ (based on wide time window).

(a) Impact of jump news on changes in yields with corrected asymptotic 95% confidence bounds

(b) Impact of timing news on changes in yields with corrected asymptotic 95% confidence bounds

(c) Impact of path news on changes in yields with corrected asymptotic 95% confidence bounds

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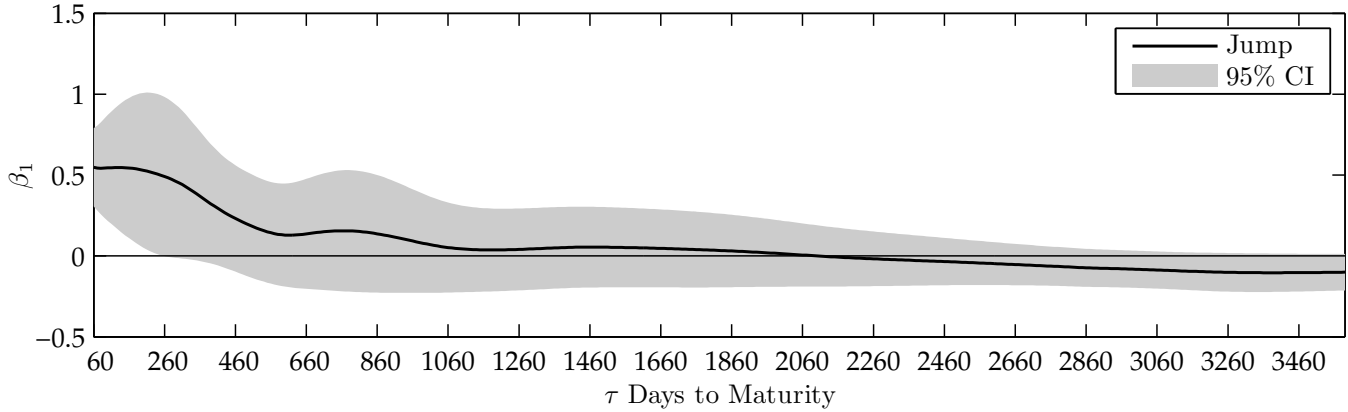
(a) Jump
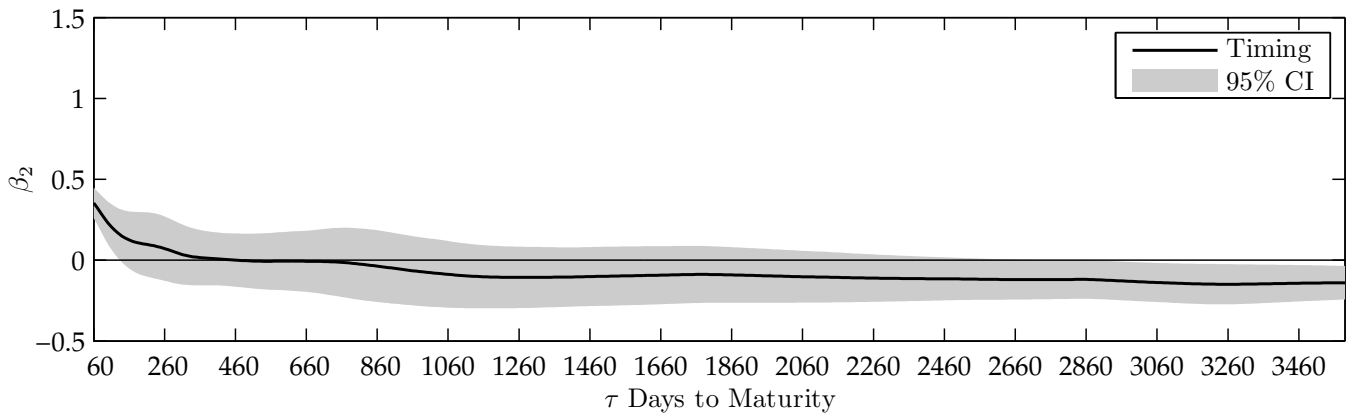
(b) Timing

(c) Path

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

TABLE 1: Comparison of β estimates from US and Euro (EUR) data.

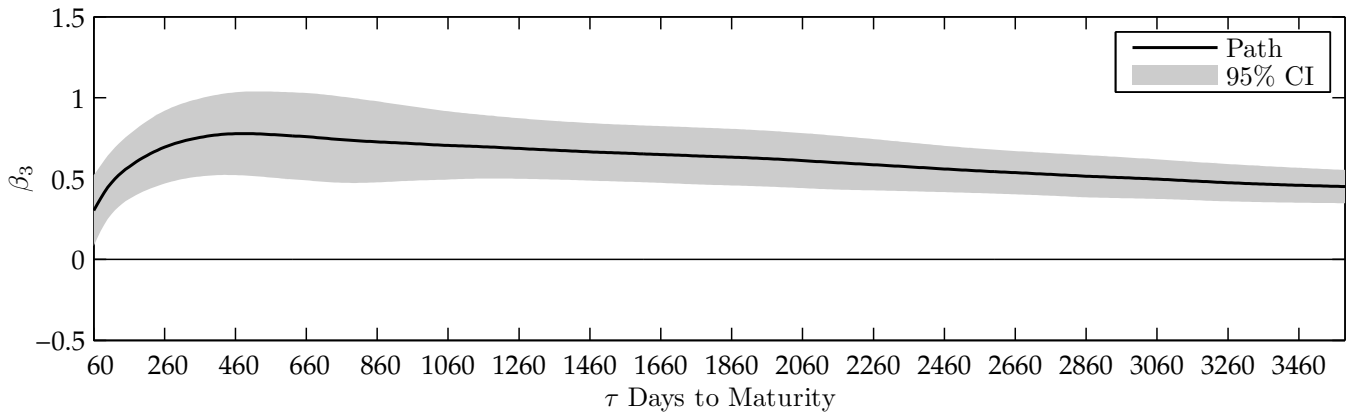| Maturity	Country	Factor Analysis				Recursive Regressions					Partitioned Windows				
		Jump	Path	Jobs	R^2	Jump	Timing	Path	Jobs	R^2	Jump	Timing	Path	Jobs	R^2
1/2 Year	US	—	—	—	—	**0.60**	**0.35**	**0.38**	—	0.81	—	—	—	—	—
180 Day	EUR	**0.35**	**0.38**	0.01	0.90	**0.65**	0.04	**0.54**	0.00	0.98	**0.55**	**0.18**	**0.50**	**−0.01**	0.71
Contribution to R^2		0.35	0.55	0.00		0.54	0.00	0.44	0.00		0.30	0.17	0.45	0.00	
2 Year	US	**0.48**	**0.41**	—	0.94	**0.64**	0.10	**0.96**	—	0.69	—	—	—	—	—
720 Day	EUR	**0.33**	**0.44**	−0.02	0.84	**0.53**	0.07	**0.57**	**−0.03**	0.70	0.14	−0.01	**0.76**	**−0.03**	0.57
Contribution to R^2		0.24	0.59	0.03		0.28	0.00	0.37	0.03		0.03	0.08	0.53	0.03	
5 Year	US	**0.28**	**0.37**	—	0.80	**0.40**	−0.01	**0.81**	—	0.45	—	—	—	—	—
1800 Day	EUR	**0.17**	**0.38**	−0.02	0.76	**0.29**	−0.01	**0.47**	**−0.03**	0.55	0.04	−0.09	**0.64**	**−0.03**	0.53
Contribution to R^2		0.10	0.64	0.05		0.13	0.00	0.37	0.05		0.01	0.04	0.48	0.05	
10 Year	US	**0.13**	**0.28**	—	0.74	**0.22**	0.02	**0.60**	—	0.32	—	—	—	—	—
3650 Day	EUR	0.03	**0.22**	−0.03	0.45	0.07	−0.03	**0.23**	**−0.03**	0.26	−0.10	−0.14	**0.45**	**−0.03**	0.47
Contribution to R^2		0.01	0.38	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 *et al.* (2005) and Table 3 in Gürkaynak (2005). Contributions to R^2 are the squared correlations between the yield changes and the regressors.

TABLE 2: Forward rate regressions results.

Days to Maturity	Factor Analysis				Recursive Regressions					Partitioned Windows				
	Jump	Path	Jobs	R^2	Jump	Timing	Path	Jobs	R^2	Jump	Timing	Path	Jobs	R^2
180 Day	0.15	**0.67**	0.02	0.90	**0.55**	−0.29	**1.00**	0.00	0.99	**0.56**	−0.22	**0.50**	−0.00	0.62
720 Day	**0.29**	**0.61**	−0.02	0.88	**0.56**	−0.06	**0.75**	−**0.04**	0.66	**0.34**	−0.03	**0.76**	−**0.04**	0.35
1800 Day	**0.17**	**0.26**	−0.03	0.44	**0.21**	0.10	**0.28**	−**0.04**	0.26	0.10	−0.01	**0.64**	−**0.03**	0.34
3650 Day	−0.14	**0.18**	−0.02	0.14	−0.06	−0.08	**0.19**	0.01	0.06	−0.01	−0.07	**0.45**	0.02	0.05

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