The Impact of Central Bank Announcements on Asset Prices in Real Time: Testing the Efficiency of the Euribor Futures Market

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Abstract

This paper examines the effect of European Central Bank communication on the price discovery process in the Euribor futures market using a *new* tick-by-tick dataset. First, we show that two pieces of news systematically hit financial markets on Governing Council meeting days: the ECB policy rate decision and the explanation of its monetary policy stance. Second, we find that the *unexpected* component of ECB explanations has a significant and sizeable impact on futures prices. This indicates that the ECB has already acquired some credibility: financial markets seem to believe that it does what it says it will do. Finally, our results suggest that the Euribor futures market is semi-strong form informational efficient.

Keywords: market efficiency, central bank communication, news shock, tick-by-tick Euribor futures data, event-study analysis.

JEL classification: E52, E58, G14.

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[*] The authors thank seminar participants at the Kiel Institute for the World Economy, London School of Economics, LUISS, Royal Economic Society annual meeting, and University of Ancona and especially Gianluca Benigno, Willem Buiter, Kai Carstensen, Jonas Dovern, Michael Ehrmann, Christian Julliard, Thomas Lux, Jochen Mankart, Andrew Patton, Riccardo Puglisi, Dennis Snower, Rick Van Der Ploeg, Michela Verardo, Pietro Veronesi and Alwyn Young for very helpful conversations and comments. An earlier version of this paper appears in a doctoral dissertation at the London School of Economics. The first author is extremely grateful to Gianluca Benigno and Leonardo Felli for their guidance, continuous stimulus, and support throughout his graduate studies. All remaining errors are ours.

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"Financial markets evidence indeed indicates that we as a central bank have managed to be understood by market professionals. (...)
One of the main goal of a responsible central bank now is to have a reliable communication guiding expectations in a rapidly changing environment."
Trichet (2005)

"A month ago Jean-Claude Trichet gave what markets see as his standard nod and wink: the European Central Bank (ECB), said its president, would continue to exercise "vigilance" against inflationary pressures. Stand by, in other words, for another increase in interest rates at the bank's next rate-setting meeting on October 5. ECB-watchers were therefore well prepared when rates duly rose, by a quarter of a percentage point, to 3.25%."
The Economist (October 2006)

1 Introduction

Do European Central Bank (henceforth ECB) announcements affect market expectations about the future path of its monetary policy? How long does it take for these messages to be promptly incorporated into asset prices? Is it possible to assess the effect of central bank communication without relying on the exogeneity assumption of monetary policy shocks? Is the Euribor futures market informational efficient? To address these questions, this paper uses a novel data set to present extensive evidence on market efficiency in relation to central bank announcements.

The value added of this study to the empirical finance literature on the efficient market hypothesis (i.e. in an efficient capital market, security prices fully reflect all available information) is two-fold. First, we test market efficiency for a *new type of news item*, specifically for the information originating from central bank announcements. Second, we analyze the efficiency of a *new financial market*, the Euribor futures market, *in real time*. By doing so, we address two shortcomings of the existing literature. On the one side, we investigate the efficiency property using a high-frequency tick-by-tick dataset. As vividly point out by Busse and Green (2002), even though in practice prices do not respond instantaneously to news, nowadays market efficiency should really be gauged in real time. On the other side, we analyze a *European money market* while most empirical studies focus on the US foreign exchange and stock market.

Our work also contributes to the rapidly expanding literature on central bank communication. Since central banking is increasingly becoming the art of managing expectations, communication has developed into a key monetary policy instrument. In this paper we examine the real-time effects of central bank announcements on financial markets. We show that market participants respond to *two different pieces of news* rather than just one piece of news, as is commonly analyzed in the monetary economics literature. Therefore, in order to properly describe the central bank conduct of monetary policy we find that two dimensions are needed: both central bank actions and central bank words. Put it differently, whereas the workhorse model

so far used in the literature (Kuttner, 2001) has been based only on monetary policy shocks, i.e. a single factor, our results suggest that nowadays central banks are also able to affect asset prices through their bias statements, a second policy instrument.

We apply our empirical methodology to investigate the effectiveness of the ECB communication policy because of its unique institutional characteristic of first announcing its policy rate decisions (i.e. the minimum bid rate for the main refinancing operations of the Eurosystem) and then, after about 45 minutes, explaining its monetary policy stance.[1] By using a *new* intraday dataset, we are able to neatly investigate the effects on asset prices of the latter announcement separately from the policy decision. We can thus circumvent the endogeneity and omitted variables problems (i.e., interest rate changes and monetary policy shocks can be influenced by each other and by other common variables) that affect most of the previous work.

Our main findings can be summarized as follows. First, by using number of transactions and volumes data, we show qualitatively that financial markets immediately react to the two pieces of news that systematically reach them on Governing Council meeting days, that is the policy decision announcement communicated at 12:45 (throughout the paper, London time is always used) and the ECB President monthly press conference starting at 13:30.

Second, by using a new tick-by-tick dataset, we show quantitatively that innovations in market expectations about future monetary policy can be explained by *unexpected* ECB announcements, i.e. the difference between what the ECB announces and what the market expects the ECB to announce. In particular, we find that the news shock is not only statistically and economically significant, but also quantitatively important. This evidence suggests that even if the ECB is a relatively young central bank, it has already acquired some credibility.[2] In other words, financial markets believe that the European Central Bank does what it says it will do. Hence, the econometric results presented in this paper indicate that ECB words and deeds have been consistent with each other, otherwise market participants would not have reacted to central bank announcements.

Third, futures prices incorporate the news stemming from the ECB President speech very quickly, in around one hour. Moreover, the Euribor futures market satisfies the semi-strong form definition of informational efficiency, i.e. public information cannot be used to make abnormal profits relative to the risks being borne.

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[1] In particular, during the monthly press conference the ECB President explains the Bank's assessment of the economic situation, the risks to medium term price stability and the way in which they systematically affect policy decisions.

[2] We have in mind Blinder (1998, page 64) definition of credibility: "Matching deeds to words. (…) Credibility means that your pronouncements are believed – even though you are bound by no rule and may even have a short-run incentive to renege. In the real world, such credibility is not normally created by incentive compatible compensation schemes nor by rigid precommitment. Rather, it is painstakingly built up by a history of matching deeds to words. A central bank that consistently does what it says will acquire credibility by this definition almost regardless of the institutional structure."

Fourth, by estimating a state space model, we find that the importance of the ECB press conference has increased over time, especially during the first years of the ECB life. This evidence suggests that financial markets participants needed around three years to learn how to interpret the central bank announcements.

The rest of the paper is organized as follows. In the next section, we discuss the measurement of the tone of ECB announcements. In Section 3, we describe the rolling 3-month Euribor futures data. And, in order to illustrate the advantages of using high-frequency data, we analyse the futures price dynamics in specific announcement days. Finally, we provide some qualitative analysis based on number of transactions and volumes of contracts exchanged during a trading day. In Section 4, we estimate the effect of the news shock using intraday tick-by-tick data from the Euribor futures market. In Section 5, we perform some important robustness checks and sensitivity analysis. In Section 6, we discuss the implications of our findings for testing the market efficiency hypothesis in real time. In Section 7, we analyse the implications of our findings for central bank communication and monetary policy. In Section 8, we suggest some important issues left for future research and conclude.

2 Measuring the tone of ECB announcements

Since its inception, the ECB has paid a great deal of attention to its announcement policy, and especially to its choice of medium, form and content. In order to properly communicate with the public, and address the informational needs of the various target groups, politicians, academics, the press, financial markets, etc., it uses many different instruments. These include the Monthly Bulletin, the President's monthly press conference (and its Questions and Answers session), the Testimony to the Committee on Monetary Affairs of the European Parliament (nowadays four times a year) and frequent speeches by its President and / or members of the Governing Council.

In its Monthly Bulletin of November 2002 (page 64), the ECB said that "The monthly press conferences held by the President and the Vice-President and the Monthly Bulletin are two of the most important communication channels adopted by the ECB." In particular, the press conference is a timely instrument to communicate concisely to the public the ECB Governing Council's view of recent economic developments. Indeed, in its Monthly Bulletin of January 2006 (page 57), the ECB confirmed that the President press conference "provides a detailed explanation of the economic outlook for the euro area and the risks to price stability. This communication is aimed at improving the public's understanding of the current decision and the possible future course of policy interest rates."

For simplicity and consistency, in this paper we restrict our econometric analysis only to the wording of the press conferences. We consider this research work as a first step in a broader

research agenda that aims to investigate the real-time effectiveness of all ECB communication channels. It seems to us that the introductory statement to the monthly press conference represents a natural candidate for the first step, as it is simple, relatively short compared to the Monthly Bulletin and systematic in terms of its frequency and structure.

In order to make the European monetary authority's statements suitable for statistical computation, we assign a number to each ECB monthly announcement. This number is intended to summarize the ECB overall monetary policy stance as communicated by its Governing Council.[3]

Since words are not precise quantitative data, the ranking of statements according to their assessment (tightening, neutral or easing) of ECB future policy rate setting behaviour is necessarily influenced by personal judgement. Although we acknowledge that our assessment is subjective, it should be noted that the overall tone of ECB announcements is usually unambiguous.[4]

The classification of statements is often referred to as content analysis (Krippendorf, 2004 and Weber, 2004): it consists of a set of techniques to systematically extract the content of a message.

In order to analyse the contents of the introductory statement of the ECB President monthly press conference held on Governing Council meeting days, we follow Rosa and Verga (2007) methodology based on a glossary that translates the qualitative information of the press conferences into an ordered scale.[5]

When more than one word or string from Table 1 (our mapping between words and numbers) features in a given press conference, our coding corresponds to the mean of the indices of each single expression used by the ECB rounded to its nearest integer. Note that the coding attributed to the relative statement (bottom panel of Table 1) constitutes one of the components of the calculated mean of indices.

The wording indicator, *Index*, is converted into a variable on a five-value scale from -2 to +2. The value of zero suggests that the current level of the Repo rate is appropriate to maintain price stability over the medium term. The value -1 characterizes an easing period: it is possible that the Repo rate will be cut in the near future. The value -2 indicates that the Governing Council is increasingly inclined to cut interest rates. The values +1 (+2) characterizes a (strong) likelihood of future monetary policy tightening.

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[3] The seminal paper of Romer and Romer (1989) pioneered this so called narrative approach. In particular, they examined the records of Federal Reserve policy deliberations in order to identify exogenous (according to their claim) monetary policy shocks.

[4] We do however exclude one press conference (June 2000) because it does not describe the ECB overall monetary policy stance, but rather it focuses on the recent (past) economic developments.

[5] For further details about the construction of the glossary, caveats, advantages and disadvantages of this methodology, see Rosa and Verga (2006) and Rosa (2006).

Our assigned value of risk, *Index*, to each ECB monetary policy announcement is reported in the working paper version of this article (Rosa and Verga, 2006), where we also provide a few examples of introductory statements along with our coding.

All the econometric results that we present in this work are qualitatively very similar, and remain highly statistically significant even if we use other people's wording indicators of the ECB monetary policy stance, such as Musard-Gies (2006).

3 Euribor futures market data

3.1 Description

On 1 January 1999, the Euro became Europe's main currency. Since then, new financial markets have been set up, including Euribor,[6] the Eonia (Euro OverNight Index Average) and Euro denominated short-term interest rate derivatives market. This last gives hedgers and speculators easy access to exposure to the Euribor benchmark through trading futures contracts, options on the futures contract, and a one-year mid-curve option on the futures contract.

The three-month Euribor futures contracts are cash-settled short-term interest rate financial instruments with the Euribor rate for a three-month Euro deposit of a face value of € 1,000,000 as the underlying asset.

The Euribor futures contract that we consider in this study is traded at the Euronext Liffe (London International Financial Futures and Options Exchange) from 7 to 18.[7] Futures prices are quoted on a daily basis and the contracted interest rate equals 100 less the futures price. Each contract moves in fixed increments (or discrete units / ticks) of 0.005, which corresponds to a value of 12.5 €.

The last trading day of each futures contract is two trading days prior to the third Wednesday of the delivery month, while the delivery date is the first business day after the last trading day. At a given point in time twenty-five contracts are usually being actively traded. The standard delivery months are March, June, September and December, known as quarterly expiries. There are also serial expiry contracts that expire in the nearest following six calendar months and that do not correspond to the quarterly sequence. Typically serial expiry contracts exhibit lower liquidity.

[6] The Euribor (Euro Interbank Offered Rate) is a daily reference rate based on the interest rates at which banks offer to lend unsecured funds to other banks in the euro wholesale (or "interbank") money market. Euribor is determined (fixed) by the European Banking Federation (EBF) at about 10:00 each day, and is a filtered average of inter-bank deposit rates offered by a large panel of designated contributor banks (currently more than 50), for maturities ranging from one week to one year. Euribor rates can be downloaded at www.euribor.org (last accessed on 31 August 2006).

[7] Euribor futures contracts are also traded at the Eurex (see www.eurexchange.com, last accessed on 1 October 2006). However, this market displays less liquidity than the LIFFE (anecdotal evidence provided by practitioners and traders).

It is possible to build two different types of futures price time series: by position and by contract. Position time series are constructed by merging price data of different futures contracts. At a given point in time, the first position is defined as the contract which expires next in the quarterly sequence. The second position is represented by the second contract to expire in the same quarterly sequence. The third, fourth, etc. positions are constructed similarly. On the other hand, as the name suggests, the contract time series starts on the opening date of the contract and stops when the futures contract expires.

In this paper we restrict our attention to the first position 3-month Euribor futures contracts (basically 3-month rolling futures contracts) for two reasons. First, we do not need to adjust futures prices for a different number of months left to expiration and thus we avoid unnecessary complications. For example, Piccinato et al. (1999) find that the intraday statistical properties of futures prices are a function of the time left before expiry (i.e. seasonality that depends on the "time-to-maturity" effect). Second, studying futures by position can be justified on the basis of how the futures market works. In fact, in order to stay in the market, traders holding close-to-expiry contracts need to roll their position forward into the next expiry futures contract. By doing so, they are constructing a time series by position that extends beyond the expiry of each contract.

Nowadays, the first position contract displays very high liquidity. For instance, during the last quarter of 2005, the average daily volume (i.e. number of exchanged contracts) was approximately 125,400 futures contracts, with an increase of 50% compared to the same period in 2004 (83,842 futures contracts) and 68% compared to two years earlier (74,317 in the fourth quarter of 2003).

The data used in this study is provided by The Institute for Financial Markets. The dataset contains several pieces of information such as transaction by transaction price (around 2,500,000 transaction ticks), time of trade execution to the nearest second (both January 1999 - June 2006), and volumes (July 2003 - June 2006). We have trade data (transaction prices) in our database. However, we do not have bid-ask quotes.

As expected, the rolling 3-month futures rate is very similar to, almost undistinguishable from, the 3-month-forward 3-month-ahead (implicit) Euribor rate, where this rate is derived from the Euribor term structure (Figure available upon request).

3.2 Specific announcement days

The ECB conduct of monetary policy is characterized by the unique institutional feature that on the same day and at two different points in time, the ECB Governing Council announces its monetary policy decision and explains its monetary policy stance. At 12:45, the ECB communicates the new level of its policy rate through a press release. After 45 minutes, at 13:30,

the monthly press conference starts and the ECB President explains to the public the monetary policy decision taken and also the Governing Council's view of recent economic developments. The speech is very important, especially for traders, because it conveys strong hints about the future path of ECB monetary policy.

The advantages of using high-frequency data are best illustrated in Figure 1, which reports the tick-by-tick three-month Euribor futures price movements on a set of specific days:

1) On 6 April 2006 (Governing Council meeting day), financial market participants fully anticipated no change in the policy rate. In particular, there is no sharp market reaction at around 12:45 GMT. Nevertheless, the futures price jumped up at around 14:00 (this means of course that the interest rate fell sharply). Everything happened in twenty minutes: it went from a rate of 3.085 at 13:33 to 2.98 at 13:56. One explanation could be a dovish speech given by ECB President Trichet; recall that the press conference starts at 13:30. One of his answers to journalists questions (reported below) was extremely clear about ECB future monetary policy moves, and it may shed light on the immediate response of the 3-month futures price movements. In his monthly introductory statement, the President did not mention explicitly the key word "vigilant" which seems to indicate a strong risk for policy rate spikes in the near future (cf. glossary in Table 1).

> **Question:** Mr Trichet, the markets were expecting you to say vigilance in order to prepare them or prepare for an interest rate rise in May. *You did not say vigilance, was that deliberate?* And second, did the Council discuss raising rates today?
> **Trichet:** As we do in all our meetings which concentrate on monetary policy, we discussed the issue of rates. We discussed it at length. It is our responsibility to be as clear and transparent as possible with market participants, investors and savers. *I would say 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. I would also add that the sentiment that I see from time to time in some remarks or market literature concerning the perception that we do not increase rates when we are out of Frankfurt is equally not at all the sentiment of the Governing Council.* I trust that, for the sake of clarity, transparency and simplicity, it was perhaps useful to make these two remarks. And *it is true, vigilance is not mentioned in the introductory remarks, as you very wisely remarked*. [Emphasis added][8]

This example illustrates two important points. First, the ECB is able to move asset prices using words alone, without any need for implementing policy deeds. Second, the immediate response of the futures price is consistent with semi-strong form informational efficiency.

[8] Note that the ECB Governing Council meeting of June 2006 was held outside Frankfurt (in Madrid) and it featured a policy rate increase of 25 basis points, as Trichet anticipated in April, while in May 2006 there was no Repo change.

2) On 31 March 2004, financial markets assigned a probability of around 70% that the ECB would cut its policy rate in the near future.[9]

On 1 April, Trichet turned market expectations upside down. In particular, he declared that: "On the basis of our regular economic and monetary analysis, we have not changed our assessment that the current stance of monetary policy remains in line with the maintenance of price stability over the medium term". Thus, he signalled that the ECB was not going to change its policy rate in the near future by using the keyword "in line" (cf. glossary in Table 1). As shown in Figure 1 (b), the market reacted immediately: the 3-month futures rate jumped up. The probability of a policy rate cut was drastically reduced.

3) At the beginning of November 2005, the ECB left its policy rate on hold. However, Trichet said the Bank remained highly vigilant on inflation and stood ready to raise interest rates. He added: "We stand ready to move any time when it is required by our mandate and by the situation … we are very clear that we clearly could move any time."

On Friday afternoon 18 November at around 14, at the European Banking Congress in Frankfurt, Trichet told the press that: "After two years and a half of maintaining rates at a historical low, I consider that the Governing Council is ready to take a decision to move interest rates from the present level in order to take into account the level of risk." Panel (c) of Figure 1 clearly shows that traders immediately placed bets that the ECB would increase the policy rate in December: the 3-month futures rate jumped up steeply.

The takeaway of this last example is that, as long as it is not fully anticipated, ECB communication is able to move asset prices on any day, not only during Governing Council scheduled meeting days.

4) Finally, Panels (d) and (e) report two cases where the news is represented by ECB monetary policy actions rather than by announcements on its overall monetary policy stance. Note that futures prices adjust immediately: in both cases it took less than 60 seconds to completely price in the monetary policy shock.

Indeed, it can be shown econometrically (results are available from the authors upon request.) that monetary policy shocks, defined as the difference between the one-month Euribor rate quoted at 10:00 and the new Repo rate communicated at 12:45, are incorporated in less than five minutes. In this respect, it *seems* that financial markets understand numbers better than words.

This claim should be taken with caution because the monetary policy decision (hard information, quantitative) and the press conference announcement (soft information, qualitative)

[9] This probability is computed by using market-based measures of monetary policy expectations, i.e. the implied rates from the Euribor yield curve, and an ordered probit regression (whose methodology is described in Section 5) with five dependent variables: policy rate increases of 50 or 25 basis points, no change in the policy rate, policy rate cuts of 25 or 50 basis points.

are two different kinds of news items (see Petersen, 2004). The former concerns a fact about the immediate future, while the latter is a probability assessment about the near future.

3.3 Qualitative analysis of volumes and number of transactions

In this subsection in order to better understand the relationship between the price discovery process and ECB communication, we present some qualitative results on average number of transactions ticks, a proxy for the market activity, and volumes by distinguishing between Governing Council meeting days and all other Thursdays. Note that since Governing Council meetings take place on Thursday and in order to explicitly take into account day-of-the-week effects, we compare market activity between Governing Council meeting days and all other Thursdays, rather than to all other trading days.

Figure 2 shows that the five-minute average number of transactions is substantially higher on Governing Council meeting days (full sample January 2000 – June 2006). A value larger than zero indicates that monetary policy decisions and communication induce a larger number of transactions than could be considered "normal" had the announcements not been made. For instance, a value of one indicates that the five-minute average number of transactions in that time window has been twice as much during Governing Council meeting days compared to all other Thursdays. Of course, the greater the news content of an announcement, the stronger the financial market activity should be.

It is eye-catching that there are two peaks: the first one corresponds closely to the new Repo rate announcements (12:45), while the second one takes place at the starting of the ECB President press conference (13:30). Market expectations seem to be quite heterogeneous at the time of the surprise, but then they start to converge.[10] It is interesting to note that the convergence is much faster for monetary policy shocks than for news shock. Apparently, quantitative announcements are easier to interpret than qualitative ones.

Figure 3 plots the ratio between futures price volatility on Governing Council meeting days with respect to all Thursdays. [11] Again, two pieces of news seem to systematically hit the

[10] Recall that according to no trade theorems (Fudenberg and Tirole, 1991, Chapter 14) it is impossible for risk-averse agents take opposing sides of the same purely speculative bet under common knowledge. Hence, by using the contra-positive argument, if we observe trade market participants should have heterogeneous views. Note that we are abstracting from noise trader and portfolio rebalancing considerations. In particular, even if a monetary policy action or announcement is fully anticipated by market participants, it may still trigger portfolio adjustments by those agents who deviated from on average (correct) expectations.

[11] We use the absolute deviation of the (5-minute window) futures prices because it better captures the autocorrelation and the seasonality of the data (Piccinato et al., 1999) compared to the more usual standard deviation definition. For completeness, the latter measure of the volatility is also computed. There are no significant differences between the two definitions.

market. Moreover, it is clear that futures prices incorporate the first one, the monetary policy shock, very quickly.

These findings are completely corroborated if we use average volumes rather than either average number of transactions or asset price volatility. In Figure 4 we plot the ratio between average volumes on Governing Council meeting days and all other Thursdays for the sample period July 2003 – June 2006 (recall that we do not have volume data before July 2003). Contrary to Figure 2 and 3, financial market participants' expectations of future monetary policy actions now seem to be less heterogeneous than their expectations about ECB announcements.

This result is also confirmed by Figure 5, which plots the ratio between the average number of transactions on Governing Council meeting days and all other Thursdays restricting the sample period to July 2003 – June 2006.

A possible explanation for this phenomenon is that ECB monetary policy actions have recently become more predictable than at the beginning of its life. Indeed, Figure 6 plots the monetary policy shock for the whole sample (January 1999 – June 2006) and shows that its absolute value is much smaller nowadays. Recall also that from June 2003 to December 2005 the ECB did not move its policy rate.[12]

Hence, on Governing Council meeting days two pieces of news systematically hit financial markets: the ECB policy rate decision (standard in the literature), and the explanation of its monetary policy stance. In order to describe central bank monetary policy we need two dimensions: both the current policy rate and its future path. We conclude that, at least qualitatively, financial markets seem to pay attention to both news items.

4 Tick-by-tick data: econometric results

In this section we estimate the impact of unexpected central bank announcements on the short-end of the term structure, using a *new* tick-by-tick dataset from the Euribor futures market

Since we are interested in investigating and measuring only the innovations in expectations caused by the ECB President's press conference, we restrict our econometric analysis to Governing Council meeting days. In other words, we apply a standard event-study approach.

Both Mackinlay (1997) and Campbell et al. (1997, Chapter 4) provide detailed surveys of the event study methodology. In this case, a clear advantage of using an event-study analysis is

[12] Prior to November 2001, the ECB Governing Council could change the policy rate twice a month. For this reason, prior to November 2001 when we calculate the change in the one-month Euribor rate, we get not only the monetary policy surprise at the current meeting but also the change in market expectations for the next intra-month meeting. Figure 7 would remain qualitatively very similar, and so our conclusions, if we used the change in the one-week Euribor rates as a proxy of the monetary policy shock. Note that unfortunately two and three week Euribor rates data are not available prior to October 2001.

that it can attenuate or even eliminate the joint hypothesis problem intrinsic in all statistical tests of the market efficient hypothesis (i.e., market efficiency must be tested jointly with an asset pricing model). In other words, we do not need to specify a model of market equilibrium. Moreover, the way we measure daily abnormal innovations in market expectations (our dependent variable) has little impact on inferences (cf. Brown and Warner, 1985).

The initial task of conducting an event study is to identify the so-called event window, the period over which the asset price involved in the event is examined.

We first introduce some definitions and notations. Let the event take place today (date *t*) at time *t2* and define the event window between the interval *t1* and *t3*. The timing sequence is illustrated in Figure 7.

Our goal is to analyse the abnormal asset price change between *t3* (post-event window) and *t1* (estimation period). The abnormal asset price change is defined as the difference between actual ex-post security price change over the event window and its normal change. In turn, the normal change is defined as the change that would be expected if the event did not take place. In the literature, there are two common choices for modelling the normal return (cf. Campbell et al., 1997, p. 153): the constant-mean-price-change model (used later in this chapter) and the market model. The first model assumes that the mean change is constant over time. The second posits that there is a stable linear relationship between the market movements and the security return.

In order to check whether financial markets react to ECB communication, it is crucially important to realize that the news does not consist of the ECB announcement itself but rather by its unexpected component, i.e. the difference between what the ECB declares and what the market expects the ECB to declare. Therefore, to verify empirically the effectiveness of ECB words, we need to proceed in two steps. First, we have to pin down what the market expects the ECB to declare. Second, we investigate the sensitivity of asset prices to the news shock.

We first posit and then verify empirically that the market tries to predict the ECB announcement through the following regression:

$$Index_{t2} = \alpha + \gamma_1 (f_{t1} - R_{NEW}) + \gamma_2 Index_{t1} + \varepsilon_{t2} \qquad (1)$$

where α is a constant and γs are regression coefficients. f_{t1} stands for the Euribor futures rate quoted on day *t* from *t1* averaged over a 15-minute window. R_{NEW} stands for the new Repo rate level communicated at time 12:45. ε_{t2} stands for a zero-mean noise term uncorrelated with the regressors. Note that the market expectation about the ECB's announcement is conditional on time *t1* information set, that is immediately before the ECB President press conference takes place.

In words, we assume that *Index* follows an AR (1) process: the economic environment usually does not change too much in the course of one month, and thus also the ECB monetary

policy stance cannot be completely revised. However, the ECB's declaration has been released on the previous month, and in the last thirty days many other news may have hit the marketplace.

In order to be successful, an event study has to identify precisely both the date of the event and the new (unexpected) information released. Obviously, in a rational marketplace, prices do not respond to old information. The issue of anticipated announcements is successfully dealt by our approach, since we use the very latest (indeed, real-time) information to construct market expectations about ECB declarations, viz. the slope of the term structure immediately before the ECB President press conference takes place.

If the futures rate (net of the risk premium already captured by α [13]) is higher than the new level of the Repo rate, then the market expects the ECB to increase its policy rate in the near future. Hence, other things being equal, it expects a greater value of *Index* to be announced. In other words, if the very short-end of the term structure is upward sloping, a hawkish declaration is likely. Vice versa, if the short-end of the term structure is downward sloping, then the market expects the ECB to cut its policy rate in the near future. It expects a dovish announcement.

Since the wording indicator variable, *Index*, takes only discrete values (i.e. integers from -2 to +2), ordered probit regression is the most appropriate estimator.

Table 2 reports the estimated coefficients of Equation (1) for the period January 2000 – June 2006.[14] Interestingly, both coefficients γ_1 and γ_2 are positive, and both have the expected sign and are highly statistically significant. Note that the parameter estimates do not have the usual interpretation: in the ordered probit model the marginal effect depends both on the dependent variable and on the time *t* of the explanatory variables, making them cumbersome to report.

Furthermore, the independent variables explain fairly well the announced tone of ECB President's declaration (the goodness of fit measured by the pseudo-R^2 is around 0.55).

We construct market participants' expectations about the ECB announcement as follows:

$$E_{t1}[Index_{t2}] = \sum_{i=-2}^{+2} \Pr(Index_{t2} = i) \cdot i \qquad (2)$$

[13] Note that the futures contract is different from a Repo contract stipulated with the central bank. In fact, the futures contract refers (more or less) to a three-month-ahead three-month-forward rate, while the Repo refers to an immediate one-month-forward rate. For this reason, a more sophisticated approach would consider a risk premium that varies over time. In this case, business cycle indicators, such as the default spread (i.e., a return increase from high-grade to low-grade bonds, from bonds to stocks, and from large to small stocks) and term spread (i.e., premium for maturity risks form long-term to short-term securities), track risk premium dynamics.

[14] Our dataset starts in January 1999. However, on the one side we consider the year 1999 as a learning period to well interpret ECB announcements. On the other, the practitioners whom we consulted suggested us that the Euribor futures market was not very liquid in the beginning. This fact is confirmed by volume and number of tick data in 1999 compared to the following years.

where Pr$(Index_{t2} = i)$ is computed analytically by the ordered probit model (see Ruud, 2000, or the working paper version of this article, Rosa and Verga 2006, for more details).[15]

Figure 8 shows the futures rate response to unexpected hawkish, neutral and dovish announcements made by the ECB President during the monthly press conference. A statement is defined hawkish when the news surprise, the difference between $Index_{t2}$ and $E_{t1}[Index_{t2}]$ as given by Equation (2), is higher than the median of the positive news shocks observed in our sample period (i.e. 0.184). Vice versa, a statement is defined dovish when the news surprise is lower than the median negative news shock observed in our sample period (i.e. -0.367). In the remaining cases, the central bank statement is classified as neutral.

Overall, the price response is consistent with the sentiment of the news. Indeed, futures rate increase after an unexpected hawkish announcement, decrease after a dovish one, and are basically unaffected by neutral declarations.

However, there are marked differences in the pattern and magnitude of the responses. In particular, the reaction to future monetary tightening announcement is much stronger (almost double size) than to monetary easing statements. Moreover, dovish announcements are usually followed by a small and quick reversion: it seems that market participants need more time, around one hour, to correctly interpret monetary easing announcements. This phenomenon can be due to the difficulty of market participants in understanding the de facto almost lexicographic ECB utility function, where price stability represents the primary objective. Only without prejudice to it, the European monetary authority can legitimately pursue other objectives such as employment and output.[16]

So far, a dovish ECB statement has been characterized by two components (excerpts available upon request): no risk to price stability together with contemporaneous downward economic danger. It turns out that traders need not only the information contained in the introductory statement to the monthly press conference, but also its questions and answers, and some additional processing time, to correctly distinguish a neutral statement, where only no risk to price stability is reported, from a dovish declaration.

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[15] In order to have a straightforward interpretation of our empirical results, we also estimate Equation (1) by Ordinary Least Squares (OLS) estimation with White-t statistics (White, 1980). All the econometric evidence that we present in this section continue to hold both qualitatively and quantitatively (results available in the working paper version, Rosa and Verga, 2006).

[16] Article 105 of the Maastricht Treaty states: "The primary objective of the ESCB shall be to maintain price stability. Without prejudice to the objective of price stability, the ESCB shall support the general economic policies in the Community with a view to contributing to the achievement of the objectives of the Community as laid down in Article 2" [i.e., "the objectives of the Union are a high level of employment and sustainable and non-inflationary growth"]. Moreover, according to the ECB website (http://www.ecb.int/mopo/intro/html/objective.en.html, last accessed on 15 August 2006): "The Treaty establishes a clear hierarchy of objectives for the Eurosystem. It assigns overriding importance to price stability. The Treaty makes clear that ensuring price stability is the most important contribution that monetary policy can make to achieve a favourable economic environment and a high level of employment."

We now test econometrically the effectiveness of ECB communication by estimating the following regression:

$$f_{t3} - f_{t1} = \alpha + \beta_1 NS_{t2} + \beta_2 JC_{t2} + \varepsilon_{t3} \quad (3)$$

where NS_{t2} stands for news surprise just after ECB announcements and JC_{t2} stands for the surprise component of the release of US jobless claims figure, defined as the difference between the actual release and market expectations measured through the mean response of a Bloomberg survey among market participants.[17] The rest of the notation is the same as above.

In order to precisely measure the effect of ECB communication it is important to control for the surprise component of the release of US jobless claims figures, which occurs every Thursday at 13:30. Note that if we omit this regressor our estimates will be less efficient but not biased as long as this kind of news is not systematically correlated with the error term.

Table 3 reports the estimations for three different time windows, specifically for *t3* = 14:45, 15:45 and 16:45, and *t1* = 13:15 (all averaged for a 15-minute interval).

We restrict our sample only to Governing Council meetings that take place on Thursday.[18]

It turns out that the coefficient on the news shock (β_1) is always positive (as expected), and statistically significant at the 1% level: the news shock can systematically explain the futures price change around the time of ECB President's announcements. However, we find no statistically significant effect for the surprise component of the US jobless claims figures. This may be due either to the overwhelming importance of the press conference compared to the macro release or to the small sample size that prevents us from obtaining statistically significant effects. In fact if we consider all Thursdays but Governing Council meeting days, the US jobless claim has a negative and statistically significant effect on the futures prices.

Table 3 suggests that the ECB can influence the money market interest rates to some extent simply by using words, rather than deeds, such as a change in its policy rate. For example, when the ECB President declares: "It is imperative to contain upward pressure to price stability", while the market is expecting a value of *Index* of zero, the futures rate jumps up on average by about 4 basis points.[19] This finding shows that the ECB unexpected announcements have a significant and sizeable impact on futures prices.

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[17] We kindly thank Michael Ehrmann for sharing with us the JC_{t2} time series.

[18] In three occasions (5/1/2000, 11/4/2001 and 4/5/2005) the members of the ECB Governing Council did not meet on Thursday. Alternatively we could consider all Governing Council meeting days and posit that the surprise of the US jobless claims figure is equal to zero when the meeting is not scheduled on Thursday. Nothing changes neither qualitatively nor quantitatively in the results reported below.

[19] Because of attenuation bias due to measurement error in the explanatory variable (Johnston and DiNardo, page 154) of Equation (2) (also due to the artificial discreteness of our wording indicator), this

So far, we have shown that asset prices react to ECB communication, but how long does it take? In other words, what is the degree of efficiency (i.e., the speed with which prices incorporate information) of the Euribor futures market? We answer this question, and hence we measure the speed of futures price response to ECB announcements, by estimating the following regression for different f_t:

$$f_{17:00} - f_{13:15} = \alpha + + \beta_1 NS_{t2} + \beta_2 JC_{t2} + \gamma (f_t - f_{13:15}) + \varepsilon_{t3} \quad (4)$$

where f_t stands for the (15-minute average) futures rate at time t.

Table 4 clearly indicates that as time unfolds futures rates incorporate more and more the news shock. At around 15:00, unexpected announcements are no longer significant. Hence, in about one hour after the ending of the press conference, futures prices have completely incorporated the news originating from the ECB President monthly press conference.

The seemingly quick adjustment in asset prices is consistent with the semi-strong form of market informational efficiency. In particular, widespread profitable trading opportunities do not persist for long.

To further illustrate this last finding, we also estimate the effect of news shocks after 15:00. In Table 5 we report the estimations of the following regression:

$$f_{t4} - f_{t3} = \alpha + \beta_1 NS_{t2} + \beta_2 JC_{t2} + \varepsilon_{t3} \quad (5)$$

where both *t4* and *t3* are placed after the ECB President's announcement. More precisely, *t3* is the 15-minute average price quotation starting at 15:00 and *t4* is the 15-minute average starting at 17:30, and 9:00 and 11:00 of the day after the ECB Governing Council meeting.

As we expect, neither the constant nor the news shock can systematically explain the futures price change.

Surprisingly, the coefficient of the surprise release of the US jobless claim figure is statistically significant at the one percent level when *t4* = 9:00 or *11:00* a.m. of the day following the Governing Council meeting. We think that this is not an evidence against the efficiency of the Euribor futures market. In fact, if we analyze all Thursdays but Governing Council meeting days, the regressor coefficient of the surprise component of the US jobless claim releases is never statistically significant in the three time windows considered in Table 5.

Throughout the paper we use a 15-minute average quotation rather than specific ticks, since the initial reaction of bond prices to the "unexpected" ECB announcement may be larger (overshooting) or smaller (undershooting) than its "true" effect (cf. Faust et al., 2004). Asset

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number should be interpreted as a lower bound on ECB ability in moving asset prices by simply making announcements.

prices should incorporate news instantaneously but actually do not. This procedure may introduce a possible bias in our estimations (cf. Blume and Stambaugh, 1983). Nevertheless, we think that this bias is not important since we consider a very liquid market. Ideally, we want to give more importance to a quotation price that corresponds to a high traded volume. However, we can not construct average futures prices weighted by volumes, since volume data are available only from July 2003.

Note that none of the econometric results reported in this paper would change if we used a 5-minute window rather than a 15-minute one to compute average futures rates (results not reported but available upon request).

As a further robustness check we also re-run the previous regressions (estimations not reported but available upon request) using equally-spaced data instead of averaged tick-by-tick data. We construct these artificial data by linear interpolation of the transaction prices immediately before and after the relevant point in time. Then we obtain futures rate returns as the first difference of the new prices (see Andersen et al., 2003, page 593). Our empirical findings discussed in this section are qualitatively very similar if we use equally-spaced data.

5 Robustness checks: Ordered Probit and generated regressor issue

5.1 Generated regressor issue

So far the econometric estimations have been carried out in two steps. First, we determine market expectations about ECB announcements immediately before the start of the press conference. Then, we use the news shock to explain the futures price discovery process. In other words, in the second step we employ generated regressors (cf. Oxley and McAleer, 1993).

This fact may give rise to underestimated standard errors and hence to spurious significant regressor coefficients. In order to solve this issue and to check the statistical validity of our conclusions, we re-estimate the same regressions of the previous subsection all in one step. More formally, we estimate the following regression by OLS:

$$f_{t3} - f_{t1} = c_1 + c_2 \cdot (Index_{t2} - c_3 \cdot (f_{t1} - R_{NEW}) - c_4 \cdot Index_{t1}) + c_5 JC_{t2} + \varepsilon_{t3}$$

$$f_{17} - f_{13:15} = c_1 + c_2 \cdot (f_t - f_{13:15}) + c_3 \cdot (Index_{t2} - c_4 \cdot (f_{t1} - R_{NEW}) - c_5 \cdot Index_{t1}) + c_6 JC_{t2} + \varepsilon_{t3}$$

$$f_{t4} - f_{t3} = c_1 + c_2 \cdot (Index_{t2} - c_3 \cdot (f_{t1} - R_{NEW}) - c_4 \cdot Index_{t1}) + c_5 JC_{t2} + \varepsilon_{t3}$$

where cs are regressor coefficients, and the rest of the notation is the same as before.

All the econometric results continue to hold both qualitatively and quantitatively (results available upon request).

In order to account for the generated regressor problem when computing coefficient estimates' standard errors, we also check the robustness of our conclusions by using a bootstrap approach to statistical inference (see for example Efron and Tibshirani, 1993). More specifically we apply a sampling-with-replacement raw residuals bootstrap scheme with 1,000 repetitions. The empirical results (not reported here but available upon request) are qualitatively very similar to those obtained in the previous section when White's robust standard errors are used. In particular, the ninety-nine percent confidence bands of the coefficient of the news shock in equation 3 never include negative numbers. This fact confirms that the ECB is indeed able to move asset prices in the desired direction.

5.2 State space model

An implicit assumption of all the econometric models specified so far is that the regressor coefficient of the news shock remains constant over time. This implies that we have completely ruled out by assumption a learning period.

In this section we specify and estimate a state space model that explicitly allows to incorporate unobservable variables, known as state variables, into the observable model. In other words, we relax the above assumption and allow the regressor coefficient of the news shock to vary over time. Specifically, we specify the following linear state space representation:

$$\Delta f_t = \alpha + \beta_t (Index_t - \gamma_1 Index_{t-1} - \gamma_2 S_t) + \gamma_3 JC_t + \varepsilon_t$$
$$\beta_t = \beta_{t-1} + u_t$$

where Δf_t is defined as the difference between f_{t3} and f_{t1} in day t and S_t is the slope of the term structure in day t immediately before the starting of the press conference (i.e. $f_{t1} - R_{NEW}$ in day t). ε_t and u_t are random variables assumed to be serially independent and independently normally distributed with variances $exp(\delta_\varepsilon)$ and $exp(\delta_u)$ respectively. The rest of the notation is the same as before.

For simplicity we assume that the unobserved state variable β_t moves over time as a first-order autoregression, specifically a random walk, stochastic process.

To solve for the model's parameters we use the Kalman filter, which is a recursive algorithm for sequentially updating the one-step ahead estimate of the state mean and variance (i.e. $E_{t-1}[\beta_t]$ and $Var_{t-1}[\beta_t]$).

In order to implement the Kalman filter we maximize the sample log likelihood function using numeric derivatives and standard iterative techniques (Marquardt optimization algorithm) and taking into account that ε_t and u_t are normally distributed.[20]

Table 6 reports the estimation results. The regression coefficients of the surprise component of ECB announcement is statistically significant and economically meaningful, that is with the expected positive sign. The coefficient of the surprise macro release is still not significantly different from zero.

The bottom part displays the final one-step ahead forecast value of the state variable, $E_{T-1}[\beta_T]$ where T stands for the final sample date, and its root mean square error (MSE) value. It is statistically significant and with a magnitude of 0.021. For example, if the ECB makes today a very hawkish declaration (*Index* = *+2*) while the market expects a neutral statement, the futures rate immediately jumps up by about 4 basis points.

Figure 9 displays the entire path of the one-step-ahead forecast of the state variable together with its confidence bands. This chart suggests that the coefficient of the news shock has varied over time. In particular, financial market participants needed around three years to believe, and thus react to, ECB announcements. It is interesting to see that after this learning period the coefficient of the news shock has stayed relatively constant over time.

6 Testing the market efficiency hypothesis in real time

In this paper we investigate the effect of a new type of news item, specifically the information originating from central bank announcements (cf. next section), in real time.

Since the early studies of market efficiency (for two excellent surveys, see Fama 1991 and 1970), many changes have taken place in security markets. In particular, the technology revolution of the last decade has dramatically accelerated the pace at which information becomes publicly available and at which market participants operate. For this reason, even though in practice prices do not respond instantaneously to news, nowadays market efficiency should really be gauged in real time (Busse and Green, 2002).

One major contribution of this paper consists in providing a methodology to pin down the *true real-time news*. Obviously, in a rational market place, prices do not respond to old information.

We address this issue by defining the news (shock) as the difference between what the ECB announces and what the market expects the ECB to announce. Notice that in our empirical exercise market participants form expectations rationally (using all available information) and in real time, just immediately before the press conference takes place.

[20] Those readers that desire greater details are directed to for example Hamilton (1994, chapter 5 and chapter 13).

European money market rates should not be driven by the tone of the ECB declaration, but rather by its unexpected component. For instance, if the ECB had been dovish in the last three months, a further dovish announcement today would not be completely unexpected.

To test this hypothesis, we re-estimate the regressions reported in Tables 3 and 4 by adding the tone of ECB announcements, our wording indicator $Index_{t2}$, as right-hand side explanatory variable. More formally, we estimate the following equations:

$$f_{t3} - f_{t1} = \alpha + \beta_1 NS_{t2} + \beta_2 Index_{t2} + \beta_3 JC_{t2} + \varepsilon_{t3}$$
$$f_{17:00} - f_{13:15} = \alpha + \beta_1 NS_{t2} + \beta_2 Index_{t2} + \beta_3 JC_{t2} + \gamma (f_t - f_{13:15}) + \varepsilon_{t3}$$

We find (see Table 7 and 8) that the coefficient of the news shock is statistically and economically significant as before. Instead, the coefficient of *Index* is never statistically significant. Moreover, in Table 7 it has always the wrong sign (i.e. an hawkish ECB announcement decreases market rates).

The news shock is equal to *Index* in only one special case, i.e. when the market expects a neutral ECB announcement. In general, if we use *Index*, instead of the news shock, as explanatory variable our model is misspecified and of course the estimations are biased.

The above observation, namely only unexpected announcements move asset prices, has important implications for studying the price adjustment process that follows other news events, such as analysts' recommendations. In particular, in this latter case the news is not represented by the face value of the broker's recommendation, viz. buy or sell, but rather by its unexpected component, the difference between the recommendation and what the market expects to be recommended. In other words, in order to have consistent and unbiased estimates, we need to construct a (real-time) measure of the news that is free of endogenous and anticipatory movements. Note that Busse and Green (2002, page 422) recognize this problem but do not solve it. In fact, they observe: "The small response to positive [analysts'] reports during the Morning Call suggests that the segment provides information that is (…) not new."

Our study also adds to the empirical finance literature by assessing the degree of informational efficiency of a *new European money market*. By doing so, we address two shortcomings of the existing literature. First, we analyze a *money market* while most empirical studies focus on the foreign exchange and stock market. Second, we investigate the efficiency property of a *European financial market*, while most finance literature studies US markets.

Also Bernoth and Von Hagen (2004) documented the efficiency of the Euribor futures market. However, they use daily data and thus are not able to quantify the degree of efficiency. Moreover, on a typical Governing Council meeting day a large, potentially uncountable, number of news items hit the financial market, which make our estimates much more efficient, resulting in smaller standard errors in the coefficients of the news shock. Finally, they only analyze the

response of futures rate to monetary policy shocks, while we separately identify the effect of the two systematic events that takes place on Governing Council meeting days: the ECB policy rate announcement and especially the ECB press conference.

7 Central bank communication and monetary policy making

Central bank communication and its effects on financial markets have recently received increasing attention in the monetary economics literature both theoretically (Woodford, 2005) and empirically (Ehrmann and Fratzscher (2005a,b,c) Gerlach (2004), Heinemann and Ullrich (2005), Kohn and Sack (2003), Jansen and deHaan (2006a,b, 2005)).

The workhorse model so far used in the literature (Kuttner, 2001) to describe the effects of central bank interest rate setting behaviour has been based only on monetary policy shocks, i.e. a single factor. However, nowadays central banks have adopted a more and more transparent conduct of monetary policy up to pre-announcing their future policy moves. Hence, it turns out that central banks mostly affect asset prices through their bias statements (a second policy instrument) by influencing financial market expectations of their future policy actions, rather than by unexpected deeds, i.e. monetary policy shocks. We show that the former effect is not only significant but has also a sizeable impact on futures prices.

Also Bomfim (2003) and Gurkaynak et al. (2005) find that at least two factors are required in order to capture adequately the effects of U.S. monetary policy on asset prices. They interpret the first one as the current federal funds target rate and the second one as the future path of policy, which is closely associated with FOMC announcements. We solve a related empirical exercise. However, there remain important differences. First, the methodology is different. Before we identify the surprise component of the ECB press conference. Then, we use it to explain the change in the futures rate. While they assume that the second factor of a factorial analysis on the futures price changes with maturity less than a year corresponds to central bank announcements. Then they use both factors to explain other asset price movements. By doing so, they implicitly assume that the two factors are at least weak exogenous with respect to bond and stock prices, while we do not make any exogeneity assumption. Put it differently, *before* we measure explicitly the news shock and *then* explain its effects, while they do not interpret central bank statements simply because the surprise is posited equal to the second factor, rather than derived from first principles. Second, we analyse the ECB while they focus on the US Fed. This is extremely important because we are able not only to separately and sequentially identify both the monetary policy and the news shock but also to separately investigate their effects. Finally, we also test the Euribor futures market efficiency in real time.

Like Rosa and Verga (2007), in this paper we also examine the effect of ECB communication on the price discovery process for the European money market rates. However,

we use *high-frequency intraday data* rather than daily data.[21] As we mentioned above, this is a crucial improvement because it allows to fully exploiting the unique institutional feature of ECB monetary policy conduct (i.e. on the same Governing Council meeting day, the ECB announces its policy decision and explains its monetary policy stance in two different points in time). Hence, we can distinguish one surprise, monetary policy shock, from the other, news shock.[22] So, on the one side, we do not need to worry about the validity of the exogeneity assumption of the monetary policy shock typically encountered in the literature. On the other, we do not need to implement complicated identification procedures such as Rigobon and Sack (2004) that solve the simultaneity problem through a heteroskedasticity-based method of identification.

Moreover, by using tick data, we characterize very precisely the response of yields to monetary policy and news shocks. In fact, on a typical Governing Council meeting day a large, potentially uncountable, number of news items hit the financial market, and using daily data would make our estimates much less efficient.

Romer and Romer (2004) also develop a measure of *unanticipated* policy deliberations. They regress their previous (1989) measure of Federal Reserve's intentions for the Federal funds rate around FOMC meetings on the Federal Reserve's internal forecasts. However, they use simply one dimension to describe monetary policy conduct.

In Figure 6 we show that the absolute magnitude of the monetary policy shocks has substantially decreased over time, and this is true even when the official rate has been changed. In the first years of the ECB life the source of the surprise was often represented by the President press conference rather than by the announcement of the monetary policy decision. In this respect, a change in emphasis within the press conference has also taken place. In particular, in recent months the introductory statement has simply conveyed the overall monetary policy stance communicated by the Governing Council, and its content was similar to what the market expected, while through the Questions and Answers section the ECB now sends fairly unambiguous signals about the likely future dynamics of policy rates (some selected excerpts from the Questions and Answers section are available upon request).

There is an open question that this paper brings to the fore: if the words of the ECB President can be easily and unambiguously quantified in the way we suggest, then the question presents itself why this piece of information is not presented in a precise numerical form, analogous to the ECB policy rate decision.

[21] Moreover, we look at the Euribor *futures* market, instead of the Euribor market.

[22] Since writing this paper, we have learned that a very recent paper by Brand et al. (2006) also investigates the impact of ECB monetary policy decisions and communication on the yield curve by using high-frequency data. However, there remain important differences with the present work. First, the methodology is different: we show that the news shock explains innovations in futures prices, while, similar to Gurkaynak et al. (2005), they extract surprise measures from the money market yield curve. The dataset used is also different: we use futures tick-by-tick data from LIFFE (and we complement our analysis by studying volumes and number of transactions data), while they use real time quotes of deposit and swap rates from Reuters observed at five minute intervals.

As we mentioned at the beginning of this section, central banks directly control only a very short-term interest rate, while they need to influence interest rates at all maturities in order to conduct an effective monetary policy and thus achieve their aims. Moreover, monetary policy makers are much more interested in the futures price impact of their announcements over longer horizons, rather than the precise estimates of the timing and impact of news, i.e. its initial reaction.

Table 9 provides the futures price change for four weeks, 22 trading days, following the ECB President press conference. Unexpected hawkish or dovish announcements are defined as in Section 4, specifically as in Figure 8.

It is interesting to see that the initial impact to ECB statements is part of a larger, long-term reaction. However, the evidence indicates that there is an asymmetric long-term response. On the one hand, the futures price change becomes increasingly negative and increasingly significant during the month after a dovish announcement. This statistical pattern is uncovered despite standard errors increase with the measurement interval, and so even if the multi-day tests lack power against the alternatives that the price react permanently to the tone of the central bank declaration over the following month.[23] On the other hand, futures prices increase, but not in a statistically significant way, by about 3-4 basis points after an hawkish announcement and maintain the new level over the following month.

Overall, we provide strong and economically relevant evidence that central bank communication impacts futures prices permanently, and not only transitorily. Hence, central bankers' announcements seem to be a very powerful tool to systematically drive market expectations and eventually, through it, the actual evolution of the real economy.

8 Conclusions

Event study analysis is now an important part of finance, especially corporate finance where it is used to highlight empirical regularities in the response of stock prices to investment decisions, financing decisions, and changes in corporate control. In this paper, we apply its methods in order to investigate the reaction of asset prices to unexpected central bank announcements.

Given the unique institutional features of ECB monetary policy conduct, we think that high-frequency intraday is the proper frequency for our event-study analysis. Since the news shock and monetary policy shock hit the financial market in two different point in time, not only we can tell apart one surprise from the other, but we can also investigate their effect independently.

[23] Technically, future prices follow a unit-root process, thus the variance of futures price changes between date t and $t+m$ is proportional to m.

The interpretation of central bankers' statements and actions is of considerable importance to monetary policymakers, financial market participants, and more generally the overall public.

In this paper we analyze the relationship between central bank words and deeds and changes in asset prices. More specifically, we examine the effect of European Central Bank communication on the price discovery process in the Euribor futures market using a *new* tick-by-tick dataset.

First, we find that the number of transactions and the number of exchanged futures contracts (volume) data confirm that two news items systematically hit financial markets on Governing Council meeting days: ECB policy rate decision and the explanation of its monetary policy stance.

Second, we show that when the tone of the press conference is different from what the market expects, the futures rate experience a statistically and economically significant quick (less than an hour) reaction. Put it differently, we show that communication is an important tool in the process of conducting monetary policy stance.

Finally, our results suggest that the Euribor futures market is semi-strong form informational efficient.

The fact that the ECB is able to move asset prices by simply using words seems to indicate that financial markets believe that the European Central Bank does what it says it will do. In other words, even if it is a relatively young central bank, the ECB has already acquired some reputation for telling the truth. Hence, the ECB has already built up some credibility capital. However, credibility is a matter of degree and this paper does not answer the question of how credible the Central Bank is.

There are of course several important issues not considered here, which require further study.

To interpret an event study, we need to assess quantitatively our ability to detect the presence of an abnormal asset price change. In other words, we also need to evaluate the power of the test, that is the probability of rejecting a false null hypothesis (i.e., ECB unexpected announcements have no impact on the behaviour of asset prices).

In this paper we make specific assumptions about the distribution of abnormal price changes. Hence we use parametric estimation methods. Alternatively, non parametric methods (such as either the sign or the rank test), which are free of specific distributional assumptions, are available and can be used.

As a first step, we restricted our sample to Governing Council meeting days. It would be interesting to extend our analysis to include all ECB President speeches. We would thus be able to break down news shocks further into two separate factors: path (change in the near-term path of policy expectations) and time (changes in the expected timing of policy speeches). Moreover,

we could also disentangle and separate news about the future path of monetary policy from news about the future economic outlook i.e., the evolution of macroeconomic or monetary variables, such as output, price indexes, exchange rates, M3 growth, etc.

We test market efficiency in real time. We look at the effects of ECB President announcements on Euribor futures rates using a new high-frequency dataset. We explain price changes but we do not statistically investigate the informational content of the number of observations and volumes (number of exchanged contracts) within a specific time interval (Demos and Goodhart, 1996).

We apply standard event study econometric methods, but at the same time we overlook market microstructure issues, such as non-synchronous trading effects (transactions usually take place at time intervals of irregular length and thus transaction data are sampled at irregular random intervals) and price discreteness (prices are always quoted in discrete units). We believe that the three-month futures market institutional structure can be safely ignored for our purpose of assessing the response of asset prices to ECB unexpected announcements. However, it is possible that our results could be biased (cf. Campbell et al., 1997, Chapter 3), the computation of further diagnostic tests could be particularly fruitful to gauge the robustness of our preliminary findings.

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Table 1. *– Glossary of ECB's official statements and their ranking*

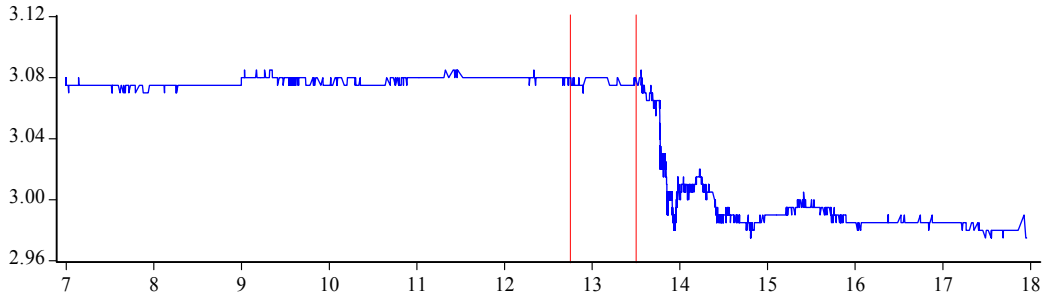
ECB's main statements: the most important keywords	*Index*
Imperative that upward pressure to be contained – Risks [to price stability] are upward (upside) – The risks to price stability are confirmed (or: remain) – Vigilant (vigilance) [with regard to upside risks to price stability]– Close monitored (or: continuous close attention) [upside risks] – Several [upward] factors need to be monitored carefully	+2
Both confident and vigilant (or: Good however vigilant) [upside risks] – Upward pressure remains contained – A number of (or: Some) upside risks need to be carefully monitored – Alert to emerging of upward risks – Vigilance with regard to the materialisation of upside risks	+1
Appropriate – Favorable – Compatible – Consistent – In line – Balanced – Absence of significant (or: No strong) pressures either upwards or downwards – The downside risks have disappeared –	0
Favorable, but there are some [downside] risks – Appropriate but remain downside risks – Downside risks are not vanished – Some of the downward risks had materialised	-1
Consistent, but carefully monitor all [downside] risks to economic growth – Balanced but monitor closely all [downside] factors – Monitor carefully all [downside] factors relevant to economic growth – Downside risks are still relevant – Economic slowdown is still cause for concern – [Strong] downside risks for economic activity – Monitor closely the downside risks to economic growth.	-2

ECB's main statements: Comparisons	*Index*
Somewhat less favorable – [Price perspectives are] less satisfactory but further evidence is needed – move towards the upside	+1
Confirmed – not altered – not changed (or: no fundamental changes)	0
More balanced – Inflationary pressures have further diminished (or: are lower, are easing)	-1

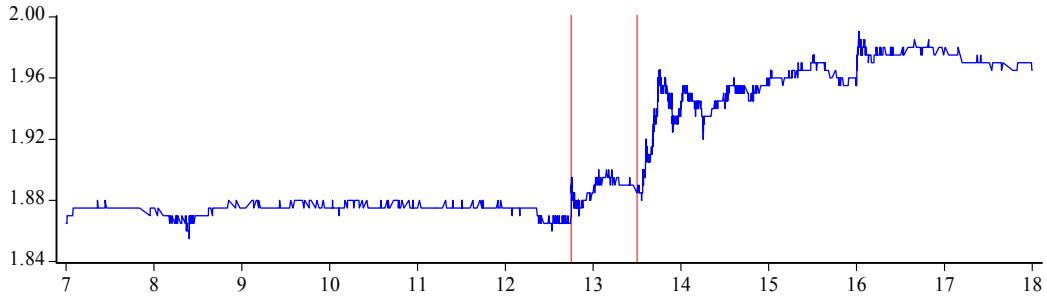
NOTE: Source: Rosa and Verga (2007)

Figure 1. *– 3-month Euribor futures tick-by-tick rate:*

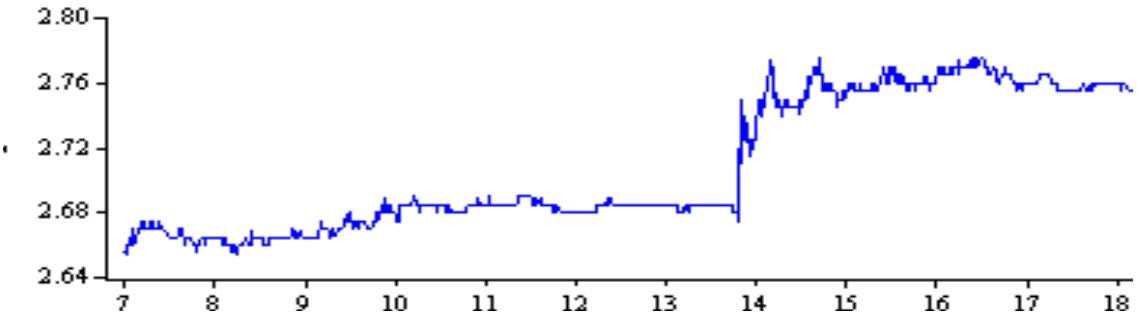
a) 6 April 2006



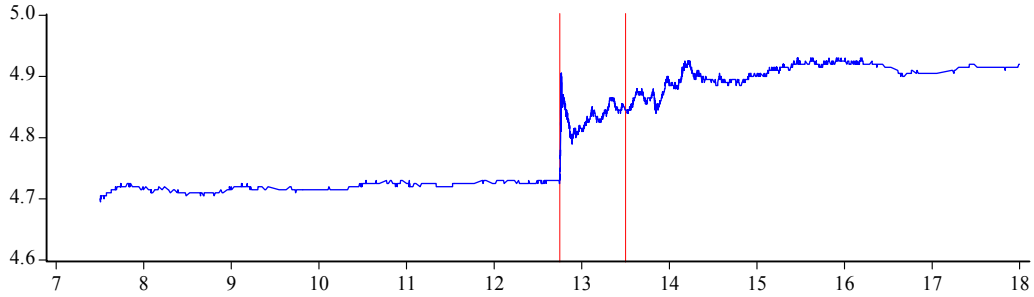
b) 1 April 2004



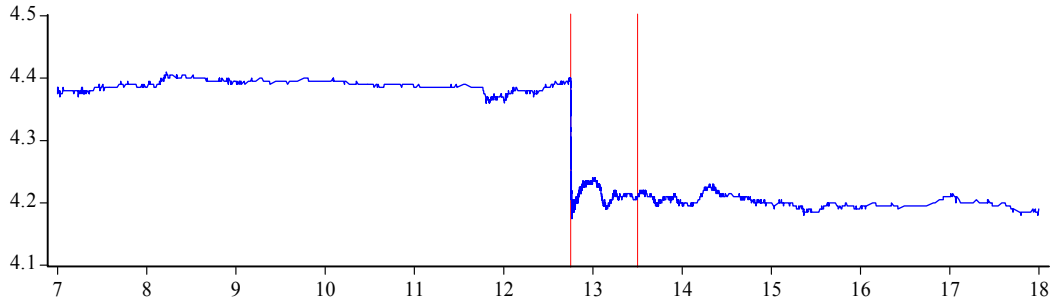
c) 18 November 2005



d) 8 June 2000

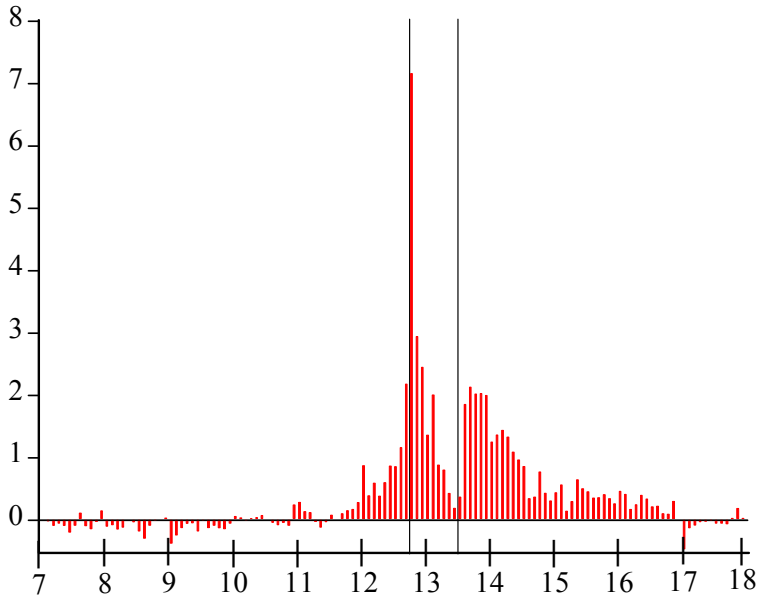


e) 10 May 2001



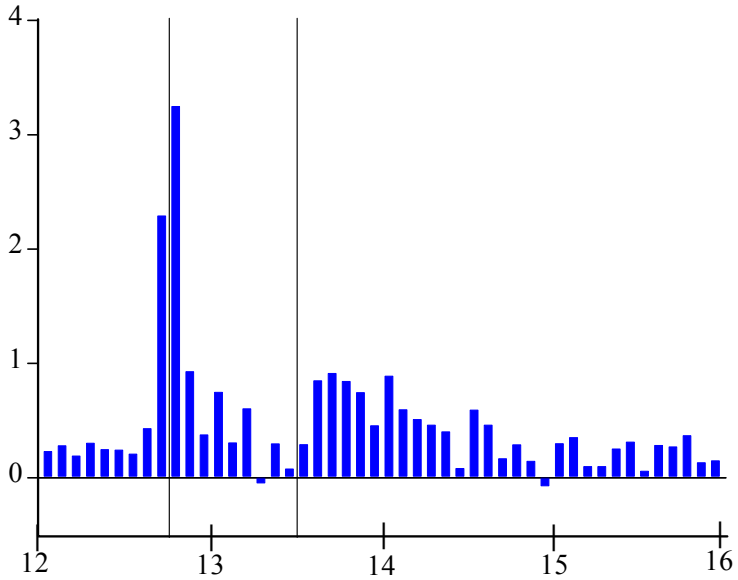
NOTE: The contracted futures rate equals 100 less the futures price.

Figure 2. *– Ratio of average number of transactions per quarter of an hour (from January 2000)*



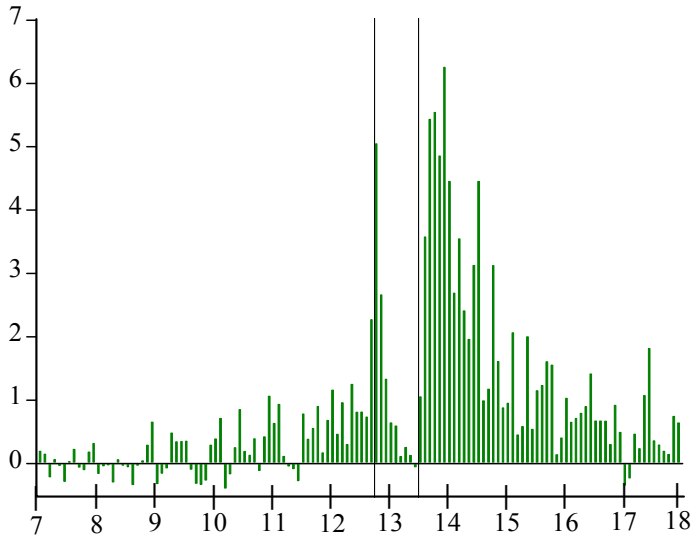
NOTE: Plot of the ratio between the average number of transaction on Governing Council meeting days and all other Thursdays. Two vertical lines indicate 12:45 and 13:30 London time.

Figure 3. *– 5-minute futures price volatility (from January 2000)*



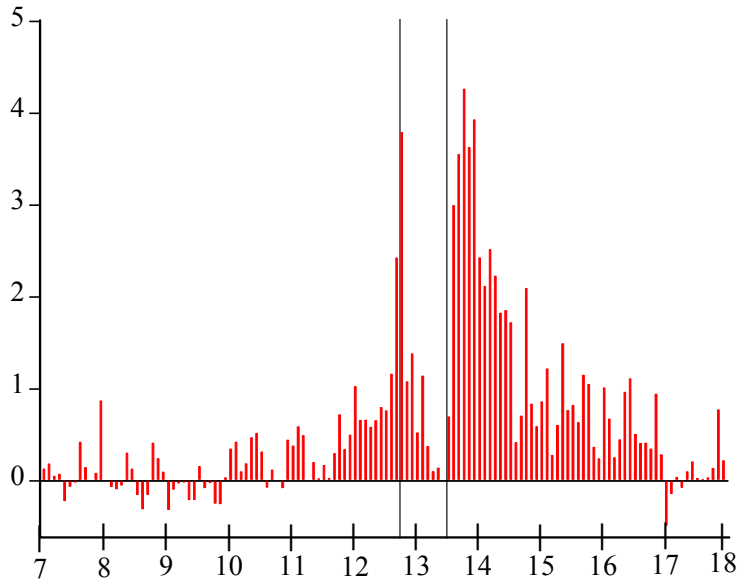
NOTE: Plot of the ratio between futures price volatility (measured as the 5-minute absolute deviation) on Governing Council meeting days with respect to all other Thursdays.

Figure 4. *– Ratio of average volume (from July 2003)*



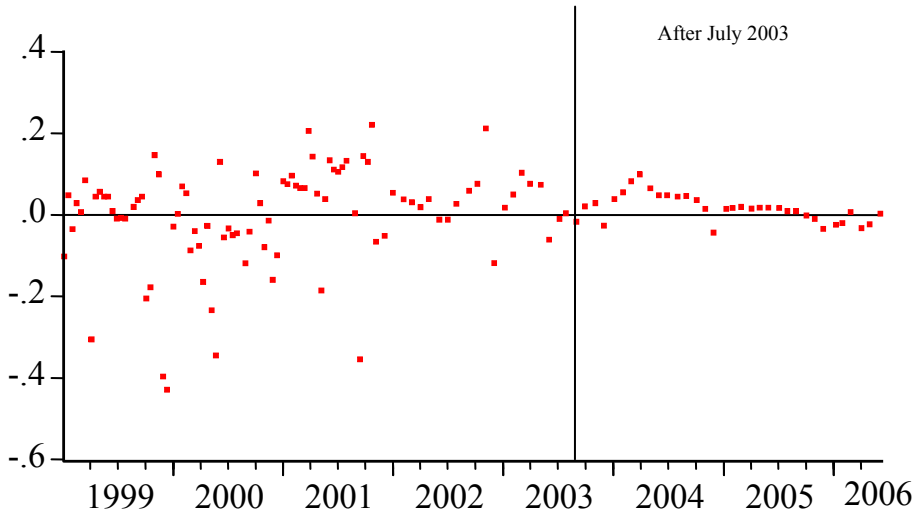
NOTE: Plot of the ratio between the average number of transaction on Governing Council meeting days and all other Thursdays. Two vertical lines indicate 12:45 and 13:30 London time.

Figure 5. *– Ratio of average number of transactions per quarter of an hour (from July 2003)*



NOTE: Plot of the ratio between the average number of transaction on Governing Council meeting days and all other Thursdays. Two vertical lines indicate 12:45 and 13:30 London time.

Figure 6. *– Monetary policy shocks*



NOTE: The monetary policy shock is defined as the difference between the new Repo rate communicated at 12:45, and the one-month Euribor rate quoted at 10:00. We add to it the mean equilibrium (liquidity and risk) spread between the Repo and the one-month Euribor rate, in the specific case 0.11.

Figure 7. *– Time line for the event study on ECB announcements*

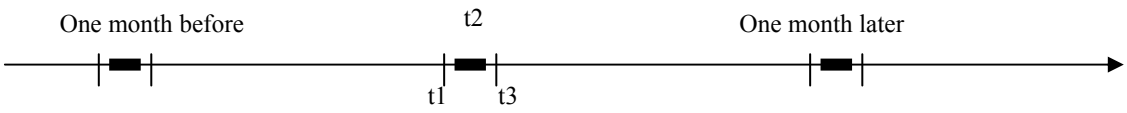
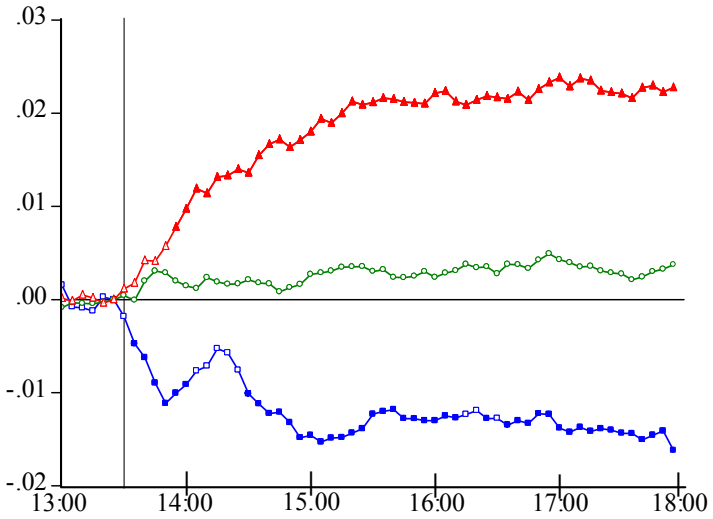


Table 2. *– Auxiliary regression to measure the expected ECB announcement using Ordered Probit*

$f_{t1} - R_{NEW}$	2.637** (0.721)
$Index_{t1}$	1.551** (0.243)
δ_1	-2.987** (0.436)
δ_2	-1.718** (0.363)
δ_3	1.056** (0.296)
δ_4	3.260** (0.484)
Log Likelihood	-45.468
Pseudo-R^2	0.554
Observations	69

NOTE: Monthly observations on days of ECB Governing Council meetings, January 2000 – June 2006. The econometric method is ML – Ordered Probit (Quadratic hill climbing). One and two stars denote significance at the five and one percent level, respectively.

Figure 8. *– Futures rate reactions to central bank announcements*



NOTE: The chart plots average futures rate changes following unexpected hawkish (red line - triangle), neutral (green line – circle), and dovish (blue line - square) ECB announcements on Governing Council meeting days. A statement is defined hawkish when the news surprise, the difference between $Index_{t2}$ and $E_{t1}\,[Index_{t2}]$ as given by Equation (2), is higher than the median of the positive news shocks observed in our sample period (i.e. 0.184). A statement is defined dovish when the news surprise is lower than the median negative news shock observed in our sample period (i.e. -0.367). In the remaining cases, the central bank statement is classified as neutral. A solid marker denotes that the futures price change is significantly different from zero at the five percent level.

Table 3. *– Explanation of innovation in expectations (Future rates), dependent variable* $f_{t3} - f_{t1}$

	t3 = 14:45 t1 = 13:15	t3 = 15:45 t1 = 13:15	t3 = 16:45 t1 = 13:15
Constant	0.003 (0.003)	0.005 (0.004)	0.006 (0.004)
NS_{t2}	0.021** (0.005)	0.025** (0.007)	0.026** (0.007)
JC_{t2}	0.017 (0.015)	0.012 (0.017)	0.005 (0.017)
R^2	0.169	0.174	0.157
Adj. R^2	0.144	0.148	0.131
Observations	67	67	67

NOTE: Monthly observations on days of ECB Governing Council meetings, January 2000 – June 2006. The econometric method is Ordinary Least Squares. Heteroskedasticity - Consistent standard errors in brackets. One and two stars denote significance at the five and one percent level, respectively.

Table 4. *– Time needed to incorporate the news shock (Future rates), dependent variable* $f_{17} - f_{13:15}$

	t = 14:15	t = 14:30	t = 14:45	t = 15:00
Constant	0.002 (0.002)	0.002 (0.002)	0.003 (0.002)	0.001 (0.002)
$f_t - f_{13:15}$	1.091** (0.098)	1.071** (0.081)	1.077** (0.064)	1.080** (0.050)
NS_{t2}	0.015** (0.005)	0.009** (0.003)	0.005 (0.004)	0.002 (0.003)
JC_{t2}	-0.004 (0.012)	-0.012 (0.010)	-0.012 (0.009)	-0.014 (0.008)
R^2	0.745	0.802	0.821	0.870
Adj. R^2	0.733	0.793	0.812	0.863
Observations	67	67	67	67

NOTE: Monthly observations on days of ECB Governing Council meetings, January 2000 – June 2006. The econometric method is Ordinary Least Squares. Heteroskedasticity - Consistent standard errors in brackets. One and two stars denote significance at the five and one percent level, respectively.

Table 5. *– Explanation of innovation in expectations (Future rates), dependent variable* $f_{t4} - f_{t3}$

	t4 = 17:30 t3 = 15:00	t4° = 9:00 t3 = 15:00	t4° = 11:00 t3 = 15:00
Constant	0.001 (0.002)	-0.002 (0.003)	-0.001 (0.003)
NS_{t2}	0.004 (0.003)	0.011 (0.006)	0.010 (0.006)
JC_{t2}	-0.012 (0.007)	-0.035** (0.012)	-0.028* (0.013)
R^2	0.051	0.150	0.112
Adj. R^2	0.021	0.123	0.084
Observations	67	66	66

NOTE: Monthly observations on days of ECB Governing Council meetings, January 2000 – June 2006. The econometric method is Ordinary Least Squares. Heteroskedasticity - Consistent standard errors in brackets. One and two stars denote significance at the five and one percent level, respectively.
° stands for the morning of the day after the Governing Council meeting.

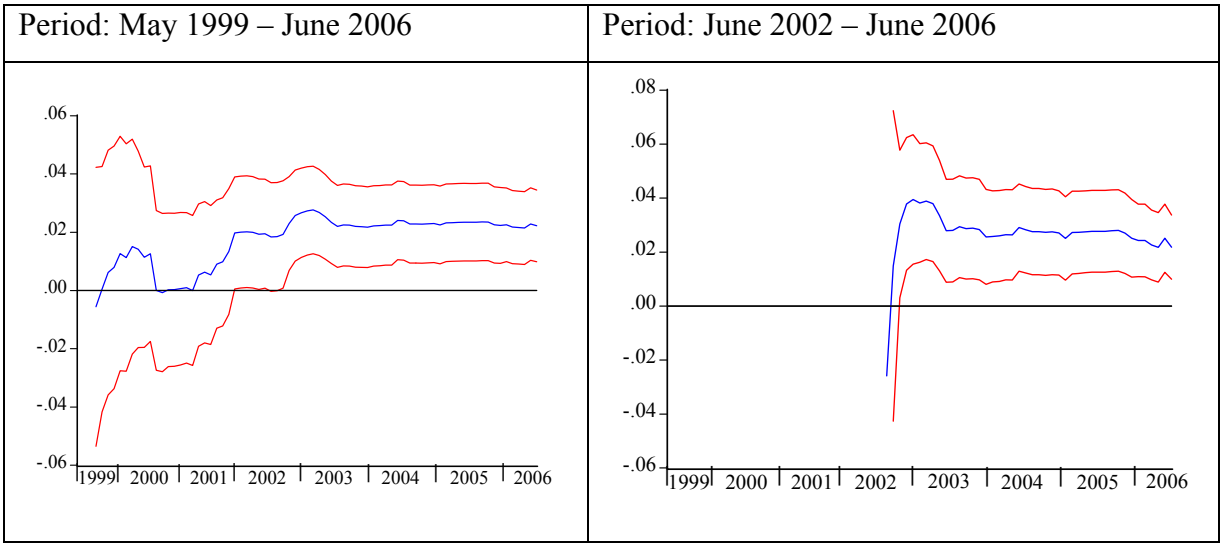
Table 6. *– State space model (Futures rates)*

δ_1	-7.397** (0.179)
δ_2	-13.408** (3.537)
α	0.007* (0.003)
γ_1	2.319** (0.884)
γ_2	0.656* (0.266)
γ_3	-0.021 (0.015)
R^2	0.274
R^2 Adj.	0.220
Loglikelihood	133.936
Observations	75

$\beta_{T/T-1}$	0.021** (0.007)

NOTE: Monthly observations on days of ECB Governing Council meetings, January 1999 – June 2006. The dependent variable is the 15-minute average change in futures prices between 13:15 and 14:45. The econometric method is Maximum likelihood (Marquardt optimization algorithm). ML standard errors in brackets. One and two stars denote significance at the five and one percent level, respectively.

Figure 9. *– One-step-ahead state variable prediction*



NOTE: The chart displays the entire path of the state variable (the blue line) together with its confidence bands of two standard deviations (the red lines). Two sample periods have been considered: May 1999 – June 2006 (left panel), and June 2002 – June 2006 (right panel). Note that the results are mutually consistent. The signal variable is the 15-minute average futures rate quoted at 15:45. To facilitate the readability of the right panel we drop the first observation (centred at zero) that features very large confidence bands.

Table 7. *– Explanation of innovation in expectations (Future rates), dependent variable* $f_{t3} - f_{t1}$

	t3 = 14:45 t1 = 13:15	t3 = 15:45 t1 = 13:15	t3 = 16:45 t1 = 13:15
Constant	0.006 (0.004)	0.009* (0.004)	0.009* (0.004)
NS_{t2}	0.025** (0.006)	0.029** (0.008)	0.029** (0.008)
$Index_{t2}$	-0.006 (0.003)	-0.007 (0.004)	-0.005 (0.004)
JC_{t2}	-0.020 (0.014)	-0.016 (0.016)	-0.009 (0.016)
R^2	0.194	0.179	0.150
Adj. R^2	0.156	0.140	0.110
Observations	67	67	67

NOTE: Monthly observations on days of ECB Governing Council meetings, January 2000 – June 2006. The econometric method is Ordinary Least Squares. Heteroskedasticity - Consistent standard errors in brackets. One and two stars denote significance at the five and one percent level, respectively.

Table 8. *– Time needed to incorporate the news shock (Future rates), dependent variable* $f_{17} - f_{13:15}$

	t = 14:15	t = 14:30	t = 14:45	t = 15:00
Constant	0.002 (0.003)	0.002 (0.002)	0.002 (0.002)	0.000 (0.002)
$f_t - f_{13:15}$	1.107** (0.102)	1.095** (0.081)	1.105** (0.066)	1.100** (0.051)
NS_{t2}	0.013* (0.006)	0.007 (0.005)	0.002 (0.005)	-0.001 (0.004)
$Index_{t2}$	-0.000 (0.002)	0.001 (0.002)	0.002 (0.002)	0.001 (0.002)
JC_{t2}	0.002 (0.013)	0.011 (0.010)	0.012 (0.009)	0.014 (0.008)
R^2	0.736	0.798	0.821	0.871
Adj. R^2	0.719	0.785	0.809	0.863
Observations	67	67	67	67

NOTE: Monthly observations on days of ECB Governing Council meetings, January 2000 – June 2006. The econometric method is Ordinary Least Squares. Heteroskedasticity - Consistent standard errors in brackets. One and two stars denote significance at the five and one percent level, respectively.

Table 9. *– Futures price response over longer horizons*

Days	Hawkish	Dovish
0	0.023**	-0.012*
1	0.025*	-0.024*
2	0.020*	-0.031*
3	0.026*	-0.028
4	0.027*	-0.032*
5	0.038*	-0.045*
6	0.043*	-0.052*
7	0.049**	-0.057*
8	0.049*	-0.067*
9	0.038	-0.072**
10	0.039	-0.071**
11	0.039	-0.076**
12	0.022	-0.088*
13	0.022	-0.094**
14	0.025	-0.102**
15	0.022	-0.101**
16	0.023	-0.108*
17	0.015	-0.101*
18	0.005	-0.110**
19	0.018	-0.117**
20	0.037	-0.117**
21	0.026	-0.124**
22	0.025	-0.132**

NOTE: We compute futures price changes as the difference between the one-hour average futures rate (between 16 and 17, London time) on trading day t after the press conference and the 30-minute average futures rate (between 1300 and 1330, London time) taken on Governing Council meeting days, that is immediately before the press conference takes place. A statement is defined hawkish when the news surprise, the difference between $Index_{t2}$ and $E_{t1}\,[Index_{t2}]$ as given by Equation (2), is higher than the median of the positive news shocks observed in our sample period (i.e. 0.184). A statement is defined dovish when the news surprise is lower than the median negative news shock observed in our sample period (i.e. -0.367). In the remaining cases, the central bank statement is classified as neutral. One and two stars denote significance at the five and one percent level, respectively.