The Impact of Central Bank Announcements on Asset Prices in Real Time*

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This paper examines the effect of European Central Bank (ECB) communication on the price discovery process in the Euribor futures market using a *new* tick-by-tick data set. 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 sizable impact on futures prices. Third, we investigate how communication interacts with learning by the public about the credibility of the central bank: financial market participants needed around three years, from 1999 through 2001, to learn how to interpret and believe ECB announcements. Finally, our results suggest that the Euribor futures market is efficient.

JEL Codes: E52, E58, G14.

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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 goals 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%."*
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> (*The Economist*, October 2006)

1. Introduction

Do European Central Bank (ECB) qualitative announcements affect market expectations about the future path of the ECB's 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 statements without relying on the exogeneity assumption of monetary policy shocks? What is the degree of efficiency of the Euribor futures market? To address these questions, this paper uses a novel data set to present extensive evidence regarding the impact of central bank announcements on asset prices.

This work 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. The value added of this study consists in examining the real-time effects of central bank announcements on financial markets. We show that market

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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 differently, whereas the workhorse model used so far 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's 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 forty-five minutes, explaining its monetary policy stance. By using a *new* intraday data set, 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—i.e., the policy decision announcement communicated at 12:45 (throughout the paper, London time is always used) and the information released at the ECB President's monthly press conference starting at 13:30.

Second, by using a new tick-by-tick data set, we show quantitatively that changes in market interest rates 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 ECB words and deeds have been consistent with each other; otherwise, market participants would not have reacted to central bank announcements.

Third, we qualify the degree of efficiency of the Euribor futures market: futures prices incorporate the news stemming from the ECB actions very quickly, in less than five minutes, and the news stemming from the ECB President's speech in around one hour.

Fourth, by estimating a state-space model, we investigate how communication interacts with learning by the public about the credibility of the central bank.[1] We find that the importance of the ECB press conference has increased over time: financial market participants needed around three years, from 1999 through 2001, to learn how to interpret and believe 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 three-month Euribor futures data. And, in order to illustrate the advantages of using high-frequency data, we analyze 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 on futures rates using intraday tick-by-tick data. In section 5, we perform some important robustness checks and sensitivity analysis. In section 6, we analyze the implications of our findings for central bank communication and monetary policy. In section 7, we summarize and conclude by suggesting some important issues for future research.

2. Measuring the Tone of ECB Announcements

Since its inception, the ECB has paid considerable attention to its announcement policy, and especially to its choices of medium, form, and content. In order to communicate with the public effectively and address the informational needs of various target groups such

[1]We have in mind Blinder's (1998, 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."

as politicians, academics, the press, and participants in the financial markets, the ECB uses various 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 (which currently takes place four times per 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 noted 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, in its *Monthly Bulletin* of January 2006 (page 57), the ECB confirmed that its President's 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."

In this study we restrict the analysis to the text of the introductory statements to the monthly ECB press conferences. We consider this analysis as the first stage of a broader research agenda, which will eventually analyze all ECB channels of communication. The introductory statement to the monthly press conference represents a natural candidate to initiate this research agenda, since it is simple 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 monthly announcement. This number is intended to summarize the ECB's overall monetary policy stance as communicated by its Governing Council.[2] In his press conferences, the ECB President employs

[2]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. More generally, the classification of statements is often referred to as content analysis (see Krippendorf 2004 and Weber 2004): it consists of a set of techniques to extract the content of a message. A similar methodology for the classification of monetary policy statements is also applied by, among others, Ehrmann and Fratzscher (2007a), Gerlach (2007), Guthrie and Wright (2000), and Jansen and De Haan (2005).

a very standardized form of language, and its main conclusions consist of a limited number of keywords or strings.[3] Hence, it is possible to represent explicitly our mapping between words and numbers (therefore, an ordered scale) through the construction of a glossary that is reported in table 1.[4] It should be emphasized that over the years, the ECB has made considerable effort to systematically explain to the public the "meaning" that it attaches to most of the code words reported in table 1. For instance, on 6 March 2003, during the Questions and Answers session, President Duisenberg highlighted that if the ECB "use[s] the word 'appropriate' we expect it [the level of the policy rate] to remain valid for a considerable period of time." In another occasion, on 6 July 2006, President Trichet commented that "it is up to you to draw the appropriate conclusion from the words that are in the introductory statement and those that I use in this session. Until now, it seems to me, these have been quite well understood."

The wording indicator, *Index*, is converted into a variable on a three-value scale from −1 to +1. 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—whereas the value +1 assigned to the press conference statement suggests the ECB desires tighter monetary conditions. In the appendix, we report our assigned value of risk, *Index*, for each ECB monetary policy announcement, along with a few examples of introductory statements and our coding.

Since words are not precise quantitative data, the ranking of statements according to their assessment of ECB future monetary policy moves (tightening, neutral, or easing) is necessarily influenced

[3]There is no difference between the tone of Duisenberg's and Trichet's speeches: the President, in fact, simply reads a statement prepared by the whole Governing Council.

[4]Even though we have done the coding of each statement by reading the full press conference, including its Questions and Answers section, the synthetic assessment of the ECB perceived risk to price stability seems the most important. The keywords reported in the glossary only serve to provide a *parsimonious* and *transparent* background of the coding.

Table 1. Glossary of ECB's Official Statements and Their Ranking

ECB's Main Statements: The Most Important Keywords	***Index***
Strong vigilance/vigilant [with regard to upside risks to price stability] It is imperative that upward pressure be contained Monitor closely/carefully all upward risks/pressures Risks to price stability are upward/upside Upward pressure remains	+1
Appropriate Favorable Compatible Consistent In line Balanced Absence of significant pressures either upward or downward	0
Appropriate/favorable, but there are/remain some [downside] risks Some of the downward risks had materialized Downside risks are relevant/still cause for concern	−1
Note: Based on Rosa and Verga (2006).	

by personal judgment. Although we acknowledge that our assessment is subjective, given the ECB's success in explaining its meaning, the overall tone of its announcements is usually unambiguous. Moreover, since the main goal of this article is to propose a methodology to assess the informational value of the ECB press conference and disentangle the effects of qualitative announcements compared with monetary policy decisions, it is important to note that *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 those of 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 the Euribor,[5] the Eonia (Euro OverNight Index Average), and the euro-denominated short-term interest rate derivatives market. In particular, 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. 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.

[5]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. The Euribor is determined (fixed) by the European Banking Federation (EBF) at about 10:00 each day and is a filtered average of interbank deposit rates offered by a large panel of designated contributor banks (currently more than fifty), for maturities ranging from one week to one year. Euribor rates can be downloaded at www.euribor.org.

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 that 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 three-month Euribor futures contracts (basically the three-month-forward three-month-ahead—implicit—Euribor rate) 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 remaining 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, an increase of 50 percent compared with the same period in 2004 (83,842 futures contracts) and 68 percent compared with 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 (www.theifm.org). The data set 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.

3.2 Specific Announcement Days

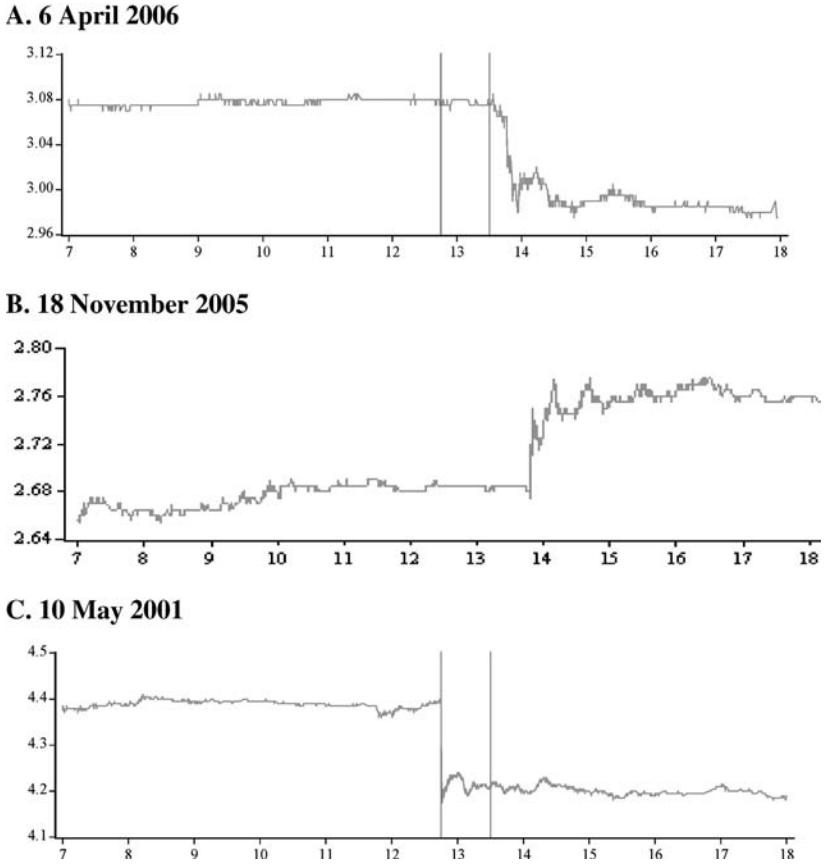
The ECB conduct of monetary policy is characterized by the unique institutional feature that on the same day and at two different points in time, the ECB Governing Council announces its monetary policy decision and explains its monetary policy stance. At 12:45, the ECB communicates the new level of its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

- On 6 April 2006 (Governing Council meeting day), financial market participants fully anticipated the ECB policy rate decision. Indeed, there was no sharp market reaction at around 12:45. However, the futures rate fell sharply at around 14:00. 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 more dovish (than expected) 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 three-month futures price movements. In his monthly introductory statement, the President did not mention explicitly the keyword "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

Figure 1. Three-Month Euribor Futures Tick-by-Tick Rate



Note: The horizontal axis represents the time of the day, while the vertical axis represents the futures rate that equals 100 less the futures price. The vertical lines are placed at 12:45 and 13:30.

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]

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

- 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 14:00 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 B of figure 1 clearly shows that traders immediately placed bets that the ECB would increase the policy rate in December: the three-month futures rate jumped up steeply. The message 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.
- Finally, panel C reports a case 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: it took less than sixty seconds to completely price in the monetary policy shock. Indeed, it can

be shown econometrically (see separate technical appendix, available at www.ijcb.org) that monetary policy shocks are completely incorporated in futures rates in less than five minutes.[6] Therefore, this finding implies that we can assess how central bank qualitative announcements affect yields, safely disregarding the surprise in the target release. Moreover, it suggests that financial markets seem to understand numbers better than words.

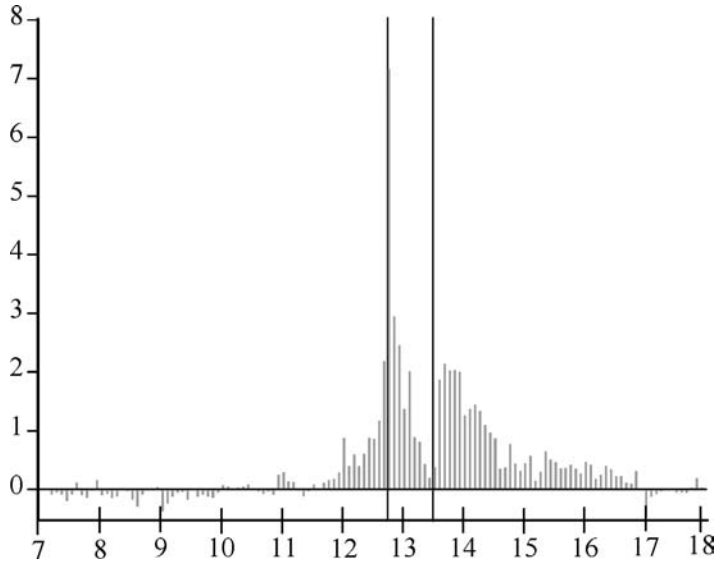
3.3 Qualitative Analysis of Volumes and Number of Transactions

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, 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 on Governing Council meeting days with market activity on all other Thursdays, rather than with activity on 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 100 percent higher during Governing

[6]We approximate monetary policy shocks by the difference between the new repo rate communicated at 12:45 and the one-month Euribor rate quoted at 10:00. By doing so, we are implicitly assuming that the risk premia have stayed constant during our sample period. An alternative measure of monetary policy shocks, which is free of both the risk-premium issue and market noise, is provided by survey data. However, as shown by Andersson (2007, appendix B), these two proxies are very similar, with a correlation coefficient of 0.75 for the ECB target surprise and 0.80 for the Federal Reserve target surprise. Moreover—and this is a crucial aspect for our exercise—expectations derived from the financial markets are real time, i.e., based on the latest available information.

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 transactions on Governing Council meeting days and all other Thursdays. Two vertical lines indicate 12:45 and 13:30 London time.

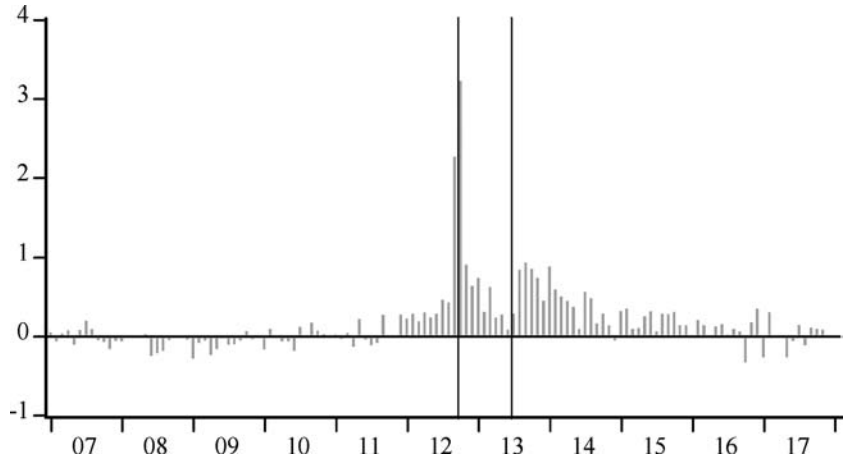
Council meeting days compared with all other Thursdays. Of course, the greater the news content of an announcement, the stronger the financial market activity should be.

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 start of the ECB President's press conference (13:30). Market expectations seem to be quite heterogeneous at the time of the surprise, but then they start to converge. It is interesting to note that the convergence is much faster for monetary policy shocks than for news shocks. 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.[7] Again,

[7]We use the absolute deviation of the (five-minute window) futures prices because it better captures the autocorrelation and the seasonality of the data

Figure 3. Five-Minute Futures Price Volatility (from January 2000)



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

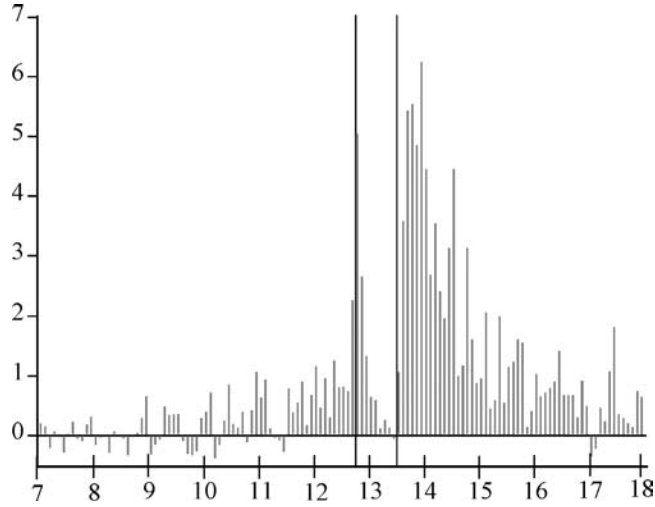
two pieces of news seem to systematically hit the market. Moreover, it is clear that futures prices incorporate the first one, the monetary policy shock, very quickly.

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 figures 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 plotting the ratio between the average number of transactions on Governing Council meeting days

(Piccinato et al. 1999) compared with 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.

Figure 4. Ratio of Average Volume (from July 2003)

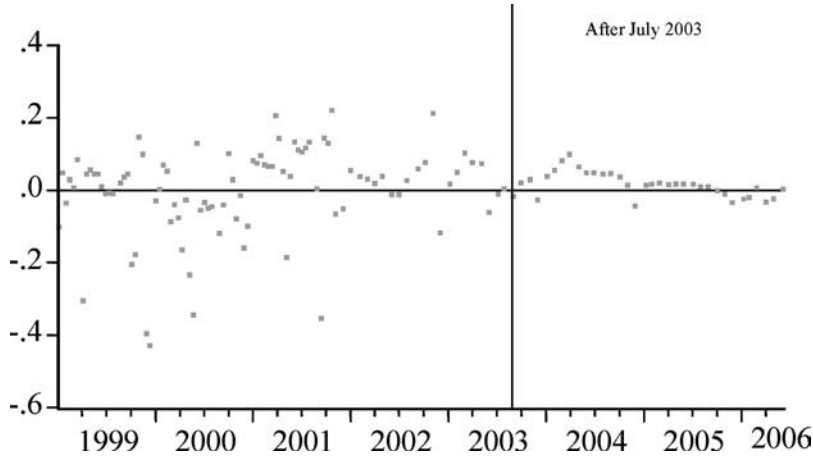


Note: Plot of the ratio between the average volume on Governing Council meeting days and all other Thursdays. Two vertical lines indicate 12:45 and 13:30 London time.

and all other Thursdays, restricting the sample period to July 2003–June 2006 (figure available in the working paper version of this article, Rosa and Verga 2006). A possible explanation for this phenomenon is that ECB monetary policy actions have recently become more predictable than they were at the beginning of the ECB's life. Indeed, figure 5 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.[8]

[8]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 intramonth meeting. Figure 5 would remain qualitatively very similar, as would 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.

Figure 5. 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. The vertical line indicates July 2003, which corresponds to the starting point of the data on volumes.

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 data set 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 (see, among others, Campbell, Lo, and MacKinlay 1997, chap. 4, and MacKinlay 1997).

Our goal is to assess quantitatively whether financial markets react to ECB communication and, more specifically, to examine the informational value of the press conference beyond that contained in the monetary policy decision. In this respect, it is crucially important to realize that the news does not consist of the ECB announcement itself but rather of 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 new ECB announcement, $Index_t^{NEW}$, through the following regression:

$$Index_t^{NEW} = \alpha + \gamma_1 Index_t^{OLD} + \gamma_2 \left(f_{t-h} - R_t^{NEW}\right) + \varepsilon_t, \qquad (1)$$

where α is a constant term and γs are regression coefficients. f_{t-h} stands for the Euribor futures rate quoted immediately before the press conference takes place, i.e., at 13:25. R_t^{NEW} stands for the new repo-rate level communicated at time 12:45. $Index_t^{OLD}$ is the wording indicator for the previous month's press conference. ε_t stands for a zero-mean noise term uncorrelated with the regressors.

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 the ECB monetary policy stance and its statement also cannot be completely revised. However, in order to construct market expectations about ECB declarations using the very latest (indeed, real-time) market participants' information, we include as an explanatory variable the slope of the term structure immediately before the ECB President's press conference takes place, approximated by $f_{t-h} - R_t^{NEW}$. The rationale for including this term is as follows. If the futures rate (net of the risk premium

already captured by α[9]) 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 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. Therefore, it expects a dovish announcement.

Since the wording indicator variable, *Index*, takes only discrete values (i.e., integers from -1 to $+1$), ordered-probit regression is the most appropriate estimator. Table 2 reports the estimated regressor coefficients of equation (1), together with its limit points δs, for the period January 2000–June 2006.[10] Interestingly, both coefficients γ_1 and γ_2 have the expected positive sign and are highly statistically significant.

Furthermore, the independent variables explain fairly well the announced tone of the ECB President's declaration (the goodness of fit measured by the pseudo-R^2 is around 0.57).

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

$$E_{t-h}\left[Index_t^{NEW}\right] = \sum_{i=-1}^{+1} \Pr\left(Index_t^{NEW} = i\right) \cdot i, \qquad (2)$$

where $E_{t-h}[.]$ stands for the expectation operator conditional on the time $t-h$ information set, which is immediately before the ECB's

[9]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 contract 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 from long-term to short-term securities), may track risk-premium dynamics.

[10]Our data set starts in January 1999. However, on the one hand, we consider the year 1999 as a period when financial market participants were learning to better interpret ECB announcements. On the other hand, the practitioners whom we consulted suggested 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 with the following years.

Table 2. Auxiliary Regression to Measure the Expected ECB Announcement using Ordered Probit

$f_{t-h} - R_t^{NEW}$	1.871**
	(0.742)
$Index_t^{OLD}$	1.967***
	(0.354)
δ_1	−1.553***
	(0.348)
δ_2	1.180***
	(0.333)
Log-Likelihood	−30.030
Pseudo-R^2	0.574
Observations	70

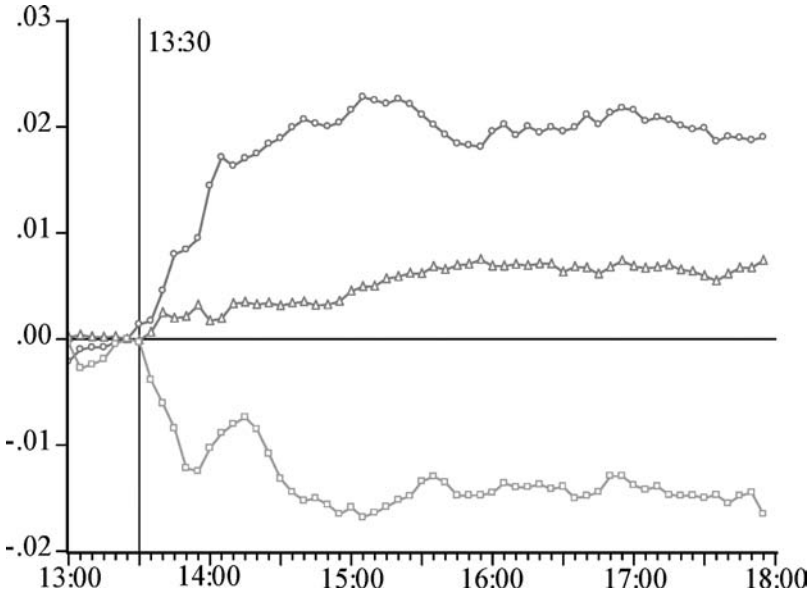
Note: Monthly observations on days of ECB Governing Council meetings, January 2000–June 2006. The econometric method is ML – Ordered Probit (Quadratic hill climbing). ***, **, and * denote significance at the 10, 5, and 1 percent level, respectively.

press statement is released. $\Pr(Index_t^{NEW} = i)$ 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). Then we define the measure of unexpected central bank announcement, the *news shock*, as follows:

$$NS_t = Index_t^{NEW} - E_{t-h}\left[Index_t^{NEW}\right]. \tag{3}$$

Figure 6 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 as hawkish when the news surprise belongs to the top 20th percentile of the news shocks observed in our sample period (i.e., 0.142). Vice versa, a statement is defined as dovish when the news surprise belongs to the bottom 20th percentile of the news shocks observed in our sample period (i.e., −0.228). In the remaining cases, the central bank statement is classified as neutral. Overall, the price response is consistent with the tone of the news. Indeed, futures rates increase after an unexpected hawkish announcement, decrease after a dovish one, and are basically unaffected by neutral declarations.

Figure 6. Futures Rate Reactions to Central Bank Announcements



Note: The chart plots average futures rate changes following unexpected hawkish (line with circles), neutral (line with triangles), and dovish (line with squares) ECB announcements on Governing Council meeting days. A statement is defined as hawkish when the news surprise, the difference between $Index_t^{NEW}$ and $E_{t-h}[Index_t^{NEW}]$, belongs to the top 20th percentile of the news shocks observed in our sample period (i.e., 0.142). A statement is defined as dovish when the news surprise belongs to the bottom 20th percentile of the news shocks observed in our sample period (i.e., −0.228). In the remaining cases, the central bank statement is classified as neutral. The horizontal axis is time of the day, and the vertical axis is futures rates (basis points/100).

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

$$f_{t+h} - f_{t-h} = \alpha + \beta NS_t + \varepsilon_t, \tag{4}$$

where NS_t stands for the news surprise defined in equation (3), and f_{t-h} and f_{t+h} stand for, respectively, the futures rate quoted

Table 3. Explanation of Innovation in Expectations (Futures Rates), Dependent Variable $f_{t+h} - f_{t-h}$

	$t + h = 14{:}45$ $t - h = 13{:}25$	$t + h = 15{:}45$ $t - h = 13{:}25$	$t + h = 16{:}45$ $t - h = 13{:}25$
Constant	0.003	0.005	0.006
	(0.003)	(0.004)	(0.004)
NS_t	0.031**	0.033**	0.038***
	(0.012)	(0.013)	(0.014)
R^2	0.152	0.130	0.156
Observations	70	70	70

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 are in parentheses. ***, **, and * denote significance at the 10, 5, and 1 percent level, respectively.

immediately before and immediately after the ECB announcement. The rest of the notation is the same as above.[11]

Table 3 reports the estimations for three different time windows—specifically, for $t + h =$ 14:45, 15:45, and 16:45—and for $t - h =$ 13:25 (all averaged for a five-minute interval).

It turns out that the coefficient on the news shock, β, is always positive (as expected) and statistically significant at least at the 5 percent level: the news shock can systematically explain the futures

[11]Since every Thursday at 13:30 there is the release of a U.S. jobless claims figure, as a robustness check we estimate equation (4) by also controlling for its surprise component, defined as the difference between the actual release and market expectations measured through the mean response of a Bloomberg survey among market participants. However, this surprise component is never significant, and for this reason it has been dropped. We kindly thank Michael Ehrmann for sharing with us the surprise component of the U.S. jobless claim figures.

As a further robustness check (see separate technical appendix) we reestimate equation (4) by also controlling for the surprise in the target release on the right-hand side, approximated by the difference between the new repo rate communicated at 12:45 and the one-month Euribor rate quoted at 10:00. All the econometric results hold both qualitatively and quantitatively. Hence, the dependent variable is not simply picking up a delayed effect of the policy rate release.

price change around the time of the ECB President's announcements. Table 3 suggests that the ECB can influence the money-market interest rates to some extent by simply 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 increases on average by about 4 basis points.[12] This finding shows that the ECB unexpected announcements have a significant and sizable impact on futures prices. To gain some idea of the importance of the news shock, note that the standard deviation of the daily percentage price change for the three-month futures is 0.026 on Thursdays with no Governing Council meeting. Thus, a one standard deviation of the news shock, corresponding to 0.365, leads to a price change of about 50 percent of the normal daily volatility of price changes. The size of the response of the futures price induced by the news shock is comparable to the reaction due to the monetary policy shock and generally much greater than the reaction of the bond market to macroeconomic news (see, e.g., Balduzzi, Elton, and Green 2001). Is the response of futures prices to the news shock "appropriate," or is it an overreaction? Unfortunately, in the absence of a fully developed structural asset pricing model, we cannot provide a definitive answer to this question. Preliminary evidence based both on visual inspection of figure 6 and more formal regression analysis indicates that the adjustment of futures rates to the news shock is gradual, thus suggesting that there may not be overreaction. Moreover, the additional volatility of futures prices on Governing Council meeting days compared with all other Thursdays (between 16:00 and 13:30) has the same order of magnitude of the reaction of futures rates to a one standard deviation of the news shock. Hence, market participants seem to give the "appropriate" weight to the new public information released by the central bank.

So far, we have shown that asset prices react to ECB communication, but how long does this reaction take? In other words, what

[12]Because of attenuation bias due to measurement error in the explanatory variable (Johnston and DiNardo 1996, 154) of equation (2) (also due to the artificial discreteness of our wording indicator), this number should be interpreted as a lower bound on the ECB's ability to move asset prices by simply making announcements.

Table 4. Time Needed to Incorporate the News Shock (Futures Rates), Dependent Variable $f_{17} - f_t$

	t = 14:15	t = 14:30	t = 14:45
Constant	0.002	0.003	0.003*
	(0.002)	(0.002)	(0.002)
NS_t	0.020**	0.012*	0.008
	(0.009)	(0.007)	(0.005)
R^2	0.120	0.054	0.030
Observations	70	70	70

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 are in parentheses. ***, **, and * denote significance at the 10, 5, and 1 percent level, respectively.

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^*} (see Balduzzi, Elton, and Green 2001):

$$f_{17:00} - f_{t^*} = \alpha + \beta NS_t + \varepsilon_t, \tag{5}$$

where f_{t^*} stands for the (five-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 14:45, unexpected announcements are no longer significant. Hence, about one hour after the end of the press conference, futures prices have completely incorporated the news originating from the ECB President's monthly press conference.

The seemingly quick adjustment in asset prices is consistent with the efficiency of the Euribor futures market. 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. This makes our estimates much more efficient, resulting in smaller standard errors in the coefficients of the news shock. Finally, and most importantly, Bernoth and von Hagen (2004) only analyze the response of futures rates to monetary policy shocks, while we separately identify the effect of the two systematic events that take place on Governing Council meeting days: the ECB policy rate announcement and, especially, the ECB press conference.

Throughout the paper, we use a five-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, Swanson, and Wright 2004). Asset 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 cannot construct average futures prices weighted by volumes, since volume data are available only from July 2003.

As a further robustness check, we also rerun the previous regressions (see separate technical appendix) 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, 593). Our empirical findings discussed in this section are qualitatively very similar if we use equally spaced data.

5. Robustness Checks: Generated-Regressor Issue and State-Space Model

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 reestimate the same baseline regression of the previous subsection all in one step. More formally, we estimate the following equation by OLS:

$$f_{t+h} - f_{t-h} = c_1 + c_2 \cdot \left(Index_t^{NEW} - c_3 \cdot \left(f_{t-h} - R_t^{NEW}\right) - c_4 \cdot Index_t^{OLD}\right) + \varepsilon_t,$$

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

The econometric results continue to hold both qualitatively and quantitatively (see separate technical appendix).

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, e.g., Efron and Tibshirani 1993). More specifically, we apply a sampling-with-replacement raw residuals bootstrap scheme with 1,000 repetitions. The empirical results (see separate technical appendix) are qualitatively very similar to those obtained in the previous section when White's (1980) robust standard errors are used. In particular, the 99 percent confidence bands of the coefficient of the news shock in equation (4) never include negative numbers. This fact confirms that the ECB is indeed able to move asset prices significantly 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 us 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:

$$\begin{aligned} f_{t+h} - f_{t-h} &= \alpha + \beta_t \big(Index_t^{NEW} - \gamma_1 Index_t^{OLD} \\ &\quad - \gamma_2 \cdot \big(f_{t-h} - R_t^{NEW} \big) \big) + \varepsilon_t \\ \beta_t &= \beta_{t-1} + u_t, \end{aligned}$$

where t stands for a Governing Council meeting day. ε_t and u_t are random variables assumed to be serially independent and independently normally distributed. 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.

Table 5 reports the estimation results. The regression coefficients γs are statistically significant and economically meaningful, i.e., with the expected positive sign.

The bottom part (row 4 of the table) 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-squared error (MSE) value. It is statistically significant and has a magnitude of 0.030.

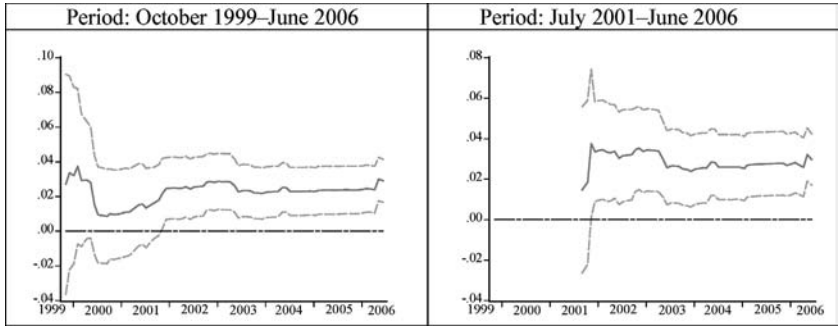
Figure 7 displays the entire path of the one-step-ahead forecast of the state variable together with its confidence bands. This chart suggests that the coefficient of the news shock has varied over time. In particular, financial market participants needed around three years to believe, and thus react to, ECB announcements. It is interesting

Table 5. State-Space Model (Futures Rates)

α	0.006*
	(0.003)
γ_1	0.775***
	(0.260)
γ_2	1.112**
	(0.460)
$\beta_{T/T-1}$	0.030***
	(0.006)
Log-Likelihood	154.590
Observations	73

Note: Monthly observations on days of ECB Governing Council meetings, October 1999–June 2006. The dependent variable is the five-minute average change in futures prices between 13:25 and 14:45. The econometric method is maximum likelihood (Marquardt optimization algorithm). ML standard errors are in parentheses. ***, **, and * denote significance at the 10, 5, and 1 percent level, respectively.

Figure 7. One-Step-Ahead State Variable Prediction



Note: The chart displays the entire path of the state variable (solid line) together with its confidence bands of two standard deviations (dashed lines). Two sample periods have been considered: May 1999–June 2006 (left panel) and July 2001–June 2006 (right panel). Note that the results are mutually consistent. The signal variable is the five-minute average futures rate quoted at 14:45. To facilitate the readability of the right panel, we drop the first observation (centered at zero) that features very large confidence bands.

to see that after this learning period, the coefficient of the news shock has stayed relatively constant over time.

5.3 Using Alternative Wording Indicators

In order to investigate the effects of central bank qualitative announcements on asset prices, a key step is represented by the application of the narrative approach to categorize the hawkishness of the ECB rhetoric. In this section, as a robustness check we consider alternative classification schemes of the tone of the announcement. In particular, we use both a wording indicator based on a more finely graded scale ranging from -2 (strong inclination to lower rates) to $+2$ (strong inclination to increase rates), coded as *Index2*, and other people's wording indicators of the ECB monetary policy stance, such as those used by Musard-Gies (2006). Then, we employ these new *Indexes* to construct market participants' expectations about the ECB declaration, given by equation (2), and to construct the related news shock, given by equation (3). Finally, as we did before, we investigate the impact of the surprise component of central bank announcements on asset prices.

By reestimating the baseline regressions of section 4, we find that the econometric results remain qualitatively very similar and highly statistically significant despite the fact that we employ a different wording indicator.[13] However, we do find that a more finely graded scale produces more precise point estimates (see tables 6 and 7) compared with a scale that ranges from -1 to $+1$—i.e., one that only distinguishes between easing, neutral, and tightening. This evidence suggests that although a three-value classification of the announcement is arguably less controversial, it represents a measure of the tone of the statement that is too coarse and that may neglect important slight nuances. For instance, in the latter case, all the qualifications of the keyword "vigilance"—such as strong, extreme, moderate, etc. (see Jansen and de Haan 2007a for an exhaustive list)—are not differentiated with a substantial information loss.

[13]In the interest of space, we report in a separate technical appendix the econometric analysis using Musard-Gies' (2006) wording indicators.

Table 6. Auxiliary Regression to Measure the Expected ECB Announcement using Ordered Probit

$f_{t-h} - R_t^{NEW}$	2.448***
	(0.691)
$Index2_t^{OLD}$	1.496***
	(0.237)
δ_1	−2.896***
	(0.422)
δ_2	−1.648***
	(0.347)
δ_3	1.012***
	(0.288)
δ_4	3.254***
	(0.482)
Log-Likelihood	−47.688
Pseudo-R^2	0.538
Observations	70

Note: Monthly observations on days of ECB Governing Council meetings, January 2000–June 2006. The econometric method is ML – Ordered Probit (Quadratic hill climbing). ***, **, and * denote significance at the 10, 5, and 1 percent level, respectively.

Table 7. Explanation of Innovation in Expectations (Futures Rates), Dependent Variable $f_{t+h} - f_{t-h}$

	$t+h =$ 14:45 $t-h =$ 13:30	$t+h =$ 15:45 $t-h =$ 13:30	$t+h =$ 16:45 $t-h =$ 13:30
Constant	0.003	0.005	0.005
	(0.003)	(0.004)	(0.004)
NS_t	0.023***	0.028***	0.029***
	(0.006)	(0.007)	(0.007)
R^2	0.188	0.199	0.195
Observations	70	70	70

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 are in parentheses. ***, **, and * denote significance at the 10, 5, and 1 percent level, respectively.

6. Central Bank Communication and Monetary Policymaking

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 2007a, 2007c; Gerlach 2007; Kohn and Sack 2003; Jansen and de Haan 2005, 2006, 2007a, 2007c; Rosa 2007a, 2007b, 2007c; Rosa and Verga 2007).

The workhorse model used so far in the literature (Kuttner 2001) to describe the effects of monetary policy on asset prices has been based only on monetary policy shocks, i.e., a single factor. However, nowadays central banks have adopted a 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. The former effect is not only significant but also has a sizable impact on futures prices.

In addition, Bomfim (2003) and Gurkaynak, Sack, and Swanson (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 target federal funds rate and the second one as the future path of policy, which is closely associated with Federal Open Market Committee announcements. We solve a related empirical exercise. However, there remain important differences. On the one hand, the methodology is different. We first identify the surprise component of the ECB press conference. Then, we use it to explain the change in the futures rate. While Gürkaynak, Sack, and Swanson (2005) 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 differently, *first* 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. On the other hand, we analyze the ECB, while they focus on the U.S. Federal Reserve. 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. We also test the degree of efficiency of the Euribor futures market.

Rosa (2007b) applies the methodology developed in this paper to investigate the impact of the unexpected component of the Federal Reserve's monetary policy decisions and balance-of-risk statements on the full spectrum of the U.S. yield curve. Then he does a comparative study exercise between the effectiveness of the ECB and Federal Reserve communication on their domestic interest rates, and study the cross-effects—namely, the Federal Reserve's ability to move European interest rates and the corresponding ECB's capacity to move U.S. rates. 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. As we mentioned above, this is a crucial improvement for the identification of the effects of the news shocks because it allows us to fully exploit the unique institutional feature of ECB monetary policy conduct, i.e., the fact that on the same Governing Council meeting day, the ECB announces its policy decision and explains its monetary policy stance at two different points in time. Since the monetary policy shock is immediately incorporated into asset prices, we can separately analyze the effects of the news shock, and thus we do not need to make any exogeneity assumption of the monetary policy shock that is typically encountered in the literature. Second, we can investigate how communication interacts with learning by the public about the credibility of the central bank. Third, by considering a narrower time window—i.e., the futures price change immediately before and after the press conference takes place—we not only avoid potential bias due to omitted variables, but we also obtain more efficient point estimates of the regressor coefficients. Finally, we provide a thorough qualitative description of the market reaction (volume, number of transactions, volatility, etc.) to qualitative information, and this is interesting from a market microstructure standpoint.

Brand, Buncic, and Turunen (2006) investigate the impact of ECB monetary policy decisions and communication on the

yield curve by using high-frequency data. Their methodology is based on Gürkaynak, Sack, and Swanson (2005), and thus the news shock is assumed rather than derived from first principles. Moreover, 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. Also, Ehrmann and Fratzscher (2007b) analyze the information content of the ECB press conference. However, the present work goes one step further by explaining the change in the level of futures rates caused by the ECB's unexpected announcement, rather than looking only at changes in second moments such as absolute returns. In other words, we document the ability of the ECB to move rates in the *desired direction*, instead of simply introducing noise, when its announcement differs from what the market expected.

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 why is this piece of information not presented in a precise numerical form, analogous to the ECB policy rate decision?

Monetary policymakers are interested in permanently moving futures rates using their statements rather than the precise estimates of the timing and impact of news, i.e., its initial reaction. Table 8 addresses this question and provides the futures price change for three weeks, fifteen trading days, following the ECB President's press conference. Unexpected hawkish or dovish announcements are defined as in section 4, specifically as in figure 6.

It is interesting to see that the initial response 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 increasing with the measurement interval; this holds true even if the multiday tests lack power against the alternatives that the price reacts permanently to the tone of the central bank declaration over

Table 8. Futures Price Response over Longer Horizons

Days	Hawkish	Dovish
1	0.022**	−0.014*
2	0.022*	−0.017
3	0.019*	−0.023*
4	0.021*	−0.017
5	0.016	−0.022
6	0.030	−0.031*
7	0.040	−0.046**
8	0.043*	−0.052***
9	0.045*	−0.061***
10	0.041*	−0.067***
11	0.036	−0.070***
12	0.027	−0.076***
13	0.008	−0.081***
14	0.006	−0.084***
15	−0.013	−0.098***

Note: We compute futures price changes as the difference between the five-minute average futures rate (between 17:00 and 17:05, London time) on trading day t after the press conference and the thirty-minute average futures rate (between 13:25 and 13:30, London time) taken on Governing Council meeting days, which is immediately before the press conference takes place. A statement is defined as hawkish when the news surprise, the difference between $Index_t^{NEW}$ and E_{t-h} $[Index_t^{NEW}]$, belongs to the top 20th percentile of the news shocks observed in our sample period (i.e., 0.142). A statement is defined as dovish when the news surprise belongs to the bottom 20th percentile of the news shocks observed in our sample period (i.e., –0.228). In the remaining cases, the central bank statement is classified as neutral. ***, **, and * denote significance at the 10, 5, and 1 percent level, respectively.

the following month.[14] On the other hand, futures prices increase, but only in a marginally significant way, by about 3–4 basis points after a hawkish announcement and maintain the new level for about two weeks.

[14]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.

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, the actual evolution of the real economy.

7. 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 qualitative 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 at two different points in time, not only can we distinguish one surprise from the other, but we can also investigate their effects independently.

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 data set.

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: the 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 experiences a statistically and economically significant quick (less than an hour) reaction. Put differently, we show that communication is an important tool in the process of conducting monetary policy stance.

Third, our results establish the degree of efficiency of the Euribor futures market.

Finally, by estimating a state-space model, we find that the importance of the ECB press conference has increased over time, especially since the first years of the ECB's life. This evidence suggests that financial market participants needed around three years to learn how to interpret (and also fully believe) the central bank announcements.

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 ECB is.

There are, of course, several other important issues not considered here that 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, i.e., the probability of rejecting a false null hypothesis (i.e., ECB unexpected announcements have no impact on the behavior of asset prices). In this paper, we make specific assumptions about the distribution of abnormal price changes. Hence we use parametric estimation methods. Alternatively, nonparametric 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 the ECB Presidents' announcements on Euribor futures rates using a new high-frequency data set. 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, Lo, and MacKinlay 1997, chap. 3). The computation of further diagnostic tests could be particularly fruitful to gauge the robustness of our preliminary findings.

Appendix

Coding of ECB President Press Conferences

Table 9 reports the assigned value of risk, *Index*, for each ECB monetary policy announcement from January 2000 through June 2006.

Examples of Introductory Statements and Their Coding

It should be noted that the excerpts reported in this appendix only provide some references to the classification but do not completely exhaust the information we use to pin down the ECB future policy inclination (see Rosa and Verga 2007 for further details). Emphasis has been added.

Date: 2 March 2000
The Governing Council also concluded that **the balance of risks to price stability in the medium term remains on the upside. These upside risks will need to be monitored and assessed**

Table 9. ECB President Announcements about Future Monetary Policy Moves

Date	*Index*	*Index2*	Date	*Index*	*Index2*
05/01/2000	1	2	03/04/2003	0	0
03/02/2000	1	2	08/05/2003	−1	−1
02/03/2000	1	2	05/06/2003	−1	−1
13/04/2000	1	2	10/07/2003	−1	−1
11/05/2000	1	2	NA		
08/06/2000	1	2	04/09/2003	0	0
06/07/2000	1	2	02/10/2003	0	0
NA			06/11/2003	0	0
14/09/2000	1	2	04/12/2003	0	0
05/10/2000	1	2	08/01/2004	0	0
02/11/2000	1	2	05/02/2004	0	0
14/12/2000	1	2	04/03/2004	0	0
NA			01/04/2004	0	0
01/02/2001	1	1	06/05/2004	0	0
01/03/2001	1	1	03/06/2004	1	1
11/04/2001	1	1	01/07/2004	1	1
10/05/2001	0	0	NA		
07/06/2001	0	0	02/09/2004	1	1
05/07/2001	0	0	07/10/2004	1	1
NA			04/11/2004	1	1
30/08/2001	−1	−1	02/12/2004	1	1
11/10/2001	−1	−1	13/01/2005	1	1
08/11/2001	0	0	03/02/2005	1	1
06/12/2001	0	0	03/03/2005	1	1
03/01/2002	0	0	07/04/2005	1	1
07/02/2002	0	0	04/05/2005	1	1
07/03/2002	0	0	02/06/2005	1	1
04/04/2002	0	0	07/07/2005	1	1
02/05/2002	0	0	NA		
06/06/2002	1	1	01/09/2005	1	1
04/07/2002	0	0	06/10/2005	1	2
NA			03/11/2005	1	2
12/09/2002	−1	−2	01/12/2005	1	1
10/10/2002	−1	−1	12/01/2006	1	2
07/11/2002	−1	−2	02/02/2006	1	2
05/12/2002	−1	−2	02/03/2006	1	2
09/01/2003	−1	−1	06/04/2006	0	1
06/02/2003	−1	−2	04/05/2006	1	2
06/03/2003	−1	−1	08/06/2006	1	2

Note: January 2000–June 2006. We report the monetary policy intentions indicators communicated by the ECB on Governing Council meeting days. *Index* ranges from −1 to +1, while *Index2* ranges from −2 to +2. Note that we have considered only the first press conference of each month. NA indicates that the press conference did not take place.

continuously in order to ensure that timely action can be taken, if and when required. (...)

The Governing Council concluded that **vigilance is required** and pointed to several factors.
Coding: +1

Date: 14 September 2000
The annual rate of increase in the Harmonised Index of Consumer Prices (HICP) was 2.4% in July 2000. Recent consumer price developments in the euro area have been very much influenced by the strong rise in oil prices and the depreciation of the exchange rate of the euro.

While monetary policy cannot address short-term developments in prices, **it is imperative for monetary policy that medium-term upward pressure on prices be contained**. The risk that the current pressure on the HICP might spill over onto costs and prices determined in the domestic economy must be taken seriously. This holds true in particular in the context of the favourable prospects for economic growth.
Coding: +1

Date: 7 March 2002
As usual, at today's meeting we examined recent monetary, financial and economic developments. The Governing Council concluded that the information which had become available in recent weeks confirmed that the current level of key ECB interest rates remains **appropriate** for the maintenance of price stability over the medium term. Against this background, the Governing Council decided to leave the key ECB interest rates unchanged.
Coding: 0

Date: 4 March 2004
Overall, the Governing Council confirmed its previous assessment of a **favourable outlook for price stability** in the euro area over the medium term. Against this background, we concluded that the **current stance of monetary policy remains appropriate**. The key ECB interest rates have therefore been left unchanged at their low levels. Our monetary policy stance provides support to the economic recovery in the euro area. (...)

To sum up, the economic analysis continues to indicate that the main scenario for price developments in the coming years **is in line with price stability**. Cross-checking with the monetary analysis does not alter this picture for the time being.
Coding: 0

Date: 7 November 2002
We have reviewed monetary, financial and economic developments and updated our assessment in the light of the information available. In view of the high uncertainty on future growth, and its implication for medium-term inflationary developments, the Governing Council **has discussed extensively the arguments for and against a cut in the key ECB interest rates**. The view has prevailed to keep interest rates unchanged. However, the Governing Council **will monitor closely the downside risks** to economic growth in the euro area.
Coding: −1

Date: 12 September 2002
Our conclusion is that risks to price stability appear rather **balanced**. Against this background, the current level of key ECB interest rates is **appropriate**.

(. . .) Nevertheless, **risks to the economic outlook**, both inside and outside the euro area, **need to be monitored closely**.
Coding: −1

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