Using Intraday Data to Gauge Financial Market Responses to Federal Reserve and ECB Monetary Policy Decisions*

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This paper examines bond and stock market volatility reactions in the euro area and the United States following their respective economies' monetary policy decisions, over a uniform sample period (April 1999–May 2006). For this purpose, intraday data on the U.S. and euro-area bond and stock markets are used. A strong upsurge in intraday volatility at the time of the release of the monetary policy decisions by the two central banks is found, which is more pronounced for the U.S. financial markets following Federal Reserve monetary policy decisions. Part of the increase in intraday volatility in the two economies surrounding monetary policy decisions can be explained by both news of the level of monetary policy and revisions in the expected future monetary policy path. The observed strong discrepancy between asset-price reactions in the United States and in the euro area following monetary policy decisions still remains a puzzle, although some tentative explanations are provided in the paper.

JEL Codes: E52, E58, G14.

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1. Introduction

How do financial markets react to the release of monetary policy decisions? The answer to this question is of fundamental interest to monetary policymakers, as it provides them with information as to first, how well decisions are anticipated by market participants, and second, how these agents adjust their views about future monetary policy, output growth, and inflation in response to a given decision. Such information enables a central bank to judge the immediate "success" of any decision taken, i.e., whether market participants reacted in accordance with the policymakers' intentions.

The purpose of this paper is to assess bond and stock market reactions in the euro area and the United States following monetary policy decisions by the European Central Bank (ECB) and the Federal Reserve over a uniform sample period (April 1999–May 2006). Intraday data are used, and the asset-price reaction is measured in terms of derived realized volatility measures over five-minute intervals. Two different angles are viewed. First, asset-price volatility on monetary policy announcement days is compared with the volatility observed on non-announcement days. Second, the volatility pattern when the central bank changes policy rates as opposed to when the monetary policy rates are left unchanged is examined. Conditional on these two events, the extent to which monetary policy target and path surprises can explain the observed volatility is analyzed.

The paper contributes to the existing literature in two main aspects. First, a direct comparison of the U.S. and euro-area bond and stock market intraday volatility patterns following monetary policy decisions is novel. Second, this paper is the first to examine the influence that monetary policy target and path surprises exert on intraday financial market volatility patterns, conditional on whether monetary policy rates have been altered or not.

The paper reaches three main findings. First, intraday U.S. and euro-area stock and bond market volatility strongly increases at the time of the release of monetary policy decisions and is particularly pronounced for the U.S. financial markets. Second, monetary policy target and path surprises by the ECB both significantly move the euro-area financial markets, whereas path surprises by the Federal Reserve have, on average, a larger influence on U.S. bond and stock market volatility compared with the target surprises. Third,

the yield response sensitivity for the German bond markets following an ECB monetary policy target surprise is stronger on the occasions when the monetary policy rates have been altered compared with periods when the ECB decided to leave it unchanged.

Although some tentative explanations are given in the paper, the observed discrepancy between asset-price reactions in the United States and in the euro area following monetary policy decisions still remains a puzzle.

The remainder of this paper is organized as follows. Section 2 presents some background and related literature, while section 3 discusses the data used. The bond and stock market volatility reactions in the euro area and the United States following their respective economies' monetary policy decisions are elaborated upon in section 4. Section 5 concludes.

2. Background and Related Literature

Volatility of prices of financial assets such as stocks and bonds surrounding monetary policy decisions can be used to gauge the extent to which they contain "new news" for market participants that would lead them to revise their expectations about the future monetary policy path and/or the macroeconomic outlook. If a monetary policy decision causes market participants to revise their expectations, this should then be reflected in higher volatility of financial market prices compared with a period free of such an event.

Several differences can be noted in both the frequency and magnitude of interest rate settings between the two central banks (see table 1). First, the ECB conducts monetary policy decisions meetings more frequently compared with the Federal Reserve. Second, the Federal Reserve has, on average, changed the interest rate more often and by larger magnitudes than the ECB over recent years.

Both the degree of predictability of monetary policy decisions and the influence the decisions exert on financial asset prices have been discussed in the literature. As regards the former, many papers have shown that U.S. monetary policy decisions in general have been well anticipated among market participants (see, for example, Bernanke and Kuttner 2004 and Fleming and Piazzesi 2005). The same holds true for the euro area, where financial markets have also been able to foresee the ECB's monetary policy decisions (see,

Table 1. Federal Reserve and ECB Monetary Policy Decisions (April 1999–May 2006)

	ECB	Federal Reserve
Total Number of Events	118	54
Number of Events in Which the Monetary Policy Stance Was Changed	16	32
Number of Increases, 25 bp	7	21
Number of Increases, 50 bp	2	1
Number of Reductions, 25 bp	3	4
Number of Reductions, 50 bp	4	6

Notes: In this study, for comparison, the data start in April 1999, as the ECB then began to release its monetary policy decisions at the regular time of 13:45 (CET). All statistics exclude the September 17, 2001 observation. Unscheduled monetary policy meetings by the Federal Reserve are also excluded.

for instance, Wilhelmsen and Zaghini 2005 and European Central Bank 2006). In addition, monetary policy communication plays a key role in enhancing short-term predictability by allowing the public to understand monetary policy decisions, a fact which has been documented in a number of studies by Ehrmann and Fratscher (2005a, 2005b, and 2007).

A number of papers have also examined the impact monetary policy decisions exert on the level of financial asset prices. Applied to U.S. data, Gürkaynak, Sack, and Swanson (2005) and Wongswan (2006) find that the U.S. stock and bond markets react significantly to news about the near-term level of monetary policy and to changes in expectations of the path of monetary policy. Similarly, for the euro area, Brand, Buncic, and Turunen (2006) suggest that revised ECB monetary policy expectations have a significant and sizable impact on the level of medium- to long-term interest rates in the euro area. In a closely related paper, Rosa (2008) adopts yet another approach and compares, among other things, the ability of the ECB and the Federal Reserve to influence domestic interest rates by means of various communication channels. By contrast with this paper, Rosa evaluates the way in which central bank communication affects the direction of asset-price movements. The results show that long-term bond yields in the United States are more sensitive to the Federal

Table 2. Data Used To Measure Financial Market Reactions

Asset	Exchange
German Bond Futures	EUREX
U.S. Bond Futures	Chicago Board of Trade
EURO STOXX 50 Futures	EUREX
S&P 500 Index	Chicago Mercantile Exchange

Reserve's statements than European bond yields are to statements by the ECB.

Fewer studies have been conducted on volatility reactions surrounding monetary policy communications. Applied to the United States, Andersen et al. (2005) find a significant rise in U.S. long-term bond yield volatility surrounding monetary policy decisions by the Federal Reserve. Similarly, Ehrmann and Fratzscher (2003) show that the volatility on euro-area money market rates tends to be higher following Governing Council statements by the ECB. This paper fills a gap in the existing literature by conducting a direct comparison between the U.S. and euro-area bond and stock market intraday volatility pattern following monetary policy decisions.

3. Description of Data Used

The data used to measure financial market reactions consist of intraday data on euro-area and U.S. bond and stock prices (see table 2).

The data have been provided by TickData, Inc. The dates and times of when the Federal Reserve's monetary policy decisions have become available to the public are taken from the paper by Fleming and Piazzesi (2005).[1] The actual and expected outcome of the Federal Reserve's interest rate decisions are taken from the Bloomberg survey. The dates and times for the ECB's monetary policy decisions have been collected internally. With regard to market expectations for ECB monetary policy decisions, the expected outcome from the Reuters survey is used.

[1]The exceptions are the 2005 and 2006 decisions, which are taken from Bloomberg.

Table 3. Descriptive Statistics, Five-Minute Returns

	German Bond Futures	U.S. Bond Futures	EURO STOXX 50 Futures	S&P 500 Index
Mean	0.0001	0.0001	−0.0001	−0.0003
Standard Deviation	0.0258	0.0398	0.1252	0.1048
Skewness	−0.24	−0.30	−0.57	0.16
Kurtosis	17.73	55.07	37.82	12.43

Notes: April 1999–May 2006. The overnight returns are omitted when computing the descriptive statistics.

This paper derives a volatility measure V using regularly spaced five-minute intervals:

$$V_t = abs\left(100 * \log\left(\frac{P_t}{P_{t-1}}\right)\right), \tag{1}$$

where P_t is the five-minute prices of the four assets.[2]

Table 3 summarizes the descriptive statistics for the four return series used in the paper. The sample mean of the asset returns are all small and, given the sample standard deviations, not statistically different from zero. The returns are obviously not normally distributed, given the large magnitudes of the skewness and kurtosis statistics.

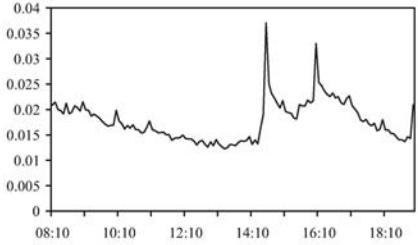
Volatility is normally not constant throughout a trading day, but tends to be higher at opening and closing hours than during the middle of a trading day. This feature has to be taken into account when gauging whether policy decisions by central banks induce elevated price fluctuations. Figures 1A–1D show the average five-minute volatility during the trading days for the U.S. and euro-area bond and stock series.[3]

[2]As an alternative, the squared return could also be used as a measure of realized intraday volatility. This measure does not, however, change the interpretations.

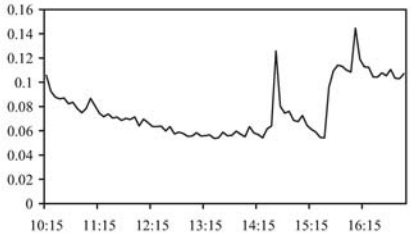
[3]Over the sample under consideration, the trading hours of the STOXX futures and the German bond futures have not remained constant. The intraday volatility shown in figures 1A and 1B is therefore calculated using only hours which have been traded over the entire sample.

Figure 1. Intraday Volatility in the Euro-Area and U.S. Stock Markets

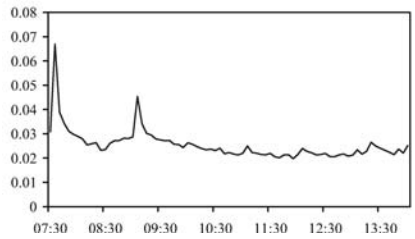
A. German Intraday Bond Market Volatility (April 1999–May 2006, 8:00–19:00 CET)



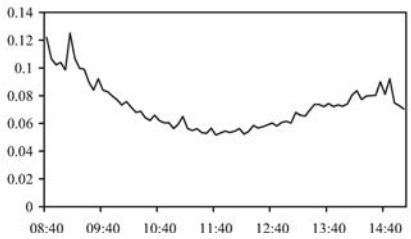
B. Euro-Area Intraday Stock Market Volatility (April 1999–May 2006, 10:15–17:00 CET)



C. U.S. Intraday Bond Market Volatility (April 1999–May 2006, 07:20–14:00 CST)



D. U.S. Intraday Stock Market Volatility (April 1999–May 2006, 08:30–15:00 CST)



The German bond and euro-area STOXX future contracts display a number of interesting intraday features (figures 1A and 1B). First, volatility in general tends to be higher at the opening and closing hours of the trading day. At opening hours, prices normally have to adjust to new information, which may induce heightened price fluctuations. Higher volatility close to the end of the trading day is probably linked to some investors closing their trading books to avoid having open positions overnight. Second, the two spikes—occurring at 14:30 and 16:00 (Central European time, or CET)—correspond to the release of several important U.S. macro announcements, such as the non-farm payroll, producer price index, retail sales, consumer price index, ISM, and consumer confidence. In addition, at 14:30 on the first Thursday of each month, the ECB holds a press conference at which information about the considerations concerning the monetary policy decision is conveyed. Third, the

level of intraday volatility is higher for the euro-area stock markets compared with the German bond future markets, which is something that is also observed for much lower frequencies such as daily data.

The U.S. bond and stock markets show a broadly similar pattern to their European counterparts (figures 1C and 1D). The spikes occurring at 07:30 and 09:00 (central standard time, or CST) mainly arise from releases of the above-reported U.S. macro announcements. Overall, bond and stock markets on both sides of the Atlantic seem to display generally similar levels of volatility.

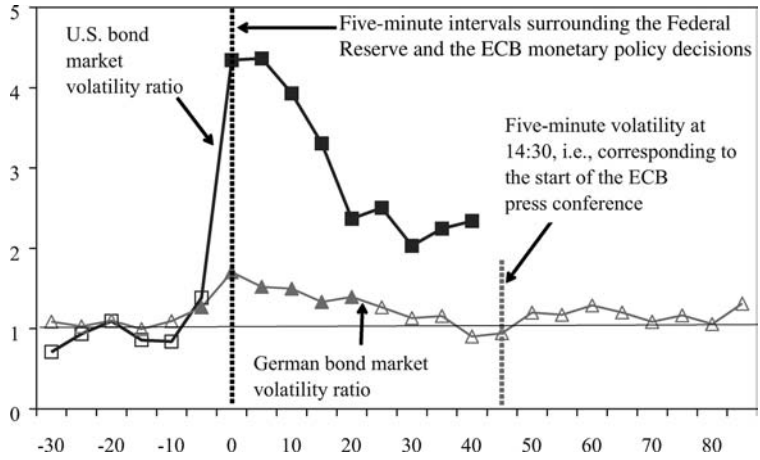
4. Asset-Price Reactions Following Monetary Policy Decisions by the ECB and the Federal Reserve

The following four subsections examine financial market intraday volatility patterns surrounding monetary policy decisions by the ECB and the Federal Reserve. Target and path surprises implicitly embedded in the monetary policy decisions are computed. These surprises are used as explanatory variables to the observed intraday volatility pattern. In section 4.1 the general volatility pattern is analyzed. Section 4.2 provides some tentative explanations for the observed discrepancy between asset-price reaction in the United States and in the euro area following monetary policy decisions. Section 4.3 regresses the general intraday volatility pattern on monetary target and path surprises. Section 4.4 evaluates if the volatility pattern in financial markets differs depending on if monetary policy rates have been altered or not.

4.1 General Intraday Volatility Pattern Surrounding Monetary Policy Decisions

Figures 2 and 3 display the ratio between five-minute bond and stock market volatility surrounding monetary policy decisions by the Federal Reserve and the ECB, respectively, and the average five-minute volatility on the same weekdays and the same times but on non-announcement days, thereby controlling for both intraday and "weekday" effects. A ratio above 1 can be interpreted as the monetary policy decisions inducing "higher than normal" volatility. As regards the timing, the Federal Reserve's interest rate decisions are

Figure 2. U.S. and German Bond Market Volatility Ratio Surrounding Monetary Policy Decisions by the Federal Reserve and the ECB (April 1999–May 2006)



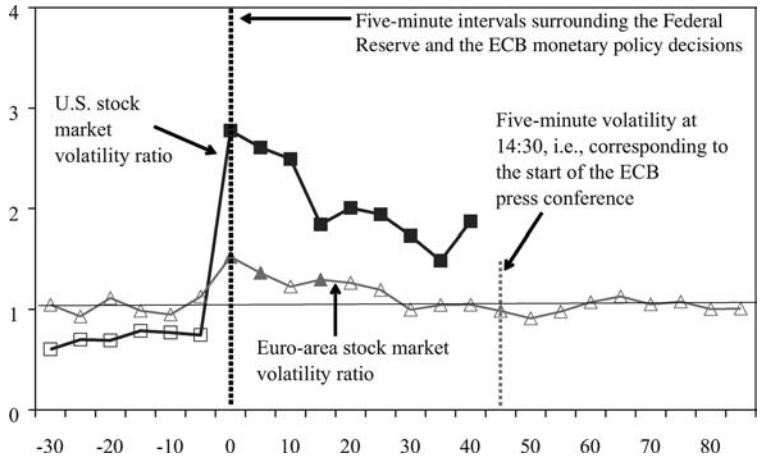
Notes: The volatility measures are calculated as the ratio between (i) five-minute intraday volatility on the U.S. and German long-term bond futures markets surrounding interest rate decisions by the Federal Reserve and the ECB, and (ii) "normal volatility," the latter computed as the average absolute returns on the same weekdays and same times but on non-announcement days. Using a one-sided t-test, the filled dots imply that the ratio is significantly higher than 1 and empty dots that the ratio cannot be deemed as exceeding 1.

usually released at 13:15, and the ECB's interest rate decisions at 13:45 (both local times).

It should be noted that the Federal Reserve's interest decisions are also accompanied by a statement in which the outlook for the future monetary policy stance is conveyed.[4] This implies that, particularly for the Federal Reserve, there are two potential sources of new information arising from the interest rate decisions—a target surprise and a path surprise. The target surprise can be defined

[4]The trading of the U.S. ten-year Treasury future note closes at 14:00 (CST), i.e., forty-five minutes after the Federal Reserve's interest rate decisions. To enable a consistent comparison between the U.S. bond and stock markets, the volatility window spans from thirty minutes before to forty minutes after the decisions for these two markets.

Figure 3. U.S. and Euro-Area Stock Market Volatility Ratio Surrounding Monetary Policy Decisions by the Federal Reserve and the ECB (April 1999–May 2006)



Notes: The volatility measures are calculated as the ratio between (i) five-minute intraday volatility on the U.S. (S&P 500) and euro-area (EURO STOXX) stock markets surrounding interest rate decisions by the Federal Reserve and the ECB, and (ii) "normal volatility," the latter computed as the average absolute returns on the same weekdays and same times but on non-announcement days. Using a one-sided t-test, the filled dots imply that the ratio is significantly higher than 1 and empty dots that the ratio cannot be deemed as exceeding 1.

as the degree to which market participants have been able to anticipate the actual monetary policy decisions. The path surprise instead measures to what degree market participants have revised the future expected monetary policy path following the actual decision and/or monetary policy statements.

In contrast to the Federal Reserve, the ECB's interest decisions and statements are released to the public at separate times. Announcements of the actual outcome of monetary policy decisions are released at 13:45 local time. However, details about the economic and monetary analyses underlying each interest rate decision are instead conveyed in the introductory statement read by the ECB President forty-five minutes later. As seen in the figures, the volatility pattern for the euro-area bond and stock markets is therefore extended to include any financial market movements that take place surrounding the press conference as well.

Four interesting features can be inferred from the two figures. First, monetary policy decisions on both sides of the Atlantic tend to induce significantly "higher than normal" volatility on their respective economies' bond and stock markets. Second, this feature seems to be particularly pronounced for the U.S. bond and stock markets following interest rate decisions by the Federal Reserve. Third, some volatility persistence can be observed, in particular for the U.S. bond and stock markets, where "excess" volatility can be noted up to forty minutes after the decisions have taken place. Fourth, in the euro area, the introductory statement read by the ECB President induces somewhat "higher than normal" volatility on the euro-area bond market.

Potentially, any interpretations on the basis of figures 2 and 3 could be spurious if important macro announcements were systematically released on the same days and at the same times as the monetary policy decisions of the Federal Reserve and the ECB. To examine this in detail, forty-three U.S. and euro-area macro announcements were collected and tested to establish whether they were made within a sixty-minute window of the monetary policy announcements by the two central banks.[5] The results of this examination suggested that none of the announcements under consideration occurred at the same time as the Federal Reserve decisions. The monetary policy decisions of the ECB coincided with the release of macro statistics on only two occasions, and both concerned the German CPI statistics released on March 23, 2001 and April 26, 2001. These two instances of concurrence should not, however, distort the interpretation, as previous announcement papers have found that the German CPI does not move the euro-area financial markets in any significant way—see Ehrmann and Fratzscher (2003) and Andersson, Hansen, and Sebestyén (2006).

The small number of macro releases occurring at the time of the monetary policy decisions suggests that the observed upsurge in volatility is prompted by the actual decisions and does not reflect market reactions to macro news. In stark contrast, the ECB press conference is usually held at times of important U.S. macro

[5]See Andersson, Hansen, and Sebestyén (2006), table 1, where the forty-three announcements are listed.

announcements—in particular, the weekly initial jobless claims—making the volatility ratio difficult to interpret.[6] An analysis of the ECB press conference is, however, outside the scope of this paper, which purely concentrates on market reaction to the actual decisions.

The average reaction to asset prices shown in figures 2 and 3 may not be static but, rather, changing over time. There are several reasons why price reaction can change over time. Andersson, Hansen, and Sebestyén (2006) suggest that policymakers can sometimes signal a preference for one or more macroeconomic indicators as input for their policy decisions. In addition, some macroeconomic releases may behave in an unusual manner at a certain point in the business cycle, which can in turn have an impact on monetary policy decisions. To check for potential time variation, yearly averages were computed.[7] The yearly averages are broadly similar across the years, suggesting that the pattern shown in figures 2 and 3 can be deemed a general feature.

4.2 Why Intraday Asset-Price Movements Are Stronger in the United States Than in the Euro Area: Some Tentative Explanations

The finding that there is a higher intraday asset-price reaction in the United States than in the euro area following their respective economies' monetary policy decisions is interesting but somewhat puzzling. The three best possible explanations for this discrepancy, in order of significance, are as follows. First, "more" information becomes available during the release of Federal Reserve interest rate decisions. This comes from the fact that U.S. interest rate decisions are released together with an accompanying statement that contains crucial information about the future monetary policy stance, as seen

[6]Over the sample April 1999–May 2006, the initial jobless claims announcement was released within a sixty-minute window surrounding the 14:30 press conference 106 times. Similarly, the release of the Philadelphia Federal Index occurred five times, durable goods two times, business inventories three times, retail sales four times, CPI two times, advanced GDP three times, GDP preliminary two times, and GDP final two times.

[7]See appendix A in the working paper version (ECB Working Paper No. 726). It shows the yearly volatility ratios for the five-minute periods immediately surrounding and thirty minutes ahead of the monetary policy decisions, respectively.

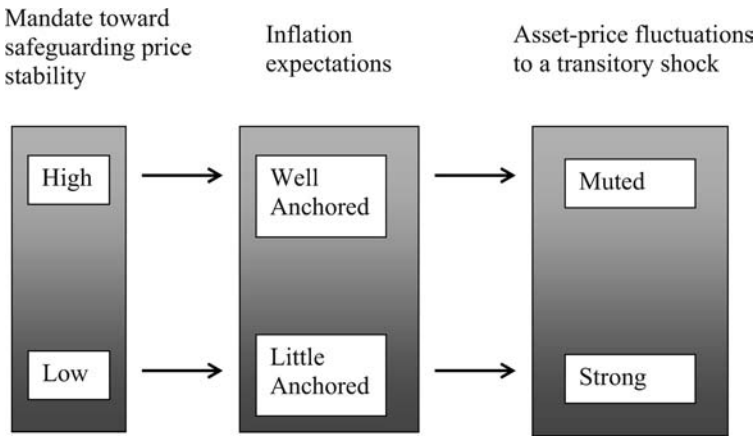
through the eyes of the Federal Reserve. In contrast, the ECB monetary policy decisions are not accompanied by any forward-looking statement.

As a consequence of the Federal Reserve communication strategy, even though the actual decisions by the Federal Reserve have been anticipated by the markets, heightened volatility could still arise given an unexpected change in the tone of the accompanying statement. An interesting example of this took place in January 2004 when the Federal Reserve, as expected, held the policy rate unchanged (at 1 percent) but at the same time significantly changed its wording in the statement following the decision. As the *Wall Street Journal* wrote in its market commentary column the day after the decision, "While investors had expected the Fed's decision to keep short-term interest rates on hold at 1%, the absence of the 'considerable period' phrasing, used since August 2003 to describe how long the bank would keep rates low, caught market participants off guard. . . . Prices plummeted in the immediate aftermath of the Fed's decision and the yield on the 10-year note shot up to 4.26%."

Second, part of the asymmetric asset-price responses in the two economies may be derived from the differences in mandates given to the central banks. Similarly, Orphanides and Williams (2005) introduce learning in a two-equation macroeconomic model where the central bank aims at minimizing a loss function that equals the variance of the output gap and deviations of actual inflation from a target rate. Instead of assuming that all agents know perfectly the structure of the economy and the central bank's policy, agents form expectations based on learning. The authors show that this setup is consistent with excess sensitivity of long-run inflation expectations and long-term bond yields to transitory aggregated shocks. The magnitude of the positive correlation between transitory shocks on the one hand and inflation expectations (and asset-price fluctuations) on the other is smaller if the central bank is vigilant in responding to inflationary threats and the public can be certain of its long-run inflation expectations.

Very simplified, the right-hand panel in figure 4 shows the results proposed by Orphanides and Williams (2005), namely that asset-price fluctuations to transitory shocks tend to be less pronounced for those economies with inflation expectations anchored more firmly. Furthermore, how well market participants' inflation expectations

Figure 4. Central Bank Mandate and Asset-Price Movements



are anchored partly originates from the inflation mandate given to the central bank. As shown by Gürkaynak, Levin, and Swanson (2007), inflation targeting helps to anchor private-sector perceptions of the future distribution of long-run inflation outcomes. The authors show that government bond yields in the United States and the United Kingdom (prior to Bank of England independence) respond significantly to economic news while little movements can be found in the United Kingdom after central bank independence and in Sweden. In the same vein, Rosa (2008) suggests that the asymmetric asset-price responses in the two economies can be linked to the fact that the U.S. long-term inflation objective is not well known to investors.

For the purpose of this paper, the first feature to note is the differences in mandates given to the Federal Reserve and the ECB. The Federal Reserve Act states that the Federal Reserve should seek "to promote effectively the goals of maximum employment, stable prices, and moderate long-term interest rates" whereas the ECB has a price stability objective, laid down in the Maastricht Treaty. The price stability objective has been quantified by the ECB (in May 2003) to aim at inflation rates of below, but close to, 2 percent over the medium term. Thus, even though the objectives of the central banks in this study differ less than those of the central banks

included in the study by Gürkaynak, Levin, and Swanson (2007), it would be safe to say that the ECB has a greater orientation toward price stability than the Federal Reserve.

Partly on account of the different inflation objectives, the question then arises if inflation expectations, in the eyes of investors, differ across the Atlantics. To this end, a recent study by Beechey, Johannsen, and Levin (2007) derives comparable survey-based measures of inflation expectations in the United States and in the euro area (using the ECB Survey of Professional Forecasters and the Federal Reserve Bank of Philadelphia Survey of Professional Forecasters).[8] The authors show that inflation expectation is higher and more volatile in the United States than in the euro area over the 2000–06 period. In addition, the Survey of Professional Forecasters data also allow for an assessment of the uncertainty surrounding the most likely outcome, as the survey respondents report their respective probabilities of inflation outcomes falling into prespecified intervals. Using these additional data, evidence is provided that the disagreements between forecasters are higher in the United States than in the euro area.[9]

All in all, bringing together the theoretical results by Orphanides and Williams (2005) and the fact that long-term inflation expectations seem to be less firmly anchored in the United States than in the euro area gives some economic justification to the asymmetric asset-price responses in the two economies.

Third, uncertainty regarding the timing of the Federal Reserve decisions may also explain part of the differences in asset-price fluctuations. Fleming and Piazzesi (2005) suggest that some uncertainty exists about the exact release of the U.S. monetary policy announcements, which in turn have an impact on intraday market pricing in the U.S. Treasury markets. In particular, liquidity tends to be

[8] See figures 1 and 2 in Beechey, Johannsen, and Levin (2007).

[9] It should, however, be pointed out that disagreement, measured by the standard deviation of the panelists' point estimates, can differ substantially from investors' true uncertainty about long-term inflation expectations; see Giordani and Söderlind (2003) and García and Manzanares (2007b). In addition, the presence of substantial heterogeneity in the central tendencies reported as point estimates may also distort the degree of disagreement (for U.S. evidence, see Engelberg, Manski, and Williams 2007 and for the euro area, see García and Manzanares 2007a).

low if an announcement is released minutes later than the expected 13:15. Everything else held equal, a buy or sell order during imperfect liquidity conditions should result in higher asset-price responses compared with periods of high financial market liquidity. In contrast, timing uncertainty for the ECB's monetary policy decisions should not exist given the exact 13:45 release.

4.3 Evaluating the Impact Monetary Policy Surprises Have on Intraday Financial Market Volatility

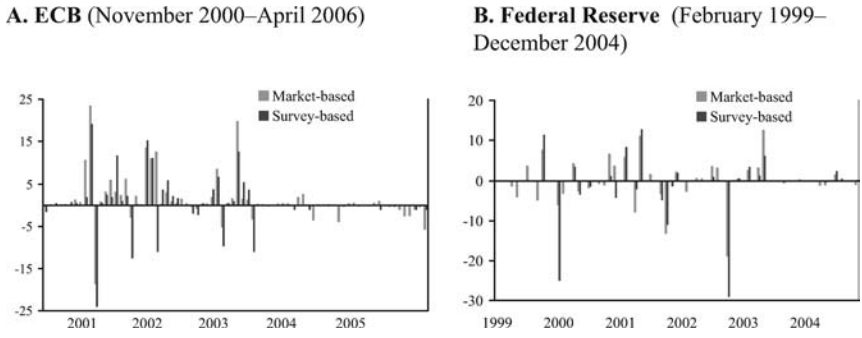
All in all, it is reasonable to assume that the arrival of new information could induce heightened volatility surrounding monetary policy releases. To assess this in more detail, this and the next subsection will focus on the strong upturn observed at the time "0" in figures 2 and 3, which corresponds to the realized asset-price volatility immediately surrounding the monetary policy decisions by the Federal Reserve and the ECB, respectively. The idea is to analyze to what extent the upswing in volatility can be explained by monetary policy surprises.

Monetary policy surprises are divided into two types: target surprises and path surprises. A target surprise is defined as the degree to which market participants have been able to anticipate the actual monetary policy decisions, whereas a path surprise measures the degree to which market participants have revised the future expected monetary policy path following the actual decision and/or monetary policy statements.

The target surprise can be derived from either available surveys or financial market prices. Both measures have their pros and cons. The main advantage of the former is that, in principle, they should contain the "true" mean expectations about upcoming future monetary policy decisions. On the other hand, financial market expectations benefit from the fact that they are available at a much higher frequency compared with survey-based measures. But, as shown by Piazzesi and Swanson (2004) and applied to U.S. data, expectations derived from the financial markets could contain risk premia and market noise, which may blur the interpretation.

This paper uses a survey-based measure for the target surprise which represents the difference between the actual outcomes and the mean of analysts' expectations concerning the outcomes

Figure 5. Market- and Survey-Based Target Surprises



Notes: (A) The market-based measure comes from Brand, Buncic, and Turunen (2006) and represents the thirty-minute changes in the thirty-day maturity euro-area interest rates surrounding the ECB monetary policy decisions (interest rates are filtered using sixty-four instruments; deposit rates, EONIA and EURIBOR swap rates). The survey-based measure represents the difference between the actual outcome of the monetary policy decisions and analysts' mean expectations taken from the Reuters survey. (B) The market-based measure comes from Fleming and Piazzesi (2005) and represents the one-hour changes in federal fund futures contracts surrounding the Federal Reserve monetary policy decisions. The survey-based measure represents the difference between the actual outcome of the monetary policy decisions and analysts' mean expectations taken from the Bloomberg survey.

of the monetary policy decisions. This measure is chosen because the methodology used is identical for both the euro area and the United States. As a cross-check, figures 5A and 5B show the target surprise used in this paper compared with market-based measures employed in some earlier studies. Overall the two measures exhibit very similar patterns, which are also confirmed by the estimated correlation coefficients of 0.75 for the ECB target surprises and 0.8 for the Federal Reserve target surprises. Thus, the survey-based measure should therefore be a good indicator of the target surprise as perceived among investors.

The path-surprise component employed in this study is derived in line with Gürkaynak, Sack, and Swanson (2005):

$$\Delta f_{t-30,t} = \alpha + \beta^* TS_t + PS_t, \tag{2}$$

where $\Delta f_{t-30,t}$ represents the intraday changes in the expected three-month interest rate in six months' time surrounding the

monetary policy decisions (Euribor and Eurodollar future contracts for the euro area and the United States, respectively). The *TS* represents the target-surprise component as described above. The innovation from the regression in equation (2) is defined as the path surprise (*PS*).[10] Given that the purpose of this exercise is to examine the effects on financial markets surrounding the actual monetary policy decisions, potential information about future ECB monetary policy conveyed in the introductory statement at the ECB press conference is not included in the derived ECB path surprises.

To evaluate how the changes in the volatility ratios surrounding the monetary policy decisions by the Federal Reserve and the ECB as shown in figures 2 and 3 can be explained by the target and/or path surprises, the following regression setup is used:

$$\Delta Volratio_{t-30,t} = \alpha + \beta_1{}^* Abs(TS) + \beta_2 Abs(PS) + \varepsilon_t. \qquad (3)$$

The $Abs(TS)$ and $Abs(PS)$ variables in equation (3) correspond to the absolute values of the target and the path surprises, respectively. The $\Delta Volratio_{t-30,t}$ represents the difference between the observed volatility ratio in the period immediately surrounding the monetary policy decisions and the volatility ratio thirty minutes ahead of the decisions. The appendix shows details of how the volatility ratio is calculated. The choice of the intraday impact relative to that of non-announcement days as a dependent variable is in line with the procedure by Ederington and Lee (1993). Table 4 outlines the results of the regression.

Three notable features can be inferred. First, a monetary policy target surprise induces significantly higher than normal volatility in the German bond markets. Second, the ECB path surprises have a highly significant impact on the euro-area stock markets. Third, in the United States the results suggest that path surprises, on average, have a larger influence on the U.S. bond and stock market volatility compared with target surprises.

[10]The derived path surprise may be distorted by the term premium investors usually demand to hold government bonds. However, it is reasonable that the term premia demanded on shorter-maturity bonds are relatively small in magnitude and remain broadly unchanged on an intraday basis. As a result, the bulk of the five-minute changes in near-term forward rates surrounding monetary policy decisions should accurately capture investors' revisions in future monetary policy path and, to a lesser extent, revisions in the term premia they demand.

Table 4. Regression Results

Dependent Variable $\Delta Volratio_{t-30,t}$	Constant	$Abs(TS)$	$Abs(PS)$	R2	Corr ($Abs(TS)$, $Abs(PS)$)
German Bond	−0.34*	0.22***	0.29	0.38	0.56
Markets	(0.18)	(0.09)	(0.24)		
Euro-Area Stock	−0.64***	0.06*	0.90***	0.38	0.56
Markets	(0.13)	(0.04)	(0.12)		
U.S. Bond	1.25*	−0.10	0.77***	0.40	0.10
Markets	(0.70)	(0.09)	(0.20)		
U.S. Stock	0.82	−0.05	0.43**	0.20	0.10
Markets	(0.68)	(0.06)	(0.21)		

Notes: The regression specifications are $\Delta Volratio_{t-30,t} = \alpha_{1,t} + \beta_1 * Abs(TS) + \beta_2 * Abs(PS) + \varepsilon_t$ for the four asset classes, respectively. $\Delta Volratio$ represents the changes in the volatility ratio (thirty minutes before and five minutes after the monetary policy decisions) between observed volatility on monetary policy events and volatility on non-announcement days. $Abs(TS)$ and $Abs(PS)$ correspond to the absolute values of the target and the path surprises, respectively. Newey-West heteroskedasticity-consistent standard errors are in parentheses. *, **, and *** denote significance at the 10, 5, and 1 percent levels, respectively.

One potential problem with the equation (3) regression specification could be presence of multicollinearity between the explanatory variables. However, the classic symptoms of multicollinearity, such as (i) high R2 and few significant t-ratios and (ii) high pairwise correlations between the regressors, cannot be detected. This suggests that it should be possible to isolate the individual impact that the target and the path surprises have on financial market prices.

4.4 Impact of Monetary Policy Surprises on Intraday Financial Market Volatility, Conditional on Whether Policy Rates Have Been Altered or Not

One possible source for the different reaction patterns between the two economies could be that the markets react differently depending on whether monetary policy rates are changed or not. In this regard, monetary policy moves usually take place when market uncertainty can be expected to be higher than normal, such as risks of very

low inflation or outright deflation,[11] or when there is uncertainty regarding an expected future strengthening of economic activity.[12] Furthermore, some interest rate moves take place during extreme market conditions. One example was the joint interest rate reduction of 50 basis points by the ECB and the Federal Reserve in the aftermath of the September 11 terrorist attack. Using daily data, Wilhelmsen and Zaghini (2005) find less predictability—the latter measured as the standard deviation in money market rates—when a modification in the official policy rate is decided on, compared with days when the monetary policy authority does not change the official rate. This pattern holds true for all fourteen economies included in their study.

Figures 6A–6D decompose the volatility pattern between monetary policy events when policy rates are adjusted and when they remained unchanged. As seen in figures 6A and 6B, the elevated volatility in euro-area stock and bond markets during monetary policy announcements seems to be related to the periods when the ECB decided to change rates. In contrast, monetary policy decisions by the Federal Reserve induce elevated stock and bond market volatility independent of the outcome (see figures 6C and 6D).

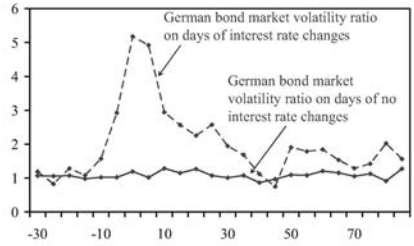
One possible explanation for the different pattern of behavior across the two markets can be related to an asymmetry in the monetary policy surprises, i.e., that they are higher in magnitude when the ECB changes rates compared with no change events. Table 5 summarizes the mean and the standard deviation of the surprises conditional on whether rates have been altered or not. Overall, the mean

[11] An example of this was the 25-basis-point rate reduction by the Federal Reserve in June 2003. The accompanying statement justified the decision: "The Committee perceives that the upside and downside risks to the attainment of sustainable growth for the next few quarters are roughly equal. In contrast, the probability, though minor, of an unwelcome substantial fall in inflation exceeds that of a pickup in inflation from its already low level."

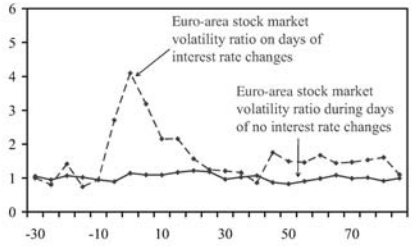
[12] An example of this was the increase of 25 basis points by the ECB in December 2005. The accompanying introductory statement explained why: "On the basis of our regular economic and monetary analyses, we have decided to increase the key ECB interest rates by 25 basis points, after two and a half years of maintaining rates at historically low levels. Looking ahead, on the external side, ongoing growth in global demand should support euro area exports, while on the domestic side, investment should benefit from continued favourable financing conditions and the robust growth of corporate earnings."

Figure 6. Volatility Ratios on Days with and Days without Changes in Monetary Policy Rates

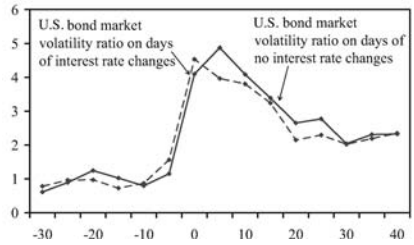
A. German Bond Markets (30 minutes before to 85 minutes after the decisions)



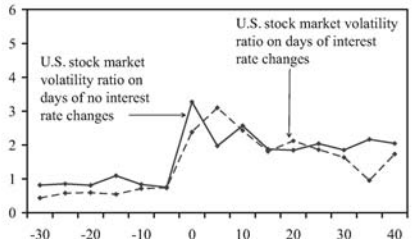
B. Euro-Area Stock Markets (30 minutes before to 85 minutes after the decisions)



C. U.S. Long-Term Bond Markets (30 minutes before to 40 minutes after the decisions)



D. U.S. Stock Markets (30 minutes before to 40 minutes after the decisions)



of the (absolute) surprises is somewhat higher in both economies (and for both categories of surprises) when rates were changed compared with those meetings when they remained unchanged. However, the difference is particularly pronounced for the computed target surprise of the ECB, which could partly explain why asset-price volatility in the euro area is higher when policy rates are adjusted compared with periods when policy rates are left unchanged.

To examine the asymmetric issue further, a slight modification of the regression setup in equation (3) is used:

$$\Delta Volratio_{t-30,t+5} = \alpha_1 + \alpha_2 D + \beta_{1,t} X + \beta_{2,t} DX + \varepsilon_t, \qquad (4)$$

where D is a dummy variable which takes on a value of 1 when interest rates are changed, and a value of 0 if they are unchanged. The matrix X corresponds to the independent variables (i.e., the

Table 5. Summary Statistics of the Monetary Policy Surprises

	ECB		Federal Reserve	
	Target Surprise	**Path Surprise**	**Target Surprise**	**Path Surprise**
Mean of the Absolute Surprises				
Total Sample	3.0	1.0	2.5	3.4
When Rates Were Left Unchanged	1.5	0.6	0.6	2.8
When Rates Were Changed	13.0	1.4	4.0	4.0
Standard Deviation of the Absolute Surprises				
Total Sample	5.6	1.4	5.6	3.2
When Rates Were Left Unchanged	3.2	0.5	1.0	2.6
When Rates Were Changed	7.7	1.9	7.1	3.5

absolute values of the target and path surprises). Equation (4) has the following implications:

Mean volatility when $D = 0$ (i.e., monetary policy rates are unchanged):

$$E(\Delta Volratio|D = 0, X) = \alpha_1 + \beta_1 X. \tag{5}$$

Mean volatility when $D = 1$ (i.e., monetary policy rates are altered):

$$E(\Delta Volratio|D = 1, X) = (\alpha_1 + \alpha_2) + (\beta_1 + \beta_2)X. \tag{6}$$

Four different possibilities can be tested using this setup:

(i) $\alpha_1 = \alpha_2$ and/or $\beta_1 = \beta_2$; the two regressions are the same.

(ii) $\alpha_1 \neq \alpha_2$ and/or $\beta_1 = \beta_2$; the two regressions differ in the intercept.

Table 6. Regression Results Conditional on Altered Monetary Policy Rates

Dependent Variable $\Delta Volratio_{t-30,t}$	Constant	Constant $\lvert D=1$	$Abs(TS)$	$Abs(TS)$ $\lvert D=1$	$Abs(PS)$	$Abs(PS)$ $\lvert D=1$
German Bond	0.00	−0.36	0.09*	0.25**		
Markets	(0.15)	(1.58)	(0.05)	(0.11)		
Euro-Area Stock	−0.39**	0.29	0.03	0.00	0.56***	0.43*
Markets	(0.19)	(1.00)	(0.06)	(0.08)	(0.20)	(0.26)
U.S. Bond	1.83	−1.40			0.60***	0.24
Markets	(1.14)	(1.35)			(0.22)	(0.34)
U.S. Stock	0.81	−0.40			0.59***	−0.20
Markets	(0.88)	(0.99)			(0.19)	(0.19)

Notes: The regression specification follows the one specified in equation (4) to test whether price sensitivity differs during periods when the central banks change policy rates. Newey-West heteroskedasticity-consistent standard errors are in parentheses. *, **, and *** denote significance at the 10, 5, and 1 percent levels, respectively.

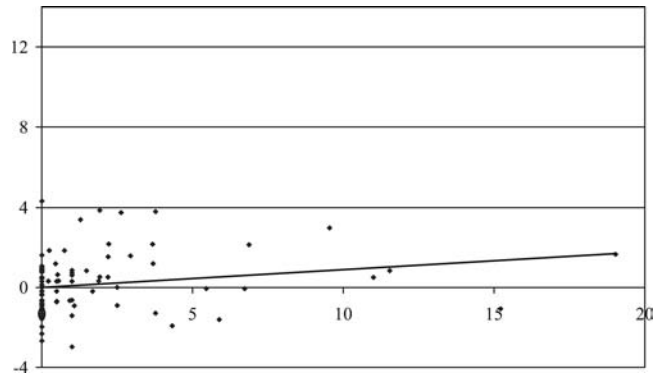
(iii) $\alpha_1 = \alpha_2$ and/or $\beta_1 \neq \beta_2$; the two regressions have the same intercept but different slopes.

(iv) $\alpha_1 \neq \alpha_2$ and/or $\beta_1 \neq \beta_2$; the two regressions have different intercepts and different slopes.

Thus, a significantly positive α_2 coefficient suggests that volatility on average is higher when monetary policy rates are altered compared with periods when rates are left unchanged. In the same vein, a significant positive coefficient of β_2 implies stronger asset-price sensitivity when monetary policy rates are altered compared with periods when rates are left unchanged. Of particular interest is to test the significance of α_2 and/or β_2 for the German bond markets and the euro-area stock markets. This could shed further light on the factors driving the elevated volatility following alterations of the ECB's monetary policy rates, as shown in figure 6. Table 6 outlines the results of the regressions after dropping the non-significant variables from equation (3).

The table reveals that asset-price sensitivity is not linear for the German bond markets and the euro-area stock markets. Instead, the volatility pattern is different depending on if policy rates have been

Figure 7. Changes in German Bond Volatility Ratio (y-axis) and the ECB Monetary Policy Target Surprise (x-axis): Sample Includes Only Observations when the ECB Left Monetary Policy Rates *Unchanged* (April 1999–May 2006)



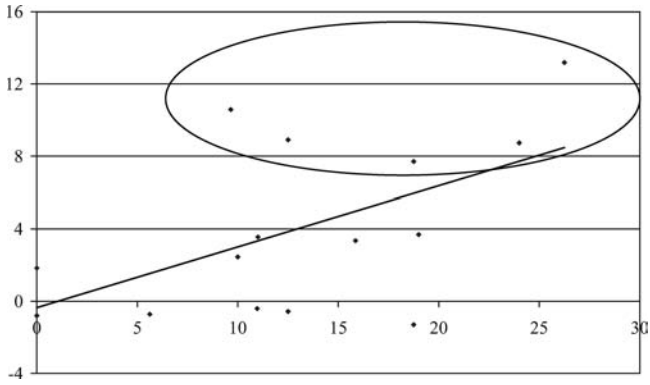
altered or not. For the German bond market, the null hypothesis of equal slope coefficient can be rejected at the 5 percent level. For the euro-area stock markets, the null hypothesis of equal slope coefficient can be also be rejected, but only at the 10 percent level. As regards the United States, no differences in the asset-price reaction following either scenario can be detected.

Figures 7 and 8 illustrate the differences in asset-price pattern for the German bond market volatility ratio by scatter-plotting the volatility ratios against the target surprises. The figures suggest that intraday volatility tends to be of larger magnitude (see figure 8) when interest rates are changed than when they are not changed (see figure 7), even when the surprises are of the same magnitudes. Comments from the financial press after the interest rate decisions highlighted in figure 8 seem to suggest that the interest rate decisions took the markets by surprise during these occasions; see table 7.

5. Concluding Remarks

Monetary policy decisions and the expected path of future policy rates strongly influence asset prices. Among the worlds' leading central banks, monetary policy actions by the Federal Reserve and the

Figure 8. Changes in German Bond Volatility Ratio (y-axis) and the ECB Monetary Policy Target Surprise (x-axis): Sample Includes Only Observations when the ECB *Altered* Monetary Policy Rates (April 1999–May 2006)



ECB are particularly monitored among investors, as they control short-term interest rates in the two major economies. This paper tries to shed some light on the link between monetary policy decisions and asset-price reactions. Using long-time series of intraday data, U.S. and euro-area bond and stock market intraday volatility patterns surrounding monetary policy decisions by the two central banks are derived. Overall, both the ECB and the Federal Reserve decisions induce an upsurge in intraday volatility on their respective bond and stock markets. The reactions of U.S. financial markets following the Federal Reserve's decisions are more pronounced compared with the reaction the ECB exerts on the German bond markets and the euro-area stock markets. Although this paper provides some tentative explanations that partly explain this discrepancy between the two markets, their decoupling patterns still remain a puzzle.

As a next step, monetary policy target and path surprises are used as explanatory variables when explaining these upsurges in volatility. Monetary policy surprises are suitable candidates for this purpose, as only new news should in theory affect asset prices. The paper finds that monetary policy target surprises by the ECB significantly induce higher than normal volatility in the German bond

Table 7. Financial Market Comments to ECB Monetary Policy Decisions

Date	Interest Rate Move	Target Surprise	Comment
June 8, 2000	+50 bp	26.25	*Financial Times* (June 9, 2000): "The ECB rate rise demonstrated the bank is not afraid of making decisions that surprise the markets. . . . Most investors expected rates to go up by 25 basis points and did not price in a 50 basis points rise. . . . German 10-year bund prices advanced despite the surprisingly aggressive rise in interest rates while the short-dated bonds sold off."
May 10, 2001	−25 bp	−24	*Financial Times* (May 11, 2001): "Interest rates fall across Europe. . . . Markets were stunned by the ECB's 0.25 percentage point reduction in its main interest rate to 4.5 per cent. It was the ECB's first cut for more than two years and caught investors unprepared."
Oct. 5, 2000	+25 bp	18.75	*Financial Times* (October 6, 2000): "The biggest surprise in the government bond markets yesterday was the European Central Bank's decision to raise interest rates by 25 basis points to 4.75 per cent, with prices on government bonds falling in response. . . . After the initial shock wore off, bond prices recovered."

(continued)

Table 7. (Continued)

Date	Interest Rate Move	Target Surprise	Comment
March 6, 2003	−25 bp	12.5	*Financial Times* (March 7, 2003): "Short-dated eurozone government bond prices recovered their early losses yesterday, despite the European Central Bank's decision to lower interest rates by a quarter rather than a half point. The ECB cut rates to 2.5 per cent, but comments by Wim Duisenberg, ECB president, suggested further easing was on the cards."
Dec. 5, 2002	−50 bp	−9.6	*Financial Times* (December 6, 2002): "European government bond trading was dominated yesterday by interest rate decisions, notably the European Central Bank's half-point cut to 2.75 per cent. . . . Eurozone bonds initially rose on the ECB's announcement of its first reduction in rates for more than a year."

markets. In addition, path surprises by the Federal Reserve have, on average, a larger influence on U.S. bond and stock market volatility compared with target surprises.

When decomposing the asset-price reaction based on whether monetary policy rates have been altered or not, the level of intraday volatility of the German bond markets and the euro-area stock markets is found to be higher when interest rates are changed. This can probably be linked to two factors. First, monetary policy surprises are, on average, of a larger magnitude when the ECB decides to

change rates compared with meetings which resulted in no change. Second, there is a non-linear asset volatility price sensitivity—which is particularly pronounced for the German bond markets—in that bond markets react significantly stronger to a given target surprise by the ECB when there has been a change in the official rate compared with periods when the policy rates have not been altered.

Building on this study, a key direction for future research would be to find further evidence of factors that could explain the pronounced asset-price reaction in the U.S. financial markets following interest rate decisions by the Federal Reserve, compared with the more muted feedback on euro-area asset prices surrounding the ECB's monetary policy decisions.

Appendix

The volatility measure used as the dependent variable in regressions (3) and (4) is defined as the ratio between volatility on monetary policy days and volatility on the same weekdays and hours but when no monetary policy decisions are taking place. More specifically, let $k = 1, 2 \ldots K$ be the days of monetary policy decisions and $d = 1, 2 \ldots D$ be the same weekdays, but when no monetary policy decisions are taking place. The intraday change in the volatility ratio for asset i on a monetary policy decision day k is then calculated as

$$\Delta Volratio^{i,k}_{t-30,t} = \left(\frac{abs(R^{i,k}_{t=0})}{\frac{1}{D}\sum_{d=1}^{D} abs(R^{i,d}_{t=0})} - \frac{abs(R^{i,k}_{t=-30})}{\frac{1}{D}\sum_{d=1}^{D} abs(R^{i,d}_{t=-30})} \right).$$

R represents the five-minute log-return.

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