

Hussain, Syed Mujahid

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Simultaneous monetary policy announcements and international stock markets response: an intraday analysis

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Syed Mujahid Hussain

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an intraday analysis**



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**Suomen Pankki
Bank of Finland
PO Box 160
FI-00101 HELSINKI
Finland
☎ +358 10 8311**

**<http://www.bof.fi>
E-mail: Research@bof.fi**



Syed Mujahid Hussain*

Simultaneous monetary policy announcements and international stock markets response: an intraday analysis

The views expressed in this paper are those of the author and do not necessarily reflect the views of the Bank of Finland.

* Correspondence to Department of Finance and Statistics, Hanken School of Economics, PO Box 479, 00101 Helsinki, Finland. Email: syed.mujahid@hanken.fi

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Syed Mujahid Hussain
Monetary Policy and Research Department

Abstract

This paper investigates the return and volatility responses of major European and the US equity indices to monetary policy surprises using extensive intraday data on 5-minute price quotes along with a comprehensive dataset on monetary policy decisions and macroeconomic news. Our results show that monetary policy decisions generally exert an immediate and significant influence on stock index returns and volatilities in both European and US markets. Our findings also indicate that European Central Bank's (ECB) press conferences following monetary policy decisions on the same day have significant impacts on European index return volatilities, implying that they convey important information to market participants. However, in contrast to some earlier evidence, we do not find any support for the hypothesis that return volatilities in European and US markets are significantly affected by the path surprises. Overall, our analysis suggests that the use of high frequency data is critical for separating the effects of monetary policy actions from those of macroeconomic news announcements on stock index returns and volatilities.

Keywords: conditional mean, conditional volatility, macroeconomic news, monetary policy, high frequency data

JEL classification numbers: G14, G15

Uutisoitujen rahapoliittisten päätösten vaikutukset kansainvälisten osakemarkkinoiden päivänsisäiseen vaihteluun

Suomen Pankin keskustelualoitteita 8/2010

Syed Mujahid Hussain
Rahapolitiikka- ja tutkimusosasto

Tiivistelmä

Tässä tutkimuksessa tarkastellaan markkinat yllättävien rahapoliittisten toimenpiteiden vaikutuksia osakemarkkinoiden tuottoihin ja hintojen vaihteluun Euroopassa ja Yhdysvalloissa. Vaikutusten mittaamisessa käytetään viiden minuutin välein poimittuja hintahavaintoja Yhdysvaltain ja Euroopan suurista arvopaperipörseistä sekä kattavaa rahapoliittisista päätöksistä ja kokonaistaloudellisista uutisista koostuvaa havainto-aineistoa. Empiiristen tutkimustulosten mukaan rahapoliittisia toimenpiteitä koskevilla päätöksillä on suoria ja selvästi erottuvia vaikutuksia osakemarkkinaindeksistä laskettuihin tuottoihin Euroopassa ja Yhdysvalloissa. Tulokset viittaavat myös siihen, että EKP:n neuvoston kokousta seuraava lehdistötilaisuus vaikuttaa selvästi saman päivän osakemarkkinaindeksistä laskettujen tuottojen vaihteluun Euroopassa. Neuvoston rahapoliittisten päätösten julkistaminen sisältää siis arvokasta informaatiota osakemarkkinoiden toimijoille. Tutkimustulokset eivät kuitenkaan tue aiemmissa tutkimuksissakin esitettyä käsitystä, että tulevaa rahapolitiikan linjaa koskevat markkinoiden odotuksiin nähden yllättävät uutiset vaikuttaisivat merkittävästi osakemarkkinoiden tuottojen vaihteluihin Euroopassa ja Yhdysvalloissa. Tästä tutkimuksesta voidaan lisäksi päätellä, että tiheään poimitut osakemarkkinoiden hintahavainnot ovat kriittisen tärkeitä, kun tavoitteena on erottaa rahapoliittisten toimenpiteiden vaikutukset muista kokonaistaloudellisten uutisten vaikutuksista osakemarkkinaindeksistä laskettuihin tuottoihin ja niiden vaihteluihin.

Avainsanat: ehdollinen odotusarvo, ehdollinen volatiliteetti, kokonaistaloudelliset uutiset, rahapolitiikka, tiheään poimitut havainnot

JEL-luokittelu: G14, G15

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1 Introduction

The objective of this paper is to investigate the effects of monetary policy actions on major European (France, Germany, Switzerland and UK) and the US stock index returns and volatilities utilizing high frequency 5-minute observations along with extensive dataset on monetary and macroeconomic news announcements.

There are several channels through which monetary policy announcements may affect equity prices. First, monetary policy decisions simultaneously affect many firms' cash flows and may influence the risk-adjusted discount rate. Second, these announcements may also convey information about future economic activity and thus, act as a signal. Finally monetary policy decisions may lead to change in equity prices through portfolio adjustments in multiple markets.

Traditionally many papers studying the effects of monetary policy announcements on asset prices have relied on lower frequency observations.¹ However, an important issue that arises when measuring the effect of monetary policy on equity markets is that changes in interest rates can coincide with changes in business cycle conditions and other relevant economic variables. It is therefore not clear whether the effect attributed to monetary policy in those papers reflects other factors. Moreover, as argued by Rigobon and Sack (2004), the relation between equity prices and interest rates can be causal, and not accounting for endogeneity may cause a significant bias in empirical estimation of the reaction of equity returns to monetary policy.²

Another important issue that arises when measuring the effect of monetary policy on equity indices is the correct proxy of monetary policy. Typically, event studies have relied on monetary policy changes that are simply measured as changes of policy rates on days of monetary policy decisions.³ However, Kuttner (2001) convincingly shows that markets generally react to the unexpected component of the monetary policy announcement, which is consistent with the efficient markets hypothesis that asset prices should only react to new information. Moreover, Gürkaynak, Sack and Swanson (2005) argue that monetary policy surprises contain more than just a surprise to the announced target rate. They demonstrate that two factors are needed to capture monetary policy surprises; the target and the path surprise. The target surprise is defined as the degree to which market participants have been able to predict the actual monetary policy decisions. The path surprise reflects news that market

¹ See for example, Bredin et al (2003, 2007), Conover, Jensen and Johnson (1999), and Ehrmann and Fratzschr (2004), among others.

² Rigobon and Sack (2004) deal with the potential endogeneity of policy issues, ie, the effects of equity price movements on interest rates, and the effect arising from the implied aggregate demand also affects equity prices. This causality may cause endogeneity bias in empirical estimation.

³ See for example, Bomfim (2003) and Durham (2003). Moreover, Rigobon and Sack (2004) argue that event study approach may give biased estimates.

participants have learned from the monetary policy statements about the future path of policy in addition to what they have learned about the level of target rate.

Fewer papers so far have investigated the response of equity prices to monetary policy actions using high frequency data. Among the earlier papers based on intraday observations, Farka (2009) reports a significant impact of monetary policy shocks on the level and volatility of stock returns in the US. Utilizing Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model, author also reports that the response of conditional volatility depends on the type and timing of the policy shocks. Andersson (2007) examines bond and stock market volatility reactions in the euro area and the US following their respective economies' monetary policy decisions.⁴ He finds a strong upsurge in intraday volatility at the release of the monetary policy decisions by two central banks. Moreover, his results also indicate a significant increase in stock index volatility in connection with target and path surprises. Wongswan (2005) studies the impact of US monetary policy surprises on equity indices in sixteen countries. The author finds that the US and most of the foreign equity indices react only to surprise changes in the current target rate by FOMC, not to path surprises. However, his analysis is limited to measure the effect of FOMC monetary policy surprises on the US and foreign stock markets.

This paper contributes to the existing literature in many ways. First, it utilizes extensive data on 5-minute price quotes from major European and the US equity indices along with a comprehensive set of monetary and macroeconomic news announcements. Our dataset allows us to measure the precise effect of monetary policy actions on stock index returns and volatilities.⁵ Second, this paper explicitly measures the effect of ECB press conference on European markets volatilities, which, to our knowledge, not has been addresses in earlier research.⁶ Moreover, following Gürkaynak, Sack and Swanson (2005), we also check the return and volatility response to both the target and the path surprise of the monetary policy decisions. Finally, drawing on the methodology proposed by Andersen et al (2003), our robust estimation procedure takes into account strong intraday seasonalities typically found in volatility of financial markets. These

⁴ Author employs high frequency data on STOXX50 as a representative index for the Euro area.

⁵ This setting particularly facilitates measuring the effect of European monetary policy decisions on European stock indices since they share same trading hours, implying that various different economic news from European markets may potentially affect equity prices during a trading day. Thus, utilizing high frequency data enables us to separate the effects of monetary policy actions from those of other macroeconomic variables on the stock index returns and volatilities. Moreover, the use of such data also reduces the problems of endogeneity and omitted variable bias.

⁶ The monetary policy announcements by the European Central Bank (ECB) at 13:45 Central European Time (CET) are typically followed by a press conference where President of the ECB comments on the considerations underlying monetary policy decisions and gives his views on general economic outlook at 14:30 Central European Time (CET). Since, timing of the ECB press conference coincides with key US macroeconomic announcements, it is important to isolate the effect of ECB press conference from those of US macroeconomic news announcements.

seasonalities have important implications for modeling volatility of high frequency data. Andersen and Bollerslev (1997, 1998) argue that standard time series models of volatility fail to capture strong intraday seasonalities when applied to high frequency return data. Overall, this paper presents fresh empirical evidence on the precise effect of monetary policy surprises on major European and the US stock indices.

The main results of this paper are as follows: First, monetary policy decisions generally exert significant influence on stock index returns and volatilities in both European and the US markets. Moreover, the response of the stock indices to monetary policy actions is usually swift and fades away quickly within 5–10 minutes after the announcements. Second, our results show that European stock index volatilities are significantly influenced by the European Central Bank's (ECB) press conference that is held 45 minutes after the monetary policy decisions on the same day, implying that it contains important information for market participants. However, in contrast with some earlier evidence, our results suggest that dividing the monetary policy surprises into two components; target and path surprises does not yield any significant results as the European and the US markets do not generally respond to path surprises. Overall, our analysis suggests that the use of high frequency data is critical to separate the effect of monetary policy actions from those of macroeconomic news announcements on the stock index returns and volatilities.

The strategy for this paper is twofold. First, a descriptive analysis is carried out of the volatility behaviour to determine the extent to which intraday seasonalities could be explained by the monetary policy surprises. Second, a robust estimation procedure is specified to test the effect of monetary policy surprises on stock indices. The rest of the paper is structured as follows: The data are described in section two. A descriptive framework is outlined in section three. The methodology is presented in section four. The empirical findings are reported in section five, and a summary and conclusions follow in section six.

2 Data

The primary data set consists of 5-minute price quotes on five major equity indices from September 1, 2000 through September 30, 2008. The four European stock markets; Germany, France, Switzerland and the UK have same opening time for auctions, ie 09:00 Central European Time (CET)⁷, whereas the closing times vary. Continuous trading ends at 17:20 for the Swiss market and ten minutes later for the other markets. The US market opens at 15:30 CET and trading

⁷ Hereafter, all times are given in Central European time (CET).

continues until 22:00 CET. After filtering the data for outliers and other anomalies (such as September 11–12, 2001) and observations influenced by brief lapses in the Reuters data feed, the continuously compounded returns are calculated as $R_{i,t} = 100 \times \log(P_{i,t}/P_{i,t-1})$, where $P_{i,t}$ represents the price level on market i at time t . Summary statistics for 5-minute intraday returns are presented in Table 1. Mean returns for all markets, which were virtually zero, are dwarfed by their standard deviations, the most volatile market being CAC40. Judged by auxiliary statistics, such as sample minimum and maximum of -7.18 and 7.80 (DAX30), the existence of jumps is evident. These minima and maxima were 25–50 times greater than their respective standard deviations. Assuming normality, the probability of such extreme values is practically zero.

The French equity market index displays evidence of significant negative first order autocorrelation (-0.12), typically attributed to market microstructure effects. The high first order autocorrelation coefficient of the absolute returns implies that the volatility of the 5-minute returns exhibits volatility clustering.

Table 1. **Summary statistics for intraday 5-minute returns**

	CAC40	DAX30	FTSE100	SMI	SP500
Mean	-0.0003	-0.0001	-0.0002	-0.0001	-0.0002
Median	0.0000	0.0002	0.0000	0.0000	0.0000
Maximum	5.2804	7.8015	3.6521	6.0515	3.9173
Minimum	-6.5391	-7.1862	-4.3593	-4.6689	-5.3686
Std. Dev.	0.1635	0.1536	0.1050	0.1175	0.1197
Skewness	-0.2773	0.3024	-0.5718	0.6307	-0.5056
Kurtosis	82.6737	143.2605	102.0392	178.8012	100.7855
AC(1) Return	-0.1190	-0.0040	0.0420	-0.0030	0.0370
AC(1) Absolute Returns	0.2980	0.2390	0.2610	0.2260	0.2100
Observations	199511	205529	201653	198899	149369

Note: This Table reports summary statistics for intraday 5-minute returns from September 1, 2000 through September 30, 2008 for major European and the US stock indices, namely CAC40 of France, DAX30 of Germany, FTSE100 of UK, SMI of Switzerland, and SP500 of the US. AC (1) is the autocorrelation coefficient at first lag.

2.1 Monetary and macroeconomic announcements

The announcement data consist of monetary policy and macroeconomic news announcements for the period September 1, 2000 through September 30, 2008. The monetary policy announcements from European Central Bank (ECB), Bank of England (BOE), Swiss National Bank (SNB) and Federal open market committee (FOMC) are collected from Bloomberg world Economic Calendar (WECO). Furthermore, the major macroeconomic news announcements are also

obtained from Bloomberg for the US and respective European countries. These data contain date, time, actual release and the mean forecast for the indicator.

The European Central Bank (ECB) reveals its monetary policy decisions at 13:45 CET followed by a press conference at 14:30. While the Bank of England (BOE) and Swiss National Bank (SNB) make their monetary policy decisions public at 13:00 and 14:00 CET, respectively. Federal open market committee meeting (FOMC) releases its monetary policy decisions at 20:15 CET. Furthermore, major US macroeconomic news announcements are made at 14:30 CET which coincide with ECB press conference.⁸

Table 2 presents descriptive statistics for monetary policy surprises for ECB, BOE, SNB and FOMC.⁹ Average surprise is negative for ECB (though seen with a positive sign), implying a bigger change in interest rates than anticipated by the market, while BOE, SNB and FOMC display higher value of mean expectation compared to the actual announcement, implying a positive surprise (with a negative sign). The ECB announcements were in most cases similar to the mean forecast (71%). While, in case of BOE and FOMC, approximately half of the actual monetary policy decisions were predicted in advance.

Table 2. **Descriptive statistics for monetary policy surprises**

	ECB	BOE	SNB	FOMC
Mean	0.008	-0.005	-0.008	-0.021
Maximum	0.250	0.250	0.100	0.127
Minimum	-0.250	-0.250	-0.120	-0.500
Std. Dev.	0.058	0.116	0.045	0.100
Non-zeros	31	42	7	35
Observations	108	87	17	69

Note: This table reports descriptive statistics for monetary policy surprises (Actual announcement – mean expectation) from European Central Bank (ECB), Bank of England (BOE), Swiss National Bank (SNB), and Federal Open Market Committee (FOMC).

Following Balduzzi, Elton and Green (2001), we use standardized surprise for our estimation procedure. That is, we divide the surprise by its sample standard deviation to facilitate interpretation. The standardized news associated with indicator k at time t is

⁸ The selected thirteen US macroeconomic releases at 14:30 CET are: Advanced Durable Goods; Consumer Price Index; Housing Starts; Personal Income; Producer Price Index; Real GDP; Retail Sales; Trade Balance; Unemployment rate; Personal Spending; Initial Jobless Claims; Import Price Index and Nonfarm, Productivity.

⁹ Surprises are defined as the difference between the actual monetary policy announcements and the mean expectations from the analyst's surveys that are collected from Bloomberg.

$$S_{k,t} = \frac{A_{k,t} - E_{k,t}}{\hat{\sigma}_k} \quad (2.1)$$

where $A_{k,t}$ is the announced value of indicator k , $E_{k,t}$ is the market expected value of indicator and $\hat{\sigma}_k$ is the sample standard deviation of each indicator's surprise element, $A_{k,t} - E_{k,t}$. The use of standardized news facilitates meaningful comparisons of responses of different indices to different pieces of news. The standardization affects neither the statistical significance nor the fit of the regression, because $\hat{\sigma}_k$ is constant for any indicator k , and we estimate responses by regressing stock index returns and volatilities on standardized surprises.

Table 3 presents summary of simultaneous announcement dates which serves as the basis for our further analysis. As shown in Table 3, about 40% of the ECB monetary policy announcement dates coincide with US macroeconomic releases at 14:30, which also happens to be the time of ECB press conference followed by the monetary policy decisions at 13:45 CET.¹⁰ This makes it difficult to segregate the effect of the ECB press conference on European stock return volatilities from that of US macroeconomic announcements at 14:30 CET. Furthermore, about 28% of the ECB monetary policy announcement dates coincide with US macroeconomic releases at 16:00.¹¹

Table 3. **Simultaneous announcements dates**

ECB Dates that coincide with US 1430 macroeconomic Announcement dates	42
ECB Dates that coincide with US 1600 macroeconomic Announcement dates	30
ECB Dates that coincide with Bank of England monetary policy announcement dates	58
ECB Dates that coincide with German macroeconomic announcement dates	39
ECB Dates that coincide with UK macroeconomic announcement dates	44
ECB Dates that coincide with Swiss macroeconomic announcements	23
BOE Dates that coincide with UK macroeconomic announcement dates	15
FOMC Dates that coincide with US macroeconomic announcement dates	23

Note: This table reports monetary policy announcement dates of European Central Bank (ECB), Bank of England (BOE), and Federal Open Market Committee (FOMC) that coincide with other monetary policy and macroeconomic variables.

Another important observation from Table 3 is that approximately 54% of the ECB monetary policy announcement dates correspond to the similar announcements by the Bank of England (BOE). Moreover, sizeable ECB monetary policy announcement dates also coincide with German and UK macroeconomic announcements. Similarly, as shown in Table 3, considerable

¹⁰ The total numbers of monetary policy announcements during our sample period are: ECB; 108, BOE; 87, SNB; 17, and FOMC; 69.

¹¹ The selected nine US macroeconomic releases at 16:00 CET are: Index of Leading Indicators; ISM-Index Manufacturing; ISM-Index Services; House Price Index; Existing Home Sales; New Home Sales; Factory Orders; Consumer Confidence; Business Inventories.

number of BOE and FOMC monetary policy decisions corresponds to their respective macroeconomic releases. Therefore, it is not clear whether the effect attributed to monetary policy announcements in earlier studies that have relied on low frequency observation such as daily data reflects other factors. These descriptive analyses highlight the importance of using high frequency and longer span of data in order to measure the precise effect of monetary policy announcements on stock indices.

3 Descriptive analysis of announcements effect

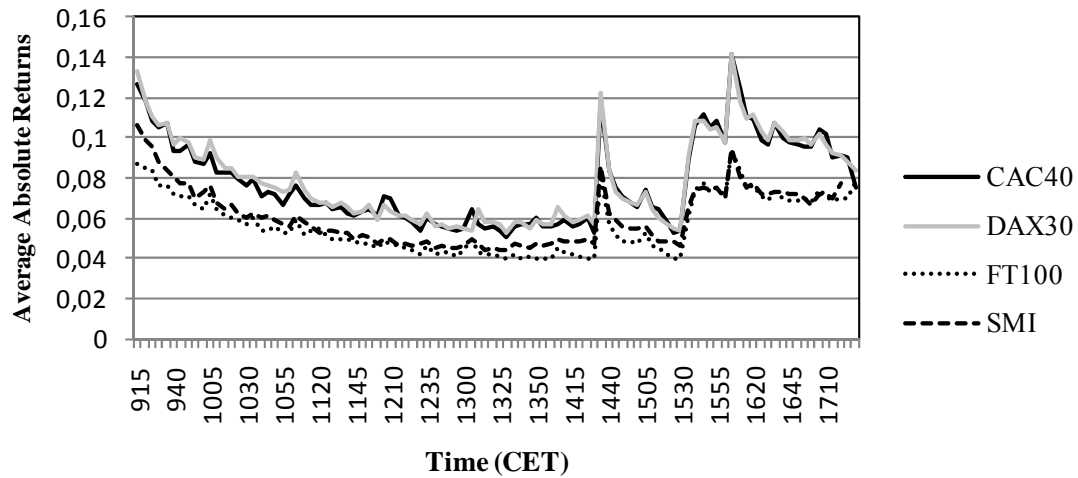
We start our analysis by plotting the average absolute returns for each 5 minute period across all the trading days in our sample. Figures 1a and 1b display the intraday average volatility for European and the US equity indices respectively for each 5-minute interval.¹² In Figure 1a, the periodic pattern across all European markets demonstrates remarkable similarities. European stock markets exhibit a decaying pattern of volatility until 14:30 CET before they escalate at 14:35, which could potentially be caused either by the US macroeconomic news announcements or the ECB press conference at 14:30 CET. However, interestingly, Figure 1a does not apparently show any major response of the European intraday volatilities to any of the monetary policy announcements by ECB at 13:50, BOE at 13:05 or SNB at 14:05 CET.

Intraday average volatility for SP500 index is shown in Figure 1b. Contrary to what is seen in Figure 1a, the intraday volatility for SP500 follows the somewhat usual reverse J-shaped pattern that is typically observed in financial markets.¹³ However, the US stock index does not either seem to show any major response of the intraday average volatility to monetary policy announcements by FOMC at 20:20 CET.

¹² First two 5-minute intervals (opening) have been left out in order to avoid over night returns and stale quotes.

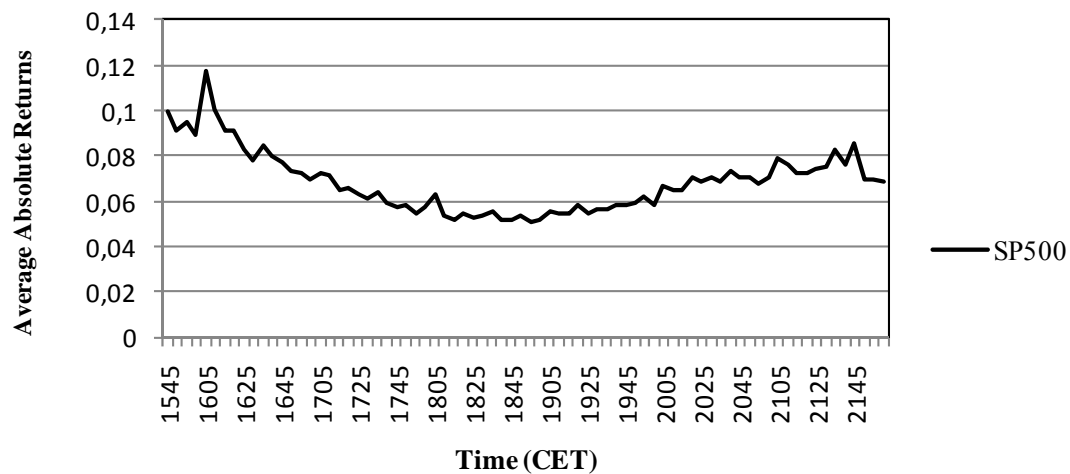
¹³ Among others, Wood et al (1985) and Harris (1986) have documented reverse J-shaped pattern of intraday volatility for financial markets.

Figure 1a.

Intraday average volatility classified by time

Note: This figure reports the 5-minute average absolute returns for four European indices, namely CAC40 of France, DAX30 of Germany, FT100 of UK and SMI of Switzerland. These averages are calculated for each 5-minute period across all trading days in our sample for respective markets.

Figure 1b.

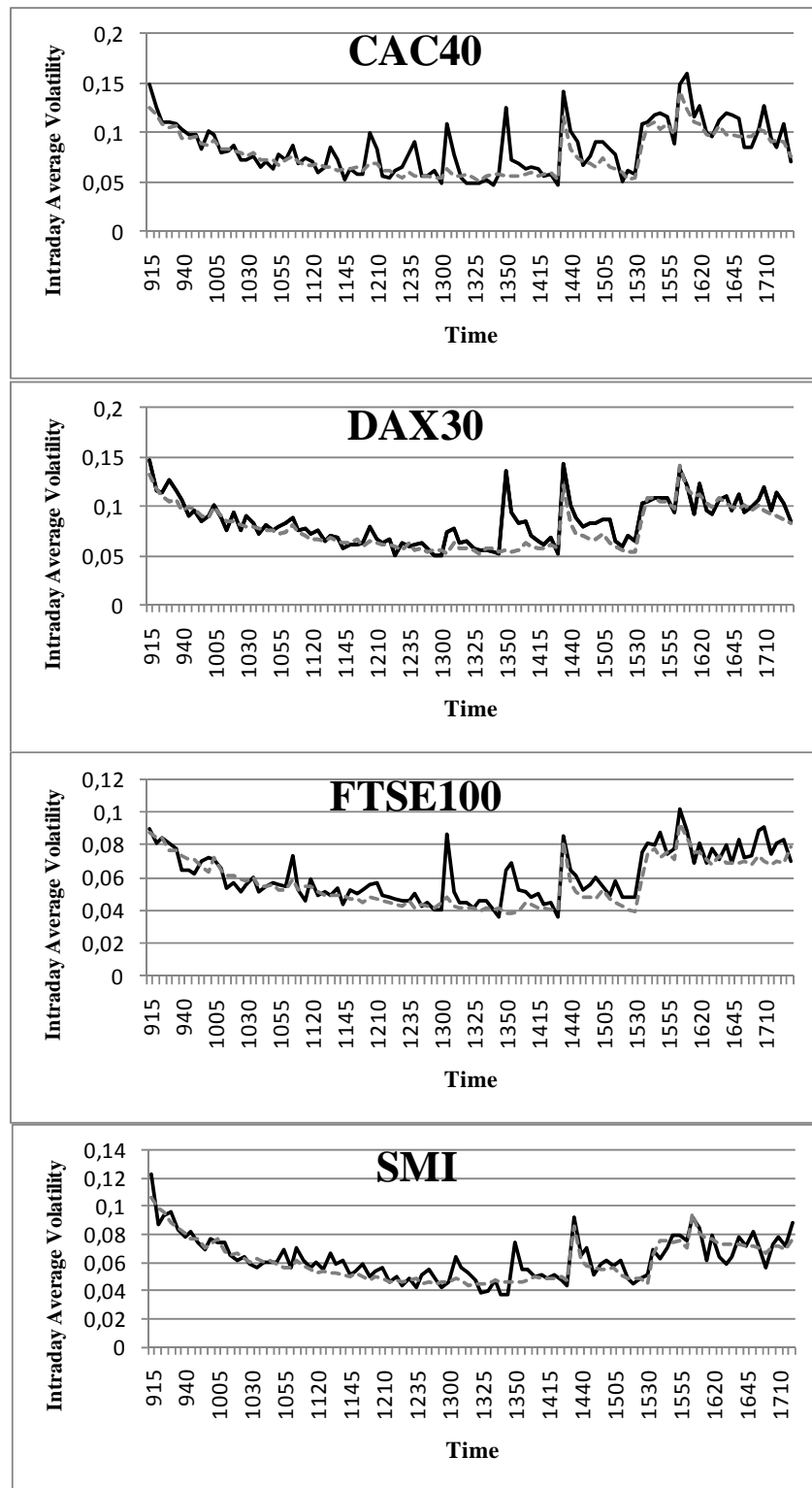
Intraday average volatility classified by time

Note: This figure reports the 5-minute average absolute returns for SP500 index. These averages are calculated for each 5-minute period across all trading days in our sample.

In order to analyze more carefully, we split the data into two pieces. Figures 2a and 2b compare the intraday volatility pattern of four European and the US equity indices for the days when the ECB and FOMC monetary policy announcements were made (solid lines) with those when there was no monetary policy announcement by ECB and FOMC (dashed lines) respectively.

Figure 2a.

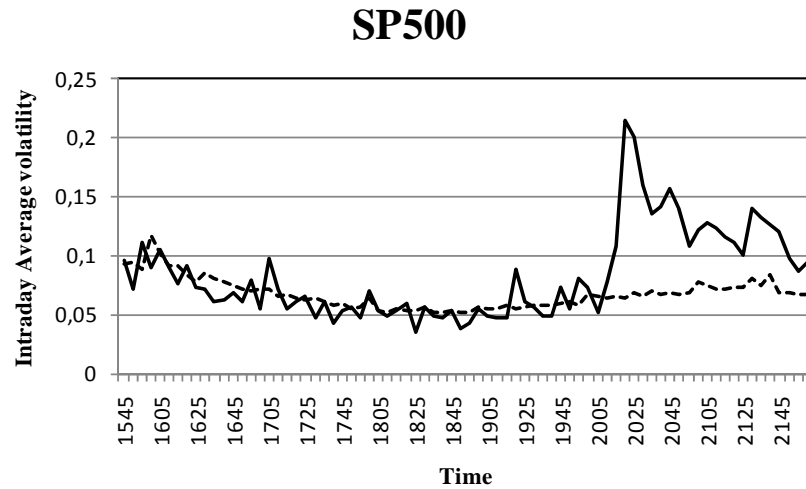
Intraday average volatility for ECB announcement days versus no ECB announcement days



Note: The solid line shows average 5-minute period volatility on ECB monetary policy announcement days versus the days when no such announcement was made by ECB which is represented by dashed line.

Figure 2b.

Intraday average volatility of SP500 with and without FOMC monetary policy announcements



Note: The solid line shows intraday average volatility for SP500 for days when there were FOMC monetary policy announcements at 20:15 CET versus the days when there was no monetary policy announcements by FOMC (dashed line).

The findings are interesting and revealing. Figure 2a shows that on those days when there was no ECB monetary policy decision, the intraday average volatility exhibited the same trend as shown in Figure 1a. But for those days when ECB revealed its monetary policy decisions, the average absolute returns show clear rise at 13:50 following the monetary policy releases by ECB. Similar conclusion can be drawn from looking at Figure 2b for SP500 index. Intraday volatilities in SP500 responded even more strongly to FOMC monetary policy announcements (approximately four times) than their European counterparts which Farka (2009) coined as tent shaped.

We now turn our attention to analyzing the effect of ECB press conference on European stock markets volatilities. However, as noted earlier, since 40% of the ECB monetary policy announcement dates coincide with US macroeconomic releases at 14:30, it is important to isolate the effect of ECB press conference from that of US macroeconomic news announcements.

Let us first look at the effect of US 14:30 macroeconomic news announcements on European stock indices. Appendix 1 compares intraday volatilities of four European indices on days of US macroeconomic news announcements at 14:30 CET with those when no US announcement was made. The dashed line plots the seasonal volatility on those days when the US news was released, and the solid line shows the days when no macro announcements were made in the US. The volatilities of the two separate groups clearly show that US

macroeconomic news releases at 14:30 have a clear impact on the volatilities of the four European markets.¹⁴

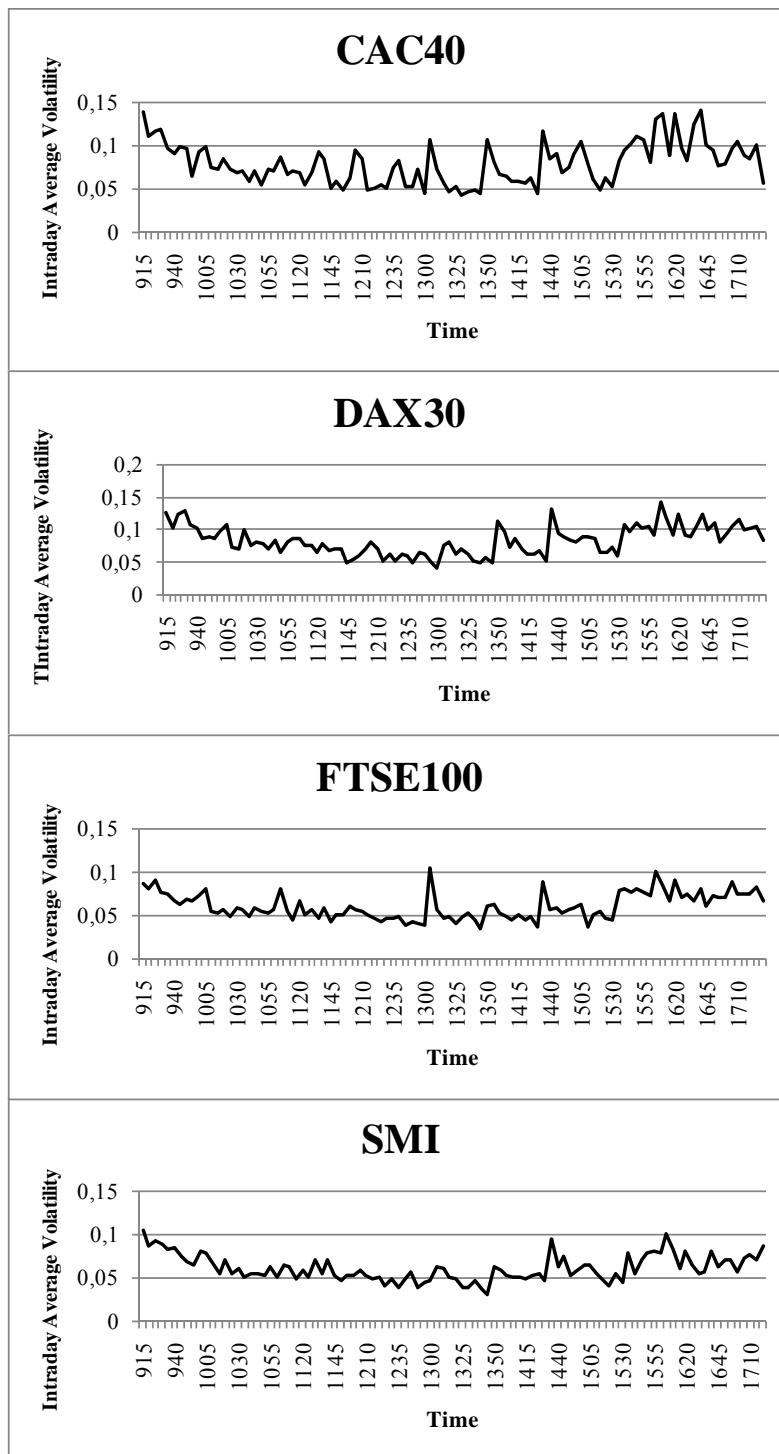
Nevertheless, in order to separate the effect of ECB press conference on European markets' volatilities from that of US macroeconomic releases at 14:30 CET, we split the volatility data according to the days when ECB press conference was held but no US macroeconomic news announcements were made at 14:30 CET. This division was necessary in order to measure the precise effect of ECB press conference on European markets' intraday volatilities.

Figure 3 displays the 5-minute average absolute returns for four European indices for days when ECB held the press conference at 14:30 CET followed by its monetary policy announcement decision but no US macroeconomic announcement was made on those days. As can be seen in Figure 3, all four European indices responded immediately to the ECB press conference at 14:30 as a clear rise in intraday volatility is observed at 14:35. Two important observations can be made when looking at Figure 3. Firstly, the response is swift and fades away quickly. Secondly, the two European indices; FTSE100 and SMI respond moderately compared to the German and French stock indices. This is intuitive in the sense that these two countries belong to the European monetary union (EMU) and are directly affected by ECB monetary policy actions. However, it is interesting to note that ECB press conference where the details of its monetary policy decisions are revealed also matters to non-EMU countries, albeit moderately. This implies that both the initial monetary policy surprise by ECB and details of its decision given in the press conference 45 minutes later are considered important by European investors for pricing stocks.

¹⁴ Harju and Hussain (2009) convincingly show that intraday volatilities of European equity markets are significantly affected by the US macroeconomic news releases at 14:30 and 16:00 CET.

Figure 3.

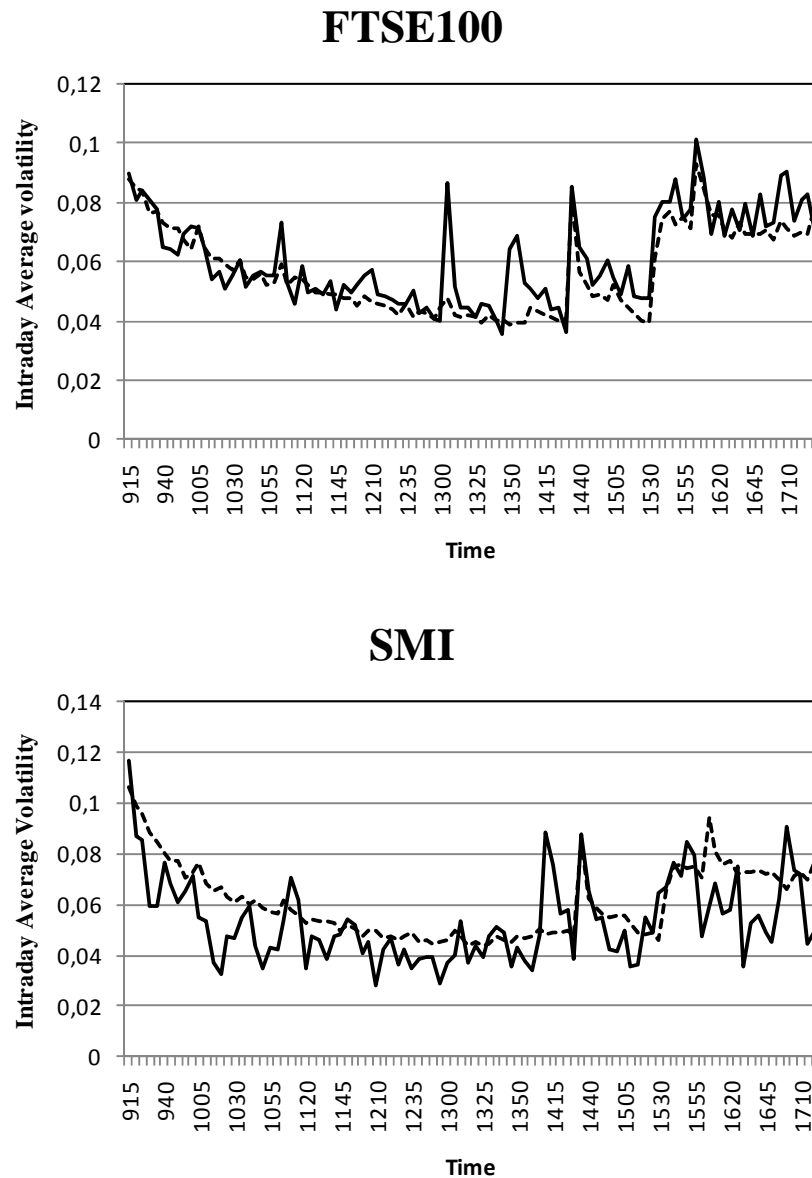
**Intraday average volatility in european markets
with ECB announcement days but with no 14:30
US announcement**



Note: This figure shows average 5-minute period volatility for four European indices on days when there were monetary policy announcement by ECB but no macroeconomic news announcements were made at 14:30 CET in the US.

Figure 4.

Intraday average volatility for two european stock indices namely FTSE100 and SMI



Note: This figure compares intraday average absolute returns for days when there was BOE and SNB announcements for FTSE100 and SMI respectively, with those when there were no monetary policy announcement were made.

We now look at the effect of the BOE and SNB on their respective indices. Since these two countries have not joined EMU, it is important to analyze the effect of their own central banks' monetary policy decisions on respective equity indices. As described earlier, since these announcements coincide with several domestic and foreign macroeconomic announcements, it again seems necessary to employ

high frequency data to isolate the effect of monetary policy decisions. Figure 4 compares intraday average volatility for days when there were BOE and SNB announcements for FTSE100 and SMI respectively, with those when there were no monetary policy announcement were made. It is clearly seen in Figure 4 that both markets react to the monetary policy decisions by their central banks. The important observation that can be made from Figure 4 is that response from UK and Swiss stock is again immediate and is noticed within 5 minutes following the monetary policy announcements.

Overall, our descriptive analysis suggests that monetary policy announcements clearly influence European and US stock indices. The next section will develop a robust estimation procedure to test the hypothesis that whether monetary policy surprises significantly affect stock returns and their respective volatilities.

4 Methodology

Our methodology for testing the effect of monetary policy surprises on the conditional means and conditional variances of the European stock indices is based largely on time series models for high frequency data proposed by Andersen et al (2003). The following return and volatility models allowed us to investigate the impact of monetary policy surprises on international stock markets.

4.1 Return generating model

We specify a time series model to investigate the impact of monetary policy actions on European and the US stock index returns. The return-generating model isolates the impact of foreign economic surprises and their own autoregressive moving average (ARMA) terms on stock index returns. Thus, for each market, the 5-minute stock index return R_t was modeled as an ARMA(p,q) process and J lags of news on each of K monetary surprises

$$R_t = \Phi(L)R_t + \Theta(L)\epsilon_t + \sum_{k=1}^K \sum_{j=0}^J \beta_{k,j} S_{k,t-j} + \epsilon_t, \quad t = 1, \dots, \quad (4.1)$$

where $\Phi(L)$ and $\Theta(L)$ are polynomial lag operators of order p and q, respectively, for the AR(p) and MA(q) processes, and $S_{k,t}$ is the standardized news associated with monetary surprise k at time t. A significant $\beta_{k,j}$ coefficient would imply that European and the US markets respond to monetary surprises, while the use of standardized news facilitates meaningful comparisons of surprise response

coefficients. The numbers of lagged values in model (4.1) are based on the Schwarz information criteria. Contemporaneous response, ie, (J=0), refers to the same 5-minute return periods within which the news was released.

4.2 Volatility response model

The disturbance volatility was approximated using the following model

$$|\hat{\epsilon}_t| = \Phi(L)|\hat{\epsilon}_t| + \Theta(L)\mu_t + \Psi \frac{\hat{\sigma}_{d(t)}}{\sqrt{N}} + \sum_{k=1}^K \sum_{j=0}^J \beta_{k,j} |S_{k,t-j}| + \left[\sum_{x=1}^X \left[\delta_x \cos\left(\frac{x2\pi t}{N}\right) + j_x \sin\left(\frac{x2\pi t}{N}\right) \right] + \sum_{m=1}^M \gamma_m D_m \right] + \mu_t \quad (4.2)$$

The left hand side term, $|\hat{\epsilon}_t|$ is the absolute value of the residual of model (4.1), which proxies volatility in 5-minute time interval. The right-hand side of the model (4.2) indicates that the 5-minute volatility is driven partly by its own ARMA terms, partly by the average volatility over the trading day in respective market, $\frac{\hat{\sigma}_{d(t)}}{\sqrt{N}}$, partly by the monetary policy surprises, $S_{k,t}$, and partly by the seasonal pattern. N is the number of intraday intervals within a trading day. The seasonal component was split into two parts. The first is flexible Fourier form (FFF) with trigonometric terms that obey the strict periodicity of one day. To obtain strictly periodical data, the few missing observations were replaced by linear interpolation. The second is a set of dummy variables, $D_{m,t}$, capturing the equity markets' opening and closing times, as well as other abrupt periods in intraday volatility series.

The ARMA terms in model (4.2) are included to capture the short run volatility dynamics or volatility clustering effect within the intraday data, while $\hat{\sigma}_{d(t)}$ is intended to capture the 'average' level of volatility on day $d(t)$. It is interesting to note that this setting facilitates modeling the impact of monetary policy surprises on stock return volatility by taking into account the pronounced intraday seasonalities, distortions that arise from the distinct periods, and its own time varying volatility behaviour.

Our estimation procedure involves the determination of a daily volatility factor, $\hat{\sigma}_{d(t)}$. The daily volatility, which is a one-day ahead forecast for day $d(t)$ from the daily ARMA(1,1)-generalized autoregressive conditional heteroskedasticity (GARCH)(1,1) model, was computed using the intradaily stock returns calculated over the sample period for each market. As noted by Andersen and Bollerslev (1997), given the relative success of the daily GARCH models in

explaining the aggregate results for intradaily frequencies in financial markets, the use of ARMA(1,1) – GARCH(1,1) appeared to be a natural choice. Next, the FFF, as proposed by Gallant (1981, 1982) and advocated by Andersen and Bollerslev (1997, 1998), was employed to account for the pronounced intraday periodicity. Moreover, the set of dummy variables $D_{m,t}$ is included to minimize the distortions that may otherwise arise from these distinct periods.

It is noteworthy that models (4.1) and (4.2) offer flexibility and could be estimated using standard time-series techniques. Both models were estimated using Newey-West standard errors and covariance consistent estimators that are known to be robust for the presence of both heteroskedasticity and autocorrelation of unknown form.

5 Empirical findings

Models (4.1) and (4.2) provide a good approximation of both conditional mean and conditional volatility dynamics, as shown by the residual statistics and the resulting fit of the intraday seasonalities.¹⁵ The results are shown in Tables 4a and 4b. Monetary policy surprises have generally statistically significant influence across all markets.

5.1 European markets responses

Estimation results for European equity indices are provided in Table 4a. As shown in upper panel of the Table 4a, the monetary policy surprises from Bank of England (BOE) and European Central Bank (ECB) generally exert negative and significant influence on index returns across all four European markets.¹⁶ The only exception, however, is the FTSE100 return which though responds negatively to the ECB monetary policy surprises but is not statistically significant at 5% level. Translated in traditional policy moves, a 25 basis points surprise tightening of BOE monetary policy causes a decline of roughly 0.47% in French, 0.24% in German, 0.36% in UK, and 0.125% in Swiss stock index returns. While, a similar surprise (25 basis points) in ECB monetary policy announcements reduces index returns approximately by 0.50% in French, 0.34% in German, 0.14% in Swiss stock markets. Another appealing feature is that the response is

¹⁵ The fitted values of intraday volatilities are not shown here for saving the space. However, results can be obtained from author upon request.

¹⁶ We dropped the monetary policy announcement data from Swiss National Bank (SNB) in our econometric estimation, since there were too few observations for SNB surprises, and our results could have been seriously biased if we had included them.

usually swift and fades away very quickly, ie, within 5 minutes after the announcement, which speaks for the use of high frequency data in measuring the response of equity index return to monetary policy announcements.

Turning to the volatility dynamics of European equity markets, as seen in lower panel of the Table 4a, the volatility response coefficients are positive and significant at the 5% level for all four indices. This implies that monetary policy surprises raise the level of volatility in European equity markets.¹⁷ The BOE and ECB monetary policy surprises not only exert immediate influence on intraday volatilities but the volatility response also generally persists as compared to the returns response. Furthermore, the ECB press conference dummy at 14:30 CET also has a positive and statistically significant coefficient across all four European stock indices, suggesting that not only the ECB monetary policy decisions affect the intraday volatility level of the European stock indices but the content of the press conference also matters across all European countries.

Table 4a. **Return and volatility response estimates to monetary policy surprises for European markets**

Announcements	CAC40		DAX30		FTSE100		SMI	
<i>Panel A: Contemporaneous return response coefficients</i>								
	b _{k,0}	t-stat	b _{k,0}	t-stat	b _{k,0}	t-stat	b _{k,0}	t-stat
BOE monetary surprises	-0.220	-2.339	-0.111	-3.699	-0.168	-6.188	-0.058	-3.849
ECB monetary surprises	-0.120	-3.870	-0.080	-2.056	-0.028	-1.560	-0.033	-2.021
R-squared	0.015		0.000		0.002		0.000	
Residual diagnostics	AC	Q-stat	AC	Q-stat	AC	Q-stat	AC	Q-stat
	0.001	0.110	-0.004	3.007	0.000	0.003	-0.003	1.345
<i>Panel B: Contemporaneous and lagged volatility response coefficients</i>								
	b _{k,0}	t-stat	b _{k,0}	t-stat	b _{k,0}	t-stat	b _{k,0}	t-stat
BOE monetary surprises (-1)	0.135	2.796	0.035	2.113	0.055	3.441	0.014	2.042
ECB monetary surprises (-1)	0.059	2.643	0.077	2.967	0.029	2.523	0.029	2.906
BOE monetary surprises (-2)	0.032	1.602	0.056	2.423	0.043	2.100	0.024	1.779
ECB monetary surprises (-2)	0.026	2.191	0.033	3.510	0.038	2.233	0.009	1.438
ECB press conference	0.036	2.735	0.045	2.686	0.030	2.777	0.033	3.267
R-squared	0.307		0.342		0.324		0.335	
Residual diagnostics	AC	Q-stat	AC	Q-stat	AC	Q-stat	AC	Q-stat
	0.097	1874.800	0.009	17.992	0.028	152.870	0.009	17.798

Note: The conditional mean model (4.1), and the conditional disturbance volatility model (4.2), for four European stock indices, namely France (CAC40), UK (FT100), Switzerland (SMI) and Germany (XDAX) was estimated. We report the estimates and t-stats for the contemporaneous equity markets' return and volatility response to standardized monetary policy surprises by Bank of England (BOE) and European Central Bank (ECB). Contemporaneous response refers to the same 5-minute period within which the news was released. Significant coefficients are shown in bold on 5% significance level. The effect of ECB press conference held at 14:30 following the monetary policy decisions at 13:45 is also reported in the table. The residual autocorrelation coefficients and their respective Ljung-Box Q statistics are reported as well.

¹⁷ We also checked response asymmetry using model (4.2), where a dummy variable was included to capture the asymmetric effect. The dummy variable took the value 1 when there was a negative monetary policy surprise (higher than mean expectation) and zero otherwise. But none of the asymmetric response coefficients was significant in our analysis.

Another important finding is that the contemporaneous volatility response coefficients, although statistically significant, were smaller than their counterparts reported in the mean equation. However, stock return volatilities adjust relatively gradually, with complete adjustment occurring usually after two 5-minute periods, indicated by significant coefficients of the lagged terms.

5.2 US market response

Estimation results for the US stock index, SP500 are provided in Table 4b. Contemporaneous return response coefficient is shown in the upper panel of Table 4b. Contrary to what is seen for European indices, effect of the FOMC announcements on the US stock index return is much weaker (statistically significant at 10% level). However, the sign of the coefficient is negative as for the European indices, and if interpreted in traditional policy moves, 25 basis points shock in FOMC monetary policy decisions depresses the aggregate US equity returns by approximately 0.25%.

Table 4b. **Return and volatility response estimates to monetary policy surprises for US market**

Announcements	SP500	
Panel A: Contemporaneous return response coefficients		
	b _{k,0}	t-stat
FOMC Monetary policy surprises	-0.111	-1.696
R-squared	0.002	
Residual diagnostics	AC	Q-stat
	0.000	0.035
Panel B: Contemporaneous volatility response		
	b _{k,0}	t-stat
FOMC Monetary policy surprises (-1)	0.123	2.794
FOMC Monetary policy surprises (-2)	0.048	1.331
R-squared	0.199	
Residual diagnostics	AC	Q-stat
	-0.014	28.529

Note: The conditional mean model (4.1), and the conditional disturbance volatility model (4.2), for US stock index, namely SP500 was estimated. We report the estimates and t-stats for the contemporaneous equity markets' return and volatility response to standardized monetary policy surprises by FOMC. Contemporaneous response refers to the same 5-minute period within which the news was released. Significant coefficients are shown in bold on 5% significance level. The residual autocorrelation coefficients and their respective Ljung-Box Q statistics are reported as well.

The lower panel of Table 4b presents the intraday volatility response estimates for the US stock index. Similar to what is seen for European equity indices, the SP500 intraday volatility is clearly affected by the FOMC monetary policy surprises. However, the response fades away quickly and can only be seen within five minutes from the US news release.

5.3 Target versus path surprises

Following Gürkaynak et al (2005) and Andersson (2007), we divide the monetary policy surprises into two types: target and path surprise. In order to calculate path surprise for our analysis, we acquired tick data for Euribor and Eurodollar futures contracts for European and the US markets, respectively.¹⁸ The target surprise (TS) is calculated as the difference between the actual monetary policy decision and the mean expectation. The path surprise is defined as the component of the change in Euribor and Eurodollar interest rate futures in a thirty minute window around the monetary policy announcements (ie, ten minutes before and twenty minutes after) from ECB and FOMC respectively. To derive the path surprise (PS), we run a regression of the change in Euribor and Eurodollar interest rate futures on a constant and a target surprise for ECB and FOMC, respectively. The innovation from the regression in equation (5.1) is defined as the paths surprise.

$$\Delta f_{t-30,t} = \alpha + \beta * TS_t + PS_t \quad (5.1)$$

To test whether intraday returns and volatility surrounding the monetary policy decisions by the FOMC and ECB can be explained by the target and/or path surprises, we re-estimate our models (4.1) and (4.2). The estimation results are shown in Table 5a and 5b for the European and the US markets, respectively.¹⁹

Table 5a shows whether European equity markets are significantly affected by ECB path surprises. As seen in the upper panel of Table 5a, the inclusion of path surprise in return equation offers mixed results for European stock indices. Two of the four European index returns respond significantly to ECB path surprises, namely DAX30 of Germany and SMI of Switzerland. However, it is interesting to note that CAC40 of France that belongs to the Euro area is not significantly influenced by ECB path surprises, while the Swiss equity index reacts to ECB

¹⁸ Tick data for Euribor and Eurodollar was purchased from tickdata.com. We were also interested in acquiring similar data on LIBOR future contracts in order to measure European markets' response to Bank of England (BOE) path surprise. However, this data was not available for this study.

¹⁹ Results displaying the stock indices response only to path surprises are reported here, since by definition; our target surprise is fundamentally the same as standardized surprise employed in previous regressions.

path surprise in a significant manner. One probable explanation is that this effect reflects close linkages between German and Swiss stock indices, ie, SMI returns are influenced by German returns in that particular period.

The lower panel of table 5a reports the volatility response estimates for European markets to ECB path surprises. Interestingly, none of the coefficients is significant at the 5% level, suggesting that volatility of the European stock markets is not affected by path surprises. This implies that investors do not view path surprises as an important factor in formulating their short-term investment strategies. This finding differs from that of reported by Andersson (2007), who documents significant results for the Euro Stoxx 50 futures index.

Table 5a. **Return and volatility response estimates to monetary policy surprises for european markets**

Announcements	CAC40		DAX30		FTSE100		SMI	
Panel A: Return response coefficient								
	b _{k,0}	t-stat	b _{k,0}	t-stat	b _{k,0}	t-stat	b _{k,0}	t-stat
ECB Path surprise	2.930	1.057	-2.109	-2.690	0.198	0.786	-0.460	-2.084
R-squared	0.015		0.000		0.002		0.000	
Panel B: Volatility response coefficient								
	b _{k,0}	t-stat	b _{k,0}	t-stat	b _{k,0}	t-stat	b _{k,0}	t-stat
ECB Path surprise	2.043	0.871	0.116	0.214	-0.159	-1.444	0.075	0.365
R-squared	0.308		0.342		0.324		0.335	

Note: The conditional mean model (4.1), and the conditional disturbance volatility model (4.2), for European stock indices, namely CAC40 of France, DAX30 of Germany, FTSE100 of UK, and SMI of Switzerland were re-estimated with ECB path surprise as exogenous variable. We only report the estimates and t-stats for the equity markets' return and volatility response to Path surprises by European Central Bank (ECB), since rest of the results are same as reported in table 4a. Significant coefficients are shown in bold on 5% level.

The return and volatility response to path surprises for SP500 index are reported in Table 5b. As shown in the upper panel of the Table 5b, the return response coefficient for the US stock index is not significantly affected by the FOMC path surprise. With respect to volatility response coefficient, the lower panel of the Table 5b presents results similar to those reported for the European counterparts. These findings are consistent with those reported in Wongswan (2005) and Gürkaynak, Sack and Swanson (2005) for the US equity markets, but contradict the earlier results of Farka (2009) and Andersson (2007).

Table 5b.

**Return and volatility response estimates to
monetary policy surprises for the US market**

Announcements	SP500	
	$b_{k,0}$	t-stat
<i>Panel A: Contemporaneous return response</i>		
FOMC Path surprise	0.594	0.989
R-squared	0.002	
<i>Panel B: Contemporaneous volatility response</i>		
FOMC Path surprise	0.611	1.487
R-squared	0.199	

Note: The conditional mean model (4.1), and the conditional disturbance volatility model (4.2), for US stock index, namely SP500 was re-estimated with FOMC path surprise as exogenous variable. We only report the estimates and t-stats for the US stock index return and volatility response to FOMC path surprise, since rest of the coefficients are same as reported in Table 4b. Significant coefficients are shown in bold on 5% level.

One possible explanation for these results is that as suggested by our descriptive analysis, the response of stock indices to monetary policy surprises is often very quick and usually fades away within 5–10 minutes. Since path surprises, by construction, capture changes in interest rate futures in a thirty minute window around the monetary policy announcements ie, ten minutes before and twenty minutes after, the coefficients tend to be generally positive but not significant.

6 Summary

This paper investigates the effects of monetary policy announcements on European and the US stock index returns and volatilities utilizing high frequency 5-minute observations along with extensive data on monetary and macroeconomic news announcements.

Our setting provides interesting insights into intraday dynamics of international equity markets. This paper mainly contributes in the existing literature by segregating the effect of monetary policy surprises on stock indices from those of other macroeconomic variables. The analysis reveals that that the use of high frequency data is not only critical to separate the effect of monetary policy actions from that of macroeconomic news announcement on the stock index returns and volatilities but it also reduces the problems of endogeneity and omitted variable bias in econometric estimation. Thus, this paper presents fresh evidence on the immediate response of the major European and US equity markets to monetary policy surprises.

We report significant impact of monetary policy surprises on both stock index returns and volatilities. Moreover, our results show that European stock index volatilities are significantly influenced by the European Central Bank's (ECB) press conference that is held 45 minutes after the monetary policy decisions on the same day implying that it contains important information for market participants. However, both European and the US markets do not generally respond to path surprises.

These results have important implications for market participants and central banks as monetary policy decisions have direct and immediate impact on asset prices. Thus, accurate estimates of responsiveness of asset prices to monetary policies can be of help to central banks in making effective monetary policy decisions. The results and the approach to estimating market responses to changes in monetary policy help market participants in formulating effective investment decisions and appropriate risk management strategies.

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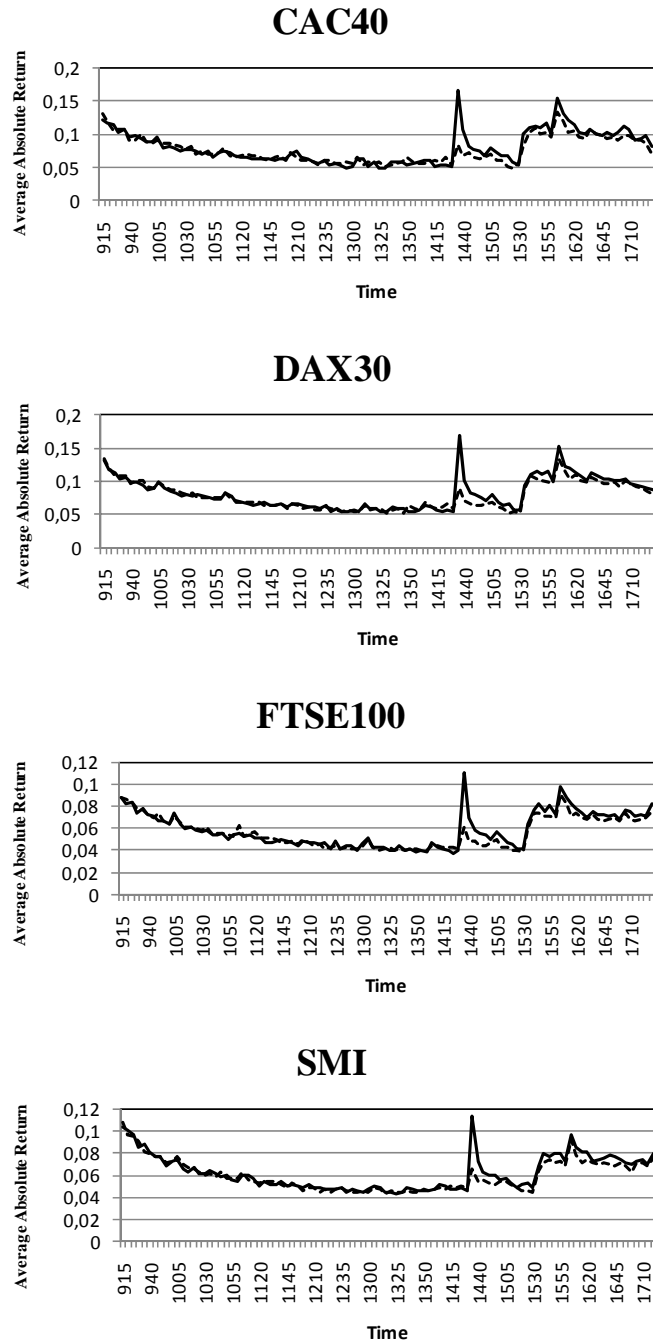
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Appendix 1

Figure 5.

Intraday average volatility in european stock indices with respect to 14:30 US macroeconomic news announcements



Note: This figure shows the average intraday volatility for four european stock indices namely CAC40 of France, DAX30 of Germany, FTSE100 of UK, and SMI of Switzerland for days when there were 14:30 (CET) US macroeconomic news announcements (solid line) versus when no 14:30 (CET) US macroeconomic news announcements were made for selected indicators in our sample period (dashed line).

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Suomen Pankki
Bank of Finland
P.O.Box 160
FI-00101 HELSINKI
Finland



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