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This paper documents that ECB announcements on monetary policy increase stock market volatility in the euro area (EA) using several volatility measures from January 1999 to December 2019. Employing event study methods, a more pronounced impact exists following the global financial crisis starting in 2007. All assets react similarly so that no national peculiarities arise. The effects also spill over to 12 non-EA markets analyzed. Stock markets are more sensitive to negative monetary policy news than to positive ones. Further weighting the announcements by financial market reactions, stock markets behave in a more heterogeneous way.

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Keywords: ECB announcements, asset price volatility, event study

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This paper documents that ECB announcements on monetary policy increase stock market volatility in the euro area (EA) using several volatility measures from January 1999 to December 2019. Employing event study methods, a more pronounced impact exists following the global financial crisis starting in 2007. All assets react similarly so that no national peculiarities arise. The effects also spill over to 12 non-EA markets analyzed. Stock markets are more sensitive to negative monetary policy news than to positive ones. Further weighting the announcements by financial market reactions, stock markets behave in a more heterogeneous way.

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1 Introduction

Monetary policy and financial market activity are highly intertwined. Asset pricing models like Drechsler et al. (2018) emphasize the relevance of the nominal interest rate set by central banks. A reduction in the nominal rate creates more liquidity which, in turn, leads to higher asset prices and volatility. Uncertainty about the future path of interest rates helps predict future variance of equity returns (Kaminska and Roberts-Sklar, 2018). However, given the lower bound in many economies, the interest rate is usually insufficient to fully understand current developments on financial markets. If the interest rate instrument is not available, then the communication of non-standard monetary policy tools may have a first-order impact on the volatility of financial markets. This indicates the relevance of central bank announcements for asset price volatility, which this study empirically assesses.

The importance of central bank communication is well-established (see Blinder et al. (2008) for a survey). Yet numerous questions remain unanswered because monetary policy announcements are complex. They occasionally concern aspects beyond the actual nominal interest rate such as legislation, forward guidance, and quantitative easing measures. Not only the content but also the channel of communication counts. Gertler and Horvath (2018) detect stock market responses by considering various communication tools around scheduled meetings such as speeches, media interviews, and conference discussions. Schmeling and Wagner (2019) show that the specific tone inherent to central bank statements moves asset prices. Many event studies document how financial markets react to central bank announcements. Unconventional monetary policy surprises affect the Eurostoxx 50 as shown in Haitsma et al. (2016), while Fausch and Sigonius (2018) detect significant reactions of German stock returns. European Central Bank (ECB) policies boosted equity prices between 2007 and 2012 (Fratzcher et al., 2016). Relatedly, Georgiadis and Gräb (2016) provide evidence for an increase in equity returns in reaction to the ECB's asset purchase program announcements. These studies, however, mainly pay attention to *level* effects on financial markets.

To my knowledge existing event studies have not explicitly addressed financial markets' *volatility* yet. Volatility in financial markets has large implications for real economic activity. Financial volatility represents uncertainty, which is not harmful per se. However, extreme market movements or volatility that is not based on economic fundamentals are undesired because they impair the economic activity. For example, investors reduce the funding in projects in

response to an increased level of uncertainty. Volatility measures indicate investors' sensitivity, that is whether they are getting more nervous (volatility increase) or calmer (volatility decrease). A quantification of volatility reactions would be a useful tool for both policymakers and practitioners. It adds important information to any statement about an increase/decrease of an asset in reaction to announcements. The volatility (second moment) mirrors the immediate reaction on financial markets during an announcement day while the return (first moment) shows merely the outcome at the end of the trading day. For instance, a rise in a specific asset at the end of the trading day could be either caused by a few transactions leading to a smooth price increase or by many transactions overshooting and undershooting the final price. The asset's volatility measure reflects which of the two scenarios is more appropriate for the trading day.

Policymakers have been aware of the relevance of their announcements since the early stages of the euro. Willem Duisenberg, former president of the ECB, remarked at a press conference in November 2001: '[...] bi-monthly meetings of the Governing Council also lead, every two weeks, to speculation in the markets and higher volatility [...] but we thought that it might inspire some calm in the markets if [...] the monetary policy stance will only take place once a month.[...]' (ECB, 2001). This communication strategy took effect in 2002. In 2015, the ECB further reduced its monetary policy meeting frequency from every four to every six weeks. In accordance with this amendment, the ECB also reduced the number of publications explaining economic and monetary developments, for example the Monthly Bulletin was replaced by the Economic Bulletin, which appears eight times a year. Thus, the ECB follows the Federal Reserve that has 8 scheduled meetings per year. Other major central banks reduced their number of regular meetings as well. In 2016, the Bank of Japan reduced from 14 to 8 meetings per year and the Bank of England changed from a monthly to an eight-meeting schedule. These adjustments aim to reduce financial volatility. The paper examines the success of these policy changes, namely whether fewer announcements lead to less volatility. While the paper uses the euro area (EA) as a laboratory to tackle this research question, the findings are presumably relevant for other central banks, as well. The ECB's behavior is not only relevant for the world economy¹, but the focus on the ECB is especially interesting given the EA's unique structure of several countries sharing a common central bank.

Central bank announcements are typically not limited to a special sector but concern the

¹The EA accounts for a large portion of world GDP and the euro serves as an important reserve currency.

whole economy. Therefore, the analysis focuses on national stock market indices. Sosvilla-Rivero and Morales-Zumaquero (2012) distinguish a different volatility behavior between core and peripheral EA sovereign bond yields. The present study checks whether the same holds for major national stock market indices. In contrast to the work that tries to predict volatility and optimize the quality of forecast models, this study infers asset volatility reactions from crucial events. News from different sources simultaneously influences asset prices, and a quantification of the effect of a single event on financial markets is not a trivial task. However, to quantify the central bank's contribution is worthwhile so that a central banker is aware of the consequences for financial stability when uttering a statement related to monetary policy. Besides the main objective of an effective communication of monetary policy measures, the reduction of stock market volatility is in the interest of the ECB: If volatility on financial markets spills over to real market prices, the ECB's target of price stability is at risk. At the same time, asset price developments can also be a driver of monetary policy. For instance, Cieslak and Vissing-Jorgensen (2017) assess the impact of the stock market on U.S. monetary policy using a textual approach. They find that the Federal Reserve reacts with accommodative communication to low stock market returns. One needs to bear in mind this interplay between financial markets and central bank communication when deducing the influence of the ECB's announcements on the stock markets of its respective member economies.

Announcements by the ECB provide new information to the market. On the one hand, this can resolve uncertainty for market participants and thus asset volatility decreases. On the other hand, if the provided information does not meet market participants' expectations, adjustments on the financial market increase the volatility level. A volatility enhancement is expected because any communication consists of releasing private information to the public. This release is very likely to provoke some market reactions equivalent to an increase in volatility. For instance, credibly announced accommodative measures such as asset purchase programs might further reinforce volatility on financial markets: An increased demand for assets causes more transactions and higher asset prices. Moreover, studies like Fratzscher et al. (2016) support a volatility increase. They prove a significant equity price rise in response to the ECB announcements.

This paper provides new insights into the understanding of stock market reactions to central bank communication. Using several volatility measures from January 1999 to December 2019, monetary policy announcements by the ECB increase stock market volatility in the EA. Hence, such communication rather irritates than calms financial markets. A more pronounced impact

exists following the global financial crisis starting in 2007. All assets react similarly so that no national peculiarities arise. The effects also spill over to 12 non-EA markets analyzed. Stock markets are more sensitive to negative monetary policy news than to positive ones. Further weighting the announcements by financial market reactions, stock markets behave in a more heterogeneous way.

The rest of the paper proceeds as follows. Section 2 describes the methodology and the data. Section 3 presents the empirical findings comprising robustness checks. The implications of announcements for future volatility will be assessed in Section 4. Section 5 confronts positive and negative news and Section 6 introduces a market-specific weighting of the announcements. Section 7 discusses the main findings, while Section 8 concludes.

2 Methodology and Data

To assess the effect of monetary policy on financial markets, key stock market indices of different EA economies serve as dependent variables. This goes beyond studies like Haitsma et al. (2016) that only look at an aggregated European index. Empirical studies typically use European indices or take the German market as a proxy for the EA. Cieslak and Schrimpf (2019) use futures of the DAX 30 and 3-month-Euribor around events to construct monetary policy surprises of ECB communication. National equity markets differ in many dimensions such as regulations, market capitalization, number of traded firms and turnover. A separate consideration of national markets allows a country-specific comparison of the effects or an allocation of assets to certain groups such as core versus peripheral countries in the EA. Related literature distinguishes core countries and periphery countries (e.g., Urbschat and Watzka, 2019). For this data set, core countries are Austria (AT), Belgium (BE), Finland (FI), France (FR), Germany (DE), and the Netherlands (NL). Periphery countries are Greece (GR), Ireland (IE), Italy (IT), Portugal (PT), and Spain (ES). The latter are also referred to as distressed countries. Moreover, the Eurostoxx 50 index (EU) represents European financial markets on the aggregate level. The ECB's policy communication does not only affect its member countries but potentially extends to non-EA markets; McQuade et al. (2015) for example, uncover reactions in Eastern European countries whereas Korus (2019) detects spill-over effects for Scandinavian financial assets. To test for possible spill-over effects, the model also includes the stock markets of Bulgaria (BG), Czech Republic (CZ), Denmark (DK), Great Britain (GB), Hungary (HU), Japan (JP), Norway

(NO), Poland (PL), Sweden (SE), Switzerland (CH), and the United States (US).²

The model estimates the ordinary least squares regression

$$vol_{i,t} = \alpha_i + \beta_{i,j} \sum_{j=1}^4 X_j + \gamma_i ECB_t + \varepsilon_{i,t}, \quad (1)$$

where $vol_{i,t}$ is the volatility measure of market i on day t . The constant α_i captures the influence of unobserved factors. X_j covers four control variables. First, the change of the logarithmic prices of the country-specific Morgan Stanley Capital International (MSCI) Index, $\Delta MSCI_{i,t} = \ln(MSCI_{i,t}/MSCI_{i,t-1})$, controls for surprises other than monetary policy. Market volatility is part of the risk premium and should therefore affect the returns. To overcome this reverse causality concern for the national MSCI indices, the model uses the value of the previous trading day $\Delta MSCI_{i,t-1}$. Following Haitsma et al. (2016) the daily change of the MSCI World (excluding Europe) index, $\Delta MSCI_t^w$, captures movements in the rest of the world as a second control. Third, the CBOE Volatility index, VIX_t , controls for global risk. Finally, the first lag of the dependent variable $vol_{i,t-1}$ is included to account for possible trends in the data. The Citigroup Economic Surprise Index as in Georgiadis and Gräb (2016) is not applicable as the time series are only available from 2003 onwards. All variables are obtained from Datastream.³

Further control variables such as surveys on expectations of financial traders could refine the analysis. For instance, the Ifo Business Climate Index represents beliefs on the German economy while the European Commission’s Economic Sentiment Indicator captures developments at the European level. However, those indicators are issued monthly and a transformation to a daily frequency would bias the results. Moreover, such a control variable should be available from 1999 onwards at a daily frequency to be suitable for the study. Relevant macroeconomic reports such as monthly unemployment statistics or quarterly GDP growth figures commonly differ from their predicted values and constitute surprises that potentially affect asset price movements. These figures are released on dates at the end of the month. In contrast, monetary policy announcements are spread throughout the month. They typically do not occur on the very last day of a month, which cushions the concern of an overlap with macroeconomic news.

The dummy variable ECB_t captures monetary policy announcements and measures their

²For the US market, two important stock market indices are analyzed, the S&P 500 (US_SP) to cover the general sentiment of the economy, and the Dow Jones (US_Dow) to focus on the biggest industries, which should be more responsive to news due to a relatively high degree of internationalization.

³See the descriptive statistics in Table A1 and Table A2 in the appendix for details.

impact on assets' volatility. It is replaced by three distinct dummies according to the following specifications. There is a consensus in the literature that scheduled board meetings and their following press releases are the main methods of communication to financial markets (Ehrmann and Fratzscher, 2007) and recent empirical studies rely on those days only (Altavilla et al., 2019; ter Ellen et al., 2020). Hence, the dummy variable $scheduled_t$ takes the value of 1 on such a day, and 0 otherwise.⁴ However, several unconventional measures were communicated by the ECB – also on days other than scheduled board meetings. Rieth and Wittich (2020) consider both board meeting days and unconventional policy announcements since 2007. Unconventional press releases are adopted from Fendel and Neugebauer (2019) as well as Rieth and Wittich (2020) and updated until 2019. The dummy UMP_t captures 96 unconventional monetary policy announcements, whereof 55 dates coincide with board meeting days. In line with Rieth and Wittich (2020), who do not further differentiate between unconventional and conventional announcements due to the limited number of events, an additional specification also summarizes all announcements in dummy $policy_t$. An ECB announcement gives private information to the market. Asset markets should immediately react and exhibit an increased volatility during that day. This expectation translates into the hypothesis of $\gamma > 0$. The error term $\varepsilon_t \sim (0, \sigma^2)$ is independent and identically distributed.

Prices on financial markets may move due to phenomena outside economic fundamentals and the general sentiment. Noise resulting from imprecise public information could affect stock market volatility. For instance, Li (2005) proposes a model in which more noisy information can increase stock return volatility. However, Chahrour and Jurado (2018) find that news and noise are empirically the same. The paper therefore confidently focuses on news released by the ECB and forgoes to quantify rumors, which are surely present among the market participants.

The model assumes that ECB announcements affect stock market volatility but that ECB's policymakers do not immediately react to stock market volatilities. The ECB is unlikely to react to asset price movements on the same day. The communication of a well-founded monetary policy decision requires adequate preparation time. Even if the ECB officials wished to adopt the communication to current volatility on financial markets, they would have to collect and interpret data of multiple stock markets, and instantly change the content of the announcement. Given that the Governing Council has to coordinate its decisions with the national

⁴Section 3.3 considers multiple event sets. It turns out that scheduled meetings are the main driver for asset price volatility.

member banks, this scenario is deemed very improbable. Hence, endogeneity concerns are not justified for ECB_t .

To make the results of the different markets better comparable, $vol_{i,t}$ is standardized by the past 30 trading days.⁵ Thus, the model considers the current volatility level around the specific announcement. Taking the overall average for the standardization instead could bias the results because the time series has phases of lower and higher volatility. The effect of an announcement that takes place in times of high volatility would be overestimated while an announcement effect during a lower volatility phase would be underestimated when using the full-sample mean.

Three distinct volatility measures are analyzed and act as $vol_{i,t}$ in Equation (1). First, a realized volatility measure uses intraday data for selected stock market indices. Second, a (daily) price range measure approximates volatility to enlarge both the observation period and cross-section of stock markets. Third, a volatility measure is constructed based on future standard deviations of asset returns. Furthermore, measures of implied volatilities are incorporated in this context. The section continues by illustrating these measures.

2.1 High-frequency realized volatility

Realized variance is defined as the sum of squared log returns

$$RV_{i,t} = \sum_{j=1}^n r_{j,i,t}^2, \quad (2)$$

with $r_{j,i,t} = \ln(p_{j,i,t}) - \ln(p_{j,i,t-1})$ for all $j = 1, \dots, n$ intraday values for market i at day t . Realized variances for 7 different national EA and 8 non-EA stock market indices as well as the Eurostoxx 50 index are obtained from Heber et al. (2009). They are available at a 5 and 10 minutes frequency. To make the results comparable across different markets, one takes the square root of the realized variance and the values are annualized by the multiplier $\sqrt{252}$ as a year has 252 trading days, on average. Hence, the realized volatility measure is

$$RVol_{i,t} = \sqrt{252 RV_{i,t}} \quad (3)$$

⁵More specifically, the standardization uses values from $t - 31$ to $t - 2$. One stops at $t - 2$ because the value of $t - 1$ already enters as a lagged dependent variable. For each day t , the standardized value is $vol_{i,t}^{st} = \frac{vol_{i,t} - \text{mean}(vol_{i,t \in [t-31, t-2]})}{\text{std.dev.}(vol_{i,t \in [t-31, t-2]})}$. The results are robust to shorter standardization windows until 10 trading days.

for each market $i = (BE, CH, DE, DK, ES, EU, FI, FR, GB, IT, JP, NL, NO, SE, US_Dow, US_SP)$ based on the 5 minutes frequency observations.⁶

2.2 Daily price range

In order to include more economies for a longer period, a range measure, which is based on daily prices of national stock market indices, acts as a cautious proxy of volatility. This measure allows to start the analysis from the beginning of the EA in 1999, and to include the markets of Austria, Bulgaria, Czech Republic, Ireland, Greece, Hungary, Poland, and Portugal as well. This extension is essential for a comprehensive study of the core/periphery pattern in the EA and possible spill-over effects to the non-EA markets.

The price range has been proven to serve as a suitable volatility proxy in finance (e.g., Alizadeh et al., 2002; Yang and Zhang, 2000). In this paper, the range measure is defined as the difference between the maximum price p_t^{max} and the minimum price p_t^{min} during a day, divided by the opening price p_t^{open} to make the values comparable across the different country indices i :

$$range_{i,t} = \frac{p_{i,t}^{max} - p_{i,t}^{min}}{p_{i,t}^{open}}. \quad (4)$$

It is a simple approximation of daily volatility because it depicts the daily price range taking into consideration the intraday highest and lowest price. In this way a high number reflects a high fluctuation while a low number represents a steady development during that day. Taking into account more observations during the day would not add further information to the range. Additionally, the typical trading pattern likely biases the results. High trading activity at the beginning and at the end of the trading day contrasts with low activity at lunch time. Individual regressions are executed for the extended data set $i = (AT, BE, BG, CH, CZ, DE, DK, ES, EU, FI, FR, GR, GB, HU, IE, IT, JP, NL, NO, PL, PT, SE, US_Dow, US_SP)$.

2.3 Future volatility

A third measure of volatility considers future developments on the financial markets. Specifically, the standard deviations of stock prices on future dates are taken into account. After calculating the daily return $r_{i,t}$ using close prices $P_{i,t}$ for each market i

⁶The results are robust when using 10 minutes frequency instead. Note that the number of n per trading day depends on the specific stock market. For example, the German DAX refers to the stock market in Frankfurt, which is open for trade from 8am until 8pm. Considering 5 minutes frequency, this results in $n = 144$ observations to determine the realized volatility on a particular day.

$$r_{i,t} = \ln \left(\frac{P_{i,t}}{P_{i,t-1}} \right), \quad (5)$$

the annualized future volatility of the present day $vol_{i,t}^f$ is defined by

$$vol_{n,i,t}^f = \sqrt{252} \sqrt{\frac{1}{n-1} \sum_{k=1}^n (r_{i,t+k} - \bar{r})^2}, \quad (6)$$

where $k = 1, \dots, n$ represents the number of considered future trading days and \bar{r} is the mean for this horizon. As in Equation (3), the daily volatilities are annualized by the multiplier $\sqrt{252}$. The superscript f indicates future values, that is the forward looking character. The higher n is, the stronger is the view that ECB's announcements will impact the future volatility. For instance, if one assumes a monthly horizon, one would set $n = 20$ trading days.

2.4 Implied volatility measures

Country-specific volatility indices measure the implied volatility, that is the expected fluctuations on derivative markets during a defined future horizon (typically 30 days). They exist only for a few national stock markets and are available for a shorter period than the original market indices. Nonetheless, the study incorporates the respective volatility indices of the DAX 30, CAC 40, AEX, and Eurostoxx 50 as dependent variables, too. Next to the level values also the price ranges are considered. The reasoning is as follows. A variation of these indices is a valid measure of volatility because it refers to the degree of change in market participants' expectations. If the announcements alter market expectations, then the prices of options change which, in turn, move the respective volatility index. Hence, the degree of this change reflects the impact of the new information provided by the ECB. Moreover, the analysis applies the measure of future volatility on the four implied volatility measures.

One can deduce the surprise effect by relating the implied value of the previous day ($vol_{i,t-1}^{impl}$) to the realized volatility of the present day ($RVol_{i,t}$):

$$surprise_{i,t} = \frac{RVol_{i,t}}{vol_{i,t-1}^{impl}} \quad (7)$$

For the four market indices, the surprise measure is inserted as dependent variable in Equation (1).

2.5 Descriptive statistics

Starting with the introduction of the euro, the paper examines a period longer than 20 years to establish whether there is a persistent trend irrespective of financial crises. This contributes to the field as most related studies begin their analysis from 2007 onwards (e.g., Fratzscher et al., 2016; Georgiadis and Gräb, 2016; Sosvilla-Rivero and Morales-Zumaquero, 2012). The data availability varies across the countries and measures, meaning that one has to interpret the long-term results with caution. Specifically, data for $range_t$, $vol_{n,t}^f$, and implied volatility are available between January 1999 and December 2019, while the observations of RV_t start in January 2000. The ECB issued monetary policy announcements on 308 days from January 1999 until December 2019.

The visual representation of the applied dependent variables appears stationary. Figure 1 serves as an example for the German stock market. The other assets' series are not reported because they behave similarly. All measures show a similar pattern. For instance, they peak during the Dotcom bubble in 2001 and during the financial crisis in 2008. The volatility has declined since 2010 and has exhibited lower volatility peaks in the recent past. The advantage of realized volatility over the range measure is that intraday data should better proxy the behavior of the financial market during an announcement day. Nonetheless, the subsequent results are very similar for both specifications supporting the use of the range measure as a proxy.⁷ Moreover, the range measures are highly correlated with their respective realized volatility counterparts (correlation coefficients around 0.78 for all indices except for Finland whose is only 0.42).

[Figure 1 about here]

Since the augmented Dickey Fuller (ADF) unit root test is rejected it is deemed appropriate to work with level data of the constructed measures in Section 2.1 through Section 2.4.⁸ In contrast, the ADF test for the MSCI does indicate integration of order 1. Therefore, its (logarithmic) first-differences are justified. The Breusch-Godfrey and White test indicate autocorrelation and heteroskedasticity, respectively, in this data set. To deal with these properties,

⁷In fact, when comparing the regression coefficients of $RVol_t$ to those of $range_t$ by country, they are qualitatively similar. Table A3 in the appendix shows the regression output of the 16 markets for which both volatility measures are available. It considers the same period (2000-2019) and thus number of events. The similar relative announcement impact supports the choice of $range_t$ as an appropriate proxy for $RVol_t$.

⁸Using first differences or growth rates slightly deteriorates the significance of the results (available upon request). However, the overall results remain unchanged, confirming the subsequent conclusions.

the standard errors follow Newey and West (1987)⁹.

The correlation coefficients of the dependent variables in Table A4 in the appendix give additional insights. Due to the larger sample, the discussion that follows focuses on the coefficients of $RVol_t$, however, the relationships are similar for those of $range_t$ and $vol_{n,t}^f$. The positive signs throughout the correlation coefficients indicate that European markets move in the same direction. Therefore, all stocks should be affected in the same direction as well – merely the extent differs, which this paper aims to identify. Specifically by exploiting a large cross-section the paper intends to test for groups that are more sensitive to the ECB announcements than others. Building on the established research on government bond yields, which are highly intertwined with stock prices, one expects more intense impacts in periphery markets than in core markets. Comparatively low effects should appear in non-EA markets taking into account that they should rather react to communications of their own central bank. There still should be a difference between non-EA countries. For example, one expects a more pronounced response of the Danish stock market because Denmark is part of the EU for a longer time as compared to the Bulgarian stock market or markets outside Europe like Japan. Varying cross-European correlation coefficients ranging between 0.6 and 0.9 motivate an evaluation of distinct effects across different markets. For instance, high coefficients around 0.9 exist for German vis-à-vis Dutch and French stock markets whereas the market of Finland has a correlation lower than 0.7 with respect to the other assets. The coefficients also indicate spill-over effects. In general, the correlations are higher for European markets. While Japan has relatively low coefficients the market of Great Britain seems to show a similar volatility behavior with respect to the stock markets of core countries (around 0.8).

3 Results

The first part presents the findings for the full sample to quantify the overall effect. Subsequently, the data are split up into different periods. Finally, several robustness checks support the validity of these findings.

⁹The maximum lag length in the autocorrelation structure is adjusted according to the Bartlett Kernel with $T^{\frac{1}{3}}$ for each regression.

3.1 Long-term period

Table 1 displays the results of the realized volatility specification explained in Section 2.1 for 8 EA and 8 non-EA stock market indices for the full sample. It further differentiates between three scenarios: (1) scheduled board meetings days $scheduled_t$, (2) scheduled board meeting days versus unconventional monetary policy announcements ($scheduled_t, UMP_t$) and (3) scheduled board meeting days joint with unconventional monetary policy announcements ($policy_t$).¹⁰

[Table 1 about here]

The board meetings in the first column significantly boost realized volatility in all EA and most non-EA markets. Italy shows an elevated magnitude while the other EA markets seem to be equally affected with similar estimators and significance levels. For instance, a board meeting by the ECB increases DE by around 60 basis points (bps), on average. This translates to a 60 per cent higher volatility level in terms of standard deviations. However, there is a discrepancy between both groups: While the realized volatility is highly affected in EA countries with estimators at a 1% significance level, non-EA markets are less affected. The estimators of the Japanese and U.S. Dow index are even insignificant. When enlarging the event set from $scheduled_t$ to $policy_t$ (fourth column) the British market becomes less significant while the US Dow market becomes more significant. For the other markets, only the coefficients' magnitude changes slightly. As more than half of the unconventional announcements happen on scheduled meeting days the similar result is not surprising. However, disentangling the events (second and third column) shows that UMP_t per se only affect the volatilities of some markets. Unconventional monetary policy announcements do spill over to a few non-EA markets (CH, DK).

Consequently, the previously stated hypothesis $\gamma > 0$ is confirmed. New information itself seems to increase assets' volatility. Traders are presumably nervous because they expect new information from the ECB, typically a change in the monetary policy stance. They react accordingly – independent of the actual message of the respective press release. This reaction induces more trading activity which is reflected by an increased volatility during those days.

¹⁰The following tables only display the estimated coefficients of the dummy variables for the sake of clarity. Note that the control variables are highly significant. Table A5 in the appendix serves as an example. The complete output tables are available upon request. Due to time differences the dummy is adopted for the Japanese and U.S. market. Since Japan is eight hours ahead of Europe, its dummy variable takes the value of 1 one day after an ECB announcement. In contrast, the dummy variable takes the value of 1 before the day of an ECB announcement in the U.S. considering that in New York it is six hours later than in Frankfurt.

In sum, no striking differences among the countries can be claimed. Their stock market indices react similarly to monetary policy announcements. Figure A1 in the appendix confirms a similar reaction by sorting and plotting the respective t-statistics of the dummy variable $scheduled_t$. No distinct pattern such as core/periphery or EA vs. non-EA can be established. This seems to be reasonable because most ECB press releases concern the entire EA. Even stock markets which do not belong to the EA show significant responses, highlighting the role of the ECB's communication for global financial markets.

Table 2 depicts the result of the range specification introduced in Section 2.2 for each asset under consideration. In line with the realized volatility measure, the estimators are very similar in size and significance indicating an equal impact across the EA countries. Except for Greece and Ireland – which are special cases in light of the European debt crisis – every country's stock market index is influenced by the ECB announcements. Greece and Ireland are deeply indebted so that national news determine asset volatility rather than information released by the ECB. A highly significant and positive estimator implies that a monetary policy announcement increases the asset volatility on that day for the respective stock market index. For instance, a board meeting by the ECB increases the daily price range of the German index by 40 bps, on average.

[Table 2 about here]

Compared to realized volatility, there are also substantial spill-over effects. Interestingly, there are diverse reactions in Eastern European markets. While the Czech and the Polish stock markets have a higher volatility on ECB announcement days, the Bulgarian and the Hungarian stock market are unaffected. One explanation might be that the latter markets are less financially integrated with the EA. This highlights the heterogeneity of European stock markets and their reaction to ECB communication. Figure A2 in the appendix sorts and plots the respective t-statistics of the dummy variable $scheduled_t$. Interestingly, the highest values belong to core countries (EU, FR, DE, FI, NL). However, the differences across the markets are too small to claim substantial differences.

The price range in most non-EA countries increases to a similar (statistical) degree in response to the ECB's announcements. On the one hand, these spill-over effects stand to reason in light of highly intertwined global financial markets activity. On the other hand, despite its particular role during the European debt crisis it is puzzling that the Irish and Greece stock markets do not seem to react to the ECB's releases whereas even the non-European U.S. Dow market

shows an increased volatility for $policy_t$. Communication by other central banks potentially biases the results hinting at spill-over effects that could originate from reactions to news from their domestic central bank. One can evaluate this a minor risk as scheduled announcements by major central banks typically do not coincide (Brusa et al., 2019).

Table 3 shows the result of the future volatility specification defined in Section 2.3 using a 20-day forward looking window.¹¹ One can only detect spurious effects in some markets. Hence, while the ECB announcements increase the volatility on the same day, the future development of volatility does not seem to be affected by such communication. Merely unconventional announcements reduce future volatility in a few EA markets.

[Table 3 about here]

Table 4 shows the results of the 4 implied volatility measures described in Section 2.4. Considering the level values in the top, implied volatility decreases on ECB board meeting days for all markets. This means that the ECB announcements conveyed a clear message so that market participants' expectations change significantly in response to the ECB's press releases. However, looking at UMP_t all markets are unaffected. This is an argument that unconventional announcements were made especially for distressed countries because markets in the Netherlands, Germany, and France are unaffected. Distressed economies could be affected, though. Unfortunately, implied volatility measures of distressed economies are unavailable to test for it. The price ranges values in the second part of Table 4, by contrast, increase in response to ECB announcements. The values of the future volatility give an ambiguous picture: the VAEX slightly reduces on announcement days, while the other three markets are unaffected.

Overall, the ECB announcements reduce implied volatility but increase the price range of the implied volatilities. The surprise measure suggest that ECB announcements reveal more information than investors anticipated on the day before the announcement takes place. However, given the limited availability of only 4 markets, one has to refrain from deducing a specific claim. In conclusion, only the first two volatility measures (realized volatility and price range) show consistent effects throughout the markets. The analysis that follows therefore concentrates on those volatility measures.

¹¹A standardization of $vol_{n,i,t}^f$ is not sensible because the standard deviation of future values incorporates neighboring trading days and therefore already implicitly controls for the current trend. A standardization of a measure based on future values with the values of the past trading values would confound and bias the forward looking character intended for this volatility measure.

[Table 4 about here]

3.2 Comparison of different periods

The statistically significant effect of announcements on stock market volatility since the financial crisis possibly outweighs the pre-crisis period. After the outbreak of the financial crisis in 2007, financial markets have tended to be more responsive to central bank announcements. In particular, market participants have become more receptive to new information, which increases the impact of monetary policy communication on volatility. To test this hypothesis, this section estimates two distinct regressions and compares them to detect whether there is a different pattern/perception before and following the financial crisis. Therefore, the data are split up into two sub-samples. Since the financial crisis comprises several events, it is hard to find a clear-cut date when the crisis actually starts; hence, a certain degree of arbitrariness remains irrespective of the date one chooses. Following Fausch and Sigonius (2018), August 22, 2007 is regarded as the beginning of the crisis period. Accordingly, the pre-crisis period lasts from January 1999 (January 2000 in case of realized volatilities) to August 21, 2007 and the post-crisis period¹² starts on August 22, 2007 and ends in December 2019.

Following ter Ellen et al. (2020), another specification takes the effective lower bound (ELB) as a turning point starting on July 6, 2012 to create two distinct sub-samples. The post-crisis period of the first specification might be biased because the effects could be entirely driven by announcements during the global financial crisis. To tackle this concern, an explicit comparison of the crisis period (2007-2012) with the following period (2013-2019) is necessary. The latter period is further disentangled to assess the effects during the zero lower bound (ZLB). Hence, the sample is split up on March 16, 2016 when the main refinance rate was lowered to zero percent.

Table 5 presents the results for the realized volatility measure of these four specifications: (1) pre-crisis versus post-crisis, (2) effective lower bound, (3) crisis vs. following the crisis, and (4) zero lower bound.¹³ The vertical lines in Figure 1 illustrate the assignment into those periods for the German stock market. The first specification (columns 1 and 2) demonstrates that communication effects before the financial crisis only appear in certain markets, whereas in the

¹²This term demarcates the period before and after the outbreak of the financial crisis. In this context post-crisis does not mean that the crisis has terminated during this period.

¹³To enhance readability, the following tables only display the results of the dummy $scheduled_t$. The results for the other event sets are very similar and available upon request.

period that follows all markets are affected (including spill-over effects). The second specification (columns 3 and 4) further reveals that volatility effects are stronger with the start of the ELB as significance levels and magnitudes are higher in the post-ELB period. The third specification (columns 5 and 6) highlights that announcements effects are persistent after the recovery of the European economies. Following the crisis, the coefficients are even higher compared to the crisis period. The fourth specification (columns 7 and 8) shows a decreasing influence of ECB announcements during the ZLB (magnitude of coefficients in column 8 lower than in column 7). As the main policy instrument is already at its limit, the communication of the ECB has less leeway to surprise the markets. In sum, stock market volatility is especially responsive to ECB communication during and following the financial crisis but not before the outbreak of the global financial crisis. There are multiple reasons for the more pronounced announcement effects since the financial crisis: Market participants have become more attentive to new information, investors have achieved a better understanding of the announcements, the way of communication by the ECB has been adjusted (e.g. tone, provided details), announcements have become more/less predictable, or the economic and financial environment has changed. The study cannot rule out either reason, possibly a combination of all aspects matters.

[Table 5 about here]

Table 6 presents the results for the daily price range of the different periods. They are similar to the realized measure so that the above conclusions hold. Lower significance levels and magnitudes still support a more pronounced impact after the outbreak of the financial crisis. The significance level is lower in all EA markets in the pre-crisis compared to the post-crisis period (exception FI). The quantitative influence of an announcement is higher following the financial crisis. For instance, the daily price range in the Dutch and French market almost quadruples in response to an announcement: 82 bps and 99 bps following the crisis (column 6) compared to 21 bps and 25 bps before the crisis (column 1), respectively. Apart from the significance in the case of Ireland, the post-crisis period's results in the second column correspond qualitatively to the full sample displayed in Table 2.

[Table 6 about here]

One might argue the asset volatility increases in general following the financial crisis. The results suggest that press releases by the ECB are one factor that contribute to this fact. However, Figure 1 indicates the contrary having lower peaks since 2013. In a similar vein, the

VSTOXX, a measure of the implied volatility in Europe, shows a negative trend for the sample period (see Figure A3 in the appendix). In addition, ECB (2017) emphasizes that favorable market developments across global economies have led to low levels of equity market volatility and yields in advanced economies. Having said that, the increasing sensitivity of the volatility to announcements is astonishing. A possible explanation could be that the overall volatility decreases, but those changes in volatility attributable to monetary policy announcements increase over time.

It is worth emphasizing that the non-significance in the pre-crisis period is not due to the number of events. The number of pre-crisis events ($RVol_t$: 116, $range_t$: 139) lies between the long-term period (RV_t : 244, $range_t$: 267) and the post-ELB period (68 for both RV_t and $range_t$), which exhibit both high significance levels. Although following the crisis fewer press releases occur during a longer period, these announcements affect the asset's volatility more markedly than those before the crisis. Moreover, the application of randomly drawn events in Section 3.3 demonstrates that the timing and not the quantity of events matters.

This finding is backed when splitting up the sample into three distinct periods that take into account the frequency of scheduled meetings. Let us consider only scheduled meetings, $scheduled_t$, as only those reflect the change in the communication strategy, whereas unscheduled announcements could be involuntary reactions to current developments. Meetings happen every two weeks (1999-2001), every four weeks (2002-2014), or every six weeks (2015-2019). Differentiating periods of 3 years (2 years in case of $RVol$), 13 years, and 5 years, respectively, this imbalanced separation is not ideal to compare. However, the results displayed in Table A6 and in Table A7 in the appendix convey a clear message. In the short period with announcements happening every two weeks, hardly no effects emerge, which is reasonable as this period belongs to the pre-crisis period. Despite the reduced number of scheduled meetings, the EA markets have higher estimated coefficients between 2015 and 2016 compared to the period with monthly scheduled meetings (2002-2015). Interestingly, spill-over effects to non-EA markets diminish in the six-week cycle. Overall, one cannot claim that the policy change of the ECB to reduce the number of scheduled meetings calmed down stock market volatility – even the contrary seems to hold for the EA markets.

3.3 Robustness checks

This part presents several robustness checks. Specific output tables for each robustness check are omitted to conserve space and are available upon request. The current economic conditions could influence how central bank announcements are perceived on financial markets. In times of economic turmoil, monetary policy announcements presumably drive the volatility of financial markets more than in times of an economic boom. The full-time regressions are compared with the scenario of only considering announcements during a recession. Similar to the task of determining the start (and the end) of the financial crisis, an unambiguous method to declare a period as a recession or expansion is hard to determine – in particular when comparing several national markets. Based on the OECD Composite Leading Indicators, which identify troughs and peaks for the EA, the Federal Reserve Bank of St. Louis suggests a classification of recession periods.¹⁴ A recession dummy takes the value of 1 during a recession, and 0 otherwise. This recession dummy interacts with ECB_t so that only announcements during a recession are considered. Counterintuitively, markets do not react more sensitively to announcements that take place in a recession. By contrast, the coefficients of the original specification are higher for most markets. Merely in the case of $RVol_t$, the UMP_t dummy shows higher coefficients for the recession specification (while the results for $range_t$ are mixed). Hence, economic conditions are not the main driver of financial market reactions to the ECB announcements.

There are many monetary policy announcements other than policy rate decisions.¹⁵ To guarantee an objective choice of announcements, one might include every press release on monetary policy from the ECB's homepage, independent of its specific decision. Thus, the number of events increases from 267 to 345. This approach is in line with studies like Brusa et al. (2019), which exclude unscheduled announcements and rely on central banks' websites as the only source of announcements. Consequently, information on forward guidance, asset purchase announcements, interest rates, legal regulations and so forth are all equally weighted. Additionally, following Collingro and Frenkel (2019) another robustness check adds ECB's macroeconomic announcements (ECB Bulletin) to the scheduled announcements, which results in a total number of 497 events. In both cases the results remain qualitatively unchanged compared to the smaller event set of board meetings. Interestingly, when only considering the ECB's unconventional announcements that do not overlap with board meeting days no volatility re-

¹⁴See Federal Reserve Bank of St. Louis (2020). For the sample of this paper, a recession is present in 01/1999, 03/2001-06/2003, 03/2008-06/2009, 06/2011-03/2013, and 12/2017-12/2019.

¹⁵See <https://www.ecb.europa.eu/press/pr/activities/mopo/html/index.en.html>.

action appears in any market. A final test also includes all identified announcements into one single dummy $ECB_communication_t$ consisting of 613 events. The overall effect is similar to the scheduled announcements, albeit the estimated coefficients become smaller, most probably because of several events that are not as relevant as board meeting dates and therefore dilute the financial market effect. To summarize, scheduled announcements are dominating financial market effects and non-scheduled announcements as well as monthly Bulletin releases are negligible as they do not show an effect on their own.

ECB's communication is very present also outside scheduled meetings. ECB's representatives regularly give speeches in public. Roughly every three trading days comprise a speech by an ECB board member.¹⁶ Even if one considers speeches only by the ECB's president, 613 event dates remain for the examined sample, i.e. the same number as considering all monetary policy press releases and Monthly Bulletin dates together. Including all 613 events in one dummy, this dummy is insignificant for all markets for $RVol$ and $range$ so that a speech by the president of the ECB on its own does not have an impact on market volatility. A topical distinction of these speeches would require a thorough textual analysis, which is outside the scope of this paper.

Further disentangling the events according to their type of announcements, for example focusing only on asset purchase program announcements, gives additional insights. Fendel and Neugebauer (2019) suggest 26 crucial asset purchase announcements APA_t .¹⁷ On the one hand, APA_t of realized volatilities has weaker significance levels than ECB_t . This result underpins that every announcement by the ECB concerns asset volatility – regardless of its specific content. On the other hand, for APA_t of price ranges Austria and Belgium are unaffected while the other countries' coefficients are higher compared to ECB_t . If events are restricted to asset purchase announcements, they affect some price ranges stronger whereas they affect two countries and the realized volatilities weaker than in ECB_t .

The significant response on ECB announcement days could be pure coincidence. Therefore, randomly drawn dates are assigned to a dummy variable $random_t$ instead of using the respective number of ECB announcement dates. No market index is significant in any volatility measure. Even after multiple iterations of any randomly chosen event set, merely one or two stock indices occasionally become significant. This result stresses the appropriateness of ECB announcements

¹⁶In the sample period, speeches by ECB board members happen on 1742 days. Overall, 2297 speeches are listed on the ECB's homepage because on many days several speeches take place.

¹⁷Refer to Table A1 in Fendel and Neugebauer (2019) for an overview of all relevant events. Note that for this specification the observation period ends in August 2017.

as a contributor to assets' volatility and underlines the non-negligible impact of the ECB's press releases.

Markets potentially need some time to digest new information or reversely even react in anticipation before an announcement is made. The former motivates studies to use two-day event windows (e.g., Altavilla et al., 2016; Brusa et al., 2019). On the contrary, the content of an announcement sometimes becomes apparent even before its release. Cieslak et al. (2018) detect effects of informal communication of Fed officials with market participants prior to scheduled meetings. Lucca and Moench (2015) find large average excess returns in the U.S. equity market in anticipation of those meetings. For this purpose, the dummy ECB_t is adopted to ECB_{t-1} and ECB_{t+1} to account for a one day anticipated and delayed effect. Only a few anticipated effects appear. Similarly, significant delayed effects exist only for the price ranges of Italy, Portugal, VDAX, and VSTOXX and for the realized volatility of the U.S. whereby the last three possess a positive sign. Investors seem to become calmer in the first and more nervous in the latter markets one day after an ECB's press release. However, these minor delayed effects are negligible. Hence, the hypothesis of market efficiency generally holds meaning prices and quantities immediately adjust after a policy announcement.

A related concern states that financial markets should be especially uncertain before important decisions, which would lead to a higher volatility before scheduled meetings. Another test therefore uses lagged values of one day or two days as dependent variables, i.e. $vol_{i,t-1}$ or $vol_{i,t-2}$ enter on the left side of Equation (1). The idea is the following: Since investors are eagerly awaiting the scheduled monetary policy announcements, stock market volatility should be especially elaborated just before an announcement takes place. It turns out that there is no significant announcement effect on $vol_{i,t-1}$ or $vol_{i,t-2}$ for any specification; the volatility level is not higher a few trading days before an announcement as opposed to a regular trading day. Hence, one can deny an increase in volatility before ECB announcements – at least for the measures and framework employed in this analysis. Financial markets rather react to news released by the ECB rather than to rumors just before monetary policy communication days.

Given the significance of the lagged dependent variable as explanatory variable (cf. Table A5), another robustness check allows for multiple lags. The lagged dependent variables stay highly significant until the third lag. Most importantly, employing lagged values of up to 5 trading days does not modify the results. A lagged structure for a longer time span seems inadequate. Although past volatilities play a role in the present volatility, they do not challenge

the findings of the detected announcement effects on stock market volatility.

One might argue that the similar results of $Rvol_t$ and $range_t$ could be a coincidence and that $range_t$ would measure a level rather than a volatility effect. In the hypothetical case when there is only one big price movement, $range$ would indeed just measure a level effect and suggest a higher volatility than in the case of multiple small price changes. To show that the price range depicts more than level effects, let us consider an indisputable level measure: the difference between the closing and the opening price, i.e. $diff_{i,t} = p_{i,t}^{close} - p_{i,t}^{open}$. This measure summarizes the level effect of the trading day. Interestingly, when inserting $diff_{i,t}$ as dependent variable in Equation (1), the coefficients of ECB_t are insignificant for all analyzed markets. The estimated coefficients of $range_t$ and $diff_t$ are therefore incomparable. This exercise highlights that $range_t$ captures more than just a level effect and acts as a suitable approximation for volatility.

Regular monetary policy meetings usually take place on Thursdays. Many but not all events included in ECB_t coincide with this day of the week. For this purpose an additional dummy $Thursday_t$ is added to control for a general effect of this day, taking the value of 1 on each Thursday, and 0 otherwise. Testing for the Thursday effect in general, that is replacing ECB_t by $Thursday_t$, the coefficients are lower compared to ECB_t , and Austria becomes insignificant. Regarding realized volatilities, the coefficients of the Dutch, French, German and European market have a lower significance level. Hence, only considering Thursdays slightly reduces the impact on volatility. The last tests considers both effects, ECB announcements and Thursdays. To prevent double accounting, the dummy is adjusted to $adj_Thursday_t$, which only takes the value of 1 on Thursdays when there is not an ECB announcement on the same day. Despite the inclusion of $adj_Thursday_t$ the coefficients of ECB_t are still highly significant at a similar magnitude. Only six coefficients of $adj_Thursday_t$ imply a Thursday effect on its own. Neither of the range or realized volatility measures react in the EA except for the Italian $RVol_t$, which requires a cautious interpretation due to limited data availability. In sum, the ECB announcements raise volatility while a Thursday effect is negligible.

An inspection of Figure 1 suggests many peaks and one cannot exclude that findings could be influenced by outliers. Therefore, the raw data that are used to construct the volatility measures are winsorized at the 5th and 95th percentile. The results are qualitatively unchanged to such a data cleaning.

The country-specific control variable $MSCI_t$ is replaced by several global alternative mea-

tures.¹⁸ They impose that national indices are insufficient controls as financial developments across Europe and the world come into play. The MSCI Europe Index and the MSCI World Index are broad global equity indices comprising 15 and 23 developed countries, respectively. Following Georgiadis and Gräb (2016) the Citigroup Economic Surprise Index for the Eurozone (CESI) covers weighted historical standard deviations of macroeconomic data surprises. The surprises are constructed as the difference between consensus expectations and economic releases. The V2TX index is based on Eurostoxx 50 realtime option prices and reflects market uncertainty in Europe. Applying those controls and multiple combinations of them the results persist. The coefficients' magnitude and significance level remain stable. The same holds for the application of the daily surprise and uncertainty indices by Scotti (2016). The country-specific MSCI indices are preferred because they are available for a longer period compared to the other control variables (cf. Table A2). There is no double accounting problem when using national instead of global measures as control variables because the results are invariant to the implementation of CESI and MSCI World.

4 Effects on subsequent days

ECB communication may not be limited to same-day effects but also influence stock price volatility the next days. Investors might be interested in the persistence of stock market volatility following ECB announcements. To test for this, the present volatility measure is replaced with the cumulative future values over the next 1, 3, 5 and 10 days, respectively. If there are still significant effects, one can claim that the ECB communication triggers uncertainty in stock markets.

Equation (1) changes accordingly to

$$\sum_{l=1}^m vol_{i,t+l} = \alpha_i + \beta_{i,j} \sum_{j=1}^4 X_j + \gamma_i ECB_t + \varepsilon_{i,t}, \quad (8)$$

with $m = 1, 3, 5$, and 10 giving the horizon of the aggregated future volatility.

Table 7 displays the results of Equation (8) for the realized volatility measure. Future cumulated realized volatility reduces for the 3, 5, and 10 days horizon. For instance, an announcement made this day decreases the Italian future volatility in total by 110 bps for the next 10 trading

¹⁸Since the global indices are available for a shorter period, the following robustness checks refer to a shortened period starting in 2003.

days. This means the increased volatility on an announcement day reverts the following days, which hints at an information processing of financial investors: Once the market participants digested the new information, the markets calm. Spill-over effects appear mainly at the 3-day horizon.

The results of Equation (8) for the price range measures can be found Table 8. Negatively significant coefficients exist for most EMU markets at a 3 to 10 days horizon. The markets of Ireland and Greece do not revert back as these markets are not affected on the announcement day, which backs the previous results. The extent of price range reduction seems to reflect the country's solvency rating. The lower the rating is, the more elaborated is the decline in (aggregated) future volatility. Take the stock markets of Germany and Italy at a 3-day horizon as an example. The price range decreases by around 39 bps in the German market and by around 55 bps in the Italian market. To summarize, while there is an immediate increase in volatility for both volatility measures on the day of announcement (cf. Table 1 and Table 2), in turn the cumulated future volatility at the horizons from 3 to 10 days declines (cf. Table 7 and Table 8). It is worth emphasizing that the decrease in volatility from 3 days onward is not caused by a week-end bias because the analysis only considers trading days. Moreover, a Thursday effect is ruled out in Section 3.3.

[Table 7 and Table 8 about here]

5 Asymmetric effects: positive versus negative announcements

So far, all information provided by the ECB is taken into consideration in an equal way. From a policy perspective, it is interesting whether the type of announcement determines the volatility reaction. Economic reasoning such as the prospect theory (Kahneman and Tversky, 1979) suggests that investors are more responsive to negative news than to positive news. However, the empirical evidence is mixed. Bomfim (2003) finds that positive surprises of the target federal funds rate has larger effects on the US stock market volatility than negative surprises. Ferreira and Gama (2007), on the contrary, discover that only negative but not positive sovereign debt rating news spill over to international stock markets. Altavilla et al. (2019) state that "euro area financial market participants do not perceive monetary policy effects to be asymmetric with respect to positive surprises and negative in providing asset price responses" (p. 164).

To contribute to this discussion, this section classifies each announcement as positive, nega-

tive, or neutral. Related studies use textual analysis to assign the announcements.¹⁹ In contrast, this study takes financial market reactions as determinants. Different time series are suitable to classify the type of event. On the one hand, the daily change in sovereign yields on the announcement day, more specifically the average of the analyzed national EA markets determines the ECB communication. A decrease in yields implies a reduction of the risk premium and therefore represents positive news whereas a yield increase stands for negative news. On the other hand, the daily change of the MSCI Europe is chosen because an accommodative announcement is likely to raise stock market prices.²⁰ An increase in the MSCI translates into positive news. The analysis that follows use the MSCI changes as a classifier because sovereign yields as determinant will be discussed in more detail in Section 6.

The paper makes two distinctions. First, the dummy is split up into a positive and a negative dummy according to the sign of the classification measure. Second, the dummy is split up into a positive, a negative and a neutral dummy. Events are classified as neutral if on that date the determinant lies in the 20 percent percentile around the median (i.e. 10 percent below and 10 percent above, the median is very close to zero for the determinants). Values above this range result in positive news and values below mean negative news. Table 9 and Table 10 present the results with dummies that (1) differentiate between positive and negative news and (2) positive, negative and neutral news. Both tables demonstrate a higher effect for negative news than for positive news. This relationship persists when introducing neutral news. However, while in Table 9 neutral news and positive news have similar effects, neutral news has almost no influence for the price range measure in Table 10.

[Table 9 and Table 10 about here]

6 Weighting the individual announcements

The event set comprises monetary policy decisions that differ in many dimensions. The announcement made on March 7, 2019 when the "Governing Council [...] expects the key ECB interest rates to remain at their present levels *at least through the end of 2019*", has a different qualitative meaning compared to the announcement on November 4, 2010 when the Governing Council of the ECB decided to keep interest rates unchanged without any explicit time

¹⁹There is a growing literature that uses dictionary-based methods to assign a value to central bank statements. See Armelius et al. (2020) as a recent example.

²⁰The use of the average of the first-differences of the MSCI indices of the EA markets under consideration instead results in a very similar classification of the events.

frame. Announcements not related to the interest instrument are harder to classify, for example the Federal Reserve and the ECB agree on a swap arrangement up to \$50 billion on September 13, 2001. Some announcements are more technical as on March 22, 2013 when the ECB announces changes to the use as collateral of certain uncovered government-guaranteed bank bonds.

Instead of screening the released information by its content, this section uses financial data to weight the relevance of an announcement. There is a large body of literature that uses high-frequency data to deduce monetary policy shocks. For instance, Rogers et al. (2014) compare the reaction to announcements by four major central banks using tight windows of 15 minutes before and after the event. Cieslak and Schrimpf (2019) rely on equity and interest futures to construct shocks around a comprehensive set of communication events appertaining to those banks. Unfortunately, this type of data is not available for all assets and the time span under consideration. Nevertheless, the paper adopts this idea to the daily data set.²¹ Other events taking place during that day could confound the measure. Since government bond yields are particularly responsive to central bank communication and less susceptible to non-monetary news, this is considered as an acceptable risk. Gürkaynak et al. (2005) support this view by claiming that "the surprise component of monetary policy announcements can be measured very well using just daily data" (p.66) and "estimated coefficients do not differ greatly across the intraday and daily regressions" (p. 68). Consider the first-differences of the 10-year government bond benchmark yield of each analyzed EA country (obtained from Datastream, cf. Table A2 in the appendix). These changes are then regressed on realized volatility. The (equally-weighted) dummy ECB_t is refined by letting it interact with the particular change in yields, $sovereign_t$, on the respective announcement day. More specifically, the model takes the yield change in growth rates in order not to overestimate a market with a high sovereign yield level or to underestimate a market with a low yield level. Thus, Equation (1) becomes

$$vol_{i,t} = \alpha_i + \beta_{i,j} \sum_{j=1}^4 X_j + \gamma_i \Delta sovereign_t \times ECB_t + \varepsilon_{i,t}, \quad (9)$$

The paper uses two specifications. The first specification takes the absolute value of $sovereign_t$ because the direction of the surprise should not matter for the volatility. A restrictive and an

²¹The event set provided by Altavilla et al. (2019) offers intraday changes only for the sovereign yields of Germany, France, Italy, and Spain. Using the values for the 10-year maturity for each the press release, the press conference and the monetary event window, it turns out that the results resemble the findings above that use unweighted dummies. The four markets show highly significant coefficients with similar magnitudes.

expansive policy announcement should similarly affect stock market volatility. Hence, the extent to which the announcement shifted the respective government bond yield enters in Equation (9). This approach to assess the sensitivity rather than the sign of yield changes is consistent with current work (e.g., Cieslak and Schrimpf, 2019). The second specification keeps the sign of the yield change to test whether the direction matters for volatility. To weight the announcements for non-EA markets, a simple average of the eleven EA yields is taken into account.²²

Table 11 shows the results for the realized volatility measure with the yield interaction as defined in Equation (9).²³ As opposed to the unweighted specifications above, the markets show quite a heterogeneous reaction. While the Italian and Spanish stock markets stand out by having highly significant estimated coefficients of around 3,000 bps, the German and the Finish market are not affected anymore. This implies that markets of periphery countries are relatively sensitive to the ECB announcements whereas core markets show comparatively moderate volatility effects. Table 12 confirms this finding based on the price range with Portugal belonging to the most affected markets. Hence, assuming that bond markets reflect how ECB announcements are perceived by market participants, stock markets do show quite a heterogeneous picture. Spill-over effects are negligible; however, one should bear in mind that an average yield change applied to non-EA countries is not equivalent to the country-specific yield changes applied to EA countries, which impairs a comparison of the two country groups in this setting.

[Table 11 and Table 12 about here]

7 Discussion of main findings

Considering multiple volatility measures, this paper sheds more light on the understanding how central bank communication affects stock market volatility. While the volatility on the announcement day increases (measures of realized volatility and price range), the announcements do not move the future volatility measure. Regarding the implied volatility measure, there is a

²²The paper refrains from constructing a weighted average (e.g. according to GDP, market size) for the following reason. Due to the long observation period one would have to adjust the weights over time. The frequency of this adjustment is arbitrary especially in light of daily data and weights deduced from lower frequency data. In case of $range_t$ the yield of Greece is excluded in the calculation of the yield before April 1, 1999 due to data unavailability. As a robustness check, the average yield change is also assigned to the shock of EA markets. The results (available upon request) are almost identical.

²³Only the first specification taking the absolute growth rate is presented in the following. Interestingly, if one applies the second specification that keeps the sign, none of the estimated coefficients of the announcement dummy is significant. A possible explanation for this puzzling finding could be that negative and positive values within the dummy cancel out each other. In any case, it is more sensible to apply absolute values because the volatility measure to be estimated cannot be negative by definition.

decrease of the level values on an announcement day, but an increase of the surprise measure (past implied volatility related to present realized volatility). Having a look at the cumulated volatility on the subsequent days after an announcement, significantly negative estimated coefficients suggest a mean-reverting process. On the announcement day, the surprising effect prevails, presumably because the content does not meet the anticipated expectations. The analysis cannot deduce the exact cause for this result, e.g. an imprecise communication style, without further screening the announcements' wording. After the market participants have digested the new information, the stock market volatility reduces the next days due to the new information given by the ECB.

Figure 2 illustrates the main findings of this paper by means of the price range measure. The upper left panel (a) presents the estimated coefficients of the unweighted dummy $scheduled_t$ sorted by size (cf. first column in Table 2). The EA markets on the left show mainly similar magnitudes. However, the reactions of AT, PT, IE and GR are substantially lower than most market reactions of non-EA markets on the right. In contrast, the estimated coefficients of a weighted dummy $scheduled_t$ presented in the upper right panel (b) show a completely different pattern. High price range reactions in periphery markets (IT, ES, PT) dominate, while in the other markets only negligible announcement effects appear (cf. first column in Table 12). If one considers each announcement equally, the stock market volatility reacts similarly comprising substantial spill-over effects. If one weights each announcement according to market-specific reactions as the determinant, in turn, a few EA markets stand out while the other markets seem unaffected, such that spill-over effects do not exist in this specification.

[Figure 2 about here]

The lower left panel (c) confronts the estimated coefficients of the pre-crisis period with those of the post-crisis period (cf. first two columns in Table 6). The announcement effects dominate after the global financial crisis for both EA markets on the left and non-EA markets on the right. For instance, the announcement effect more than doubles for BE, DE, ES, FR, NL, PT, PL in the post-crisis period with respect to the pre-crisis period. The lower right panel (d) compares the coefficients when splitting up the announcements into positive monetary policy news and negative monetary policy news (cf. first two columns in Table 10). This task highlights an asymmetric market reaction to the communication of the ECB. Negative news provoke more pronounced volatility effects than positive news in the majority of markets (exceptions: FI,

PL, US_Dow, US_SP). This finding is consistent with the finance literature (e.g., Epstein and Schneider, 2008). Still both news types work in the same direction, i.e. they increase stock market volatility on the announcement day.

This study has a comprehensive character with a long time span and multiple markets analyzed. Moreover, it combines two dimensions of central bank communication. On the one hand, the selection of the announcement days represents the sending side, i.e. the aspect a policymaker can control. On the other hand, the study also covers the recipient side in Section 5 and in Section 6, which is out of the control of a central bank. Instead of an indirect measure of the recipient's reaction such as media coverage, the paper uses financial market measures as determinants. They reflect the reaction in a more direct way because they refer to actual responses (e.g. buying/selling of a bond that moves the sovereign yields in Section 6).

The econometric framework (OLS with robust standard errors) fits to the present research question: the announcement effects of ECB communication on stock market volatility. However, the volatility measures presented in this paper could be used for further exercises, which require other approaches. For instance, if one wants to shed more light on the persistence of announcement effects, the local projections framework proposed by Jordà (2005) could be a suitable path. In order to explicitly investigate the direction of forecasting, a GARCH approach (Bollerslev, 1986) or the use of a HAR-RV model introduced by Corsi (2009) are possible methods.

8 Conclusion

This study evaluates the influence of ECB announcements on asset price volatility in the EA between January 1999 and December 2019 with the help of several volatility measures. First, a realized volatility measure is based on intraday data for 8 EA stock market indices and 8 non-EA markets. Second, a price range measure approximates volatility using daily prices from key national stock market indices of 12 EA and 12 non-EA economies. Third, a measure for future volatility considers the standard deviations of the following trading days. Fourth, four European implied volatility indices are analyzed. The specifications highlight that announcements increase the volatility level on the same day. Anticipated, delayed and Thursday effects are negligible. Since every asset seems similarly affected, no national peculiarities arise. The effects also spill over to non-EA markets underlining the role of the ECB's communication in global financial markets. Previous studies classify European countries when investigating

volatility on sovereign bond markets. In contrast, the findings do not allow a classification of national stock markets.

This study extends the existing literature by also including the pre-crisis period, which results in a comprehensive observation period longer than twenty years. A break is detected claiming that ECB announcements have a more intense impact following the global financial crisis. A general positive effect on asset volatility emerges. This effect reinforces over time. While it is weak and only exists in a few countries of the EA before 2007, it becomes more significant following the financial crisis. The mere number of announcements does not seem to matter. Although following the crisis fewer press releases occur during a longer period, these announcements affect the asset's volatility more strongly than those before the crisis. Consequently, fewer announcements do not lead to less financial volatility. To reduce volatility, policymakers should focus on the quality of their announcements and they can possibly neglect the announcement frequency. The findings are in line with Kurov and Stan (2018) who state that 'when monetary policy uncertainty is high, policy expectations become more sensitive to economic news, which affects the response of a variety of markets to such fundamental news' (p. 128). The present study confirms this assertion for European stock markets. Overall, both daily and intraday data suggest a significantly positive impact of the ECB's press announcements on asset volatility in EA countries.

Looking ahead, the cumulated future volatility at the horizons from 3 to 10 days declines, meaning that the initial information released during an announcement day resolves uncertainty – and thus stock market volatility – the following days. Negative news induce a higher increase in asset volatility than announcements that are positively or neutrally perceived. Classifying the announcements by the market-specific yield change during the announcement day, the periphery markets are more affected than the core markets.

Due to the varied data available among the assets under consideration, pooling them in a panel is problematic. The proportion of missing data is yet too diverse to reasonably apply imputation methods. For future research, it will be interesting to use a panel and to account for interaction effects within the EA. One could disaggregate the analysis to different sectors, examining whether the assets of financial institutions are more concerned than other sectors about the ECB's information releases.

Financial markets are subject to political factors as well. Global trade war rhetoric from the USA move stock markets (Burggraf et al., 2019). ECB (2018) relates higher volatility levels

in US and European equity and credit markets to tax reforms. Future research might have a closer look at those factors in order to explain volatility on financial markets more accurately.

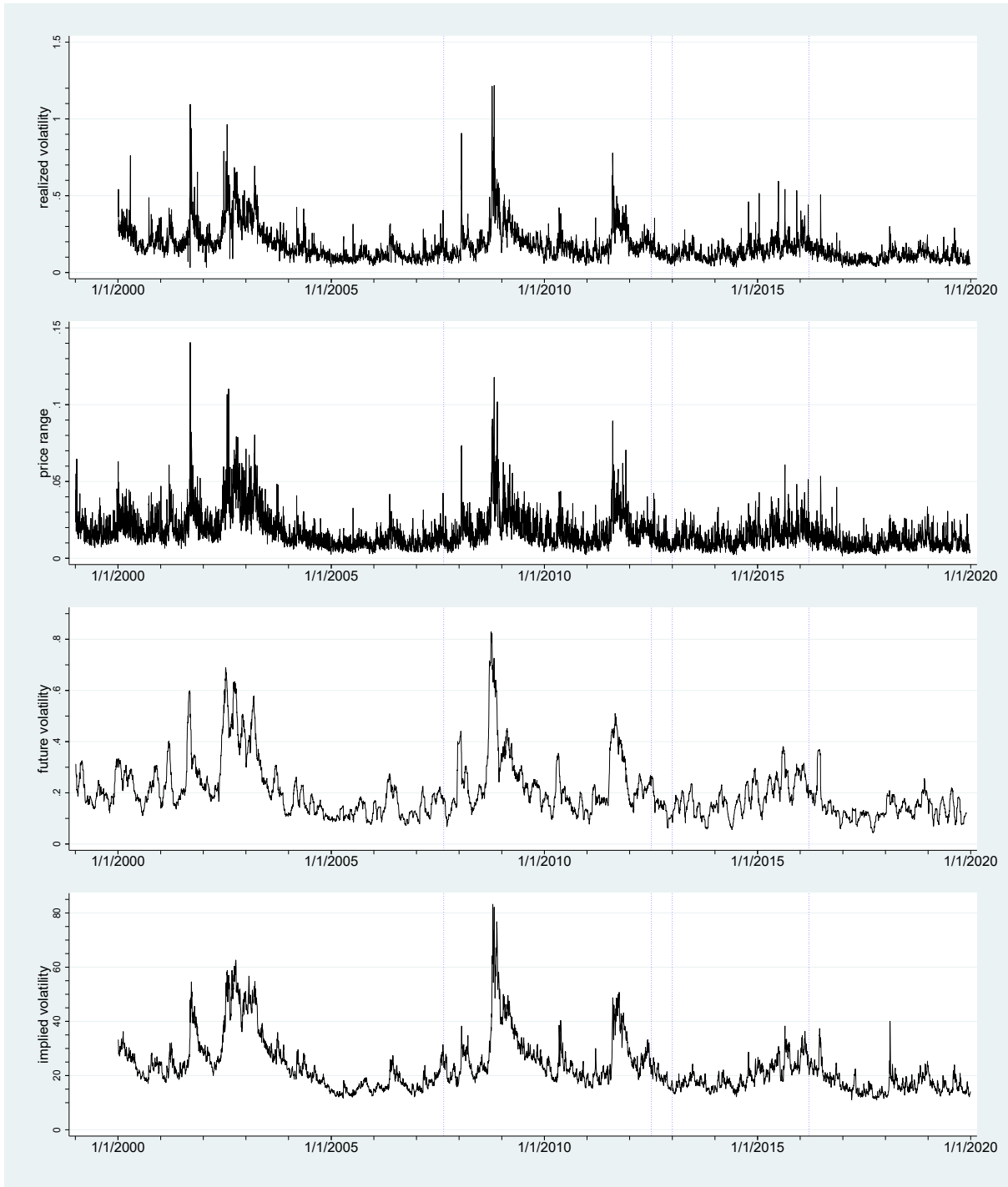
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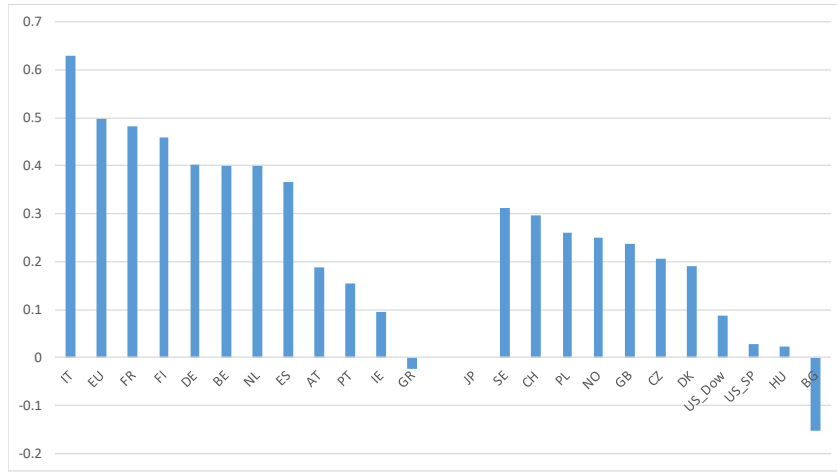
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Figure 1: Volatility measures of the German DAX 30 stock market index

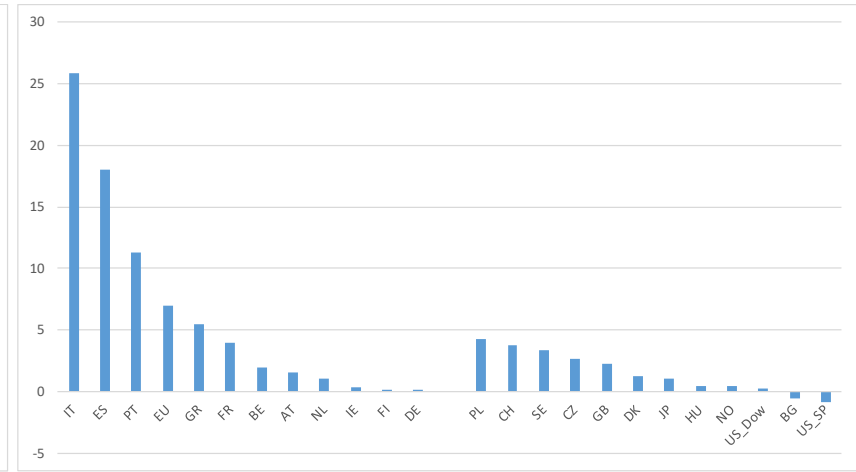


The first panel shows the realized volatility measure from Section 2.1. Source is Heber et al. (2009) using 5 minutes frequency data. Using a 10 minutes frequency produces a similar pattern. The second and third panel show the daily price range and the future volatility measure as outlined in Section 2.2 and Section 2.3, respectively. The fourth panel shows the implied volatility measure VDAX mentioned in Section 2.4. Source for these time series is Datastream. The four dotted vertical lines refer to the dates that separate the specifications (1) to (4) defined in Section 3.2, that is 22/08/2007, 06/07/2012, 01/01/2013, and 16/03/2016. The results for these periods can be found in Table 5 and Table 6. Time span: January 2, 1999 (January 3, 2000 for the first and fourth panel) to December 31, 2019.

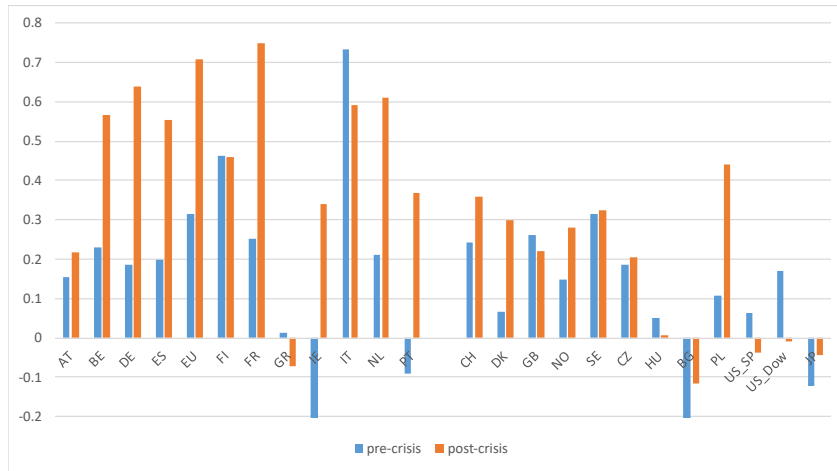
Figure 2: Illustration of main findings: example of price range measure



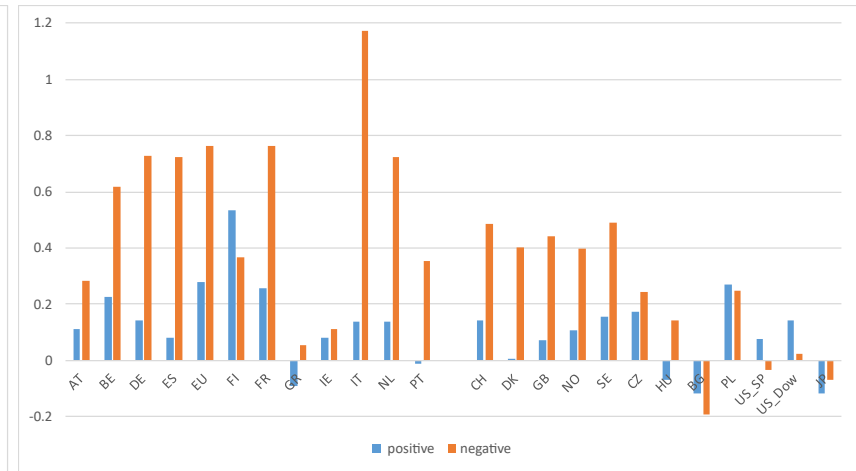
(a) Estimated coefficients of unweighted dummy



(b) Estimated coefficients of weighted dummy



(c) Comparing pre-crisis and post-crisis period



(d) Classifying announcements as positive and negative

The upper left panel (a) shows the coefficients sorted by size of the first column in Table 2. The upper right panel (b) shows the coefficients sorted by size of the first column in Table 12. The lower left panel (c) shows the coefficients of the first two columns in Table 6. The lower right panel (d) shows the coefficients of the first two columns in Table 10. The left side of each panel shows the EA markets and the right side the non-EA markets.

Table 1: Effect of ECB announcements on realized asset volatility

	(1) <i>scheduled</i>	(2) <i>scheduled</i>	<i>UMP</i>	(3) <i>policy</i>	observations
BE	0.623***	0.509***	0.516***	0.560***	5,064
DE	0.594***	0.486***	0.494***	0.528***	5,038
ES	0.741***	0.622***	0.543***	0.658***	5,031
EU	0.612***	0.511***	0.461***	0.526***	5,066
FI	0.706***	0.592***	0.320	0.541***	3,542
FR	0.687***	0.571***	0.527***	0.608***	5,066
IT	1.118***	1.001***	0.275	0.833***	2,654
NL	0.589***	0.491***	0.449***	0.519***	5,066
CH	0.546***	0.496***	0.227*	0.469***	4,977
DK	0.336***	0.251**	0.238*	0.267***	3,509
GB	0.227**	0.242**	-0.0707	0.169*	5,011
JP	0.0743	0.0189	0.244	0.107	4,833
NO	0.318***	0.274**	0.165	0.276***	4,538
SE	0.437***	0.373***	0.182	0.330***	3,542
US_Dow	0.0428	0.0300	0.0568	0.102	4,982
US_SP	0.141*	0.120	0.0910	0.189**	4,985
announcements	244	244	96	285	

Note: ***, **, and * denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. Sample period: January 2000 to December 2019. The dashed horizontal line separates the volatility measures. The upper part considers 8 EA national stock market volatility measures and the lower part 8 non-EA stock markets. To enhance legibility, only estimated coefficients of the dummy variables are displayed. Full regression output is available upon request. 55 UMP announcements happen on scheduled meeting days.

Table 2: Effect of ECB announcements on daily price range

	(1) <i>scheduled</i>	(2) <i>scheduled</i>	<i>UMP</i>	(3) <i>policy</i>	observations
AT	0.187**	0.158*	0.154	0.174**	5,177
BE	0.400***	0.305***	0.469**	0.371***	5,289
DE	0.401***	0.298***	0.518***	0.367***	5,297
ES	0.366***	0.269**	0.475***	0.356***	5,264
EU	0.498***	0.394***	0.535***	0.462***	5,172
FI	0.459***	0.418***	0.210	0.387***	5,235
FR	0.482***	0.361***	0.607***	0.450***	5,335
GR	-0.0238	-0.0703	0.231	0.0450	5,101
IE	0.0946	-0.00781	0.446***	0.111	4,911
IT	0.629***	0.551***	0.258	0.510***	4,138
NL	0.399***	0.284***	0.569***	0.380***	5,303
PT	0.155*	0.0734	0.353**	0.156*	4,962
BG	-0.153	-0.238**	0.261	-0.0179	3,601
CH	0.297***	0.238***	0.291*	0.268***	5,212
CZ	0.206**	0.157	0.207	0.250***	4,847
DK	0.190**	0.139*	0.238	0.166**	5,031
GB	0.238***	0.199**	0.195	0.229***	5,273
HU	0.0235	-0.00906	0.159	0.0174	5,170
JP	-0.0958	-0.132*	0.181	-0.0299	5,118
NO	0.249**	0.178	0.192	0.171*	3,355
PL	0.259***	0.228**	0.157	0.246***	5,220
SE	0.313***	0.277***	0.143	0.243***	4,610
US_Dow	0.0884	0.0530	0.173	0.124*	5,280
US_SP	0.0272	-0.0156	0.210	0.0921	5,249
announcements	267	267	96	308	

Note: ***, **, and * denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. Sample period: January 1999 to December 2019. The dashed horizontal lines separate the volatility measures. The upper part considers 12 EA national stock market volatility measures and the lower part 12 non-EA stock markets. To enhance legibility, only estimated coefficients of the dummy variables are displayed. Full regression output is available upon request. 55 UMP announcements happen on scheduled meeting days.

Table 3: Effect of ECB announcements on future volatility: 20-day window

	(1) <i>scheduled</i>	(2) <i>scheduled</i>	<i>UMP</i>	(3) <i>policy</i>	observations
AT	-0.000175	0.000238	-0.00217	-0.000333	5,184
BE	-0.000537	0.000232	-0.00386*	-0.000956	5,342
DE	-0.000296	9.35e-05	-0.00196	-0.000199	5,309
ES	-0.00132	-0.000257	-0.00534	-0.00183	5,307
EU	-0.00100	-0.000155	-0.00428*	-0.00133	5,355
FI	-0.00216	-0.00187	-0.00147	-0.00216	5,249
FR	-0.000886	-6.38e-05	-0.00414*	-0.00124	5,345
GR	0.000457	0.000960	-0.00256	-0.000460	5,189
IE	-0.000353	0.000681	-0.00520**	-0.00125	5,295
IT	-0.000877	0.000256	-0.00569**	-0.00123	5,304
NL	-0.00108	-0.000328	-0.00376*	-0.00142*	5,342
PT	-0.000726	-0.000267	-0.00231	-0.00106	5,323
BG	-0.00107	-0.000365	-0.00213	-0.00159*	3,571
CH	-4.03e-05	0.000111	-0.000757	9.24e-05	5,259
CZ	-0.00124*	-0.00101	-0.00113	-0.00166**	5,232
DK	-0.000318	-0.000296	-0.000108	-0.000356	5,225
GB	-0.000286	0.000377	-0.00334**	-0.000615	5,284
HU	-0.000673	-0.000699	0.000128	-0.000414	5,219
JP	0.000265	0.000883	-0.00307**	-6.97e-05	5,132
NO	-0.000335	-0.000236	-0.000497	-0.000183	5,242
PL	-0.000904	-0.000868	-0.000179	-0.00103	5,234
SE	-0.000793	-0.000497	-0.00153	-0.000765	5,251
US_Dow	0.000211	0.000738	-0.00260**	-0.000295	5,263
US_SP	0.000274	0.000762	-0.00241*	-0.000250	5,261
announcements	267	267	96	308	

Note: ***, **, and * denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. Sample period: January 1999 to December 2019. The dashed horizontal lines separate the volatility measures. The upper part considers 12 EA national stock market volatility measures and the lower part 12 non-EA stock markets. To enhance legibility, only estimated coefficients of the dummy variables are displayed. Full regression output is available upon request. 55 UMP announcements happen on scheduled meeting days.

Table 4: Effect of ECB announcements on implied volatilities

		(1) <i>scheduled</i>	(2) <i>scheduled</i>	<i>UMP</i>	(3) <i>policy</i>	observations
level	VAEX	-0.334***	-0.357***	0.111	-0.267***	5,064
	VCAC	-0.373***	-0.383***	0.0451	-0.303***	5,064
	VDAX	-0.256***	-0.240**	-0.0792	-0.247***	5,325
	VSTOXX	-0.237**	-0.230**	-0.0374	-0.209**	5,324
range	VAEX	0.0944*	0.108	-0.0315	0.0697	2,776
	VCAC	0.141**	0.0877*	0.127	0.125**	2,776
	VDAX	0.00962**	0.00751	0.00626	0.00750**	3,561
	VSTOXX	0.0103**	0.00730	0.00887	0.00855**	3,563
future	VAEX	-0.00682*	-0.00519	-0.00747	-0.00672**	5,076
	VCAC	-0.0287	-0.0308	0.00949	-0.0250	5,060
	VDAX	0.00303	0.00358	-0.00278	0.00192	5,266
	VSTOXX	0.00253	0.00316	-0.00321	0.00177	5,277
surprise	VAEX	0.0365***	0.0323***	0.0192**	0.0316***	5,066
	VCAC	0.0408***	0.0368***	0.0178*	0.0353***	5,066
	VDAX	0.0323***	0.0282***	0.0185**	0.0282***	5,038
	VSTOXX	0.0332***	0.0293***	0.0176**	0.0282***	5,066

The dashed horizontal lines separate the volatility measures according to level values, price ranges, future volatility and surprise measure.

Table 5: Distinguishing observation periods for realized volatility: Coefficients of $scheduled_t$

specification sub-sample	(1) pre-crisis versus post-crisis		(2) effective lower bound		(3) crisis vs. following the crisis		(4) zero lower bound	
	pre-crisis	post-crisis	pre-ELB	post-ELB	crisis	following crisis	pre-ZLB	post-ZLB
BE	0.330*	0.885***	0.443***	1.091***	0.673***	1.150***	1.318***	0.992***
DE	0.336*	0.826***	0.414***	1.051***	0.636***	1.079***	1.264***	0.879***
ES	0.455	1.002***	0.541**	1.248***	0.742***	1.321***	1.511***	1.125***
EU	0.304*	0.888***	0.386***	1.164***	0.638***	1.193***	1.550***	0.826***
FI	0.199	0.800***	0.283**	1.190***	0.399***	1.066***	0.773***	1.397*
FR	0.430	0.922***	0.478**	1.221***	0.655***	1.262***	1.623***	0.894***
IT		1.118***	0.522***	1.384***	0.719***	1.424***	1.632***	1.214***
NL	0.377*	0.797***	0.405***	1.044***	0.562***	1.103***	1.267***	0.925***
CH	0.531*	0.576***	0.523***	0.653***	0.564***	0.672***	0.654***	0.674***
DK	-0.0991	0.426***	0.421***	0.233**	0.645***	0.216*	0.269*	0.153
GB	0.249	0.215**	0.298**	0.0620	0.426***	0.0396	0.121	-0.0250
JP	0.0200	0.143	0.0802	0.145	0.146	0.183	0.236	0.0824
NO	0.266	0.355***	0.322**	0.295**	0.409***	0.255*	0.163	0.299
SE	0.332	0.473***	0.304***	0.593***	0.418***	0.598***	0.827***	0.370**
US_Dow	0.248*	-0.143	0.0975	-0.0889	-0.112	-0.154	-0.227	-0.0518
US_SP	0.306**	-0.00986	0.179*	0.0461	0.00165	-0.00793	-0.124	0.147
announcements	116	128	176	68	65	63	34	29
period	01/01/2000- 21/08/2007	22/08/2007- 31/12/2019	01/01/2000- 05/07/2012	06/07/2012- 31/12/2019	22/08/2007- 31/12/2012	01/01/2013- 31/12/2019	01/01/2013- 15/03/2016	16/03/2016- 31/12/2019

Note: ***, **, and * denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. The dashed horizontal line separates the volatility measures. The upper part considers 7 EA stock markets and the Eurostoxx while the lower part covers 8 realized volatility measures of markets that do not belong to the EA. The observations of the Italian stock index start in June 2009 so that there are no results for the pre-crisis period.

Table 6: Distinguishing observation periods for daily price range: Coefficients of $scheduled_t$

specification sub-sample	(1) pre-crisis versus post-crisis		(2) effective lower bound		(3) crisis vs. following the crisis		(4) zero lower bound	
	pre-crisis	post-crisis	pre-ELB	post-ELB	crisis	following the crisis	pre-ZLB	post-ZLB
AT	0.153	0.216**	0.193**	0.189	0.293**	0.145	0.354*	-0.0848
BE	0.231	0.565***	0.318***	0.686***	0.423**	0.784***	0.976***	0.578**
DE	0.187	0.640***	0.290***	0.761***	0.538***	0.776***	0.910***	0.655**
ES	0.199	0.555***	0.292**	0.594***	0.498***	0.657***	0.976***	0.355
EU	0.316**	0.707***	0.361***	0.887***	0.508***	0.956***	1.258***	0.647**
FI	0.464***	0.461***	0.394***	0.656***	0.262*	0.674***	0.594***	0.727*
FR	0.251*	0.750***	0.333***	0.905***	0.572***	0.991***	1.238***	0.746**
GR	0.0135	-0.0709	0.0396	-0.177*	0.0471	-0.170	-0.208	-0.245
IE	-0.215**	0.341***	-0.0599	0.508***	0.225*	0.499***	0.618**	0.360
IT	0.733*	0.591***	0.538**	0.742***	0.473***	0.747***	1.237***	0.258
NL	0.212*	0.609***	0.281***	0.774***	0.453***	0.822***	1.032***	0.578**
PT	-0.0908	0.367***	0.0721	0.373***	0.395**	0.377***	0.459**	0.309
BG	-0.231	-0.117	-0.159	-0.177	-0.0629	-0.176	-0.368**	0.0642
CH	0.244*	0.360***	0.261**	0.468***	0.285*	0.503***	0.512**	0.448**
CZ	0.187	0.205**	0.224**	0.176	0.221	0.204	0.383	0.0215
DK	0.0664	0.300***	0.200**	0.197	0.399**	0.242*	0.460**	0.00697
GB	0.260*	0.222**	0.284***	0.117	0.369**	0.104	0.320	-0.131
HU	0.0513	0.00561	0.0146	0.0647	-0.0311	0.0747	0.117	0.00686
JP	-0.123	-0.0442	-0.112	0.0209	-0.111	0.0822	0.0354	0.0971
NO	0.147	0.280**	0.274*	0.208	0.408**	0.166	0.141	0.196
PL	0.107	0.440***	0.208**	0.435***	0.472**	0.412**	0.460	0.263
SE	0.316*	0.325***	0.301***	0.352**	0.329**	0.389**	0.616**	0.153
US_Dow	0.171*	-0.00735	0.0947	0.126	-0.00811	0.0522	-0.119	0.273
US_SP	0.0639	-0.0372	0.0420	0.0470	-0.0237	0.00238	-0.121	0.146
announcements	139	128	199	68	65	63	34	29
period	01/01/1999- 21/08/2007	22/08/2007- 31/12/2019	01/01/1999- 05/07/2012	06/07/2012- 31/12/2019	22/08/2007- 31/12/2012	01/01/2013- 31/12/2019	01/01/2013- 15/03/2016	16/03/2016- 31/12/2019

Note: ***, **, and * denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. The dashed horizontal line separates the volatility measures. The upper part considers 11 EA stock markets and the Eurostoxx and the lower part covers 12 price range measures of markets that do not belong to the EA.

Table 7: ECB's announcement effects on future cumulated realized volatilities

	1 day	3 days	5 days	10 days
BE	0.0829	-0.720***	-0.428***	-0.508***
DE	0.127	-0.716***	-0.311**	-0.519***
ES	-0.0908	-0.884***	-0.495**	-0.712***
EU	0.0788	-0.704***	-0.315**	-0.493***
FI	0.136	-0.598***	-0.398*	0.111
FR	0.112	-0.829***	-0.447***	-0.598***
IT	-0.122	-1.141***	-0.923***	-1.098***
NL	0.141	-0.791***	-0.361***	-0.506***
CH	-0.0149	-0.665***	-0.411***	-0.375**
DK	0.0553	-0.385***	-0.193	-0.154
GB	0.127	-0.352***	-0.0833	-0.106
JP	-0.241***	-0.133	0.210*	-0.0177
NO	0.186*	-0.436***	-0.0658	-0.112
SE	0.0999	-0.435***	-0.304**	-0.251*
US_Dow	0.0748	-0.260**	0.249*	0.0577
US_SP	0.0597	-0.368***	0.173	0.0343

Note: ***, **, and * denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. The dashed horizontal line separate the volatility measures according to EA and non-EA markets. Estimated coefficients of $scheduled_t$.

Table 8: ECB's announcement effects on future cumulated price ranges

	1 day	3 days	5 days	10 days
AT	-0.00618	-0.157*	-0.175*	-0.0857
BE	0.0402	-0.480***	-0.308**	-0.317***
DE	0.0451	-0.393***	-0.265**	-0.351***
ES	-0.0308	-0.438***	-0.296***	-0.380***
EU	0.0252	-0.414***	-0.393***	-0.378***
FI	-0.0157	-0.240*	-0.159	0.120
FR	0.0260	-0.490***	-0.391***	-0.426***
GR	-0.125**	0.132	-0.0264	0.0533
IE	0.0142	-0.0945	-0.0490	-0.150
IT	-0.0164	-0.554***	-0.601***	-0.614***
NL	0.0709	-0.445***	-0.319***	-0.394***
PT	-0.0142	-0.240**	-0.144	-0.228*
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BG	0.0198	0.00782	-0.0500	0.212
CH	0.0459	-0.292***	-0.198*	-0.161
CZ	-0.0990	-0.155	-0.128	-0.105
DK	0.228	-0.117	-0.0630	-0.132
GB	0.0112	-0.325***	-0.180*	-0.0559
HU	-0.0476	-0.111	0.123	0.00855
JP	-0.0182	0.0603	0.0847	0.138
NO	0.106	-0.181*	-0.145	-0.165
PL	-0.0446	-0.148	-0.152	-0.0911
SE	-0.116	-0.417***	-0.268**	-0.157
US_Dow	0.0971	-0.234**	0.103	0.0137
US_SP	0.138	-0.179*	0.145	0.105

Note: ***, **, and * denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. The dashed horizontal line separate the volatility measures according to EA and non-EA markets. Estimated coefficients of $scheduled_t$.

Table 9: ECB's announcement effects on realized volatilities: types of news

	(1) positive	negative	(2) positive	negative	neutral
BE	0.353***	0.945***	0.332***	1.131***	0.313**
DE	0.262***	0.990***	0.283***	1.129***	0.279**
ES	0.296***	1.267***	0.306***	1.447***	0.366**
EU	0.295***	0.990***	0.335***	1.128***	0.260*
FI	0.823**	0.591***	0.628**	0.727***	0.823
FR	0.301***	1.146***	0.295***	1.322***	0.357**
IT	0.572***	1.830***	0.507***	2.155***	0.913***
NL	0.272***	0.967***	0.294***	1.110***	0.265*
CH	0.327***	0.804***	0.352***	0.954***	0.210
DK	0.182	0.483***	0.233*	0.572***	0.0849
GB	0.0720	0.412**	0.153	0.499**	-0.111
JP	-0.107	0.288**	-0.0786	0.408**	-0.496***
NO	0.278*	0.361***	0.127	0.322**	0.681*
SE	0.171*	0.700***	0.208*	0.862***	0.0943
US_Dow	0.141	-0.147	0.0762	-0.0884	0.312
US_SP	0.264**	-0.0653	0.156	0.0281	0.434
announcements	132	112	104	90	50

Note: ***, **, and * denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. The dashed horizontal line separate the volatility measures according to EA and non-EA markets. Estimated coefficients of $scheduled_t$. Classification according to MSCI Europe.

Table 10: ECB's announcement effects on price ranges: types of news

	(1) positive	negative	(2) positive	negative	neutral
AT	0.112	0.282**	0.0984	0.340***	0.112
BE	0.225**	0.616***	0.222**	0.765***	0.149
DE	0.141	0.726***	0.237**	0.890***	-0.0816
ES	0.0813	0.724***	0.163*	0.877***	-0.0606
EU	0.279***	0.763***	0.391***	0.938***	-0.0421
FI	0.536***	0.365***	0.603***	0.526***	0.0429
FR	0.256**	0.764***	0.307***	0.939***	0.0754
GR	-0.0901	0.0556	-0.0563	-0.0185	0.0316
IE	0.0813	0.110	0.0857	0.219*	-0.107
IT	0.139	1.173***	0.176	1.501***	0.0412
NL	0.137	0.724***	0.219**	0.912***	-0.0905
PT	-0.0124	0.353**	0.0404	0.437**	-0.115
BG	-0.116	-0.190*	-0.227	-0.225*	0.105
CH	0.143	0.484***	0.235**	0.615***	-0.115
CZ	0.175	0.244**	0.185	0.332**	0.0299
DK	0.00538	0.403***	0.0460	0.548***	-0.157
GB	0.0739	0.443***	0.198*	0.665***	-0.394***
HU	-0.0711	0.141	-0.00435	0.252**	-0.314***
JP	-0.117	-0.0693	-0.116	0.0763	-0.317*
NO	0.105	0.396**	0.172	0.558***	-0.184
PL	0.269**	0.247**	0.249**	0.361**	0.108
SE	0.157	0.492***	0.268**	0.614***	-0.134
US_Dow	0.142	0.0215	0.193*	0.0758	-0.0400
US_SP	0.0775	-0.0358	0.114	0.0954	-0.152
announcements	147	120	115	96	56

Note: ***, **, and * denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. The dashed horizontal line separate the volatility measures according to EA and non-EA markets. Estimated coefficients of $scheduled_t$. Classification according to MSCI Europe.

Table 11: Effect of ECB announcements on realized asset volatility: weighted events

	(1) <i>scheduled</i>	(2) <i>scheduled</i>	<i>UMP</i>	(3) <i>policy</i>	observations
BE	2.732**	1.890**	5.426*	2.641**	5,064
DE	0.245	-0.0225	5.788**	0.257	5,038
ES	32.83***	28.58***	6.226	28.58***	5,031
EU	9.801**	6.937**	7.451*	8.021***	5,066
FI	0.163	1.471**	-1.327*	0.157	3,542
FR	5.213**	3.962*	4.072	4.447**	5,066
IT	37.86***	37.00***	1.133	28.95***	2,654
NL	1.155*	1.583**	-0.437	0.795**	5,066
CH	5.744***	4.652**	2.842	4.175**	4,977
DK	1.769*	0.359	3.171***	1.703**	3,509
GB	2.670	2.162	1.321	1.771	5,011
JP	0.942	0.212	1.905	1.101	4,833
NO	2.069	1.258	2.165	2.084*	4,538
SE	4.052**	2.693	3.633	3.011*	3,542
US_Dow	-1.493	-2.638*	2.980*	0.334	4,982
US_SP	-0.709	-1.828*	2.911**	0.612	4,985
announcements	244	244	96	285	

Note: ***, **, and * denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. Sample period: January 2000 to December 2019. The dashed horizontal line separates the volatility measures. The upper part considers 8 EA national stock market volatility measures and the lower part 8 non-EA stock markets. To enhance legibility, only estimated coefficients of the dummy variables are displayed. Full regression output is available upon request. 55 UMP announcements happen on scheduled meeting days.

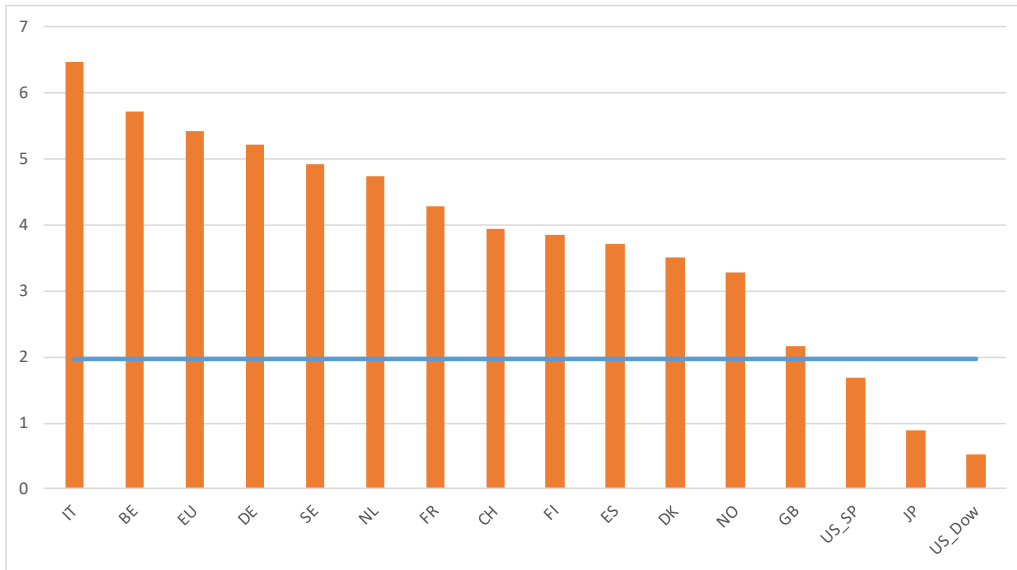
Table 12: Effect of ECB announcements on daily price range: weighted events

	(1) <i>scheduled</i>	(2) <i>scheduled</i>	<i>UMP</i>	(3) <i>policy</i>	observations
AT	1.563	2.375***	-1.330	1.168	5,177
BE	1.960*	1.190***	4.962*	1.997**	5,289
DE	0.0715	-0.125	4.244**	0.0927	5,297
ES	18.06***	7.455	15.77*	19.64***	5,264
EU	6.951**	4.117	7.528*	6.026**	5,172
FI	0.108	0.856*	-0.759	0.0999	5,235
FR	3.962*	2.566	4.550*	3.538**	5,335
GR	5.432	-0.703	15.48***	12.99***	5,101
IE	0.308	-1.925	2.262	0.418	4,911
IT	25.88***	18.35***	10.42*	24.15***	4,138
NL	1.089**	1.177**	-0.0904	0.779**	5,303
PT	11.25***	8.739**	5.155	9.687***	4,962
BG	-0.572	-0.676	0.267	-0.167	3,601
CH	3.771**	2.436	3.477	3.190**	5,212
CZ	2.621**	1.573	2.722	3.271***	4,847
DK	1.296	-1.117	5.474***	1.874	5,031
GB	2.233	1.089	2.977	1.899	5,273
HU	0.495	0.00838	1.266	0.292	5,170
JP	1.021	0.616	1.061	1.122	5,118
NO	0.430	-0.709	2.934	0.781	3,355
PL	4.248***	4.020***	0.595	3.698***	5,220
SE	3.384**	2.856*	1.422	2.271	4,610
US_Dow	0.217	-1.015	3.211**	1.026	5,280
US_SP	-0.895	-2.001***	2.883**	0.0502	5,249
announcements	267	267	96	308	

Note: ***, **, and * denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. Sample period: January 1999 to December 2019. The dashed horizontal lines separate the volatility measures. The upper part considers 12 EA national stock market volatility measures and the lower part 12 non-EA stock markets. To enhance legibility, only estimated coefficients of the dummy variables are displayed. Full regression output is available upon request. 55 UMP announcements happen on scheduled meeting days.

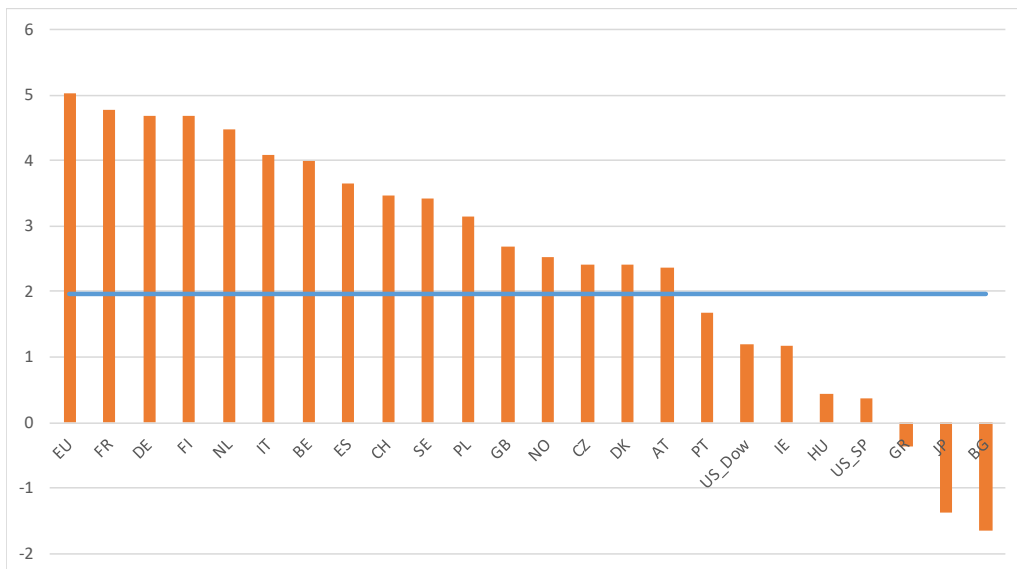
Appendix

Figure A1: Sorted t-statistics of $scheduled_t$ for realized volatilities



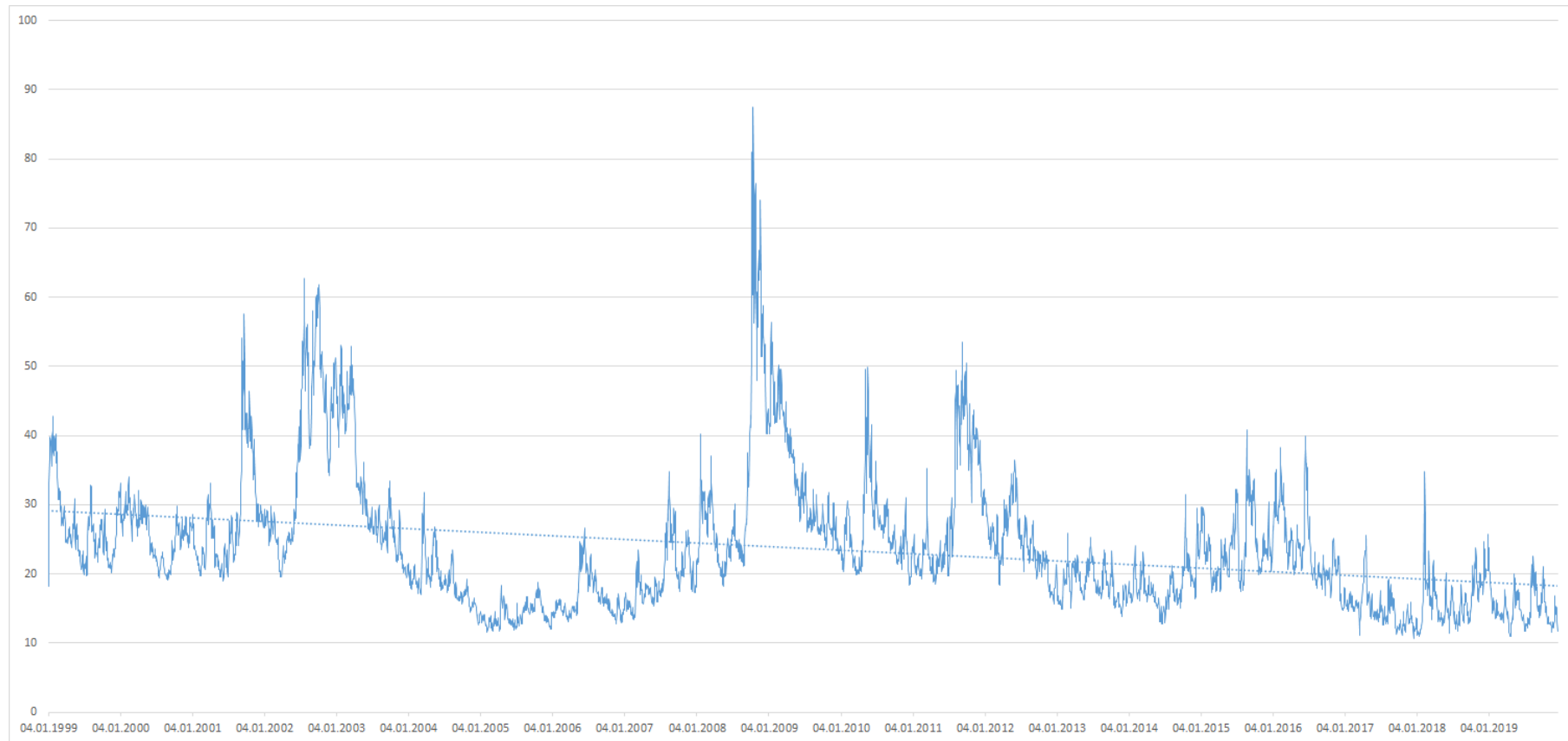
The horizontal line presents the threshold for a significance level of $\alpha = 0.5\%$.

Figure A2: Sorted t-statistics of $scheduled_t$ for price ranges



The horizontal line presents the threshold for a significance level of $\alpha = 0.5\%$.

Figure A3: Development of the VSTOXX index



Time span: January 1999 until December 2019. The dotted line indicates a trend with $y = -0.0014x + 80.017$.

Table A1: Descriptive statistics: dependent variables

Variable	Observations	Mean	Std. Dev.	Min.	Max.	Source
<i>RVol_{BE}</i>	5,096	0.1290641	0.0707091	0.0317941	0.9297159	Bel 20
<i>RVol_{DE}</i>	5,070	0.1711709	0.1069162	0.0323051	1.217634	DAX 30
<i>RVol_{ES}</i>	5,063	0.1658997	0.0872344	0.0321413	1.178356	IBEX 35
<i>RVol_{EU}</i>	5,098	0.1675846	0.1034716	0.0015302	1.651767	Eurostoxx 50
<i>RVol_{FI}</i>	3,574	0.1358838	0.1027013	0.0319313	2.378875	OMX Helsinki 25
<i>RVol_{FR}</i>	5,098	0.1571272	0.0907829	0.0262683	1.136116	CAC 40
<i>RVol_{IT}</i>	2,686	0.151746	0.0745505	0.013885	0.7472074	FTSE MIB
<i>RVol_{NL}</i>	5,098	0.1431309	0.0886509	0.0199811	0.9556439	AEX
<i>RVol_{CH}</i>	5,009	0.1231789	0.0730192	0.0390627	1.03098	Swiss Stock Market
<i>RVol_{DK}</i>	3,541	0.1473594	0.0998279	0.0415979	1.750454	OMX Copenhagen 20
<i>RVol_{GB}</i>	5,043	0.1432767	0.0914893	0.0183236	1.63439	FTSE 100
<i>RVol_{JP}</i>	4,866	0.1404197	0.0764778	0.0228099	0.9020374	Nikkei 225
<i>RVol_{NO}</i>	4,570	0.1505924	0.0940883	0.0409316	1.355599	Oslo All Share
<i>RVol_{SE}</i>	3,574	0.1278403	0.0934115	0.024579	1.629354	OMX Stockholm
<i>RVol_{US_Dow}</i>	5,014	0.1342118	0.0942001	0.0220001	1.474195	Dow Jones
<i>RVol_{US_SP}</i>	5,017	0.133234	0.0936834	0.01752	1.397294	S&P 500
<i>range_{AT}</i>	5,209	0.0159217	0.0112216	0.0033403	0.1347715	ATXINDX
<i>range_{BE}</i>	5,353	0.0131221	0.0087119	0.0021763	0.1125419	BGBEL20
<i>range_{DE}</i>	5,329	0.0170749	0.0118459	0.0014377	0.1405444	DAXINDX
<i>range_{ES}</i>	5,328	0.0169448	0.010498	0.0028445	0.1427609	IBEX35I
<i>range_{EU}</i>	5,365	0.0164375	0.0110636	0.0001584	0.1121307	DJES50I
<i>range_{FI}</i>	5,267	0.0194565	0.0203591	0.0025717	0.2706402	HEXINDX
<i>range_{FR}</i>	5,367	0.0155359	0.0101548	0.0013887	0.0953724	FRCAC40
<i>range_{GR}</i>	5,190	0.0207326	0.0142561	0.0031493	0.2287592	GRAGENL
<i>range_{IE}</i>	5,039	0.0160121	0.0118551	0.0026408	0.2713273	ISEQUIT
<i>range_{IT}</i>	4,170	0.0163721	0.0108182	0.0022998	0.1238377	FTSEMIB
<i>range_{NL}</i>	5,367	0.01448	0.0104451	0.0019376	0.1226604	AMSTEOE
<i>range_{PT}</i>	5,052	0.0129653	0.0081492	0.0000961	0.0887101	POPSI20
<i>range_{BG}</i>	4,690	0.0122552	0.0132504	0.0001072	0.2322138	BSSOFIX
<i>range_{CH}</i>	5,277	0.0124734	0.0086919	0.0021526	0.1452622	SWISSMI
<i>range_{CZ}</i>	4,966	0.0130771	0.009238	0.0017986	0.1344408	CZPXIDX
<i>range_{DK}</i>	5,063	0.0156531	0.0123337	0.0029396	0.1946582	DKKFXIN
<i>range_{GB}</i>	5,306	0.0140636	0.0094618	0.002325	0.1019542	FTSE100
<i>range_{HU}</i>	5,235	0.0173159	0.0102533	0.0032224	0.1642317	BUXINDX
<i>range_{JP}</i>	5,151	0.0137383	0.009147	0.0017629	0.1285823	JAPDOWA
<i>range_{NO}</i>	3,419	0.0156597	0.0116743	0.0029061	0.1161843	OSLOASH
<i>range_{PL}</i>	5,253	0.0167418	0.0096107	0.0034584	0.12708	POLWG20
<i>range_{SE}</i>	4,642	0.0158658	0.0108222	0.0027936	0.1179102	SWEDOMX
<i>range_{US_Dow}</i>	5,314	0.014098	0.0105365	0.0015729	0.1133744	DJCOMP65
<i>range_{US_SP}</i>	5,283	0.0130671	0.0097704	0.0014575	0.1121896	S&PCOMP
<i>vol_{AT}^f</i>	5,185	0.1881772	0.1095469	0.051882	1.007112	ATXINDX
<i>vol_{BE}^f</i>	5,343	0.1675779	0.0947403	0.0385259	0.795821	BGBEL20
<i>vol_{DE}^f</i>	5,310	0.203788	0.1085007	0.0437787	0.8289387	DAXINDX
<i>vol_{ES}^f</i>	5,308	0.2026319	0.1039383	0.0576793	0.8603936	IBEX35I
<i>vol_{EU}^f</i>	5,356	0.1993931	0.1073767	0.0479505	0.8245734	DJES50I
<i>vol_{FI}^f</i>	5,250	0.2353401	0.1432149	0.0486811	0.825707	HEXINDX
<i>vol_{FR}^f</i>	5,346	0.1973864	0.1051282	0.0400996	0.8737845	FRCAC40
<i>vol_{GR}^f</i>	5,190	0.2624999	0.1352888	0.066743	0.9096428	GRAGENL
<i>vol_{IE}^f</i>	5,296	0.1836521	0.1056794	0.0534685	0.9763133	ISEQUIT
<i>vol_{IT}^f</i>	5,305	0.2104056	0.108379	0.0485514	0.8570396	FTSEMIB
<i>vol_{NL}^f</i>	5,343	0.1853836	0.115145	0.0477348	0.8972627	AMSTEOE
<i>vol_{PT}^f</i>	5,324	0.1636716	0.0827019	0.037119	0.7420694	POPSI20
<i>vol_{BG}^f</i>	4,684	0.1733898	0.1442743	0.030385	1.233877	BSSOFIX
<i>vol_{CH}^f</i>	5,260	0.1583953	0.0906778	0.0460518	0.8062429	SWISSMI
<i>vol_{CZ}^f</i>	5,233	0.1782307	0.1102422	0.0402987	1.269173	CZPXIDX
<i>vol_{DK}^f</i>	5,226	0.1783081	0.0864474	0.0597231	0.871164	DKKFXIN
<i>vol_{GB}^f</i>	5,285	0.1609436	0.0909148	0.0365144	0.8202893	FTSE100
<i>vol_{HU}^f</i>	5,220	0.2121199	0.1024191	0.0625843	1.1111	BUXINDX
<i>vol_{JP}^f</i>	5,133	0.2111451	0.1031832	0.0583849	1.184291	JAPDOWA
<i>vol_{NO}^f</i>	5,243	0.183335	0.1039746	0.0576747	0.9227617	OSLOASH
<i>vol_{PL}^f</i>	5,235	0.2162311	0.0902772	0.0678811	0.7190694	POLWG20
<i>vol_{SE}^f</i>	5,252	0.2055686	0.1066464	0.0510621	0.7242901	SWEDOMX
<i>vol_{US_Dow}^f</i>	5,264	0.1527694	0.0892273	0.0266211	0.7897841	DJCOMP65
<i>vol_{US_SP}^f</i>	5,262	0.1616768	0.0997571	0.0328369	0.851887	S&PCOMP
VAEX	5,217	21.84341	10.26377	9.192	81.22	AEXVOLI
VCAC	5,217	22.11465	8.786353	0.429	78.05	CACVOLI
VDAX	5,478	23.29892	9.407048	10.98	83.23	VDAXNEW
VSTOXX	5,477	23.70796	9.466148	10.68	87.51	VSTOXXI

Note: The solid lines separate the used variables by type. The first part presents 16 realized volatility indices obtained from Heber et al. (2009). The second part shows $range_t$, which are calculated from the raw minimum, maximum and opening prices of the data source. The third part gives future volatilities for a 20-day window. The dashed lines demarcate EA markets versus non-EA markets. The fourth part gives implied volatilities. The last column gives the Datastream mnemonics. All dependent variables are displayed in their non-standardized form.

Table A2: Descriptive statistics: Control variables

Variable	Observations	Mean	Std. Dev.	Min.	Max.	Source
<i>MSCI_{Europe}</i>	5,478	1451.42	292.9926	726.164	2235.356	MSEROP\$
<i>MSCI_{World ex}</i>	5,478	127.2639	44.18952	56.193	252.888	MSWXEUE
<i>MSCI_{World}</i>	5,478	1394.992	372.7746	688.638	2364.904	MSWRLD\$
<i>CESI</i>	4,435	3.079076	55.48404	-188.6	162.5	EKCESIR
<i>surprise</i>	5,580	-0.0595907	0.3773679	-1.653775	1.059795	from Scotti (2016)
<i>uncertainty</i>	5,580	0.9892397	0.3564789	0.2795983	2.461624	
<i>MSCI_{AT}</i>	5,478	588.6563	260.4859	298.043	1437.188	MSASTRL
<i>MSCI_{BE}</i>	5,478	954.9987	257.676	351.33	1481.435	MSBELGL
<i>MSCI_{DE}</i>	5,478	731.0092	185.0909	282.724	1106.945	MSGERML
<i>MSCI_{ES}</i>	5,478	903.4653	178.0576	498.199	1471.388	MSSPANL
<i>MSCI_{FI}</i>	5,478	681.8774	287.0068	323.632	2120.131	MSFINDL
<i>MSCI_{FR}</i>	5,478	1510.698	312.3381	793.03	2234.516	MSFRNCL
<i>MSCI_{GR}</i>	5,478	736.5894	625.851	35.621	2435.018	MSGREEL
<i>MSCI_{IE}</i>	5,478	278.4473	135.8296	85.838	592.674	MSEIREL
<i>MSCI_{IT}</i>	5,478	932.321	301.9921	464.289	1625.89	MSITALL
<i>MSCI_{NL}</i>	5,478	1120.386	314.8478	507.284	1929.967	MSNETHL
<i>MSCI_{PT}</i>	5,478	141.0271	49.22144	70.369	266.644	MSPORDL
<i>MSCI_{BG}</i>	3,806	312.2937	265.9036	94.989	1045.102	MSBLG\$NL
<i>MSCI_{CH}</i>	5,478	957.0436	192.4709	481.432	1442.577	MSSWITL
<i>MSCI_{CZ}</i>	5,478	257.4234	109.7712	66.715	552.307	MSCZCHL
<i>MSCI_{DK}</i>	5,478	4295.197	2388.133	1245.81	9612.529	MSDNM\$KL
<i>MSCI_{GB}</i>	5,478	1741.96	275.9479	986.384	2276.19	MSUTDKL
<i>MSCI_{HU}</i>	5,478	1116.43	439.2953	383.992	2196.968	MSHUNGL
<i>MSCI_{JP}</i>	5,478	773.1016	191.8054	426.666	1146.638	MSJPANL
<i>MSCI_{NO}</i>	5,478	2138.946	678.0053	762.244	3501.445	MSNWAYL
<i>MSCI_{PL}</i>	5,478	1532.934	387.0939	720.233	2690.306	MSPLNDL
<i>MSCI_{SE}</i>	5,478	8435.813	2738.152	2914.851	14267.56	MSSWDNL
<i>MSCI_{US}</i>	5,478	1488.155	549.423	645.347	3085.403	MSUSAML
<i>sovereign_{AT}</i>	5,478	2.985036	1.723774	-0.46	5.8683	OEBRYLD
<i>sovereign_{BE}</i>	5,478	3.158474	1.692766	-0.3826	5.8813	BGBRYLD
<i>sovereign_{DE}</i>	5,478	2.723032	1.761783	-0.7197	5.6463	BDBRYLD
<i>sovereign_{ES}</i>	5,478	3.716266	1.53469	0.0446	7.59	ESBRYLD
<i>sovereign_{FI}</i>	5,478	2.892369	1.732697	-0.5199	5.8401	FNBRYLD
<i>sovereign_{FR}</i>	5,478	3.000672	1.638468	-0.4381	5.8334	FRBRYLD
<i>sovereign_{GR}</i>	5,414	7.414311	5.807878	1.6195	48.602	GRBRYLD
<i>sovereign_{IE}</i>	5,478	3.779747	2.267529	-0.3853	13.895	IRBRYLD
<i>sovereign_{IT}</i>	5,478	3.885459	1.315623	0.8243	7.288	ITBRYLD
<i>sovereign_{NL}</i>	5,478	2.895935	1.731695	-0.5824	5.7808	NLBRYLD
<i>sovereign_{PT}</i>	5,478	4.590025	2.372587	0.0817	16.211	PTBRYLD

Note: The dashed lines demarcate EA markets versus non-EA markets. The last column gives the Datastream mnemonics. Both surprise and uncertainty index are obtained from Scotti (2016).

Table A3: Comparison of $scheduled_t$ between $RVol_t$ and $range_t$ for the same periods

	$RVol_t$	observations	$range_t$	observations
BE	0.623***	5,064	0.436***	5,041
DE	0.594***	5,038	0.463***	5,044
ES	0.741***	5,031	0.383***	5,014
EU	0.612***	5,066	0.530***	4,950
FI	0.706***	3,542	0.431***	3,545
FR	0.687***	5,066	0.518***	5,081
IT	1.118***	2,654	0.635***	2,654
NL	0.589***	5,066	0.427***	5,082
CH	0.546***	4,977	0.332***	4,960
DK	0.336***	3,509	0.253**	3,528
GB	0.227**	5,011	0.215**	5,022
JP	0.0743	4,833	-0.125*	4,874
NO	0.318***	4,538	0.249**	3,355
SE	0.437***	3,542	0.323***	3,545
US_Dow	0.0428	4,982	0.0829	5,027
US_SP	0.141*	4,985	0.0249	4,999

Note: The horizontal dashed line separates EA and non-EA markets. Since data on $RVol_t$ are available from 2000 onwards, the samples of range are adjusted to take into account the same number of events and observations. For the Norwegian market, data for the range measure are only available from April 2006 onwards.

Table A4: Correlation coefficients of country-specific RV_t

	BE	DE	ES	EU	FI	FR	IT	NL	CH	DK	GB	JP	NO	SE	US_SP	US_Dow
BE	1															
DE	0.8881	1														
ES	0.7944	0.7377	1													
EU	0.9088	0.9089	0.8436	1												
FI	0.6707	0.65	0.5779	0.6627	1											
FR	0.9395	0.9239	0.8381	0.9544	0.6753	1										
IT	0.8401	0.8002	0.8654	0.8633	0.6188	0.8661	1									
NL	0.9342	0.9114	0.7632	0.9167	0.6733	0.9547	0.8089	1								
CH	0.7928	0.8082	0.6365	0.7813	0.5589	0.7997	0.6751	0.8205	1							
DK	0.5569	0.5349	0.4012	0.5437	0.436	0.5302	0.451	0.5776	0.5278	1						
GB	0.7923	0.7674	0.6454	0.8563	0.5814	0.8021	0.6619	0.8097	0.7235	0.541	1					
JP	0.362	0.3407	0.3283	0.383	0.2355	0.3604	0.3027	0.3879	0.3947	0.2808	0.4036	1				
NO	0.7252	0.6951	0.586	0.761	0.5603	0.7218	0.6122	0.7442	0.6593	0.5453	0.8297	0.3731	1			
SE	0.7305	0.7197	0.6008	0.729	0.8586	0.7418	0.6505	0.7436	0.6378	0.4549	0.6713	0.2546	0.6307	1		
US_SP	0.7527	0.7279	0.6144	0.758	0.5514	0.7686	0.6399	0.78	0.681	0.4864	0.7698	0.3835	0.7297	0.6315	1	
US_Dow	0.715	0.6905	0.5808	0.7234	0.5076	0.731	0.5879	0.7496	0.6544	0.4648	0.7453	0.3825	0.7029	0.5832	0.9742	1

Note: The dashed lines separate EA and non-EA markets. Only 5 minutes frequency. Values of 10 minutes frequency very similar.

Table A5: Full regression output of Table 1: realized volatility reactions to $scheduled_t$

	constant	national MSCI	MSCI World	VIX	$RVol_{i,t-1}$	$scheduled$	Observations
BE	-0.113**	-11.07***	-14.20***	0.00530*	0.473***	0.619***	5,064
DE	-0.118**	-11.63***	-19.33***	0.00545*	0.454***	0.590***	5,038
ES	-0.115**	-11.24***	-15.84***	0.00506*	0.427***	0.740***	5,031
EU	-0.123**	-12.01***	-17.25***	0.00615**	0.441***	0.610***	5,066
FI	-0.0852	-12.11***	-12.61***	0.00532	0.321***	0.772***	3,542
FR	-0.124**	-10.96***	-18.43***	0.00549*	0.454***	0.681***	5,066
IT	-0.286***	-11.34***	-26.20***	0.0156***	0.456***	1.106***	2,654
NL	-0.125**	-10.45***	-20.03***	0.00592**	0.476***	0.582***	5,066
CH	-0.126**	-13.98***	-19.55***	0.00663**	0.458***	0.540***	4,977
DK	-0.0563	-11.52***	-9.571***	0.00556	0.308***	0.328***	3,509
GB	-0.125**	-18.36***	-11.79***	0.00778**	0.353***	0.227**	5,011
JP	-0.0871	-12.33***	-8.015***	0.00583*	0.455***	0.0743	4,834
NO	-0.0640	-14.13***	-10.64***	0.00437	0.334***	0.329***	4,538
SE	-0.102	-17.64***	-17.19***	0.00727*	0.321***	0.434***	3,542
US_Dow	-0.124**	0.0428	-20.87***	0.00812**	-17.63***	0.426***	4,982
US_SP	-0.0930*	-17.33***	-22.83***	0.00618**	0.485***	0.141*	4,985

Note: ***, **, and * denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. Sample period: January 2000 to December 2019. The dashed horizontal line separates the volatility measures. The upper part considers 8 EA national stock market volatility measures and the lower part 8 non-EA stock markets.

Table A6: Splitting up sample according to the frequency of scheduled meetings: realized volatility

	(1) every two weeks 2000-2001	(2) every four weeks 2002-2014	(3) every 6 weeks 2015-2019
BE	0.232	0.648***	1.067***
DE	0.173	0.620***	1.068***
ES	-0.0285	0.895***	1.151***
EU	0.220	0.660***	0.961***
FI	NA	0.504***	1.532**
FR	0.138	0.778***	1.023***
IT	NA	1.042***	1.206***
NL	0.0784	0.642***	1.006***
CH	0.326**	0.634***	0.642***
DK	NA	0.411***	0.111
GB	0.197	0.334**	-0.0309
JP	0.115	0.0820	0.0929
NO	-0.243	0.335***	0.381**
SE	NA	0.447***	0.423***
US_Dow	0.510*	-0.0287	-0.114
US_SP	0.543**	0.0609	0.0571

Note: The table presents the estimated coefficients of $scheduled_t$. The horizontal dashed line separates EA and non-EA markets. For period (1), no data are available for the Danish, Finnish, Italian and Swedish stock market.

Table A7: Splitting up sample according to the frequency of scheduled meetings: price range

	(1) every two weeks 1999-2001	(2) every four weeks 2002-2014	(3) every 6 weeks 2015-2019
AT	0.106	0.265***	0.0527
BE	0.0245	0.501***	0.700***
DE	0.0240	0.492***	0.770***
ES	0.113	0.485***	0.412*
EU	0.182	0.585***	0.791***
FI	0.496***	0.349***	0.869***
FR	0.0629	0.583***	0.901***
GR	0.0326	-0.00575	-0.126
IE	-0.244	0.118	0.338
IT	NA	0.692***	0.417**
NL	0.0345	0.492***	0.753***
PT	-0.157	0.178	0.317*
BG	NA	-0.203*	-0.0456
CH	0.113	0.338***	0.479***
CZ	0.0255	0.280***	0.0522
DK	0.166	0.252**	0.0391
GB	0.318**	0.290**	0.0149
HU	0.167	-0.0121	0.0338
JP	-0.0573	-0.155*	0.161
NO	NA	0.300**	0.182
PL	0.0973	0.294***	0.346**
SE	0.323	0.311***	0.260
US_SP	0.136	-0.0134	0.0776
US_Dow	0.325**	0.00188	0.179

Note: The table presents the estimated coefficients of $scheduled_t$. The horizontal dashed line separates EA and non-EA markets. For period (1), no data are available for the Bulgarian, Italian, and Norwegian stock market.