



*Financial Market Reactions to Central Bank Communication*

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## List of Abbreviations

**(T)LTRO** (Targeted) Longer-Term Refinancing Operations

**ABSPP** Asset-Backed Securities Purchase Programme

**bps** basis points

**CBPP** Covered Bond Purchase Programme

**CESI** Citigroup Economic Surprise Index for the Eurozone

**CSPP** Corporate Sector Purchase Programme

**e.g.** *exempli gratia* (for example)

**EA** euro area

**EAPP** Expanded Asset Purchase Programme

**ECB** European Central Bank

**EGARCH** exponential generalized autoregressive conditional heteroscedastic (model)

**ELB** effective lower bound

**et al.** *et alii* (and others)

**FG** forward guidance

**FOMC** Federal Open Market Committee

**GARCH** generalized autoregressive conditional heteroscedastic (model)

**GDP** gross domestic product

**HAR-RV** heterogeneous autoregressive model of realized volatility

**i.e.** *id est* (that is)

**MSCI** Morgan Stanley Capital International (market index)

**OMT** Outright Monetary Transactions

**PSPP** Public Sector Purchase Programme

**SMP** Securities Markets Programme

**SUR** seemingly unrelated regression

**TIPS** U.S. Treasury Inflation-Protected Securities

**U.S.** United States

**VAR** vector autoregressive (model)

**VIX** Chicago Board Options Exchange Volatility Index

**vs.** versus

**ZLB** zero lower bound



# Chapter 1

## Introduction

*‘[...] what happened in communication by central banks over the last ten, fifteen years is a complete transformation.’*

Mario Draghi, during an ECB press conference on October 24, 2019

Central bank communication has become a novel monetary policy tool. Besides the traditional monetary policy instrument of the interest rate, central banks increasingly pay attention to the way of information disclosure, i.e., how to communicate new measures such as forward guidance and asset purchase programs. Market participants may interpret the same policy decision differently depending on the chosen communication approach. Possible determining factors comprise the level of detail, timing, and frequency of monetary policy announcements. An enhanced communication strategy, for example by addressing a specific group, has the objective to lower financial market volatility after monetary policy decisions as well.

Recent empirical literature stresses the relevance of central bank communication and offers diverse approaches to measure its impact on financial markets. Evaluating six major central banks in an event study framework, Ehrmann et al. (2019) emphasize that the type of forward guidance plays a key role in the future path of interest. In contrast, according to a survey in the United States (U.S.) by Lamla and Vinogradov (2019), announcements have no measurable effect on consumers' perceptions and expectations of inflation and interest rates. Based on a semantic analysis of press releases by the European Central Bank

(ECB), Beaupain and Girard (2020) report that a common understanding between policymakers and market participants reduces sovereign yield spreads in core and distressed countries. Altavilla et al. (2019) build an event study data base using intraday asset price changes around ECB press conferences. They show that policy surprises affect stock prices by means of a daily vector autoregressive (VAR) model. An exponential generalized autoregressive conditional heteroscedastic (EGARCH) model proposed by Ehrmann and Talmi (2019) suggests that similar press releases by the Bank of Canada reduce market volatility, whereas volatility rises when substantial changes occur after sequences of similar statements. Bholat et al. (2019) conduct an online experiment with the general public of the United Kingdom in the context of monetary policy messages. The public comprehension increases if one simplifies the language and relates the content to people's lives.

This thesis aims to shed light on central bank communication and its immediate impact on financial markets. To tackle this research question, announcements regarding unconventional policies as well as information regularly released during scheduled press conferences will be assessed. Methodologically, the thesis relies on event study regressions using high-frequency data and thereby follows the current standard in academia (e.g., Altavilla et al., 2016; Georgiadis and Gräß, 2016; Haitsma et al., 2016; Fausch and Sigonius, 2018; Ambler and Rumler, 2019; Christensen and Krogstrup, 2019; Rieth and Wittich, 2020).

By analyzing different markets, periods, and types of communication in the context of statements issued by the ECB and the Federal Reserve, the thesis has a comprehensive character. From a policy perspective, it is worth examining, to what extent central banks are able to move financial markets. A better understanding of the underlying channels of communication as well as operating market mechanisms helps improve an effective monetary policy implementation. In the case of the euro area (EA), the influence of communications by the ECB may vary across member countries. Such a heterogeneity would impede the ECB's task to serve the EA as a whole. The thesis complements existing literature on financial markets reactions of core and peripheral countries (e.g., Falagiarda and Reitz, 2015; Jäger and Grigoriadis, 2017; Urbchat and Watzka, 2019) by enlarging both

the examined period and country set. Furthermore, the following models contain novel features such as interaction effects within the bond market and self-constructed stock market volatility measures.

The thesis comprises four distinct studies and is organized as follows. Chapter 2 examines the U.S. government bond market and its reaction to forward guidance statements by the Federal Reserve. Chapter 3 extracts announcements regarding the ECB's non-standard asset purchase programs and focuses on EA national 10-year government bond yields in response to such communications. Building on this exercise, Chapter 4 extends the analysis to different maturities along the yield curve. Central bank communication effects are not limited to bond markets; also stock markets move after crucial announcements. Therefore, the impact of the ECB announcements on stock market volatility will be assessed in Chapter 5. The final Chapter 6 provides concluding remarks.





# Chapter 2

## Yield reactions to forward guidance in the US\*

### 2.1 Introduction

Since the arrival at the zero lower bound, forward guidance (FG) has become an important monetary policy tool. Many studies discuss the theoretical implications (Del Negro et al., 2012; Woodford, 2013; Campbell et al., 2016; McKay et al., 2016) and empirical research (Campbell et al., 2012; Raskin, 2013; Moessner, 2015) suggests significant effects of FG in the United States. This study is an explicit extension of Moessner (2015). By using the same data sources and the identical methodology, we additionally distinguish between qualitative-based FG, date-based FG and threshold-based FG to provide a more type-specific view on the effectiveness of FG. The chapter is structured as follows. Section 2.2 briefly describes the methodology and the data. Section 2.3 presents the empirical results, while the final Section 2.4 concludes.

### 2.2 Methodology and data

The methodology is identical to the one applied by Moessner (2015). We use the same data sources but we update the data set. The sample period runs from June 1, 2004

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\* This chapter is based on Neugebauer et al. (2017), “A Note on the Reactions of Real Yields to Different Types of Forward Guidance in the US”, *Economics Bulletin*, 37(4), p.2703-2710, which is a joint work with Ralf Fendel and Nils Niederhagen.

to June 30, 2016.<sup>1</sup> For that period, we examine the reaction of U.S. Treasury Inflation-Protected Securities (TIPS) yields to FG announcements by the Federal Open Market Committee (FOMC). We formally test two hypotheses.

**Hypothesis 1:** *‘FG has a significant adverse effect on market expectations of future short-term interest rates and, thus, causes an immediate reduction in U.S. yields.’*

This hypothesis tests whether the relationship between FG and yield changes obtained by Moessner (2015) still holds in the updated data set:

$$y_t^m - y_{t-1}^m = \alpha + \beta \times d_{FG} + \sum_{j=1}^{11} (\gamma_j \times surprise_{j,t}) + \varepsilon_t, \quad (2.1)$$

$$y_t^m - y_{t-1}^m = \alpha + \beta_1 \times d_{FG}^{wap} + \beta_2 \times d_{FG}^{nap} + \sum_{j=1}^{11} (\gamma_j \times surprise_{j,t}) + \varepsilon_t, \quad (2.2)$$

where  $y_t^m - y_{t-1}^m$  represents the daily change in yields, i.e. TIPS forward, zero-coupon and par rates, respectively, with maturities from  $m = 2$  to 10 years. The rates are taken from Gürkaynak and Wright (2008). The dummy variable  $d_{FG}$  takes the value of 1 on days when FG is provided, and 0 otherwise. Similarly,  $d_{FG}^{wap}$  and  $d_{FG}^{nap}$  are dummy variables differentiating whether asset purchase announcements happened or not. All relevant FG events are deduced from FOMC press releases and depicted in Table 2.1. The variable  $surprise_{j,t}$  takes the normalized surprise value measured through the difference between actual realizations and market expectations of each macroeconomic indicator on release dates provided by Bloomberg database.

**Hypothesis 2:** *‘The Effectiveness of FG in the U.S. increases from qualitative to date-based to threshold-based guidance.’*

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<sup>1</sup> Due to public holidays the dates 09/06/2010, 02/20/2012 and 11/12/2012 are excluded from the data set. Furthermore, the dates 11/24/2011, 01/02/2012, 05/28/2012, 07/04/2012 and 09/03/2012 are omitted, since the data source shows exactly the same values for the respective previous day, which is suspicious. For the sake of brevity, the present study concentrates on TIPS yields only, while the results of Moessner (2015) were additionally checked using breakeven forward rates. We were able to replicate those findings as well, but they are less significant for the extended sample period. The results are available upon request.

Following Gersbach and Hahn (2013) as well as Filardo and Hofmann (2014), there is a trade-off in FG policy between flexibility and effectiveness. The more the central bank binds itself to its announcement, the stronger should be the effect of FG. However, the monetary authority loses flexibility at the same time. Hence, qualitative-based guidance should be less effective than date-based guidance, and threshold-based guidance should be the most effective type of FG. This distinction extends the analysis of Moessner (2015) substantially. To the best of our knowledge, it has not been tested in the empirical literature yet.

Accordingly,  $d_{FG}$  is disentangled into the aforementioned three different types:

$$y_t^m - y_{t-1}^m = \alpha + \beta_1 \times d_{QB} + \beta_2 \times d_{DB} + \beta_3 \times d_{TB} + \sum_{j=1}^{11} (\gamma_j \times surprise_{j,t}) + \varepsilon_t, \quad (2.3)$$

where  $d_{QB}$ ,  $d_{DB}$  and  $d_{TB}$  are dummy variables taking the value of one on days associated with qualitative-based, date-based and threshold-based guidance, respectively. The classification of the events can be found in Table 2.1. All other variables are identical to the notation before. Hypothesis 2 implies that  $0 > \beta_1 > \beta_2 > \beta_3$  holds.

As in Equation (2.2) before, we also control for announcements of asset purchases in order to isolate the pure effect of FG:

$$\begin{aligned} y_t^m - y_{t-1}^m = & \alpha + \beta_{1,1} \times d_{QB}^{wap} + \beta_{1,2} \times d_{QB}^{nap} + \beta_{2,1} \times d_{DB}^{wap} + \beta_{2,2} \times d_{DB}^{nap} \\ & + \beta_{3,1} \times d_{TB}^{wap} + \beta_{3,2} \times d_{TB}^{nap} + \sum_{j=1}^{11} (\gamma_j \times surprise_{j,t}) + \varepsilon_t, \end{aligned} \quad (2.4)$$

where  $d_{QB}^{nap}$  represents a dummy variable taking the value of one on days when qualitative FG is provided, but no statement concerning asset purchases is made (and zero otherwise), and  $d_{QB}^{wap}$  is a dummy variable taking the value of one on dates when qualitative FG as well as asset purchases are announced concomitantly. Analogously, the respective dummy variables are also separated for the other two forms of FG, namely date-based ( $d_{DB}^{nap}$  as well as  $d_{DB}^{wap}$ ) and threshold-based ( $d_{TB}^{nap}$  as well as  $d_{TB}^{wap}$ ) guidance.

Table 2.1: Overview of FG announcements applied by the FOMC

Date	Statement	Relevant wording	FG type	Specific asset purchase announcement
16.12.2008	The Federal Open Market Committee decided today to establish a target range for the federal funds rate of 0 to 1/4 percent. [...] the Committee anticipates that weak economic conditions are likely to warrant exceptionally low levels of the federal funds rate for some time [...]	some time	qualitative	no
18.03.2009	[...] the Committee will maintain the target range for the federal funds rate at 0 to 1/4 percent and anticipates that economic conditions are likely to warrant exceptionally low levels of the federal funds rate for an extended period.	extended period	qualitative	yes
09.08.2011	The Committee currently anticipates that economic conditions - including low rates of resource utilization and a subdued outlook for inflation over the medium run - are likely to warrant exceptionally low levels for the federal funds rate at least through mid-2013.	mid-2013	date-based	no
25.01.2012	[...] the Committee [...] currently anticipates that economic conditions [...] are likely to warrant exceptionally low levels for the federal funds rate at least through late 2014.	late 2014	date-based	no
13.09.2012	[...] the Committee expects that a highly accommodative stance of monetary policy will remain appropriate for a considerable time after the economic recovery strengthens. [...] the Committee [...] currently anticipates that exceptionally low levels for the federal funds rate are likely to be warranted at least through mid-2015.	mid-2015	date-based	yes
12.12.2012	the Committee [...] currently anticipates that this exceptionally low range for the federal funds rate will be appropriate at least as long as the unemployment rate remains above 6-1/2 percent, inflation between one and two years ahead is projected to be no more than a half percentage point above the Committee's 2 percent longer-run goal, and longer-term inflation expectations continue to be well anchored. The Committee views these thresholds as consistent with its earlier date-based guidance. In determining how long to maintain a highly accommodative stance of monetary policy, the Committee will also consider other information[...] When the Committee decides to begin to remove policy accommodation, it will take a balanced approach consistent with its longer-run goals of maximum employment and inflation of 2 percent.	6-1/2 percent	threshold-based	yes
18.12.2013	[...] now anticipates, based on its assessment of these factors, that it likely will be appropriate to maintain the current target range for the federal funds rate well past the time that the unemployment rate declines below 6-1/2 percent, especially if projected inflation continues to run below the Committee's 2 percent longer-run goal.	well past 6-1/2 percent	threshold-based	yes

Table 2.1 Overview of FG announcements applied by the FOMC (continued)

Date	Statement	Relevant wording	FG type	Specific asset purchase announcement
19.03.2014	[...] Committee continues to anticipate, based on its assessment of these factors, that it likely will be appropriate to maintain the current target range for the federal funds rate for a considerable time after the asset purchase program ends, especially if projected inflation continues to run below the Committee's 2 percent longer-run goal [...] The Committee currently anticipates that, even after employment and inflation are near mandate-consistent levels, economic conditions may, for some time, warrant keeping the target federal funds rate below levels the Committee views as normal in the longer run.	for some time after 6-1/2 percent	qualitative	yes
29.10.2014	However, if incoming information indicates faster progress toward the Committee's employment and inflation objectives than the Committee now expects, then increases in the target range for the federal funds rate are likely to occur sooner than currently anticipated. Conversely, if progress proves slower than expected, then increases in the target range are likely to occur later than currently anticipated.	sooner / later than expected (depending on the achievement of objective)	threshold-based	no
28.01.2015	In determining how long to maintain this target range, [...] will take into account a wide range of information [...] Based on its current assessment, the Committee judges that it can be patient in beginning to normalize the stance of monetary policy.	patient	qualitative	no
18.03.2015	Consistent with its previous statement, the Committee judges that an increase in the target range for the federal funds rate remains unlikely at the April FOMC meeting. [...] it will be appropriate to raise the target range for the federal funds rate when it has seen further improvement in the labor market and is reasonably confident that inflation will move back to its 2 percent objective over the medium term.	when it has seen further improvement in the labor market	threshold-based	no
16.12.2015	Given the economic outlook, and recognizing the time it takes for policy actions to affect future economic outcomes, the Committee decided to raise the target range for the federal funds rate to 1/4 to 1/2 percent. The stance of monetary policy remains accommodative after this increase, thereby supporting further improvement in labor market conditions and a return to 2 percent inflation. [...] the federal funds rate is likely to remain for some time below levels.	some time	qualitative	no

**Notes:** Events were only included if there were new information, we do not consider repeating communications as FG. Of course, it depends on the interpretation of the formulation to which FG type one assigns a press release. Source: Moessner (2015), p.2675, Federal Open Market Committee via <http://www.federalreserve.gov/monetarypolicy/fomc'historical.htm>.

## 2.3 Results

The regression output for Hypothesis 1 is presented in Table 2.2.<sup>2</sup> Standard errors are adjusted according to Newey and West (1987). In general, FG reduces the yields. For instance, a FG announcement leads to a mean reduction of eight basis points for the six years TIPS forward rate (see column 6 in Table 2.2). Hence, Hypothesis 1 can be confirmed. If additionally asset purchase announcements are considered (Equation 2.2), it becomes clear that FG is only effective when there are no announcements at the same time. This is a confirmation of Moessner (2015) for the updated sample period. However, compared to her findings we have lower and less significant estimators and the short-term yields are not affected anymore.<sup>3</sup> This might be due to the fact that our updated study includes twice as many events (12 instead of 6 FG announcements). FG is becoming more and more a conventional monetary policy tool and because of a decreasing surprise component less effective over time. If investors get used to FG and even expect it, they react less sensitively.

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<sup>2</sup> We show the output for TIPS forward rates. Since the results for TIPS zero coupon and par rates are similar they are omitted for parsimony reasons and available upon request.

<sup>3</sup> Compare Table 2.2 with the left columns in Tables 2 and 4 from Moessner (2015), p. 2677-2678.

Table 2.2: Reactions of U.S. TIPS forward rates to FG

Equation (2.1)	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years	10 years
$d_{FG}$	-0.0962	-0.1116*	-0.1067*	-0.0966*	-0.0838*	-0.0705*	-0.0582	-0.0481	-0.0407
constant	-0.0002	-0.0000	-0.0002	-0.0003	-0.0004	-0.0004	-0.0004	-0.0004	-0.0003
Observations	3036	3036	3036	3036	3036	3036	3036	3036	3036
Adjusted R-squared	0.016	0.019	0.017	0.014	0.011	0.008	0.006	0.005	0.005
Equation (2.2)	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years	10 years
$d_{FG}^{nap}$	-0.1006	-0.1089	-0.1030**	-0.0969***	-0.0886***	-0.0792***	-0.0704***	-0.0631***	-0.0578***
$d_{FG}^{wap}$	-0.0901	-0.1154	-0.1117	-0.0961	-0.0772	-0.0584	-0.0414	-0.0274	-0.0171
constant	-0.0002	-0.0000	-0.0002	-0.0003	-0.0004	-0.0004	-0.0004	-0.0004	-0.0003
Observations	3036	3036	3036	3036	3036	3036	3036	3036	3036
Adjusted R-squared	0.015	0.019	0.016	0.013	0.011	0.008	0.006	0.005	0.005

**Notes:** \*\*\*, \*\*, and \* illustrate 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. Coefficients of the eleven macroeconomic surprise variables are excluded to increase readability. Sample period: 06/02/2004 – 06/30/2016.

Decomposing FG into its three distinct forms, the results in Table 2.3 show that date-based FG is the only effective one while other forms can be neglected. Date-based FG is highly significant for all maturities whereas qualitative-based FG is only significant for the long-term yields and threshold-based FG not at all when asset purchases are not controlled for (Equation 2.3). When accounting for asset purchase announcements (Equation 2.4), date-based FG remains the dominant form. However, threshold-based FG now has a significant positive impact for long maturities.<sup>4</sup> This confirms the diluting effect of parallel asset purchases on FG announcements as  $d_{TB}^{nap}$  shows the expected signs. The significantly negative estimator for the 2-years yield of  $d_{TB}^{wap}$  and longer-term maturities displaying a positive sign suggest a rotation of the yield curve: While in the short-term the expected effect of FG shows up, inflation expectations seem to emerge in the long-term in reaction to the asset purchase announcements. This might also explain why  $d_{DB}^{nap}$  has a stronger impact than  $d_{DB}^{wap}$  for long maturities. In case of  $d_{TB}^{wap}$ , inflation expectations dominate the announcement effect so that the sign changes. Hence, Hypothesis 2 is rejected.

This is an astonishing result as we expected for all measures to be effective but to a different extent. Moreover, it is contradicting the theoretical literature because threshold-based FG should represent the strongest effect as it is the least flexible form. One explanation could be that by date-based FG investors can precisely plan their investments and therefore directly adjust the expectations which, in turn, reduces the yields. Qualitative-based FG might be too vague to have a significant impact. Threshold-based FG seems to be imprecise, too, because nobody knows when the threshold is reached. Even if the threshold is precise, the time of action after passing the threshold is in turn vaguely formulated (e.g., FG from December 18, 2013: ‘maintain the current target range for the federal fund rate *well past the time* that the unemployment rate declines below 6-1/2 percent’). In contrast, date-based FG is concrete and should have an effect if the announcement is credible.

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<sup>4</sup> To check for robustness, Equations (2.3) and (2.4) were also conducted for a three and five-day interval. The results are similar but a little less significant and available upon request.



Table 2.3: Reactions of U.S. TIPS forward rates to different types of FG

Equation (2.3)	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years	10 years
$d_{QB}$	-0.0542	-0.116	-0.1499	-0.1583	-0.1508	-0.135	-0.1161*	-0.0973*	-0.0807*
$d_{DB}$	-0.1529***	-0.1709***	-0.1593***	-0.1333***	-0.1036***	-0.0765***	-0.0547***	-0.0393***	-0.0297**
$d_{TB}$	-0.1055	-0.0614	-0.0135	0.0076	0.0141	0.0139	0.0108	0.0061	0.0005
constant	-0.0002	-0.0000	-0.0002	-0.0003	-0.0004	-0.0004	-0.0004	-0.0004	-0.0003
Observations	3036	3036	3036	3036	3036	3036	3036	3036	3036
Adjusted R-squared	0.016	0.02	0.02	0.019	0.016	0.012	0.009	0.007	0.006
Equation (2.4)	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years	10 years
$d_{QB}^{wap}$	-0.1152	-0.2265	-0.2632	-0.2598	-0.2386	-0.2099	-0.1787	-0.1479	-0.1197
$d_{QB}^{nap}$	-0.0123	-0.0401	-0.0719	-0.0886	-0.0904	-0.0835*	-0.0732*	-0.0627*	-0.0541*
$d_{DB}^{wap}$	-0.1738***	-0.1673***	-0.1433***	-0.1126***	-0.0815***	-0.0535***	-0.0301***	-0.0121***	0.0005
$d_{DB}^{nap}$	-0.1424***	-0.1727***	-0.1673***	-0.1436***	-0.1146***	-0.0879***	-0.0670***	-0.0529***	-0.0449***
$d_{TB}^{wap}$	-0.0231***	0.0226	0.0574***	0.0778***	0.0883***	0.0925***	0.0917***	0.0867***	0.0776***
$d_{TB}^{nap}$	-0.1871	-0.1448	-0.0838	-0.062	-0.0595	-0.0639**	-0.0694***	-0.0735***	-0.0758***
constant	-0.0002	0.0000	-0.0002	-0.0003	-0.0004	-0.0004	-0.0004	-0.0004	-0.0003
Observations	3036	3036	3036	3036	3036	3036	3036	3036	3036
Adjusted R-squared	0.018	0.023	0.023	0.022	0.019	0.015	0.012	0.009	0.008

**Notes:** \*\*\*, \*\*, and \* illustrate 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. Coefficients of the eleven macroeconomic surprise variables are excluded to increase readability. Sample period: 06/02/2004 – 06/30/2016.

## 2.4 Conclusion

In order to study the effectiveness of FG in the U.S., two hypotheses are tested. First, the general effectiveness of FG in reducing yields along different maturities is assessed through evaluating its influence on U.S. TIPS yields (zero coupon, par and forward rates) for the period 6/2004 to 6/2016. A significant adverse effect on all interest rate classes is detected. This suggests that FG is able to alter market expectations of future interest rates and, thus, directly reduces current yields.

Second, the effectiveness of the different types of FG in the U.S. – from qualitative to date-based to threshold-based guidance – is evaluated. Against the initial intuition, only date-based FG has a noteworthy impact on yields across the different types of guidance. Consequently, the FOMC might want to tend towards date-based guidance and re-evaluate the appeal of the other forms as market participants appear to react to date-based FG only.

For future research it seems worthwhile to employ the applied methodology to other economies and their central banks performing FG (e.g., the EU, UK, Japan). Similar results would certainly increase the general validity of the presented findings.

# Chapter 3

## Yield reactions to ECB program announcements\*

### 3.1 Introduction

National government bond yields include the risk premium of a specific country. That is why the announcement of an asset purchase by a central bank itself can already reduce the yields through amended expectations of investors. Event studies by Joyce et al. (2011) and Gagnon et al. (2011) find evidence for short-term yield reductions to quantitative easing announcements in the United Kingdom and in the U.S., respectively. Previous research, however, indicates announcement effects are somewhat specific to the respective country.<sup>1</sup> This study aims to quantify ECB program announcement effects for the euro area. In particular, the study examines 10-year government bond yields of different euro area members. Such evidence is of high relevance for ECB's policy making and communication strategy. Before making an announcement the ECB might want to assess its consequences on individual euro area members because it matters whether an announcement is per-

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\* This chapter is based on Fendel and Neugebauer (2019), "Country-Specific Euro Area Government Bond Yield Reactions to ECB's Non-Standard Monetary Policy Program Announcements", *German Economic Review*, forthcoming, which is a joint work with Ralf Fendel. A previous version was published as Fendel and Neugebauer (2018). Parts of this study have been presented at the 22<sup>nd</sup> International Conference on Macroeconomic Analysis and International Finance, the EABCN Conference on 'Measuring the Effects of Unconventional Monetary Policy in the Data: What Have We Learned?', the 11<sup>th</sup> meeting Aktionskreis Stabiles Geld, the Seminar in International Economic Policy at the University of Zurich, the 11<sup>th</sup> RGS Doctoral Conference in Economics, and the 1<sup>st</sup> CESifo EconPol Europe PhD Workshop: Economic and Fiscal Policy in Europe.

<sup>1</sup> For Japan with its long history at the zero lower bound and quantitative easing measures, no evidence of yield reactions to central bank announcements exists. In contrast, in an event study Bernanke et al. (2004) state that communications by the Federal Reserve alter market expectations and thus long-term yields change in the U.S. while statements by the Bank of Japan do not affect Japanese yields.

ceived differently within the euro area. Although asset purchase programs do not target yields directly, it is worthwhile examining yield reactions. A reduction in government bond yields could be interpreted as an intermediate objective of the ECB. It can help recover the monetary transmission mechanism to achieve the ultimate target of price stability.

In general, massive asset purchases by any central bank provide more liquidity. The present study, however, focuses exclusively on the announcements of such liquidity provisions while the actual amount of asset purchases is ignored.<sup>2</sup> Every central bank communication consists in releasing private information to the public which eventually induces market reactions. A credible asset purchase announcement directly affects investors' expectations on the (future) attractiveness of particular assets (or asset classes). As a potential consequence, the demand for these assets rises and asset prices increase. In case of government bonds, this, in turn, directly reduces the government bond yields in question. For this short-term mechanism to work, it is irrelevant whether the future quantitative easing measures have the expected effects or whether they merely work as a 'placebo' (Gros, 2018). More specifically, it is expected that ECB's asset purchase program announcements have a stronger effect on the government bonds of stressed countries, since the programs intend to foster primarily the euro area economies under stress. In contrast, the yields of more solvent countries are expected to be less sensitive to such announcements. Although, on the announcement day, it is yet unclear, what kind of assets the ECB will exactly buy, that is to which economy the purchased assets belong, the possibility that also assets from the countries under stress might be bought, substantially smooths market expectations.

Most existing literature only investigates the announcement effects on the aggregate euro area as a whole ignoring possible heterogeneity of its members. For instance, Ambler and Rumler (2019) use weighted average real yields of all euro area countries to search for announcement effects. Their research indicates that announcements significantly decrease real bond yields. The few existing disaggregated studies compare only a few countries. Altavilla et al. (2016) analyze the effects of outright monetary transactions (OMTs) announcements on the government bond yields of Germany, France, Italy and Spain, while

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<sup>2</sup> For a study that implements actual purchases to assess the impact on sovereign bond yields, see for instance Eser and Schwaab (2016).

Briciu and Lisi (2015) look exclusively at the yields of only Germany, Italy and Spain in response to ECB's balance sheet announcements. Both studies find yield reducing effects in response to ECB's unconventional monetary policy announcements.

Many studies consider the effects on yields' spreads rather than levels. For instance, Falagiarda and Reitz (2015) state that the inter-European spreads on government bond yields decrease in response to ECB's asset purchase announcements. They find a reduction of long-term yield spreads of Ireland, Italy, Portugal and Spain. Similarly, Szczerbowicz (2015) evaluates the impact of ECB's unconventional monetary policies on 10-year sovereign bond yield spreads of France, Greece, Ireland, Italy, Portugal and Spain with respect to the German sovereign yield. She also confirms spread-reducing effects. Bulligan and Monache (2018) quantify the spread reduction of Italy, France and Spain (vis-à-vis Germany) for asset purchase announcements between September 2014 and July 2017. Nevertheless, the question remains which (relative) level effects of the respective spread-defining yields exactly underlie these spread reductions.

Therefore, this study covers a large number of euro area members and focuses on the level effects. For policy making, it is essential to see the absolute (level) impact of an announcement to evaluate its costs or benefits. The relative (spread) position to another economy is less important. Furthermore, this study covers a long time span of more than ten years. So far, studies in this field of research are typically constrained to a shorter period. For instance, Christensen and Krogstrup (2019) only consider events during one month, Altavilla et al. (2016) during three months and Gagnon et al. (2011) during two years.

Hence, this study extends the existing literature in three directions. First, the separate consideration of individual euro area members allows us to compare national effects. A euro area average impact seems not entirely helpful for policy analysis. A study of differences between countries gives important insights into economic conditions of the respective countries instead. Second, the focus on the interest rate level is more valuable than an interest rate spread analysis. A reduction in spread does not explain the inherent direction of yield changes; that is whether both yields are increasing/decreasing to a different extent or whether they are moving into opposite directions. Third, the long time span guaran-

tees that announcements are considered at different states of the financial crisis. Unlike Bulligan and Monache (2018), who divide their three year observation period into subsamples, this study aims at a (time-invariant) generalization of the findings. Given some programs and their announcements last for a long time and are continuously prolonged, it would be inappropriate to include only a part of its announcement history. Our approach of considering many countries over a long time horizon stands in contrast to studies as Krishnamurthy et al. (2018) that focus on specific programs and transmission channels for a shorter period. In sum, this study has a more comprehensive character compared to existing event studies.

By covering daily data from 11 euro area countries from January 1, 2007 to August 31, 2017 and searching for country-specific level effects on 10-year government bonds yields of ECB announcements, the chapter adds three important insights to the existing literature. First, to the best of our knowledge this event study is the first to document explicitly that the effects of announcements arise with a one-day delay meaning that government bond markets take some time to react to ECB announcements. Second, it shows the country-specific quantitative extent of yield reduction is inversely related to the solvency rating of the corresponding euro area country: The worse the rating is, the bigger is the yield reduction. This also implies that the observed reduction of the yield spread between core/more solvent and periphery/less solvent countries in response to an announcement is due to a stronger decrease in the yield of the latter. Third, a group-wise panel analysis confirms these findings and adds an innovative part to the literature by letting the announcement variable interact with the country-specific spread level. A high spread on the day of the announcement reinforces the yield-reducing effect. By employing different data as control variables, these findings are robust for a given event set.

The remainder of the chapter proceeds as follows. Section 3.2 describes the methodology and the data. Section 3.3 presents the empirical results. In Section 3.4, we discuss our findings in light of previous work and possible transmission channels. Section 3.5 concludes.

## 3.2 Methodology and data

In order to investigate the short-term impact of ECB’s asset purchase announcements on the yields of individual euro area members, an event study methodology as in Moessner (2015) is applied.<sup>3</sup> The first subsection formally specifies the model. Subsequently, we motivate the identification of events in this model. Finally, the data and some descriptive statistics are discussed.

### 3.2.1 Model specification

An identical regression is carried out for each government bond yield  $y_t$  to test whether different reactions appear among the euro area countries. The baseline specification uses first-differences and is

$$\Delta y_t = \alpha + \beta \Delta y_{t-1} + \gamma APA_t + \delta \Delta X_t + \varepsilon_t, \quad (3.1)$$

with  $t = 1, \dots, T = 2784$  observations per country denoting the daily observations for each variable and  $\varepsilon_t \sim (0, \sigma^2)$  being the error term, while  $\alpha$  is a constant.

We assume the present day’s yield change is dependent on that on the previous day as common in financial time series. Therefore, a one lag estimator  $\Delta y_{t-1}$  is included in the regression as in Urbschat and Watzka (2019).<sup>4</sup> The vector  $\Delta X_t$  covers six additional control variables in their first-differences. First, the country-specific stock market indices intend to represent the investors’ perception of an economy. A rising index *ceteris paribus* reduces the default risk of sovereign debt. Thus, it decreases government bond yields. Second, the Citigroup Economic Surprise Index for the Eurozone (CESI) is defined as weighted historical standard deviations of macroeconomic data surprises and controls for

<sup>3</sup> For a concise overview of the use of event studies in macro-finance research, see Gürkaynak and Wright (2013).

<sup>4</sup> The application of the model with an additional two-day lag estimator  $\Delta y_{t-2}$  shows an insignificant estimator for all countries under consideration. A lagged dependent variable could cause endogeneity problems. Although related literature commonly applies such lags (Szczerbowicz, 2015; Jäger and Grigoriadis, 2017; Urbschat and Watzka, 2019), the model is also applied without a lagged dependent variable to overcome endogeneity concerns as a robustness check. The results (available upon request) persist highlighting that endogeneity is negligible in this kind of models.

general events taking place all over Europe. A positive development of this index increases perceived risks of investors, which, in turn, increases bond yields. The CESI arguably suffices to control for global influences because it already bundles several control factors in one variable. For instance, Georgiadis and Gräb (2016) rely on the CESI as single control variable. However, such a control disregards conventional monetary policy surprises. This is particularly important if one also incorporates the pre-crisis period when regular monetary instruments – especially the policy rate – play a decisive role in the expectation formation of market participants.

Third, a monetary surprise on the interest rate equals the difference between ECB's actual decision and market expectations, typically measured by forward rates. For the U.S., Gürkaynak et al. (2007) find that federal funds futures is the most suitable instrument to forecast monetary policy. Bernoth and von Hagen (2004) propose the 3-month-Euribor future rate as an unbiased predictor of ECB's policy rate. Based on Kuttner (2001) we include the daily change in 3-month-Euribor futures as a third control variable. It controls for the argument that not the announcement itself but the change in futures rates on the day of the announcement determines the development of government bond yields. The higher this change is, the stronger is the surprise element and accordingly the influence on yields.<sup>5</sup>

Fourth, we add a measure of global volatility, the VIX, as proposed by Szczerbowicz (2015) and Jäger and Grigoriadis (2017) to control for global risk. A rising index suggests a higher risk premium and thus boosts yields. It would be interesting to include further market sentiment measures such as the index of economic policy uncertainty by Baker et al. (2016) or the consumer confidence indicator by the European Commission. However, these indices are unavailable at a daily frequency and a transformation of monthly survey data to a daily basis would bias the results. Fifth, the U.S.-\$/€ spot exchange rate (in price notation)<sup>6</sup> and sixth, the 10-year instantaneous forward U.S. Treasury Inflation-Protected

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<sup>5</sup> Our results are robust to alternative monetary surprises that use medium-term interests (see Section III.2 in the appendix).

<sup>6</sup> Of course, one could also implement an effective exchange rate such as the rate vis-à-vis the EER-19 trading partners. However, due to gaps in the data availability (overall 52 missing observations) the spot exchange rate is convenient. Independent of the chosen exchange rate variable the results remain essentially identical.



Securities (TIPS) yields intend to control for the link between exchange rate movements and interest rates according to international arbitrage considerations. While government bond yields tend to move in the same direction, an appreciation of the euro implies falling yields in Europe. All variables are obtained from Datastream and we take end-of-business-day values ('close prices') to compute first-differences.

$APA_t$  is the variable of our main interest. It is a dummy variable taking the value of 1 on days of a specific ECB asset purchase program announcement, and 0 otherwise. Hence, each announcement is weighted equally.<sup>7</sup> In contrast to Falagiarda and Reitz (2015) who add a dummy variable for each single event, all announcements are represented by one common dummy variable in order to detect a generalized effect of an ECB announcement. An overall effect is more suitable for policy making because the ECB is interested in gauging the average effect of similar future announcements.<sup>8</sup> If each announcement is considered individually, the result is only indicative for an identical announcement in the future. Even measuring the effect of one single announcement is challenging given joint policy announcements that cover different topics. If one detects a yield reaction triggered by a certain press release it is hard to disentangle which specific topic of the joint announcement predominantly moves the market. The coefficient  $\gamma$  measures the general announcement effect and it is expected to have a negative sign ( $\gamma < 0$ ). It could be problematic to draw quantitatively conclusions from a qualitative (dummy) variable. Previous event studies like Falagiarda and Reitz (2015) report that announcements not linked to a specific size have quantitative effects, though.

### 3.2.2 Identification of events

An integral element in the analysis is the identification of ECB's asset purchase announcements that can be classified as non-standard monetary policy announcements. Press releases and statements by ECB's officials are therefore carefully categorized according to their content. This approach of deliberately determining events is common in related lit-

<sup>7</sup> This assumption is modified by accounting for interaction effects in Section 3.3.4.

<sup>8</sup> In light of the Lucas critique announcements will not work in the same manner because rational expectations will change after the disclosure of the announcement. However, this limitation independently exists whether one considers effects of single announcements or an aggregate announcement impact.

erature and ‘entails a certain degree of subjectivity’ (Ambler and Rumler, 2019, p. 10). Table A1 in the appendix lists potentially relevant events that might affect the European government bond market. Out of this list, 26 events are chosen and denoted in bold. That means,  $APA_t$  is equal to 1 on these days, and 0 otherwise. Furthermore, the keywords indicating why a certain event is included are denoted in italics. They typically refer to formulations that induce an increase of asset purchases such as ‘supplementary’ or ‘adding’ and the name of the respective ECB’s program. The provision of an exhaustive keyword list is unfeasible because the announcements have to be evaluated in its full textual context. For a similar reasoning, we refrain from machine learning techniques to identify events as they easily become non-transparent.

The ECB typically covers several topics during one single press conference. The information ranges from statistics, legal information, supervision, bank notes, payment system, financial stability, monetary policy, conferences, human resources decisions, policy recommendations and so forth. Market participants are confronted with such statements and need to decide which are eventually relevant for government bond yields. Most information simultaneously disclosed on dates illustrated in Table A1 unlikely dilutes the effects of the announced programs, as the following examples illustrate.<sup>9</sup> The statement regarding the ECB’s macroprudential policy on December 15, 2016 is not directly linked to the announcement of purchasing asset backed securities. On September 14, 2014, the ECB declares its first list of voting rotation in the Governing Council, which is a political statement rather than an economic one. The declaration about the single resolution mechanism on November 8, 2013 is related to supervision of credit institutions instead of monetary policy program measures. Similarly, on September 4, 2014, the ECB publishes a final list of significant credit institutions. Since the supervised entities are spread around all economies under consideration, we do not expect a (country-specific) financial market reaction. On May 10, 2010, the ECB reactivates U.S.-dollar liquidity providing operations in accordance with other central banks. Such a measure is designed to help improve liquidity conditions in U.S.-dollar funding markets and not linked to the euro area government

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<sup>9</sup> Certainly, the parallel disclosure of a change in the policy rate is a crucial announcement that possibly affects government bond yields. We account for this argument in Section III.1 in the appendix.

bond market. Many simultaneous announcements have a statistical topic, for example the disclosure of Annual Accounts of the ECB for the year 2012 on February 21, 2013, the bank lending survey on October 31, 2012, or the survey on the Access to Finance of Enterprises in the Euro Area on June 1, 2016. On July 3, 2014, the ECB adjusts its frequency of monetary policy announcements from four to six weeks starting in 2015. This measure presumably helps calm future financial markets' volatility but it does not provide information on monetary policy itself.

Given the long period under consideration, 26 announcements is a small number. In general, a long observation history increases the validity and reliability of findings, by improving statistical properties with additional observations. However, many observations enhance the common issue in event studies of having only few events with respect to the sample size. Therefore, one should be careful deducing causal effects; instead, the dummy variable's coefficient gives an idea of correlation. This caveat requires a cautious interpretation of the results that follow.

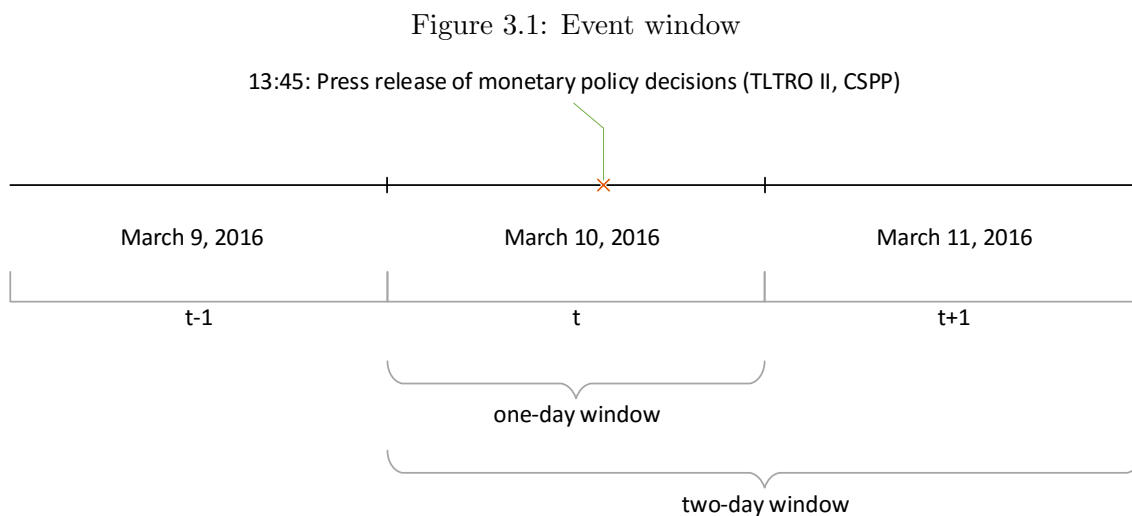
All events refer to specific asset purchase programs. Other monetary policy statements, for example press releases regarding conventional monetary policy tools or forward guidance statements<sup>10</sup> are omitted because the study focuses merely on unconventional quantitative easing measures. Announcements on purely technical details of asset purchase programs are excluded as they do not provide new information to the market. Confirming announcements such as the press releases by the ECB on January 19, 2017 or July 20, 2017 are possibly ineffective. However, they are included for the following reason. Since investors believe that there may be an end of the extreme expansionary monetary policy a repeated announcement that contradicts this expectation can trigger surprise effects. Some studies rely on news from other sources than ECB officials, for example Altavilla et al. (2015) use a news database to screen articles for keywords in order

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<sup>10</sup> Since forward guidance was recently implemented in the euro area, studies that look explicitly at forward guidance are limited to the Federal Reserve that implemented it earlier (Moessner, 2015; Neugebauer et al., 2017). Moreover, also considering statements about forward guidance is complex and would merit an individual paper. There is the basic differentiation between Delphic and Odyssean forward guidance (Campbell et al., 2012). One can further distinguish between calendar-based (time-dependent), data-based (state-dependent) and purely qualitative (open-ended) forward guidance (Filardo and Hofmann, 2014). A classification of the announcements to the corresponding types is not trivial. We leave this task for future research. See also the regime test in Section III.1 in the appendix.

to detect relevant dates. However, this approach is less helpful for working out policy implications because the media are out of control of the ECB and can only be indirectly influenced by its policy statements. In sum, only statements that encompass information about new, supplementary or extended measures are selected which result in the 26 chosen events denoted in Table A1.

The choice of the correct event window width is another debatable element in any event study. While a long window width induces the risk of contamination of news not related to monetary policy, a short window width potentially neglects delayed effects of monetary policy announcements. Recent literature typically uses either one-day windows (e.g., Glick and Leduc, 2012; Georgiadis and Gräß, 2016; Haitzma et al., 2016) or two-day windows (e.g., Altavilla et al., 2015; Szczerbowicz, 2015; Christensen and Krogstrup, 2019). Figure 3.1 exemplifies the event window for the announcement made on March 10, 2016: the dummy variable either is set to 1 on March 10 only (one-day window) or on both March 10 and March 11 (two-day window).



This study sets the window width to one day because we evaluate the risk of including effects from other events higher than the possibility of excluding delayed effects. Further-

more, a high trading frequency on financial markets supports this choice.<sup>11</sup> To capture potential delayed reactions to an announcement, we will instead lag the dummy maintaining a one-day window to the March 11 rather than expanding the window width. The timing is important to consider: An announcement usually takes place in the middle of the day. Recall this study uses end-of-business-day values. One would expect different reactions in case of start-of-business-day values ('open prices') or daily averages.

### 3.2.3 Data and descriptive statistics

The analysis employs 10-year benchmark government bond yields to redemption.<sup>12</sup> The data set consists of daily yields (per bank working day) of Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, and Spain from January 1, 2007 to August 31, 2017. These are the founding members of the euro area except Luxembourg, while Greece (which joined in 2001) is additionally included. While a small country like Luxembourg presumably biases the results and is therefore excluded, we include Greece as an economy heavily hit during the sovereign debt crisis. The time span is chosen according to the appearance of ECB's non-standard measures starting in 2007. Incorporating data beyond 2017 is deemed inappropriate because the announcements from then on rather refer to an ending of quantitative easing measures. We decide to consider such a long time frame because several announcements belong to each other. Thus, they need to be considered as a group of consecutive announcements. For example the announcement of the second covered bond purchase programme on October 6, 2011 cannot be considered ignoring the previous announcement of the first one on May 7, 2009. The study is limited to long-term yields to overcome the lower bound problematic or even negative yields that are partly present for short-term yields. Furthermore, related event

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<sup>11</sup> The website <https://www.investing.com/rates-bonds/european-government-bonds> provides an illustrative overview of European bonds with different maturities. The live data demonstrate frequently changing yields where bonds with a larger maturity typically have a larger volume and are more frequently traded. Applying a two-day event window does not change the results but the coefficients become smaller, most probably due to the contamination with other news. This further underpins the use of a one-day event window.

<sup>12</sup> The results hold taking 10-year zero coupon government yields as dependent variable instead of yields to redemption.

studies commonly use this maturity (e.g., Falagiarda and Reitz, 2015; Georgiadis and Gräß, 2016; Jäger and Grigoriadis, 2017).

The yields differ substantially in their level. They range from a minimum of -0.22% in Germany to a maximum of 48.6% in Greece. This underpins the choice of applying first-differences instead of absolute values. Table A2 in the appendix presents the descriptive statistics in daily variations. The yields vary considerably across countries. Their standard deviations range from 0.04 points (the Netherlands) to 0.63 points (Greece). The same holds for the stock indices. The Dutch market behaves calmly (around 5 points) whereas the Italian market fluctuates heavily (about 347 points).

The data set motivates to distinguish two country groups: The first group consists of Austria, Belgium, Finland, France, Germany and the Netherlands. Their bonds show moderate yields over time with an average smaller than 3% and a maximum smaller than 6%. In contrast, the second group consisting of Greece, Ireland, Italy, Portugal and Spain possesses high bond yields with an average higher than 3% and a maximum up to 48%. The former group is labeled ‘core countries’ and the latter group is referred to as ‘periphery countries’ below. These expressions are synonyms for the more solvent and the less solvent countries, respectively. The grouping corresponds to the common distinction of stressed countries and other euro area members.<sup>13</sup>

Plotting the dependent variable over time gives additional insights. Figure A1 in the appendix shows that the divergence in yields emerges from 2010 onwards and it demonstrates the varying levels across countries. Since mid-2014, all yields except for Greece persist at a lower level than in 2007. To detect possible differences within both groups, Figure A2 and Figure A3 in the appendix plot the yields of core countries and periphery countries, respectively. While the yields of core countries are similar and follow the same (negative) trend, the yields of periphery countries do not. The high peaks of Ireland, Greece and Portugal explain its high standard deviations compared to the other bonds (see Table A2). In contrast, Italy and Spain only exceed the 6%-threshold marginally in 2012. The figures indicate non-stationary data. All variables are integrated of order 1 according

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<sup>13</sup> Belgium with values close to the threshold lies somewhere between these groups and could also belong to periphery countries, for example if one decides for a maximum of 5% for core countries.

to the augmented Dickey-Fuller test.<sup>14</sup> Taking first-differences makes them stationary. Apart from this econometric argument, it guarantees comparability of various bond yields and control variables. Furthermore, first-differences allow a better interpretation of the development of time series than absolute values. Robust standard errors according to the Newey-West methodology are applied to treat heteroscedasticity and autocorrelation.<sup>15</sup>

### 3.3 Results

This section presents the results of (i) the baseline specification, (ii) an extended case of program-specific effects, and (iii) a panel analysis. For each of these specifications, the immediate effects, that is the effects on the announcement day itself, are investigated first. In turn, all specifications are analyzed with a delay of one day. The delay assumes that investors take some time to digest the new information and to react accordingly to it. Another motivation are transactional frictions. Subsequently, the model is augmented by including (iv) an interaction effect taking into account the current yield spread as a determinant of the announcement impact. We assess (v) the effects of individual announcements in the final subsection.

#### 3.3.1 Baseline specification

Table 3.1 shows the results of the baseline specification defined in Equation (3.1) assuming immediate (same-day) effects. The announcements do not seem to influence the yields (negatively) at all. Counterintuitively, even a significantly positive effect for the German bond shows up. Two possible explanations emerge. Either government bond markets do not respond at all to such announcements or, which seems more plausible, there is a delayed reaction, which is tested and discussed below.

<sup>14</sup> Interest rate time series have to be stationary by definition since they do not have a long-term growth trend such as the gross domestic product (GDP) or debts. The time span of ten years, however, might be too short as it reveals a negative trend.

<sup>15</sup> More specifically, the Bartlett Kernel with  $T^{\frac{1}{3}}$  as number of maximum lags is used. Applying the regressions with normal standard errors is not appropriate. The Breusch-Godfrey test indicates autocorrelation while the White test signals heteroscedastic error terms for all countries under consideration.

Table 3.1: Immediate effects of ECB announcements on 10-year government bond yields

	$\Delta y_{t-1}$	$\Delta stock_t$	$\Delta future_t$	$\Delta CESI_t$	$\Delta VIX_t$	$\Delta exch_t$	$\Delta TIPS_t$	$APA_t$
$\Delta y_{DE}$	0.0929***	0.000118***	0.297***	0.000430***	-0.00101*	0.545***	0.197***	0.0204*
$\Delta y_{FR}$	0.0698***	0.000145***	0.334***	0.000548***	-0.000106	0.0756	0.177***	0.0155
$\Delta y_{NL}$	0.0873***	0.00218***	0.293***	0.000469***	-0.000390	0.347***	0.203***	0.0103
$\Delta y_{AU}$	0.0938***	0.000200***	0.345***	0.000576***	-0.000750	0.00891	0.180***	0.00630
$\Delta y_{FI}$	0.0817***	9.81E-05***	0.328***	0.000467***	-0.00106**	0.365***	0.213***	0.00562
$\Delta y_{BE}$	0.187***	9.96E-05***	0.336***	0.000492***	-0.000178	-0.285**	0.159***	-0.000723
$\Delta y_{ES}$	0.195***	-8.36E-05***	0.449***	0.000626***	-0.00200	-1.006***	0.0990***	-0.0588
$\Delta y_{IT}$	0.0930***	-4.52E-05***	0.466***	0.000508***	-0.00107	-0.831***	0.0815***	-0.0368
$\Delta y_{IR}$	0.231***	-1.52E-06	0.348***	0.000617**	0.00133	-1.011***	0.0822***	-0.0381
$\Delta y_{GR}$	0.0944**	-0.00112***	1.228***	0.00116	0.0184**	-2.237	-0.0449	-0.168
$\Delta y_{PT}$	0.243***	-0.000229***	0.446***	0.000398	0.00132	-1.069***	0.0894**	-0.0726

**Notes:** 2,782 Observations. \*\*\*, \*\*, and \* denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. Constant omitted. The horizontal middle line separates core countries (above) and periphery countries (below). Sample period: January 1, 2007 to August 31, 2017.

The yield changes of the previous day ( $t - 1$ ) determine those of the actual day ( $t$ ) for all bonds as the positive and significant estimators of the lagged yield change affirm. There is also a significantly positive effect of the CESI and TIPS on most yields. The future rate has a significant and positive influence on all yields, as well. Surprisingly, the national stock market raises the yields of core countries while it lowers the yields of periphery countries, though the absolute size of the effect is small. A positive development in a national stock market implies a higher trust level of the investors in the respective economy. This should reduce a country's risk premium, which, in turn, reduces its government bond yield. Hence, the analysis confirms the expected reducing effect merely for periphery countries. As a result, the mechanism that rising stock prices reduce government bond yields is not empirically valid for all countries. We observe the opposite of the expected effect for core countries.

The different effects induced by the stock markets might occur, because a positive development of the stock market in a stressed economy is perceived as a signal that also the state will be better off. The demand for those bonds rises so that the government can reduce the offered interest. In contrast, investors already have a rather positive perception of solvent countries so that a movement in the stock market does not change the trust level. In consequence, the positive effect on the government bond yield can be induced by a change in portfolio holdings: Investors switch from core countries to periphery countries, which explains the opposing signs during an increase in the stock market. Most likely European stock indices develop similarly according to a common trend so that the opposing



effect is credible. The same logic applies to the reaction to the exchange rate because a stronger euro decreases the yield spread between both country groups.<sup>16</sup>

Table 3.2 shows the results of the baseline specification defined in Equation (3.1) but rather assumes a delayed announcement effect, meaning the dummy variable takes the value of 1 if the event took place the day before. Hence,  $APA_t$  is replaced by  $daA_t$ , indicating the ‘day after Announcement’ dummy, in Equation (3.1). The coefficients of the dummy variable change substantially. 10 out of 11 countries display a significantly negative coefficient of  $daA_t$  indicating a reduction in yields. For instance, an ECB asset purchase program announcement made the previous day reduces the Dutch 10-year government bond yield on the actual day by about 1.5 basis points (bps) on average. The German and Greek coefficient differ by 9 bps (-0.0134 versus -0.104). Hence, on average an announcement reduces the yield spread the most between those two countries.

Table 3.2: One-day delayed effects of ECB announcements on 10-year government bond yields

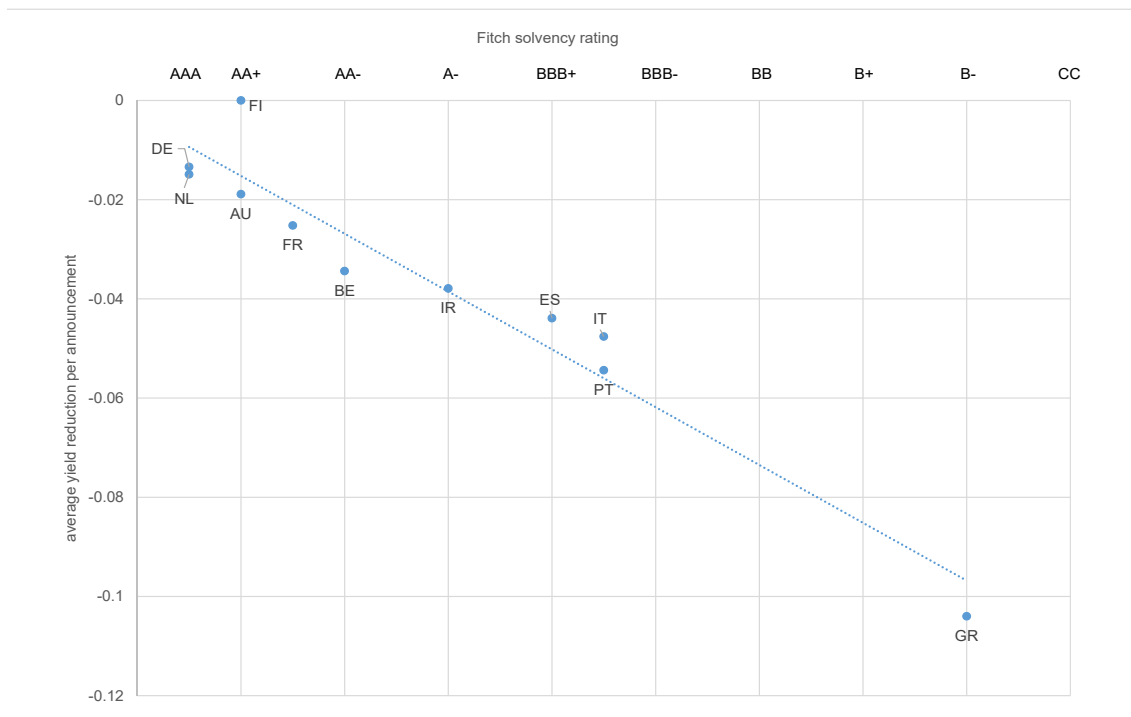
	$\Delta y_{t-1}$	$\Delta stock_t$	$\Delta future_t$	$\Delta CESI_t$	$\Delta VIX_t$	$\Delta exch_t$	$\Delta TIPS_t$	$daA_t$
$\Delta y_{DE}$	0.0956***	0.000118***	0.298***	0.000437***	-0.00102	0.545***	0.199***	-0.0134*
$\Delta y_{FR}$	0.0729***	0.000145***	0.335***	0.000559***	-0.000161	0.0740	0.178***	-0.0252***
$\Delta y_{NL}$	0.0891***	0.00218***	0.293***	0.000475***	-0.000420	0.346***	0.203***	-0.0149*
$\Delta y_{AU}$	0.0954***	0.000199***	0.346***	0.000584***	-0.000807	0.00792	0.180***	-0.0189**
$\Delta y_{FI}$	0.0825***	9.82E-05***	0.328***	0.000471***	-0.00107**	0.364***	0.214***	-0.00866
$\Delta y_{BE}$	0.188***	9.93E-05***	0.336***	0.000505***	-0.000295	-0.287**	0.159***	-0.0344***
$\Delta y_{ES}$	0.190***	-8.58E-05***	0.448***	0.000637***	-0.00231	-1.008***	0.0956***	-0.0439***
$\Delta y_{IT}$	0.0906***	-4.57E-05***	0.465***	0.000522***	-0.00132	-0.835***	0.0791***	-0.0476***
$\Delta y_{IR}$	0.230***	-1.59E-06	0.346***	0.000628**	0.00114	-1.016***	0.0796**	-0.0379**
$\Delta y_{GR}$	0.0937**	-0.00113***	1.221***	0.00118	0.0177**	-2.252	-0.0559	-0.104**
$\Delta y_{PT}$	0.241***	-0.000234***	0.444***	0.000413	0.000936	-1.071***	0.0849**	-0.0544***

**Notes:** 2,782 Observations. \*\*\*, \*\*, and \* denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. Constant omitted. The horizontal middle line separates core countries (above) and periphery countries (below). Sample period: January 1, 2007 to August 31, 2017.

In general, the extent of yield reduction seems inversely related to the solvency rating of the corresponding countries. In other words, an unfavorable rating reinforces the announcement effect. Figure 3.2 suggests a negative relationship between the announcement impact and the respective country’s solvency rating. For instance, Spain with a BBB+

<sup>16</sup> An exception is Belgium with a negative though insignificant estimator. As mentioned in Section 3.2.3, this bond could also adhere to periphery countries under another threshold.

Figure 3.2: Relationship between a country's yield reduction and solvency rating



**Notes:** The trend line suggests the following relationship:  $yield\ reduction = -0.0058 - 0.0035 \cdot ranking$ ;  $R^2 = 0.9322$ , t-values -1.1 and -13.7, respectively. For details on the ratings, see Table A3 in the appendix. The Fitch rating is scaled as 1 unit per step, meaning AAA is represented by 1 while D translates to 21. A similar pattern emerges when using the Moody's or S&P rating.

in the Fitch rating reacts more strongly to an announcement than Austria that has an AA+ rating (4.4 versus 1.9 bps reduction in bond yields).<sup>17</sup> This discrepancy has important implications for policy making. While this feature currently leads to a convergence of euro area government bond yields it can cause problems in the future. One day the ECB will have to initialize the way back to exclusively standard measures if the price development in Europe approaches the two per cent inflation target. Announcements by the ECB in the opposite direction (for example a higher main refinancing rate, redemption of assets) could diverge the yields and induce refinancing problems for periphery countries. This, in turn, can lead to a less favorable solvency rating which reinforces this mechanism. The rating is a convenient measure because it reflects several aspects such as the debt

<sup>17</sup> The ratings are as of January 2018 and can be found in Table A3 in the appendix. We assume a stable (relative) rating over time meaning that the ratings should not deviate substantially during the observation period. This assumption is suspended in Section 3.3.4 in which we introduce a daily yield spread as a proxy for a country's solvency rating.

level, the business environment, GDP growth outlooks and fiscal structure of a country. Picking only one aspect induces the risk of omitting an important factor that matters in determining announcement reactions.

Overall, the results confirm the expectation that ECB's asset purchase program announcements have a stronger effect on the bonds of periphery countries. Interestingly, significant impacts arise only one day after the announcement was made. This is a surprising finding as one would expect immediate reactions on the frequently trading financial markets, notably in the light of close price data used in the analysis. Two arguments possibly explain the delayed effect.

The first argument states that government bonds are exposed to transactional frictions. While the equity market entails a higher risk and volatility the bond market has a relatively larger volume and it is less volatile. The trade with government bonds is more complex as maturity, coupon and rating come into play. Government bonds are listed on markets like the Frankfurt stock exchange or the London stock exchange but not on electronic stock markets such as Xetra.

The second argument relates to the pace of information processing. Large institutional investors such as pension funds typically trade government bonds. They have a long-term planning horizon and are unlikely to adjust their portfolio shortly in response to market news. Moreover, regulatory issues prevent them from doing so, for example a bank that holds government bonds as collateral needs to find a substitute before liquidation. Most importantly, the decision process on how to react to market news plausibly takes longer inside a large institution compared to a small investment trust or a private individual investor. After the portfolio management department interprets new information on the announcement day, the orders of buying/selling the bonds are probably executed only on the subsequent day by the dealers. This implies that dealers predominantly trade government bonds OTC manually on the trading floor – in contrast to automatic transactions on a centralized exchange triggered by computer algorithms. Consequently, government bonds are less quickly traded upon news as opposed to equities which might lead to the observed one-day delayed effect.

A casual inspection of some events in Figure A2 in the appendix suggests a reduction in yields taking place immediately before the announcement. Market participants anticipate monetary policy decisions and react even before the actual announcement takes place. To test for this hypothesis, the same regressions are carried out putting the dummy to the value of 1 on the working day before the events outlined in Table A1, and 0 otherwise. The same analysis is done with a two-day delay, too, meaning the dummy variables take the value of 1 two days after the corresponding announcements to test for a slower reaction of market participants. The results for both alternative window settings (available upon request) do not reveal any impact on yields. In sum, when investigating announcement effects solely one-day delayed dummy variables produce significant results.<sup>18</sup> Therefore, the focus in the subsequent specifications will lie on the one-day delayed effects.

It is a strong assumption to treat each announcement equally. ECB’s asset purchase programs vary significantly in instrument, size, conditionality and duration. If the programs have different impacts, an aggregation of them could cancel out opposing effects. Therefore, each announcement is assigned to its corresponding asset purchase program below.

### 3.3.2 Program-specific effects

In order to test for program-specific effects, Equation (3.1) changes to

$$\Delta y_t = \alpha + \beta \Delta y_{t-1} + \sum_{j=1}^7 \gamma_j daPA_{j,t} + \delta \Delta X_t + \varepsilon_t. \quad (3.2)$$

The former (delayed) aggregate dummy variable  $daA_t$  is replaced by seven program-specific dummy variables  $\sum_{j=1}^7 \gamma_j daPA_{j,t}$  representing a specific asset purchase program  $j$  for the ‘day after Program Announcement’, each taking the value of 1 in case of an event belonging to the specific program taking place one day before, and 0 otherwise. More specifically, the model differentiates between (targeted) long term refinancing operations ((T)LTROs), the securities market programme (SMP), corporate sector purchase programme (CSPP),

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<sup>18</sup> If both  $APA_t$  and  $daA_t$  are jointly included in one single regression the estimators remain essentially identical to estimating two separate regressions.

public sector purchase programme (PSPP), asset-backed securities purchase programme (ABSPP), covered bond purchase programme (CBPP), and outright monetary transactions (OMT). The latter takes a special role as it has not been executed yet in contrast to the other asset purchase programs. Since this study concentrates on the announcement effects, we reasonably incorporate this program as well. On June 16, 2015 the court of Justice of the European Union brought in a verdict on the announcement made on September 6, 2012. This litigation reflects that merely the announcement of a possible OMT program in the future attracted much attention. Previous literature detects OMT announcement effects on government bond yields (Altavilla et al., 2016) and spreads (Georgiadis and Gräß, 2016). Therefore, following Altavilla et al. (2016) we consider three crucial OMT announcements in the analysis: The ‘whatever it takes’ speech on July 26, 2012, the press conference on August 2, 2012, and the announcement of OMT’s technical features on September 6, 2012.<sup>19</sup>

All programs are expected to have a negative influence on yields ( $\gamma_j < 0 \forall j = 1, \dots, 7$ ). The expanded asset purchase programme (EAPP) subsumes ABSPP, CBPP, CSPP, and PSPP, which complicates the differentiation. Yet it is impossible to pool all events and classify them as EAPP because ABSPP and CBPP already started before the introduction of EAPP. The classification of the events can be found in the second column of Table A1. In fact, (T)LTROs are not part of an official asset purchase program. But as the emphasized events refer to supplementary purchases they cannot be classified as regular, either. The extension of maturities of LTROs transfers a standard monetary policy instrument into a non-standard monetary policy measure. In the manner of the asset purchase programs they provide unexpectedly more liquidity to the market (for a much longer time than the standard instrument) and should therefore induce similar announcement effects. Furthermore, the announcements of ECB’s TLTRO I and TLTRO II are included in (T)LTRO because they provide a targeted liquidity provision giving them a non-standard character. Hence, all seven above described programs are part of ECB’s non-standard monetary policy. Since half of the 26 key events overlap, a pure separation into the diverse pro-

<sup>19</sup> As the OMT is not executed yet, it is excluded from our set of events as a robustness check. The results (available upon request) hold when only considering the 23 remaining events.

grams is unfeasible. The single effects cannot be distinguished perfectly, which impairs the program-specific analysis.

In addition, the comparison of the programs is questionable, because the applied instruments differ considerably. While CSPP refers to bonds of the private sector, PSPP is restricted to securities from the public sector. Figure A4 in the appendix juxtaposes the programs in terms of starting date, number of announcements and quantity. PSPP is by far the dominating program in size. Together with (T)LTRO it accounts for three quarters of overall asset purchases. SMP only has two events while the largest groups (T)LTRO, CBPP, ABSPP and PSPP include ten events. Still these programs could have insufficient data points considering the long examined period. Accordingly the results should be interpreted with caution.

Table 3.3 shows the results of the program-specific specification defined in Equation (3.2) assuming one-day delayed effects. To save space, we only present the announcement dummy coefficients. Distinguishing between the different programs reveals mixed results. Investors seem to be sensitive to the type of program announcement.

Table 3.3: One-day delayed effects of program-specific ECB announcements on 10-year government bond yields:  $daPA_{j,t}$

Country	<i>ABSPP</i>	<i>CSPP</i>	<i>CBPP</i>	<i>PSPP</i>	<i>(T)LTRO</i>	<i>SMP</i>	<i>OMT</i>
$\Delta y_{DE}$	-0.0501***	-0.000223	0.0535***	-0.0102	-0.0336***	0.0107	0.0309***
$\Delta y_{FR}$	-0.0312*	-0.0152	0.0446*	-0.00657	-0.0575***	0.0571**	-0.0237***
$\Delta y_{NL}$	-0.0473***	-0.0162	0.0519***	-0.000894	-0.0370***	0.0375**	0.0202
$\Delta y_{AU}$	-0.0541***	-0.00447	0.0489***	0.00490	-0.0442***	0.0229	-0.00808***
$\Delta y_{FI}$	-0.0580***	0.0137	0.0464***	-0.00574	-0.0323***	0.0379	0.0284
$\Delta y_{BE}$	-0.0388*	0.0123	0.0184	-0.00179	-0.0497***	-0.00116	-0.0409***
$\Delta y_{ES}$	-0.0656**	0.0336	0.0357	-0.0200	-0.0451***	0.0431**	-0.163***
$\Delta y_{IT}$	-0.0686*	0.00706	0.0718**	-0.0240	-0.0530***	-0.0193	-0.160***
$\Delta y_{IR}$	-0.0669**	0.0444	0.0215	-0.00474	-0.00727	-0.173	-0.0554***
$\Delta y_{GR}$	-0.160***	0.0717	0.132***	-0.0321	-0.165***	0.126	-0.455***
$\Delta y_{PT}$	-0.0386	-0.0166	0.0540*	-0.0228	-0.0418*	-0.0910	-0.155

**Notes:** 2,782 Observations. \*\*\*, \*\*, and \* denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. Controls and constant omitted. The horizontal middle line separates core countries (above) and periphery countries (below). Sample period: January 1, 2007 to August 31, 2017.

On the one hand, ABSPP and (T)LTRO both show significantly negative estimators for most bonds. For instance, an ECB announcement relating to the ABSPP the previous day reduces the Spanish 10-year government bond yield this day by 6.6 bps while an announcement relating to (T)LTRO decreases that yield by 4.5 bps on average.

On the other hand, CBPP announcements seem to have the opposite effect increasing the yields in most countries, up to 13.2 bps in Greece. Investors may substitute government bonds by covered bonds inducing a yield increase of the former. Surprisingly, SMP announcements increase the yields of France, the Netherlands and Spain. The investors' holdings change between government bonds does not seem to apply because countries of both groups are affected. A negative signaling effect could explain this positive impact instead: A rush in selling of government bonds and investors who go into more risky assets is conceivable. It remains unclear why this mechanism only appears in these three bonds, though.

In contrast, neither of the yields react to CSPP and PSPP announcements. While a missing effect of CSPP is plausible because this program directly buys bonds from companies from the non-financial sector, this is a counterintuitive finding for PSPP because this program is designed to buy public bonds and it is by far the program with the largest asset purchase volume. A potential explanation could be that these two programs were already expected (in contrast to the other five programs) so that no yield reactions occur in case of such announcements.

The apparent differences among the programs could be caused by EAPP announcements. The EAPP includes programs that have at the same time significantly positive (CBPP) and negative impacts (ABSPP) as well as non-significant impacts (PSPP, CSPP). Hence, as EAPP announcements foster all of those programs, the direction in which such an announcement influences bond yields is unclear.

In particular, the OMT seems to explain the convergence of government bond yields between core countries and periphery countries. While periphery countries' yields decrease strongly, core countries are less affected by such announcements. For instance, Italy's and Spain's yield decreases by about 16 bps whereas the French yield only falls by 2.3 bps and the German bond even increases by 3 bps. The latter suggests that investors change their holdings between government bonds as a consequence of the OMT.

Additionally, Table A4 in the appendix presents the results of the program-specific specification defined in Equation (3.2) assuming same-day effects. Distinguishing the different programs gives little insights. A noticeable result is the highly significant and

substantial reduction of 56.4 and 46.6 bps in the yields of Spain and Italy by the SMP announcements. This reduction most probably responds to the justification of the SMP on August 7, 2011.

Overall, out of the announcements of seven different programs, two programs influence some yields positively, three negatively and two not at all. Both the baseline specification and the program-specific effects indicate a similar reaction of the countries' yields to asset purchase announcements, albeit a difference in the extent between core countries and periphery countries emerges. Next, the analysis is enhanced by pooling the countries in a panel framework.

### 3.3.3 Panel analysis

When evaluating monetary policy measures it helps analyze the effects on solvent versus less solvent countries separately. Therefore, three panel regressions are carried out: one for the aggregate case of all 11 euro area countries under consideration (labeled 'aggregated countries' in the following) and one for core countries and periphery countries as group-wise panels, respectively. The former searches for an effect throughout the euro area, while the latter analyze group-specific effects of the asset purchase announcements. Equation (3.1) changes to

$$\Delta y_{i,t} = \alpha_i + \beta \Delta y_{i,t-1} + \gamma daA_t + \delta \Delta X_{i,t} + \mu_i + \varepsilon_{i,t} \quad (3.3)$$

while Equation (3.2) accordingly becomes

$$\Delta y_{i,t} = \alpha_i + \beta \Delta y_{i,t-1} + \sum_{j=1}^7 \gamma_j daPA_{j,t} + \delta \Delta X_{i,t} + \mu_i + \varepsilon_{i,t}, \quad (3.4)$$

where  $i = 1, \dots, 11$  denotes a specific country and  $\mu_i$  describes the country-specific fixed effect in the panel regressions. Time-specific effects do not apply since the dummy variables already control for events taking place at a certain point of time. Employing the test proposed by Levin et al. (2002) indicates that the panel time series are integrated of order 1 justifying a first-difference transformation for the panel specification, too. The lagged dependent variable  $\Delta y_{i,t-1}$  could cause an endogeneity problem. However, Nickell (1981)



shows that this bias is of order  $\frac{1}{T}$ , which is negligible for the present long panel with 2,784 observations for each of the 11 yields.<sup>20</sup>

Table 3.4 shows the results of the panel specifications defined in Equation (3.3) and Equation (3.4) for each of the three country groupings assuming one-day delayed effects. The results for the control variables remain stable. Similarly, both the general and the program-specific announcement effects are consistent with the findings above (see Table 3.2 and Table 3.3, respectively).

Table 3.4: Panel regression one-day delayed effects

specification	11 aggregated countries		6 core countries		5 periphery countries	
	(3)	(4)	(3)	(4)	(3)	(4)
$\Delta y_{t-1}$	0.104***	0.104***	0.108***	0.107***	0.104***	0.103***
$\Delta stock_t$	-3.78E-05**	-3.76E-05**	0.000116***	0.000116***	-4.66E-05*	-4.61E-05*
$\Delta future_t$	0.441***	0.443***	0.332***	0.333***	0.545**	0.548**
$\Delta CESI_t$	0.000614***	0.000604***	0.000509***	0.000498***	0.000704***	0.000697***
$\Delta VIX_t$	0.000631	0.000654	-0.00117*	-0.00112*	0.00496	0.00497
$\Delta exch_t$	-0.500	-0.518	0.191	0.183	-1.413**	-1.441**
$\Delta TIPS_t$	0.133***	0.134***	0.191***	0.191***	0.0514	0.0532
<i>ABSPP</i>		-0.0663***		-0.0474***		-0.0853**
<i>CSPP</i>		0.0177		-0.000585		0.0365
<i>CBPP</i>		0.0520***		0.0436***		0.0631**
<i>PSPP</i>		-0.0109**		-0.00289		-0.0246**
<i>(T)LTRO</i>		-0.0517***		-0.0425***		-0.0631*
<i>SMP</i>		-0.0126		0.0219*		-0.0437
<i>OMT</i>		-0.0905*		0.00189		-0.209**
$daA_t$	-0.0377***		-0.0196***		-0.0596***	
$R^2$	0.019	0.019	0.235	0.238	0.018	0.019

**Notes:** 30,602 Observations. \*\*\*, \*\*, and \* denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. Constant omitted. Sample period: January 1, 2007 to August 31, 2017.

An announcement taking place the present day reduces the next day's yield significantly for all country groups. The average generalized reducing effect is 3.8 bps for aggregated countries. The coefficient is three times higher in periphery countries (-0.0596) than in core countries (-0.0196). Accordingly, the extent is higher in periphery countries for each program. For instance, an ABSPP announcement reduces the yield of core countries by 4.7 bps whereas it reduces that of periphery countries by 8.5 bps on average. Hence, stressed countries are more sensible to announcements than countries that are more solvent. As before, (T)LTRO implies a significantly negative impact on yields while CBPP

<sup>20</sup> The results remain unchanged when omitting  $\Delta y_{i,t-1}$  underscoring the slim extent of the Nickell bias.

demonstrates significantly positive announcement effects. A positive influence of SMP on the yields of core countries is in line with Table 3.3 in which French and Dutch bonds yields increase in response to such announcements. OMT is only significant for periphery countries and reduces the yields by far the strongest. On average, an OMT announcement let the yield shrink by 20 bps in periphery countries. The only difference to the previous findings is that in the panel specifications PSPP produces a significantly negative estimator for periphery countries.

In addition, Table A5 in the appendix shows the results of the panel specifications of Equation (3.3) and Equation (3.4) assuming same-day effects. The results justify to separate euro area economies into two groups. While the aggregate effect of announcements is insignificant in aggregated countries, a significant and positive one appears for core countries and a significant and negative one for periphery countries. Hence, the panel analyses suggest an immediate spread-reducing effect: An ECB's announcement increases core countries' yields while it decreases periphery countries' yields at the same time. More precisely, it increases the yields of core countries by 1.0 bps and decreases those of periphery countries by 7.8 bps on average. Regarding the specific program announcements, only core countries are affected by ABSPP, CSPP, CBPP, PSPP and (T)LTRO. In contrast, the negative influence by SMP is induced by periphery countries confirming the findings in Table A4. OMT influences periphery countries three times stronger than core countries (-9.0 bps versus -2.8 bps).

### **3.3.4 Influence of yield spread on announcement effects**

Figure 3.2 suggests a relationship between a country's solvency rating and the announcement effects. Accordingly, it is conceivable to link the ratings to monetary policy announcements. Market participants are typically guided by ratings. For example, an institutional investor is forced by legal regulations or shareholders' preferences not to exceed a certain fraction of high risky assets (determined by a rating). Another example could be that a specific rating is a prerequisite for a bond to be eligible to act as a security or collateral. Consequently, ratings of government bonds play a major role and they can be expected to affect the extent to which bonds react to monetary policy announcements.

Therefore, the model is extended to test for those interaction effects. This extension accounts for the idea of each event having its own magnitude. The chapter abstains from directly assigning a certain weight to each announcement because it is hard to find an objective reason why one event should be evaluated as more effective than another. This is in line with this chapter's aim to exclusively analyze announcement effects ignoring the actual volume of asset purchases. If the exact value of purchases is still unclear on the day of the announcement, this impairs the construction of a weighting scheme. Additionally, a scaling of the events is necessary that is prone to subjectivity.<sup>21</sup> Instead, an indirect weight, that is the rating on the day of the announcement, accounts for the timing and circumstances of the announcement.

Ratings are expected to highly correlate with the respective market yields. Therefore, in order to proxy the ratings on a daily basis, the current spread between the country-specific yield and a risk-free rate is calculated. Following Jäger and Grigoriadis (2017) we use the euro swap rate *Euro Swap<sub>t</sub>* to keep the German government bond yield:  $spread_{i,t} = y_{i,t} - Euro\ Swap_t$ .<sup>22</sup> This spread is combined with the dummy variable and added to the regression as an interaction term. Since this extension captures interaction effects among the euro area countries we apply it exclusively to the panel specification. The baseline country-by-country specification only considers the time dimension and is therefore unsuitable for this extension. Hence Equation (3.3) changes to

$$\Delta y_{i,t} = \alpha_i + \beta \Delta y_{i,t-1} + \gamma daA_t + \sigma daA_t \times spread_{i,t} + \delta \Delta X_{i,t} + \mu_i + \varepsilon_{i,t} \quad (3.5)$$

while Equation (3.4) accordingly becomes

$$\Delta y_{i,t} = \alpha_i + \beta \Delta y_{i,t-1} + \sum_{j=1}^7 \gamma_j daPA_{j,t} + \sum_{j=1}^7 \sigma_j daPA_{j,t} \times spread_{i,t} + \delta \Delta X_{i,t} + \mu_i + \varepsilon_{i,t}. \quad (3.6)$$

<sup>21</sup> A possible method to determine the magnitude of an event is to consider the media coverage in printed newspapers or social media reactions. Though, the difficulty of arbitrarily classifying the events according to a certain impact factor remains.

<sup>22</sup> The results are similar when using the German government bond yield instead. Merely the interaction effect of ABSPP becomes insignificant for periphery countries and the interaction effect of CSPP becomes insignificant for core countries. We continue the analysis using *Euro Swap<sub>t</sub>* because maintaining Germany in the analysis gives 2,784 additional observations.

As in the previous specifications,  $\gamma$  captures the general announcement effect. Beyond that  $\sigma$  estimates the interaction effect, that is the relevance of the spread in determining the announcement effect. Put differently,  $\sigma$  measures the degree of interaction between current spread and announcement at a certain point of time. By construction, the general effect weights each announcement equally (dummy value is equal to 1 in case of an event) whereas the interaction effect possesses a different weight for each country and each point in time.

The conditioning of the dummy with the current spread represents an innovative extension of the literature. While the spread is typically used as the dependent variable, to the best of our knowledge it has not been yet employed to disentangle announcement effects in the event study methodology. If the interaction term turns out to be significant, then the yield (and thus the relative spread among countries) is not only determined by the monetary policy announcements but the spread itself influences the extent to which yields react to an announcement.

Table 3.5 shows the results of the panel specifications defined in Equation (3.5) and Equation (3.6) for each of the three country groups assuming one-day delayed effects. Regarding the generalized announcement effect, the estimates of  $\gamma$  are highly significant for aggregated and core countries but become insignificant for periphery countries. In contrast, the estimators of  $\sigma$  are highly significant for all country groups. This implies the current spread reinforces yield reactions to ECB's monetary policy announcements for more solvent countries. In the less solvent group, the yield reduction can be fully attributed to the newly introduced interaction term  $daA_t \times spread_{i,t}$  because the announcement effect  $\gamma$  itself seems to be irrelevant for periphery countries. Put differently, the extent of yield reduction seems entirely dependent on the current spread for periphery countries whereas there is a yield-reducing effect independent of the current spread for core countries.<sup>23</sup>

Regarding the program-specific effects, introducing the interaction effects does not modify the general effects presented in Table 3.4. As a result, the conclusions of Section 3.3.3 are robust to the inclusion of interaction effects. The only exception is the OMT

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<sup>23</sup> The stronger interaction effect of periphery countries is supported by a higher t-value of -14.84 with respect to -5.62 in core countries (t-values are not reported in Table 3.5).

Table 3.5: Panel regression one-day delayed effects: inclusion of spread interaction

		11 aggregated countries	6 core countries	5 periphery countries
generalized effect	$\gamma$	-0.0178***	-0.0224***	-0.0173
	$\sigma$	-0.0142***	-0.0291***	-0.0132***
ABSPP	$\gamma_j$	-0.0555***	-0.0526***	-0.0583***
	$\sigma_j$	-0.0110**	-0.0103	-0.0121*
CSPP	$\gamma_j$	0.0124	0.0130	0.0323
	$\sigma_j$	0.00803**	0.159*	0.00506
CBPP	$\gamma_j$	0.0504***	0.0490***	0.0554**
	$\sigma_j$	-0.000134	-0.0473*	0.000598
PSPP	$\gamma_j$	-0.0133*	-0.0116**	-0.0379*
	$\sigma_j$	0.00198	-0.0811	0.00585**
(T)LTRO	$\gamma_j$	-0.0430***	-0.0437***	-0.0405***
	$\sigma_j$	-0.0127***	-0.0307**	-0.0125**
SMP	$\gamma_j$	0.0213***	0.0236**	-0.00314
	$\sigma_j$	-0.0188	-0.0359	-0.0106
OMT	$\gamma_j$	0.00178	0.00492	-0.0358
	$\sigma_j$	-0.0233***	-0.0755***	-0.0199***

**Notes:** 30,602 Observations. \*\*\*, \*\*, and \* denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. Constant and control variables omitted. Sample period: January 1, 2007 to August 31, 2017. The solid line separates the baseline and program-specific analysis. The upper part presents coefficients belonging to Equation (3.5) while the lower part presents those of Equation (3.6). The dashed lines further separate the lower part according to the different asset purchase programs.

for which the interaction effect prevails and the announcement effect disappears for all three panel specifications. Since OMT dominates the periphery countries (see last column in Table 3.4) this could be the reason for the insignificant  $\gamma$  of the generalized effect.

The other program-specific effects of  $\sigma_j$  give further insights. First, when comparing core countries with periphery countries, the interaction effects are conflicting for each program. The significantly negative general effects on yields  $\gamma_j$  of ABSPP, PSPP and (T)LTRO coincide with significant interaction effects  $\sigma_j$  for periphery countries while core countries do not interact with ABSPP and PSPP. In contrast,  $\sigma_j$  of CSPP, and CBPP is significant for core countries coinciding with the significantly positive general effect  $\gamma_j$  of CBPP. As a result, interaction effects appearing in periphery countries tend to foster the general yield-reducing announcement effects whereas interaction effects appearing in core countries tend to explain a part of general yield-increasing announcement effects.

Second, the interaction effects  $\sigma_j$  of aggregated countries are less conclusive. In half of the programs they are significant (ABSPP, CSPP, (T)LTRO) meaning that only for these programs one country group dominates the aggregate specification while in the other programs (CBPP, PSPP) the opposing effects of core countries and periphery countries

seem to cancel out each other.<sup>24</sup> In turn, SMP does not interact in neither country group. Hence, these results are in favor of a separation into core countries and periphery countries in the analysis.

To summarize, the country's risk rating represented by current yield spreads plays a decisive role in determining short-term yield reactions to monetary policy announcements. There seems to exist a significant but program-specific interaction between yield spreads and market reactions to ECB announcements. The innovative inclusion of interaction effects supports the previous findings and is one explanation why the spreads reduce over time: The higher a spread is for the country-specific bond, the stronger is the interaction effect with the dummy reinforcing or even replacing the announcement effect, which promotes a convergence in yields among euro area members. Accordingly, the presence of a high spread/unfavorable rating reinforces the announcement effects implying ECB's monetary policy communication is more effective in times of a yield divergence within the euro area.

### 3.3.5 Testing for individual effects

Several studies consider each event separately by using one dummy for every single announcement (e.g., Falagiarda and Reitz, 2015; Altavilla et al., 2016; Ambler and Rumber, 2019). Given the chosen event set incorporates 13 events that overlap, half of the 26 announcements presented in Table 3.6 in the first column cannot be attributed to a specific program. Altavilla et al. (2015, 2016) do not face such an issue and can confidently interpret each single event. They are interested in the aggregate effect of the announcements by summing up each dummy's coefficient. This may be seen problematic because adding the announcement effects of news about asset purchases assumes permanent effects (Gürkaynak and Wright, 2013). In contrast, our study intends to assess the average effect of one non-standard monetary policy program announcement, therefore we put all events in one dummy variable in the baseline specification.

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<sup>24</sup> The significant interaction effects of ABSPP and (T)LTRO for aggregated countries are in line with periphery countries whereas that of CSPP is consistent with core countries.

Nevertheless, the different results for programs presented in the previous subsections, notably the opposite signs, question the choice to include all events in one dummy as a general ECB's asset purchase program announcement. A separate consideration of the announcements might reveal additional insights. Following Altavilla et al. (2016) we therefore test for individual effects of our event set. Consequently, the seven (delayed) dummies  $\sum_{j=1}^7 \gamma_j daPA_{j,t}$  are further disentangled per announcement  $k$  to  $\sum_{k=1}^{26} \gamma_k daE_{k,t}$ . The 26 'day after event' dummies  $daE_{k,t}$  take the value of 1 only one day after a crucial announcement in Table A1, and 0 otherwise. Hence, Equation (3.2) changes to

$$\Delta y_t = \alpha + \beta \Delta y_{t-1} + \sum_{k=1}^{26} \gamma_k daE_{k,t} + \delta \Delta X_t + \varepsilon_t, \quad (3.7)$$

and Equation (3.4) becomes

$$\Delta y_{i,t} = \alpha_i + \beta \Delta y_{i,t-1} + \sum_{k=1}^{26} \gamma_k daE_{k,t} + \delta \Delta X_{i,t} + \mu_i + \varepsilon_{i,t}. \quad (3.8)$$

Table 3.6 shows the results of the country-specific specification defined in Equation (3.7) and the panel specification defined in Equation (3.8). The individual effects confirm the previous results. Coefficients are negative on most dates and countries<sup>25</sup> and the total effect in the last row in Table 3.6 corresponds to the solvency ranking. The panel similarly suggests a three times stronger total reduction in yields for periphery countries (-50 bps) compared to core countries (-155 bps).

<sup>25</sup> To be precise, 253 out of 364 coefficients have a negative sign which corresponds roughly to 70 per cent. Only 25 coefficients are insignificant. The significance levels are not indicated by stars to enhance legibility as in Altavilla et al. (2016).

Table 3.6: Effect of single announcements (in basis points):  $daE_{k,t}$ 

date after event	$\Delta y_{DE}$	$\Delta y_{FR}$	$\Delta y_{NL}$	$\Delta y_{AU}$	$\Delta y_{FI}$	$\Delta y_{BE}$	$\Delta y_{ES}$	$\Delta y_{IT}$	$\Delta y_{IR}$	$\Delta y_{GR}$	$\Delta y_{PT}$	core	periphery	aggregate
Jul 21, 2017	-0.615	-2.95	-4.07	-2.52	-1.14	-3.59	-2.14	-3.97	1.23	-2.65	-6.34	-2.71	-2.41	-3.25
Jun 9, 2017	-0.505	-0.539	-0.465	-0.501	0.508	0.687	-1.47	-6.28	-2.16	-0.221	0.143	0.0727	-2.79	-0.764
Apr 28, 2017	2.52	0.95	1.76	0.603	2.18	1.7	2.51	1.23	3.1	-5.33	10.1	1.71	1.57	1.63
Jan 20, 2017	3.54	3.46	2.68	1.87	4.11	3.1	2.21	2.67	6.13	1.37	-1.38	3.13	2.6	2.9
Dec 16, 2016	-6.67	-2.64	-5.85	-7.33	-6.06	-5.16	-0.477	2.34	-4.18	-14.2	2.24	-5.63	-3.27	-4.56
Dec 9, 2016	-2.95	-4.29	-5.39	1.48	-1.62	-5.07	-4.27	-3.23	2.74	-3.73	0.777	-2.87	-0.707	-1.8
Mar 11, 2016	-8.37	-14.2	-12.1	-11.4	-7.24	-10.1	-7.23	-8.28	-5.01	-10.4	-12.9	-10.2	-8.44	-8.74
Dec 4, 2015	0.76	6.11	6.43	6.23	2.22	4.86	-2.12	4.48	0.769	28.8	-3.94	4.06	8.34	5.49
Jan 23, 2015	-6.13	-7.39	-6.66	-8.38	-6.71	-7.45	-4.51	-6.22	-8.31	-25.1	-13.6	-6.79	-14.4	-9.29
Dec 5, 2014	-1.26	-1.28	-0.488	0.458	-0.624	0.0448	-4.5	-4.18	-1.15	-38	-3.43	-0.269	-11.3	-4.68
Nov 27, 2014	-4.06	-5.98	-4.2	-3.61	-4.43	-5.57	-9.25	-9.31	-8.08	4.9	-10.2	-4.61	-5.88	-5.08
Nov 18, 2014	-2.76	-1.73	-2.41	-1.99	-2.07	-1.36	1.71	2.59	-0.815	22.4	-0.133	-1.94	3.99	1.14
Sep 5, 2014	-4.25	-5.7	-5.49	-6.18	-5.1	-6.93	-11.4	-10.6	-10.3	-8.95	-9.89	-5.66	-11.1	-8.22
Jun 6, 2014	-7.1	-9.26	-8.15	-8.84	-10.2	-9.02	-14.8	-14.2	-12.6	-29.4	-9.58	-8.73	-17	-12.4
Sep 7, 2012	1.33	-3.39	-1.34	-0.483	-3.57	-4.78	-29	-19	-9.52	-10.1	-38	-2.13	-23.3	-11.6
Aug 3, 2012	5.25	-1.9	6.88	-0.426	10.7	-5.98	-6.1	-22.8	-4.48	-44.1	-1.1	2.74	-16	-5.18
Jul 27, 2012	2.63	-1.92	0.5	-1.55	1.45	-1.57	-14.2	-6.05	-2.53	-82.3	-7.13	-0.0788	-23.3	-10.4
Dec 9, 2011	-0.945	-12.3	-1.59	-4.88	4.53	-13.7	3.14	-6.21	3.04	-52.5	4.98	-4.75	-8.84	-6.89
Oct 7, 2011	2.49	0.62	3.02	3.21	2.56	-5.72	2.72	10.1	-2.15	9.41	4.98	1.08	5.08	2.91
Aug 9, 2011	2.98	8.93	5.83	5.22	7.39	-2.3	3.37	-6.51	-44	21.9	-26.1	3.91	-9.51	-3.05
May 11, 2010	-4.13	-3.14	-1.89	-4.93	-2.9	-2.91	-0.285	-2.73	9.85	-13.1	3.93	-3.71	-5.59	-4.66
May 8, 2009	4.44	2.65	2.78	1.22	1.98	2.97	2.18	6.12	2.86	5.67	6.04	2.76	4.34	3.78
Oct 16, 2008	-1.4	-0.0296	0.295	1.54	-0.726	-1.18	-4.44	-7.7	-1.4	-3.68	-9.64	-1.09	-1.81	-2.69
Mar 31, 2008	-3.55	-3.68	-2.84	-1.33	-3.31	-3.8	-5.19	-4.36	-2.97	-4.76	-5.39	-3.16	-4.27	-3.74
Sep 7, 2007	-2.08	-1.59	-1.55	-1.65	-1.48	-2.3	-5.82	-8.06	-4.94	-9.98	-12.1	-2.06	-6.4	-4.56
Aug 23, 2007	-3.77	-3.77	-3.98	-4.52	-2.59	-4.29	-5.15	-3.74	-4.46	-3.95	-4.91	-3.69	-4.75	-4.22
total	-34.605***	-64.9586***	-38.288***	-48.689***	-22.142***	-89.4182***	-114.512***	-123.9***	-99.336***	-268.001***	-142.573***	-50.6151***	-155.147***	-97.924***

**Notes:** Method adopted from Altavilla et al. (2016). \*\*\*, \*\*, and \* denote significance of the F-test for 1%, 5%, and 10% levels, respectively. Newey-West-adjusted standard errors. The table depicts the estimated coefficients of 26 ‘day after event’ dummies,  $daE_{k,t}$ , which take the value of 1 only one day after a crucial announcement, and 0 otherwise. Only 25 out of 364 coefficients are insignificant. The significance levels for the individual dates are not indicated by stars to enhance legibility as in Altavilla et al. (2016). The first column displays the dates one day after a key announcement. The first vertical line separates core and periphery countries and the second line delineates the panel results. Sample period: January 1, 2007 to August 31, 2017.



The results for the three OMT announcements are similar to those in Altavilla et al. (2016). OMT announcements have a small and positive impact on German yields and a small but negative impact on French yields. The same announcements substantially decrease the yields of Italy and Spain. Different controls and periods used in our and their study explain the changed coefficients. Portugal and Spain experience their strongest yield reductions on September 7, 2012 with 38 and 29 bps, respectively. The Italian yield decreases most by 23 bps on August 3, 2012 whereas the Greek bond falls by 82 bps one day after Mario Draghi's 'whatever it takes' speech. The panel results of periphery countries underpin the relevance of OMT announcements for those countries. Hence, the individual consideration of announcements supports the previous findings in the literature on OMT.

Another three announcements seem particularly relevant. First, the day after the introduction of the ABSPP on June 5, 2014 provoked substantial reductions in yields in all markets. The aggregate panel peaks on this day (-12.4 bps) and it also represents the strongest reduction for periphery countries besides OMT announcements (-17 bps). This result is in line with the previous finding in Table 3.3 and Table 3.4 stating ABSPP as one of the programs that decreases government bond yields significantly. Second, one day after the introduction of the CSPP on March 10, 2016 the yields in core countries decline most. The core panel has its peak with -10.2 bps and the bonds of Germany, France, the Netherlands and Austria sink strongest on that day. This is an astonishing result given that CSPP is insignificant in the previous specifications. Third, Ireland's yields fall the strongest after the justification of the SMP program on August 7, 2011 while the other periphery countries reduce most due to OMT announcements.

Interestingly, the initial events of the other programs do not have a comparable impact. The first (T)LTRO announcement on August 22, 2007 has a moderate negative impact on all yields consistent with previous findings. In contrast, there is a small positive effect triggered by the start of the CBPP on May 7, 2009. This positive influence corresponds to the results in Table 3.3 and Table 3.4. Yet it is surprising given that an additional decrease in the policy rate during that day should influence government bond yields in the opposite direction. The initial announcements of SMP on May 10, 2010 and PSPP on

November 17, 2014 reveal small negative impacts on most yields but unexpectedly positive impacts in some periphery countries. For instance, the Greece yield rises by 22.4 bps in response to the introduction of the PSPP.

Overall, the results for the individual announcement effects confirm the general negative impact on yields and mirror the mixed program-specific findings. The general higher reaction of periphery countries is confirmed but for some dates core countries are more affected. Considering the panel analysis, periphery countries dominate in 19 dates whereas 7 announcements affect core countries more strongly.

An extensive number of robustness checks to challenge the findings of Section 3.1 through Section 3.5 is provided in Section III in the appendix. When modifying the choice of relevant announcements and implementing alternative variables, the results are robust for a given event set.

### 3.4 Discussion

This study gives a comprehensive overview of different ECB's non-standard monetary policy program announcements and their impact on the European government bond market. The results reveal a one-day delay of the government bond yield market in its reaction to the ECB's asset purchase program announcements. In the light of this delay, working with daily data seems appropriate to assess announcement effects on the bond markets. The use of more frequent data such as hours or minutes intervals is unlikely to give additional insights into our research question.<sup>26</sup>

The analysis suggests a general reduction in yields in response to an ECB's asset purchase announcement. It contributes to the literature by quantifying the reducing effect for each individual country. This is an important aspect for the ECB when deciding on a common monetary policy. The varying extent of the yield-reducing effect among core countries and periphery countries is in line with recent literature (e.g., Bulligan and Monache, 2018; Urbschat and Watzka, 2019) but provides additional insights. Specifically,

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<sup>26</sup> This study stands in contrast to a strand of literature that uses intraday data to identify monetary policy shocks. For instance, Gürkaynak et al. (2005), Gertler and Karadi (2015), and Jarociński and Karadi (2018) apply tight time windows of thirty minutes around a monetary policy announcement.

it is possible to observe a country ranking: The better the solvency rating for a country is, the lower is the reducing effect on the corresponding bond yield. This implies that those countries suffering most from investors' skepticism profit most in terms of yield reductions. It underlines that the risk premium is higher for periphery countries while there is not much leeway in risk premium reduction for core countries. Yet it is not possible to claim consistent program-specific effects, most likely because of press releases addressing several programs at the same time. The panel analysis justifies the separation into two country groups and reveals significant interaction effects between announcements and the current yield spread level.<sup>27</sup> Nevertheless, the country-by-country analysis seems more suitable because it enables us to measure the impact on a particular economy.

The observed pattern of core countries and periphery countries and their respective solvency rating is consistent with related literature. There is a consensus that credit ratings essentially determine sovereign bond spreads. Country-specific credit ratings play a major role in the development of the peripheral countries spreads of Greece, Ireland, Portugal and Spain vis-à-vis the German Bund between 2008 and 2011 (De Santis, 2012). Afonso et al. (2012) find a close interaction between 10-year sovereign yield spreads of 24 EU countries and credit rating announcements by Fitch, S&P, and Moody's from 1995 to 2010. This relationship is also confirmed between 1999 and 2016 by Afonso and Jalles (2019): Using time-varying coefficient models on monthly ECB's program holdings, better ratings and outlooks from all three main rating agencies decrease the sovereign yield spreads.

However, none of the aforementioned studies incorporates unconventional monetary policy announcements and credit ratings simultaneously as our study does. The explicit illustration of yield (not spread) reduction and credit ratings as a consequence from ECB announcements in Figure 3.2, as well as the interaction of the event dummy with the current spread level in Section 3.3.4 go beyond previous studies. The extensive character of this study (long time span, many economies) corroborates the previous results by authors who concentrate on shorter periods (Falagiarda and Reitz, 2015; Altavilla et al., 2016)

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<sup>27</sup> The results are robust to assigning Belgium to periphery countries.

or smaller country sets (Briciu and Lisi, 2015; Altavilla et al., 2016), but it allows us to consolidate them in a long-term context.

The present study shows that ECB's non-standard monetary policy program announcements reduce long-term government yields. Yet the economic mechanism, especially the channels through which the different programs work, are less clear. We abstain from an explicit test of channels because this would require more specific restrictions on our model. The short-term change in yields assessed in this study does not provide the complete functioning of the channel but it rather represents the first (necessary) step of a longer transmission process. The classical transmission channels do not work during unconventional times. For instance, the asset price channel usually lowers the interest rate by purchasing short-term securities. However, such purchases cannot lower the interest rates if they reach the lower bound. Simply expanding the amount of money induces people to hold the money in cash resulting in a liquidity trap (Fawley and Neely, 2013).

Krishnamurthy and Vissing-Jorgensen (2011) describe several transmission channels of quantitative easing. The *signaling channel* is based on a credible commitment of the central bank so that participants expect a longer period of expansionary monetary policy. For instance, the announcement of additional asset purchases conveys an interest rate at its lower bound for an extended period. We believe this channel to be the main driver of our results because our study evaluates announcements and short-term reactions. Signals can immediately be incorporated and do not need actual transactions. The *duration risk channel* relates to the risk premium of risk averse investors who have preferences for a specific maturity. The higher the duration of the asset is, the higher is the risk premium. Consequently, purchases of long-term bonds and their respective announcements drive up prices for bonds with a high maturity. Since we assess the impact on 10-year bonds, this channel presumably applies. The *safety channel* assumes investors to prefer safe assets. For that reason, safer assets react stronger to quantitative easing announcements than more insecure ones. This channel is unlikely to prevail in our analysis because the assets with higher risk, that is periphery bonds represented by a less favorable rating, experience a stronger yield reduction.

In contrast, substantial yield reductions of distressed countries' bonds can be attributed to the *default risk channel*. They benefit especially from an asset purchase announcement. A central bank willing to buy public bonds reduces the default risk. In turn, this channel does not affect more solvent countries because their default risk is already at a low level. Related to this reduction in the risk premium, recall the results of OMT in Table 3.5. OMT only works with the interaction of the current yield spread throughout all country groups. Hence, OMT plays an essential role in the default risk channel. The *portfolio rebalancing channel*, that is a switch from core to periphery bonds or from public to corporate bonds (and vice versa), implies an increase in yields of one group and a decrease in yields of the other group. Since all yields react to announcements in the same manner but merely the extent differs, this channel does not explain our findings well. An exception is the yield of Germany that increases in response to OMT announcements (see Table 3.3). The portfolio rebalancing channel precludes perfect arbitrage. If a central bank buys a specific asset type (e.g. duration), there exist fewer private agents holding that asset. Consequently, the asset price increases, the term premia and thus the interest rate falls. Since many announcements refer to the (T)LTRO, this channel seems notably relevant in our study given the application of 10-year government bonds yields.

Non-standard monetary policy tools such as asset purchases, extraordinary liquidity provisions and the extension of existing lending facilities increase central bank reserves. In consequence, more liquidity available for market participants cushions the liquidity premia that are typically high in times of financial distress. The reduction of the liquidity premium decreases asset prices so that government bond yields raise. This mechanism describes the *liquidity premium channel* (also labeled as *market functioning channel* in the literature). Similar to the default risk channel less solvent countries are particularly affected because their bonds are rather subject to illiquidity. The *credit channel* or *bank lending channel* refers to commercial banks that have higher reserve balances at a central bank because of supplementary asset purchases. Due to the increased balances, banks have an easier opportunity to issue loans to firms and households. Above all, (T)LTROs aim at this channel because it is the non-standard measure in this study that mostly resembles

conventional monetary policy. However, one cannot directly deduce an increased credit issuance from analyzing government bond yields.

Assigning the seven asset purchase programs to one or more distinct channels seems inadequate because purchases of any security potentially induce the portfolio rebalancing channel. Similarly, every non-standard monetary policy program announcement expresses the intentions of the ECB (signaling channel) and provides more liquidity to the market (liquidity premium channel). The positive impact on CBPP hints at the liquidity premium channel but an economic interpretation is lacking why this channel should prevail only for that program. Only the yields of France, the Netherlands and Spain increase in response to the SMP announcements impeding a generalization of a specific transmission channel. None of the channels seem to work for the CSPP and PSPP (or the respective channels neutralize each other) on the country-specific level. In contrast, the panel results in Table 3.4 indicate a response to PSPP announcements in periphery countries while CSPP remains insignificant. Consequently, the purchase of public bonds seems more relevant for yield reactions and possible underlying transmission channels than the purchase of corporate bonds.

The discussion above, however, needs to acknowledge that ‘different transmission channels may supersede and offset each other’ (Georgiadis and Gräß, 2016, p. 262). We believe a combination of the mentioned channels matters. A precise statement, which channel exactly prevails for which announcement type, would require further empirical analyses.<sup>28</sup>

### 3.5 Conclusion

This study evaluates short-term effects of the ECB’s asset purchase program announcements on 10-year government bond yields from January 1, 2007 to August 31, 2017. It distinguishes between more solvent countries (Austria, Belgium, Finland, France, Germany,

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<sup>28</sup> In line with Falagiarda and Reitz (2015) our study opts for a general assessment of program announcement effects. To test for specific transmission channels, one could use alternative dependent variables as in Georgiadis and Gräß (2016). However, this modification would imply a fundamental change of the empirical model. Krishnamurthy et al. (2018) decompose the government bond yields of Italy, Spain and Portugal into different components to search for different channels of the OMT, SMP and 3-year LTRO programs.

the Netherlands) and less solvent ones (Greece, Ireland, Italy, Portugal, Spain). The general and program-specific effects are evaluated by considering key announcements.

The contribution to the literature is threefold. First, this event study is the first explicitly documenting that the effects of ECB's asset purchase announcements on government bond yields arise with a one-day delay. This means the government bond market takes some time to react to central bank announcements. A reason for the delay is possibly the kind of transactions and agents who trade: institutional investors trade government bonds OTC on trading floors.

Second, the study quantifies country-specific yield reactions to the ECB's asset purchase program announcements. More specifically, the extent of yield reduction seems inversely related to the solvency rating of the corresponding country. The resulting reduction of the spread is due to a stronger fall in the yields of the less solvent countries compared to the more solvent countries' bond yields. Hence, the announcements lead to a convergence of government bond yields that is in the interest of a central bank responsible for several economies. A group-wise panel analysis confirms the separation into both country groups.

Third, we extend the model to test for interaction effects. By letting the announcement dummy variable interact with the current spread level the solvency rating is represented in the event study, which is an innovation in this strand of literature. We find interaction effects appearing in core countries tend to foster the general yield-reducing announcement effects whereas interaction effects appearing in periphery countries tend to fully explain the yield reduction after an announcement. This implies that the current spread reinforces short-term yield reactions to the ECB's monetary policy announcements for more solvent countries but it is the unique cause for the less solvent group. Thus, the innovative inclusion of interaction effects supports the previous findings and is one explanation why the spreads reduce over time: The higher a spread is for the country-specific bond, the stronger is the interaction effect with the dummy reinforcing or even replacing the announcement effect, which promotes a convergence in yields among euro area members. Accordingly, the presence of a high spread/unfavorable rating reinforces the announcement effects implying

ECB's monetary policy communication is more effective in times of a yield divergence within the euro area.

Mixed results for program-specific announcements lead to an ambiguous conclusion. The analysis suggests a general reduction in yields in response to an ECB's asset purchase program announcement. However, it is not possible to claim consistent program-specific effects. Only ABSPP, (T)LTRO and OMT work in the expected direction. Counterintuitively, SMP and CBPP even show positive announcement effects on some countries' yields while PSPP and CSPP announcements have no influence. Hence, investors seem to be sensitive to the type of program announcement. However, several programs are mentioned concomitantly on half of the event dates, which impairs the program-specific analysis. For the same reason, the allocation of the programs to specific transmission channels is difficult. The short-term change in yields cannot entirely explain the channels through which monetary policy works because it only indicates the first (necessary) step of a longer transmission process.

The assessment of individual announcements supports the findings. In general, periphery countries react more strongly to announcements than core countries. OMT is particularly relevant for periphery countries while the introduction of CSPP primarily reduces the yields of core countries. The first ABSPP announcement, in turn, affected the yields similarly throughout the euro area.

Overall, the study provides evidence that one has to differentiate the effects of asset purchase program announcements by the ECB on its member countries. Although the ECB's aim is to target an aggregated market of the euro area, subsequent studies should bear in mind that the ECB's communication potentially has differing effects on national markets. Finally, it would be interesting to see if the reverse effect is detectable in the hypothetical case of asset redemption announcements in the future, or the exit from the non-standard monetary policy in general.



## Appendix A

## I Tables

Table A1: Overview of ECB's program announcements

Announcement date	Program	measure/statement
<b>July 20, 2017</b>	EAPP	<i>Repetition/confirmation of decided measures.</i>
<b>June 8, 2017</b>	EAPP	<i>Repetition/confirmation of decided measures.</i>
<b>April 27, 2017</b>	EAPP	<i>Repetition/confirmation of decided measures.</i>
<b>January 19, 2017</b>	EAPP details	ECB provides further details on EAPP purchases of assets with yields below the deposit facility rate; GovC confirms that it will continue to make purchases under the asset purchase programme (EAPP) at the current monthly pace of €80 billion until the end of March 2017 and that, <i>from April 2017, the net asset purchases are intended to continue at a monthly pace of €60 billion until the end of December 2017, or beyond, if necessary, and in any case until the GovC sees a sustained adjustment in the path of inflation consistent with its inflation aim.</i>
<b>December 15, 2016</b>	ABSPP	Eurosystem to <i>take up all asset management tasks in the ABSPP from 1 April 2017.</i>
<b>December 8, 2016</b>	PSPP, EAPP, (T)LTRO	Eurosystem introduces <i>cash collateral for PSPP securities</i> lending facilities; ECB adjusts parameters of its asset purchase programme; <i>GovC decided to continue its purchases under the asset purchase programme (EAPP) at the current monthly pace of €80 billion until the end of March 2017. From April 2017, the net asset purchases are intended to continue at a monthly pace of €60 billion until the end of December 2017.</i>
June 2, 2016	CSPP	ECB announces remaining details of the corporate sector purchase programme (CSPP).
June 1, 2016	CSPP	ECB decision about CSPP.
May 3, 2016	TLTRO II	ECB publishes legal acts relating to the second series of targeted longer-term refinancing operations ((T)LTRO II).
April 21, 2016	CSPP	ECB announces details of the corporate sector purchase programme (CSPP).
<b>March 10, 2016*</b>	(T)LTRO II, CSPP	ECB announces new series of targeted longer-term refinancing operations ((T)LTRO II); ECB adds corporate sector purchase programme (CSPP) to the asset purchase programme (EAPP) and announces changes to EAPP.
<b>December 3, 2015*</b>	EAPP	<i>Extension EAPP at least until March 2017.</i>
September 10, 2015	ABSPP	Details implementation of ABSPP.
<b>January 22, 2015</b>	EAPP, ABSPP, CBPP3, (T)LTRO II	<i>ECB announces expanded asset purchase programme (EAPP) including governments, agencies and European institutions, ABSPP and CBPP3: 'add the purchase of sovereign bonds to its existing private sector asset purchase programmes', intention of the Governing Council to underpin the effectiveness of the TLTROs as key instruments supporting lending to the non-financial private sector.</i>
December 11, 2014	(T)LTRO	Amount allotted in the second (T)LTRO €129.84 billion.
<b>December 4, 2014</b>	PSPP	'Evidently we are convinced that a <i>QE programme</i> which could <i>include sovereign bonds</i> falls within our mandate.' (M. Draghi)
<b>November 26, 2014</b>	PSPP	'we will have to consider buying other assets, including sovereign bonds in the secondary market.' (V. Constâncio)
November 19, 2014	ABSPP	ECB's legal decision on ABSPP.
<b>November 17, 2014</b>	PSPP	'The Governing Council is unanimous in its commitment to using additional unconventional instruments [...] <i>Unconventional measures might entail</i> the purchase of a variety of assets, one of which is <i>sovereign bonds</i> .'
November 7, 2014	(T)LTRO	ECB suspends early repayments of the three-year (T)LTROs during the year-end period.
October 15, 2014	CBPP3	ECB's legal decision on CBPP3.
October 2, 2014	CBPP3, ABSPP	The ECB announces operational details of asset-backed securities and covered bond purchase programmes.
September 18, 2014	(T)LTRO	ECB allots €82.6 billion in first targeted longer-term refinancing operation.
<b>September 4, 2014*</b>	CBPP3, ABSPP	<i>ABS purchase programme (ABSPP) announced, CBPP3 announced.</i>
July 29, 2014	(T)LTRO	ECB publishes legal act relating to targeted longer-term refinancing operations.
July 3, 2014	(T)LTRO	Details on (T)LTRO.
<b>June 5, 2014*</b>	(T)LTRO, ABSPP	ECB announces monetary policy measures to enhance the functioning of the monetary policy transmission mechanism: <i>targeted LTROs (TLTROs)</i> and <i>asset backed securities (ABS)</i> .
November 22, 2013	(T)LTRO	ECB suspends early repayments of the three-year (T)LTROs during the year-end period.
November 8, 2013	(T)LTRO	The GovC decided to continue to conduct its main refinancing operations (MROs) as fixed rate tender procedures with full allotment (FRTPFA) for as long as necessary, and to conduct 3-month (T)LTROs as FRTPFA.
May 2, 2013*	(T)LTRO	The GovC has decided to conduct the three-month longer-term refinancing operations ((T)LTROs) as FRTPFA.
February 21, 2013	SMP	The GovC decided to publish the Eurosystem's holdings of securities acquired under the Securities Markets Programme (SMP).
December 6, 2012	(T)LTRO	The GovC decided to continue conducting its MROs as FRTPFA for as long as necessary, and to conduct 3-month (T)LTROs as FRTPFA.
October 31, 2012	CBPP2	Termination of CBPP2.
<b>September 6, 2012</b>	OMT, SMP	Termination of SMP. <i>Confirmation of OMT</i> by issuing its technical features.
<b>August 2, 2012</b>	OMT	M. Draghi claims that 'ECB may <i>undertake outright open market operations</i> .'
<b>July 26, 2012</b>	OMT	M. Draghi assures that ECB will do ' <i>whatever it takes</i> ' to preserve the euro.
June 6, 2012	(T)LTRO	The GovC decided to continue to conduct its MROs as FRTPFA for as long as necessary, and to conduct 3-month (T)LTROs as FRTPFA.

Table A1: Overview of ECB's program announcements (continued)

Announcement date	Program	measure/statement
February 29, 2012	(T)LTRO	Amount allotted in the second three-year (T)LTRO € 529.53bn.
December 21, 2011	(T)LTRO	Amount allotted in the first three-year (T)LTROs € 489.19bn.
<b>December 8, 2011*</b>	(T)LTRO	ECB announces measures to support bank lending and money market activity: expansion of eligible collateral and <i>3-year (T)LTROs</i> .
December 1, 2011	(T)LTRO	Rumours on 3-year (T)LTRO come up due to Draghis words
November 3, 2011*	CBPPs	Details on CBPP2 and legal implementation
October 25, 2011	(T)LTRO	First allotment of 36-month (T)LTRO
<b>October 6, 2011</b>	CBPP2, (T)LTRO	Details of refinancing operations, ECB announces <i>new covered bond purchase programme</i> (CBPP2) and two <i>12-month (T)LTROs</i> .
<b>August 7, 2011</b>	SMP	<i>Securities Markets Programme</i> : Statement by the ECB president to <i>justify the program</i> (Italy and Spain).
August 4, 2011	(T)LTRO	The GovC decided to continue to conduct its MROs as FRTPPFA for as long as necessary, and to conduct 3-month (T)LTROs as FRTPPFA.
June 9, 2011	(T)LTRO	The GovC decided to continue to conduct its MROs as FRTPPFA for as long as necessary, and to conduct 3-month (T)LTROs as FRTPPFA.
March 3, 2011	(T)LTRO	Fixed Rate Full Allotment Refinancing Operations details
December 2, 2010	(T)LTRO	The GovC decided to continue to conduct its MROs as FRTPPFA for as long as necessary, and to conduct 3-month (T)LTROs as FRTPPFA.
September 2, 2010	(T)LTRO	The GovC decided to continue to conduct its MROs as FRTPPFA for as long as necessary, and to conduct 3-month (T)LTROs as FRTPPFA.
June 30, 2010	CBPP1	CBPP1 terminated.
May 14, 2010	SMP	Legal declaration of SMP.
<b>May 10, 2010</b>	SMP, (T)LTRO	ECB decides on measures to address severe tensions in financial markets: continue (T)LTROs and <i>start of securities market programme</i> (SMP)
March 4, 2010	(T)LTRO	Details and enhancement of (T)LTRO provisions.
December 15, 2009	(T)LTRO	Amount allotted in third one year (T)LTRO € 96.93bn.
December 3, 2009	(T)LTRO	Details and enhancement of (T)LTRO provisions.
September 29, 2009	(T)LTRO	Amount allotted in second one year (T)LTRO € 75.24bn.
July 2, 2009	CBPP1	Details CBPP1: legal declaration.
June 23, 2009	(T)LTRO	Amount allotted in first one year (T)LTRO 442.24bn.
June 4, 2009	CBPP1	Details CBPP1: amount of 60 billion €.
<b>May 7, 2009*</b>	CBPP1, (T)LTRO	Announcement of 3 <i>supplementary liquidity-providing longer-term refinancing operations</i> ((T)LTROs) with a maturity of one year, purchase of <i>euro-denominated covered bonds</i> issued in the euro area and prolongation until the end of 2010 the temporary expansion of the list of eligible assets, announced on 15 October 2008.
March 5, 2009*	(T)LTRO	ECB decided to continue the fixed rate tender procedure with full allotment for all [...] supplementary and regular longer-term refinancing operations for as long as needed, and in any case beyond the end of 2009.
<b>October 15, 2008</b>	(T)LTRO	Renewal and <i>adding of (T)LTROs, STRO, S(T)LTRO</i> .
October 7, 2008	(T)LTRO	Increase of the allotment amount in the six-month supplementary longer-term refinancing operation that was pre-announced in the press release of 4 September 2008 from EUR 25 billion to EUR 50 billion.
September 4, 2008	(T)LTRO	Renewal of the outstanding six-month supplementary longer-term refinancing operation ((T)LTRO) of € 25 billion that was allotted on 2 April, and that will mature on 9 October 2008. Renewal of the two threemonth supplementary (T)LTROs (€ 50 billion each).
July 31, 2008	(T)LTRO	Renewal of the two three month supplementary (T)LTROs carried out through variable rate tenders, each with a preset amount of EUR 60 billion.
<b>March 28, 2008</b>	(T)LTRO	2 <i>supplementary</i> six-month longer-term refinancing operations (each 25 billion €) and continuation of the 2 supplementary three-month longer-term refinancing operations (each 50 billion €).
February 7, 2008	(T)LTRO	Renewal of the two supplementary (T)LTROs carried out through variable rate tenders, each with a preset amount of € 60 billion.
November 8, 2007	(T)LTRO	Renewal of the two supplementary (T)LTROs carried out through variable rate tenders, each with a preset amount of € 60 billion.
<b>September 6, 2007</b>	(T)LTRO	<i>Supplementary</i> liquidity-providing longer-term refinancing operation with a maturity of three months (no preset allotment amount).
<b>August 22, 2007</b>	(T)LTRO	<i>Supplementary</i> liquidity-providing longer-term refinancing operation with a maturity of three months for an amount of € 40 billion.

**Notes:** Source: <https://www.ecb.europa.eu/press/pr/activities/mopo/html/index.en.html>. The 26 baseline events are denoted in **bold** and its key statements are denoted in *italics*. An asterisk denotes dates with a decrease in the policy rate.

Table A2: Descriptive statistics in daily variations

Variable	Mean	Std. Dev.	Min	Max	Datastream mnemonic
$\Delta y_{DE}$	-0.0013142	0.043227	-0.256	0.1995	BDBRYLD
$\Delta y_{ES}$	-0.0009182	0.0689933	-0.883	0.373	ESBRYLD
$\Delta y_{IT}$	-0.0007837	0.0680118	-0.78	0.509	ITBRYLD
$\Delta y_{IR}$	-0.0011652	0.0828358	-1.0279	0.75	IRBRYLD
$\Delta y_{GR}$	0.0004382	0.6302251	-27.475	7.028	GRBRYLD
$\Delta y_{PT}$	-0.0004677	0.1240573	-1.4698	1.686	PTBRYLD
$\Delta y_{FR}$	-0.0011909	0.0436555	-0.262	0.242	FRBRYLD
$\Delta y_{BE}$	-0.0011964	0.0476313	-0.302	0.344	BGBRYLD
$\Delta y_{NL}$	-0.0012494	0.0418117	-0.224	0.1771	NLBRYLD
$\Delta y_{AU}$	-0.0012284	0.0438163	-0.217	0.254	OEBRYLD
$\Delta y_{FI}$	-0.0012981	0.0431516	-0.239	0.223	FNBRYLD
$\Delta stock_{DE}$	1.961524	102.446	-699.87	518.14	DAXIND
$\Delta stock_{ES}$	-1.382321	154.8665	-1097.6	1305.8	IBEX35I
$\Delta stock_{IT}$	-7.101753	347.1168	-2242.36	2333.59	FTSEMIB
$\Delta stock_{IR}$	-1.001412	72.07195	-581.49	383.62	ISEQUIT
$\Delta stock_{GR}$	-1.282303	35.7257	-282.84	327.78	GRAGENL
$\Delta stock_{PT}$	-2.170654	93.49474	-760.65	711.04	POPSI20
$\Delta stock_{FR}$	-0.1639131	57.7862	-368.77	367.01	FRCAC40
$\Delta stock_{BE}$	-0.1800144	36.90997	-224.64	268.92	BGBEL20
$\Delta stock_{NL}$	0.007438	4.89388	-31.46	30.17	AMSTEOE
$\Delta stock_{AU}$	-0.4421991	41.88912	-241.38	331.51	ATXINDX
$\Delta stock_{FI}$	-0.0508481	102.9363	-628.78	877.9	HEXINDX
$\Delta CESI$	-0.0032699	6.237267	-52.9	48.3	EKCESIR
$\Delta exch$	-0.0000483	0.0081933	-0.0676	0.0557	USECBSP
$\Delta Euro\ Swap$	-0.0012228	0.0413219	-0.25	0.216	ICEIB10
$\Delta iTraxx\ Europe$	0.0205641	3.618547	-30.713	29.858	DIXETMC
$\Delta MSCI\ Europe$	-0.0731401	20.81413	-139.06	124.245	MSEROP\$
$\Delta MSCI_{World}$	0.0278527	1.190067	-9.821	6.179	MSWXEEU
$\Delta MSCI_{DE}$	0.0758897	9.603461	-59.124	55.837	MSGERML
$\Delta MSCI_{FR}$	-0.0043845	19.21401	-121.697	117.029	MSFRNCL
$\Delta MSCI_{IT}$	-0.2707481	12.26912	-79.779	82.522	MSITALL
$\Delta MSCI_{IR}$	-0.1253184	4.065433	-32.629	27.683	MSEIRL
$\Delta MSCI_{ES}$	-0.1096292	14.64671	-107.365	129.022	MSSPANL
$\Delta MSCI_{PT}$	-0.0478146	1.721483	-14.643	13.322	MSPORDL
$\Delta MSCI_{NL}$	0.1650284	12.81696	-79.011	65.868	MSNETHL
$\Delta MSCI_{AU}$	-0.2429698	10.51452	-71.488	93.733	MSASTRL
$\Delta MSCI_{BE}$	-0.0523482	11.85462	-84.52	77.903	MSBELGL
$\Delta MSCI_{FI}$	-0.0344937	9.391176	-67.834	90.748	MSFINDL
$\Delta MSCI_{GR}$	-0.5648408	14.13775	-93.895	126.878	MSGREEL
$\Delta V2TX$	0.0002875	1.897658	-13.98	22.64	VSTOXXI
$\Delta VIX$	-0.0203127	1.926122	-17.36	16.54	CBOEVIX
$\Delta future$	-0.0015235	0.0312707	-0.3650002	0.2950001	LEICS30
$\Delta TIPS$	-0.0003518	0.0620315	-0.4665	-0.4665	from Federal Reserve
$\Delta surprise$	0.0001675	0.0957165	-0.9971879	1.022957	from Scotti (2016)
$\Delta uncertainty$	-0.0002068	0.0735713	-0.3504324	1.221693	from Scotti (2016)

**Notes:** 2,784 daily observations per variable. Yields are benchmark return indices and displayed in per cent.  $\Delta$  indicates daily variations.

Table A3: Euro area member solvency ratings

Country	Coefficient	Fitch	S&P	Moody's
FI	-0.00866	AA+	AA+	Aa1
DE	-0.0134*	AAA	AAA	Aaa
NL	-0.0149*	AAA	AAA	Aaa
AU	-0.0189**	AA+	AA+	Aa1
FR	-0.0252***	AA	AA	Aa2
BE	-0.0344***	AA-	AA	Aa3
IR	-0.0379**	A	A+	A2
ES	-0.0439***	BBB+	BBB+	Baa2
IT	-0.0476***	BBB	BBB	Baa2
PT	-0.0544***	BBB	BB+	Ba1
GR	-0.104**	B-	B-	Caa2

Notes: Rating according to Börsen-Zeitung (2018). Effective January 2018.

Table A4: Immediate effects of program-specific ECB announcements on 10-year government bond yields

Country	<i>ABSPP</i>	<i>CSPP</i>	<i>CBPP</i>	<i>PSPP</i>	<i>(T)LTRO</i>	<i>SMP</i>	<i>OMT</i>
$\Delta y_{DE}$	-0.0257	0.0128	0.0422	-0.0159	0.0165	0.0950**	-0.00812
$\Delta y_{FR}$	-0.0390	0.0326	0.0319	-0.0167	0.0237	0.0548***	-0.0410**
$\Delta y_{NL}$	-0.0352	0.0266	0.0434	-0.0207	0.00610	0.0387*	-0.0306
$\Delta y_{AU}$	-0.0124	0.0195	0.0223	-0.0249**	0.00106	0.0495**	-0.0270
$\Delta y_{FI}$	-0.0327	0.00574	0.0413	-0.0110	0.00413	0.0403	-0.0261
$\Delta y_{BE}$	-0.0275	0.0290	0.0105	-0.00473	0.0179	-0.103***	-0.0360*
$\Delta y_{ES}$	-0.0390	0.00685	-0.0175	0.0292	0.0429	-0.564***	-0.153
$\Delta y_{IT}$	-0.000138	0.0186	-0.0474	0.00958	0.0518	-0.466***	-0.0699
$\Delta y_{IR}$	-0.0375	0.0577*	0.0114	-0.0112	-0.0749	-0.408	-0.0287
$\Delta y_{GR}$	0.0488	-0.159*	-0.0156	0.0906	-0.208	-1.983*	-0.0483
$\Delta y_{PT}$	-0.0206	0.0277	0.0465	-0.0161	-0.0920	-0.658*	-0.175***

Notes: 2,782 Observations. \*\*\*, \*\*, and \* denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. Controls and constant omitted. The horizontal middle line separates core countries (above) and periphery countries (below). Sample period: January 1, 2007 to August 31, 2017.

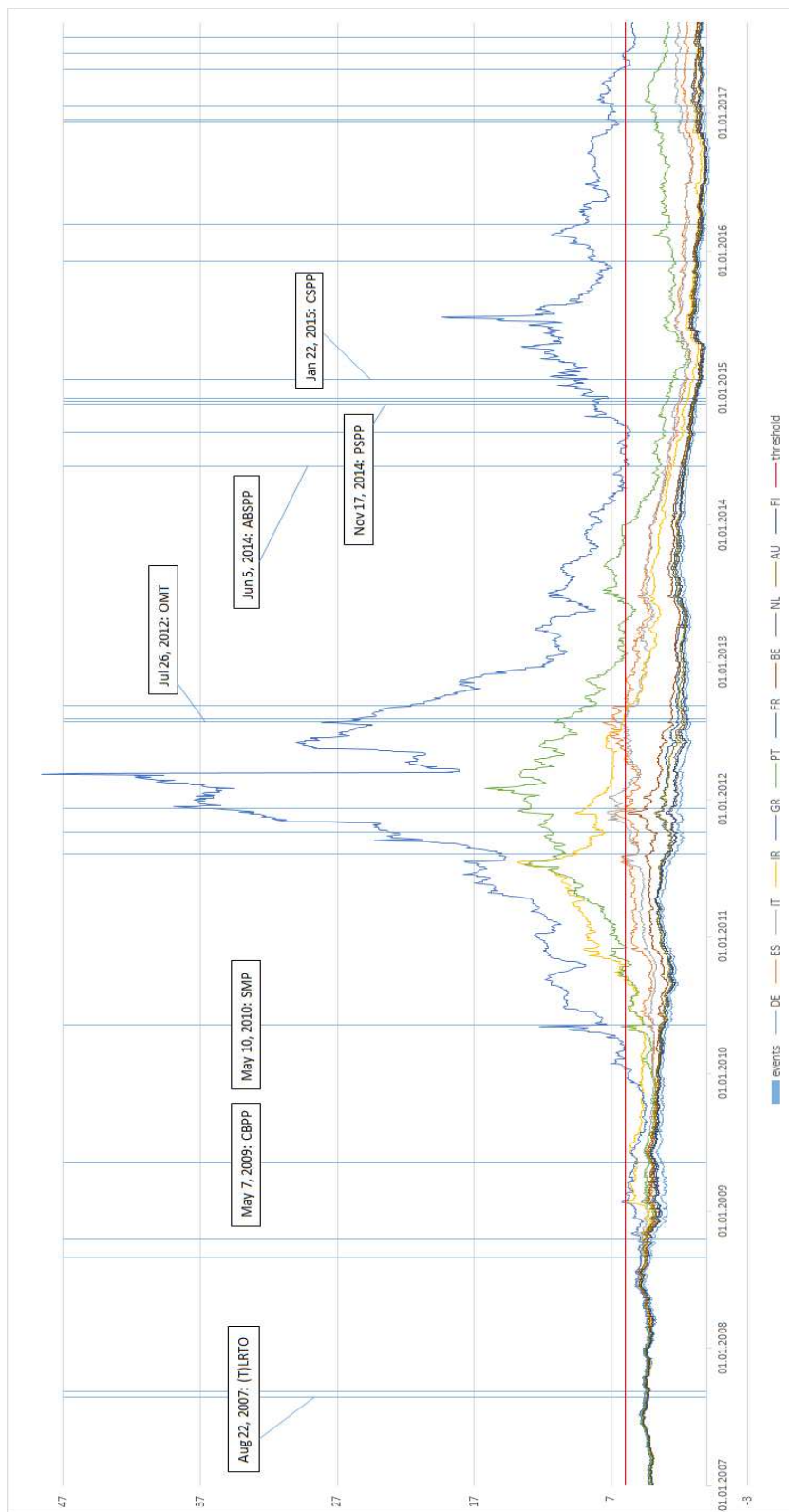
Table A5: Panel regression immediate effects

specification	11 aggregated countries		6 core countries		5 periphery countries	
	(3)	(4)	(3)	(4)	(3)	(4)
$\Delta y_{t-1}$	0.104***	0.104***	0.106***	0.105***	0.104***	0.105***
$\Delta stock_t$	-3.73E-05**	-3.31E-05*	0.000116***	0.000116***	-4.53E-05*	-3.59E-05*
$future_t$	0.442***	0.405***	0.331***	0.334***	0.548**	0.459**
$\Delta CESI_t$	0.000603***	0.000590***	0.000501***	0.000505***	0.000690***	0.000658***
$\Delta VIX_t$	0.000811	0.000943	-0.00112*	-0.00114*	0.00532	0.00571
$\Delta exch_t$	-0.495	-0.427	0.192	0.187	-1.405**	-1.253**
$\Delta TIPS_t$	0.135***	0.132***	0.190***	0.191***	0.0564*	0.0497
$ABSPP$		-0.0197***		-0.0274***		-0.0169
$CSPP$		0.00153		0.0176***		-0.00535
$CBPP$		0.0184*		0.0336***		-0.00481
$PSPP$		0.00113		-0.0160***		0.0229
$(T)LTRO$		-0.0196		0.0121**		-0.0580
$SMP$		-0.360*		0.0337		-0.849*
$OMT$		-0.0557***		-0.0279***		-0.0899**
$APA_t$	-0.0297		0.0100**		-0.0784**	
$R^2$	0.019	0.021	0.234	0.236	0.018	0.025

Notes: 30,602 Observations. \*\*\*, \*\*, and \* denote 1%, 5%, and 10% significance levels, respectively. Newey-West-adjusted standard errors. Constant omitted. Sample period: January 1, 2007 to August 31, 2017.

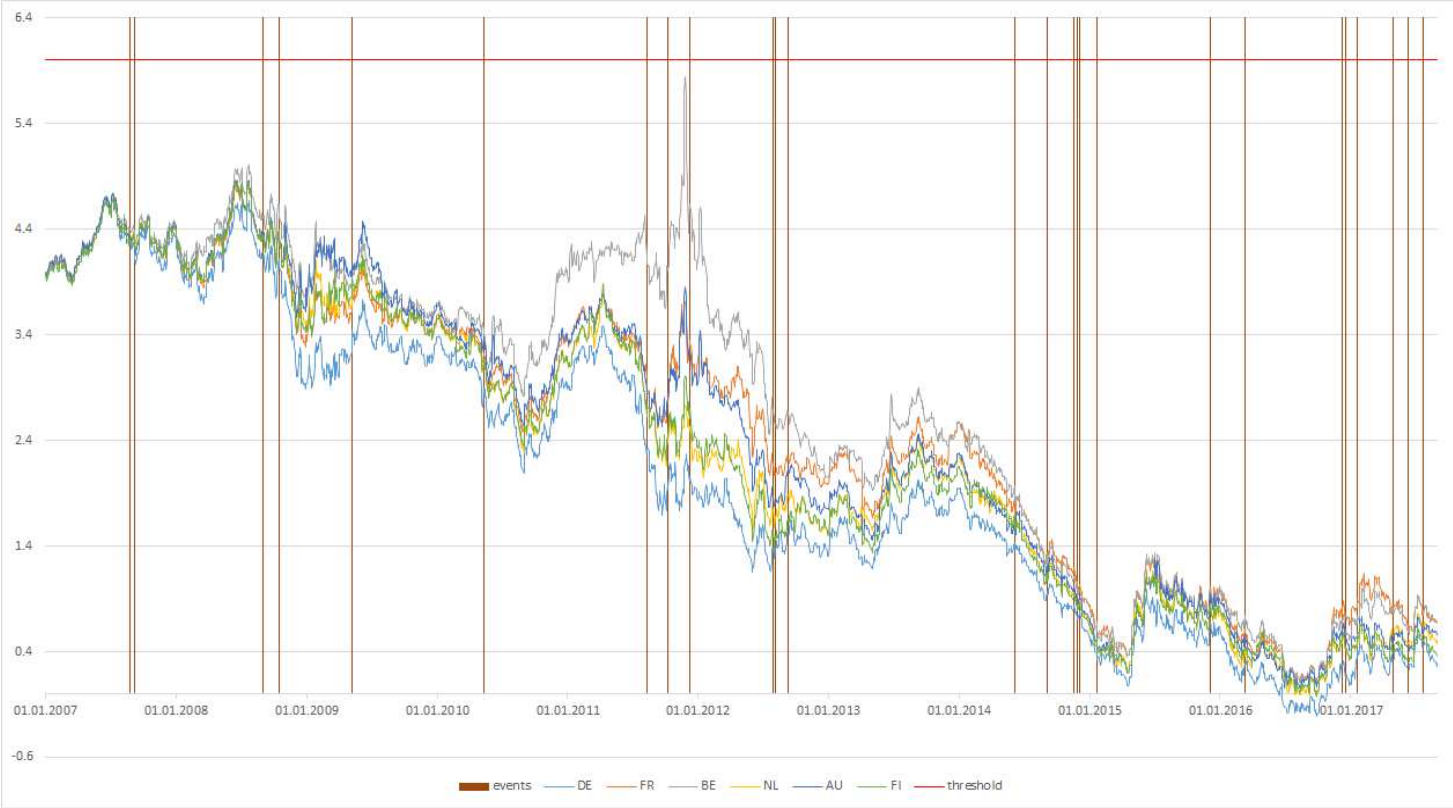
## II Figures

Figure A1: 10-year euro area government bond yields



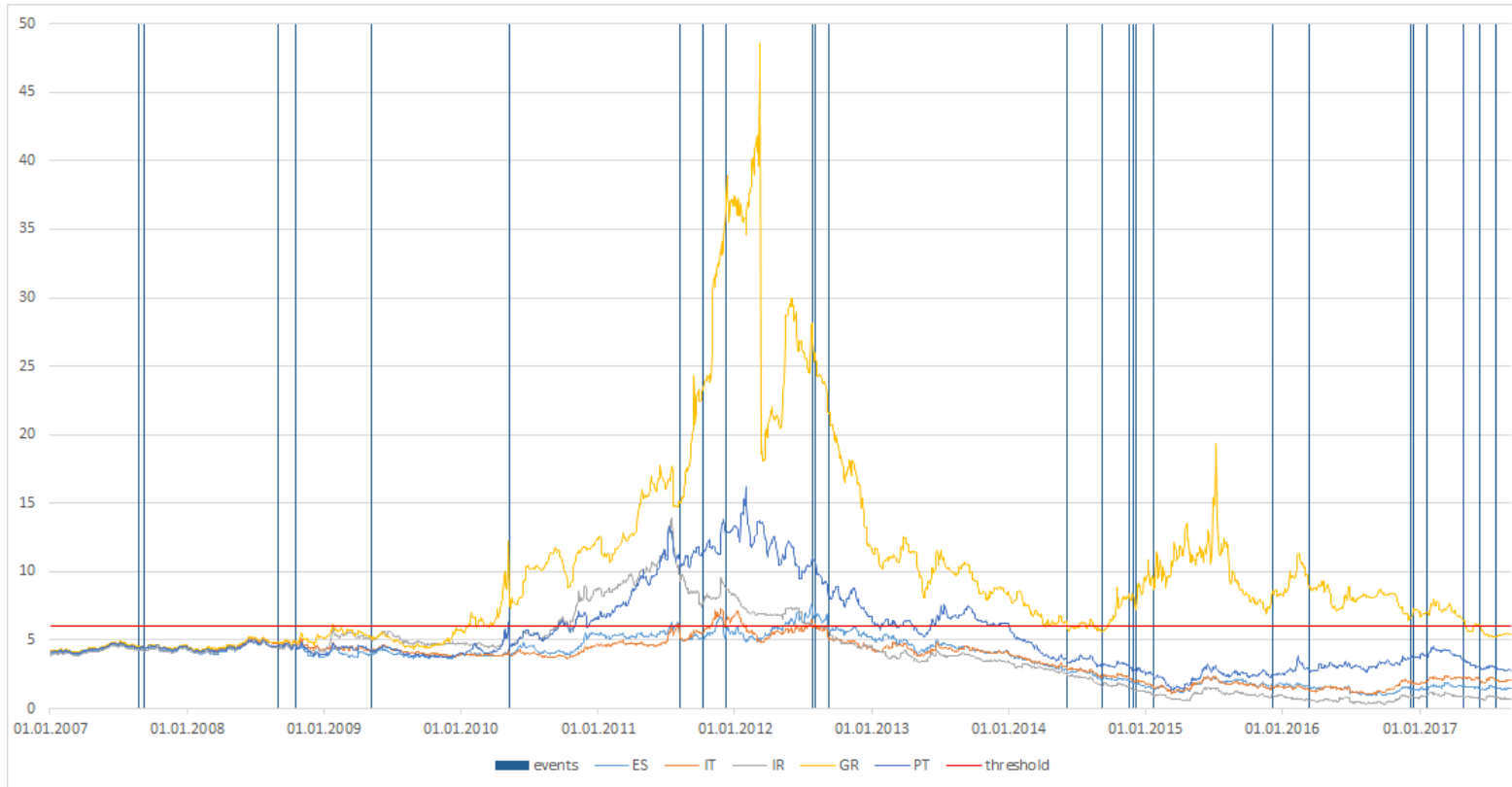
**Notes:** Source: Datastream. Time span: January 1, 2007 to August 31, 2017. Vertical lines indicate the 26 baseline announcement dates while the horizontal line represents the 6% threshold. The seven indicated dates represent the first announcement of the respective program.

Figure A2: 10-year euro area government bond yields: core countries



**Notes:** Source: Datastream. Time span: January 1, 2007 to August 31, 2017. Vertical lines indicate the 26 baseline announcement dates while the horizontal line represents the 6% threshold.

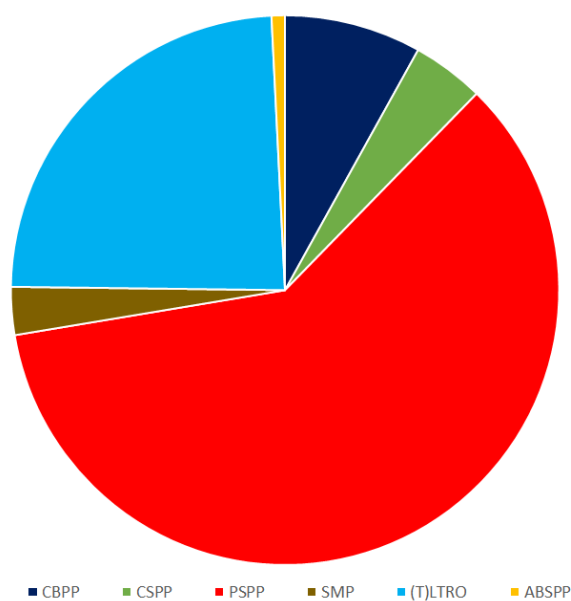
Figure A3: 10-year euro area government bond yields: periphery countries



**Notes:** Source: Datastream. Time span: January 1, 2007 to August 31, 2017. Vertical lines indicate the 26 baseline announcement dates while the horizontal line represents the 6% threshold.



Figure A4: ECB's asset purchase programs' characteristics



name	# announcements	starting date	million €
(T)LTRO: (targeted) long term refinancing operation	10	August 2007	760,639
CBPP: covered bond purchase programme	10	July 2, 2009	255,627
SMP: securities market programme	2	May 10, 2010	89,134
ABSPP: asset-backed securities purchase programme	10	November 21, 2014	25,032
PSPP: public sector purchase programme	10	March 9, 2015	1,902,213
CSPP: corporate sector purchase programme	8	June 8, 2016	134,622

**Notes:** Effective January 19, 2018. The pie diagram juxtaposes the outstanding amount in million euro. OMT is not displayed because this program is not executed yet.

### III Robustness checks

We execute various robustness checks to challenge the present findings. First, the choice of events is modified in different ways. Second, alternative variables are implemented.<sup>29</sup> The results of the subsequent robustness checks are not explicitly displayed for the sake of parsimony but available upon request.

#### III.1 Choice of events

**Initial events only:** The alternative choice of only the 7 initial events of each program tests for the hypothesis of diminishing effects. These pivotal events should induce the strongest effects. This approach assumes repeating announcements do not provide new information. In consequence, investors do not amend their choices because these announcements do not have a surprising character. An advantage of this approach is that every program is weighted equally using its first announcement only.

The only change is a weakly significant and negative coefficient of the announcement on Spanish yields in the immediate case. Hence, even focusing on the introduction of the programs, no noticeable influence emerges. For the delayed case, the negative impact is only significant for core countries while periphery countries are unaffected by initial announcements (except for Spain). The issue that periphery countries do not react to the announcements is puzzling, especially considering a negative impact on yields for both groups in the panel regressions. One explanation could be that investors need additional confirmation to change their perception on periphery countries. On the initial announcement day, they might be still skeptical about future development. After a confirming announcement they trust the policy change and adopt their expectations accordingly. Consequently, the results highlight that repeated announcements do matter.

**Excluding (T)LTRO:** One might argue the (T)LTROs belong to conventional monetary policy because they are close to the conventional LTROs. Therefore, all regressions are repeated without the announcements denoted with (T)LTRO in Table A1. As a result,

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<sup>29</sup> All additional introduced variables can be found in the descriptive statistics in Table A2.

21 events remain and the time span starts from 2009 because no other types of events happened before.

In fact, while dropping these five (pure) (T)LTRO events in question the results for the immediate case persist. In contrast, a striking difference can be found for the delayed case for which the yields of Germany, the Netherlands, Ireland and Greece become insignificant. This implies (T)LTRO announcements are crucial for the yield reduction in those economies. Hence, we confidently keep (T)LTRO events in the analysis. We observe that countries of both groups are still affected. The panel analysis is unresponsive to this modification for both same-day and delayed effects.

**Including events of technical details:** The ECB regularly announces technical details of the asset purchase programs. Investors should not react to these announcements as they do not change the situation on financial markets substantially. To test for this hypothesis, events regarding details of the programs are added. Table A1 lists all relevant 71 events; (T)LTRO is the dominating program.

The results for the immediate case persist. Assuming delayed effects significantly negative estimators exist for most countries (Austria, France, Belgium, Spain, Italy, Ireland, Portugal). This is in line with the previous findings stating little immediate influence but substantial delayed negative effects. The program-specific effects attenuate for core countries when considering the full event set. The significance levels of (T)LTRO decrease and this program becomes even insignificant for Germany and Finland. Similarly, CBPP announcements do not affect French, Austrian and Finnish bonds any more and the SMP loses its impact on the bonds of the Netherlands and Austria. The general picture of the other programs is robust to the inclusion of additional events, though. Most importantly, the effect of  $daA_t$  and the qualitative difference between core countries and periphery countries persist in the panel, albeit the estimators become smaller when accounting for technical details.

Overall, adding events that provide technical details does not change the main results. Put differently, they are not essential and can be omitted. However, when considering all 71 events, core countries seem to be less affected.

**Regime shift:** Afonso et al. (2018) detect a new bond-pricing regime for sovereign yields after the OMT announcement. The speech by Mario Draghi on July 26, 2012 might effectively have changed the perception of monetary policy announcements in general. One could split up the data sample into a pre-period and into a post-period with respect to this speech. However, the amount of announcements would reduce accordingly to 9 events before and 17 events after the speech, which impairs the program-specific analysis and the idea of assessing the average impact of announcements. Moreover, comparing two time series with varying observation lengths worsens their comparability. To keep the amount of events stable, an alternative specification adds another dummy taking the value of 1 for the time after the regime shift, and 0 otherwise. The results are robust to the inclusion of this regime dummy implying that announcement effects are not specific to a certain point of time but hold for the whole period under examination. The dummy variable itself is significant mostly for periphery countries.

Forward guidance receives increasing attention and is applied by several central bank as an additional monetary policy tool. Most importantly, forward guidance is not a non-standard monetary policy itself but a way a central bank commits to such measures. A combination of both FOMC's forward guidance and large-scale asset purchases continues to move medium- and longer-term interest rates even when short-term rates were stuck at zero for the U.S. economy (Swanson and Williams, 2014). Forward guidance is inherent in statements regarding non-standard monetary policy but it is not a measure by itself, for example on December 3, 2015, the Governing Council commits to extend the EAPP 'at least until March 2017'. Hence, since the introduction of forward guidance, any ECB communication could be classified as forward guidance because of the commitment for the future. Related to the announcement of unconventional measures one cannot disentangle the effect that is due to the measure and the effect that is due to its committing character. In the euro area, forward guidance was first implemented on the interest rate on July 4, 2013. This date arguably establishes a decisive change that alters expectations substantially for the subsequent announcements. Therefore, a regime dummy is implemented taking the value of 1 since July 4, 2013, and 0 before this date. As for the OMT regime, the regime dummy is insignificant in the country-specific analysis. The results

remain qualitatively unchanged in all specifications when accounting for the forward guidance period.

**The role of policy rate announcements:** In unconventional times, the ECB undertakes multiple measures at the same time. The communication of such tools and the explanation of their complementarities is essential (ECB, 2017). Not a single measure but the combination of both standard and non-standard announcements affects financial markets. It is in the nature of ECB's communication strategy to announce regular monetary policy decisions as the adjustment of the policy rate concomitantly with statements on non-standard measures such as asset purchase programs. For that reason we are unable to disentangle the events when there was a policy rate reduction and a non-standard measure announced at the same time.

Nevertheless, to control for effects specific to the policy rate, we isolate the corresponding nine events (denoted with an asterisk in Table A1), six of them coincidence with the chosen 26 key announcements. This goes beyond related literature that is not concerned about parallel policy rate change announcements.<sup>30</sup> A robustness check considers the remaining 20 key announcements. The coefficients of  $daA_t$  are weaker and those of Germany and the Netherlands become insignificant. However, the overall yield-reducing effect still persists. In consequence, independent of policy rate changes, non-standard monetary policy announcements affect most government bond yields. This is supported by the panel regressions which remain qualitatively unchanged when omitting the six overlapping events.

Furthermore, we test for the distinct announcement effect of a policy rate change itself. For the period under consideration, such changes were announced on 21 dates (including the six overlapping events with seminal non-standard measure announcements). Specifically, the dummy  $dapolicy_t$  ('day after policy rate change') replaces  $daA_t$  taking the value of 1 only if there is a policy rate change announced the previous day. Interestingly,

<sup>30</sup> For instance, Jäger and Grigoriadis (2017) only acknowledge July 5, 2012 as the seminal change of the deposit rate to 0 per cent. Specifically, four announcements in their event set also coincide with a parallel announcement on the change in the policy rate: May 7, 2009, August 7, 2011, November 3, 2011, December 8, 2011 (see Table A.1 in Jäger and Grigoriadis, 2017).

neither an immediate nor a delayed impact appears in any country. A further separation of the event set into 9 overlapping events and 12 pure policy rate change events does not alter the results. The panel shows a very weak impact of policy rate change announcements on government bond yields for core countries only. A potential explanation for these puzzling findings could be that the 21 changes were anticipated or at least not surprising enough to change market behavior. It is arguable whether a slight decrease in the policy rate matters given the interest rate is already close to the zero lower bound on most announcement dates. We believe the novel (non-standard) measure should outweigh the ‘old’ policy instrument during the days when there is an overlap. Consequently, our study supposes the non-standard measures are so striking that they dominate other information released on the date under consideration, even a change in the policy rate.

Overall, when comparing both types of announcements, non-standard monetary policy announcements do have a significant yield-reducing effect while announcements regarding the policy rate do not seem to affect government bond yields.

**Random selection:** The significant impact of the 26 chosen events could merely be a statistical coincidence. Therefore, iteratively 26 dates are randomly drawn from the data sample and employed in the analysis. Even after 30 iterations the results do not indicate an impact of any randomly chosen event set on government bond yields. Similarly, to control for reactions to monetary policy announcements independent of their content, 26 dates are randomly drawn from the 132 monetary policy press releases made by the ECB during the observation period. Another draw of 26 events is made from the 71 ECB announcements listed in Table A1. Both tests do not produce any significant results, either. Hence, a monetary press release per se does not affect government bond yields. This underlines the appropriateness of the chosen events.

In contrast, when considering each announcement of a random event set individually, all dates suppose a highly significant impact on all yields. This is probably due to the utilization of Newey-West standard errors. Fomby and Murfin (2005) explain this issue in econometric terms. Arbitrarily selected event dates all seem to be highly significant even without any specific event happening on the chosen date because heteroscedastic and auto-correlation robust standard errors’ t-statistics are spuriously identified. Ford et al. (2010)

illustrate this problem in a financial event study. Consequently, the focus on the aggregate announcements is less vulnerable to such econometric biases than the view on a single date.

In sum, the findings are robust to regime shifts, policy rate announcements and randomly drawn events. However, the number of events is crucial to the results. Taking few events (initial events, excluding (T)LTRO) makes the estimators of some countries insignificant. In contrast, employing many events (technical details) does not modify the estimators substantially. One should bear in mind this minor sensitivity when comparing the present findings with other studies. After all, the best way is to find economic arguments why to include the events ignoring the total number of chosen events. It has been decided to keep the baseline scenario of 26 events outlined in Section 3.2.2 as a middle way. It generates an economically meaningful result showing that both country groups are impacted by asset purchase program announcements – just the extent differs.

### III.2 Choice of variables

**Choice of control variables:** Instead of CESI, several other indices are implemented to control for macroeconomic surprises. On the one hand, the Morgan Stanley Capital International (MSCI) Europe Index as suggested by Jäger and Grigoriadis (2017) controls for European-wide events. In line with Haitsma et al. (2016) the MSCI World excluding Europe index is added to control for macroeconomic events outside Europe. On the other hand, country-specific MSCI indices replace the global variables to see whether the estimates improve. While the MSCI Europe index gives a significant estimator in most countries, the other two indices are unsuitable control variables showing significant estimators only for 5 countries: For MSCI World, the negative impact of such surprises to the yields of core countries is counterintuitive. The country-specific MSCI indices, in turn, suggest a mixed influence on yields with 6 insignificant estimators, 3 significantly positive ones (Austria, Ireland, Greece), and 2 significantly negative ones (France, Finland). Accordingly, the national indices seem to cancel out each other in the panel framework.

Applying these MSCI indices, the Dutch and German yields become insignificant.<sup>31</sup> This implies that a European surprise index as the CESI or the MSCI Europe are most suitable control variables for global surprises. We follow Georgiadis and Gräb (2016) and use ‘Citigroup Economic Surprise Indices [because they] are objective and quantitative measures of data surprises’ (p. 258). As a result, the main results are qualitatively robust to these variations.

We come to the same conclusions when employing the surprise and uncertainty indices developed by Scotti (2016) and the iTraxx Europe index to depict the investors’ preference for risk. Furthermore, the V2TX index is based on EURO STOXX 50 realtime option prices and reflects the market sentiment in Europe as in Falagiarda and Reitz (2015). It replaces the VIX. Similar to using the country-specific MSCI indices, the coefficient of  $daA_t$  becomes insignificant for Germany and the Netherlands when substituting CESI or adding VIX as an additional control. These minor variations do not change the findings of the panel analysis. Since the estimators are still higher for periphery countries than for core countries we can confidently keep the CESI as main variable to control for macroeconomic surprises.

**Effect on control variables:** One might argue that monetary policy announcements directly affect the stock market. Haitsma et al. (2016) find that unconventional monetary policy surprises move European stocks while Fausch and Sigonius (2018) detect significant reactions for German stock returns. If this holds for the country-specific stocks, the application of both  $daA_t$  and  $\Delta stock_t$  as independent variables is impossible. To test for it, we take the country-specific stock market indices as dependent variable. Accordingly,  $\Delta y_t$  is replaced by  $\Delta stock_t$  in Equations (3.1), (3.2), and (3.7). Likewise,  $\Delta y_{i,t}$  is replaced by  $\Delta stock_{i,t}$  in Equations (3.3), (3.4), (3.5), (3.6), and (3.8).

The results demonstrate that the ECB’s announcements neither have an immediate nor a delayed direct effect on the stock market indices. Hence, the choice of  $\Delta stock_{i,t}$  as

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<sup>31</sup> For the country-specific MSCI Greece becomes additionally insignificant. Though, this is negligible because MSCI Europe as a control variable performs better than its country-specific counterparts.



independent variable is appropriate. The announcements only have an indirect effect on the stock markets in the medium-term as higher liquidity induces rising asset prices.

Similarly, if the announcements directly impact global indicators such as the CESI, it is not feasible to include them as control variables. Therefore,  $\Delta CESI_t$  analogously replaces  $\Delta y_t$  as dependent variable to control for interaction effects with  $daA_t$ . Showing insignificant estimators for each specification, the ECB's announcements neither have an immediate nor a delayed direct effect on the CESI.

**Yield spreads as dependent variable:** Using the spread defined in Section 3.3.4 as dependent variable instead of the level, the results and hence the conclusions remain qualitatively unchanged. Taking the German yield as numeraire instead to calculate the spread gives similar results except there is no output for the German yields by definition. Put differently, the study confirms the spread-reducing effects worked out in related literature.

**Alternative monetary policy surprise:** The daily change in 3-month Euribor futures might be insufficient to control for monetary policy news. In particular in a low interest environment, monetary policy news is reflected in the medium-term interest rates and not necessarily visible at a short horizon. Therefore, we follow Hanson and Stein (2015) and include the change in 2-year nominal sovereign yields to approximate monetary policy news. Specifically, for each country we add  $\Delta yield_t^{2y} = y_{t+1}^{2y} - y_{t-1}^{2y}$  as an additional control in all regressions. All findings are robust to this modification. The results are also qualitatively unchanged when replacing  $\Delta future_t$  by  $\Delta yield_t^{2y}$ .

**Variables in growth rates:** Growth rates might be more suitable to compare yield dynamics of the various countries. First-differences only take the absolute differences into account regardless of the level in the respective country. For instance, periphery countries typically state higher absolute changes in yields than core countries due to its higher yield level. In contrast, if one considers growth rates instead one corrects for this shortcoming by dividing by the absolute level. This might weaken the observed differences among the countries.

When using growth rates variables the estimators of  $daA_t$  for Germany and the Netherlands become insignificant. In consequence, the estimator of  $daA_t$  becomes insignificant

for core countries in the panel specification. In addition, the coefficients of  $daA_t$  resemble in size for all bonds. Hence, the utilization of growth rates instead of first-differences relativizes the previously found quantitative differences between both country groups. Nevertheless, the first-difference analysis suits better for policy analysis because it provides the absolute changes in yields. These are more relevant for the countries because they correspond to the overall short-term costs/benefits of a euro area government's refinancing conditions in response to an ECB's asset purchase announcement. Moreover, investors are presumably more interested in the absolute yield changes that represent actual profits/losses than in an abstract growth number.

In sum, when employing different data as control variables, the results remain robust for a given event set. Thus, we are quite confident with the results.

# Chapter 4

## ECB's communication and the yield curve\*

### 4.1 Introduction

The communication of non-standard measures has become an important monetary policy tool. Many studies discuss the transmission channels of such measures (Krishnamurthy and Vissing-Jorgensen, 2011; Altavilla et al., 2015; Gertler and Karadi, 2015) and recent empirical research (Altavilla et al., 2019; Fendel and Neugebauer, 2019; Urbschat and Watzka, 2019) suggests significant effects on sovereign bond yields. However, the large body of literature assesses the effects of non-standard monetary policy announcements on sovereign yields only with respect to maturities of up to 10 years (Falagiarda and Reitz, 2015; Szczerbowicz, 2015; Altavilla et al., 2016; Krishnamurthy et al., 2018). Evidence on the longer end of the yield curve is lacking.

Hanson (2018) displays for the U.S. market that long-term and short-term maturities are intertwined. Hanson and Stein (2015) emphasize that reactions of U.S. Treasury forward rates to monetary policy news are more pronounced for longer maturities (up to 20 years). The euro area, however, should be even more interesting in this respect as the ECB communication affects multiple economies. The announcements of conventional measures during regular times should primarily affect the short-term yields. In contrast, statements regarding unconventional measures are typically made during the zero lower

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\* This chapter is based on Fendel et al. (2020), "ECB's Communication and the Yield Curve: Core versus Periphery Effects", *Applied Economics Letters*, forthcoming, which is a joint work with Ralf Fendel and Mustafa Kilinc.

bound period and should therefore particularly affect the long-term yields. To this end, our analysis gives additional insights by explicitly considering various maturities of up to 30 years.

## 4.2 Data

The sample period runs from January 1, 2007 to August 31, 2017. For that period, we examine the reaction of sovereign benchmark yields to redemption for the maturities of 2, 3, 5, 10, 20, and 30 years for Belgium, France, Germany, Italy, the Netherlands, and Spain. All data are obtained from Datastream.<sup>1</sup>

Figure 4.1: Country-specific sovereign yields



**Notes:** Source: Datastream. For every country, the yields for the maturities of 2, 3, 5, 10, 20, and 30 years are plotted.

<sup>1</sup> We restrict to these six economies due to data availability. No reliable time series exist for other countries examined in related literature for the chosen observation period and maturity spectrum. Data on 15 years maturity are only available from 2010 onwards and therefore omitted. Data for 20 years maturity are only available for France, Germany, and the Netherlands.

Figure 4.1 displays the yields of all maturities per country. The yields of Germany, the Netherlands, and France are relatively low and do not exceed 5 percent, whereas the yields of Spain, Italy, and Belgium are typically higher. While Spain and Italy (and Belgium to a lesser extent) look hump-shaped, the yields of the other countries seem to have a persistent negative trend. In line with the common distinction between core countries and periphery countries and their assignment according to solvency ratings, the visual representation supports to differentiate the markets in the first row of Figure 4.1 (Germany, the Netherlands, France) from those in the second row (Belgium, Spain, Italy), since they display quite different dynamics.

### 4.3 Model

Following Fendel and Neugebauer (2019), we employ their identical event study methodology, but we distinguish between different maturities to provide a maturity-specific view on the effectiveness of central bank communication.<sup>2</sup> We employ the following linear regressions model:

$$\Delta y_{i,t}^m = \alpha_i^m + \beta_i^m \Delta y_{i,t-1}^m + \gamma_i^m dAPA_t + \delta_i^m X_t + \varepsilon_{i,t}, \quad (4.1)$$

where  $\Delta y_{i,t}^m = y_{i,t}^m - y_{i,t-1}^m$  represents the daily change in yields with maturities from  $m = 2, 3, 5, 10, 20,$  and  $30$  years for countries  $i = \text{Belgium, France, Germany, Netherlands, Italy, and Spain}$ . The constant  $\alpha_i^m$  captures the country-specific level of the yield change. The dummy variable  $dAPA_t$  is the variable of interest. We test for delayed (i.e., next-day) effects so that  $dAPA_t$  is equal to 1 one day after a specific asset purchase program announcement takes place, and 0 otherwise.<sup>3</sup> We adopt 26 events identical to Fendel and Neugebauer (2019), which are also commonly identified by related literature (e.g.,

<sup>2</sup> Fendel and Neugebauer (2019) restrict the analysis to 10-year maturities only.

<sup>3</sup> In line with the results of Fendel and Neugebauer (2019), in our analysis only marginal immediate (i.e., same-day) effects appear directly on announcement days. That is why we only display the delayed effects. Results for the immediate effects are available upon request.

Falagiarda and Reitz, 2015; Jäger and Grigoriadis, 2017; Ambler and Rumler, 2019; Rieth and Wittich, 2020).

Figure 4.1 suggests that yields are persistent. Therefore, explaining yield changes should include lags of changes in the yields. Similar to Urbschat and Watzka (2019) we include only the first lag  $\Delta y_{i,t-1}^m$ . In order to properly differentiate the effectiveness of the ECB communications from other influences, further control variables are included in the vector  $X_t$ . We include the country-specific stock market indices, the Citigroup Economic Surprise Index for Eurozone, the 3-month-Euribor future rate, the VIX, the U.S.-\$/€ spot exchange rate, and the 10-year U.S. Treasury Inflation-Protected Securities.

The empirical analysis tests the following hypothesis.

**Hypothesis:** *‘Yields of countries with a lower solvency rating are more receptive to asset purchase announcements than those with a higher rating.’*

Equation (4.1) is initially estimated using the ordinary least squares estimator for the different countries and different maturities. The error term  $\varepsilon_{i,t}$  is assumed to be independent and identically distributed over the country-specific dimension, but over the time dimension we allow for autocorrelation with a mean equal to 0 and a variance equal to  $\sigma^2$ . To account for this, we use Newey-West standard errors. In the subsequent panel setting, we estimate the model using the fixed effects estimator.<sup>4</sup>

## 4.4 Results

Table 4.1 presents the results. The extent of yield reduction seems to be linked inversely to the respective solvency rating: the less favorable a rating is for a country, the higher is the yield reaction after ECB announcements. Interestingly, countries with a less favorable rating are affected throughout the entire yield curve while countries with high solvency ratings appear to be influenced only at the short to the medium end of the yield curve. One reason might be that in particular long-term maturities reflect investors' beliefs on

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<sup>4</sup> As a robustness check, we also estimate Equation (4.1) using the random effects estimator for a fixed maturity pooling of the data in the country dimension. The results are qualitatively the same and are available upon request.

Table 4.1: One-day delayed reactions of sovereign yields to ECB announcements

Country (rating)	2 years	3 years	5 years	10 years	20 years	30 years
Germany (Aaa)	-0.0176**	-0.0170**	-0.00714	-0.00656	-0.00523	-0.00178
Netherlands (Aaa)	-0.0129*	-0.0219***	-0.0208**	-0.00972	-0.00581	-0.00318
France (Aa2)	-0.0181*	-0.0154*	-0.0292***	-0.0233**	-0.0156	-0.0129
Belgium (Aa3)	-0.0233**	-0.0289***	-0.0377***	-0.0306***	NA	-0.0220**
Spain (Baa2)	-0.0664*	-0.0797**	-0.0612**	-0.0529***	NA	-0.0550***
Italy (Baa2)	-0.0658***	-0.0586**	-0.0602***	-0.0438***	NA	-0.0410***

**Notes:** For the sake of readability, only the estimated coefficients of  $dAPA_t$  are displayed. Moody's rating adopted from Fendel and Neugebauer (2019).

how economies will perform in the (distant) future, for example, whether they will stay in the euro area. Accommodative measures especially designed for distressed countries influence this belief and thus the very-long maturities. In contrast, the yields of Germany, the Netherlands and France only respond at maturities shorter than 5, 10, and 20 years, respectively.

Table 4.2: One-day delayed reactions of sovereign yields to ECB announcements in a panel

specification	2 years	3 years	5 years	10 years	30 years
all economies	-0.0364**	-0.0387**	-0.0371***	-0.0282**	-0.0227**
high solvency economies	-0.0159***	-0.0181**	-0.0191*	-0.0131	-0.00606
low solvency economies	-0.0524*	-0.0556*	-0.0528**	-0.0417**	-0.0386*
$dAPA_t$	-0.0158***	-0.0172***	-0.0177**	-0.0119*	-0.00472
$dAPA_t \times periphery_i$	-0.0413**	-0.0430**	-0.0388**	-0.0325**	-0.0359**

**Notes:** For the sake of readability, only the estimated coefficients of  $dAPA_t$  are displayed. The horizontal line separates two specifications. In the upper part, Equation (4.1) is estimated for the full sample in the first row and for a sub-sample in the second and third rows. The lower part covers the full sample according to the specification in Equation (4.2).

Pooling and grouping the economies in a panel confirms these findings (Table 4.2).<sup>5</sup> The significance level of high solvency economies (second row) is descending by maturity, while the significance level of low solvency economies (third row) is stable throughout the maturity level. The distinction between core and periphery countries also becomes visible in the level, because the estimated yield reductions of low solvency countries are about three times higher than those of high solvency countries (e.g., -0,0556 versus -0,0181 for

<sup>5</sup> As Belgium lies somehow in between the peripheral and core country group in Figure 4.1, an alternative specification (4 core versus 2 periphery countries) assigns Belgium to the core countries instead. The results do not qualitatively change so that we confidently maintain the present balanced grouping (3 core versus 3 periphery countries).

the 3-years maturity). Instead of splitting up the data set, the bottom part of Table 4.2 displays the results for a specification where the announcement dummy interacts with a dummy  $periphery_i$  that controls for less solvent countries, i.e. it takes the value of 1 for these economies. Hence, Equation (4.1) changes to

$$\Delta y_{i,t}^m = \alpha_i^m + \beta_i^m \Delta y_{i,t-1}^m + \gamma_{1,i}^m dAPA_t + \gamma_{2,i}^m dAPA_t \times periphery_i + \delta_i^m X_t + \varepsilon_{i,t}. \quad (4.2)$$

Compared to Equation (4.1) the interpretation of the coefficients changes slightly. The announcement effects on the changes in the yields was previously  $\gamma_i^m$ . However, in the new regression model it becomes  $\gamma_{1,i}^m + \gamma_{2,i}^m \times periphery_i$ . The interaction term  $dAPA_t \times periphery_i$  (fifth row) is statistically significant for all maturities, meaning that less solvent countries react significantly to ECB announcements for all maturities. However, more solvent countries are not significantly affected for the long maturity (see  $dAPA_t$  in the fourth row).

Table 4.3: Test for differences in the announcement effects using SUR

<i>I: P-values for 2-year maturities</i>					
Country (rating)	Netherlands	France	Belgium	Spain	Italy (Baa2)
Germany (Aaa)	0.6029	0.9391	0.5688	0.1853	0.043
Netherlands (Aaa)		0.6061	0.2956	0.146	0.0258
France (Aa2)			0.5325	0.149	0.0252
Belgium (Aa3)				0.2278	0.0422
Spain (Baa2)					0.9756
<i>II: P-values for 30-year maturities</i>					
Country (rating)	Netherlands	France	Belgium	Spain	Italy (Baa2)
Germany (Aaa)	0.5398	0.1159	0.0126	0.0003	0.0047
Netherlands (Aaa)		0.1704	0.0158	0.0003	0.0057
France (Aa2)			0.0415	0.0011	0.0135
Belgium (Aa3)				0.0139	0.1167
Spain (Baa2)					0.0665

**Notes:** For the sake of brevity, only the  $p$ -values for the 2 years (first panel) and 30 years (second panel) of maturities are shown. The regressions are performed without Newey-West Standard error correction. Moody's rating adopted from Fendel and Neugebauer (2019).

To examine whether the announcement effects differ across economies, we estimate the seemingly unrelated regression (SUR) and perform a Chi-square test. Table 4.3 presents the  $p$ -values for the 2-year and 30-year maturities. The announcement effects for the 2-year



maturities in Panel I are not statistically different for most economies. The opposite occurs for the 30-years maturities in Panel II. Economies with a relatively high solvency rating show statistically no significant difference among each other; however, they are significantly contrasting compared to the less favorable rated countries. This backs our hypothesis for the long maturity.

## 4.5 Conclusion

This chapter examines the effectiveness of the ECB's communications on the sovereign yields for different countries and maturities. The rating seems to determine the extent of yield reduction in response to an ECB announcement. While economies with a relatively low solvency rating are affected across the entire yield curve, economies with a relatively high solvency rating show significant reactions only at short maturities. Thus, investors seem to process monetary policy news in a distinct way across euro area economies. In addition, ECB communication not only affects the economies differently but also the maturity matters, as for some countries only part of the yield curve reacts to ECB announcements. Future research should address these peculiarities further to fully understand monetary policy announcement effects.



# Chapter 5

## ECB announcements and stock market volatility\*

### 5.1 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

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\* This chapter is based on Neugebauer (2020), “ECB Announcements and Stock Market Volatility”, *WHU – Working Paper Series in Economics*, 20/02, WHU – Otto Beisheim School of Management. Parts of this study have been presented at the 21<sup>st</sup> Workshop International Economics Göttingen, the Annual Conference of the German Economic Association 2019, the Fall 2019 Midwest Macroeconomics Meetings, the 13<sup>th</sup> South-Eastern European Economic Research Workshop, the 13<sup>th</sup> RGS Doctoral Conference in Economics, and the Finance Workshop at the Toulouse School of Economics.

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) report 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 (Fratzscher et al., 2016). Relatedly, Georgiadis and Gräß (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, the 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 the meetings per year from 14 to 8, and the Bank of England switched from a monthly to an eight-meeting schedule. These adjustments aim to reduce financial volatility. The chapter examines the success of these policy changes, namely whether fewer announcements lead to less volatility. While the study 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 economy<sup>1</sup>, 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 typically do not refer to a special sector but concern the 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 pattern holds for major national stock market indices, too. 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

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

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 making 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 the volatility of 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 by definition. On the one hand, this can resolve uncertainty for market participants and thus asset volatility decreases. On the other hand, if the information provided 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 chapter 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 twelve 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 chapter proceeds as follows. Section 5.2 describes the methodology and the data. Section 5.3 presents the empirical findings comprising robustness checks. The implications of announcements for future volatility will be assessed in Section 5.4. Section 5.5 confronts positive and negative news and Section 5.6 introduces a market-specific weighting of the announcements. Section 5.7 discusses the main findings, while Section 5.8 concludes.

## 5.2 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 (U.S.).<sup>2</sup>

The model estimates the ordinary least squares regression

$$vol_{i,t} = \alpha_i + \beta_{i,j} \sum_{j=1}^4 X_j + \gamma_i ECB_t + \varepsilon_{i,t}, \quad (5.1)$$

where  $vol_{i,t}$  is the volatility measure of market  $i$  on day  $t$ . The constant  $\alpha_i$  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 Chicago Board Options Exchange 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.<sup>3</sup>

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

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<sup>2</sup> For the U.S. 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.

<sup>3</sup> See the descriptive statistics in Table B1 and Table B2 in the appendix for details.



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 impact on assets' volatility. It is replaced in Equation (5.1) 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.<sup>4</sup> However, several unconventional measures were communicated by the ECB – also on days without 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  $policy_t$ .<sup>5</sup> 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

<sup>4</sup> Section 5.3.3 considers multiple event sets. It turns out that scheduled meetings are the main driver for asset price volatility.

<sup>5</sup> The following regression tables show the estimated coefficients of the dummy variables  $scheduled_t$ ,  $UMP_t$ , and  $policy_t$ , while  $ECB_t$  summarizes these dummy variables in Equation (5.1) to ease the legibility.

affect stock market volatility. For instance, Li (2005) proposes a model in which noisier information can increase stock return volatility. However, Chahrour and Jurado (2018) find that news and noise are empirically the same. The assessment 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 the ECB announcements affect stock market volatility but that the 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 tick 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 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 more easily comparable,  $vol_{i,t}$  is standardized by the past 30 trading days.<sup>6</sup> 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 (5.1). 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.

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<sup>6</sup> More 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.

### 5.2.1 High-frequency realized volatility

Realized variance is defined as the sum of squared log returns

$$RV_{i,t} = \sum_{j=1}^n r_{j,i,t}^2, \quad (5.2)$$

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 seven different national EA and eight 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

$$RVol_{i,t} = \sqrt{252 RV_{i,t}} \quad (5.3)$$

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.<sup>7</sup>

### 5.2.2 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 us 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., Yang and Zhang, 2000; Alizadeh et al., 2002). In this study, the range measure is defined as the difference between the maximum price  $p_t^{max}$  and the minimum price  $p_t^{min}$  during a

<sup>7</sup> The 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.

day, divided by the opening price  $p_t^{open}$  to make the values comparable across the different country indices  $i$ :

$$range_{i,t} = \frac{p_{i,t}^{max} - p_{i,t}^{min}}{p_{i,t}^{open}}. \quad (5.4)$$

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  $i = (AT, BE, BG, CH, CZ, DE, DK, ES, EU, FI, FR, GR, GB, HU, IE, IT, JP, NL, NO, PL, PT, SE, US\_Dow, US\_SP)$ .

### 5.2.3 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  $i$

$$r_{i,t} = \ln \left( \frac{P_{i,t}}{P_{i,t-1}} \right), \quad (5.5)$$

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

$$vol_{n,i,t}^f = \sqrt{252} \sqrt{\frac{1}{n-1} \sum_{k=1}^n (r_{i,t+k} - \bar{r})^2}, \quad (5.6)$$

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 (5.3), 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 the ECB's announcements will impact the future volatility. For instance, if one assumes a monthly horizon, one would set  $n = 20$  trading days.

### 5.2.4 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 ( $RVol_{i,t}$ ):

$$surprise_{i,t} = \frac{RVol_{i,t}}{vol_{i,t-1}^{impl}}. \quad (5.7)$$

For the four market indices, the surprise measure is inserted as dependent variable in Equation (5.1).

### 5.2.5 Descriptive statistics

Starting with the introduction of the euro, the study examines a period longer than twenty 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., Sosvilla-Rivero and Morales-Zumaquero, 2012; Fratzscher et al., 2016; Georgiadis and Gräb, 2016). The data availability varies across the countries and measures, meaning that one has to interpret the long-term results with caution. Specifically, data for  $range_t$  and  $vol_{n,t}^f$  are available between January 1999 and December 2019, while the observations

of  $RV_t$  and implied volatility 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 5.1 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.<sup>8</sup> Moreover, the range measures are highly correlated with their respective realized volatility counterparts (correlation coefficients around 0.78 for all indices except for Finland with only 0.42).

Since the augmented Dickey Fuller unit root test is rejected it is deemed appropriate to work with level data of the constructed measures in Section 5.2.1 through Section 5.2.4.<sup>9</sup> In contrast, the unit root test for the MSCI does indicate integration of order 1. Therefore, its (logarithmic) first-differences are justified. The Breusch-Godfrey test and the White test indicate autocorrelation and heteroskedasticity, respectively, in this data set. To deal with these properties, the standard errors follow Newey and West (1987)<sup>10</sup>.

The correlation coefficients of the dependent variables in Table B4 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

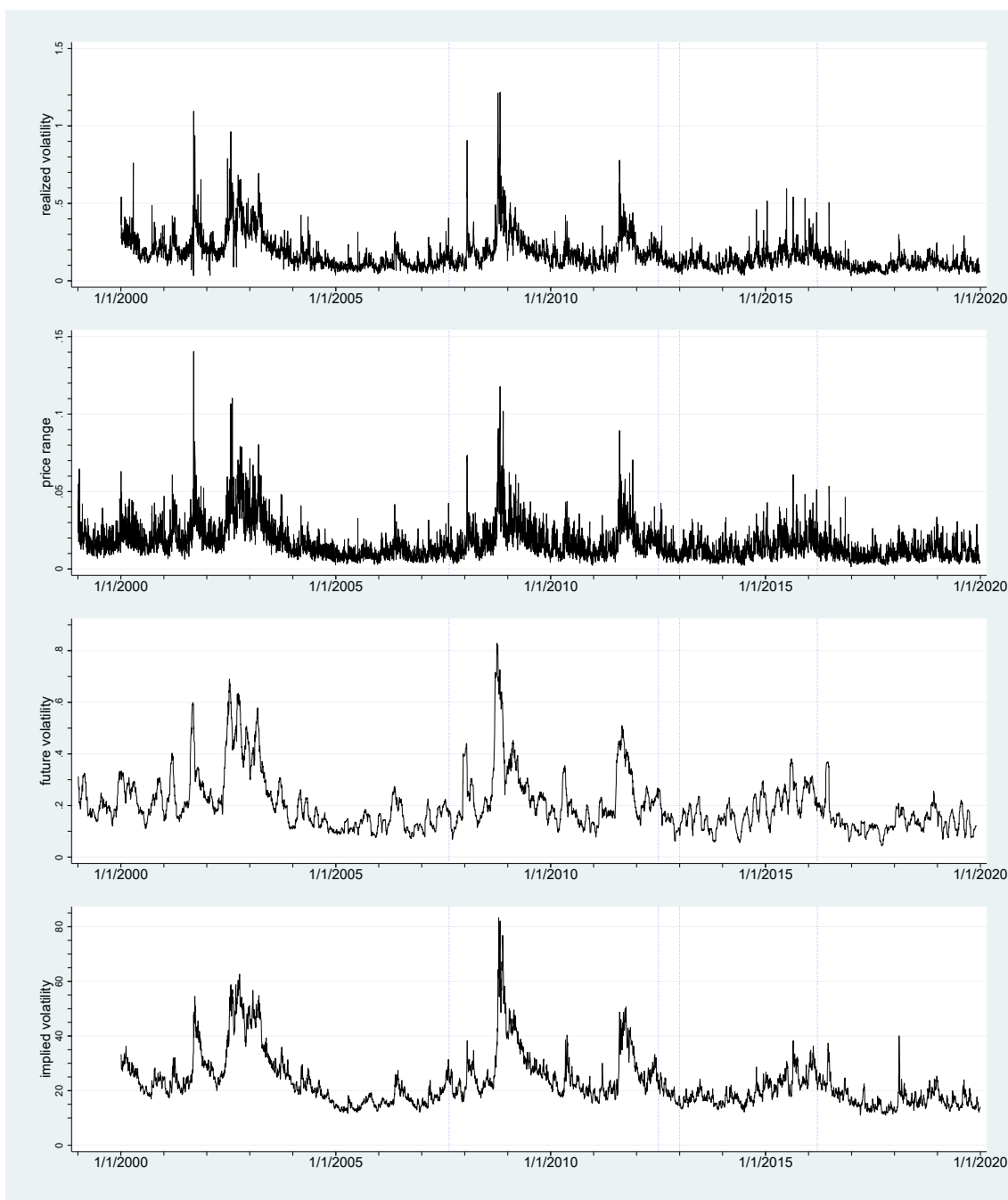
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<sup>8</sup> In fact, when comparing the regression coefficients of  $RVol_t$  to those of  $range_t$  by country, they are qualitatively similar. Table B3 in the appendix shows the regression output of the 16 markets for which both volatility measures 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  $RVol_t$ .

<sup>9</sup> Using 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.

<sup>10</sup> The maximum lag length in the autocorrelation structure is adjusted according to the Bartlett Kernel with  $T^{\frac{1}{3}}$  for each regression.

Figure 5.1: Volatility measures of the German DAX 30 stock market index



**Notes:** The first panel shows the realized volatility measure from Section 5.2.1. 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 5.2.2 and Section 5.2.3, respectively. The fourth panel shows the implied volatility measure VDAX mentioned in Section 5.2.4. 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 5.3.2, 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 5.5 and Table 5.6. Time span: January 2, 1999 (January 3, 2000 for the first and fourth panel) to December 31, 2019.

direction as well – merely the extent differs, which this chapter aims to identify. Specifically by exploiting a large cross-section, the study 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 as compared to markets outside Europe like Japan, and Denmark has been part of the EU for a longer time than Bulgaria. 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).

## 5.3 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.

### 5.3.1 Long-term period

Table 5.1 displays the results of the realized volatility specification explained in Section 5.2.1 for eight EA and eight 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 ( $policy_t$ ).<sup>11</sup>

Table 5.1: 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	

**Notes:** \*\*\*, \*\*, 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 eight EA national stock market volatility measures and the lower part eight non-EA stock markets. To enhance legibility, only estimated coefficients of the dummy variables are displayed. Full regression output is available upon request. 55 unconventional monetary policy announcements happen on scheduled meeting days.

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 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

<sup>11</sup> The 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 B5 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.

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 significance level of the British market decreases while that of the U.S. Dow market increases. 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.

In sum, no striking differences among the countries can be claimed. Their stock market indices react similarly to monetary policy announcements. Figure B1 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 5.2 depicts the result of the range specification introduced in Section 5.2.2 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 determines 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 5.2: 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	

**Notes:** \*\*\*, \*\*, 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 twelve EA national stock market volatility measures and the lower part twelve non-EA stock markets. To enhance legibility, only estimated coefficients of the dummy variables are displayed. Full regression output is available upon request. 55 unconventional monetary policy announcements happen on scheduled meeting days.

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 markets 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 B2 in the appendix sorts and plots the respective t-statistics of the dummy variable  $scheduled_t$ . 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 5.3 shows the results of the future volatility measure defined in Section 5.2.3 using a 20-day forward looking window.<sup>12</sup> 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 5.4 shows the results of the four implied volatility measures described in Section 5.2.4. 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, one cannot test this claim because implied volatility measures of distressed economies are unavailable. The price ranges values in the second part of Table 5.4, by contrast, increase in response to the ECB announcements.

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<sup>12</sup> A 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 5.3: 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	

**Notes:** \*\*\*, \*\*, 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 twelve EA national stock market volatility measures and the lower part twelve non-EA stock markets. To enhance legibility, only estimated coefficients of the dummy variables are displayed. Full regression output is available upon request. 55 unconventional monetary policy announcements happen on scheduled meeting days.

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 suggests that ECB announcements reveal more information than investors anticipated on the day before the announcement takes place. However, given the limited availability of only four 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.

Table 5.4: 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	VÄEX	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	VÄEX	-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	VÄEX	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

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

### 5.3.2 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 period<sup>13</sup> 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 refinancing rate was lowered to zero percent.

Table 5.5 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.<sup>14</sup> The vertical lines in Figure 5.1 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 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

<sup>13</sup> This 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.

<sup>14</sup> To 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.

Table 5.5: 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

**Notes:** \*\*\*, \*\*, 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 seven EA stock markets and the Eurostoxx while the lower part covers eight 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.



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 5.6 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 5.2.

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 5.1 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 B3 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

Table 5.6: 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 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

**Notes:** \*\*\*, \*\*, 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 eleven EA stock markets and the Eurostoxx and the lower part covers twelve price range measures of markets that do not belong to the EA.

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 5.3.3 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 B6 and in Table B7 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.

### 5.3.3 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 Composite Leading Indicators by the Organisation for Economic Co-operation and Development, which identify troughs and peaks for the EA, the Federal Reserve Bank of St. Louis suggests a classification of recession periods.<sup>15</sup> 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.<sup>16</sup> 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 the 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 reaction 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

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<sup>15</sup> See Federal Reserve Bank of St. Louis (2020). For the sample of this study, a recession is present in 01/1999, 03/2001-06/2003, 03/2008-06/2009, 06/2011-03/2013, and 12/2017-12/2019.

<sup>16</sup> See <https://www.ecb.europa.eu/press/pr/activities/mopo/html/index.en.html>.

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.

The ECB's communication is very present also outside scheduled meetings. The ECB's representatives regularly give speeches in public. Roughly every three trading days comprise a speech by an ECB board member.<sup>17</sup> 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 thesis.

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  $APA_t$ .<sup>18</sup> 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

<sup>17</sup> In 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.

<sup>18</sup> Refer 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.

one or two stock indices occasionally become significant. This result stresses the appropriateness of ECB announcements 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 (5.1). 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 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 (see Table B5), 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,  $range_t$  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.  $difference_{i,t} = p_{i,t}^{close} - p_{i,t}^{open}$ . This measure summarizes the level effect of the trading day. Interestingly, when inserting  $difference_{i,t}$  as dependent variable in Equation (5.1), the coefficients of  $ECB_t$  are insignificant for all analyzed markets. The estimated coefficients of  $range_t$  and  $difference_{i,t}$  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 are significant only at a lower level. Hence, only considering Thursdays slightly reduces the impact on volatility. Another test considers both effects, ECB announcements and Thursdays. To prevent double counting, 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 5.1 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 5<sup>th</sup> and 95<sup>th</sup> percentile. The results are qualitatively unchanged to such a data cleaning.

The country-specific control variable  $MSCI_t$  is replaced by several global alternative measures.<sup>19</sup> 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 Gräß (2016) the 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 (see Table B2). There is no double counting problem when using national instead of global measures as control variables because the results are invariant to the implementation of CESI and MSCI World.

## 5.4 Effects on subsequent days

ECB communication may not be limited to same-day effects but also influence stock price volatility over the subsequent few days. Investors might be interested in the persistence

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<sup>19</sup> Since the global indices are available for a shorter period, the following robustness checks refer to a shortened period starting in 2003.



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 (5.1) changes accordingly to

$$\sum_{l=1}^m vol_{i,t+l} = \alpha_i + \beta_{i,j} \sum_{j=1}^4 X_j + \gamma_i ECB_t + \varepsilon_{i,t}, \quad (5.8)$$

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

Table 5.7 displays the results of Equation (5.8) 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 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.

Table 5.7: 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

**Notes:** \*\*\*, \*\*, 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  $scheduled_t$ .

The results of Equation (5.8) for the price range measures can be found in Table 5.8. Negatively significant coefficients exist for most EA 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

Table 5.8: 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*
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

**Notes:** \*\*\*, \*\*, 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  $scheduled_t$ .

on the day of announcement (see Table 5.1 and Table 5.2), in turn the cumulated future volatility at the horizons from 3 to 10 days declines (see Table 5.7 and Table 5.8). 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 has already been ruled out in Section 5.3.3.

## 5.5 **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 have larger effects on the U.S. 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, negative, or neutral. Related studies use textual analysis to assign the announcements.<sup>20</sup> 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

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<sup>20</sup> There 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.

is chosen because an accommodative announcement is likely to raise stock market prices.<sup>21</sup> An increase in the MSCI translates into positive news. The analysis that follows uses the MSCI changes as a classifier because sovereign yields as determinant will be discussed in more detail in Section 5.6.

The study 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 5.9 and Table 5.10 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 5.9 neutral news and positive news have similar effects, neutral news has almost no influence on the price range measure in Table 5.10.

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<sup>21</sup> The use of the average of the first-differences of the MSCI indexes of the EA markets under consideration instead results in a very similar classification of the events.

Table 5.9: 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

**Notes:** \*\*\*, \*\*, 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 5.10: 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

**Notes:** \*\*\*, \*\*, 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.

## 5.6 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 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 analysis adopts this idea to the daily data set.<sup>22</sup> 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, see Table B2 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

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<sup>22</sup> The 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.

sovereign yield level or to underestimate a market with a low yield level. Thus, Equation (5.1) becomes

$$vol_{i,t} = \alpha_i + \beta_{i,j} \sum_{j=1}^4 X_j + \gamma_i \Delta sovereign_t \times ECB_t + \varepsilon_{i,t}. \quad (5.9)$$

The model 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 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 (5.9). 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.<sup>23</sup>

Table 5.11 shows the results for the realized volatility measure with the yield interaction as defined in Equation (5.9).<sup>24</sup> 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 5.12 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

<sup>23</sup> The analysis 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.

<sup>24</sup> Only 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.



Table 5.11: 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	

**Notes:** \*\*\*, \*\*, 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 unconventional monetary policy announcements happen on scheduled meeting days.

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 5.12: 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
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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	

**Notes:** \*\*\*, \*\*, 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 twelve EA national stock market volatility measures and the lower part twelve non-EA stock markets. To enhance legibility, only estimated coefficients of the dummy variables are displayed. Full regression output is available upon request. 55 unconventional monetary policy announcements happen on scheduled meeting days.

## 5.7 Discussion of main findings

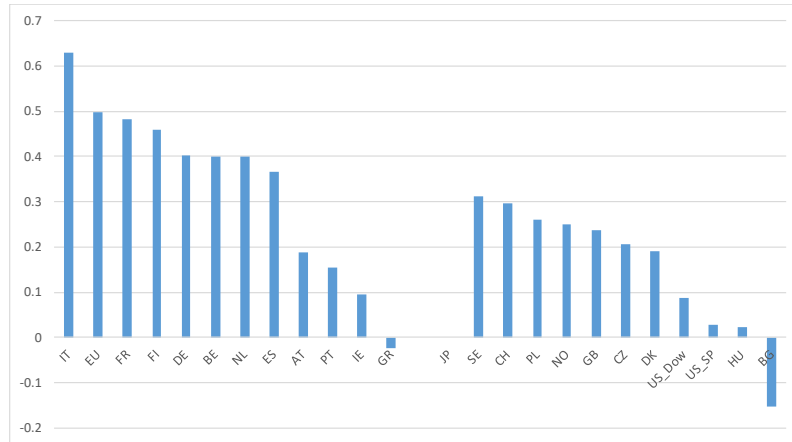
Considering multiple volatility measures, this chapter sheds more light on the understanding of how central bank communication affects stock market volatility. While the volatility on the announcement day increases (measures of realized volatility and price range), the announcements do not move the future volatility measure. Regarding the implied volatility measure, there is a decrease of the level values on an announcement day, but an increase of the surprise measure (past implied volatility related to present real-

ized volatility). When examining 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, for example an imprecise communication style, without further screening the announcements' wording. After the market participants have digested the new information, the stock market volatility reduces over the subsequent few days due to the new information given by the ECB.

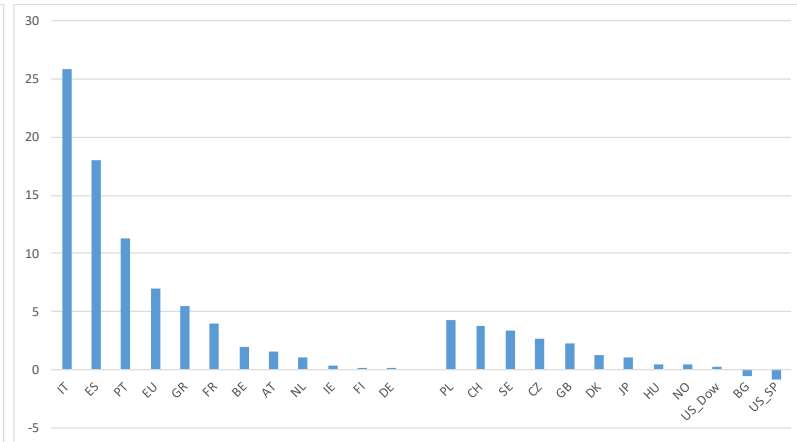
Figure 5.2 illustrates the main findings of this chapter by means of the price range measure. The upper left panel (a) presents the estimated coefficients of the unweighted dummy  $scheduled_t$  sorted by size (see first column in Table 5.2). The EA markets on the left show mainly similar magnitudes. 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 (see first column in Table 5.12). 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, so that spill-over effects do not exist in this specification.

The lower left panel (c) confronts the estimated coefficients of the pre-crisis period with those of the post-crisis period (see first two columns in Table 5.6). 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 (see first two columns in Table 5.10). This task highlights an asymmetric market reaction to the communication of the ECB. Negative news provoke more pronounced volatility effects than positive news in

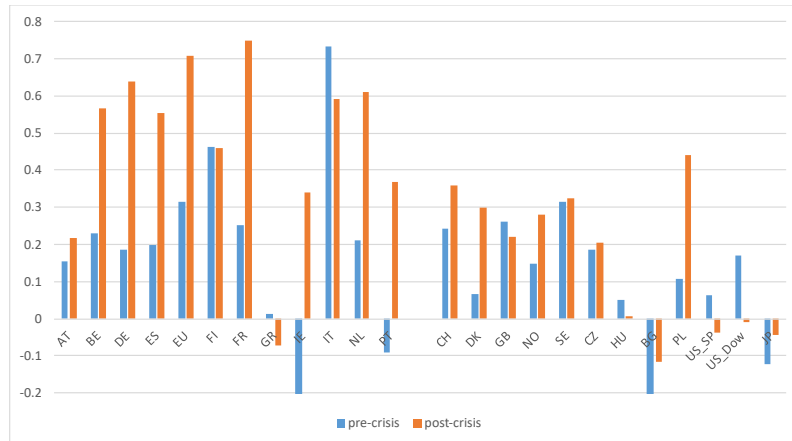
Figure 5.2: Illustration of main findings: example of price range measure



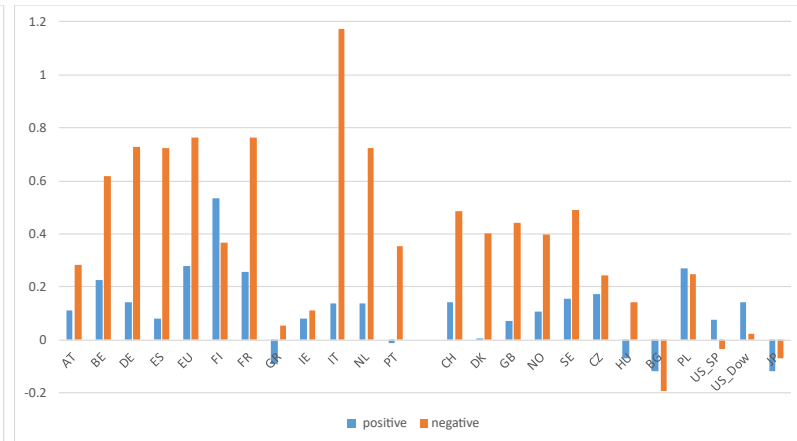
(a) Estimated coefficients of unweighted dummy



(b) Estimated coefficients of weighted dummy



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



(d) Classifying announcements as positive and negative

**Notes:** The upper left panel (a) shows the coefficients sorted by size of the first column in Table 5.2. The upper right panel (b) shows the coefficients sorted by size of the first column in Table 5.12. The lower left panel (c) shows the coefficients of the first two columns in Table 5.6. The lower right panel (d) shows the coefficients of the first two columns in Table 5.10. The left side of each panel shows the EA markets and the right side the non-EA markets.

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 multiple markets analyzed over a long time span. 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 5.5 and in Section 5.6, 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 analysis 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 5.6).

The econometric framework (ordinary least squares with robust standard errors) fits the present research question: the announcement effects of ECB communication on stock market volatility. However, the volatility measures presented in this chapter 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 generalized autoregressive conditional heteroscedastic (GARCH) approach (Bollerslev, 1986) or the use of a heterogeneous autoregressive model of realized volatility (HAR-RV) introduced by Corsi (2009) are possible methods.

## 5.8 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 eight EA stock market indices and eight non-EA markets. Second, a price range measure approximates volatility using daily prices from key national stock market indices of twelve EA and twelve 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 including the pre-crisis period, which results in a comprehensive observation period longer than twenty years. A break is detected claiming that the ECB announcements have a more intense impact following the global financial crisis. A general positive effect on asset volatility emerges. This effect is reinforced 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 three to ten days declines, meaning that the initial information released during an announcement day resolves uncertainty – and thus stock market volatility – the following days. Negative news induces 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 moves stock markets (Burggraf et al., 2019). ECB (2018) relates higher volatility levels in U.S. 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.

## Appendix B

## I Tables

Table B1: Descriptive statistics: dependent variables

Variable	Observations	Mean	Std. Dev.	Min.	Max.	Source
<i>RVol<sub>BE</sub></i>	5,096	0.1290641	0.0707091	0.0317941	0.9297159	Bel 20
<i>RVol<sub>DE</sub></i>	5,070	0.1711709	0.1069162	0.0323051	1.217634	DAX 30
<i>RVol<sub>ES</sub></i>	5,063	0.1658997	0.0872344	0.0321413	1.178356	IBEX 35
<i>RVol<sub>EU</sub></i>	5,098	0.1675846	0.1034716	0.0015302	1.651767	Eurostoxx 50
<i>RVol<sub>FI</sub></i>	3,574	0.1358838	0.1027013	0.0319313	2.378875	OMX Helsinki 25
<i>RVol<sub>FR</sub></i>	5,098	0.1571272	0.0907829	0.0262683	1.136116	CAC 40
<i>RVol<sub>IT</sub></i>	2,686	0.151746	0.0745505	0.013885	0.7472074	FTSE MIB
<i>RVol<sub>NL</sub></i>	5,098	0.1431309	0.0886509	0.0199811	0.9556439	AEX
<i>RVol<sub>CH</sub></i>	5,009	0.1231789	0.0730192	0.0390627	1.03098	Swiss Stock Market
<i>RVol<sub>DK</sub></i>	3,541	0.1473594	0.0998279	0.0415979	1.750454	OMX Copenhagen 20
<i>RVol<sub>GB</sub></i>	5,043	0.1432767	0.0914893	0.0183236	1.63439	FTSE 100
<i>RVol<sub>JP</sub></i>	4,866	0.1404197	0.0764778	0.0228099	0.9020374	Nikkei 225
<i>RVol<sub>NO</sub></i>	4,570	0.1505924	0.0940883	0.0409316	1.355599	Oslo All Share
<i>RVol<sub>SE</sub></i>	3,574	0.1278403	0.0934115	0.024579	1.629354	OMX Stockholm
<i>RVol<sub>US_Dow</sub></i>	5,014	0.1342118	0.0942001	0.0220001	1.474195	Dow Jones
<i>RVol<sub>US_SP</sub></i>	5,017	0.133234	0.0936834	0.01752	1.397294	S&P 500
<i>range<sub>AT</sub></i>	5,209	0.0159217	0.0112216	0.0033403	0.1347715	ATXINDX
<i>range<sub>BE</sub></i>	5,353	0.0131221	0.0087119	0.0021763	0.1125419	BGBEL20
<i>range<sub>DE</sub></i>	5,329	0.0170749	0.0118459	0.0014377	0.1405444	DAXINDX
<i>range<sub>ES</sub></i>	5,328	0.0169448	0.010498	0.0028445	0.1427609	IBEX35I
<i>range<sub>EU</sub></i>	5,365	0.0164375	0.0110636	0.0001584	0.1121307	DJES50I
<i>range<sub>FI</sub></i>	5,267	0.0194565	0.0203591	0.0025717	0.2706402	HEXINDX
<i>range<sub>FR</sub></i>	5,367	0.0155359	0.0101548	0.0013887	0.0953724	FRCAC40
<i>range<sub>GR</sub></i>	5,190	0.0207326	0.0142561	0.0031493	0.2287592	GRAGENL
<i>range<sub>IE</sub></i>	5,039	0.0160121	0.0118551	0.0026408	0.2713273	ISEQUIT
<i>range<sub>IT</sub></i>	4,170	0.0163721	0.0108182	0.0022998	0.1238377	FTSEMIB
<i>range<sub>NL</sub></i>	5,367	0.01448	0.0104451	0.0019376	0.1226604	AMSTEOE
<i>range<sub>PT</sub></i>	5,052	0.0129653	0.0081492	0.0000961	0.0887101	POPSI20
<i>range<sub>BG</sub></i>	4,690	0.0122552	0.0132504	0.0001072	0.2322138	BSSOFIX
<i>range<sub>CH</sub></i>	5,277	0.0124734	0.0086919	0.0021526	0.1452622	SWISSMI
<i>range<sub>CZ</sub></i>	4,966	0.0130771	0.009238	0.0017986	0.1344408	CZPXIDX
<i>range<sub>DK</sub></i>	5,063	0.0156531	0.0123337	0.0029396	0.1946582	DKKFxin
<i>range<sub>GB</sub></i>	5,306	0.0140636	0.0094618	0.002325	0.1019542	FTSE100
<i>range<sub>HU</sub></i>	5,235	0.0173159	0.0102533	0.0032224	0.1642317	BUXINDX
<i>range<sub>JP</sub></i>	5,151	0.0137383	0.009147	0.0017629	0.1285823	JAPDOWA
<i>range<sub>NO</sub></i>	3,419	0.0156597	0.0116743	0.0029061	0.1161843	OSLOASH
<i>range<sub>PL</sub></i>	5,253	0.0167418	0.0096107	0.0034584	0.12708	POLWG20
<i>range<sub>SE</sub></i>	4,642	0.0158658	0.0108222	0.0027936	0.1179102	SWEDOMX
<i>range<sub>US_Dow</sub></i>	5,314	0.014098	0.0105365	0.0015729	0.1133744	DJCOMP65
<i>range<sub>US_SP</sub></i>	5,283	0.0130671	0.0097704	0.0014575	0.1121896	S&PCOMP



Descriptive statistics: dependent variables (continued)

Variable	Observations	Mean	Std. Dev.	Min.	Max.	Source
$vol_{AT}^f$	5,185	0.1881772	0.1095469	0.051882	1.007112	ATXINDEX
$vol_{BE}^f$	5,343	0.1675779	0.0947403	0.0385259	0.795821	BGBEL20
$vol_{DE}^f$	5,310	0.203788	0.1085007	0.0437787	0.8289387	DAXINDEX
$vol_{ES}^f$	5,308	0.2026319	0.1039383	0.0576793	0.8603936	IBEX35I
$vol_{EU}^f$	5,356	0.1993931	0.1073767	0.0479505	0.8245734	DJES50I
$vol_{FI}^f$	5,250	0.2353401	0.1432149	0.0486811	0.825707	HEXINDEX
$vol_{FR}^f$	5,346	0.1973864	0.1051282	0.0400996	0.8737845	FRCAC40
$vol_{GR}^f$	5,190	0.2624999	0.1352888	0.066743	0.9096428	GRAGENL
$vol_{IE}^f$	5,296	0.1836521	0.1056794	0.0534685	0.9763133	ISEQUIT
$vol_{IT}^f$	5,305	0.2104056	0.108379	0.0485514	0.8570396	FTSEMIB
$vol_{NL}^f$	5,343	0.1853836	0.115145	0.0477348	0.8972627	AMSTEOE
$vol_{PT}^f$	5,324	0.1636716	0.0827019	0.037119	0.7420694	POPSI20
$vol_{BG}^f$	4,684	0.1733898	0.1442743	0.030385	1.233877	BSSOFIX
$vol_{CH}^f$	5,260	0.1583953	0.0906778	0.0460518	0.8062429	SWISSMI
$vol_{CZ}^f$	5,233	0.1782307	0.1102422	0.0402987	1.269173	CZPXIDX
$vol_{DK}^f$	5,226	0.1783081	0.0864474	0.0597231	0.871164	DKKFXIN
$vol_{GB}^f$	5,285	0.1609436	0.0909148	0.0365144	0.8202893	FTSE100
$vol_{HU}^f$	5,220	0.2121199	0.1024191	0.0625843	1.1111	BUXINDEX
$vol_{JP}^f$	5,133	0.2111451	0.1031832	0.0583849	1.184291	JAPDOWA
$vol_{NO}^f$	5,243	0.183335	0.1039746	0.0576747	0.9227617	OSLOASH
$vol_{PL}^f$	5,235	0.2162311	0.0902772	0.0678811	0.7190694	POLWG20
$vol_{SE}^f$	5,252	0.2055686	0.1066464	0.0510621	0.7242901	SWEDOMX
$vol_{US\_Dow}^f$	5,264	0.1527694	0.0892273	0.0266211	0.7897841	DJCMP65
$vol_{US\_SP}^f$	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

**Notes:** 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 B2: Descriptive statistics: control variables

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

**Notes:** The last column gives the Datastream mnemonics. Both surprise and uncertainty index are obtained from Scotti (2016).

Table B3: Comparison of  $scheduled_t$  between  $RVol_t$  and  $range_t$  for the same period (2000-2019)

	$RVol_t$	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

**Notes:** 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 B4: Correlation coefficients of country-specific  $RVol_t$ 

	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

**Notes:** The dashed lines separate EA and non-EA markets. The daily realized volatility  $RVol_t$  is based on intraday data of 5 minutes frequency intervals. The values based on 10 minutes intervals are very similar.

Table B5: Full regression output of Table 3.1: 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

**Notes:** \*\*\*, \*\*, 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 B6: 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

**Notes:** 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.

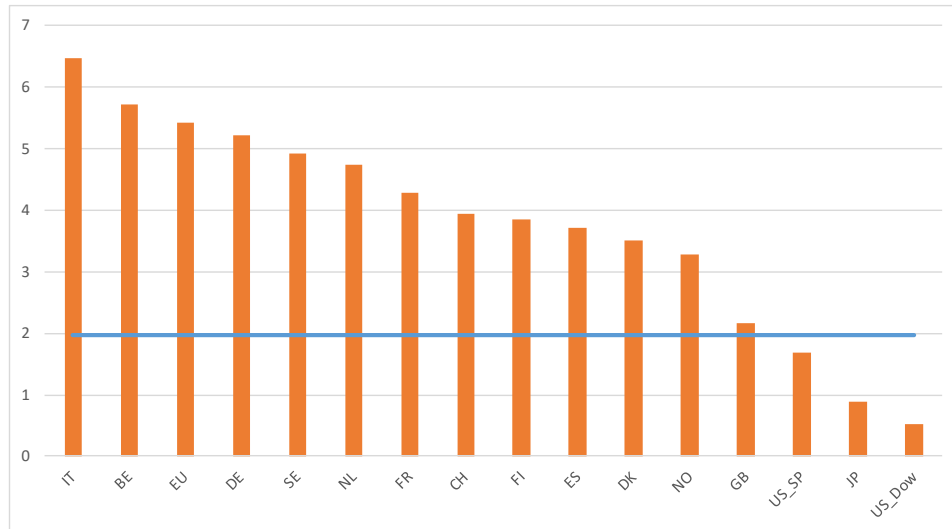
Table B7: Splitting up sample according to the frequency of scheduled meetings: price range

	(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

**Notes:** 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.

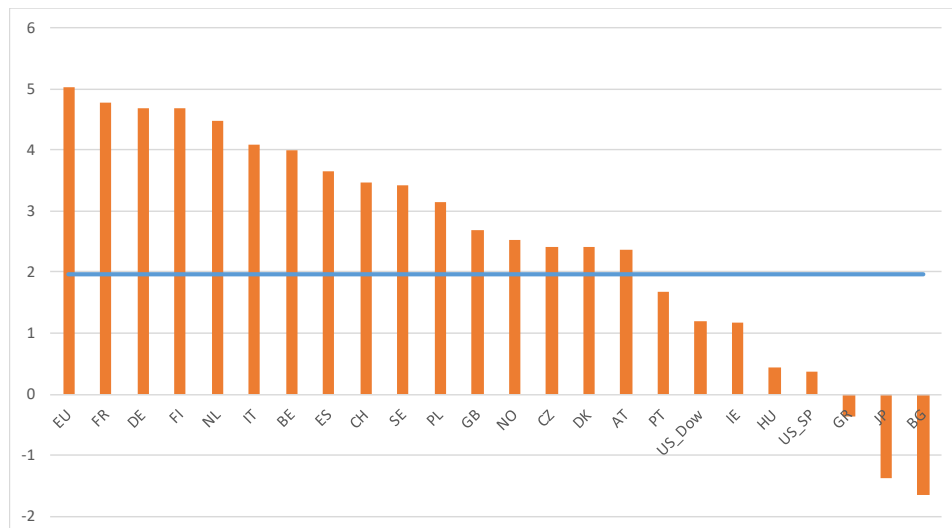
## II Figures

Figure B1: Sorted  $t$ -statistics of  $scheduled_t$  for realized volatilities



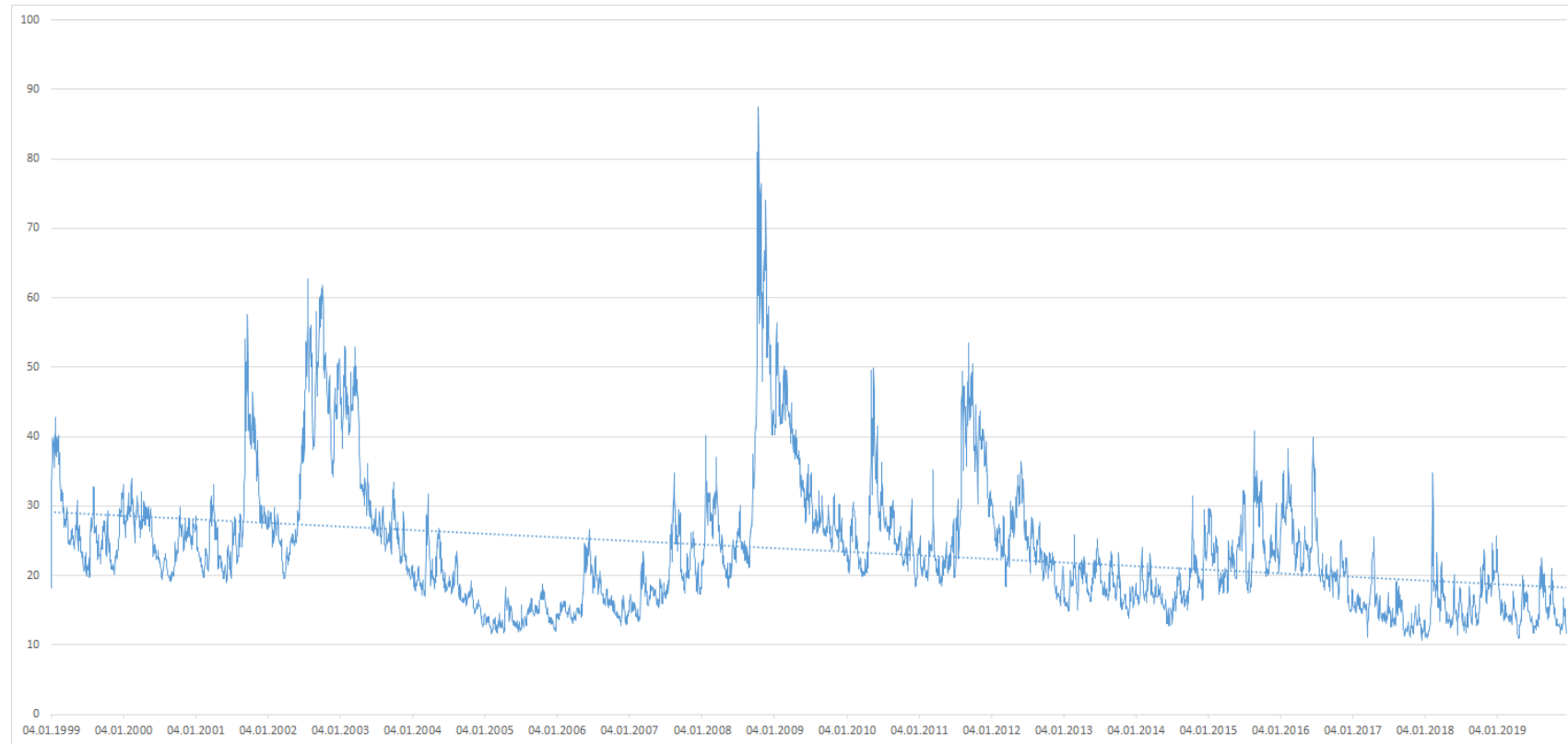
Notes: The horizontal line presents the threshold for a significance level of  $\alpha = 0.5\%$ .

Figure B2: Sorted  $t$ -statistics of  $scheduled_t$  for price ranges



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

Figure B3: Development of the VSTOXX index



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



# Chapter 6

## Conclusions

This thesis contributes to the field of central bank communication and financial markets' reactions. The presented research applies event study methods using high-frequency data of an extended period of up to twenty years. It compares multiple national markets, different maturities, and periods. More specifically, the presented studies disentangle distinct types of announcements, consider interaction effects, introduce new volatility measures, and most importantly, relate monetary policy announcements to developments in financial markets.

Chapter 2 analyzed the effectiveness of forward guidance in the United States. In general, forward guidance has a significantly adverse effect on Treasury Inflation-Protected Securities yields. However, the parallel announcement of asset purchases dampens the effectiveness of forward guidance. By additionally decomposing forward guidance into three types, date-based is the most effective form while qualitative-based and threshold-based forward guidance entail only minor impacts.

Chapter 3 evaluated the effects of the ECB's non-standard monetary policy program announcements on 10-year government bond yields of 11 euro area member states. Measurable effects of announcements arise with a one-day delay, meaning that government bond markets take some time to react to the ECB announcements. The country-specific extent of yield reduction seems inversely related to the solvency rating of the corresponding countries. The spread between core and periphery countries reduces because of a more pronounced decrease in the periphery countries. This result is confirmed by the interaction of the announcement variable with the current spread level.

The delayed effect on the sovereign bond market is confirmed in Chapter 4. The focus on different maturities in this Chapter 4 revealed a diverse reaction within the EA. While economies with a relatively low solvency rating are affected across the entire yield curve, economies with a relatively high solvency rating react significantly only at short maturities. Hence, ECB communication not only affects the economies differently but also the maturity matters.

As opposed to the bond market, stock markets react to central bank communication only on the announcement day. By using several volatility measures, Chapter 5 documented that the ECB announcements on monetary policy increase the volatility in most of the twelve examined EA stock markets. Consequently, national peculiarities are virtually absent. A more pronounced impact appears following the global financial crisis starting in 2007. The effects also spill over to some of the twelve 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.

On the one hand, the findings are generally consistent with related literature. The reduction in yields in response to forward guidance statements outlined in Chapter 2 fit into the literature (see Moessner et al. (2017) for a survey). In Chapter 3 and Chapter 4, accommodative monetary policy announcements reduce sovereign yields. Peripheral markets are quantitatively more affected by ECB announcements than core markets of the EA as in Jäger and Grigoriadis (2017), Bulligan and Monache (2018), and Urbschat and Watzka (2019). In Chapter 5, stock market volatility increases significantly due to monetary policy announcements, which is in line with previous findings on the level effects (e.g., Georgiadis and Gräb, 2016; Haitsma et al., 2016; Fausch and Sigonius, 2018). Similarly, the detected spill-over effects to non-EA markets are in accordance with established research (e.g., McQuade et al., 2015; Korus, 2019; ter Ellen et al., 2020).

On the other hand, the one-day delayed effect detected in Chapter 3 and Chapter 4 provides a new insight, which contradicts with studies that find yield reductions on the announcement day (e.g., Falagiarda and Reitz, 2015; Altavilla et al., 2016; Urbschat and Watzka, 2019). Economic theory defines threshold-based forward guidance as the most

effective form (e.g., Gersbach and Hahn, 2013; Filardo and Hofmann, 2014). The empirical analysis in Chapter 2, however, finds that date-based forward guidance is the dominant form in the United States.

To conclude, financial markets move substantially in response to central bank communication. Albeit the influence of communication lasts in both regular and crises times, the analysis suggests an increasing influence following the global financial crisis in 2007 persisting until the present. The *communication* of monetary policy is essential but it always complements the *actual* measures taken by the central bank. Future research should bear in mind this interdependence; optimal monetary policy requires a coordination of both.



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