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The variance premiums' responses to the ECB monetary announcements

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Abstract: We examine how the announcements of the asset purchase programs by the European Central Bank during the period 2009–2015 can be transmitted to stock markets through the risk-taking channel. Our preliminary findings indicate strong evidence in favour of the rejection of the hypothesis of unbiasedness of our selected national implied volatilities. Such findings are by and large compatible with general consensus emerging from literature highlighting the existence of the variance premiums. We extend the analysis to focus on the responses of the variance premiums to such announcements. We find supportive evidence that asset purchase program announcements likely involved the risk-taking channel given that the variance premiums are substantially influenced by monetary surprises embedded in such announcements. It is important to recognise that the risk-taking channel is mostly confined to the SMP programme. Finally, our findings highlight, not surprisingly, an obvious difference in the reactions of the variance premiums to monetary surprises between the crisis and post crisis periods.

Keywords: stock markets; ECB; conditional variance; monetary policy; variance premiums; implied volatility; realised volatility; GARCH model.

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1 Introduction

The announcements of the unconventional monetary policies by the European Central Bank (ECB) have by now been widely examined in the current literature focusing principally on the signalling and portfolio rebalancing channels[1] through which such news may influence financial markets. A growing empirical literature has also started to examine other potential monetary policy transmission channels, going beyond stock returns to focus on the variance premiums and, precisely, on the investor's risk aversion, for example.

The analysis of the risk-taking channel of the monetary policy has not attracted much attention in the literature. Through this channel one would expect that risk perception and tolerance may be influenced by the monetary policy actions, and mainly in the unconventional times. According to Carr and Wu (2009), Bekaert et al. (2013) and Bekaert and Hoerova (2014), the option implied volatility which quantifies the risk-neutral expected variance can be decomposed on a physical expected actual variance viewed as a proxy of equity market's uncertainty and a residual which capture the investors' risk aversion.

To fill this void, our study investigates empirically the interaction between the variance premiums for two major euro area stock markets of Germany and France and the announcements of unconventional monetary policies by the ECB in different specifications. Our paper also complements the results of papers on the risk-taking channel for both conventional (Gospodinov and Jamali, 2012; Bekaert et al., 2013) and unconventional monetary policies (Fassas and Papadamou, 2018). In a closet paper to ours, Fassas and Papadamou (2018) find evidence that more stimulative setting materialised by the announcements of unconventional monetary policies by the ECB decrease the variance premium as measured by the difference between implied volatility and conditional or realised variance.

Our paper extends the work by Fassas and Papadamou (2018) in several points. First, we focus on the main asset purchase programs by the ECB covering a large period of 2009–2015. Specially, we consider announcements of the following programmes: Covered Bond Purchase Program (CBPP), Securities Market Program (SMP), Outright Monetary Transactions Program (OMT) and Public Sector Purchase Program (PSPP).[2] The focus on this sample period allows us to account for different announced unconventional monetary measures and therefore to consider likely potential changes in the behaviour of the information flow. Second, and given the specificity of the European crisis compared to the US financial crisis, we refer to the Italian bond yield spreads as a proxy for monetary policy surprise instead of the of German bund price variations. The rationale behind this choice is that the unconventional monetary policies taken by the ECB are not addressed to affect German bund yields but rather than aimed at reducing sovereign spreads and consequently at calming conditions for the peripheral euro area countries. Third, the novel feature of this study is that it focuses on the monetary program-specific effects on variance premiums' dynamics across markets. Fourth, we consider splitting our sample period to examine the extent to which the various phases across the initial sample affected the effect of monetary policy surprises on the variance premiums. To do so, we split the sample into crisis period for May 2009 and the end of June 2012 and post crisis sample for the rest of the period.

Our current research extends the relatively few studies that focuses on the effects of shocks embedded on the ECB's monetary policy announcements on the euro area stock

markets.[3] It is important to recognise that the empirical studies to date have not yet reached an accord on the sign of the link between such news and stock prices. For example, Rogers et al. (2014), Haitsma et al. (2016) and Fratzscher et al. (2016) and more recently Chebbi (2019b) find evidence of positive impact of monetary policy shocks on stock prices. However, the findings by Hosono and Isobe (2014) lend support to a negative link between the unexpected part in the monetary news and the stock prices. In addition, there exist a few contemporaneous papers focusing on the reactions of stock market volatility to ECB's monetary announcements. A notable exception is that by Lacava et al. (2020) who confirmed a reducing effect of ECB's asset purchases on euro area stock volatility.

The main results of our empirical analysis can be summarised as follows. First, the preliminary analysis rejects the unbiasedness of the implied volatility which in turn, lends support for the presence of the variance premiums for Germany and France. Second, we find a supportive evidence of the central role of the monetary news related to ECB's asset purchase programs in detecting the risk- taking channel for the major euro area markets. In particular, we find for the entire sample that a negative monetary surprise materialised by a decline in the Italian yield spread tend to decrease the variance premiums defined as the difference between the implied volatility and its corresponding realised volatility for Germany and France. In addition, when we focus on program-specific effects, we find that the reaction of the variance premiums for the initial sample is confined to announcement of the Securities Market Program (SMP). Also, the effect of the monetary surprises on conditional variance premiums does not matters for the entire sample which might be the result of the inverse magnitudes of the early programs announced by the ECB notably the CBPP and SMP. Taking together, the results highlight the effectiveness of risk-taking channel with most emphasis on program-specific characteristics during the crisis.

The rest of this paper is structured as follows. In the Section 2, we describe the data sources and sample period. Section 3 presents the empirical framework that contains the models and the discussion of our findings. Section 4 concludes this study.

2 Data

We base this study on three sets of data: the major stock market indices in the euro area, the implied volatilities and the main announcements of asset purchase programs by the ECB. The sample begins in 7 May, 2009 and extends to 12 May, 2015 for a total of 1436 daily observations.

We use a sample of two major stock market indices in the euro area: the CAC 40 Index (France) and the CDAX Performance Index (Germany). Specifically, for each stock index we employ the daily logarithmic returns. We obtain data on all European stock market indices from Bloomberg database.

The second data consist of closing prices for the two national implied volatilities corresponding to German and French market indices, the VDAX (Deutsche Borse's DAX-30 volatility index) and the VCAC (Euronext-Paris' CAC 40 volatility index), respectively.[4] Note that the data for implied volatilities were collected at a daily frequency from the Bloomberg database.

Table 1 presents the main statistical properties of the daily stock index returns and implied volatilities from 7 May, 2009 through 12 May, 2015. First, as for the return

series, the average values vary modestly across indices and are rather close to zero. We show that the German DAX has the highest mean value (0.069). As for the standard deviation, we observe that the highest value is for French index returns (1.365). The values of skewness and kurtosis support the departure from a normal distribution and reinforce the considerable appreciation of GARCH family process in modelling the volatility of stock market returns. Second, looking for the national implied volatility series, the VCAC presents the highest average value.

Table 1 Summary statistics for stock market returns and volatilities

	Stock returns		*Volatilities*	
	DAX	*CAC40*	*VDAX*	*VCAC*
Mean	0.069	0.040	1.806	2.131
Median	0.112	0.050	1.446	1.745
Maximum	5.433	9.659	8.878	12.262
Minimum	–5.818	–5.478	0.462	0.561
Skewness	–0.060	0.120	2.266	2.176
Kurtosis	4.871	6.151	9.515	9.486
Std. Dev.	1.305	1.365	1.192	1.375
Observations	1436	1436	1436	1436

This table presents summary statistics of daily returns for selected European stock market indices, namely, CAC40 and DAX. We employ log differences in basis points of daily closing prices. For the two national implied volatility indices (VDAX and VCAC) we used the squared values. The data period is from 7 May, 2009 to 12 May, 2015.

To investigate the impact of unconventional monetary announcements by the ECB on the dynamics of the variance premiums, we refer to the main asset purchases programs occurring during the sample period. Particularly, the set of ECB announcements employed in the empirical section are related to the following programs: CBPP, SMP, OMT and PSPP. Data on selected monetary announcements are taken from the ECB's website. As well know, in respect to the specificity of the euro area debt crisis, we rely on Rogers et al. (2014) to construct the monetary policy surprise as the first difference of Italian 10 years bond yield spreads.

3 Empirical framework

This section presents the empirical methodology we employed, based primarily on the test of the hypothesis of the unbiasedness of the implied volatility which in turn allows us to study the dynamics of the variance premiums around the ECB monetary policy.

3.1 Test of the unbiasedness of the national implied volatilities

To establish a solid foundation for our empirical analysis focused on the dynamics of the variance premiums around selected ECB announcements, we try primarily to assess the ability of the implied volatility in predicting the future realised volatility. This exercise allows us to test the hypothesis of the unbiasedness of the implied volatility in the euro

area context. To do so, we draw on the regression approach specified by Day and Lewis (1992) and Christensen and Prabhala (1998).

We test our mentioned hypothesis by estimating the following model:

$$RV_{i,t+1} = \mu_0 + \mu_1 IV_t^2 + \zeta_{i,t+1} \tag{1}$$

where

$RV_{i,t+1}$: future realised volatility[5]

IV_t^2: volatility forecast: the VDAX or VCAC squared.

Table 2 reports the predictive ability of our volatility forecasts mentioned above. First, we focus on the R^2 statistic values which vary across the national implied volatilities. In particular, the values of the R^2 highlight the importance of the implied volatility squared as a forecast variable. In addition, the strong significance of the estimated parameters μ_1 at the 1% level indicates that our selected volatility forecasts convoyed important information to the future realised volatility. Second, if the volatility forecasts data are unbiased, then we should have $\mu_0 = 0$ and $\mu_1 = 1$. As we can be seen in last line of Table 2, the results for the Wald χ^2-test strongly reject the unbiasedness of these forecasts, which are consistent with early papers by Christensen and Prabhala, (1998) and Gospodinov et al. (2006) and more recently study by Pati et al. (2018).

It is important to recognise that our findings joined also a strand of literature by Bollserslev et al. (2009), Bollerslev et al. (2011) and Carr and Wu (2009) attributing the biasedness of our volatility forecast to the existence of volatility premiums.

Table 2 Predictive power regression test

	VDAX squared	*VCAC squared*
μ_0	–0.358***	–0.411***
	(0.000)	(0.000)
μ_1	0.875***	0.766***
	(0.000)	(0.000)
R-squared	0.399	0.495
χ^2	290.040***	1072.504***
	(0.000)	(0.000)

Table 2 reports the estimations of equation (1). We test the ability of two national volatilities: the VDAX (VCAC) squared to predict the future realised volatility. The study sample spans the period from 7 May, 2009 to 12 May, 2015. *** indicates statistical significance at the 1% level. p-values – are shown in parentheses.

3.2 The risk-taking channel of ECB's monetary news

In the second part of our analysis, we provide an empirical examination of the reaction of the variance premiums to shocks embedded in the ECB's monetary announcements during the period of 2009–2015. This exercise highlights the importance of the market-wide risk aversion and more generally the risk-taking channel of unconventional monetary policies in the stock markets.

We follow Bollserslev et al. (2009) to compute the variance premium as the difference between the national implied volatility and the corresponding realised volatility:

$$VP_{i,t} = IV_{i,t} - RV_{i,t} \tag{2}$$

where

$IV_{i,t}$ ($RV_{i,t}$) denotes implied (realised) volatility squared corresponding to German and French implied (realised) volatility indices at time *t*.

Following Carr and Wu (2009) and Bekaert and Hoerova (2014), we also construct the variance premium as the difference between the implied volatility and GARCH conditional volatility. Such conditional variance premium is used as an approximation of the investors' risk aversion.

$$VP_{i,t} = IV_{i,t} - GARCHCV_{i,t} \tag{3}$$

The conditional variance equation in our GARCH model is given by:

$$h_{i,t} = \omega + \alpha\varepsilon_{t-1}^2 + \beta h_{i,t-1} \tag{4}$$

where

h_t denotes the conditional variance of stock price returns at time *t* for index *i*

The parameters α and β reflect the linear relationship between the conditional variance and squared previous errors and the lagged level of conditional variance, and the sum $\alpha+\beta$ captures the degree of volatility persistence.

The reaction of variance premiums for the German and French markets to monetary shocks is studied by means of the following regression:[6]

$$\Delta VP_{i,t} = a + b\Delta VP_{i,t-1} + \varphi SpUMP_t \tag{5}$$

$SpUMP$ denotes the unexpected component embedded in the monetary news variables. It is worth noting that given the specificity of conditions facing the euro zone and notably the unprecedented sovereign debt crisis; we measure the unanticipated monetary shocks as the one-day change in the Italian 10-year bond spread relative to German Bund for announcement days (Rogers et al., 2014 and Chebbi, 2019).[7]

One challenge that the sample period facing is that it covers the European debt crisis period a crucial turning point for market participants which is characterised by extremely high uncertainty and sovereign bond spreads[8] as well as the post crisis period with relatively calm financial environment.

For this purpose, we think that options traders response in a different ways to monetary policy announcements. Johnson and So (2012) provide evidence of a strong of reaction of implied volatility to negative macroeconomic news announced on crisis period. More recently, Lee and Ryu (2019) show a positive reaction of implied volatility surrounding macroeconomic news announcements and that such response matters especially for the crisis and post crisis periods. Huang (2018) finds that the sensitivity of the volatility and jump for stock and bond markets in the United States to news varies with stress degree related to financial markets and the monetary policy stance.

We follow Chebbi (2019b) and split our initial sample into two subsample periods In particular, the crisis period begins on 7 May, 2009 and ends on 29 June, 2012, a few days before the 'whatever-it-takes' Draghi speech. The post crisis period dated from 2 July, 2012 until the end of the sample. Accordingly we estimate equation (5) for each period and focusing on the content of the monetary announcements as measured by the surprises.

The findings from estimating equation (5) using both measures of variance premiums are presented in Tables 3 and 4.

Table 3 The response of the variance premium to monetary surprises

	DAX			*CAC40*		
	Full sample	*Crisis*	*Post crisis*	*Full sample*	*Crisis*	*Post crisis*
a	0.004	0.012	–0.001	0.004	0.016	–0.002
	(0.866)	(0.773)	(0.970)	(0.866)	(0.720)	(0.908)
b	–0.304***	–0.275***	–0.426***	–0.434***	–0.453***	–0.410***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
φ	3.515***	6.006***	–0.395	4.356***	8.068***	–0.742
	(0.000)	(0.000)	(0.699)	(0.000)	(0.000)	(0.400)

Table 3 reports estimated parameters for regression defined in equation (5). The study sample is from 7 May, 2009 to 12 May, 2015 covering daily national implied and realised volatilities for Germany and France. The monetary surprise variable given only on announcement days is measured as the one day change in the Italian 10-year spread. The superscript *** indicates statistical significance at the 1% level. p-values – are shown in parentheses.

Table 3 reports the estimates based on the monetary surprises as previously defined and the variance premium given in equation (2). Columns (1) and (4) present the results for the full sample period 7 May, 2009–May 12, 2015, while in Columns (2), (3), (5) and (6) we repeat the estimation of equation (2) for the sub-sample periods as specified above. All emphasis is put on the assessment of the presence of the risk channel as measured by the estimate of the parameter φ that captures the magnitude of effect of monetary announcements on variance premiums.

The findings show positive and significant coefficients on the monetary variable both for the full sample period and for the crisis period. We lend support to a homogenous response of variance premiums to monetary shocks when the effect is significant. It is important to recognise that the results from the initial sample are mainly attributed to information convoyed by ECB's announcements taken at crisis times. These results follow the IMF (2013) in that they appreciate the effectiveness of monetary policy at such times.

We show that the stimulative financial environment associated with the ECB announcements marked and which specially by reduced credit spreads, the monetary surprise measure, strongly involved the risk-taking channel. In fact, we find that the variance premiums for both countries tended to decrease in reaction to negative monetary shock. Interestingly, for the case of the full sample period, a negative shock of monetary policy through a decline in the Italian yield spread by 1% leads to a decrease in the

volatility premium by about 3.5% (4.3%) for the DAX (CAC40). We conclude the analysis by indicating that the effect becomes larger when considering the crisis period. Such results indicate that variance premiums are more susceptible to asset purchase announcements during crisis times marked by higher uncertainty level. The estimates reveal that larger a decrease in monetary surprise by 1% tend to decrease the volatility premium by about 6% and 8% for the DAX and CAC40, respectively.

Finally, the decrease in variance premiums in the presence of negative monetary surprises can be explained as follow. It could be argued that unconventional monetary policies may serve as a signal that the monetary authorities are committed to maintain future short term yields at a lower level which consequently lessen the long term yields and to ensure a more stimulative financial environment. This expectation will weaken risk concerns which in turn may lead investors to increase their appetite.

Table 4 presents the estimates of equation (5) by employing the monetary shocks as previously defined and the conditional variance premium defined in equation (3) as a dependent variable. We begin by looking at the estimate results from our full sample period. The results show that the effect of monetary surprises on variance premiums for both countries is insignificant. When we split the sample period into subsample periods the effect becomes substantially significant; however, the noticeable difference among estimates pertains to the direction of the reaction of variance premiums. In particular, we show that the estimate effect of the monetary surprise is negative during the crisis period, and becomes positive during the post period. In particular, we show for the first sub-sample that the negative coefficient indicates that a negative shock associated with a decline in the Italian yield spread by 1% leads to a rise in the volatility premiums ranging from 1.15% to 1.60%. A same change in monetary surprise during the second sub-sample is associated with a drop in variance premiums by 0.52% and 0.68% respectively for Germany and France. Clearly, the opposite estimated coefficients for the sub-sample periods can explain the little movement in the variance premiums to monetary shocks during the full sample.

Table 4 The response of the conditional variance premium to monetary surprises

	DAX			*CAC40*		
	Full sample	*Crisis*	*Post Crisis*	*Full sample*	*Crisis*	*Post Crisis*
a	–0.001	–0.003	–0.000	–0.002	–0.004	–0.001
	(0.869)	(0.837)	(0.967)	(0.903)	(0.896)	(0.917)
b	–0.088***	–0.089**	–0.095**	–0.162***	–0.167***	–0.137***
	(0.001)	(0.020)	(0.018)	(0.000)	(0.000)	(0.000)
φ	–0.455	–1.149**	0.526*	–0.646	–1.603*	0.688*
	(0.188)	(0.047)	(0.077)	(0.241)	(0.089)	(0.098)

Table 4 reports estimated parameters for regression defined in equation (5). The study sample is from 7 May, 2009 to 12 May, 2015 covering daily national implied and expected volatilities for Germany and France. The monetary surprise variable given only on announcement days is measured as the one day change in the Italian 10-year spread. The superscript *** indicates statistical significance at the 1% level. p-values – are shown in parentheses.

The increasing-variance premiums effect of the monetary announcements during the crisis period may be attributed to the rise of investors' concerns regarding future conditions. The risk-taking channel may be complementary to the signalling channel. In fact, the monetary announcements can be viewed as a signal from the ECB's perception of current economic activity and its possible reaction to future developments (Glick and Leduc, 2012). Accordingly, when investors believe that a given statement signals about worse circumstances or that it likely increases risk concerns they become more averse.

As for the post crisis period, we show that the announcements of the monetary policies associated with stimulative financial environment explain the reduced risk concerns of market participants which in turn may lead them to increase their appetite.

Taken together, it is important to recognise that the opposite directions of the premium dynamics can be attributed to the signal perceptions of the unconventional monetary announcements by the investors in the euro area markets. More specifically, we find a supportive evidence of the connection between the signalling and risk-taking channels in explaining the response of the variance premiums to monetary news.

3.3 Robustness checks

We previously found that all shocks embedded in the announcements of asset purchase programs strongly affect the variance premiums. Naturally these findings are susceptible to the identification of the dependent variable and sample periods. We conduct a further analysis to examine the effect of each program on the risk- taking channel.

We use the following model to account for program-specific effects:

$$\Delta VP_{i,t} = a + b\Delta VP_{i,t-1} + \sum_{j=4}^{4} \varphi_j SpUMP_{j,t} \tag{6}$$

The monetary policy surprise variable given in equation (5) is replaced by $\sum_{j=4}^{4} SpUMP_{j,t}$ which intended to capture the impact of shock associated to each specific asset purchase program separately.

$$j = \{CBPP, SMP, OMT, PSPP\}.$$

Table 5 reports the results if we split ECB's asset purchase monetary surprises into program-specific shocks. Our estimation findings reported in Columns (1) and (3) show that only shocks embedded on SMP announcements significantly affect the variance premiums (specified on equation (2)). On the contrary, the effects of surprises associated to other asset purchase programs are not significant. Obviously, the effects that we found when we take all surprises are attributed to SMP surprises. Again, such results are broadly consistent with those of IMF (2013), indicating that unconventional monetary policy are more effective in stress times.

As for the conditional variance premiums, there is evidence for both countries of significant effects of the surprises related to CBPP and SMP announcements. The inverse coefficients' sign of these surprises (positive for SMP and negative for the CBPP), can be a likely reason for the little movement in the variance premiums to all monetary surprises for the initial sample.

To summarise the above robustness checks, the findings lend support to the evidence that the responses of variance premiums to surprises associated with the ECB's

unconventional monetary policies differ depending on the specific asset purchase program involved. More specifically, among the announcements associated to the four asset purchase programs we consider, it is shown that those from SMP and CBPP are of first-order importance, whereas the news related to OMT and PSPP play only an insignificant role.

Table 5 Estimation effects for different categories of unconventional monetary policies

	DAX		*CAC40*	
	ΔVP	*Conditional* ΔVP	ΔVP	*Conditional* ΔVP
a	0.005	–0.000	0.006	–0.001
	(0.843)	(0.941)	(0.796)	(0.947)
b	–0.325***	–0.094***	–0.444***	–0.165***
	(0.000)	(0.000)	(0.000)	(0.000)
φ_{CBPP}	–5.255	5.135***	–2.203	5.913**
	(0.180)	(0.000)	(0.560)	(0.016)
φ_{SMP}	7.523***	–1.668***	8.690***	–2.211***
	(0.000)	(0.000)	(0.000)	(0.002)
φ_{OMT}	–0.299	0.561	–0.339	0.712
	(0.830)	(0.306)	(0.801)	(0.417)
φ_{PSPP}	–7.700	–1.628	–12.913	–0.469
	(0.400)	(0.651)	(0.131)	(0.932)

Table 5 presents our estimation results for program-specific effects defined in equation (6). The study sample is from 7 May, 2009 to 12 May, 2015 covering daily national implied, expected and realised volatilities for Germany and France. The monetary surprise variable given only on announcement days is measured as the one day change in the Italian 10-year spread. The superscript *** indicates statistical significance at the 1% level. p-values – are shown in parentheses.

Built upon the above findings, one can argue that the direction of the reactions of variance premiums to monetary surprises depend ultimately to the employed measure. The opposite direction, that is, when we refer to conditional variance premiums can be explained as follows. A possible justification for the counter-intuitive findings for the conditional variance premiums is that it is commonly hard to consider the conditional volatility as a precise measurement for the stock risk. Early papers by Baillie and DeGennaro (1990) and Theodossiou and Lee (1995) highlighted the inappropriateness of the conditional volatility as an approximation for risk. More recent papers by Kanas (2013) and Pati et al. (2018) confirmed such evidence for US and Asia-Pacific stock markets. Therefore a lack of the accurate ability of the conditional volatility to correctly specifying the risk uncovers a serious issue related to the precision of the measurement of the conditional variance premiums.

4 Conclusions

In this paper we have investigated the information transmission of the ECB's asset purchase announcements to the German and French stock markets through the risk-taking channel. Important findings have been gleaned from the analysis of the effects of the monetary surprises embedded on such announcements on the variance premiums as measured by the difference between the implied and realised or conditional volatilities. Particularly, we find significant variance premium responses to monetary surprises which in turn affect the risk aversion for German and French stock markets, namely during the crisis period. Notably, the effect of monetary surprises is mostly confined to the SMP announcements. The results show that, not surprisingly, there is a key difference of the responses of the variance premiums between the crisis and post crisis periods. These findings present a new perspective on identifying the informational content of the implied volatility and more important on assessing the monetary transmission channels namely for European stock markets.

Taken as a whole, we find supportive evidence that the ECB's unconventional monetary policies likely work with risk-taking channel in the euro zone stock markets. It is important to recognise that since the variance premium's responses vary across different specifications, asset purchase programs, and different periods, such reactions to monetary shocks must be examined carefully.

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Notes

[1]The monetary policy transmissions to financial markets are extensively discussed by Krishnamurthy and Vissing-Jorgensen (2011), Glick and Leduc (2012) and Fratzscher et al. (2016).

[2]Unconventional monetary policies taken by the ECB are discussed with more details in Chebbi (2019ab).

[3]See also Chebbi and Derbali (2019c) for an analysis of the effects of conventional monetary surprises on euro area stock volatility.

[4]Our attention is paid to the VDX and VCAC indices given the availability of historical data. For the case of Spain and Italy their corresponding indices are created only recently.

[5]We follow Andersen and Bollerslev (1998) to construct the daily realized volatility by using the sum of squared returns for 5-min window data.

[6]We refer to the first differences of the variance premiums in the spirit of Beetsma et al. (2013) for the euro area context.

[7]Data for Italian and German sovereign bond yields was collected from the FRED database.

[8]For more discussions about the European debt crisis see Tampakoudis et al. (2012).