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CONFERENCE PAPER

The Impact of ECB's Unconventional Monetary Policy on the German Stock Market Volatility

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Abstract: This study investigated the reaction of German stock market volatility (Dax index) to the European Central Bank (ECB)'s unconventional monetary policy (UMP) announcements. The financial crisis of 2008 proved that the traditional monetary policy's tool (the short -term interest rate) has lost its effectiveness to meet the new challenges. So, the key central banks, ECB included, had to implement the new, untested and nonstandard monetary policy which so called unconventional monetary policy. In this study, we used the ECB's shadow policy rate approach to extract unconventional monetary policy. Also, We employed GJR GARCH (p,o,q) model to estimate the volatility in the German stock market. Then we calibrated both OLS (linear regression) and Markov-switching (probability-matrix of regime changes) models to examine the reaction of German stock returns volatility to UMP announcement by ECB for a period from January 2006 to December 2019. The results delivered by both models showed that the ECB's UMP had a strong and negative effect on the volatility of the German stock market. Also, both models showed that the past German stock volatility has a significant and negative effect on the dependent variable, while the volatility of the German stock returns is a function of the global volatility estimated by the VIX index. Moreover, the results showed that the Markov-switching regression model provides a better illustration of the stock market volatility impact of UMP than the OLS model because it can represent the changes into the two different regimes named ordinary regime and quantitative easing (crisis) regime. Furthermore, under the Markov-switching regression model, we can see how the output gap and the inflation gap influence the volatility of the Dax index, while the results of the OLS regression model showed that there is no significant relationship between the output gap and the inflation gap with the German stock market volatility.

Keywords: Unconventional Monetary Policy; ECB; GJR-GARCH; Markov-switching model; the shadow rate

JEL Classification: E43, E44, E52, E58

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Introduction

For the ECB, since its creation in 1998, the short-term interest rate is the primary instrument to implement desired monetary policy, such that it has decreased the rates to provide more stimulus and increased them to slow economic activity and control inflation. However, when the conditional tool of interest rate reaches the zero-lower bound (ZLB), it loses its effectiveness to meet the new challenges (Markmann, 2017). However, since the global financial crisis, some major central banks, ECB included, have adopted negative interest rates to deal with the recession which shows ZLB isn't as binding as previously thought (Ouerk, Boucher, & Lubochinsky, 2020). In addition, they have changed their monetary policies from conventional liquidity injections to several real unconventional monetary policies (UMP) based on balance sheet operations such as large-scale asset purchases, generally called quantitative easing (QE), and forward guidance with the aim of achieving their mandate of price stability. In implementing UMP, the central bank's balance sheet is actively used and expanded beyond a short-term, overnight interest rate. This feature distinguishes UMP from interest rate policy. Therefore, such unconventional policies are typically called balance sheet operations policies (Borio & Disyatat, 2010).

In this study, we investigated to what extent ECB's unconventional monetary policy has an effect on the German stock market volatility or how much the volatility of the German stock index arising from the ECB's monetary policy shocks. This study contributes to the body of knowledge in several directions: First, in order to extract UMP, we used the shadow policy rates. According to Lombardi & Zhu (2014), the shadow policy rates provide a far more realistic picture of UMP than the actual interest rate. Second, we examined the effect of UMP on German stock market in periods before and after the financial crisis. Third, in this study, we applied both market condition and macro condition variables in the regression model to control the effect of macro and market conditions on the variability of the German stock market. Fourth, we calibrated Markov-switching regression, which is able to account for non-linearity macroeconomic or macro-financial relationships and is useful for turning point detection, to know where we are actually. Finally, in this study, in order to figure out whether the impact of ECB's unconventional monetary policy on stock volatility depends on the prevailing interest rate regime, we divide the main time series into two regimes: ordinary regime and quantitative easing regime.

The examined period runs from the first quarter of 2006 to the last quarter of 2019. To estimate the volatility in the German stock market, we used the GJR GARCH (p,o,q) model. To analyze the impact of ECB's UMP on the German stock market volatility, we employed both OLS and Markov-switching regression models. Our results showed that ECB's UMP had volatility compressing effects for German stock market.

This paper is structured as follows: the second section explains the theoretical background of UMP; the third section describes data, model, and our estimation method to examine the impact of ECB's UMP on the German stock market. The fourth section explains the estimation results and discussions and the final section concludes.

Theoretical background

Unconventional Monetary Policy (UMP) can be classified into three terms that are usually used to describe the central bank's actions during the financial crisis. The first term is Forward Guidance where the central banks announce the future path of the policy rate (Del Negro, Giannoni, & Patterson 2012) with the goal of guiding the future expectations of economic participants toward long-term interest rates (Coroiu & Mitu 2016). Credit Easing is the second term that provides credits for a wide range of private sectors and financial institutions (Shleifer & Vishney 2010). The third term used extensively in the global financial crisis is Quantitative Easing which is the central banks' large-scale asset purchase programs.

The ECB similarly to other central banks from major the developed economies reacted to the global financial crisis by reducing significantly the key interest rate, changing the euro area monetary policy, and implementing a number of unconventional monetary policies (Dell'Ariccia, Rabanal, & Sandri 2018). In addition, since the Covid-19 outbreaks, the ECB's Pandemic Emergency Purchase Programme (PEPP) announcement in March 2020 was considered as the most powerful event in reducing the sovereign spread in the euro area (Havlik, Heinemann, Helbig, & Nover, 2022).

The unconventional monetary policy implemented by the central bank may affect stock markets through confidence channels (Chebbi, 2018 and Coroiu & Mitu, 2016). the bank credit risk channel (Chebbi, 2018), the portfolio-rebalancing channel (Den Haan, 2016) and the signaling channel (Chebbi, 2018 and Coroiu & Mitu, 2016).

Bohl, Siklos, & Sondermann (2008) reported that there is a negative relationship between ECB's unconventional monetary policy and European stock market returns. Arestis, Baddeley, & McCombie (2005) reached the same result. Chebbi (2018) showed that the positive ECB policy shocks lead to a rise in the German interest rate and a decrease in the domestic bond yield, which subsequently causes higher stock returns. While Kholodilin, Montagnoli, Napolitano, & Siliverstovs (2008) indicated that on the day of a monetary policy shock's announcement, for an increase in the interest rate by 25 basis points, stock market indexes decrease in the range between 0.3% and 2.0% depending on the sectors.

There are several methods that the studies used to extract unconventional monetary policy. Rabin & Stevens (2002) used two measures for monetary policy, an index of directional change in the discount rate and the federal fund rate. Fausch & Sigonius (2018) used a standard event study to measure UMP. Lombardi & Zhu (2014) used the shadow federal funds rate in the standard VAR (vector autoregressive) model to analyze unconventional monetary policy and compare it with the actual federal funds rate.

Theoretical model

We calibrated the following Markov-switching regression model to estimate the effect of unconventional monetary policy on the volatility of the German stock market:

$$\sigma_t = \alpha_0 + \beta_1 \sigma_{t-1} + \beta_2 UMP_t + \beta_3 UMP_{t-1} + \beta_4 \tilde{y}_t + \beta_5 \tilde{y}_{t-1} + \beta_6 c_t + \beta_7 c_{t-1} + \beta_8 vol_t + \beta_9 vol_{t-1} + \beta_{10} \text{crisis}_t + \varepsilon_t \quad (1)$$

Where $\boldsymbol{\sigma}_t$ is the conditional volatility of German stock index on day t, which was estimated by GJR-GARCH model; $\boldsymbol{\alpha}_0$ is the constant variable; $\boldsymbol{\alpha}_{t-1}$ is the conditional volatility of German stock index on day (t – 1) which was estimated by GJR-GARCH model; $\boldsymbol{\varepsilon}$ is residual term. Other variables can be divided into Macro condition variables and Market condition variables. Macro condition variables include the output gap, inflation gap and crisis.

$\tilde{\mathbf{y}}_t$ represents the output gap. According to Garnier & Wilhelmsen (2005), the real interest rate gap influences the output gap such that the average level of the output gap is positive in periods of expansionary monetary policy and it becomes negative with restrictive monetary policy. The output gap can be a measure of economic slack (Lombardi & Zhu, 2014). We considered the output gap as a difference between the log actual GDP (y_t) and log potential output ($\tilde{y}_t$) (estimated by an H-P filter (λ= 1600)) as follows:

$$\tilde{y}_t = 100\,(y_t - \ddot{y}_t) \quad (2)$$

$\boldsymbol{c}_t$ represents the inflation gap. According to Ben-Haim, Demertzis, & Willem (2017), the inflation gap is the difference between realized inflation rate at time t (π_t) and target inflation rate (π_t^*) which is 2% for Germany as follows:

$$\boldsymbol{c_t} = \pi_t - \pi_t^* \quad (3)$$

Crisis is also a dummy variable to control the effect of crisis on stock market returns, which takes value 1 for pre-crisis period, and zero for after- crisis period (Haitsma, Unalmis, & De Haan, 2016).

Table 1: Chronology of Euro Area Business Cycles

Date	Peak / Trough	Announcement Date
2013 Q1	Trough	1 October 2015
2011 Q3	Peak	15 November 2012
2009 Q2	Trough	4 October 2010
2008 Q1	Peak	31 March 2009
1993 Q3	Trough	22 September 2003
1992 Q1	Peak	22 September 2003
1982 Q3	Trough	22 September 2003
1980 Q1	Peak	22 September 2003
1975 Q1	Trough	22 September 2003
1974 Q3	Peak	22 September 2003

Source: EBBCN: Euro Area Business Cycle Network

Table 1 shows the chronology of Euro Area Business Cycles (the peak and trough quarters) since 1974 based on the Centre for Economic Policy Research (CEPR) classification. It shows that the euro area has seen five complete business cycles since 1974 (EBBCN: Euro Area Business Cycle Network, n.d.).

Market condition variables include European VIX and Unconventional Monetary Policy. $\boldsymbol{vol_t}$ is used to control the daily changes of the risk aversion and can be measured by the volatility index for the euro area EuroStoxx 50 Index options (European VIX) (Chebbi, 2018); $\boldsymbol{UMP_t}$ is ECB's unconventional Monetary Policy which can be estimated by using the ECB's shadow policy rate (s_t). The actual interest rate is the higher of shadow rate (s_t) and Lower Bound (LB). So, if the shadow rate is above LB, then the actual interest rate equals s_t, otherwise, it equals LB (Lemke & Vladu, 2017):

$$r_t = \max\{s_t, LB\}$$

Therefore, the shadow rate can be used as an indicator of the stance of both conventional and unconventional monetary policy and to compare the conventional and unconventional sub-samples. When the central banks implemented UMP, the shadow rate will take the negative values, which signals the existence of UMP and shows UMP is more accommodating than zero lower bounds (Rossi, 2018). Lombardi & Zhu (2014) proved that applying the shadow federal fund rates in the VAR model rather than the actual federal fund rates helps to provide a far better assessment of to what extent the policy gap has been filled by unconventional monetary policy.

Data and Methodology

In this study, first we used GJR GARCH (p,o,q) model following Cappeiello, Engle, & Sheppard (2006) to estimate volatility in German stock market as follows:

$$\sigma_t = \omega + \sum_{i=1}^{p} \alpha_i \left|\varepsilon_{t-i}\right| + \sum_{i=1}^{o} \gamma_i S^{-}{}_{t-1} \left|\varepsilon_{t-i}\right| + \sum_{j=1}^{q} \beta_i \sigma_{t-\mathrm{j}} \quad (4)$$

Where $\boldsymbol{\sigma}_t$ is conditional (time variant) variance of German stock returns at time t; $\boldsymbol{\omega}$ is constant term; $\boldsymbol{p}$ is the lag number of squared residual past $\boldsymbol{\varepsilon}_{t-1}$ shocks with α_i parameters (=1); is the lag number of past variances with parameters to show volatility persistence (q=1); $\boldsymbol{y}_i$ is transition parameter as the probability of switching from one regime to another doesn't equal to one, but it depends on a transition matrix (Chuffar, 2015); $\mathbf{S}^{-}_{t-1}$ Shows time varying asymmetry reaction in MS-GARCH models to decreasing returns relative to increasing returns (asymmetric leverage effect) such that (Cappeiello et al, 2006).

$$\begin{cases} S^{-}{}_{t-1} = 1, \text{if } \varepsilon_{t-i} < 0 \\ S^{-}{}_{t-1} = 0, if\ \varepsilon_{t-i} \geq 0 \end{cases}$$

The data related to macroeconomic condition variables was taken from Eurostat and OECD. The data frequency is quarterly. The baseline sample for estimating the models and the variation of German stock returns decomposition runs from January 2006 to December 2019. To illustrate the estimation of GJR GARCH model in MATLAB environment, we estimated the volatility of German stock market returns (standard deviation of DAX ($\boldsymbol{\sigma}_t$)) on weekly basis then collected the quarterly closing values. Then we used $\boldsymbol{\sigma}_t$ estimated by GJR GARCH model as the dependent variable for the Markov-switching regression model. Moreover, in this study two regimes for stock market volatility are introduced, ordinary regime and QE (crisis) regime.

Linear models generate proportional and symmetric responses to shocks between variables. However, in practice, macroeconomic or macro-financial relationships involve non-linearities: a monetary shock has different impact under recession or in the middle of the boom. Considering an AR(1) model with time varying ϕ parameters (5), where the shift in the mean can be captured with the $\boldsymbol{S}_t$ variable.

$$x_t = \left(\varphi_{1,0} + \varphi_{1,1} x_{t-1}\right)\boldsymbol{S_t} + \left(\varphi_{2,0} + \varphi_{2,1} x_{t-1}\right)\left(1 - \boldsymbol{S_t}\right) + e_t \quad (5)$$

In the case that $\boldsymbol{S}_t$ is known, we can use dummy variables, but if it is unknown but depends on observable variables, we can use Threshold or Smooth-Transition models. Otherwise, when it is unknown but depends on unobservable variables, we need to make additional assumptions about its generating mechanism: assuming it as a discrete binary variable, we can use Markov-switching models (Ghysels & Marcellino, 2018). An $\boldsymbol{x}_t$ variable follows a two-regime MS model (6) under the following assumptions:

$$x_t - \mu(\boldsymbol{S_t}) = \sum_{i=1}^{p} \varphi_i(\boldsymbol{S_t})\big(x_{t-i} - \mu(\boldsymbol{S_{t-i}})\big) + \sigma(\boldsymbol{S_t})e_t \qquad (6)$$

where the non-observed $\boldsymbol{S}_t$ process is an ergodic Markov chain, and it characterizes the unobserved state, or regime, of the economy at date *t*, and the parameters $\mu(\boldsymbol{S}_t)$, $\phi_i(\boldsymbol{S}_t)$, $\sigma(\boldsymbol{S}_t)$ are time-varying and describe the dependence of to the current regime. The error-term is a standardized white noise process. Each $\boldsymbol{S}_t$ regime relates to a given phase of the economic cyle and for each date *t*, the economy can either stay in the same regime at date *t + 1* or switch to the other regime. Transition probabilities are collected in the transition matrix: $\eta = \begin{pmatrix} p_{11} & p_{21} \\ p_{12} & p_{22} \end{pmatrix}$ (Hamilton, 1994).

Results and Discussion

As the first stage, in order to know what is happening without introducing regimes, the model parameters are estimated by Ordinary Least Squares (OLS) regression which is a linear model assuming that there are proportional and symmetric responses to shocks between variables. This model is calibrated in EViews 11 in which the standard deviation of DAX () is the dependent variable and the ECB's shadow rate is a measure for unconventional monetary policy.

Table 2 shows the results of the OLS regression model. If the significant value is less than 0.1, then we can say β can be asserted as a true value with a 90% level of confidence. Table (2) shows that the shadow rate as a proxy for UMP has a strong and positive relationship with the German stock return volatility (Sig= 0.0881<0.1). Moreover, autocorrelation was tested with the Durbin-Watson test. The score between 1.8 -2.2 range for this test indicates there is no autocorrelation detected in the residuals. Our results recorded a score of around 2.20 for the Durbin-Watson test. In addition, results show the past volatility of the Dax index (Sig= 0.0001) has a strong and negative effect on the dependent variable while the VIX index (Sig= 0.0000) has a strong and positive relationship with the current volatility of the Dax index. However, other independent variables like the output gap and inflation gap don't have strong relationship with the dependent variable. Also, the results showed that without introducing regimes and by using a dummy variable to control the two-time sub-periods (ordinary and crisis) in the OLS regression model, the crisis is a neutral variable that doesn't have strong relationship with the current volatility of the Dax index.

Table 2: The estimation outputs by OLS regression model

Variable	Coefficient	Std. Error	t-Statistic	sig.
const.	-0.000140	0.001430	-0.097831	0.9226
Δ STD_DAX (t-1)	-0.574921	0.128210	-4.484201	0.0001
Δ Shadow rate (t)	0.329614	0.188518	1.748445	0.0881
Δ Shadow rate (t-1)	-0.035843	0.193850	-0.184903	0.8542
Δ OUTPUT Gap (t)	-1.088009	2.310413	-0.470915	0.6403
Δ OUTPUT Gap (t-1)	0.794265	2.111432	0.376174	0.7088
Δ Inflation Gap (t)	-0.474457	0.352887	-1.344502	0.1864
Δ Inflation Gap (t-1)	0.427117	0.352633	1.211221	0.2329
Δ VIX (t)	0.001019	0.000194	5.263293	0.0000
Δ VIX (t-1)	0.000796	0.000233	3.410371	0.0015
Dummy,	0.001559	0.003792	0.411238	0.6831
R-squared	0.618073	Mean dependent var		-0.000161
Adjusted R-squared	0.522591	S.D. dependent var		0.012136
S.E. of regression	0.008385	Akaike info criterion		-6.536233
Sum squared resid	0.002813	Schwarz criterion		-6.119565
Log likelihood	177.6739	Hannan-Quinn criter.		-6.377012
F-statistic	6.473200	Durbin-Watson stat		2.185932
Prob (F-statistic)	0.000008			

Source: Authorial Computation, Eviews 11

In order to consider the regimes of stock market volatility in the regression model (ordinary and QE regimes), we calibrated the following (7) Markov switching regression model in which the model automatically controls the effect of the crisis, then we backtested these results with an the OLS model, which had a dummy variable to represent recessions. Like OLS model, in this model, the standard deviation of the DAX (σ_t) is considered as the dependent variable and the ECB's shadow rate (s_t) is a measure for unconventional monetary policy as follows:

$$\sigma_t=\alpha_0+\beta_1\sigma_{t-1}+\beta_2 s_t+\beta_3 s_{t-1}+\beta_4\tilde{y}_t+\beta_5\tilde{y}_{t-1}+\beta_6 c_t+\beta_7 c_{t-1}+\beta_8 vol_t+\beta_9 vol_{t-1}+\varepsilon_t \quad (7)$$

Table 3 shows there is a relationship between variables for two different regimes. In fact, we divided the main time series into two sub-periods (regimes), ordinary and crisis (QE) periods. The Durbin-Watson checks for no serial correlations in the squared standardized residual. It can be seen D-W test score is recorded around 2.02, which indicates there is no autocorrelation detected in the residuals. Also significant for both regimes is less than 0.1 (sig<0.1), which shows both regimes are valid. Moreover, the result shows past volatility of German stock return (STD_DAX (σ_{t-1})) has a strong and negative relationship with the German stock return volatility (Sig= 0.0000<0.1).

In addition, the model shows if the ECB's shadow rate as a proxy for UMP increased, then the volatility of German stock returns increased. Furthermore, the VIX index as a proxy for global volatility has a significant and positive effect on the Dax index. In addition, the macro condition variables have strong relationship with the German stock return volatility as well. As it can be seen from Table 3, increasing the output gap leads to increase the volatility in German Stock returns, however, the inflation gap has a strong and negative effect on the volatility of German stock returns. Moreover, table 3 and Appendix 1 show the result of the transition matrix parameters. If only one of the transition matrix parameters is significant, it means that the second regime is not consistent, and it detects mostly a set of outliers – as can be seen in the P11-C and P21-C cases. The probability matrix represents the probability of being in the state (regime) "*k*" at the time *t*, given of being in state "*i*" at time *t-1* (Chuffart, 2015). Regime 1 represents the ordinary economic condition, while the second regime represents the crisis period when the central banks implemented the unconventional monetary policy (QE).

Table 3: The estimation outputs by Markov-switching Model

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Regime 1				
LOG(SIGMA)	-9.175940	0.233578	-39.28421	0.0000
Regime 2				
LOG(SIGMA)	-4.617698	0.134223	-34.40329	0.0000
Common				
Δ STD_DAX(-1)	-0.756310	0.004388	-172.3708	0.0000
Δ SHADOW_RATE	0.281696	0.005761	48.89943	0.0000
Δ OUTPUT_GAP	1.938325	0.065992	29.37224	0.0000
Δ INFL_GAP	-0.518126	0.023814	-21.75739	0.0000
Δ VIX	0.000946	6.77E-06	139.8247	0.0000
Δ SHADOW_RATE(t-1)	0.483551	0.009363	51.64589	0.0000
Δ OUTPUT_GAP(t-1)	-1.651656	0.064284	-25.69294	0.0000
Δ INFL_GAP(t-1)	-0.139231	0.013000	-10.71006	0.0000
Δ VIX(t-1)	0.001142	9.84E-06	116.0318	0.0000
Transition Matrix Parameters				
P11-C	0.240570	0.649305	0.370504	0.7110
P21-C	-1.724979	0.553772	-3.114961	0.0018
Mean dependent var	-0.000161	S.D. dependent var		0.012136
S.E. of regression	0.009571	Sum squared resid		0.003665
Durbin-Watson stat	2.027116	Log likelihood		200.9636
Akaike info criterion	-7.371122	Schwarz criterion		-6.878695
Hannan-Quinn criter.	-7.182951			

Source: Authorial Computation, Eviews 11

Appendix 1 (Table 4) shows that there is a considerable state dependence in the transition probabilities with a relatively higher probability of remaining in the origin regime. It means that if Germany is in the ordinary economic condition or in a state of crisis, it is highly probable that it will stay there (0.55% for the ordinary state, 0.84% for the QE (crisis) state). However, the probability to move from an ordinary state to a state of crisis is 44% and from crisis to an ordinary state is 15%. These probabilities indicate that the constant expected duration in regime 1 is roughly 2.27 quarters and 6.61 quarters in regime 2. S (t) in Appendix 1 follows a market chain with finite states (regimes) S= 1,…, N and a transition matrix P. The probability of switching from one regime to another is no longer equal to one but depends on the transition matrix P (Chuffart, 2015). Appendix 1 (Figure 1) shows in which state are they and how they are moving from regime 1 to regime 2. As can be seen, the two regimes of the volatility of the stock market are defined by unconventional monetary policy, and the predicted probabilities of being in the QE state coincide with the commonly employed definition of recessions.

Compare the OLS and Markov-switching regression Models

According to Lemke & Vladu (2017), the actual interest rate equals the shadow rate in ordinary economic conditions, and it equals the lower bound in the crisis state. When the central banks implemented UMP, the shadow rate will take the negative values, which signals the existence of UMP and shows UMP is more accommodating than the zero-lower bound (Rossi, 2018). Based on the results of both OLS and Markov-switching regression models, the ECB's shadow rate has a significant and positive relationship with the volatility of the German stock returns. Moreover, both models show that the past German stock volatility has (STD_DAX (σ_{t-1})) a significant and negative effect on the dependent variable. However, the results of both models indicate that the volatility of the German stock returns is a function of the global volatility estimated by the VIX index.

On the other hand, comparing these two regression models proves that the Markov-switching regression model is a far better model for estimating the effect of UMP on the German stock volatility than the OLS regression model because of some reasons. First, the Markov-switching regression model divides the main time series into two regimes: ordinary regime and Quantitative Easing regime. Table 3 shows both regimes are valid, and it gives us a better illustration of the German stock market volatility under these two different regimes. While in the OLS regression model, we had to introduce a dummy variable to control crisis and we can see from Table 2 that in this model, the crisis is a neutral variable that does not have a strong relationship with the current volatility of the Dax index. Moreover, under the Markov-switching regression model, we can see how the output gap and the inflation gap influence the volatility of the Dax index, while the results of the OLS regression model showed that there are no significant relationships between these independent variables and the German stock market volatility.

Conclusion

This paper investigated the impact of the ECB's unconventional monetary policy on the German stock market volatility. We followed Lombardi & Zhu (2014) to use the ECB's shadow rate as a measure for unconventional monetary policy. When the central banks implemented UMP, the shadow rate will take the negative values, which signals the existence of UMP and shows UMP is more accommodating than the zero lower bound. Therefore, as Lombardi & Zhu (2014) proved, the shadow rate is a good assessment to estimate to what extent the policy gap has been filled by UMP. Also, we used the GJR GARCH (p,o,q) model following Cappeiello et al, (2006) to estimate the volatility in the German stock market. We calibrated both OLS and Markov-switching regression models for a wide period between 2006-2019. From both regression models, we found that the ECB's UMP has a strong and negative relationship with the German stock volatility. This result is in line with the study by Bohl et al, (2008) and Arestis et al, (2005) who reported a negative relationship between UMP and the volatility stock market returns. Moreover, the results of running both models showed that the past German stock volatility (STD_DAX ()) had a significant and negative effect on the dependent variable. However, the results indicated that the volatility of the German stock returns is a function of the global volatility estimated by the VIX index.

Moreover, we proved that the Markov-switching regression model provides a far better model for estimating the impact of the UMP on the German stock volatility than the OLS regression model because it divides the main time series into two regimes named ordinary regime and quantitative easing regimes such that the results showed that both regimes are valid. However, in the OLS regression model, we controlled the effect of crisis by introducing a dummy variable, and the results of running this model showed that the crisis does not have a strong relationship with the current volatility of the Dax index. Furthermore, the results of the OLS regression model showed that there is no significant relationship between the output gap and the inflation gap with the German stock market volatility. However, under the Markov-switching regression model, we can see that increasing the output gap leads to an increase in the volatility in German Stock returns and increasing the inflation gap has a negative effect on the volatility of German stock returns.

This study has some suggestions for further research. First, there are several methods to extract and identify the UMP implemented by central banks, therefore more research will in fact be necessary to compare the impact of using different methods on the research's results. Moreover, this study examined the volatility in the German stock market for a period before the Covid-19 crisis and there is also a gap in analysis of the volatility impact of UMP in the post-covid-19 economy.

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APPENDIX 1

Tab. 4: The Transition Probabilities

Constant transition probabilities:

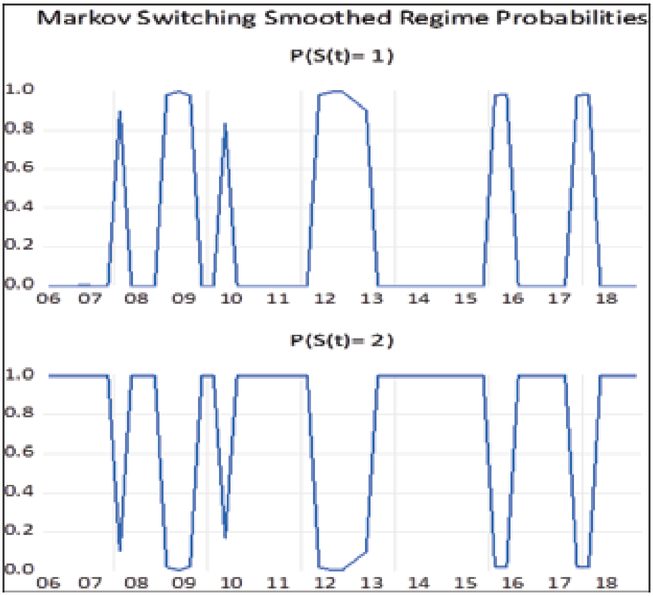
P(i, k) = P(s(t) = k | s(t-1) = i)
(row = i / column = k)

	1	2
1	**0.559854**	0.440146
2	0.151231	**0.848769**

Constant expected durations:

1	2
2.271974	6.612403

Fig. 1: Regime Probabilities



Source: Authorial Computation, Eviews 11