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Post-Brexit Stock Market Volatility and European Central Bank Reaction Function

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Abstract The European stock markets experienced enormous volatility in stock markets post-Brexit era, which wasn't observed before the shock. The volatility in financial markets has disturbed economic fundamentals including capital flow and economic growth in several European countries. To avoid such disturbances the monetary authorities have to implement a monetary reaction function by adopting an appropriate range for short-term interest rate consistent with the volatility of stock markets and depreciation of British pound. The monetary reaction function in this case shouldn't be only based on traditional Taylor's rule but also needs to take into account the volatility of stock markets and depreciation of pound versus major currencies. The goal of this paper is twofold. First, it tries to estimate the effects of Brexit on stock market volatility index for British FTSE, German DAX, and French CAC using econometric models and a dummy variable for post-Brexit. Second, it uses a Vector Auto Regression (VAR) model to stimulate the monetary reaction function of the European Central Bank (ECB) to find out how it may neutralize the adverse effects of stock market volatility on macroeconomic fundamentals.

Keywords: *Brexit, stock market volatility, Vector Auto Regression model (VAR), monetary policy reaction function, Taylor rule, currency depreciation, European Central Bank.*

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1. Introduction

As data for the EU and UK stock markets suggest and as emphasized by several authors including Raddant [1] Busch & Matthes [2] and Belke, Dubova, & Osowski [3], stock prices tumbled sharply post-Brexit. The volatility of stock market index is crucial for the related economies as it affects capital inflow and GDP growth substantially. The data suggest that French CAC and German DAX are highly and negatively correlated to the UK risks. The French CAC closed 8% lower on the day of Brexit and Germany DAX plummeted as much as 10% on the same day. Italy's FTSE/MIB and Spain's IBEX closed more than 12% lower. The unexpected result of the Britain's referendum sent the British pound to a free fall hitting its lowest level versus US dollar since 1985. Shares of French and German banks also tumbled; the uncertainty caused by Brexit not only created more volatility in the EU stock markets but also raised the idiosyncratic risk for the U.K. economy. Since stock market volatility is detrimental to capital flow, capital formation, and economic growth, it is of great importance to investigate how Brexit affected the stock market volatility in EU and how monetary authorities at ECB could react to absorb the shock by changes in short-term interest rate and adopting the appropriate monetary policy.

Indeed, stock market indexes are highly integrated among European countries as suggested by Breinlich et al. [4]; Raddant [1]; Raddant and Wagner [5]; this means a more volatile FTSE can lead to more volatility in other European stock market indices. To find out what are the outcomes of Brexit for stock markets in EU, this study implements econometric models to measure the effects of Brexit on the volatility of CAC, and DAX, and FTSE.

Indeed, the goal of this paper is twofold; first it measures the effects of Brexit on EU stock market indices including CAC, DAX, and FTSE through a dummy variable for post-Brexit; second, it implements a VAR reaction function to capture the reaction of monetary authorities and ECB to Brexit. In other words, the paper tries to answer two main questions. First, how has Brexit affected the volatility of stock market in EU, and second, what is the appropriate monetary policy reaction and the level of desirable change in short-term interest rate to neutralize the adverse effects of Brexit on stock market volatility and economic fundamentals. The results of this paper have important policy implications for monetary authorities and European Central Bank because it can help them to neutralize the adverse effects of Brexit on stock markets by adopting appropriate changes in short-term interest rate versus traditional Taylor rule.

The rest of paper is organized as follows: Section 2 reviews the literature on the effects of Brexit on European countries. Section 3 reviews data, and methodology.

Section 4 discusses the estimated econometric results, and finally section 5 provides findings and conclusions.

2. Literature Review

Post-Brexit reluctancy of entrepreneurs to trade with British firms not only has led to depreciation of British pound and a sharp drop in FTSE index but also has created more volatility in the EU stock market indices. This section briefly reviews the adverse effects of Brexit on EU economies and the relationship of stock markets with economic fundamentals.

Corradi, Distaso, & Mele [6] estimate the stock market volatility. They conclude the level of stock market volatility cannot be only explained by business cycle factors. They found industrial production growth is strongly responsible for random fluctuations of stock markets and inflation plays a limited role in this context.

Hsing [7] examines the relationship between Hungary's stock market index and relevant variables. He uses a GARCH model and finds out that stock market index has a positive relationship with real GDP, the ratio of government debt to GDP, nominal effective exchange rate, and the German stock market index, and a negative relationship with real interest rate, expected inflation, and the government bond yield, and a quadratic relationship with real M2.

Barasa [8] argues the movements in stock market prices are affected by changes in fundamentals of the economy and the expectations about future prices. He uses exchange rate, inflation, money supply and real GDP as independent variables. The estimated results for Kenya's stock market indicated that CPI has an inverse relationship with stock market index, but money supply and GDP have positive correlation with stock market index.

Gregor [9] investigate the effects of Brexit on the rest of EU and argues that the direct impact on the rest of EU would be significant. The exports, supply chain, investment would be adversely affected by Brexit, but the single biggest impact would be on the cost of raising finance in Europe, which is likely to increase.

Springford, Tilford, McCann, Whyte, & Odenhal [10] analyze the integration of the UK economy in EU. They show that Britain's EU membership has boosted its trade in goods with other EU states by 55%. Also, in 2015, the value of the UK banks' assets held in the Eurozone was 45% higher than their US assets, despite the Eurozone economy being only three-quarter of the size of the US economy.

Begg, I., and Mushovel, F. [11] estimate the economic impacts of Brexit on the UK economy. They agree that there would be a short-term negative shock to the EU economy from Brexit. Indeed, uncertainty around Brexit has deterred investment and there would be transactional costs of shifting to a new regime for trade and investment. Also, demand from other EU countries constitutes around 12% of final demand for UK goods and services and that translates to 3.3 million jobs. However, there are some import competing industries, which can be expected to see job increases if exit from EU means that they are more competitive. Also some groups in the UK, notably farmers and universities that succeeded in obtaining research grants from EU programs would potentially lose from Brexit.

Belke, Dubova, and Osowski [3] argue that financial market volatility increases with Brexit and spills over into markets through different channels. Thus uncertainty about Brexit may not only affect shares and exchange rate markets in the UK, but might also trigger spillover across EU countries. They find that there has been a considerable upward spike in stock market volatility during the Brexit referendum. According to their results, policy uncertainty shock contributed to 4.1%, and 3.2% of stock market and exchange rate volatilities, respectively. They use panel data to measure the effects of Brexit vote on stock market in several European countries and they found that an increase in the likelihood of Brexit vote has a strong negative effect on stock prices. However, the effects are stronger for countries of GIIPS (Greece, Ireland, Italy, Portugal and Spain), except Greece. Also, according to their results, Brexit vote decreased the value of pound by 0.12%.

Goodwin [12] analyses the effects of Brexit and concludes that Brexit would reduce GDP growth of the UK by 1.3 percentage point. Market prices would fall by around 15%, before recovering some of their losses, while heightened uncertainty would also drop the equity prices.

Jackson [13] discusses the immediate impact of Brexit, which is a sharp drop in British pound versus US dollar and Euro. He shows British stocks were down by 3.2% and European shares dropped by 8.6% as a result of Brexit.

Jackson, Akhtar, & Mix [14] analyze the effects of Brexit on financial market and UK economy and find that following Brexit vote pound depreciated by more than 10% at one point and the dollar appreciated against major currencies. Most major stock indexes and government bond yields tumbled. Though global financial markets relatively recovered by June 2016, the British pound and several British shares remained weak.

Kierzenkowski, Pain, Rusticelli, and Zwart [15] argue that Brexit shock acts through different channels. In the near term, the UK economy will be hit by tighter financial conditions and weaker confidence. By 2020 GDP would be 3% smaller than otherwise. In the long-term the effects would operate through capital market channel, immigration, and lower technical progress. The extent of foregone GDP would increase over time and by 2030, GDP would be 5% lower than otherwise. Brexit would also hold back GDP in other European countries due to heightened uncertainty.

Raddant [1] analyses the responses of European stock market to Brexit referendum. He finds while the impact of the vote was very similar for the stock markets in France, Germany and Spain, in Italy volatility among financial stocks intensified permanently.

Felbermayer, Fuest, Groschl, and Stohlker [16] investigate the effects of Brexit on European economy. They argue some sectors will be better off even if aggregate GDP falls. They use a Ricardian trade model where trade is driven by differences in productivity. Their simulation results suggest that Brexit will lead to a considerable decline in trade of goods and services. Under a hard Brexit UK's exports to Germany will drop by 50%, and German's exports to the UK will fall by 33%. They find that three-quarters of economic losses to Germany stems from manufacturing industries.

Bohdalova, & Gregus [17] use data from January 7, 2000 to February 3, 2017 to investigate the effects of Brexit on financial markets. They use German, French, Irish, Spanish, Turkish and Poland stock market indices. They found that Brexit uncertainty had the strongest influence on Irish stock market. They found that in bear markets, Brexit had the greatest impact on Spanish stock market, followed by the French and German markets, and followed by the Turkish and Irish stock market. However, Brexit had the smallest impact on the Polish stock market.

3. Data and Methodology

3.1. Data

The list of variables used in this study is provided in Table 1. The data on GDP, government debt, money supply, real interest rates, foreign exchange rates, and inflation have been retrieved from European Central Bank website. And the data for stock market volatility index have been retrieved from Eurostat website.

Table 1. List of Variables

SI	Stock Market Volatility Index
Y	Real output measured by GDP
Debt	Government Debt
M	Money Supply
r	Real interest rate
E	Nominal Effective Exchange Rate
SI^f	Foreign Stock Market Volatility Index
R^f	Foreign Interest Rate
π	Inflation
π^0	Expected Inflation
$\overset{0}{\xi}$	Depreciation of British Pound

3.2. Methodology

To measure the effects of Brexit on stock market indices including CAC, DAX, and FTSE, econometric models with quarterly data for the period of 2000-2015 have been used. Using Frankel [18] portfolio balance approach to exchange rate determination and following Hsing [7] and Hacker, Kim, and Mansson [19] we use the following econometric model to estimate the Brexit effects on stock market volatility, where the stock market volatility index (SI) is a function of real output Y, government debt (Debt), money supply (M), real interest rate (r), nominal effective exchange rate (E), expected inflation (π^0), foreign stock market volatility index (SI^f), foreign interest rate (R^f), and depreciation of British pound ($\overset{0}{\xi}$).

$$SI = a_0 + a_1 Y + a_2 Debt + a_3 M + a_4 r + a_5 E + a_6 \pi^0 + a_7 SI^f + a_8 R^f + a_9 Dummy. \quad (1)$$

Indeed, we embed a dummy variable to this model where the dummy takes one for the periods of post-Brexit and zero for pre-Brexit. The coefficient on the dummy variable would tell us how much Brexit has contributed to the volatility of the stock market indices versus other variables including money supply and short-term interest rate.

More importantly, the paper aims to find out how ECB can neutralize the adverse effects of Brexit using a VAR model and monetary reaction function in order to avoid capital outflow and stock market volatility. Following Gerlach-Kristen [20] we use an interest rate reaction function to Brexit shock through an expanded Taylor rule framework to find out how should monetary authorities react to Brexit in order to avoid the adverse effects on stock market volatility and economic fundamentals. Indeed, the main goal of this study is to model the behavior of short- term interest rate with respect to Brexit shock.

The traditional Taylor equation is as follows as discussed in Taylor [21]

$$r = \rho + \pi^* + k_\pi(\pi_t - \pi^*) + k_y y_t \quad (2)$$

Where ρ is real interest rate, y is the percent deviation of real GDP from a target, π is rate of inflation, and π^* is central bank inflation target. Taylor suggested the coefficient ρ =2, π^* =2, k_y =0.5 and k_π =1.5; however, as emphasized by Taylor and Volker [21] this specification suffers from omitted variables problem or misspecification, particularly when confronted with a shock like Brexit. Therefore they embedded d* into the model that captures possible deviation from the policy implied by the rule.

In other words, the simple Taylor rule would be unable to absorb the effects of Brexit shock because it lacks to take into account the effects of expected inflation and depreciation of pound; therefore, we capture post-Brexit effect in the model by embedding British pound depreciation $\overset{0}{\xi}$ and stock market volatility into the model as elements of possible deviation from the policy implied by the rule:

$$r = \rho + \pi^* + k_\pi(\pi_t - \pi^*) + k_y y_t + \xi + \overset{0}{SI}^f. \quad (3)$$

The estimated results for equation (3) with a VAR model enables us to simulate the reaction function of monetary authorities to Brexit by adopting an appropriate short-term interest rate in response to the shock. Indeed, the paper will have important policy implications for monetary authorities because it enables them to react to the adverse effects of Brexit shock on stock market indices and capital outflow through conducting appropriate monetary policy and adopting the short-term interest rate in appropriate range, which is consistent with monetary goals and stability of the markets.

4. Estimated Results

We test data for the co-integration and find out that all variables are stationary of degree 1. Therefore, we use the first difference of all variables. The estimated results for Equation 1 is provided in Table 2. More than 80 percent of changes in the stock market indices are explained by all

independent variables. The most important variable in explaining the stock market index is the real interest rate and effective exchange rate. We also used a dummy variable for post-Brexit periods; interestingly enough the related coefficient for Brexit is statistically significant for all stock markets, meaning that Brexit has led to at least 15% increase in volatility of FTSE, and 12% and 14% increase in DAX and CAC, respectively. The results here are consistent with those of Belke, Dubova, & Osowski [3] and Bohdalova, & Gregus [17], and Jackson, Akhtar, & Mix [14] who found that Brexit has led to higher volatility of stock market indices in EU.

To find out how ECB can neutralize the effects of Brexit shock on stock market volatility, a VAR model has been used to estimate the embedded Taylor equation with policy deviations using the depreciation of British pound and foreign stock market volatility index.

Table 2. Estimated Effects of Brexit on Stock Markets in EU

Independent Variables	FTSE	DAX	CAC
Y	0.01 (0.024)	0.21 (0.03)	0.14 (0.02)
Debt	0.13 (0.016)	0.14 (0.027)	0.18 (0.021)
M	0.08 (0.03)	0.17 (0.04)	0.015 (0.02)
r	0.21 (0.06)	0.31 (0.06)	0.41 (0.04)
E	0.34 (0.03)	0.43 (0.02)	0.35 (0.04)
Inf	0.07 (0.03)	0.04 (0.06)	0.07 (0.02)
FTSE	-	0.23 (0.05)	0.18 (0.04)
DAX	0.14 (0.03)	-	0.23 (0.0
CAC	0.17 (0.04)	0.25 (0.02)	-
Dummy for Brexit	0.15 (0.02)**	0.12 (0.01)**	0.14 (0.02)**
R-Squared	0.80	0.87	0.83

Note: Numbers in Parentheses are standard errors. * The variable is significant at 5% level, and ** is significant at 1% level.

Indeed, the technique used here are similar to that of Gerlach-Kristen [20] who proves that traditional Taylor rule shows sign of instability and misspecification for EU area and proposes a short-term interest rate reaction function that is related to inflation, output gap, and the long-term interest rate. Indeed, she uses a different specification in contrast to traditional Taylor rule by embedding the long-term interest rate in her reaction function. Following Gerlach-Kristen [20] we embedded a new variable into traditional Taylor rule, which accounts for policy deviation such as British pound depreciation and foreign stock market instability.

The results of the VAR model with embedded variables are provided in Table 3. The estimated results suggest that more than 73% of changes in real interest rate can be explained by expected inflation, GDP deviation form a target, depreciation of British pound, foreign stock market volatility, and lagged values of real interest rates. Also, depreciation of British pound is the most important variable after expected inflation. In other words, one percent depreciation of British pound leads to 0.3 percent increase in interest rate. Therefore, to neutralize the effects of pound depreciation, monetary authorities could reduce the short-term interest rate by 0.3 percentage point to neutralize the adverse effects of Brexit shock on the EU economies. Also, given the correlations between short-term interest rates and stock market volatility index based on our results, reducing the ECB interest rate by 1% can reduce the volatility of stock market in UK by 14%, and in Germany and France by 17% and 19%, respectively.

Table 3. The VAR model for interest rate (r)

Independent Variable	
π^0	0.36 (0.12)
y	0.12 (0.02)
ξ^0	0.34 (0.04)
FTSE	0.14 (0.01)
DAX	0.17 (0.02)
CAC	0.19 (0.02)
r_{-1}	0.15 (0.01)
r_{-2}	0.16 (0.02)
R-squared	0.76
Adjusted-R-Squared	0.73

5. Findings and Discussion

Given, the detrimental role of Brexit for the volatility of stock markets, as emphasized by several economists including Bohdalova, & Gregus [17], and Belke, Dubova, and Osowski [3] this study tried to answer two main questions: (i) what are the effects of Brexit on three main stock market indices in Europe, FTSE, DAX, and CAC, using econometric models and a dummy variable for Brexit; and (ii) how can European Central Bank (ECB) react to stock market volatility and neutralize the adverse effects of Brexit on stock market indices. To respond to this question we used Taylor and Volker [21] model with embedded variables accounting for policy deviation in the traditional Taylor model, using depreciation of British pound and volatility of foreign stock market index.

The estimated results in this study suggest that Brexit has had adverse statistically significant effects on stock market indices for FTSE, DAX, and CAC, and has led to at least 15% increase in volatility of FTSE, 12% and 14% increase in volatility of DAX and CAC, respectively. We also estimated a monetary reaction function to see how much change in interest rate is desirable to neutralize the eroding effects of Brexit on volatility of stock market. Reducing the ECB interest rate by 1% can reduce the volatility of stock market in UK by 14%, and in Germany and France by 17% and 19%, respectively. The study has important policy implications for ECB and monetary authorities and can help them to neutralize the adverse effects of Brexit by adopting appropriate changes in short-term interest rates.

This study can be expanded in different directions in the future; first by using more stock market indices of EU countries to see whether Brexit has affected other stock

market volatility or not. Second, another direction for future studies is to implement different methods of estimation including Generalized Method of Moment (GMM) and Vector Error Correction Model (VECM) to compare the validity of our results.

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