BREXIT referendum' s impact on the financial markets in the UK

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Abstract

BREXIT might be considered the most paramount event of the past 40 years in modern English history. The present research attempts to examine the impact of BREXIT referendum vote on the British financial markets. We examine the impact of money and capital markets on the forex markets in the UK. In our research, we utilize the ECM-Realized-EGARCH model. Our findings support that there is an excess volatility on the GBP after BREXIT vote. After BREXIT vote, we observed that a momentum strategy crash led to the excess volatility on the UK financial markets. Finally, we found out that a further devaluation of the GBP is likely, which may lead to a vast decrease of GBP value especially against the euro and the US dollar in the near future after BREXIT.

Keywords: forex risk, ECM-Realized-EGARCH, BREXIT, currencies, FTSE-100, stock markets

JEL: C5, F3, F31, G15, G17

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1. Introduction

The BREXIT vote event has raised high levels of alertness for the investors, multinational companies and individuals in respect to the participation of the UK in the European Single Market (ESM). Regardless of the outcome and the duration of the political negotiations between the European Union and the British government, financial markets and multinational enterprises had already prepared to confront the BREXIT event regardless the outcome of the diplomatic negotiations. Particularly, Dhingra *et al.* (2017) found out that a soft-BREXIT may decrease the average income per capita by 6.3% in the UK. On the other hand, a hard-BREXIT may weaken the average income per capita by 9.4%, partly via the decline in foreign direct investments (FDI). Actually, a potential divestment or a decline in FDIs would negatively affect the nominal exchange rate of the British pound in the long run.

Moreover, Srovnalikova and Razinskaite (2017) believe that BREXIT may have a negative impact on inward foreign direct investment. They found out that UK leaving the EU will reduce foreign direct investments. Such losses will damage the UK investment and reduced productivity will consequently reduce real incomes. Such an incident will inevitably lead to further depreciation of the British currency in international foreign exchange markets. Finally, Choudhry *et al.* (2016) investigated the relationship between stock market volatility and the business cycle in four major economies, namely the US, Canada, Japan and the UK. Their results offer that there is a bidirectional causal relationship between stock market volatility and the business cycle within each country and additionally reveal that the recent financial crisis plays a significant role in this context. Finally, Dao *et al.* (2017) studied the effect of the Brexit vote on the intraday correlation and volatility transmission among major currencies. They discovered that the vote causes an increase in the correlation among the safe-haven currencies of the Swiss franc and Japanese yen as well as gold, and also find a decrease in their correlation with the directly involved currencies of British sterling and the Euro.

Consequently, the principal research aims of this study are to examine a) the impact of BREXIT referendum on the financial markets of the UK (stock, bond and forex markets) and b) the potentials of GBP against the USD and the euro after the official BREXIT era. In specific, we test the influence of FTSE-100 and the 10-year UK government bond yield on the nominal exchange rate of sterling against the euro and the US dollar.

Under these circumstances, we attempted to investigate this issue by providing evidence from the British financial markets (stock, bond market and forex market). In particular, we used the Error Correction Model (ECM) as a mean equation and the Exponential Realized GARCH (R-EGARCH) as a conditional variance equation. Actually, we created a brand-new drift of these econometric models, ECM-R-EGARCH. This model provides the opportunity to isolate the realized long-term volatility which is the most important interest of our research. Realized long-term volatility is able to express the reaction and the impact of the control variable on the dependent variable in the long- run, from the realized volatility aspect of view (Degiannakis and Floros, 2015). The use of errors in the mean equation provides information about the realized causality of leverage effect in the long-run (asymmetries). Therefore, our results express higher validity on the estimation of the realized volatility and the realized effect of bad and good news (leverage effect) than the use of the two models (ECM and Realized-EGARCH) separately (Stoupos and Kiohos, 2017).

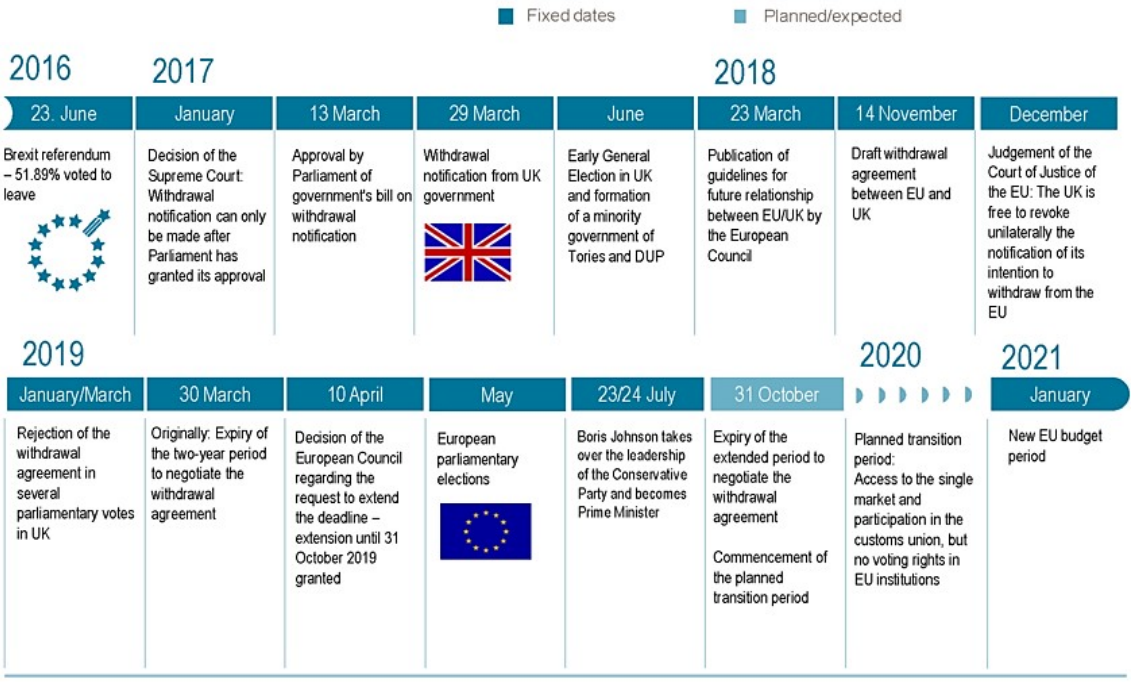
We reckon that the outcomes of the present paper provide important evidence to the academia, EU/UK policy makers, international institutions (IMF, World Bank, BIS), investors, risk managers and individual people across the globe. Particularly, if a strong political event is able to crash the currency of a highly developed country, such as the UK, we expect that similar events are able to have analogous effects. This means that they secure the value of their investments due to the upcoming BREXIT event. According to the EU officials (2019), the withdrawal of the UK from the EU (BREXIT) will commence on 31st January 2020, after the second official postponement of 29th October 2019. In the meantime, an adjustment period will take place, which will eventually terminate on 31st December 2020. Also, it was decided that only Northern Ireland will have access to the European Single Market and the customs union.

Moreover, companies and individuals could be prepared to safeguard their wealth by purchasing different currencies or investing their money in commodities or corporate and governmental bonds. Finally, the empirical findings offer sufficient evidence that a devaluation of the British pound against the euro and the US dollar may occur due to the upcoming BREXIT. A swift devaluation of GBP will shock the British economy by affecting internal consumption due to the imported inflation. Imported inflation may be set off by imports price increases, or by depreciation of a country's currency exchange rate. An increase of the general prices will lower the income of the British people when they purchase imported goods and services. On the other hand, a depreciated pound will increase British exports. However, it is not still clear if the UK will remain a member of the European Single Market after BREXIT, unless the UK signs a special trade agreement

with the EU. Otherwise, trading relationships will be set off according to the principles of the World Trade Organization (implementation of tariffs, quotas or licenses).

Before concluding, we reckon that it will be useful to present the most important political events of BREXIT negotiations from 2016 to 2020. This table will aid our analysis to explain how the political events influence the reaction in the financial markets (finance behavior).

Figure 1: Timeline of BREXIT negotiations from June 2016 to January 2021.



2. The theoretical linkages between exchange rates and stock market prices

If a country's stock exchange market is outperformed, should we expect its currency to be appreciated or depreciated? This is an important research question, especially if we take into account the excess performance of the British stock exchange market following the referendum of June 23rd, 2016 (BREXIT vote). The British pound maximum collapsed by approximately 19% against the euro (10 August 2019, 1£=1.0647€) and 19% against the US dollar (12 August 2019, 1£=1.2019$) due to the outcome of the aforementioned referendum. On the other hand, we observe that the UK stock exchange index (FTSE-100) outperforms continuously after BREXIT vote, reaching its highest historical point (7.778,79 units) on 18th May 2018.

Momentum investing strategy refers to creating a portfolio which contains only winner stocks and gets rid of all the loser stocks in the market based on the concept that stocks that performed well over a certain period in the past are expected to have the same performance over the upcoming period of time (Lui *et al*., 1999 and Hong *et al.,* 2000). This strategy is based on short-term investments which lay between a three to a twelve-month period (Lui *et al*., 1999 and Jegadeesh and Titman, 1993). Concerning the risk that this investing strategy involves, tests such as Barrett and Donald (2003) and Chan *et al.,* (2000) that were applied on momentum strategies on 24 international stock indices over a period of 11 years (1989-2000) showed that the profits were risk-adjusted (Fong *et al.,* 2005).

On the other hand, the theory of uncovered equity parity, suggests the exact opposite, invest in subsequently past losers and sell past winners. The risk increases when foreign equity holding perform better that domestic ones, as investors have to deal with higher exchange rates, so they choose to sell some of their foreign equity and repatriate it (Aftab *et al.,* 2018).

Alternatively, the uncovered equity parity (UEP) explains how equity portfolio rebalancing affects exchange rates. Outperformance of foreign stock markets, whether through the exchange rate or stock prices, leaves investors with excess exchange rate exposure. The reduction of this exposure then puts depreciation pressure on the foreign currency (Melvin and Prins, 2015).

In addition, the volatility of stock returns can be explained by many factors, including liquidity risk, information asymmetry, number of informed agents, segmentation, number of regulations and their imbedded costs quality of the banking system and the impact of investibility (i.e' the degree to which a stock can be foreign-owned on the stock return volatility') as suggested by Bae *et al.* (2004).

In an international context, the variability of forex rates is clearly a potentially interesting factor that drives the level of the volatility of stock returns. With the liberalization and the reduction of barriers to international investment, foreign investors can benefit from diversifying their portfolios (Lesmond, 2005).

As a consequence, agents are more likely to move their portfolios from a stock exchange market to another. This implies a greater sensitivity to the exchange rates and a priori a positive transmission mechanism between the stock returns volatility and the forex rates volatility (Byström, 2014).

The study of Hau and Rey (2006) suggests that the foreign exchange and the stock market returns should be negatively correlated due to portfolio rebalancing. This occurs because of the uncovered equity parity condition (Melvin and Prins, 2015). Grobys (2014) also discovered that there are negative linkages between stock markets and currencies, especially during economic recessions.

On the contrary, there are more recent studies which reinforce the fact that the linkages between stock markets and foreign exchanges are either unrelated (Cenedese *et al.* 2016) or positive (Tian and Ma, 2010). Furthermore, the research of Kutty (2010) found out that positive short-term linkages take place between the foreign exchange rate returns and stock market indices, but there is not enough evidence to support the presence of long-term dynamics notwithstanding. Similar results had been detected by Katechos (2011), indicating the positive relationships between stock market indices and currencies. Canadese *et al.* (2016) demonstrate that the positive dynamics between foreign exchange and the stock market returns exist due to the momentum strategy where, in fact, currencies' returns do not operate counterproductively against the investors. Eichler and Maltritz (2011) attempted to provide evidence with regard to the correlation between stock markets and currency crises. Their findings maintain that the successful economies -with high capital flows into their booming stock markets are particularly prone to stock market-induced currency crises. Koulakiotis *et al.* (2015) examined the relationship between stock markets indices and exchange rates. They confirmed that the relationship between stock and foreign exchange markets is sensitive to short-term good or bad news and short-term minor or major news. On the other hand, Bauer (2007) researched the volatility linkages between the stock markets and exchange rates by using a Trend-GARCH model. His results unveiled that the leverage effect was dependent on the current trend, i.e. it is differentiated between bullish and bearish markets. Panopoulou and Pantelidis (2015) investigated the periodically collapsing bubbles in the British pound to US dollar exchange rate in the post-1973 period. Their findings suggest that various robustness checks based on other exchange rates show that the optimal bubble measures and optimal predictors critically depend on the exchange rate. Kariofyllas *et. al.* (2017) discovered abnormal returns in the UK stock markets due to BREXIT referendum vote. Their findings confirm the existence of under- and over-reaction in London Stock Exchange. Recently, Davies and Studnicka (2018) show that BREXIT impact on the UK stocks' abnormal returns can be explained by the firm's global value chain, with firms heavily exposed to the EU and UK doing worse. In addition, they find that firms reliant

on imported intermediates also perform worse. This, however, is partially offset via intra-firm trade in intermediates when Sterling fell relative to host currencies.

The rest of the paper is organized as follows. Section 3 presents our data. Section 4 includes the methodology, and Section 4 presents the preliminary diagnostics tests (unit root test and co-integration test). Section 5 includes the empirical results of the combined methodology, ECM-Realized EGARCH, and Section 6 concludes.

3. Dataset Analysis

The present research uses the nominal exchange rate of EUR and the USD against the GBP and the units of FTSE-100. We selected the nominal exchange rate of EUR against the GBP because the European Union is the largest trading partner of the United Kingdom. According to HM Revenue and Customs (November 2018), the UK imports goods and service of 220,7 billion GBP from the EU. In addition, the UK exports goods and services of 151 billion GBP to the EU. Respectively, the UK is highly exposed to the US as a trade partner (2nd in rank). In specific, the UK exported annually 101 billions of GBP to the US in 2017. Also, the UK imported yearly 65 billions of GBP from the US in 2017.

In addition, we chose the nominal exchange rate of the USD because the exposure of the British stock markets to the American investors and investment institutions is equal to 21,6%. Respectively, we selected euro, since the exposure of the FTSE-100 to European investors and investment funds is equal to 30,2% (EU-27). The UK investors (individuals and institutions) hold only 12% of the total stocks in the British stock exchange market (FTSE Russel, 2018).

Also, we selected the 10-year government UK bond as a control variable, since we reckon that the yields of government bonds represent the expectations of the investors for the potentials of an economy. Also, the interconnections among the money markets (bonds) and the stocks and forex markets are strong, since the majority of investors interact simultaneously at these markets. Also, the 10-year government bond yield reflects the country risk, since the investors will demand higher interest rates in order to lend their money.

Lastly, we reckon that the selection of these variables (nominal exchange rates, FTSE-100 and 10-year UK bond yields) are suitable to display the reaction of the UK financial

markets against the timeline of BREXIT negotiations. The finance behavior of investors is significantly influenced by the political events and especially by the uncertainty conditions that political instability could emerge. Actually, we believe that the excess volatility of the UK financial markets after the UK referendum is influenced by the BREXIT negotiations between the EU and the UK. The investors will tentatively invest in the long-run on an economy when they are not certain about the outcome of their investment.

We decided to examine the impact of the British referendum (23rd June 2016) on the UK financial markets (stock, forex, bonds). We chose 60-minutes frequency intraday data from 06:00 GMT 09 June 2015 to 18:00 GMT 30 September 2019 (more recent data). We selected this frequency because we would like to examine the data which is close to the actual condition of the UK financial markets. Our dataset covers a period of over four consecutive years and the number of the observations are equal to 14.539. Our break point was at 06:00 GMT 24th June 2016. We decided to use this date because the first official results of the UK referendum presented a tendency that a BREXIT vote was imminent. The GBP was extremely volatile against the leading currencies at that time. In addition, the FTSE-100 pre-block reporting starts at 06:00 and closes at 17:30. Moreover, we selected the 09th June 2015 as the start date since, the House of Commons authorized the British Government to hold an EU participation referendum on 23rd June 2016. Also, we mention that we have empirically divided our dataset into two periods (pre-Brexit referendum and post-Brexit referendum) by using the Perron breakpoint unit root test. No dummy variable was used in our estimation model. The data was extracted from the official database of Bloomberg®.

Table 1 presents the features of each variable by indicating the nature, the acronym and the official symbol at the international markets.

Table 1: Data Presentation

Variables	Acronym	Measure	Symbol	Frequency
Euro	EUR	EUR/GBP	€/£	60 minutes
US Dollar	USD	USD/GBP	$/£	60 minutes
FTSE-100	UKX:IND	GBP	£	60 minutes
10Y UK Bond	UK10Y	GBP	£	60 minutes

Source: Bloomberg ®

Important milestones for the construction of the intra-day time series are the following:

1) Non-trading hours: We excluded any trading from the dataset that took place from Friday 18:00:01 GMT until Monday 05:59:59 GMT.
2) Holidays: We do not include any bank holidays in our dataset where the trading activity is extremely low. In particular, we removed the following bank holidays: Christmas, Boxing Day, New Years' Eve, Catholic Good Friday, Catholic Easter Monday, International Workers' Day and Thanksgiving Day.
3) Common sample: We chose the trading days when the currencies (EUR, USD), 10-year UK bond yield and FTSE-100 are traded in order to have a common sample across each time series.
4) Time zone: We decided to use the Greenwich Mean Time (GMT) as our time-zone in order to construct and weight our dataset.
5) Calendar sampling: We selected the calendar sampling as it is most commonly used in the global literature and hence, permits the comparability of the results.
6) Common Trading hours: We used common trading hours (early, regular and late) for 10 year UK government bond, FTSE-100 and the currencies (EUR, USD) from 06.00 GMT to 18:00 GMT (official trading hours of FTSE-100).

4. Methodology

We produced our empirical results by using two diagnostics tests (Perron breakpoint unit root test and Johansen co-integration breakpoint test) and a combination of the ECM with the Realized Exponential GARCH. The use of Perron breakpoint unit root test will reveal the cut point of our dataset and the non-stationarity of our time series, the ECM will unveil the existence of short- and long-term realized dynamic linkages and the Realized EGARCH will show the realized volatility in the long-run.

3.1 Johansen's Co-integration test with structural breaks

The Johansen's Co-integration Test with structural breaks is based on a model which allows for any pre-specified number of sample periods (q) of length $T_j - T_{j-1}$ *for* $j = 1,\ldots,q$ *and* $0=T_0 < T_1 < T_2 < \ldots < T_q = T$. It follows that the last observation in the jth sample is T_j while T_{j+1} is the first observation in sample period number (j+1). A vector autoregressive model of order k is considered. In analogy with the usual models without structural breaks, the model is

formulated conditionally on the first k observations of each sub-sample, $X_{T_{j-1}+1}, \ldots, X_{T_{j-1}+k}$, and it is given by the equation:

$$\Delta X_t = (\Pi, \Pi_j)\begin{pmatrix} X_{t-1} \\ t \end{pmatrix} + \mu_j + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-1} + \varepsilon_t \quad (1)$$

for j = 1,…,q and $T_{j-1} + k < t \leq T_j$. The innovations are assumed to be independently, identically normally distributed with mean zero and variance Ω. The parameters vary freely, so Π, Γ_i, Ω which relate to the stochastic component of the time series are the same in all sub-samples and of dimension (p x p) with Ω being symmetric and positive definite, while the p-vectors Π_j, μ_j relate to the deterministic component and could be different in different sample periods (Johansen *et al*. 2000).

3.2 The Error Correction Model (ECM)

Engle and Granger (1987) claimed that movements of a group of variables may be best described by using the ECM if the examined series are stationary and co-integrated in the long run. Our ECM model is the following:

$$\Delta FOREX_t = \theta_i * \Delta log(FTSE100)_t + \psi_i * (FOREX_{t-1} - \lambda_i * log(FTSE100)_{t-1}) + a_i * UKB + e_t \quad (2)$$

where,

θ shows the short term dynamics
ψ displays the adjustment speed back to equilibrium
λ expresses the long term equilibrium relationship
α is the coefficient of the 10-year British government bond

FOREX is the value of nominal exchange rate of EUR/GBP, CHF/GBP or USD/GBP (dependent variable)
log(FTSE100) is the logarithmic value of FTSE100 (units) (independent variable)
UKB is the 10 year UK government bond yield (control variable)

3.3 Rolling Regression

Rolling approaches (also known as rolling regression, recursive regression or reverse recursive regression) are often used in time series analysis to assess the stability of the model parameters with respect to time (Banerjee *et al.* 1992). A common assumption of time series analysis is that the model parameters are time-invariant. However, as the economic environment often changes, it may be reasonable to examine whether the model parameters are also constant over time. One technique to assess the constancy of the model parameters is to compute the parameter estimates over a rolling window with a fixed sample size through the entire sample. If the parameters are truly constant over the entire sample, then the rolling estimates over the rolling windows will not change much. If the parameters change at some point in the sample, then the rolling estimates will show how the estimates have changed over time (Banerjee *et al.* 1992).

3.4 The Exponential Realized GARCH model (R-EGARCH)

According to Hansen and Huang (2012), an Exponential Realized GARCH is structurally improved than the Realized GARCH (Hansen *et al.* 2012). This happens because the model shows three advantages:

a) Shares the simple structure of GARCH, while keeping some characteristics (leverage effect, skewness and kurtosis) of stochastic volatility (SV) models.
b) Improves the empirical fit of data and provides better forecasting performance than GARCH models.
c) Enables the observation insights on the properties (accuracy, bias, variance) of different realized measures.

According to Hansen and Huang (2012), a Realized EGARCH with K realized measures is given by the following equations:

$$\log(h_t) = \omega + \beta \log(h_{t-1}) + r(z_{t-1}) + \gamma u_{t-1} \quad (3)$$

$$\log(x_{k,t}) = \xi_k + \varphi \log(h_t) + \delta_k(z_t) + u_{kt}, k = 1, \dots, K \quad (4)$$

Where, β is the persistence parameter, $\delta(z_t)$ is the leverage effect and $r(z_{t-1}) + \gamma u_{t-1}$ captures the volatility shock. φ parameter has the restriction to be close to unity.

5. Empirical Results

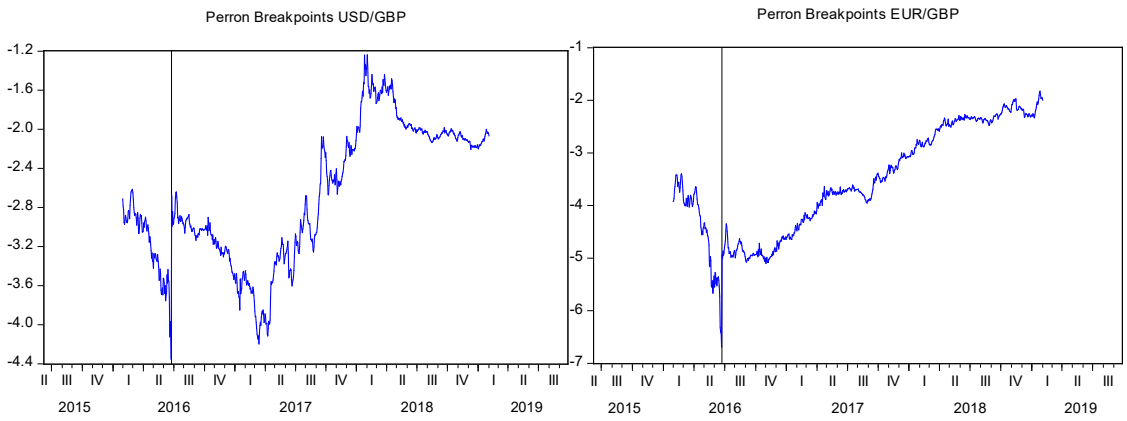
The ECM is suitable to explore short- and long-term interrelationships among a group of variables and the condition of their equilibrium. Additionally, the Realized EGARCH (Hansen and Huang, 2012) is more appropriate for the intraday data and more precise than the typical EGARCH model (Nelson and Cao, 1992). The Realized EGARCH captures the volatility persistence and asymmetry, as well as, the volatility shocks' responses. The development of our model is based on a combination of ECM with Realized EGARCH, by creating a new ECM-R-EGARCH model. In detail, we used the ECM as the mean equation and the Realized EGARCH (1,1) as the conditional variance equation.

Table 2: Estimation Results of Perron breakpoint unit root test		
Series – Values	**t-statistic**	**Probability**
EUR/GBP	-6.69*	0.000*
USD/GBP	-4.35*	0.003*
Log(FTSE100)	-5.04*	0.000*
10Y UK BOND	-3.43*	0.009*

**statistically significant at 0.01 level*

Table 2 provides evidence about the stationarity of the time series (first differences) by using the unit root breakpoint test of Perron (1997). We observe that both examined variables are non-stationary at 1% level of significance. The Perron breakpoint unit root test is most suitable in order to empirically determine the cut point of our dataset. According to this test, we have found out that the Brexit referendum's is our breakpoint date.

Figure 2: Perron unit root test Breakpoint



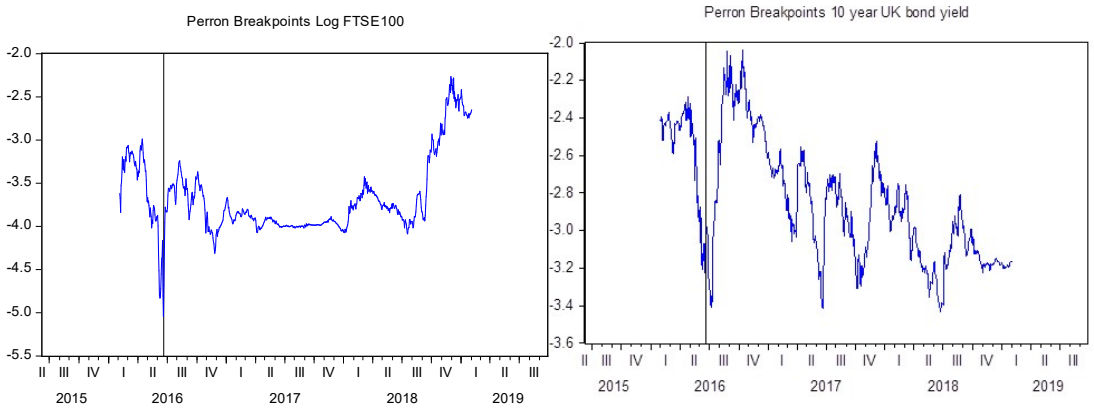


Figure 2 reveals that the breakpoint is the date of BREXIT vote (24/06/2016). This breakpoint is the same for the three examined variables (endogenous and exogenous). Therefore, we are statistically eligible to use this date as a break point in our empirical analysis.

Table 3 shows the empirical findings of structural breakpoint co-integration preliminary test (Johansen *et al.,* 2000) for EUR/GBP, USD/GBP and the 10-year UK bond yield against the logarithmic value of FTSE-100. We decided to use the logarithmic value of FTSE-100, since the logarithms create more stable and reliable results at the forecasting of a model.

Table 3: Johansen's Co-integration test with structural breaks EUR/GBP vs log(FTSE100)				
Hypothesized No. of CE(s)	**Eigen Value**	**Trace statistic**	**Critical Value**	**Probability**
None	0.001224	20.555	15.495	0.0079**
At most 1	0.000190	2.759	3.8415	0.0967
Johansen's Co-integration test with structural breaks USD/GBP vs log(FTSE100)				
Hypothesized No. of CE(s)	**Eigen Value**	**Trace statistic**	**Critical Value**	**Probability**
None	0.000837	15.698	15.495	0.0466**
At most 1	0.000003	3.528	3.8415	0.0603
Johansen's Co-integration test with structural breaks 10YUK vs log(FTSE100)				
Hypothesized No. of CE(s)	**Eigen Value**	**Trace statistic**	**Critical Value**	**Probability**
None	0.004425	23.439	25.872	0.0975*
At most 1	0.001176	4.914	12.518	0.6088

**statistically significant at 0.1 level, **statistically significant at 0.05 level,*

The results of Johansen's Co-integration test with structural breaks show that there is a long-

term tendency between the nominal exchange rate of EUR/GBP and the UK stock market index (FTSE100). Similar results revealed for USD/GBP and 10-year UK bond yield against the FTSE-100.

Table 4 displays the findings of the ECM-R-EGARCH(1,1) model during the total period, as well as, the two sub-periods for the euro and the US dollar. It is important to remind that we used the ECM as the mean equation and the Realized EGARCH as the conditional variance equation in our analysis. Moreover, we mention that the nominal exchange rates of euro and US dollar vis-à-vis sterling are the dependent variables. The logarithmic value of FTSE-100 is the independent variable and the yield of 10-year UK bond is a control variable.

One interesting feature of the results reposted in Table 4 is the speed with which the exchange rate adjusts to its equilibrium value. The empirical evidence of ECM supports that a disequilibrium exists between the nominal exchange rate of EUR/GBP or USD/GBP and the FTSE100 before BREXIT vote. The adjustment speed back to equilibrium is -0.0059 (statistically significant) for euro and -0.0027 for US dollar. This means that the -0.59% of a deviation from the error correction mechanism (ecm) is corrected within 60 minutes for the euro, and the -0.27% of a deviation from the error correction mechanism (pre-UK referendum era).

Additionally, it is clear that the FTSE100 does not influence (statistically insignificant) the exchange rate USD/GBP in the short-run. This means that possible reductions of the FTSE-100 influenced the nominal exchange rate between the US dollar and the pound neutrally. On the contrary, the UK stock market index has a short-term positive impact on the exchange rate of EUR/GBP. This indicates that possible increases of the FTSE-100 overvalue sterling against euro before BREXIT referendum vote. However, the long-term dynamics reveals a negative tendency between the UK stock market and the nominal EUR/GBP (-0.208) and USD/GBP (-0.202). Also, the estimation of the model reveals that there is a positive relationship (statistically significant) between the euro and the 10-year UK bond yield (0,16%) only for the pre BREXIT referendum era. For instance, if the FTSE-100 and the 10-year UK bond yield increases by 5%, the sterling shall fall by 1,44% (on average) against the euro and 0,65% (on average) against the US dollar, before the UK referendum era.

On the other hand, we observe that there are neutral short-term linkages between the EUR/GBP or the USD/GBP and FTSE-100 after BREXIT referendum vote. This signifies that possible fluctuations of the FTSE-100 have no impact on the nominal exchange rate between the euro or the US dollar and the pound. Additionally, a negative adjustment speed

back to equilibrium takes place after BREXIT referendum vote (disequilibrium). Its value is equal to -0.0263 or -2.63% which indicates that -2.63% of a deviation from the error correction mechanism is corrected within 60 minutes for the euro dynamics. Respectively, the value of ecm for US dollar is equal to -0.040 or -4% which indicates that -4% of a deviation from the error correction mechanism is corrected within 60 minutes.

Table 4: Empirical Results of ECM-Realized EGARCH EUR/GBP vs log(FTSE100)

Time	ψ	θ	λ	α	ω	β	r+γ	ξ	φ	δ
Total Period	0.0922 (2.52)*	-0.0057 (-2.45)*	-0.231 (-3.72)*	0.0012 (1.73)	0.00007 (3.02)*	0.903 (50.77)*	0.115 (6.58)*	-0.0008 (-1.55)	1.01 (3.59)*	-0.075 (-4.80)*
Pre-BREXIT vote	0.103 (2.85)*	-0.0059 (-2.51)*	-0.208 (-4.69)*	0.0016 (2.01)*	0.00002 (1.44)	0.901 (26.59)*	0.206 (3.27)*	-0.0039 (-2.15)*	1.03 (5.81)*	-0.252 (-3.24)*
Post-BREXIT vote	0.0332 (0.54)	-0.0263 (-3.87)*	-0.291 (-32.99)*	0.0003 (0.48)	0.00001 (3.29)*	0.867 (28.65)*	0.071 (3.07)*	-0.0005 (-0.69)	0.957* (2.51)*	-0.019 (-0.91)

Empirical Results of ECM-Realized EGARCH USD/GBP vs log(FTSE100)

Time	ψ	θ	λ	α	ω	β	r+γ	ξ	φ	δ
Total Period	-0.0681 (-1.03)	-0.0092 (-2.95)*	-0.263 (-9.47)*	0.0022 (2.35)*	0.0003 (3.74)*	0.779 (18.70)*	0.197 (7.09)*	-0.0009 (-1.46)*	0.976 (2.32)*	-0.128 (-5.33)*
Pre-BREXIT vote	-0.0379 (-0.41)	-0.0027 (-2.87)*	-0.202 (-32.11) *	0.0015 (0.91)	0.0001 (7.03)*	0.968 (175.61)*	0.108 (7.23)*	0.0023 (3.01)*	1.07 (4.51)*	-0.222 (-7.40)*
Post-BREXIT vote	-0.086 (-0.93)	-0.040 (-5.68)*	-0.368 (-19.64)*	0.0053 (4.17)*	0.0006 (5.06)*	0.733 (16.22)*	0.053 (2.78)*	-0.0008 (-0.81)	0.939 (2.25)*	0.005 (0.18)

**statistically significant at 0.05 level*

The most important finding is that the long-term dynamics after BREXIT referendum vote between the variables (euro and US dollar) are strictly negative. This indicates that possible increases of the FTSE-100 have a larger negative impact on the nominal exchange rate between the euro or the US dollar against the sterling, than the pre-BREXIT referendum era. Actually, whereas the FTSE-100 increases, the nominal exchange rate of the EUR/GBP or the USD/GBP decreases.

The dynamics between the USD/GBP and the 10-year UK bond yield (0.53%) are positive (statistically significant) only after the BREXIT referendum period. For instance, if the FTSE-100 and the 10-year UK bond yield increases by 5%, the sterling shall fall by -2.97% (on average) against the euro and -6.02% (on average) against the US dollar, after the UK referendum era.

The results of Realized EGARCH reveal that the β coefficient is lower after BREXIT referendum vote. This implies lower realized volatility persistence of the EUR/GBP or USD/GBP against the shocks of FTSE-100 after BREXIT vote. The size effect (r+γ) is statistically significant and positive during the two eras. This means that once the asymmetric impact of innovations is accounted for, the absolute size of the innovation is also important. The φ parameter fulfills the stability criteria of realized EGARCH since its value is close to unity.

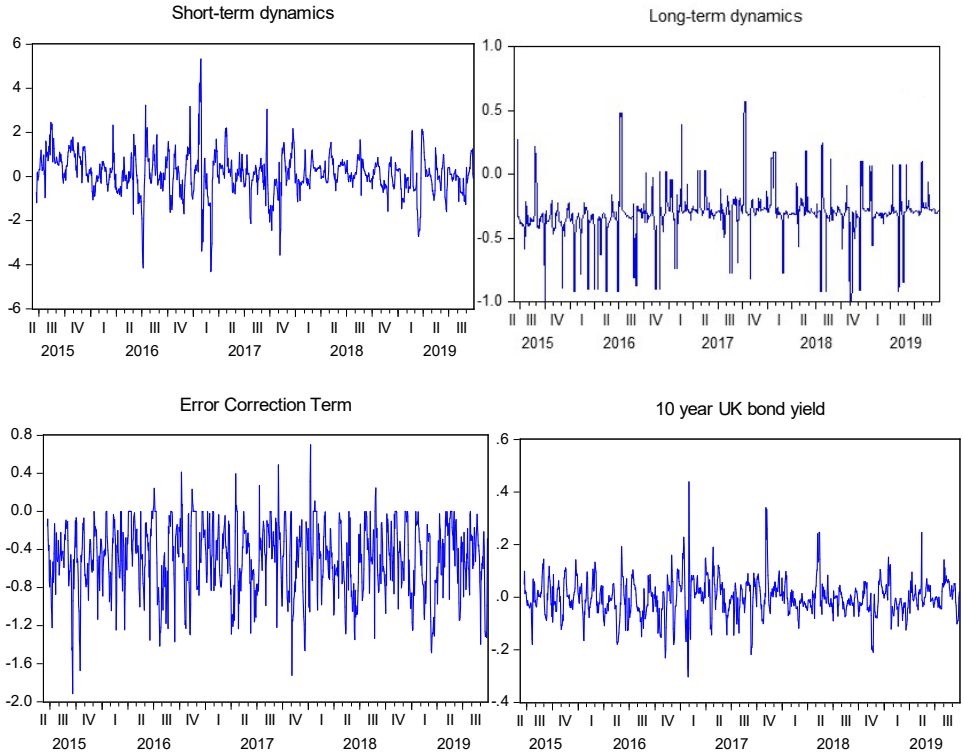
Also, we observe that the leverage effect is negative before BREXIT referendum vote, suggesting that positive shocks imply a higher next period conditional variance than the negative shocks of the same sign. Thus, the increase of FTSE-100 influences higher the EUR/GBP or USD/GBP instead of the decrease of FTSE-100. Particularly, the good news of the FTSE-100 (stock index rise) shows a 25.2% greater impact than the bad news of the FTSE-100 (stock index decrease) on the nominal EUR/GBP exchange rate before BREXIT vote referendum. Additionally, the good news of the FTSE-100 (stock index increase) shows a 22.2% greater impact than the bad news of the FTSE-100 (stock index fall) on the nominal USD/GBP exchange rate before BREXIT vote referendum. On the other hand, the leverage effect is not statistically significant after BREXIT referendum vote for both currencies indicating equal impact of negative and positive shocks' responses.

Figure 3 presents the results of rolling regression[3] by clearly supporting the findings of the ECM model for EUR or USD.

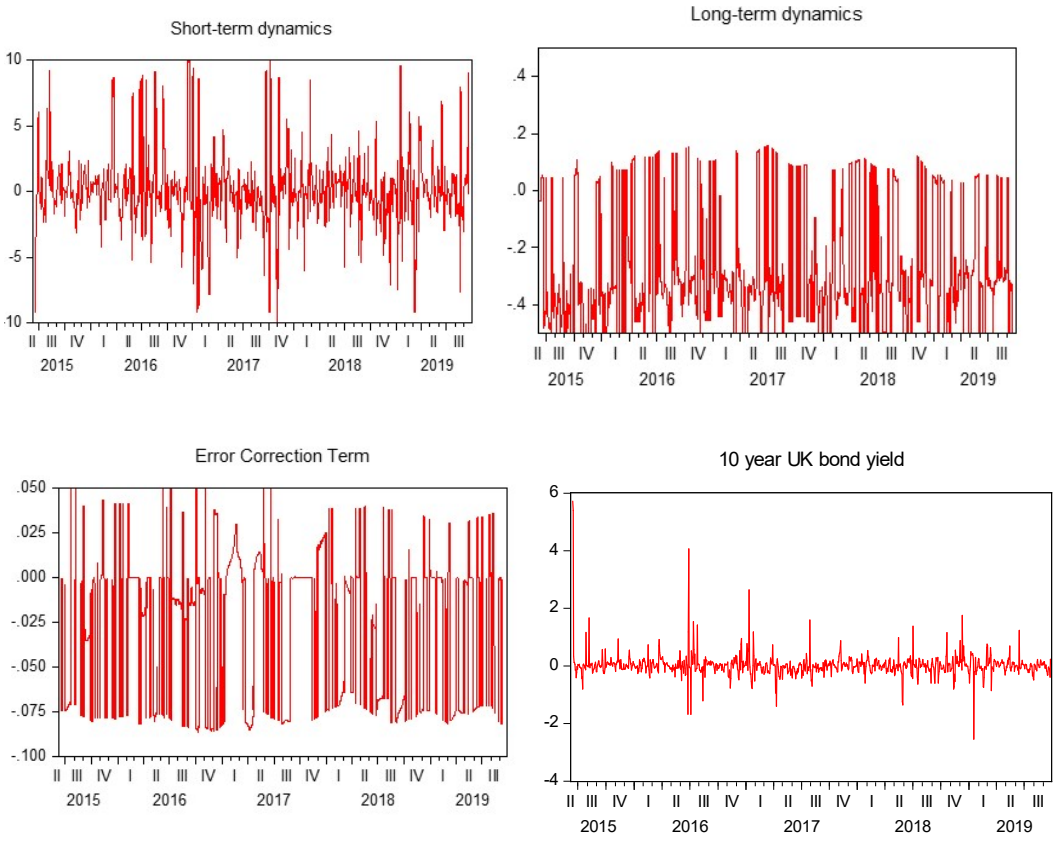
The results of the rolling window reveal that the stock market and the forex market in the UK are not in equilibrium from BREXIT referendum's announcement (mid-2015) vote until the third trimester of 2019. This means that there are internal and/or external forces that prevent market equilibrium from being reached or cause the market to fall out of balance. This could be a short-term impact of a change in the UK stock market index or a result of long-term structural imbalances.

[3] Also known, as rolling window, recursive regression or reverse recursive regression.

Figure 3: Rolling Regression Outcome EUR/GBP vs log(FTSE100)



Rolling Regression Outcome USD/GBP vs log(FTSE100)



Furthermore, we observe that there are periodically strong, positive and negative short-term reactions from BREXIT referendum's vote until the third trimester of 2019. These reactions seem to be related with the political events regarding the possible outcome of negotiations between the EU and the UK. This means that the markets reacted positively when good news emerged and negatively at bad news. Also, we observe that the reactions are sharper and more violent for USD vis-à-vis GBP nominal exchange rate in the short-run. On the contrary, the results of the long-term dynamics reveal that the reactions are constantly negative from BREXIT referendum's first announcement until nowadays (October 2019). The realized responses seem to be stronger against the US dollar instead of the euro. We reckon that this behavior in the UK financial markets come from the US investors rather than the EU investors. Also, there strong indications that a momentum investing takes place in the UK financial markets after the BREXIT referendum's era, since the investors do not wish to invest in the long-run due to uncertainty conditions.

Lastly, the 10-year UK bond yield (money markets) play no important role on the nominal exchange of euro or US dollar against the sterling. However, we observe strong reactions of the UK government bond when important political events occurred. For instance, we mention that strong responses take place during the BREXIT referendum's outcome (23 June 2016) and when there was an official announcement that the British government and the European Commission came to a final decision concerning the terms of BREXIT.

In summary, our empirical results highly suggest that there is a higher volatility impact of FTSE-100 on the volatility of the nominal exchange rate of the euro against the British pound after the BREXIT referendum. In addition, the long-term effect is strictly negative. This means that European and the American forex traders and equity investors will meet higher volatility of the euro or the US dollar against the British pound due to BREXIT negotiations. We reckon that the uncertainty economic conditions, due to upcoming BREXIT and the future economic and trade relationship of the UK-EU, made the investors more skeptical about their potential investment returns on the UK financial assets. A momentum investing condition characterizes the post-BREXIT referendum's period. Therefore, the investors across the globe could repatriate their funds from the UK stock market since they are not certain if their investments will be affected by a possible devaluation of the sterling in the future. Finally, we believe that the excess speculation over the UK financial markets is significantly influenced by the announcements concerning the BREXIT timeline negotiations. When a positive announcement occurred, the reaction of the investors as

positive also. On the other hand, the investors attitude was at the opposite when a negative announcement took place. This reveals that finance behavior and investment psychology plays an important role on the financial markets, and especially on the UK financial markets due to upcoming BREXIT.

6. Conclusions

This paper attempts to provide evidence regarding the impact of the BREXIT referendum vote on the linkages between the British currency and the UK stock market index. We used the combination of ECM with the Realized EGARCH in order to support our hypothesis that a momentum strategy investing takes place, due to BREXIT referendum vote in the UK financial markets. We explored the realized responses of FTSE-100 on the nominal exchange rate of the euro and the US dollar against the sterling. Our findings indicate the following:

A disequilibrium exists between the FTSE-100 and the euro and US dollar from BREXIT referendum's announcement until nowadays (October 2019). Moreover, there are important and negative long-tern dynamics between the FTSE-100 and the euro or the US dollar. We observed that the dynamics between the UK stock market index and the US dollar are more negative and violent in the long-run. Also, the short-term dynamics follow the announcements during the negotiations of the UK-EU (positive reactions on good news and negative reaction on bad news). The 10-year UK bond yields seem to play in general no important role on the nominal exchange rate of the euro or the US dollar against the sterling. In fact, there is no connection between the money and forex markets. This may happen due to different categories of investors that they participate in these markets (risk-averts in money markets, risk-lovers in stock/forex markets). The most important outcome among others of this paper is that we discovered enough indications that a potential further devaluation of GBP may occur in the UK if the final negotiations between the UK-EU lead to a hard or no-deal BREXIT.

The theory of momentum investing is closely related to the BREXIT topic as the uncertainty conditions that exist in the UK market due to the referendum on June 23, 2016 and of the overall topic of BREXIT, has led investors to make only short-term investments in FTSE-100 and not long-term ones. The investors' decision to sell a great number of stocks in order to have satisfactory profit returns and protect themselves from

any further risk has as a result the liquidation of the stocks in sterling pounds. In addition to that, the investors' desire to secure their profits gained from their short-term investments, leads to the exchange of those pounds with other currencies and their transfer in other countries. The aftereffects of those actions are that the increase in sale of the sterling pounds is translated into a decrease in the exchange rates of the sterling pounds towards other currencies in the long-run and the capital outflows in other countries creates a decrease in the stock market liquidity which is also visible in the GBP rates (Levine and Zervos, 1998).

Our evidence is aligned with the findings of the research of Eichler and Maltritz (2011), Davies and Studnicka (2018) as well as Grobys (2014). On the contrary, our results do not agree with the papers of Canadese *et al.* (2016), Katechos (2011) and Kutty (2010).

Finally, we assume that a potential collapse of the GBP in the UK, due to the upcoming BREXIT, would increase the cohesion of the European Union and might decrease the impact of Euro-skeptical voices across the European continent. Nevertheless, we should mention that our results are based on the financial behavior of the UK financial markets (stock and forex markets). BREXIT is a political issue and its outcome, as well as, its consequences are not certain. Until now (October 2019), the BREXIT negotiations were between the hammer and the anvil. Recently (October 2019), the House of Commons partially accepted the deal between the EU and the UK. However, a second BREXIT postponement agreed until 31/01/2020 in order to be achieved a final vote on BREXIT deal. However, it is not certain if England, Scotland and Wales (Northern Ireland under specific status) will have access at the European Single Market during the post-BREXIT era. Also, it is not clear if the UK will adopt a similar status to Norway or Switzerland or will sign a specific trade agreement with the EU.

This means that a political event or an official announcement could change the behavior of the investors and individuals in the UK financial markets. Moreover, a possible UK access to the European Single Market or the EU customs union (soft-BREXIT) may lead to a recovery of the pound. This event would create currency stability and positive expectations about the British economy and the funding access of the UK banking institutions and companies in the EU. Accordingly, a possible barrier to the European Single Market (hard-BREXIT) might create a further devaluation of the pound against the global leading currencies. This event would arise currency instability and negative expectations of the investors and individuals about the English economy and the funding access of the UK banks and companies in the EU. Nevertheless, political and diplomatic

analyses are not the aims of this academic research. In conclusion, we mention that the Governor of Bank of England recently expressed his opinion about BREXIT; *"No-deal Brexit or even the Prime Minister's deal with the EU will leave Britain poorer, weaker and more isolated"* (28/11/2018) (Bloomberg, 2018).

References

1. Aftab, M., Ahmad, R., and Ismail, I. (2018). Examining the uncovered equity parity in the emerging financial markets. *Research in International Business and Finance*, 45, 233-242.
2. Bae, K., Chan K., and Ng, A. (2004). Invisibility and return volatility. *Journal of Financial Economics*, 71, 239-263.
3. Banerjee, A. R. Lumsdaine and J.H. Stock (1992). "Recursive and Sequential Tests of the Unit Root and Trend Break Hypothesis: Theory and International Evidence," *Journal of Business and Economic Statistics*, 10(3), 271-288.
4. Bauer, C. (2007). A Better Asymmetric Model of Changing Volatility in Stock and Exchange Rate Returns: Trend-GARCH. *The European Journal of Finance*, 13(1), 65-87.
5. Barrett, G., & Donald, S. (2003). Consistent tests for stochastic dominance, *Econometrica*, 71, 71-104.
6. Bloomberg. (2018). Bloomberg Database. Bloomberg Terminal. https://www.bloomberg.com/professional/expertise/universities/students/
7. Byström, H. (2014). The impact of currency movements on asset value correlations. *Journal of International Financial Markets, Institutions and Money*, 31, 178-186.
8. Bloomberg. (2018). *Carney Says BOE Ready for the Worst in Brexit Recession Warning.* https://www.bloomberg.com/news/articles/2018-11-28/boe-warns-disorderly-brexit-could-unleash-a-savage-recession. Bloomberg Online.
9. Cenedese, G., Payne, R., Sarno, L., & Valente, G. (2016). What Do Stock Markets Tell Us about Exchange Rates? *Review of Finance, 22*(3), 1045-1080.
10. Chan, K., Hameed, A., & Tong, W. (2000). Profitability of momentum strategies in the international equity markets, *Journal of Financial and Quantitative Analysis*, 35, 153-172.
11. Choudhry, T., Papadimitriou, F., & Shabi, S. (2016). Stock market volatility and business cycle: Evidence from linear and nonlinear causality tests, *Journal of Banking and Finance*, 66, 89-101.

12. Daniel, K., Moskowitz, T. (2016). Momentum crashes. *Journal of Financial Economics*, 122, 221-247.

13. Davies, R. & Studnicka, Z. (2018). The heterogeneous impact of Brexit: Early indications from the FTSE. European Economic Review, 110, 1-17.

14. Degiannakis, S., & Floros, C. (2015). *Modelling and Forecasting High Frequency Financial Data*. London: Palgrave MacMillan.

15. Dhingra, S., Huang, H., Ottaviano, G., Pessoa, J.P., Sampson, T., & Reenen, J.V. (2017). The costs and benefits of leaving the EU: trade effects. *Economic Policy,* 32(92), 651-705.

16. Dao, T., Mc Groarty, F., & Urquhart, A. (2018). The Brexit vote and currency markets. *Journal of International Financial Markets, Institutions and Money*. article in press.

17. Grobys, K. (2014). Momentum in global equity markets in times of troubles: Does the economic state matter?. *Economics Letters,* 123(1), 100-103.

18. Engle, R.F. & Granger, C.W. (1987). Co-integration and Error Correction: Representation, Estimation and Testing. *Econometrica*, 55(2), 251-276.

19. Eichler, S., & Maltritz, D. (2011). Currency crises and the stock market: empirical evidence for another type of twin crisis. *Journal of Applied Economics, 43*(29), 4561-4587.

20. Fong, W., Wong, W., & Lean, H. (2005). International momentum strategies: A stochastic dominance approach, *Journal of Financial Markets*, 8(1), 89-109.

21. FTSE Russel. (2018). *FTSE domestic and global exposure - Index series. FTSE Russel Report*. 1-20.

22. Hansen, P.R., & Huang, Z. (2012). Exponential GARCH Modeling With Realized Measures of Volatility. *Journal of Business & Economic Statistics, 34*(2), 269-287.

23. Hansen, P. R., Huang, Z., & Shek, H. H. (2012). Realized GARCH: a joint model for returns and realized measures of volatility. *Journal of Applied Econometrics, 27*(6), 877-906.

24. Hau, H., & Rey, H. (2006). Exchange rates, equity prices, and capital flows. *Review of Financial Studies, 19*(1), 273-317.

25. HM Revenue and Customs. (2018). *UK overseas Trade in Goods Statistics Report*, 1-13.

26. Hong, H., Lim, T., & Stein, J. (2000). Bad News Travels Slowly: Size, Analyst Coverage, and the Profitability of Momentum Strategies, *The Journal of Finance, 55(1),* 265-295.
27. Jegadeesh, N., & Titman, S., (1993). Returns to buying winners and selling losers: implications for stock market efficiency, *Journal of Finance*, 48, 65-91
28. Johansen, S., Mosconi, R. & Nielsen, B. (2000). Cointegration Analysis in the Presence of Structural Breaks in the Deterministic Trend, *The Econometrics Journal*, 3(2), 216-249.
29. Kariofyllas, S., Philippas, D. and Syriopoulos, C. (2017). Cognitive biases in investors' behaviour under stress: Evidence from the London Stock Exchange. *International Review of Financial Analysis*, *54*, 54-62.
30. Katechos, G. (2011). On the relationship between exchange rates and equity returns: A new approach. *Journal of International Financial Markets, Institutions and Money*, 21(4), 550-559.
31. Koulakiotis, A., Kiohos, A., & Babalos, V. (2015). Exploring the interaction between stock price index and exchange rates: an asymmetric threshold approach. *Journal of Applied Economics. 47*(13), 1273-1285.
32. Kutty, G. (2010). The relationship between exchange rates and stock prices: The case of Mexico. *North American Journal of Finance and Banking Research,* 4(4), 1-12.
33. Lesmond, D., (2005). Liquidity of emerging markets. *Journal of Financial Economics.* 77, 411-452
34. Levine, R. and Zervos, S. (1998). Stock Markets, Banks, and Growth, *American Economic Review*, 88(3), 537-558.
35. Lui, W., Strong, N., & Xu, X. (1999). The Profitability of Momentum Investing*, Journal of Business Finance & Accounting,* 26(9)&(10)*,* 1043-1091.
36. Melvin, M., & Prins, J. (2015). Equity hedging and exchange rates at the London 4p.m. fix. *Journal of Financial Markets,* 22, 50-72.
37. Nelson, D. & Cao, C. (1992). Inequality constraints in the univariate GARCH model. *Journal of Business & Economic Statistics*, 10, 229-235.
38. Office of National Statistics. (2018). *UK National Accounts, The Blue Book: 2017,* 1-50.
39. Perron, P. (1997). Further Evidence on Breaking Trend Functions in Macroeconomic Variables. *Journal of Econometrics*, 80(2), 355-385.
40. Panopoulou, E., & Pantelidis, T. (2015). Regime-switching models for exchanges rates. *The European Journal of Finance*, 21(12), 1023-1069.

41. Ramiah, V., Pham, H. N., & Moosa, I. (2017). The sectoral effects of Brexit on the British economy: early evidence from the reaction of the stock market, *Applied Economics*, 49(26), 2508-2514.
42. Srovnikova, P., & Razinskaite, J. (2017). The Eurozone crisis and the effect of BREXIT. *Journal of Management*, 30(1), 95-102.
43. Stoupos, N., & Kiohos, A. (2017). EU Unification and Linkages among the European Currencies: New Evidence from the EU and the EEA. *Research in International Business and Finance,* 41, 28-36.
44. Tian, G. G., & Ma, S. (2010). The relationship between stock returns and the foreign exchange rate: the ARDL approach. *Journal of the Asia Pacific Economy, 15*(4), 490-508.