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ABSTRACT

The world economy has been punctuated by uncertainty as a result of the 2008 subprime crisis, the European sovereign debt crisis, Brexit, and the 2016 US presidential elections, to mention but a few of the reasons. This study explores how the UK real exchange rate reacts to economic policy uncertainty (EPU) shocks using monthly data for the period 1998 to 2020. We contribute to the literature by identifying the long-run and short-run impacts of EPU using a cointegrated ARDL model, and by studying a country that has been through periods of both relatively low and high uncertainty. Results confirm that EPU has an important effect in the long run by depreciating the exchange rate. In addition to urging policymakers and regulators to concentrate on the sometimes difficult task of keeping policy uncertainty to a minimum as a way of sustaining exchange rate stability and thus promoting long-term economic growth, further evidence is provided on exchange rate fundamentals.

Keywords: Real Exchange Rate, Economic Policy Uncertainty, ARDL model, Brexit.

JEL CLASSIFICATION: C52, E50, F55

1. INTRODUCTION

The world economy has been punctuated by uncertainty in recent years as a result of the 2008 global financial crisis, the European sovereign debt crisis, the unexpected result of the United

Kingdom referendum on the European Union, and the 2016 United States presidential elections, to mention but a few of the reasons. In such circumstances, economic agents are conscious of their limited knowledge about the present and the unpredictable outlook for the economy.

Policy uncertainty, namely the economic risk associated with unpredictable future government policies, ambiguous future regulatory frameworks or uncertainty over electoral outcomes, is a particular type of uncertainty (Al-Thaqeb and Algharabali, 2019). If we focus on economic policy uncertainty, we think of agents who are unable to foresee the outcomes of fiscal, regulatory, monetary and trade policies (Kaya et al., 2018).

This paper was motivated by Brexit and the ensuing impact of economic policy uncertainty on the UK's real exchange rate. The Economic Policy Uncertainty index (EPU), developed by Baker, Bloom and Davis (2013, 2016) and used in several applications, is selected to address this issue. Although uncertainty understood as a general concept is a universal characteristic of economic activity (Beckert and Berghoff, 2013), it has significant negative economic effects. Aisen and Veiga (2006) argue that politically unstable countries are often susceptible to political shocks that lead to erratic monetary and fiscal policies and high inflation volatility, which have negative effects on productive economic decisions.

Since the mid-2000s, there has been a significant body of research on the impact of EPU on macroeconomic and financial market outcomes, such as monetary policy, investment decisions, economic growth, exchange rate. In particular, important studies have examined the effect of EPU on firm investment activities (Gulen and Ion, 2016; Nguyen and Phan, 2017), exchange rate volatility (Krol, 2014; Beckmann and Czudaj, 2017; Wang and Morley, 2018), asset prices (Brogaard and Detzel, 2015; Dong et al., 2019), demand for money (Ivanovski and Churchill, 2019), world trade growth (Constantinescu et al., 2019), forecasting future recessions (Karnizova and Li, 2014), exchange rate market pressure (Olanipekun et al., 2019), economic growth (Bloom, 2009), financial trading (Mueller et al., 2017), international commodity markets (Andreasson et al., 2016), and bond market yields (Baker and Bloom, 2013). For a detailed discussion of studies on economic policy uncertainty see Al-Thaqeb, and Algharabali (2019).

Nilavongse et al. (2020) contributed to the literature with a study on the impact of EPU shocks in the aftermath of UK's 2016 Leave vote. Our study follows the same line by looking at the impact of economic policy uncertainty on the UK's real effective exchange rate, encompassing the period from January 1998 to June 2020 and analysing the long-run and short-run dynamics.

The remainder of this paper is structured as follows. Ensuing a literature review in the next section, Section 3 sets out the stylised facts about Brexit and UK EPU. Section 4 presents the econometric methodology and data. Section 5 discusses the results and finally Section 6 concludes.

2. LITERATURE REVIEW

Economic uncertainty affects the economy through several channels, the most important of which, as we analyse below, are the cost of debt, stock market, and economic growth; this, in turn, impacts the exchange rate market.

Wisniewski and Lambe (2015) studied the relationship between the US and European economic policy uncertainty indices and the cost of credit insurance - credit default swap (CDS) spreads. Within a vector autoregressive (VAR) methodology and employing monthly data from October 2006 to March 2014, they found that economic policy uncertainty increases CDS spreads.

Bernal et al. (2016) focused on the impact of economic policy uncertainty on the spillover risk between sovereign bond markets within the Eurozone from Q4 2008 to Q2 2013, using the EPU indices for Germany, France, Italy and Spain, as well as for the United States. Their study relies on the Conditional Value at Risk methodology to analyse the determinants of systemic risk, assessing a given country's marginal contribution to the risk of the Eurozone as a whole by using a set of macroeconomic variables as determinants of the spillover risk. They not only found strong evidence of economic policy uncertainty in Europe enhancing the transmission of risk, but also of the importance of the US EPU index in explaining the transmission of risk within the Eurozone sovereign bond market.

Arouri et al. (2016) analyse the impact of economic policy uncertainty on stock markets, using the NYSE (New York Stock Exchange) for the period 1900–1925 and the S&P500 over the period 1925-2014. A three-regime switching model is used to distinguish the impact of EPU on stock returns during normal, high and extreme volatility periods. They found that an increase in US EPU is associated with a decrease in stock returns, with the impact differing across market states.

Although the literature on the effects of economic policy uncertainty has recently grown substantially, covering different issues from multiple perspectives, further analysis of the impact on the real effective exchange rate is still required. On one hand, note that economic policy uncertainty adversely impacts several variables related with the exchange rate: private investment (Bonaime et al., 2018; Gulen and Ion, 2016), GDP growth (Sahinoz and Cosar, 2018), employment (Leduc and Liu, 2016), private consumption (Bloom, 2016), and the stock market (Arouri et al., 2016; Phan et al., 2018). On the other, EPU increases bonds' credit risk (Wisniewski and Lambe, 2015; Chi and Li, 2017), stocks' risk premium (Pástor and Veronesi, 2013), and financial costs (Arouri et al., 2016).

Thus, a high level of economic policy uncertainty worsens the economic outlook (notably GDP growth) and depresses the stock market, causing the exchange rate to depreciate. Moreover, the increase in the credit risk of bonds (of both public and private issuers) leads investors away from domestic bonds, contributing to a decline in the demand for domestic currency. Only safer currencies, such as the US Dollar or the Swiss Franc, may benefit from economic uncertainty. In general, higher economic policy uncertainty is expected to depreciate the exchange rate, although the impact of economic and political factors can be highly correlated with complex interactions (Wang et al., 2019).

Dai et al. (2017) employ a quantile causality test (based on a perspective of sample distribution) on monthly data from 2006:M01 to 2017:M01 to examine the relationship between EPU and the US dollar exchange rate against the Renminbi. Since macroeconomic volatility often increases the EPU, the causality test in their study is analysed from the investment perspective. They found there is a causal interaction in both directions between the EPU and the exchange rate, which is more probable in extreme situations in the exchange rate market or in the economic policy variable. When uncertainty increases, investors demand a higher risk premium on the currency, leading to a devaluation.

The impact of economic policy uncertainty of key currencies may go beyond the national currency. Kido (2016) analyses the effect of the US EPU index on the real effective exchange rates (REER) of several countries, employing monthly data from January 2000 to 2014. The author finds that when the US EPU remains low, currencies such as the US dollar, Euro and the currencies of Australia, Brazil, Korea, and Mexico generally tend to appreciate, while the yen depreciates. The opposite occurs when US economic policy uncertainty rises.

Besides impacting the exchange rate level, economic policy uncertainty is also expected to affect exchange rate volatility. Krol (2014) investigates the impact of both home economic policy uncertainty and US economic policy uncertainty on exchange rate volatility, which are determined by the expectations of economic fundamentals and policies. The study is conducted for ten industrial and emerging economies from June 1990 to February 2012. The results confirm that whereas both economic policy uncertainty indices increase exchange rate volatility in industrial countries when the economies are performing poorly, for some of the emerging countries only home economic policy uncertainty drives the exchange rate volatility.

The reaction of the UK economy to EPU shocks in the aftermath of UK's 2016 Leave vote was addressed by Nilavongse et al. (2020). They studied the impact of foreign (US) and domestic (UK) EPU shocks on the UK economy within a structural VAR model for monthly data from January 1986 to January 2019, incorporating five variables, one of which is the real effective exchange rate of the British pound to the US dollar. They find that an increase in the EPU worsens economic outputs, and that the dynamics of the UK currency are attributed to both US and UK EPU shocks while the depreciation of the UK REER between May 2016 and October 2016 can be attributed to the rise in economic uncertainty in the UK.

Our research is framed by the reviewed papers that explore the effects of economic policy uncertainty on economic and financial variables. In the present study, we debate the hypothesis that EPU might impact the UK's REER in both the short-run and in the long-run.

3. BREXIT VOTE RESULT AS A GENERATOR OF UNCERTAINTY

Bootle and Mills (2016) state that despite the fundamental role of the exchange rate in the success and strength of the UK's economy, the Sterling Pound has been neglected as a policy variable. For several periods, this produced exchange rate misalignments translated in a currency that was over appreciated for the health of the UK's economy. The authors argue that there are two main reasons for this evidence. First, the UK can attract private capital flows that push up the real exchange rate because of the country's political stability and the extraordinary liquidity and attraction of its asset markets. Secondly, a history of high inflation has led to the UK policy authorities using a strong currency to reduce inflation.

In 2016, economic uncertainty increased dramatically when 52% of the British voted to leave the EU. The leave option won by a narrow margin, something that was also used as an argument for another referendum that included more specific and detailed options. Nonetheless, referendum results on 23 June were a shock to both the UK and the EU, and created uncertainties affecting worldwide relationships. The shock disrupted the governing of Europe's everyday projects and transported the Union to a place of uncertainties and a period of trade negotiations with an unclear outcome. Seddon and Niemeyer (2018) state that there were no obvious plans to put the result of the referendum into practice. As a result, the economic policy uncertainty was amplified by the fact that the timing, negotiation outcomes and implementation of trade agreements were themselves uncertain. The effects of Brexit are also visible at a strategic level as it is likely to fragment EU solidarity, opening fissures that will be difficult to close (Riley and Ghilèa, 2016).

Mendez-Parra and Papadavid (2016) state that the trade effects will depend on two elements: the trade policy that the UK would apply after leaving the EU, and the ultimate UK economic structure after the agreement is finalised with the EU. Ries et al. (2017) acknowledge that an array of concerns will come into play as the process develops and argue that if there is one certainty about Brexit, it is that the issues involved are complex and interdependent. The uncertainty and the reality of Brexit effects on the global economy will exert its influences for years to come given that no other country had ever decided to leave the European Union so it is a unique process.

As expected, the UK EPU index increased substantially after June 2016 when the leave vote won the referendum (Figure 1 below). Kostka and Van Roye (2017) noted that the referendum did not have a greater impact on financial conditions due to the Bank of England’s clear commitment to an accommodative monetary policy by means of conventional and unconventional tools.

4. EMPIRICAL STRATEGY

Our goal herein is to analyse the long-run relationship between the real exchange rate and EPU for the UK. The Behavioural Equilibrium Exchange Rate (henceforth BEER) approach provides an empirical link between the real exchange rate and a set of macroeconomic variables, which is not predefined by theory but rather determined on an *ad hoc* basis (Clark and MacDonald, 1998). Clark and MacDonald (1998) define the actual real effective exchange rate, q_t as:

$$q_t = \beta_1^{'} Z_{1t} + \beta_2^{'} Z_{2t} + \tau^{'} T_t + \varepsilon_t \qquad (1)$$

where Z_{1t} and Z_{2t} are vectors of variables influencing the exchange rate over the long and medium run, T_t is a transitory vector affecting the real exchange rate in the short run, β and τ are reduced-form coefficients of the vectors, and ε_t is a white noise process.

The current equilibrium rate is defined as the level of exchange rate given by the current values of Z_{1t} and Z_{2t}, that is:

$$q_t^{'} = \beta_1^{'} Z_{1t} + \beta_2^{'} Z_{2t} \tag{2}$$

To avoid the spurious regression in the presence of nonstationary series, cointegration analysis is the best tool to estimate the equilibrium exchange rate. Nkoro and Uko (2016) state that cointegration establishes a stronger statistical and economic basis for an error correction model, which brings together short and long-run information in modelling variables. According to Engle and Granger (1987), non-stationary time series are cointegrated if their linear combination is a stationary process. If there is a cointegration relationship, the authors proposed an error correction mechanism where the residuals of equilibrium regression are used in the error correction model. The cointegration relationship is a way of distinguishing between random fluctuations and the equilibrium level of the exchange rate.

Later, Pesaran et al. (1996), Pesaran (1997) and Pesaran et al. (2001) proposed a single equation Autoregressive Distributed Lag (ARDL) approach or the bound test of cointegration as an alternative to the Engle and Granger cointegration technique. The ARDL bounds test approach for cointegration is applied to test the long-run relation between the dependent and the independent variables when they have different orders of integration. This is the exact situation with our data, as we will see in Section 4, and we therefore now explain the ARDL approach in detail. This method is also chosen because it uses a sufficient number of lags to capture the data generating process from a general to specific modelling framework, providing both short-run and long-run equilibrium coefficients.

The Autoregressive Distributed Lag model is one of the most general dynamic unrestricted models in econometric literature. Following the work of Pesaran and Shin (1998) and Pesaran et al. (2001), in the case of one independent variable, the ARDL(p,q) model can be represented by the following equation where the dependent variable is expressed by the current value and the first *q* lags of the independent variable, and the *p* lags of the dependent variable:

$$\mathrm{y_t} = \beta_0 + \beta_1 \mathrm{T} + \sum_{i=1}^{p} \phi_i \, \mathrm{y_{t-i}} + \sum_{j=0}^{q} \delta_j \, \mathrm{x_{t-j}} + \varepsilon_\mathrm{t} \tag{3}$$

where y_t and x_t are the dependent and independent variables respectively, β_0 , β_1 are the drift and trend coefficients respectively, ϕ_i and δ_j are coefficients to estimate, and ε_t is the white noise error term.

The ARDL model helps detect a single long run relationship equation. If there is one cointegrating vector, the ARDL model is reparametrised into an error correction model (ECM). The reparametrised result provides the ARDL short-run dynamics and long run relationship in a single equation. Equation (3) can be specified in the ARDL bounds test representation using the following unrestricted error correction model:

$$\Delta y_t = \beta_0 + \beta_1 T - \alpha(y_{t-1} - \theta x_{t-1}) + \sum_{i=1}^{p-1} \omega_{yi} \Delta y_{t-i} + \sum_{j=0}^{q-1} \omega'_{xi} \Delta x_{t-j} + \varepsilon_t \qquad (4)$$

where Δ is the difference operator, α is the speed of adjustment coefficient which is defined as - $\alpha = \left(1 - \sum_{j=1}^{p} \phi_i\right)$; θ are the long run coefficients where $\theta = \frac{\sum_{j=0}^{q} \delta_j}{\alpha}$, and ω_{yi} and ω'_{xi} are the short run coefficients; ε_t is white noise error. The speed of adjustment α is negative and represents the extent to which any disequilibrium in the previous period is being adjusted in the current period. In the long run equilibrium, the system is stable, which implies there is no tendency for change over a period of time i.e., $y_t = y_{t-1} = y$ and $x_t = x_{t-1} = x$. If an equilibrium exists, the first difference variables in equation (4) must be zero i.e. $\Delta y_{t-i} = \Delta x_{t-j} = 0$.

The ARDL estimation process involves the following steps. Firstly, the ARDL Bounds test model developed by Pesaran et al. (2001) is specified to check if the series are cointegrated or not. The hypotheses to be tested in equation (4) are H_0: $(\alpha = 0) \cap (\sum_{j=0}^{q} \delta_j = 0)$ *vs.* H_1: H_0: $(\alpha \neq 0) \cup (\sum_{j=0}^{q} \delta_j \neq 0)$. The existence of cointegration is statistically evident if the null hypothesis is rejected. The test has two critical values, one assuming that all the variables are I (0) – lower critical bound, meaning that there is no cointegration among the underlying variables; and another assuming that all the variables are I (1) – upper critical bound. In order to confirm whether there is a long run relationship, the F statistics is computed out on the joint null hypothesis that the coefficients of the variables in levels and lagged are zero. When the F statistic is above the critical upper bound, we conclude there is cointegration; when it is below the lower critical value, there is no cointegration, and, finally, when it is between the lower and upper critical values, no conclusion can be drawn.

Secondly, if the F statistic bound test shows there is cointegration, it is possible to determine the long-run equilibrium relationship as a stationary linear combination of the non-stationary variables in a least-square regression. The selection of appropriate lag of each variable in variations is based on the AIC, Akaike Information Criterion (Akaike, 1974). Pesaran et al. (2001) suggest that the ARDL model can be modelled with equal or a different number of lag lengths for variables without affecting the asymptotic distribution of the test statistic.

The third step consists of diagnostic and stability tests. Relevant post-estimation diagnostic tests (normality, functional form, heteroskedasticity and serial correlation) and stability tests are to be performed to check the goodness of fit of the estimated ARDL, given that the validity of the bounds test relies first on serially uncorrelated error terms (Pesaran et al., 2001) and second on the stability of the coefficients over time. On the one hand, the LM test assesses the null hypothesis that the errors are serially independent, and on the other hand the cumulative sum of recursive residuals (CUSUM) test and CUSUM square test are applied to determine the stability of the coefficients.

Variables and Data

Within the literature, a large spectrum of fundamentals has been used to model the real effective exchange rate in the long-run, with the exact choice depending on the question at hand and research purposes. Studies by Clark and MacDonald (1999), Ricci et al. (2013), Zhang and MacDonald (2014), Tipoy et al. (2017), Comunale (2019), among others, use some of the following major fundamentals for the long run real effective exchange rate: terms of trade, relative productivity of the tradable sector, net foreign asset position, interest rates differentials, government spending, financial development, aid flows, and openness.

To reduce the number of parameters to be estimated in our study, we were parsimonious in our selection of control variables, selecting one related with trade flows (terms of trade) and a second one related with financial flows (the real interest rate), as in Clark and MacDonald (1998).

In sum, we estimate a long-run equation for the real effective exchange rate using the EPU index, terms of trade and real interest rate as explanatory variables, using monthly data. The data is used in accordance with the availability of the full sample of the UK EPU index, implying that we study the period from January 1998 to June 2020. This period covers months of both low and high uncertainty. For the latter case, recent emblematic examples are the Brexit, the global financial crisis, and the European sovereign debt crisis.

The variables in the present research are expressed either in levels, as in the case of the real interest rates, or in logarithms, namely for the remaining variables. The observations are obtained on a consistent basis from several sources and their definitions and sources are provided below.

Economic policy uncertainty index: *LNEPU*

This is our most important variable and the most difficult to measure. As already explained, we opted for the Economic Policy Indicator developed by Baker et al. (2013, 2016) due to its widespread use in the literature and its solid methodology. These authors have developed comprehensive indices on EPU for about 25 countries worldwide using words such as "economic" or "economy"; "uncertain" or "uncertainty"; "deficit", "legislation", or "regulation" employing a newspaper-based approach. An article is only considered as meeting the criteria if it contains terms in all three categories pertaining to uncertainty, economy, and policy. In addition to these criteria, the measure of the UK EPU index is based on the relative frequency of the number of newspaper articles on policy uncertainty containing the key words "tax", "spending", "regulation", "Bank of England", "budget", and "deficit". The 11 UK newspapers used are: *The FT, The Times and Sunday Times, The Telegraph, The Daily Mail, The Daily Express, The Guardian, The Mirror, The Northern Echo, The Evening Standard,* and *The Sun*.

The Google Economic Policy Uncertainty index (hereafter GEPU) developed by Kupfer and Zorn (2020) for Eastern European Countries is an alternative indicator that is language independent. It is based on Google search volume in combination with search topics and search categories rather than newspaper articles. The GEPU index was first validated by comparison with the EPU index, using a set of five western European economies: France, Germany, Italy, Spain and the United Kingdom. The conclusion obtained when linking both indices to macroeconomic variables within a VAR model was that shocks were found to have similar effects for both uncertainty indicators.

We retrieved the data from the Economic Policy Uncertainty webpage (http://www.policyuncertainty.com), for the maximum sample period available (1998 to 2020) and at a monthly frequency. An increase in this index is expected to depreciate the currency, as explained above, and taking into account that, as shown by Backer et al. (2016), an increase in the index is generally associated with a decline in economic performance.

Real effective exchange rate: *LNREER*

LNREER is used as the dependent variable and is based on the nominal exchange rate and a multilateral consumer price index. The weights are based on the UK trade pattern, with 2010 as the indices' base year, and the variable was retrieved from the Bank of England. REER is the weighted averages of bilateral exchange rates adjusted by relative consumer prices, and it calculates the number of units of foreign goods that will pay for 100 units of equivalent domestic goods, with a weighting pattern time varying - an increase in REER is a real appreciation.

Terms of Trade: *LNTOT*

The Terms of Trade is expressed in logarithms and obtained from the Office for National Statistics/OECD; it corresponds to the ratio of the price of exportable goods and services to the price of importable good and services (2013=100). The seven most important partners of the UK are the reference group.

The influence of the TOT on the REER is not defined *a priori* because it depends on whether the income effect or the substitution effect is dominant (for further discussion see Comunale, 2019; Fidora et al., 2018). If the income effect (the increase in the relative price of exports increases the overall demand for domestic goods) dominates the substitution effect (the rise in the relative price of exports leads to a decline in the demand for domestic goods), a positive impact occurs, given that a positive shock should generate additional export revenues and contribute to real effective exchange rate appreciation.

Real interest rates: *RIR or r-r**

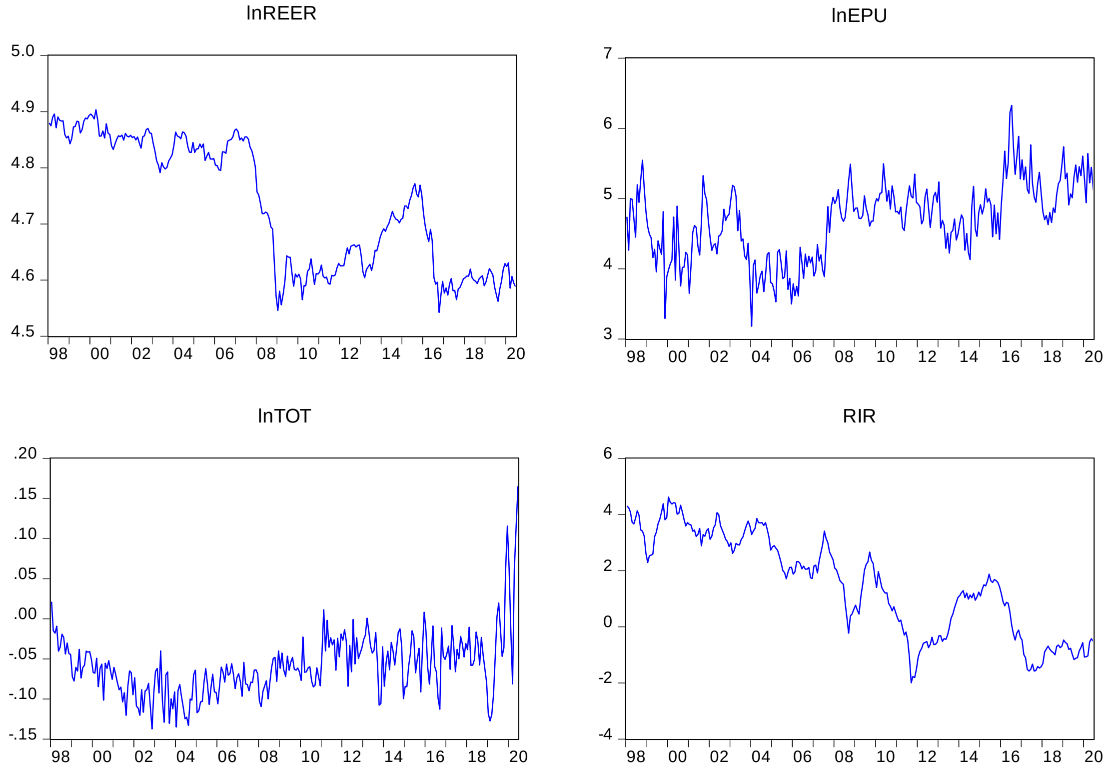
The real interest rate variable (RIR) is the difference between the domestic and foreign real interest rates (r-r^*) – data from OECD, Office for National Statistics, Bank of England database. As in Clark and MacDonald (2004), the domestic real interest rate, r, is defined by the difference between the UK average nominal long term government bond yield minus the changes in CPI. The foreign real interest rate, r^*, is the weighted average of the real interest rates of G7 partner countries computed in the same way as r. The impact of real interest rates on the real effective exchange rate is likely to be positive because higher interest rates will attract capitals to the domestic economy. Clark and MacDonald (2004) starting from the uncovered interest parity (UIP) condition, which states that the difference in the nominal interest rates between two countries equals the relative expected change in exchange rate, find that real interest rate differentials have a positive effect on the real exchange rate by using the following equation:

$$q_t = E_t(q_{t+k}) + (r_t - r_t^*) + e_t \qquad (5)$$

where $E_t(q_{t+k})$ is the expectation of the real exchange rate in period $t+k$, $t+k$ defines the maturity horizon of bonds, $(r_t - r_t^*)$ represents the real interest rate differentials, and e_t is the error term.

Figure 1 presents graph of the four variables in levels.

Figure 1. The variables in levels



Following the data description above and equation (4), the ARDL model can be represented as follows:

$$\Delta \text{LNREER}_t = \beta_0 + \beta_1 \text{T} + \sum_{i=1}^{p} \phi_i \, \Delta \text{LNREER}_{t-i} + \sum_{i=0}^{q} \phi_j \, \Delta \text{LNEPU}_{t-i} + \sum_{i=0}^{r} \phi_k \, \Delta \text{LNTOT}_{t-i} + \sum_{i=0}^{s} \phi_l \, \Delta \text{RIR}_{t-i} + \gamma_1 \text{LNREER}_{t-1} + \gamma_2 \text{LNEPU}_{t-1} + \gamma_3 \text{LNTOT}_{t-1} + \gamma_4 \text{RIR}_{t-1} + \upsilon_t \quad (6)$$

where β_0 is the intercept, β_1 the trend coefficient, *p, q, r and s* the chosen lag lengths of the variables, Δ the difference operator, $\phi_{i,\ldots,l}$ the short run effects captured by the coefficients of the first difference variables, γ_i(i=1,…,4) the long run coefficients, and υ_t the white noise. The F statistics are applied to check for the presence of a long run relationship where the null hypothesis is H_0: $\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0$.

5. EMPIRICAL ANALYSIS AND DISCUSSION

We start by looking at the simple correlation between the variables (Table 1). Two of the correlation signs were expected: LNEPU is negatively correlated with LNREER, and the RIR is positively correlated with LNREER and has the highest coefficient. The negative relationship between LNTOT and LNREER was not totally expected, but it can be explained by the dominance of the substitution effect.

Table 1. Correlation matrix between variables

Correlation	LNREER	LNEPU	LNTOT	RIR
LNREER	1			
LNEPU	-0.62	1		
LNTOT	-0.39	0.35	1	
RIR	0.89	-0.57	-0.42	1

Unit root tests

To ensure that the ARDL does not crash in the presence of I (2) variables, we start by employing the unit root tests and the stationarity test to identify the order of integration of the variables. The ADF test (Dickey Fuller, 1979), and the PP test, (Phillip and Perron, 1988) were conducted for all variables in levels and in first differences (including an intercept only, or intercept and trend, or none deterministic component) to test the null hypothesis of a unit root against the alternative hypothesis of no unit root. The KPSS stationarity test (Kwiatkowski-Phillips-Schmidt-Shin, 1992) was employed for all the variables expressed in levels and first differences (including intercept, and intercept and trend) to test the null hypothesis of stationarity against the alternative hypothesis of non-stationarity. Table 2 presents the results of the three abovementioned tests. The tests were also conducted for all the variables expressed in first differences to ensure that the variables which were nonstationary in levels would be I (1).

Table 2. ADF, PP unit root tests and KPSS stationarity test for model variables in levels and in first differences

Variables	**LNREER**	**LNEPU**	**LNTOT**	**RIR**
Intercept				
ADF test	-1.136699	-3.081310*	-1.500781 (4)	-1.613109 (1)
	(0.7018)	(0.0292)	(0.5319)	(0.4745)
PP test	-1.210566	-4.707134*	-5.228514*	-1.642610
	(0.6706)	(0.0001)	(0.0000)	(0.4594)
KPSS test	1.700521*	1.071649*	1.045927*	1.828222*
Intercept and trend				
ADF test	-2.106267	-4.727480*	-6.805235 *	-2.991902
	(0.5395)	(0.0008)	(0.0000)	(0.1364)
PP test	-2.335698	-6.366760*	-6.423745*	-3.050919
	(0.4128)	(0.0000)	(0.0000)	(0.1205)
KPSS test	0.148273*	0.136357	0.219333*	0.079918

None				
ADF test	1.169906	-0.189678*	-1.123336	-1.846281
	(0.2209)	(0.0001)	(0.2374)	(0.0619)
PP test	-1.103351	-0.091195	-3.079344*	-1.865565
	(0.2447)	(0.6514)	(0.0022)	(0.0593)
	ΔLNREER	**ΔLNEPU**	**ΔLNTOT**	**ΔRIR**
Intercept				
ADF test	-14.97394*	-16.11917*	-13.22714*	-13.37303*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
PP test	-14.97394*	-29.40096*	-25.96648*	-13.39093*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
KPSS test	0.051924	0.058649	0.458078	0.035468
Intercept and trend				
ADF test	-14.94561*	-16.09600*	-13.37471*	-13.35153*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
PP test	-14.94561*	-29.38486*	-28.86437*	-13.36990*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
KPSS test	0.051603	0.044370	0.124435	0.030026
None				
ADF test	-14.93709*	-16.14913*	-13.24072*	-13.34219*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
PP test	-14.93709*	-29.42914*	-25.52941*	-13.36313*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Notes: The ADF, PP critical value at 5% significance level is -2.872 for the model with an intercept. The ADF, PP critical value at 5% significance level is -3.426 for the model with both intercept and trend. The ADF, PP critical value at 5% significance level is -1.942 for the model with none intercept or trend.

The KPSS critical value at 5% significance level is 0.463 for the model with an intercept. The KPSS critical value at 5% significance level is 0. 146 with trend and intercept. The critical values according to Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

* denotes the rejection of the null hypothesis at the 5% significance level. Within the round parentheses are represented the p-values.

The ADF, PP and KPSS tests indicate that LNREER is integrated of order one. For LNEPU, the ADF, PP and KPSS mostly indicate that the variable is stationary. The exceptions pointing to nonstationarity are the PP test with no deterministic trend and the KPSS test with intercept.

For LNTOT, the null hypothesis of a unit root is not rejected by the ADF test (including an intercept, or without any deterministic component), but is rejected by the PP test. Thus, the KPSS is employed to obtain a conclusion. The KPSS result points to the nonstationary of LNTOT. Based on the similarity of the ADF and KPSS results, we can conclude that LNTOT is nonstationary in levels.

For the RIR, the presence of a unit root is not rejected by the ADF and PP test. The stationarity is not rejected by the KPSS test with the inclusion of both intercept and trend, but it is rejected when it contains only an intercept. Based on most of the tests results, we conclude that the RIR is nonstationary in levels.

Since the unit root tests and stationarity test results indicate that the order of integration is a mixture of variables that are integrated of order zero and variables that are integrated of order one, the Autoregressive distributed lag (ARDL) bound test stands out as the most appropriate approach. In addition, Tursoy and Faisal (2018) state that the dependent variable in the model should be I (1) when the cointegration analysis is performed with ARDL bound test, which is the case of LNREER. We choose to estimate a model with a restricted constant and no trend due to the absence of a clear trend in LNREER. The maximum lag allowed was twelve due to the monthly nature of the data.

ARDL bounds test and diagnostic tests

The absence of serial correlation is a key element in the ARDL bounds test, a condition fulfilled by the present model (see the Breusch-Godfrey Serial Correlation LM Test in Table 4, Panel C). The results of the bounds test are presented in Table 3; it shows that the calculated F-statistic value 4.61 is above the I (1) table critical values value for 5% confidence intervals, thus indicating cointegration between UK REER and its determinants.

Table 3. ARDL bounds test Lags (2, 0, 9 0)

$F_{LNREER}(LNREER|LNEPU, LNTOT, RIR)$

F-statistic	*Significance level*	*Lower bound*	*Upper bound*	*Decision*
	10%	2.37	3.20	Cointegration
4.61	5%	2.79	3.67	Cointegration
	1%	3.65	4.66	We cannot conclude

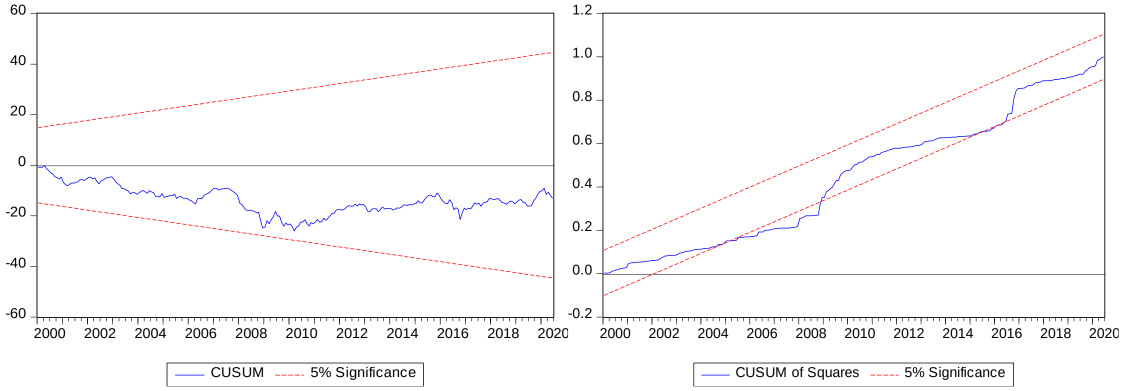
The results of further diagnostic tests are shown in Panel C of Table 4: the Ramsey RESET test, the Jacque-Bera normality test, and the ARCH test. The model has a correct functional form, but residuals are non-normal and show heteroscedasticity. The fact that the error term does not follow a normal distribution is not a major issue for the validation of the model, because the OLS estimation does not require this condition to produce unbiased estimates with the minimum variance. The large number of observations used (261) allows to conclude by the Central Limit Theorem that the distribution of the error term is approximate normal.

Moreover, although the existence of heteroscedasticity does not compromise the unbiasedness of the OLS estimators, it requires the HAC (Newey-West) correction of the covariance matrix. Newey and West (1987) argue that it is possible to account for both heteroscedasticity and autocorrelation in the error term by using the Newey-West estimator for the variance-covariance matrix.

The cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMSQ) are performed to determine the structural stability of the model - Figure 2. Miller (1982) states that whereas the plot of CUSUM involves a plot of the cumulative sum of recursive residuals against the ordering variable (time in this case) and checking for deviations from the expected value of zero, CUSUMSQ involves plotting the cumulative sum of squared recursive residuals against the ordering variable.

From the CUSUM test, on the left-hand side, we conclude for the ARDL model parameter stability as the blue lines representing the recursive residuals lie within the red line boundary, at 5% significance level. The CUSUMSQ is plotted on the right-hand side; it allows us to observe a structural change between from 2005 and 2009, but this is reverted later on.

Figure 2. Plot of CUSUM test and CUSUM of squares test for equation (4)



Long run and short run ARDL results

We now assess the short-term and long-term dynamics of the model. The error correction form of the ARDL model is presented in Table 4: the short run coefficient estimates are in Panel A and the long run coefficients in Panel B.

Table 4. Short run, long run ARDL cointegration model in equation (4) and diagnostic tests

	Coefficient	Std.Error	t-Statistic
	Panel A. Short run coefficient estimates		
$\Delta \mathbf{LNREER_{t-1}}$	0.120**	0.059	2.016
$\Delta \mathbf{LNTOT_{t}}$	0.007	0.033	0.227
$\Delta \mathbf{LNTOT_{t-1}}$	-0.096***	0.037	-2.606
$\Delta \mathbf{LNTOT_{t-2}}$	-0.016	0.040	-0.412
$\Delta \mathbf{LNTOT_{t-3}}$	-0.117***	0.043	-2.664
$\Delta \mathbf{LNTOT_{t-4}}$	-0.026	0.045	-0.587
$\Delta \mathbf{LNTOT_{t-5}}$	-0.031	0.044	-0.722
$\Delta \mathbf{LNTOT_{t-6}}$	0.023	0.042	0.559
$\Delta \mathbf{LNTOT_{t-7}}$	-0.017	0.040	-0.433
$\Delta \mathbf{LNTOT_{t-8}}$	-0.094***	0.037	-2.517
$\mathbf{ECT_{t-1}}$	-0.061***	0.013	-4.683
	Panel B. Long run coefficient estimates		
$\mathbf{LNEPU_{t}}$	-0.133***	0.046	-2.872

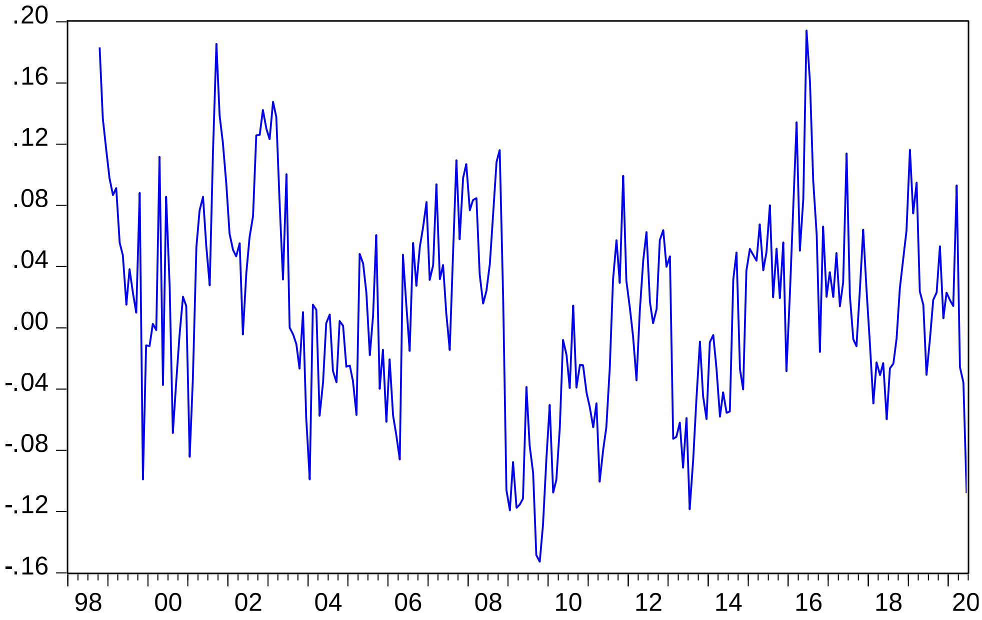
$\mathbf{LNTOT_t}$	0.475	0.799	0.594
$\mathbf{RIR_t}$	0.033***	0.013	2.470
C	5.320**	0.242	21.953
	Panel C. Diagnostic tests		
$\mathbf{Adj. R^2}$	0.98		
Functional form	$\chi^2(1)$ = 1.865 [0.063]		
Normality	$\chi^2(1)$ = 72.23 [0.000]		
Serial correlation	$\chi^2(2)$ = 0.177 [0.827]		
Heteroscedasticity	$\chi^2(1)$ = 23.73 [0.000]		

* Denotes significance at 10% level, ** indicates significance at 5% level and ***indicates significance at 1% level. In Panel C the p-values are represented in squared brackets.

In Panel B, LNEPU and RIR have the expected sign and their coefficients are statistically significant at 1%. LNTOT does not affect the exchange rate in the long run. The economic policy uncertainty coefficient shows a negative sign, which means that the variable leads to a depreciation of the real effective exchange rate: if a 1% shock occurs on the economic policy uncertainty index, the real exchange rate will decline by 0.133 %. This result confirms the main hypothesis of the paper: economic policy uncertainty contributes to a long-run depreciation of the exchange rate because of its multiple negative and permanent impacts on the economy. In addition, when the real interest rate increases by 1 pp., it produces a 3% appreciation of the REER. Higher interest rates attract foreign investment, causing an increase in the demand for the UK's pound sterling.

Panel A shows that the real exchange rate in the short run is explained only by its lags, the past values of the terms of trade, and the error correction term. The latter has a negative sign and is statistically significant at 1% level, and it shows a monthly speed of adjustment of 6% toward the long run equilibrium. Although this value appears small at first sight, since we are using monthly data the annual correction is significant (72%=6%*12). As shown in Figure 3, the deviations of the real exchange rate from its equilibrium value tend to be relatively short-lived.

Figure 3. Deviations from the long run equilibrium



The significant and positive impact of the lagged dependent variable implies that previous trends in the real effective exchange rate affect its current trends, which is probably explained by the inertia in the inflation rate.

A curious result is that although the terms of trade are not significant in the long-run, they appear to be important in the short-run. The lags one, three and eight of the change in terms of trade have a statistically significant and negative effect on the real exchange rate. The first lagged coefficient suggests that when the change in the terms of trade increases 1 pp., the change in the real exchange rate reduces 0.09 pp. after one month. If the change in the terms of trade remains for at least 9 months, then the cumulative impact on the real exchange rate is a decrease of 0.307 pp.[1] As already mentioned, this result can be interpreted by the dominance of the substitution effect of the terms of trade, in other words an increase in the relative price of exports leads to a worsening of the trade balance. The adjusted R^2 of 98% suggests a very good explanatory power of the model.

[1] Sum of the statistically significant coefficients of the change in the terms of trade up to lag 8: 0.096+0.117+0.094=0.307.

6. CONCLUDING REMARKS

This paper has examined how economic policy uncertainty (EPU) affects exchange rate dynamics in the UK using monthly data for the period 1998 to 2020. The existing literature has already analysed the impact of EPU on several variables and concluded that it reduces productivity, investment, consumption, international trade, and economic growth. The impact on the exchange rate has also been studied but we contribute to this debate by using both long-run and short-run perspectives, and examining a country that has been through periods of relatively low and very high uncertainty, namely during the Brexit process. We use additional control variables (terms of trade and the real interest rate) in a cointegrated ARDL model, chosen due to the presence of integrated variables of order one and zero. The model confirmed cointegration between the variables, and the long-run importance of EPU for the depreciation of the exchange rate. However, as no short-run role was identified, this warrants further investigation. Interestingly, the oscillations in uncertainty did not cause structural breaks in the exchange rate relationship.

Our evidence suggests that EPU has marked long-run negative impacts on the exchange rate. Periods of high uncertainty may devaluate the exchange rate significantly. The good news of our research is that the impact is more pronounced in the long-run, which gives economic agents time to adapt. Additionally, we found that the velocity of adjustment towards equilibrium in the one-year horizon is quite good (72%). Nonetheless, large swings in uncertainty may create considerable exchange rate fluctuations, with significant adjustment costs in foreign trade and investment. This should urge policymakers and regulators to maintain policy uncertainty low as a way of elevating long-term economic growth.

Finally, it is a well-known fact that the more "traditional" exchange rate fundamentals, such as money, interest rate, GDP, and trade, are unable to explain the high exchange rate volatility observed. The literature has advanced some possible explanations such as irrational expectations, bubbles, omission of volatile fundamentals, or the "Peso" problem. This issue relates to the probability of the occurrence of significant events that are rare and difficult to measure. Regarding the "Peso" problem and the omission of fundamentals, this paper underlines the idea that economic policy uncertainty may play an important role in exchange rate dynamics.

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