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Essays on the relationships between political indicators, and real exchange rate and inflation

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PhD in Economics

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June, 2021

To my son

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Resumo

Esta tese de doutoramento reexamina um longo debate sobre a ligação entre a taxa de câmbio e os seus fundamentos macroeconómicos, com particular atenção a duas medidas: a instabilidade política e a incerteza de política económica. Esta análise foca-se na dinâmica da taxa de câmbio efectiva real no Reino Unido nos últimos 24 anos. Adicionalmente, estudamos no mesmo contexto a relação entre a incerteza de política económica e a taxa de inflação.

A tese aborda estas questões em três estudos empíricos diferentes. O impacto da estabilidade e incerteza na dinâmica da taxa de câmbio será estudada nos dois primeiros capítulos empíricos, enquanto que o impacto da incerteza da política económica na taxa de inflação será o tema do último estudo empírico. As aplicações empíricas analisam a relação entre as variáveis utilizando o Modelo de Correcção de Erros Vectoriais (VECM), o Modelo Autoregressivo de Lag Distribuído (ARDL) e o Modelo Vectorial de Autoregressão (VAR).

A contribuição da tese para a literatura centra-se em três pontos principais. Em primeiro lugar, aplica-se e testa-se o Modelo de Equilíbrio Comportamental (BEER) e o Modelo de Equilíbrio Permanente (PEER) numa economia desenvolvida, a fim de calcular os desalinhamentos cambiais. Em segundo lugar, sublinha-se o impacto da estabilidade política e da incerteza da política económica na taxa de câmbio efectiva real do Reino Unido. Em terceiro lugar, relaciona-se a taxa de inflação com a incerteza da política económica no rescaldo da votação de 2016 no Reino Unido para deixar a UE.

Concluímos que os nossos resultados empíricos são consistentes com as conclusões da literatura, sugerindo que o indicador de estabilidade política e o índice de incerteza da política económica explicam flutuações de longo prazo na dinâmica da taxa de câmbio. O valor da taxa de inflação aumenta devido aos choques na incerteza da política económica, enquanto a moeda britânica deprecia-se devido aos choques de incerteza e de instabilidade.

Palavras-chave: Taxa de Câmbio de Equilíbrio Comportamental, Desalinhamentos Cambiais, Indicador de Estabilidade Política, Índice de Incerteza da Política Económica, Taxa de Inflação

JEL: F21, F31, F62, P33

Abstract

This PhD thesis re-examines a long-standing debate about the link between the exchange rate and its macroeconomic fundamentals, with particular attention to two measurements - first, instability and second, uncertainty - in explaining the dynamics of the real effective exchange rate over the past 24 years. At the same time, studies the relationship between economic policy uncertainty and inflation rate.

The mission of this thesis is to address these matters of interest in three different studies as follows, the impact of stability and uncertainty on exchange rate dynamics in the first two empirical chapters and the impact of economic policy uncertainty on inflation rate in the last empirical study. The empirical applications emphasise the use of the Vector Error Correction Model (VECM), Autoregressive Distributed Lag Model (ARDL) and Vector Autoregression Model (VAR) in assessing the relationship between the variables under analysis.

The thesis contribution to the literature can be seen in three main ways. Firstly, it applies and tests both, the Behavioural Equilibrium Exchange Rate (BEER) and Permanent Equilibrium Exchange Rate (PEER) framework in a single developed economy in order to compute currency misalignments. Secondly, it emphasises the impact of political stability and economic policy uncertainty on the UK real effective exchange rate and thirdly, links inflation rate to economic policy uncertainty in the aftermath of the 2016 UK vote to leave the EU.

We conclude that our empirical results are consistent with literature findings, suggesting that the political stability indicator and the economic policy uncertainty index explain long run fluctuations in the exchange rate dynamics. The value of the inflation rate increases due to the shocks on economic policy uncertainty while the UK currency depreciates due to uncertainty shock.

Keywords: Behavioural Equilibrium Exchange Rate, Currency Misalignments, Political Stability Indicator, Economic Policy Uncertainty Index, Inflation rate

JEL Classification System: F21, F31, F62, P33

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Abbreviations

ADF Augmented Dickey Fuller test
AIC Akaike Information Criterion
AR Autoregressive
ARDL Autoregressive Distributed Lag
ARMA Autoregressive Moving Average
ARIMA Autoregressive Integrated Moving Average
BEER Behavioural Equilibrium Exchange Rate
B-N decomposition Beveridge and Nelson decomposition method
BoP Balance of Payments
Brexit the withdrawal of the United Kingdom from the European Union
CDS Credit Default Swap
CDX North America and Emerging Markets Tradable Credit Default Swap
CM Current Misalignment
CoVaR Conditional Value at Risk
CPI Consumer Price Index
CPIH Consumer Prices Harmonised Index
ECM Error Correction Model
EMU Economic and Monetary Union
EPU Economic Policy Uncertainty Index
EU European Union
FEER Fundamental Equilibrium Exchange Rate
FRED Federal Reserve Economic Data
G7 Group of Seven
GD GDP Deflator
GEPU Google Economic Policy Uncertainty index
HP Hodrick–Prescott filter
IFS International Financial Statistics
IMF International Monetary Fund
iTraxx European, Asian and Emerging Market Tadable Credit Default Swap Index
KPSS Kwiatkowski–Phillips–Schmidt–Shin
MA Moving Average
NYSE New York Stock Exchange
OECD Organisation for Economic Co-operation and Development
OLS Ordinary Least Squares

ONS Office for National Statistics
OOH Owner Occupiers' Housing
PEER Permanent Equilibrium Exchange Rate
PP Phillips Perron test
PPP Purchasing Power Parity
REER Real Equilibrium Exchange Rate
SC Schwarz Information Criterion
TM Total Misalignment
UIP Uncovered Interest Parity
UK United Kingdom
VAR Vector Autoregressive Model
VECM Vector Error Correction Model
WGI Worldwide Governance Indicators
WPI Wholesale Price Index
WR Wage Rate Index

CHAPTER 1

Introduction

1.1. Overview of Chapter 1

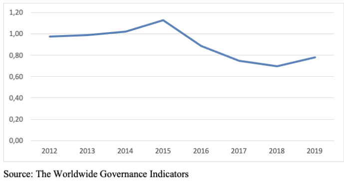
This PhD thesis explores the role of a set of economic fundamentals on the UK real exchange rate, with particular attention to two measurements - first, political instability and second, policy uncertainty - with focus over the past 24 years and the dynamics of the inflation rate over the past 22 years. Therefore, special emphasis for exchange rate movement analysis is placed on a governance indicator, on a policy index, the terms of trade and the interest rates with two distinct empirical studies. The third study is related to the possible impact of economic policy uncertainty on the inflation rate. We consider that the effects of Brexit must be understood empirically. Thus, under such consideration, the mission of each individual study is to address each of these matters, the impact of political stability and policy uncertainty on exchange rate dynamics, and the dynamics of the inflation rate due to economic policy uncertainty shocks.

This PhD thesis contributes to the field of financial market analysis, namely to foreign exchange market and exchange rate behaviour offering empirical research of the effects of a set of macroeconomic fundamentals and variables such as a political stability indicator and an economic policy uncertainty index on a single currency exchange rate. This study re-examines a longstanding debate about the link between exchange rates and their macroeconomic fundamentals; nevertheless, the novelty is that, beside those determinants, the analysis is extended to consider instabilities due to the dynamics of the political environment and uncertainties due to economic policies and realities around the Brexit phenomenon. At the same time, it tries to connect inflation rate behaviour and economic policy shocks.

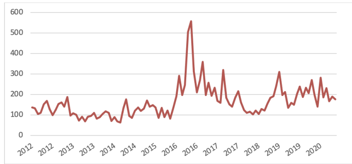
In summary, this PhD thesis contributes to exchange rate literature in two very significant ways:

1. It applies and tests both, the Behavioural Equilibrium Exchange Rate (BEER) and Permanent Equilibrium Exchange Rate (PEER) framework against a single developed economy in order to compute currency misalignments.

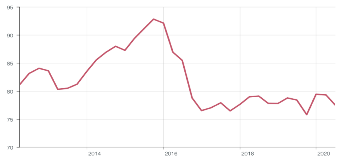
2. It emphasises the impact of political instability and economic policy uncertainty on the UK real effective exchange rate and inflation rate in the period from 1996 to 2020 with special attention paid to the period since the 2016 UK vote to leave the EU. There is an emerging Brexit literature since, more recently, the debate has turned to this largely unexpected event which is seen by Bloom et al. (2019) as an “ideal uncertainty shock” on the world’s economic outlook.



(A) The UK political stability indicator from 2012 to 2018



(B) The UK economic policy uncertainty index from 2012 to 2020



(C) The UK real effective exchange rate from 2013 to 2020

Fig. 1-1. Development of the UK political stability indicator, economic policy indicator, real effective exchange rate

The behaviour of the three main variables around the year of Brexit are represented in figure 1-1. First, we present the UK political stability indicator (figure 1-1. (A)) secondly the UK economic policy uncertainty index (figure 1-1.(B)) and lastly the UK real effective exchange rate (figure1-1.(C)).

Visual inspection of the above-mentioned figures reveals that, in the year of the Brexit referendum, the observed values of the variables registered significant changes in their behaviour. We can see that the political stability indicator worsens its position, meaning that a decreased value is translated into less stability when compared with the preceding years. The economic policy uncertainty index increases its values in 2016 and, since registered values never been, it is likely to presume that the shock of Brexit had a great impact on the UK index. The value of the real effective exchange rate began to decrease from 2016. The value of the REER in 2015 had not recovered by 2020, and since 2017, we can observe that no significant changes were registered.

This introduction presents the comprehensive framework in which this dissertation is developed. This thesis sheds light on the behaviour of the United Kingdom exchange rate. The question of the interrelationships between the four variables: the real effective exchange rate, political stability indicator, in one study; economic policy uncertainty in the other study; and terms of trade and the real interest rate common to first two empirical studies, are considered as being the main drivers of currency exchange rate movements through this dissertation. In the third empirical chapter, the variables under consideration are the inflation rate, the unemployment rate, the economic policy uncertainty and the real effective exchange rate.

Broadly, the theoretical debate which this thesis seeks to engage with is about what happens to the UK real effective exchange rate and inflation rate in the aftermath of the Brexit shock in the presence of economic policy uncertainty and political instability. To explore the debate, firstly we present the main methodological approaches and secondly the UK's economic activity is briefly outlined.

The subsequent three chapters are devoted to empirical research. In Chapter 4 and Chapter 5, we interrogate the dynamics of the UK real effective exchange rate by estimating a VECM and an ARDL, respectively, to capture its behaviour and movements in relation to the variables being studied. In Chapter 6 a VAR model is used to assess the relationship between the variables under analysis, and to capture the dynamics of the inflation rate following an uncertainty shock. The final chapter, Chapter 7, concludes the thesis with a summary of the main results, limitations and highlights possible directions for future research.

1.2. Overview of Chapter 2

Chapter 2 starts with an analysis of the importance of equilibrium exchange rate models, and it defines the concept of equilibrium itself and the exchange rate applicable to our study. Then, we do a brief review of the relevant modelling equilibrium exchange rate theories, namely Purchasing Power Parity (PPP), Fundamental Equilibrium Exchange Rate (FEER), Behavioural Equilibrium Exchange Rate (BEER) and Permanent Equilibrium Exchange Rate (PEER), is undertaken. Although we will describe each one of these theories' strengths and weaknesses, our primary focus is on only two approaches (BEER and PEER), informing the development of the fourth chapter of the current thesis.

Purchasing Power Parity theory claims that goods in one country will cost the same in another country, when converted to the same currency. It predicts that in a perfect competition market, the real exchange rate should adjust to equate the prices of national baskets of goods and services between two countries or the real exchange rates converge to a common stationary value in the long-run. However, in the exchange rate modelling literature, we find several authors acknowledging that the theory does not always hold due to factors such as market imperfections, sticky prices, transaction costs, goods that are not traded easily, basket composition, and the fact that the equilibrium values of the exchange rate do not always equal its PPP rate.

The Fundamental Equilibrium Exchange Rate approach states that the exchange rate is at its equilibrium value when it satisfies the condition of simultaneous internal and external balance. In the determination of the equilibrium exchange rate, only the role of fundamentals is considered, rather than short-run disturbances. Having established the limitations of the first two approaches, we move forward in modelling exchange rate theories through the Behavioural Equilibrium Exchange Rate and Permanent Equilibrium Exchange Rate.

The Behavioural Equilibrium Exchange Rate framework developed by MacDonald (1997) and Clark and MacDonald (1998) takes exchange rate short-run dynamics as its starting point and it proves itself able to capture the behaviour of the exchange rate. The Permanent Equilibrium Exchange Rate approach was proposed by MacDonald (2002) and aims to decompose the long-term cointegration vector into a permanent and transitory component where the permanent component is seen as the long-run effect of a set of fundamentals in the real effective exchange rate.

While the above four approaches could be used to provide a general explanation about the relationship between the real effective exchange rate and the variables under analysis here, since the purpose in the fourth chapter is to capture both the short-term and the long-term movements of this relationship and to measure the currency misalignments, only the former two will be used (the Behavioural Equilibrium Exchange Rate and the Permanent Equilibrium Exchange Rate). What is most important is whether the chosen model is most similar to economic reality in ways that are fundamental for the research in hand.

1.3. Overview of Chapter 3

In an attempt at framing the behaviour of the exchange rate we needed to observe the British economy during the period 1996 to 2020. The current environment is one of uncertainty, where the uncertainties around the British outlook were brought to scholars' attention following the 2016 vote for the country to leave the EU. Brexit, itself a shock, provides an interesting framework to analyse the response of the real effective exchange rate to factors such as low political stability and high economic policy uncertainty. The tableau of Brexit is briefly sketched, pointing out the key dates in its evolution to capture the political turmoil, and both the decline in the political stability indicator and the increase in the economic policy uncertainty index, which are going to be used in the three empirical studies. As its impacts are more likely to be mirrored in the balance of payments, we followed up our analysis by presenting the UK Balance of Payments with its components for the year 2018. In the subsequent step, we focus on the UK's consumer price index composition as the measurement of the cost of living aiming to capture all monetary expenditure on consumer goods and services in the UK. The consumer price index is the headline measure for the real effective exchange rate as being the weighted average of bilateral real exchange rates with trading partners. Moreover, the real effective exchange rate is considered a measurement of the country's competitiveness by computing changes in the demand for goods produced by a country as a function of changes in world relative prices, the consumer prices index.

In order to get insights into the UK's trade, we acknowledge the importance of the UK economy within the world economy, we rank the UK's goods and services imports and exports from the results published in the Office for National Statistics, ONS release. As in the empirical chapters, the two factors impacting the real effective exchange rate, the political stability indicator and the economic policy uncertainty index, are described, defining and representing them in comparison to the other G7 countries. The motivation for the comparison with these trade partners' indicators is due to the fact that all the variables used here are weighted against the UK's G7 trade partners.

1.4. Overview of Chapter 4

The fourth chapter uses a major political stability indicator developed on behalf of The Worldwide Governance Indicators (WGI) project to study its impact among a set of variables on the real effective exchange rate, with a main emphasis on the period following the UK's decision to leave the European Union in the 23 June 2016 referendum. By definition, the governance term is associated with the selection or replacement of governments and their capacity to formulate policies effectively. The analysis spans political stability indicators in assessing the real effective exchange rate equilibrium under the development of the Behavioural Equilibrium Exchange Rate and Permanent Equilibrium Exchange Rate frameworks. It therefore covers both topics associated with the equilibrium exchange rate outcomes as mentioned in the third chapter as the two main approaches to be used.

We present an empirical model which explains the equilibrium relationship between the four variables mentioned above, through the Behavioural Equilibrium Exchange Rate from 1996 to 2019. The model suggests that the political stability indicator can be used to explain the movements of the real effective exchange rate. Further on, as we continue to investigate if this equilibrium exchange rate is sustained by this indicator in the context of the other two macroeconomic variables, we develop the second empirical model in this study, the Permanent Equilibrium Exchange Rate model.

Using the Johansen (1995) procedure, the test of the cointegration relationship between variables is conducted. The results provide favourable evidence for supporting a cointegration relationship among the variables under study and for continuing the empirical work a model is estimated for the considered data. Thus, in order to assess the equilibrium model, the data is fitted using a Vector Error Correction Model (VECM) model. The BEER is derived from the cointegration relationship to find the currency's current misalignments. The currency's current misalignments are obtained by subtracting from the real effective exchange rate actual value its equilibrium level given by the macroeconomic fundamentals and the political stability indicator.

As we would have to conclude with currency total misalignments, we have to obtain those values. Thus, to obtain the new equilibrium values, the PEER, we decompose the long-term cointegration vector of variables into a permanent and a transitory component using the Beveridge and Nelson (1981) decomposition method. The currency total misalignments are given by the difference between the actual observed level of real effective exchange rate and its permanent level achieved with the PEER model.

As concerns the real effective exchange rate link with the variables under analysis, we conclude that the empirical results are consistent with literature findings, moreover it suggests that the political stability indicator explains long-run real effective exchange rate dynamics.

1.5. Overview of Chapter 5

In Chapter 5, the Economic Policy Uncertainty index, developed by Baker et al. (2016), was used to examine the movements of the real effective exchange rate. A high level of economic policy uncertainty will be translated into a decrease in economic outlook and therefore into a depreciation of the currency.

It is important to understand the behaviour of variables under analysis, to study their interactions and establish their integrations over time. Thus, Chapter 5 explores how real effective exchange rates is affected by the economic policy uncertainty index, terms of trade and real interest rates. These variables are insert into a cointegrated Autoregressive Distributed Lag (ARDL) model for the British economy. The ARDL bound testing, which allows to study long-run equilibria for time series with different order of integration and error correction model (ECM) were applied in this analysis to the UK's monthly data for the period from 1998 to 2020. The sample period is restricted by the available data for the economic policy uncertainty index.

The set-up of the model is as follows. First, test for the presence of long-run relationships between time-series, followed by the determination of the long-run equilibrium relationship based on the F statistics bound test. The stationarity of the time series is examined by conducting a unit root test. Although the ARDL model does not seek to test for the stationarity of the time series, in the context of rigorous empirical work and for confirmation that we are not dealing with a higher order of integration time series, we conduct two unit root tests, the ADF test and the PP test and one stationarity test, the KPSS test, for both variables in levels and in their first differences. The last step was to check the goodness of fit of the model, therefore we ran diagnostic and stability tests.

The empirical evidence presented in this chapter entirely supports the previous findings. Moreover, as a novelty for exchange rate literature, the ARDL model's results show that the UK economic policy uncertainty measure has no short-run effect on the UK's real effective exchange rate, but rather a long-run effect. Furthermore, this study confirmed the presence of negative and short-term effects of the terms of trade, as well as positive long-run effects of the real interest rates on the real effective exchange rate.

1.6. Overview of Chapter 6

The economic empirical models explaining inflation in the Phillips curve literature generally fail to account for the effect on it of an economic policy uncertainty factor. One possible reason could be that economic policy uncertainty is considered one of the variables that is hard to measure in a way which can be used in econometric work. An economic policy uncertainty shock affecting the economic activity can be seen as a negative shock on inflation because more uncertainty would be harmful for economic performance. Thus, the purpose of this chapter is twofold: it aims to strengthen the hypothesis that economic policy uncertainty can impact the inflation rate; and it intends to share new understanding about the link between economic performance and economic policy uncertainty.

The Economic Policy Uncertainty index developed by Baker et al. (2016) is also used in this study. We develop a function of inflation rate, unemployment rate, economic policy uncertainty index and real effective exchange rate, by applying a VAR model. The Johansen (1995) cointegration methodology was used, but no evidence of cointegration among the variables was founded. The class of VAR models is useful, firstly, because it is able to capture and describe dynamics between economic time series and, secondly, because from its representation it is possible to draw conclusions about variable interactions.

From the short review above, key findings emerge as follows. In the Granger causality test, the model finds no evidence of a relationship between inflation rate and unemployment rate, contrary to economic theory which states that there is trade-off between the variables of the Phillips curve. Moreover, none of the variables under study Granger causes inflation. By tracing the effect of one unit-shock in the economic policy uncertainty variable in the current and future values of inflation rate, unemployment rate and real effective exchange rate, the model predicts that, although the shocks are mostly statistically insignificant, the trajectory of the variables in the sequence of the shock is in line with our prior expectations (an increase in economic policy uncertainty will corresponds to an increase in inflation, a decline in unemployment and a drop in real effective exchange rate). At the same time, the model predicts that economic policy uncertainty reduces the value of the real effective exchange rate as was also established in our previous study, in the fifth chapter.

1.7. Overview of Chapter 7

Finally, the seventh chapter discusses the main results obtained in the previous chapters, establishes the limitations of the work, proposes prospective work to be developed, and outlines some potential research lines in the presence of political stability and economic policy uncertainty.

From the econometric analysis in the fourth chapter, a clear pattern of currency undervaluation, on average in the period 1996 – 2019, has been observed. The currency misalignments were assessed through calculation of BEER and PEER using a VAR model and the Johansen (1988) cointegration methodology. In accordance with our primary research question, the impact of the UK political stability indicator on the UK real effective exchange rate was tracked, and from the obtained results we can conclude that it has a predictive ability in determining the values of the UK real effective exchange rate for the analysed period and under this particular framework.

According to econometric estimates obtained in the ARDL bounds test framework, in Chapter 5, the REER is quite sensitive to a negative sign in terms of an increase in economic policy uncertainty. Thus, the UK EPU in relation to the real interest rate is an important factor explaining a depreciated real effective exchange rate in the long-run.

Results in Chapter 6 could provide a basis for including economic policy uncertainty in the study of a country's economic performance. Using time series from 1998M01-2020M08, we showed that, although economic policy uncertainty does not statistically significantly affect the variables under analysis (with the exception of the impact on the real exchange rate), a positive innovation in our UK EPU index foreshadows a weakening of the real effective exchange rate and unemployment rate and a rise in the inflation rate.

The results obtained in the econometric analysis in all three chapters are in line with previous findings, although in the exchange rate literature we have not noticed many studies examining the dynamics of the exchange rate and inflation rate as we achieved. One limitation of our research might be linked to the lack of results to compare with ours. Thus, significant effort has been made to clarify and provide distinctions between the political stability and economic policy uncertainty with respect to macroeconomic performance.

This chapter has outlined the research hypothesis, research methodologies, and strategy used in the study of exchange rate and inflation behaviour.

CHAPTER 2

Theoretical framework of modelling equilibrium exchange rates

2.1. Introduction

The Bretton-Woods System founded in 1944 formalised a system of fixed exchange rates using the U.S. dollar as a reserve currency and on it the world economic structure was based. The Bretton Woods Agreement created two organizations, the first one the International Monetary Fund (IMF) established to monitor exchange rates and lend reserve currency to nations that needed it, to support their currencies and settle their debts, and the second one, the World Bank which was established to provide assistance to countries that had been physically and financially devastated by World War II. After the collapse in 1971 of the Bretton-Woods System, the foreign exchange market has changed substantially. The foreign exchange market develops and expands due to the introduction of floating exchange rates. The trading in this market determines the rates at which currencies are exchanged, which further determines the cost of purchasing foreign goods and financial assets.

Despite empirical literature on exchange rates having evolved around the development of several methods for modelling exchange rate using positive concepts (in the modelling context, equilibrium is described as the value of the exchange rate that is consistent with a set of macroeconomic fundamentals), defining exchange rate in different ways, no consensus or standardised approach has been reached in this particular sense so far. Sarno and Taylor (2002) state that although the theory of exchange rate determination has produced a number of plausible models, empirical work on exchange rates has still not produced models that are sufficiently statistically satisfactory to be considered reliable and robust. Therefore, several equilibrium exchange rate definitions and methodologies exist.

The most widespread equilibrium exchange rate concepts in macroeconomic literature involving exchange rate modelling are: (1) Purchasing Power Parity (PPP), (2) Behavioural Equilibrium Exchange Rate (BEER) and (3) the Macroeconomic Balance (MB) approach (Williamson, 1994; MacDonald and Clark, 1998; Driver and Westaway, 2004; Taylor and Taylor, 2004; Couharde et al., 2019). Purchasing Power Parity proposes that the equilibrium exchange rates should be constant; the Behavioural Equilibrium Exchange Rate estimates an equilibrium real exchange rate for each country as a function of medium to long term fundamentals of the real effective exchange rate; and the Macroeconomic Balance approach provides estimates of the medium-term exchange rate associated with a given current account position. In this outline of different equilibrium exchange rate models, we emphasise with policymakers' concerns about the concept of equilibrium exchange rate mainly due to the relationship between the exchange rate and macroeconomic fundamentals.

The main aim of this research in the first empirical study is to assess the reliability of the second mentioned approach, the Behavioural Equilibrium Exchange Rate. Through the first empirical chapter we attempt to answer the following primary research questions, while the subsequent questions are common to entire dissertation:

1. How can an equilibrium exchange rate be assessed? Which economic fundamentals should be considered as causal factors in exchange rate dynamics? By answering these primary questions, an understand would be expected of the dynamics of the exchange rate while at the same time addressing the following subsidiary research objectives.

2. Is the real effective exchange rate linked to its economic fundamentals? Does real effective exchange rate converge to its equilibrium level? What does it mean for a currency to be misaligned?

3. Which macroeconomic fundamentals lead to an appreciation/depreciation of the currency in the medium and in the long-run horizon? Besides the common fundamentals, can we account for other variables linked to exchange rate dynamics?

Many authors suggest that the concept of equilibrium itself is a difficult concept to define because, generally, the word equilibrium means such different things to different people, and thus far the concepts of equilibrium exchange rates are not less stress out of this affirmation. Defining equilibrium, it seems, is by no means an easy task, given that economic theory abounds with different nuances of economic equilibrium. The arguments over what constitutes the equilibrium have spanned issues such as uniqueness, optimality, determination, evaluation over time. We consider, then, is necessary to define the concept of the equilibrium exchange rate as the starting point in answering the primary research question. We used the concept of equilibrium exchange rate that was first developed by Ragnar Nurkse (1945). He defined equilibrium exchange rate as the exchange rate that is associated with the simultaneous attainment of both internal and external balance: "the equilibrium rate of exchange is to define it as that rate which, over a certain period of time, keeps the balance of payments in equilibrium" (Reinert et al.,2009, p. 28). Frenkel and Goldstein (1986) define the equilibrium real exchange rate as the rate that makes the "underlying" current account equal to "normal" net capital flows, where the underlying current account is the actual current account adjusted for temporary factors, and the normal net capital flows are estimated on the grounds of an analysis of past trends.

To have a clear distinction between equilibrium concepts, which are considered to be time varying (by this we mean that they differ according to the time horizon to which they are applied), it is necessary to define them as short-run equilibrium exchange rate, medium-run equilibrium exchange rate and long-run equilibrium exchange rate. To define these concepts from a formal perspective, we consider Clark et al. (2000) and Driver and Westaway (2005). The real exchange rate q_t at time t is represented as a function of a vector of economic fundamentals Z_t, a vector of transitory factors T_t and a random disturbance ϵ_t:

$$q_t = \beta' Z_t + \tau' T_t + \epsilon_t \tag{2.1}$$

where β and τ are vectors of coefficients, $\beta'$and τ' are the transposed.

Short-run equilibrium exchange rate

The short-run equilibrium that can be derived from equation (2.1) is as follows:

$$q_t = \beta' Z_t + \tau' T_t \tag{2.2}$$

Williamson (1983) defines the short-run equilibrium as the exchange rate which would apply when its fundamental determinants are at their current settings after extracting the influence of random effects. In the literature, the following models are mentioned in the category of short-run equilibrium models: Flexible Price Monetary Models (FPMM), Sticky Price Monetary Models (SPMM) proposed by Dornbusch (1976), the Portfolio Balance model presented by Frankel and Chinn (1993), MacDonald and Taylor (1992) and Taylor (1995) and the Behavioural Equilibrium Exchange Rate model presented by Clark and MacDonald (1998, 1999).

Medium-run equilibrium exchange rate

The medium-run equilibrium that can be derived from equation (2.1) is as follows:

$$q_t = \beta' Z_t \tag{2.3}$$

Robinson (2010) states that the exchange rate is at medium-run equilibrium when the internal and external economic affairs of a country are brought to a point where there is no natural tendency for change. The class of the medium-run equilibrium exchange rate models include the Fundamental Equilibrium Exchange Rate model, proposed by Williamson (1985).

Long-run equilibrium exchange rate

The long-run equilibrium exchange rate can be defined as the point where stock-flow equilibrium is achieved for all agents in the economy, meaning that no forces would operate in the economy to change the vector of the fundamentals, there is no endogenous tendency to change. The model which reflects such a behaviour is the Permanent Equilibrium Exchange Rate developed by Clark and MacDonald (2004). On the same basis, following equation (2.1), the long-run equilibrium exchange rate can be represented by the formula:

$$q_t = \beta' \overline{Z}_t \tag{2.4}$$

where $\overline{Z}_t$ denotes the long-run representation of the fundamentals or the long-run value of Z_t.

Driver and Westawa (2013) suggest that the choice of macroeconomic fundamentals is determined by this theoretical framework, while the value of the fundamentals will be determined by the type of equilibrium of the interest. Although standard theory assumes that the equilibrium exchange rate is a function of observable macroeconomic variables, and that the actual exchange rate converges to the equilibrium rate after some time, an essential issue to highlight is that the equilibrium exchange rate is not observable. Komárek and Motl (2012) pointed out that the exchange rate should reflect the best possible assessment of the equilibrium exchange rate and therefore it is important for a country to attain its equilibrium level of exchange rate and to be able to respond with the most appropriate policy measures to the dynamic changes in these levels.

The structure of the present chapter includes seven sections. The first section will give a brief overview of the real effective exchange rate. The rest of the chapter is organised as follows: the subsequent four sections are dedicated to each particular equilibrium exchange rate approach, explaining the methodology and some of the specific issues that are considered important to highlight. The four approaches to equilibrium exchange rate to be reviewed are: Purchasing Power Parity (PPP), Fundamental Equilibrium Exchange Rate (FEER), Behavioural Equilibrium Exchange Rate (BEER) and Permanent Equilibrium Exchange Rate (PEER). These methods are explained and critically evaluated in order to establish their strengths and weaknesses in the support of the first empirical chapter. The definition of the Behavioural Equilibrium Exchange Rate is explained in more depth, and its distinctive characteristic, namely its medium-term nature, is analysed.. Finally, issues related to the calculation of the Permanent Equilibrium Exchange Rate are considered in the attempt of assessing the currency equilibrium level and calculating its misalignments in Chapter 4.

Analysing each method provides the motivation for choosing to develop further only two methods in our first empirical chapter, namely the BEER and the PEER. The subsequent sections explore the extent to which the real effective exchange rate equilibrium assessed by these two approaches is the most appropriate method with which to investigate these settings and answer the research questions. It therefore discusses the most appropriate methods with which to translate this into first empirical work.

The last section of this chapter briefly reviews the existing studies of the long-run relationship between real effective exchange rate and its determinants using the aforementioned two approaches, the BEER and the PEER.

2.2. Real Effective Exchange Rate

It is not an easy task to judge which exchange rate is more appropriate to be considered as the most important for an accurate research because each currency has as many exchange rates as there are other currencies. Depending on the investigation question at hand, the real exchange rate can be defined in different ways. The real exchange rates are the relative prices of two goods from two countries, and under a floating rate regime they may be viewed as being determined by the interplay of supply and demand in foreign exchange market. The rate of exchange is determined by the stock supply and the stock demand for the various currencies and the mechanism of transmission is the external balance. A competitive and stable real exchange rate can be understood as an important tool for macroeconomic stability and future development at the same time. Real exchange rate as a macroeconomic variable determines the relative price of domestic products relative to foreign, and therefore directly influences exports and imports and thus aggregate demand, output, unemployment and inflation. The real exchange rate, Q, derived from adjusting the bilateral nominal exchange rate is expressed as:

$$Q_{it} = \prod_{i=1}^{n} \frac{P_{it}S_{ijt}}{P^*_{jt}}^{w_i} \tag{2.5}$$

where index i and j represent the domestic economy, respectively foreign economy, P_i denotes the price level in the home country or domestic economy, P^*_j denotes the prices in the foreign economy, S_{ijt} represents the nominal exchange rate, is the home currency price of currency i, and w_i effective trade weights and sum to unity. It is used to determine an individual country's currency value relative to the other major currencies in the index, as adjusted for the effects of inflation. An increase in Q_{it} implies that the currency has appreciated, or alternatively that it has become less competitive.

Marsh and Tokarick (1994) state that the choice of price index is also important because real exchange rates defined using different price indices can move in very different ways. Usually, the real exchange rate tracks changes over time, starting with a base year index of 100, and is weighted to reflect the relative importance of foreign countries' economies in terms of domestic country's trade. In our research, in all empirical studies, we will use the Consumer Price Index, hereafter referred as CPI. CPI attempts to quantify the aggregate price level in an economy, to measure the purchasing power of a country's unit of currency relative to its partner trading countries.

The real effective exchange rate, hereafter referred as REER, is considered one of the important economic indicators of an economy's international competitiveness, because it represents the whole economy measure of the exchange rate. In this research into the effect of exchange rate changes on the competitiveness of a given country's exports in the world market, the appropriate weight would be the volume of exports. The reason behind this weighting system is that the change of the domestic currency in relation to currencies of trading partners weighted by the share of exports would help indicate the cost of the home country's exports to foreign customers. A real appreciation decreases price competitiveness, lowers the demand for domestic products, decreases exports and increases imports, inhibiting economic activity, raising unemployment and lowering inflation; the opposite happens with real depreciation. Increasing deficit of current account is caused due to the overvaluation of the exchange rate and implies that a coherent depreciation of exchange rate is required in order to maintain the equilibrium level. Overvaluation occurs when actual exchange rates exceed the estimated equilibrium value, while undervaluation implies that the actual exchange rate falls short of the estimated equilibrium value prevailing at that point in time. The presence of misalignments suggests that for a particular period of time the importance of the external balance to the exchange rate can be more than offset by capital flows. The costs of exchange rate misalignment are mainly seen as higher unemployment when the currency is overvalued and higher inflation when it is undervalued.

The general aim of our research is to consider the real effective exchange rate among a set of fundamentals in the determination of the dynamics of the exchange rate. Having said this, we proceed in this research using an individual exchange rate as a benchmark. The REER is used in literature for purposes such as valuing the drivers of trade flows, reallocation of production between the tradable and non-tradable sectors and evaluating the equilibrium value of a currency. An appreciation of it will raise the other currencies' values while a fall in the other currencies' basket will depreciate the currency. Blanchard and Milesi-Ferretti (2012) point out that the persistence of large current account imbalances and large net foreign assets positions are a threat to the world economy. In making efficient monetary policy decision, central banks need to know whether the currency is close to its equilibrium level value.

Currency misalignments are calculated from the value of REER that is consistent with the macroeconomic internal and external balances over the long-term. Logically in the case of a stable but misaligned exchange rate, over time will be expected to come up against highly unstable exchange rate. In the literature, authors including Maeso-Fernandez et al. (2002), Rahn (2003), Clark and MacDonald (2004), Lebdaoui (2013), Tipoy et al. (2016), Amoah (2017), Bui et al. (2017), Comunale (2019) use the REER in their studies as an approach to equilibrium rate over time.

For economic research purposes, institutions like World Bank, Bank for International Settlements, the OECD, publish various indicators for REER. The International Monetary Fund provides REER data that may be accessed through the International Financial Statistics (IFS) datasets.

2.3. Purchasing Power Parity (PPP) approach

The oldest theory of exchange rate determination is considered to be the Purchasing Power Parity theory, henceforth abbreviated as PPP. The concept of PPP was formalised by Cassel (1916), stating that PPP refers to the internal value of the currencies concerned, which can be measured using the general price level. In terms of its purposes, Rogoff (1996) states that it is almost always the first reference for estimating an equilibrium exchange rate due to its simplicity. Its influence is well known due to its application to a large exchange rate literature mainly due to this feature and is based on The Law of One Price. PPP theory implies that under certain assumptions such as no barriers to international trade and capital flows, simultaneously domestic and foreign economies operating at full employment level in a market-based price system, when expressed in a common currency all identical goods should be equal. This is due to the observation that goods market arbitrage forces the price of a product in two different countries to converge. Furthermore, PPP theory claims that price levels determine the equilibrium exchange rate, since the difference between prices in two countries is not permanent if these prices are measured using the same exchange rate, implying that prices converge towards price equilibrium. PPP assumes a base period at which the real exchange rate is assumed to be at its equilibrium level, thereby suggesting that price equalisation should hold in the very long-run.

In support of PPP equilibrium level, Rogoff (1996) highlights two main rules in PPP theory, first that nominal interest rates tend toward PPP in the long-run and second, the short-run deviations from PPP are substantially large. In spite of the purported advantages of using PPP benchmarks, whether long-run PPP holds or whether real exchange rate is stationary, has significant economic implications, given Rogoff's (1996) support for "... instinctively believing in some variant of purchasing power parity as an anchor for long-run real exchange rates". Marsh et al. (2012) reviewing the literature on PPP theory found that that PPP is a good first approximation of the long-run behaviour of exchange rates, and that adjustment to PPP displays significant non-linearities.

Taylor and Taylor (2004) stress that PPP theory articulates that nominal exchange rates should evolve to neutralise competitiveness changes induced by movements in price indexes across nations. If nominal exchange rate changes do not influence trade flows, real exchange rates are mean reverting processes. In the literature we can find well documented studies detailing that exchange rate is non-stationary or, if it is mean reverting its adjustment speed to the equilibrium values is very slow. The slow adjustment is translated into prolonged deviations from its equilibrium which cannot be explained through the concept of PPP (Bahmani-Oskooee et al. , 2008). Officer (2006) points out two groups of arguments against PPP theory - first, arguments that PPP theory is inaccurate and, second, arguments proposing that PPP theory is biased.

Although PPP can be seen as one of the most useful descriptions of the long-run exchange rate, when short-run relative price effects have worked themselves out, there is also substantial evidence that it is unrealistic to expect that it will hold continuously, since there are many shocks to exchange rates. It can be said that PPP does not take into consideration the fact that the real exchange rate may need to adjust to real shock when monetary policies produce different inflation rates between countries. In the following section, we explore some reasons why PPP does not always hold in practice, drawing from a large number of authors that have developed theoretical models on PPP theory:

- the composition of the basket of goods and services included in measures of national price levels differs across countries.
- many goods are not easily traded and when they are produced in different countries, they may not always be perfect substitutes.
- the presence of significant transactions costs for traded goods.
- aggregate price levels are sticky, meaning that the real exchange rates are not constant in the short-run.
- the degree of openness of each country.

PPP predicts that the exchange rate should adjust to equate the prices of national baskets of goods and services between two countries because of market forces driven by arbitrage. Johansen and Juselius (1990) have suggested that one possible reason why many investigations have failed to find evidence supporting these parity conditions is the fact they have ignored the links between goods and capital markets when modelling the exchange rate. If fundamentally, the exchange rate is influenced by monetary as well as real factors, consequently, the equilibrium value of the exchange rate does not always equal its PPP rate. Besides this, both Balassa (1964) and Samuelson (1964) argued that PPP would not hold in the long-run because of different rates of productivity growth in the traded-goods sector between countries. Relatively high rates of productivity growth would raise wages in the economy, push up the relative prices of nontraded goods, and cause the real exchange rate to appreciate because of the higher overall price level.

Despite its limitations in exchange rate equilibrium determination, which are summarised in Taylor and Taylor (2004), PPP is still widely used in empirical research (Siregar and Rajan, 2006; Bergin et al., 2017; Tran et al., 2018; Yoon, 2019).

2.4. Fundamental Equilibrium Exchange Rate (FEER) approach

To overcome the aforementioned disadvantages in PPP framework, an alternative developed and implemented approach to estimate the real equilibrium exchange rate is the Fundamental Equilibrium Exchange Rate (henceforth, FEER) approach, proposed by Williamson (1983, 1994). In contrast with the PPP model, the FEER model makes use of some variation of the current account approach and is seen as an alternative exchange rate determination model suitable for medium-run analysis (Wren-Lewis and Driver,1998; Coudert and Couharde, 2005). Wren-Lewis (1992) defines the FEER as "a method of calculation of a real exchange rate which is consistent with medium-term macroeconomic equilibrium" being defined in terms of the real effective exchange rate.

The FEER approach indicates that the exchange rate is at its equilibrium value when it satisfies the condition of simultaneous internal and external balance. Heriqbaldi et al. (2019) argue that the "internal balance refers to the condition where the level of output which is consistent with the state of full employment and low inflation and the external balance refers to the situation where there is a current account balance that is sustainable". As per this set up, were imposed at least three assumptions on the FEER:

- it requires either full employment or maintenance employment rate in the long-term.
- it assumes a low and sustainable domestic inflation rate.
- it assumes that the country does not have restrictions to free trade and is trying to attain internal balance.

Williamson (1983) interprets the external balance condition in terms of current account balance and states that the current account must be sustainable since the FEER measure was derived from a standard world trade model, in which all the variables are endogenous except the external equilibrium (sustainable current account determined by structural parameters) and the internal equilibrium (full utilisation of productive potential).

Since it allows the equilibrium real exchange rate to vary over time, FEER was developed to assess the degree to which exchange rates are consistent with macroeconomic fundamentals. Berger and Kempa (2012) found that the notion of a sustainable current account is not immediately operational which can be justified in open economy models as allowing for smooth intertemporal consumption and investment reflecting global rate of return opportunities. There is substantial uncertainty as to the exact magnitude of a sustainable external balance and whether divergences of the current account balance from the target are transitory or permanent, since the internal balance is usually defined as economic activity evolving at potential, so that the output gap is zero.

Égert and Lahrèche-Révil (2003) using the FEER approach studied the equilibrium exchange rate for real and nominal exchange rates. Their investigation was based on the notion of internal and external balances, which were defined in terms of the relative price of non-tradable goods and the long-run sustainability of the current account position.

One limitation of FEER is that it only considers the role of fundamentals in determining equilibrium exchange rate, meaning that it does not consider short-run disturbances. Several studies pointed out another limitation in that the approach allows a vast number of parameters which should be estimated, and the estimators can be subject to an idiosyncratic judgement. Those parameters cannot be estimated exactly as a general rule because, for instance, the sustainable or equilibrium current account balance is at least determined by the estimation of the economy's potential output gap, the existence of non-tradable goods, preference differences, economic shocks, and changes in foreign exchange markets among others.

2.5. Behavioural Equilibrium Exchange Rate (BEER) approach

Jiang et al. (2016) mention that a new strand of literature identifies one of the major shortcomings of traditional exchange rate models in their minimal attention to the market's expectations of future values of macroeconomic fundamentals. Macroeconomic fundamentals approaches remain significant in explaining fluctuation in real effective exchange rates especially in the medium and long-run (MacDonald, 2007).

Taking the Fundamental Equilibrium Exchange Rate (FEER) approach advocated by Williamson (1995) and its limitations as a starting point, MacDonald (1997) and Clark and MacDonald (1998), based on the co-integration methodology of Johansen and Juselius (1995) develop a more inclusive and flexible approach, the Behavioural Equilibrium Exchange Rate (henceforth BEER). The BEER approach is an empirical method linking the real exchange rate to a set of macroeconomic variables. The coefficients of the estimated equation may be derived either based on an observed series or using long-term values of the fundamentals. Couharde et al. (2018) state that the BEER approach does not require estimates or to make assumptions on the long-run values of economic fundamentals, and Schnatz (2011) finds that when dealing with small samples, in judging the actual rate, the BEER as a measure of the equilibrium real effective exchange rate is more reliable. This approach links the real exchange rate to a set of fundamentals through a single equation, where the set of macroeconomics variables is not predefined by the theory, but rather is determined on an *ad hoc* basis.

The original BEER approach is not based on any specific exchange rate model, meaning that it may be regarded as a very general method for modelling equilibrium exchange rates. A central element of most BEER applications is the condition that the current account should equal zero in equilibrium. Furthermore, the BEER takes as its starting point the proposition that real factors are a key explanation for the slow mean reversion to PPP observed in the data. In this sense the BEER is similar to some variants of the internal external balance approach such as the FEER but incorporating short-run in the BEER framework makes it better able to capture the dynamic of behaviour of the exchange rate. As a result of this, BEER is more realistic than FEER. According to Driver and Westaway (2001), BEER can be classified as "current and cyclical equilibrium exchange rates", since their computation is based on the current levels in the fundamental factors.

To represent the BEER approach, we follow MacDonald (1997), Clark and MacDonald (1998), where the actual value of the real effective exchange rate, q_t can be determined as follows:

$$q_t = \beta_1' Z_{1t} + \beta_2' Z_{2t} + \tau' T_t + \epsilon_t \tag{2.6}$$

where Z_{1t} and Z_{2t} are vectors 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, ϵ_t is a white noise process. Current equilibrium rate is defined as the level of exchange rate given by the current values of the Z_{1t} and Z_{2t}, that is:

$$q_t' = \beta_1' Z_{1t} + \beta_2' Z_{2t} \tag{2.7}$$

Current misalignment, cm_t is defined as the gap between actual exchange rate and real exchange rate given by the current values of all the economic fundamental and is given in the following equation:

$$cm_t = q_t - q_t' = \beta_1' Z_{1t} + \beta_2' Z_{2t} + \tau' T_t + \epsilon_t - \beta_1' Z_{1t} - \beta_2' Z_{2t} = \tau' T_t + \epsilon_t \tag{2.8}$$

Therefore, current misalignment is simply the sum of the transitory vector and random errors. In the BEER approach, the distinction between the current misalignment and total misalignment is made explicit (MacDonald 2007). The total misalignment, tm_t is defined as before but the real exchange rate is given in the long-run values of economic fundamentals which are denoted by $\overline{Z}_{1t}$ and $\overline{Z}_{2t}$:

$$tm_t = q_t - \beta_1' \overline{Z}_{1t} - \beta_2' \overline{Z}_{2t} \tag{2.9}$$

Total misalignment can be decomposed into two components, by adding and subtracting q_t from the right-hand side of equation (2.9) and using equation (2.7), we get:

$$tm_t = (\tau' T_t + \epsilon_t) + [\beta_1'(Z_{1t} - \overline{Z}_{1t}) + \beta_2'(Z_{2t} - \overline{Z}_{2t})] \tag{2.10}$$

The first component is the current misalignment, cm_t and the second shows the effect of departures of the current fundamentals from their sustainable values.

According to equation (2.9), the total misalignment of the currency at any point of the time could be decomposed into the effects of transitory factors, random disturbance, and the extent to which the economic fundamentals depart from their sustainable values. These misalignments may be the consequence of future evolution of the exchange rate and not of market forces. In an attempt to determine an equilibrium exchange rate function, the real effective exchange rate may be driven by real incomes, money supply and government expenditures but also by specific country indicators such as political stability indicator, agricultural development indicator, growth indicator.

Égert (2004) and Égert et al. (2006) conduct studies in order to calculate the REER applying the BEER approach by estimating the long-run cointegrating relationship between the exchange rate and fundamentals using observed fundamental variables. In order to capture the permanent component of the fundamentals under analysis, the Hodrick-Prescot (HP) filter may be applied, to decompose a time series into a permanent and a temporary component, introduced by Beveridge and Nelson (1981), Gonzalo and Granger (1995). By estimating the REER using only the permanent component of the fundamentals, studies such as MacDonald (2002), Maeso-Fernandez et al.(2002), Alberola (2003) and Rahn (2003) and Bénassy-Quéré et al. (2009) define a new model as being the long-run BEER or the Permanent Equilibrium Exchange Rate model.

2.6. Permanent Equilibrium Exchange Rate (PEER) approach

The misalignment rate captured using the steps above is often referred to as the current misalignment rate, a variant of BEER is the Permanent Equilibrium Exchange Rate (henceforward PEER) approach first proposed by MacDonald (2002).Clark and MacDonald (2004) argue that it would be advantageous to supplement BEER analysis with the PEER approach. Conducting their study for the exchange rates dynamics of the USA, Canada, and the UK they used the following as fundamentals: the real interest rate differential, net foreign assets, and relative price of nontraded/traded goods as explanatory variables. They found that the BEER and PEER move closely together for the U.S. and Canadian dollars, whereas for the pound sterling the BEER and PEER diverge sharply.

In the PEER framework, the difference between the actual real exchange rate and the real PEER is referred to as total misalignment. The PEER may be considered an augmented BEER representation and aims to decompose the long-term cointegration vector (fitted value) into a permanent and transitory component with the permanent component being interpreted as the equilibrium exchange rate. As stated before, the missing part from the BEER approach is the decomposition of each relevant variable into its temporary and permanent component using one of the decomposition methods mentioned in the exchange rate literature. The most commonly used techniques for this purpose were introduced by Stock and Watson (1988), Clarida and Gali (1994) and Gonzalo and Granger (1995) who have showed that if the cointegration exists amongst several variables, then the vector will also show a common trend (to have a cointegration vector means that the real exchange rate and the vector of fundamentals form a valid long-run relationship).

Formally, taking equation (2.6), after decomposing the fundamentals into permanent and transitory components the relation between REER and its fundamentals can be expressed as:

$$q_t = PEER_t + \tau' T_t + \epsilon_t \tag{2.11}$$

The decomposed permanent component is considered to be the long-run PEER. The currency misalignment in this framework is written as:

$$misalignment_t = q_t - PEER_t \tag{2.12}$$

Ca' Zorzi et al. (2020) state that the BEER models show a powerful adjustment mechanism which ensures that the initial exchange rate misalignment is absorbed, especially over longer horizons. Benassy-Quere et al. (2008) state that although the BEER and the PEER appear to be complementary views of equilibrium their computation may produce consistent assessments in the exchange rate equilibrium theory.

Duval (2001) points out that the advantages of the PEER model are related to its dynamic adjustment to the long-run equilibrium level and with the capture of Balassa-Samuelson effects. The Balassa- Samuelson effect, in general, explains why the prices of tradable goods tend to converge at the international level, while this is not true for the prices of non-tradable goods, which tend to be higher in countries where labour productivity in the tradable sector is higher. Estimating the long-run dynamics in the REER for each EU member using a set of fundamentals, Comunale (2015) calculates the currency misalignment as being the difference between the observed REER and the PEER model estimation into a cointegration framework. Couharde and Sallenave (2013) in their study involving panel data for 25 industrial countries, the real effective exchange rate misalignments are generated as being the difference between the REER and the BEER.

Studying the impact of real exchange rate misalignment on the economy, Wong (2019) show that an increase in real exchange rate misalignment can lead to a decrease in the economy. Regarding the value of misalignments of a currency, which may be undervalued or overvalued, in our study the following concepts are used: undervaluation is to be assessed when the market value of the currency is below its equilibrium value, while overvaluation is assessed when the market value of a currency exceeds its equilibrium value.

2.7. The fundamentals of REER: a brief literature review

In the standard economic models, the most used fundamentals that influence the exchange rates are relative inflation rates, interest rates, and money supply.

Exchange rate determinants in the long-run has been the subject of numerous theoretical and empirical works. Krugman and Obstfeld (2009) state that the real exchange rate of a currency is the price of foreign products in terms of domestic products.

Abreu et al. (2007) detail four factors that affect exchange rates in the long-run as follows:

- relative price level - the demand for a currency is determined by foreign buyers of goods and services while the supply of a currency is determined by domestic buyers of foreign goods and services. When prices are lower in one country relative to another country, more of the cheaper goods and services will be needed, so more of that currency is demanded (there is an appreciation).
- relative trade barriers - the taxes on imported goods, transport costs, governmental trade restrictions make trade expensive it means that the demand for domestic over foreign goods increases, allowing the domestic currency to appreciate without injuring sales of domestic goods.
- preferences for domestic and foreign goods- an increase in the preferences for domestic goods leads to a real appreciation because the demand for exported goods and services increases. Instead, the preferences for foreign goods have the opposite effect, sustaining demand for foreign goods will depreciate the domestic currency.
- relative productivity - as a country becomes relatively more productive than other countries, the price of its goods and services tend to fall, meaning that its currency appreciates because its exports were not harmed. The currency will depreciate if a country's productivity lags that of other countries.

Within the literature, a large spectrum of fundamentals are used to check whether the real effective exchange rate converges or not to its equilibrium level, such as: oil price, government consumption, liquidity, total reserves including gold, net capital flows, trade openness, government fiscal stance, foreign reserve level, index of monetary policy, relative productivity, interest rate differential, domestic foreign asset holding, domestic and foreign inflation rates productivity differentials, index of crude oil price volatility. The fundamental variables used depend on the question on hand and research purposes (Alonso-Gamo et al., 2002; Maeso-Fernandez et al., 2002; Rahn, 2003; Giannellis et al., 2007; Giannellis, 2010; Plecitá et al., 2012; Lebdaoui, 2013; Hiri, 2014; Rafindadi, 2015; Tipoy et al. (2016)). Studies like Clark and MacDonald (1999), Ricci et al. (2013), Zhang and MacDonald (2014), Tipoy et al. (2017), Comunale (2019) use some of the following as the major fundamentals behind long-run movements of the 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.

Christiansen et al. (2009) conducted an analysis of the REER determinants in the long-run by adding a population growth and old-age dependency ratio and an external financing aid. From the population indicator an appreciation of the real exchange rate was expected because a higher share of inactive dependent population reduces national savings and the current account balance. Secondly, the external financial aid flow accounted for two components - grants and concessional loans since the former enters the current account and the latter the financial account. Although no consensus on the impact of this variable it was prior assigned, a strong significance was found between those variables in the samples under analysis.

Giannellis (2010) in a BEER framework investigates whether the nominal exchange rate of the euro against the currencies of the four major trading partners of the eurozone, namely China, Japan, the UK and the USA, converges or not to its equilibrium level using as exchange rate determinants domestic and foreign inflation rates, and fundamentals defined by the monetary model. They found that at the end of the estimated period, the euro/ Chinese yuan and the euro/UK pound nominal exchange rates follow an equilibrium process. The BEER analysis indicates a general overvalued euro in relation to the Chinese yuan. This finding explains the huge increase of the China 's foreign exchange reserves and the expansion of its current account surplus.

Zhang and MacDonald (2014) examined the links between real exchange rates, the trade balance and net foreign assets for three different panels (a panel of 23 selected OECD countries, a panel containing the 23 OECD countries and China, and a panel containing the same OECD countries and four less mature economies: China, Malaysia, Pakistan and the Philippines) for the period from 1980 to 2011. They found a cointegrating relationship between the trade balance and net foreign assets, a significant negative relationship between real exchange rates and the trade balance in the majority of estimations, an increase in the trade balance results in a real depreciation of the real exchange rate.They did not find a significant link between real exchange rates and net foreign assets.

Four of the reviewed papers, Lebdaoui (2013) for Morocco, Hiri (2014) for Algeria, Rafindadi (2015) for Nigeria and Amoah (2017) for Ghana are using the BEER approach and the Hodrick-Prescott (H-P) filter to remove short-term variation of the exchange rate and to obtain the PEER model.

Lebdaoui (2013) uses the following set of the fundamentals: real net capital flows, terms of trade shocks, trade openness, government fiscal stance, foreign reserve level, index of monetary policy and relative productivity and finds that the main fluctuations of the real effective exchange rate are due to trade openness, government spending, terms of trade, productivity progress, monetary policy and net capital inflow, the misalignment from the equilibrium level needs from five to six years to be eliminated.

Hiri (2014) based on macroeconomic fundamental as oil price, government consumption, liquidity (M2/GDP), total reserve include gold, net capital flows, capital flows, trade openness, and terms of trade. The results point that all the fundamentals are contributing for the dynamics of the Algerian Dinar real effective exchange rate and the degree of misalignment ranged between almost -28% and 36%.

Fundamentals such as net foreign assets, terms of trade shocks, index of crude oil price volatility, government fiscal stance, monetary policy and productivity were included in Rafindadi (2015)'s research. The results of the BEER and PEER estimation confirmed that Nigeria is experiencing high degrees of currency overvaluation and undervaluation with an unprecedented peak of 46.87%. Nigerian RER is affected positively by the index of monetary policy performance, and index of crude oil price volatility, the terms of trade, and net foreign assets. The study discovered that Nigeria's RER appreciates with changes in terms of trade conditions, monetary policy, volatility in oil prices, and changes in net foreign assets but that it depreciates when there are low foreign reserves and high levels of government spending.

Amoah (2017) founds that the movements in Ghana exchange rate have been largely inconsistent with the path dictated by the macroeconomic fundamentals of the economy leading to two extremes of undervaluation and overvaluation. The macroeconomic fundamentals under investigation were terms of trade, trade policy/trade restrictions, fiscal stance, investment/ productivity, net foreign assets and real interest rate differential.

Comunale (2019) explores the role of economic fundamentals in explaining long-run movements in the REER for 28 EU countries over the period 1994–2012 and calculates currencies misalignments. The determinants of the REER are NFA position, trade balance and current account. From the research's findings we would highlight only the fact that the UK has an advantage in terms of competitiveness arising from an undervalued REER for almost all the analysed years.

The link between political stability and exchange rate has a limited number of representations in papers. Saeed et al. (2012) studies the determinants of exchange rates in Pakistan from 1982 to 2010 including a dummy variable as a proxy for political instability, finding that it significantly impacts the exchange rate. Bouraoui and Hammami (2017) investigate the relationship between political instability and exchange rates in five Arab Spring countries over the period 1992Q1–2016Q4 and find evidence of significant drop in the value of all currencies due to political instability. In Chapters 4 and 5 we will return to more papers on the link between political instability/uncertainty and exchange rate.

Traditional research papers on equilibrium exchange rate follow various approaches to address the equilibrium condition such as purchasing power parity (PPP), uncovered interest parity (UIP), macroeconomic balance approach, Fundamental Equilibrium Exchange Rate (FEER) approach, Behavioural Equilibrium Exchange Rate model. However, when adopted in different contexts, these theories showed many limitations and usually provided poor estimations of equilibrium exchange rates.

All things being equal, it is not an easy task to judge different models and select just one as being the solution without specifying a structure by which selection is made. What is most important is whether the chosen model is most similar to economic reality in ways that are fundamental for the research in hand. In our view, the central issue of this research is how important the determinants for exchange rate dynamics are in any situation of disorder that might occur in the financial market.

CHAPTER 3

Overview of the UK economy from 1996 to 2020

3.1. Introduction

Since the overall economic conditions can change on a daily basis, the currency trends are more likely to respond to those changes almost immediately. If the fundamentals of the economy remain inconsistent with the exchange rate dynamics, economic problems will almost certainly occur. Miller and Weller (1990) noted that in models in which asset prices are determined by expectations, the general possibility of "rational bubbles" emerges. In some situations, bubble may deviate the exchange rate from the economic fundamentals and make the exchange rate inconsistent with equilibrium values. Priewe (2014) acknowledges that explaining exchange rate bubbles is difficult mainly because it cannot be nominated a particular reason for their occurrence. Towe (1989) states that the task, of distinguishing between fundamental versus bubble determinants of the exchange rate is complicated by the lack of consensus as to which fundamental relationships, and therefore which fundamental economic variables, are at work in foreign exchange markets.

Jirasakuldech et al. (2006) investigated the presence of bubbles in the bilateral exchange rates between the US Dollar and five currencies including the British pound for the period between 1989 and 2004. The exchange rate fundamentals included in their study are money supply, income and interest rates. They found that the UK exchange rates were not influenced by bubbles, moreover the Johansen cointegration test indicates evidence of a long-run relationship between the British pound exchange rate and the fundamentals under analysis.

Hu and Oxley (2017) investigate for the presence of nominal exchange rate bubbles in some G 10, Asian and BRICS countries, then explore whether the explosiveness in the nominal exchange rate is driven by rational bubbles or exchange rate fundamentals. Their results suggest that firstly, there is no evidence of bubbles in the exchange rate pairs in G10 countries, only with the exception of the pairs Sterling- Swiss Franc and Sterling-Japanese Yen where little evidence of bubbles was detected; and secondly, newly emerging economies are more likely to exhibit bubbles in the exchange rate than more developed countries.

Regarding the theoretical literature of exchange rate modelling, the role of macroeconomic fundamentals is fairly established and in assessing long-horizon equilibrium exchange rate changes, different studies tried to renew the use of those macroeconomic fundamentals see, for instance, Engel and Granger (1987), Zhang (2002), Clark and MacDonald (2004), Cheung et al. (2007). Exchange rates may be affected by economic or political factors that can be highly correlated and interactive in a very complex way. [1]

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 has been neglected as a policy variable. For several periods, this fact was translated into economy's harms. One of the harms made by this disregard is considered to by the exchange rate misalignment. The misalignments were caused by the currency's tendency to settle at too high level for the health of the UK's economy. Bootle and Mills, (2016) defended that this evidence occurs for two main reasons. First, because of the UK's political stability and the extraordinary liquidity and attractions of its asset markets, it has a decided tendency to attract private capital flows that push up the real exchange rate and second, because of a history of inherently strong domestic inflationary pressure, the UK policy authorities have tended to welcome, and even encourage, a strong exchange rate as a way of bearing down on the UK inflation. We can say that as the exchange rate plays a significant role in international trade, the policymakers could consider it as an economic policy tool to correct the overall balance of trade. By allowing international trade the countries were provided with access to foreign markets where to export their goods and services. The competition between domestic and foreign markets increases while international trade is continuously improving the quality of goods and services provided.

Chinn and Cheung (2018) suggest new challenges in modelling equilibrium exchange rates, assessing exchange rate misalignment, and evaluating their roles in re-balancing external imbalances, and shock determinants of a country's economic outlook. A strong currency makes a country's imports cheaper and its exports more expensive in foreign market while a weaker domestic currency stimulates exports and make imports more expensive. Is to be said that if the value of a country's exports rises by a greater rate than that of its imports, the country's balance of trade has improved. If a country imports too much, the balance of trade is more likely to be distort and the currency to be depreciated.

It is acknowledged that the UK has a substantial economy with average living standards which are higher than in many other parts of the world. According to the International Monetary Fund World Economic Outlook (October 2018), in terms of gross domestic product (GDP) per head on a purchasing power parity basis, the UK comes in at 7 out of 211 countries. Kierzenkowski et al. (2016) mention that "Since becoming a member of the European Union (EU) in 1973, GDP per capita in the UK has doubled, outperforming other affluent non-EU English-speaking countries". One of biggest problems of British economy in the last decade, among the 2009 economic crises, 2013 sovereign debt crises, is considered to be the 2016 Brexit decision. The vote for Brexit has resulted in a significant subsequent depreciation of sterling. Clearly, Brexit

[1] See Wang et al.(2004), Forecasting foreign exchange rates with artificial neural networks:A review.

means that the future structure of the UK economy is liable to change in some basic ways, and major policy challenges are more likely to arise.

The current environment is one of uncertainty and this will continue to be the case, at least until the UK formally leaves the European Union (EU) and until new trade terms will be negotiated. Brexit could change the way of the UK's actual trade relationships with the EU countries and may arise new trade opportunities directly with Non-EU countries. The uncertainties around the British outlook are brought to scholars' attention since 2016 favourable EU leave vote and there are several studies that have reached mixed conclusions about its impact on both, the UK economic output and global economic outlook in general.[2]

While Minford (2019) argues that Brexit will have a positive effect on the UK economy, Born et al. (2019) are predicting negative effects of Brexit on UK trade, and Steinberg (2019) argues that Brexit will reduce overall economic activity in the UK.

Thus, it is not an easy task to predict how and when the British pound sterling will recover from the Brexit impacts as there will be further considerable uncertainty surrounding any estimate of its impacts across the global economy. In general, the economic uncertainty and political instability can be seen as negative factors in the currency market. However, the uncertainty began prior to the result of the UK 2016 referendum mainly because of the unclear outcome of both the referendum and the possible Brexit negotiations that could follow. We consider that the period surrounding the referendum provides an interesting framework to analyse how the political (in)stability and economic policy uncertainty could have real effects on the UK exchange rate. According to the OECD (2016), both instability and uncertainty, on one hand, would generate persistent adverse consequences on economic activity in the UK, and on the other hand would result in negative near-term spillovers elsewhere, particularly in the rest of the EU.

In this chapter we intend to give some insides into the UK economy and to expose some stylized facts about this economy from the perspective of the real exchange rate as a price depending on consumer price measurement. We rely our chapter on the below understandings of the stylised facts: the stylized facts can be defined as broad descriptions of findings, which need of causal explanations and identified as especially worthy of investigation.

Specifically, this chapter briefly exposes the events following the 2016 United Kingdom Leave European Union referendum, describes the UK balance of payments experience since 1996 to 2020 and describes the composition of the consumer price index. It is important to point out the limitation in exposing the UK balance of payments. First, although we review the literature to the extent that is relevant for the UK real effective exchange rate, this is not a complete survey of that literature. Second, the financial account and the financial account are reviewed only for the year 2018 as per the complete Office for National Statistics data report available at the moment of the research and the 2019 report

[2]For a further analysis of the economic impact of Brexit see EU withdrawal scenarios and monetary and financial stability, Bank of England, published on 28 November 2018.

will be only mentioned as numbers which are not developed in tables. The consumer price index (CPI) issues will not be discussed in depth only to the extent that it sustains the calculation of the real effective exchange rate.

The reminder of the chapter is structured as follows. Since the main objective of this chapter is to frame and explain the context of the next chapters and to provide insights about the concepts of matter, we would first expose the Brexit context. The next section exposes relevant balance of trade data for this study and attempts to capture the magnitude of the imports and export of goods and services and to highlight the most important sectors in this balance. For 2019 the balance of trade data will be given on the UK's imports, exports of goods and services with EU countries and Non-EU countries, and with the world total trade partners. The section 3.4 indicates the methodology used in the calculation of the UK REER. Then, putting all these aspects together, we explore the evolution of two factors that could impact the real effective exchange rates of the UK's economy, the political stability indicator and the economic policy uncertainty index. Throughout the chapter emphasis will be given to these two particular indicators. The final section summarizes and looks forward.

3.2. The UK European Union membership 2016 referendum

Considering Brexit as one of the most significant events of recent political and economic in the UK history, we formulate the hypothesis that first, a political stability indicator and second an economic policy uncertainty index might impact the UK's real effective exchange rate and inflation rate dynamics in the recent past. Due to the favourable 2016 EU Referendum, the UK's political landscape has obscured the nation's exit path from the EU, with little consensus on how that will be eventually achieved. It is hard to accurately predict what will happen and to believe that any economic disruption will have short-term and minor effects on the UK further development. From the time the EU leave Referendum results were released, the government has been negotiating the terms of the country's exit. The UK Parliament has increasing uncertainty and the risk of the "no deal" scenario between the UK and the EU, since January 2019 when the withdrawal agreement was rejected three times by the ex-Prime Minister Theresa May. The UK did not leave the EU on 29 March as previously planned because of the vote against the prospect of the UK leaving the EU without any deal and in favour of a delay to Brexit.

The EU and UK agreed on a further delay to Brexit until 31 October because of the continuous political impasse. In the meantime, the Prime Minister Theresa May resigned on June 7th, 2019. Boris Johnson, won the Conservative Party leadership competition at the end of July, thus becoming the UK's Prime Minister. On 17 October 2019 the EU and the UK government reached a new agreement on a revised deal on Brexit. The UK Parliament voted to force the government to seek an extension to the deadline and also delayed a vote on the new deal and the Prime Minister was forced to ask the EU for another extension of the negotiating period until January 31, 2020. The UK has officially left the European Union on 31 January 2020, but it sets out a transition period which lasts until 31 December 2020. The transition period can be seen as in Anievas and Nişancioğlu (2017) a time between formal membership of the EU and the beginning of a new relationship (Gieseck and Largent, 2016).

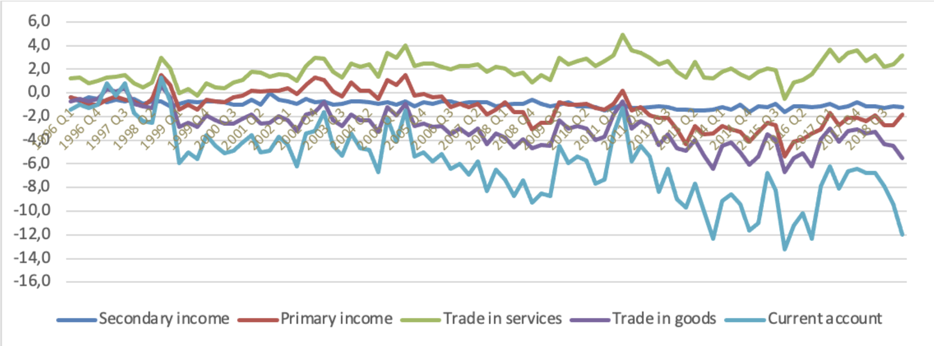
Aisen and Veiga (2013) state that political instability is likely to shorten policymakers' horizons leading to suboptimal short-term macroeconomic policies. It may also lead to a more frequent switch of policies, creating volatility and thus, negatively affecting macroeconomic performance. According to Uddin et al. (2017) an unstable political regime generates what is known as a political instability risk; this phenomenon is a significant deterrent to economic growth because it has a negative impact on investment and human capital, which could affect the economic health of a country or region. Therefore, we expect the political instability generated by the 2016 referendum to have impact on the real exchange rate.

3.3. The UK balance of payments (BoP)

The UK's balance of payments (BoP) is a measure of cross-border transactions between the UK as the domestic economy and rest of the world. It draws a series of balances between inward and outward transactions, provides a net flow of transactions between UK residents and the rest of the world and reports how that flow is funded. The balance of payments is an official account of international payments, published in a document called the Pink Book.

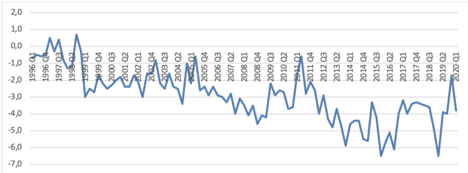
Statistics on the UK imports and exports have been gathered since 1687. As an official record, the balance of payments is broken down into three basic accounts: the current account, and the capital and financial account. The relation between them is that, by definition, the sum of the current and capital account balances equals the balance of the financial account. Consecutively, a current account deficit implies running a surplus on the financial and capital account meaning that as a net borrower, the UK should attract net financial inflows to finance its current and capital account deficits. According to the ONS, International economic statistics: UK ' s current account explained (2019) released on 31 October 2019, "an increasingly significant deficit may begin to suggest some warning signs like a leakage of domestic currency to the rest of the world partly because of the requirement to purchase foreign currency to meet cross-border payment obligations. This mass purchasing of foreign currency can depreciate the value of that domestic currency if enough of this activity happens".

3.3.1. The current account shows flows of goods, services, primary income, and secondary income between residents and non-residents figure 3-1. According to Office for National Statistics (ONS), Balance of payments: 2019Q3 released on 20 December 2019, the UK's current account deficit (a measure of the country's balance of payments with the rest of the world in trade, primary income and secondary income) narrowed to £15.9bn (2.8% of GDP) in 2019Q3, compared with £24.2bn (4.4% of GDP) in 2019Q2, an improvement of £8.3bn. From figure 3-1.(A) we can check that over the long-run, the current account deficit follows mostly the same path as the trade balance and primary



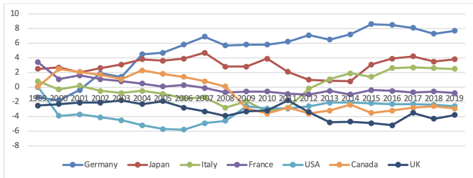
Source: ONS Balance of Payments, 31 October 2019

(A) The UK current account 1996Q1-2019Q1



Source: ONS Balance of Payments, 31 October 2019

(B) The UK current account deficit as % of GDP 1996Q1-2020Q1



Source: ONS Balance of Payments, 31 October 2019

(C) G7 countries current account deficit as % of GDP year 1999 to 2019

FIG. 3-1. Development of the UK and the G7 current accounts from 1996 to 2020

income balance. The UK deficit (figure 3-1.(B)) was kept on average around the same values from 2006Q4 to 2019Q1, but from 2007Q1 it tended to increase compared to, for example, 2004Q3. Some improvement episodes in the current account deficit can be observed from 2009Q2 until 2012Q, from 2016Q4 to 2017. In the first quarter of 2019 the deficit worsened sharply followed by an improve in it in the last quarters of 2019.
Amongst the G7 economies, the UK consistently experienced a current account deficit since 1999 to 2019 as we can check on figure 3-1.(C), meaning that to fund its own economy, the UK is conditioned by the amount of money flow from abroad, which flow is less than the outgoing flow to foreign investors.

3.3.2. The capital account shows credit and debit entries for non-produced nonfinancial assets and capital transfers between residents and non-residents. Its records acquisitions and disposals of non-produced nonfinancial assets, such as land sold to embassies and sales of leases and licenses, as well as capital transfers, that is, the provision of resources for capital purposes by one party without anything of economic value being supplied as a direct return to that party. In the lately ONS data released, Balance of payments, UK: December 2019, is mentioned that the primary income deficit widened by £3.7 billion to £7.1 billion, or 1.3% of GDP in 2019Q2; this was because of increased payments to foreign investors on their direct investments in the UK.

3.3.3. The financial account shows net acquisition and disposal of financial assets and liabilities. The financial account recorded a net inflow into the UK of £21.1 billion in 2019Q2, an increase from a net inflow of £15.1 billion in 2019Q1. The economic fundamentals we derive for our research scope are driven from the UK balance of payments (BoP) based on the framework details from the IMF website. The main strength of the UK national account system is that it allows analysis of the various economic indicators both, in isolation and in conjunction with others. Based on the UK balance of payment presented facts, we can conclude that due to the deficit of the current account and capital account, the UK exchange rate does not seem to be in equilibrium.

3.4. The UK Consumer Price Index as a base measure for the Real Effective Exchange Rate

According to the UK Office for National Statistics, since 1996, the UK tracks Consumer Price Index (CPI). The CPI came into existence in the late 1990s and is identical to the Harmonised Index of Consumer Prices (HICP) which is produced for Eurostat according to European regulations. From 1997, the Consumer Price Index was published in the UK as the Harmonised Index of Consumer Prices (HICP) until December 2003, when the UK inflation target was changed to one based on the CPI. The CPI reflects well its origin, as a measurement of the cost of living aiming to capture all monetary expenditure on consumer goods and services in the UK.[3]

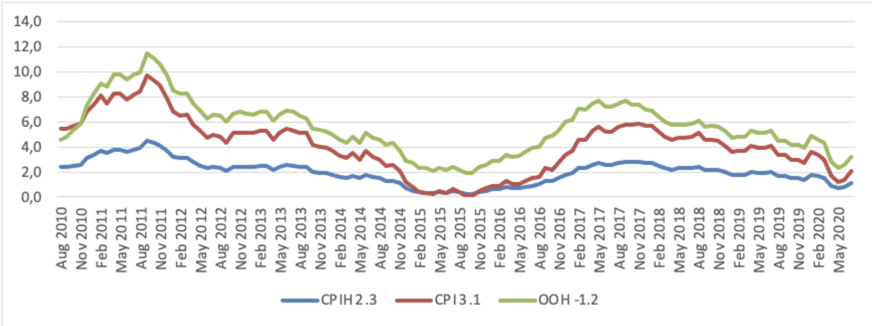
The CPIH (Consumer Price Index Harmonised) is the UK's lead measure of inflation[4], and is identical to the former lead inflation measure, the Consumer Prices Index (CPI), save for the treatment of owner occupiers' housing costs (OOH) costs, which are excluded from the CPI. The CPIH, which compensated for the lack of a measure of OOH in CPI, was introduced in 2013. OOHs are a major part of household budgets and, as such, are an important aspect of consumer price inflation.

Consumer Price Index is the headline measure of inflation in the UK and is a Lowe price index, meaning that quantity weights should be fixed at some point in the past. In the UK ´s case two years before price collections and is used to calculate the average price increase, as a percentage for an annual revised basket, in consumer spending habits. The UK Office for National Statistics acts so to avoid potential biases that might otherwise develop over time, for example, due to the development of entirely new goods and services, or the tendency for consumers to move away from buying goods and services that have risen relatively rapidly in price and to goods and services whose prices have fallen. Broadly, the UK shopping basket covers the following groups: Food, Alcoholic drink (off sales) and tobacco, Clothing and footwear, Housing, fuel and light, Household goods and domestic services, Personal goods and services (health related), Motoring expenditure, fares and other travel costs, Leisure goods and services, Catering and alcoholic drink (on sales), Personal goods and services. Currently, around 180,000 separate price quotations are used every month in compiling the indices, covering around 700 representative consumer

[3]See Courtney (2014) for further details about the Consumer Price Indices in the UK, who bases his research mainly on the 2010 edition of the Office of National Statistics, Consumer Prices Index Technical Manual

[4]CPIH is the ONS's preferred measure, and it is different from the HICP from Eurostat. It builds on CPI to include various costs associated with living in your own home, such as council tax.

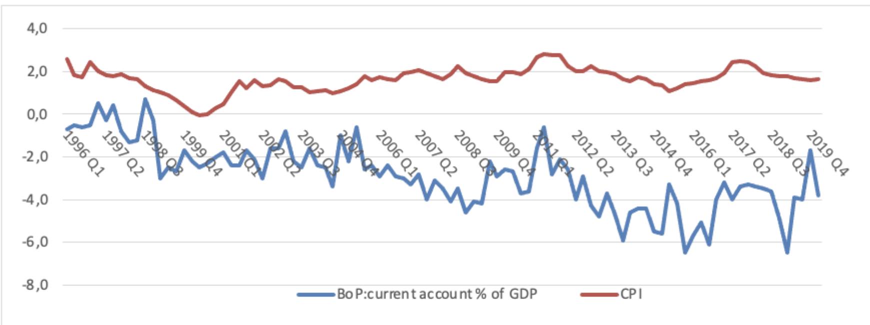
goods and services. These prices are collected in around 140 locations across the UK. On 31 July 2017 the Consumer Prices Index including owner occupiers' housing costs was re-assessed.



Source: ONS Consumer price inflation

Fig. 3-2. CPIH, OOH component and CPI 12-month rates for the last 10 years, 2010M08 to 2020M04

The evolution of the Consumer Price Index is shown in the figure above and it compares the 12-month inflation rates for CPIH, CPI and the OOH component of CPIH. Given that OOH accounts for around 17% of CPIH, it is the main driver for differences between the CPIH and CPI inflation rates. The Consumer Prices Index including owner occupiers' housing costs (CPIH) 12-month inflation rate was 1.7% in August 2019, down from 2.0% in July 2019 while The Consumer Prices Index (CPI) 12-month rate was 1.7% in August 2019, down from 2.1% in July 2019. The CPIH and CPI 12-month inflation rates were about 1.1% in July 2020, compared with 2.0% in July 2019.



Source: ONS Balance of Payments

Fig. 3-3. The UK CPI and BoP: current account percent of GDP 1996Q1-2020Q1

According to the IMF rankings based on nominal GDP data for year 2019, the British economy is the sixth largest economy in the world. In the macroeconomic outlook are mentioned two prominent economic factors in the British economy, the increasing current account deficit and the low level of inflation. According to the ONS, the UK's current account has been in deficit since 1984, reaching a record level in 2016 of 5.2% of GDP. While the deficit narrowed in 2017 to 3.5%, a deterioration in the trade deficit has led to the current account deficit widening again in 2018 to 4.3%. While the current account deficit is turning larger every year, according to the Bank of England, the consumer price index (CPI) or the inflation rate has been below 2% as per the figure 3-3 shows.

3.5. The UK's Real Effective Exchange Rate

The main purpose behind the construction of REER is the aim of having a measurement of the country competitiveness by computing changes in the demand for goods produced by a country as a function of changes in world relative prices. Conventionally, in the calculation of the REER it is assumed that every country exports only final goods produced without using imported intermediate goods. For the estimation of the real effective exchange rate, Edwards (1996) suggested the following price indices: Consumer Price Index (CPI), Wholesale Price Index (WPI) which measures the average price of goods at the wholesale stage, GDP Deflator (GD) which is one way of measuring the price level and it is defined as the ratio of nominal to real GDP, and Wage Rate Index (WR) which measures changes in the price of labour (changes in the average rates actually paid by employers to their employees for work during normal working hours). In the present study, our attention felt on the Consumer Price Index in measuring the UK real effective exchange rate.

Hence, the real effective exchange rate aims to assess a currency area's cost competitiveness relative to its principal competitors in international markets where the changes in cost and price competitiveness depend not only on exchange rate movements but also on cost and price trends. In the UK economy, the Real Effective Exchange Rate (hereafter referred as REER) measure is deflated by the price index (total economy) CPI, against a panel of 60 economies in the case of Real (CPI-based) Broad Indices [5] and a panel of 27 countries [6] for the Real (CPI-based) Narrow indices. In both datasets are included individual euro area countries and, separately, the euro area as an entity. The most recent weights are based on trades in the 2014-2016 period, with 2010 as the indices' base year. REER is the same weighted averages of bilateral exchange rates adjusted by relative consumer prices, and it calculates the number of units of a domestic good that will pay for 100 units of equivalent foreign good where the weighting pattern is time varying.

[5] The panel of 60 countries entering the Broad index calculation are: Algeria, Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, Chinese Taipei, Colombia, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Euro area, Finland, France, Germany, Greece, Hong Kong SAR, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Malaysia, Malta, Mexico, Netherlands, New Zealand, Norway, Peru, Philippines, Poland, Portugal, Romania, Russia, Saudi Arabia, Singapore, Slovakia, Slovenia, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, United Arab Emirates, United Kingdom and United States

[6] The panel of 27 countries entering the Narrow index calculation are: Australia, Austria, Belgium, Canada, Chinese Taipei, Denmark, Euro area, Finland, France, Germany, Greece, Hong Kong, SAR, Ireland, Italy, Japan, Korea, Mexico, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, United States

Mathematically, we can express the REER formula as follows:

$$REER_{country\ i} = \sum_{j=1}^{N} trade\ weight(country\ j) \times Real\ Exchange\ Rate(country\ j)$$

country j=1,2,. . . ,N are country i's trading partners, exchange rates in natural logarithms (geometric averages). In this particular case, the UK N it goes until 27 on broad bases index and until 60 on the narrow-based index.

Source: Bank of England, 2019: (2010 = 100)

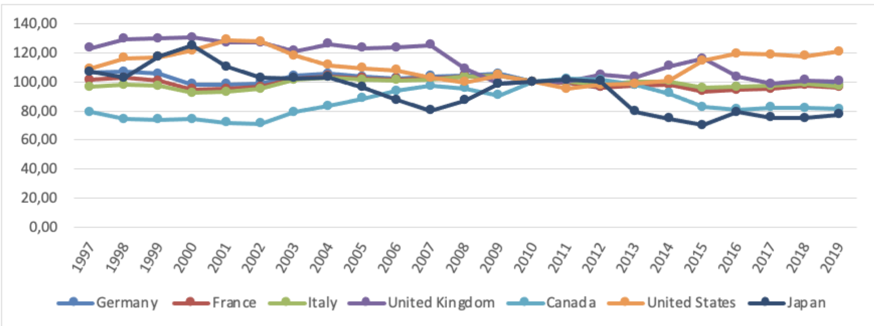
FIG. 3-4. Monthly Real Effective Exchange Rate based on CPI from 1996M3 to 2020M06

In figure 3-4 is shown the evolution of the UK REER for the British pound that exhibits two large depreciations within the period for which data has been collected, the period corresponding to world economic crisis of 2007-08 and the period after 2016. It is clear that amongst the many factors that may be responsible for determining the exchange rate behaviour after the BREXIT vote, the referendum result is only one cause of the most recent observed currency depreciation.

The figure 3-5 and the table 3-1, provide more information about the G7 countries REER evolution for the period 1997-2019.

Table 3-1. G7 REERs based on CPI, 2010 = 100

Year	Germany	France	Italy	UK	Canada	US	Japan
1997	106.52	101.58	96.45	123.22	79.04	109.18	107.06
1998	107.09	102.72	97.88	129.61	74.32	116.3	102.88
1999	105.54	100.64	97.34	130.14	73.95	117.04	117.53
2000	98.42	94.92	92.48	130.66	74.22	121.68	124.99
2001	98.27	95.12	93.05	127.06	71.85	128.81	110.63
2002	99.05	96.65	95.15	127.11	71.17	127.77	102.94
2003	104.15	102.2	101.54	121.46	79.05	118.02	102.64
2004	105.5	103.93	103.2	126.01	83.56	111.69	103.05
2005	103.57	102.37	101.55	123.26	88.67	109.3	96.28
2006	102.61	101.7	101.09	123.57	93.74	108.04	87.59
2007	103.91	102.28	101.97	125.56	97.16	102.86	80.35
2008	104.5	103.93	103.45	109.1	95.47	99.77	87.07
2009	105.61	104.36	104.77	98.96	90.83	104.77	98.59
2010	100	100	100	100	100	100	100
2011	99.43	99.4	100.14	100.55	102.21	95.13	101.54
2012	96.13	96.21	98.25	104.94	101.39	98	100.36
2013	98.24	97.76	100.07	103.38	98.05	98.6	79.69
2014	99.04	98.09	100.32	110.71	92.08	101.16	74.74
2015	94.65	93.44	95.84	116.15	82.83	114.65	70.12
2016	96.15	94.67	96.65	103.54	80.91	119.4	79.27
2017	97.08	95.12	97.18	98.75	82.27	118.73	75.52
2018	99.66	97.6	99.04	101.01	82.04	117.8	74.96
2019	98.13	96.2	96.85	100.53	81.32	120.8	77.44



Source: Eurostat

Fig. 3-5. G7 monthly Real Effective Exchange Rate based on CPI from 1996M3 to 2020M06

For the entire analysed period we can observe that the REERs of three countries, Germany, France and Italy have followed almost the same path with little variation in their recorded values.probably because they belong to the euro area.

Considering the real effective exchange rate as indicators for the average price competitiveness into economy, a consumer price-based measurement, we can observe that from 2007 to 2009, the UK sees its international competitiveness significantly increasing when comparing to the previous ten years period, from 1997 to 2007. The gain in competitiveness can be also observed during Brexit and during the periods after the 2016 referendum. Since 2012 to 2019, we can observe that according to the country level REER, Japan is experiencing international competitiveness improvement.

3.6. The UK foreign trade

3.6.1. Brief trade overview

The terms of trade fluctuate in line with changes in export and import prices. An improvement in the UK terms of trade means that export prices are increasing faster than import price. An improvement in the term of trades will generally lead to an improvement in living standards as imported goods appear cheaper to consumers while a deterioration in terms of trade leads to a decline in living standards as foreign currency earnings are relatively less and imported consumer goods more expensive. Changes in the terms of trade can have important effects on economic aggregates and on the UK's current account of the balance of payments. According to ONS, in 2018 the exports and imports of goods and services individually accounted for around 62% of GDP in the UK. In the following we will overview very briefly the UK balance of trade for 2018 and for 2019, but the main analysis will be made on the 2018 balance of trade.

In 2018, the UK's exports of goods and services totalled 642 £bn and imports totalled 680£bn while in 2019 accounted for 700£bn in the exports of goods and services, respectively 724 £bn the UK's imports. On one hand the EU, taken as a block, is the UK's major trading partner it accounted for 46% in 2018, respectively 43% in 2019 of the UK exports of goods and services and for 54% and 49% of imports. On the other hand, the USA, as a country including Puerto Rico, is the UK's largest trading partner, accounted for almost 19% of UK exports and just 8.7% of imports in 2018 and 20% in 2019 exports and 13% of 2019 imports. The top ten UK's trade partners accounted for 61,7% of UK's total trades. The value of imports from both, the EU countries and the US are present in the top ten trade countries. Germany is the most representative country in relation with the UK's import for goods and services and the USA has the second highest value of the UK import market. The imports from the US (where US* denotes the inclusion of Puerto Rico in the analysis) and Netherlands were equivalent to 8.7% and 7.4% of total UK services imports respectively, as shown in table 3-2.[7]

[7]Further analysis on the UK's trade balance can be found in the UK Balance of Payments, The Pink Book: 2019 released on 31 October 2019

Table 3-2. Top 10 UK's partners total trade(TT), exports and imports for goods and services £bn (% of total trade) for 2018

Country	£bn(% of TT)	Country	UK exports	Country	UK imports
US*	173.6 (14.7%)	US*	118.2 (18.6%)	Germany	77.3 (11.6%)
Germany	132.7 (10.2%)	Germany	55.4 (8.7%)	US*	55.4 (8.7%)
Netherlands	93.1 (7.2%)	Netherlands	44.0 (6.9%)	Netherlands	49.1 (7.4%)
France	84.9 (6.5%)	France	42.1 (6.6%)	China	45.4 (6.8%)
China	68.5 (5.3%)	Ireland	38.3 (6.0%)	France	42.8 (6.4%)
Ireland	60.2 (4.6%)	China	23.1 (3.6%)	Spain	32.3 (4.9%)
Spain	49.9 (3.8%)	Italy	19.7 (3.1%)	Belgium	29.1 (4.4%)
Belgium	48.5 (3.7%)	Switzerland	19.6 (3.1%)	Italy	24.8 (3.7%)
Italy	44.5 (3.4%)	Belgium	19.4 (3.1%)	Ireland	21.9 (3.3%)
Switzerland	30.5 (2.3%)	Spain	17.6 (2.8%)	Switzerland	10.9 (3.3%)
Total	£803.4bn (61.7%)	Total	£397.4bn (62.5%)	Total	£399.8bn (60.5%)

In 2018, the UK's exports to the EU were 289£bn (46% of all UK exports). UK imports from the EU were 353£bn (54% of all UK imports). The UK had an overall trade deficit of –64£bn with the EU in 2018. A surplus of 29 £bn on trade in services was outweighed by a deficit of 93£bn on trade in goods (Table 3-3). The UK had a trade surplus of 33£bn with non-EU countries obtained from a 345£bn billion in total exports and 312£bn in total imports.

Table 3-3. The UK trade with EU member states and Non-EU £bn for 2018

	Trade balance- £bn		
	Goods exports	**Service exports**	**Total exports**
EU28	172. 2	116.7	288.9
Non-EU	178.5	166.6	345.1
	Goods imports	**Service imports**	**Total imports**
EU28	265.6	87.3	352.9
Non-EU	223.2	88.9	312.1
	Goods balance	**Services balance**	**Total balance**
EU28	-93.4	29.4	-64
Non-EU	-44.6	77.7	33.1

In 2019, the UK's exports of goods and services totalled 700£bn, from which a percentage of 43% were the exports to the EU countries and 57% to the Non-EU partners. The imports of goods and services summed about 724£bn with the EU states accounting for 51% of the UK's 2019 imports. In sum, the UK overall trade deficit in 2019 was 24£bn, a trade deficit with the EU countries of 72£bn and a trade surplus of 48£bn with Non-EU trade partners.

3.6.2. Trade in goods and services

In 2018, the trade in goods was dominated by the cars sector both in exports and imports. Total export was valued at around 33.3£bn, 9.5% of all UK goods exports and 33 £bn, 6.7% of all UK imports of cars. The second most traded good was the Medicinal and pharmaceutical products having the same value of 24.7£bn but with different weight in export trade, namely 7.1% and 5% in the import trade goods for 2018 as it is shown in table 3-4. There is a substantial trade in both directions in crude oil and power generation equipment.

Table 3-4. Top 10 UK goods imports and exports in £bn and as % of total goods trade with the EU countries

Goods Exports (2018)	£bn as % of total goods exports	Goods Imports (2018)	£bn as % of total goods exports
Cars	33.3 (9.5%)	Cars	33.0 (6.7%)
Medicinal and pharmaceutical products	24.7 (7.1%)	Medicinal and pharmaceutical products	24.7 (5.0%)
Mechanical power generators (intermediate)	24.7 (7.0)	Refined oil	22.7 (4.6%)
Crude oil	20.2 (5.8%)	Mechanical power generators(intermediate)	20.6 (4.2%)
Aircraft	15.2 (4.3%)	Clothing	19.9 (4.1%)
Refined oil	14.0 (4.0%)	Crude oil	19.7 (4.0%)
Non-ferrous metals	9.6 (2.7%)	Telecoms and sound equipment (capital)	19.3 (3.9%)
Scientific instruments (capital)	9.3 (2.6%)	Miscellaneous electrical goods (intermediate)	16.1 (3.3%)
Miscellaneous electrical goods (intermediate)	9.2 (2.6%)	Road vehicles other than cars (intermediate)	14.3 (2.9%)
Organic chemicals	9.1 (2.6%)	Other manufactures (consumer)	13.3 (2.7%)
Total goods exports	£350.7bn	Total goods imports	£488.7bn

The top five export service are presented in table 3-5 and reveals that largest export service type is Other business services, which includes research and development, professional and management consulting services, and technical, trade-related and other business services not included elsewhere, accounting for 28.7% of total services exports in 2018.

Table 3-5. Top 5 UK services imports and exports as % of total trade services with the EU

Service Exports (2018)	£bn as % of total services exports	Service Imports (2018)	£bn as % of total services imports
Other business services	81.3 (28.7%)	Travel services	56.8 (32.2%)
Financial services	61.4 (21.7%)	Other business services	40.8 (23.1%)
Travel services	38.9 (13.7%)	Transport services	23.9 (13.6%)
Transport services	30.2 (10.7%)	Financial services	18.4 (10.5%)
Telecomms, computer and information	20.8 (7.3%)	Telecomms, computer and information	12.9 (7.3%)
UK total services exports	£283.4bn (82.1%)	UK total services imports	£176.3bn (86.7%)

The Travel services represents the most significant type of the UK service imports, account for 32.2% of the total services imports in 2018 followed by Other business services which made up 23.1% Besides the top five export services presented above, the UK is well known also for its financial sector as an important exported service. Its contribution usually includes retail banks, investment banks, hedge funds among the activities of a broad range of firms.

3.7. Evolution of the UK Political Stability Indicator and the UK Economic Policy Uncertainty index from 1996 to 2020

3.7.1. The UK Political Stability Indicator

The political stability plays an important role in the economic development of the UK, meaning that an unstable political situation as the withdrawal of the United Kingdom (UK) from the European Union (EU) could seriously hinder its development prospects. The consequences of the leave vote (BREXIT) may have several effects by disrupting market activities and labour relations which eventually will be translated into a direct adverse effect on UK productivity and profitability. A lower level of productivity may generate income inequalities and rising inequality means falling growth an increasing socio-political instability will fuel social discontent.

Alesina and Perotti (1996) testing the hypothesis of income inequality, found the risk averse economic agents may avoid taking important economic decisions or might exit the economy, preferring to invest abroad. As a result of the June 2016 UK referendum vote, a massive decision of investors investing abroad UK will have a great impact on the BoP. In their study, Serwicka and Tamberi (2018) mentioned two hypothesis, first, multinational firms may be temporarily holding off investment, waiting for clarification regarding the nature of the future relationship between the UK and the EU and second, there is the possibility that the Brexit vote has dented investors' confidence in the UK, making the UK permanently less attractive to investors. Their analysis showed that the Brexit vote may have reduced the number of foreign investment projects to the UK by some 16-20 percent.

Asteriou and Price (2001) test for the influence of political instability on the UK economic growth between 1961 and 1997 and find that instability in the government will cut the progress of the on-going long-term projects and will create disturbances for the economy progress. Furthermore, Barro (2013) finds that political conditions and stability also affects the level of economic growth and development in the country. For instance, economic growth is connected with persistent policies of government and how government implements these policies when the government launches policies to improve capabilities and skills, bring new technology in the country, and increase domestic and foreign investment by developing friendly policies and favourable environment to foster economic growth in a country.

The political stability concept has many broad definitions and meanings. The Worldwide Governance Indicators (WGI) are a research dataset summarising the views on the quality of governance. It provides the political stability indicator based on six broad dimensions of governance, namely: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law and control of corruption. [8] Due to the UK country specificity, a developed country, we will focus our analysis only on two out of six dimensions, the political stability as the absence of violence and the political stability as the government efficiency.

Political stability as the absence of violence The UK political instability is an illustration of the confusion existing in the UK's political system since the Brexit came into worlds' attention. A stable polity it should be seen as peaceful society and not as the source of unproductive and anomic experiences which only resolve issues through political daily disagreements.

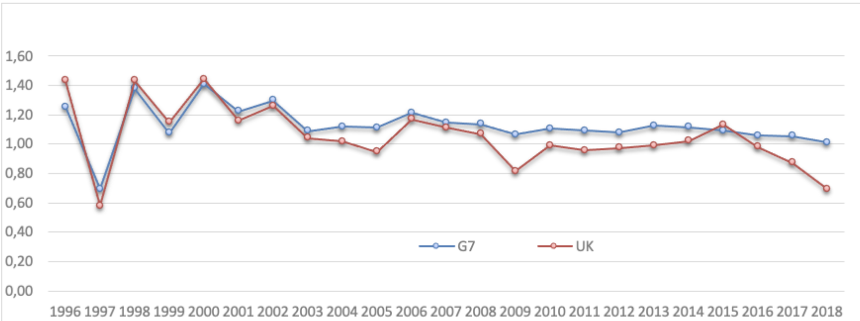
The concept of political instability as if a country is considered as stable if it has been a liberal and consistent democracy or dictatorship for 25 years was defined by Lipset (1960). Henceforth, the political instability concept is referred on by Gyimah-Brempong (1999) as situations, activities or patterns that threaten to change or actually change the political behaviour that threaten to change or actually change the political system in a non-constitutional way. As a measurement, the Political Stability and Absence of Violence/Terrorism indicator provided by The World Bank in the WGI database measures the perceptions of the likelihood of political instability using politically motivated violence, including terrorism to occur.

Political stability as the government efficiency The political stability approach uses the concept of stability as the efficiency of the government system depending primarily on the consistency of strong political government where the government is considered to be inefficient if policy objectives vary over a short period of time. Consequentially, a political instability situation is a concept broadly understood to refer to any situation in which there is believed to be a lack of government effectiveness and control over the decision-making process. The Government Effectiveness indicator driven from the WGI database, captures the perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy

[8] http://info.worldbank.org/governance/wgi/

formulation and implementation, and the credibility of the government's commitment to such policies.

Having described above very briefly a small chain of the lack of political stability implications, we can agree that a high level of political instability could harm the UK's economic, social, political activities. In our knowledge, in the literature only few papers have performed related work in the attempt to link the political stability to the exchange rate and none that have attempted to explain the UK real effective exchange rate behaviour in the context of political instability generated by the positive vote on leave EU Referendum on June 2016.



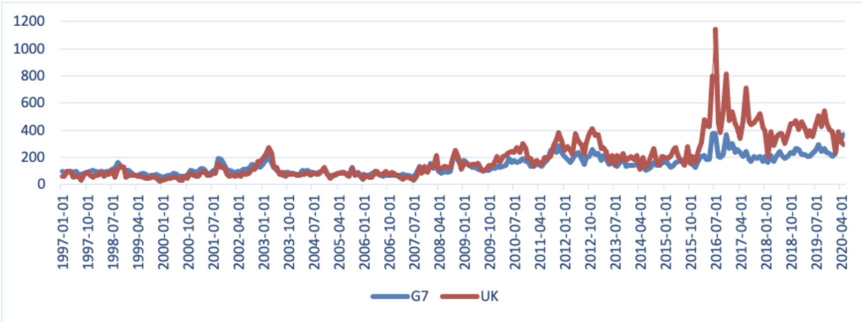
Source: Worldwide Governance Indicators

FIG. 3-6. Annual Political Stability Indicator in the UK and in G7 countries 1996-2018

Figure 3-6 depicts the evolution of the aggregate UK political stability measure together with the aggregate G7 countries measure of political stability since 1996 to 2018. Overall, the UK individual indicator captured in our index follow broadly in line with the G7 indicator. Focusing on the aggregate measure of the UK political stability indicator, it can be seen that it worsens during three periods (1996/97, 2008/09, 2016/18) and improve temporarily (1997/98, 2001/02, 2014/15). The impact of Brexit is clear in reducing political stability in the UK.

3.7.2. The UK Economic Policy Uncertainty index

As an alternative indicator to capture political unrest, in our research we use the monthly index of economic policy uncertainty (EPU), developed by Baker et al. (2016). Although for each country the newspapers are specific to that country, the searched terms are the same for all countries. According to the UK EPU index the authors count the number of newspaper articles (in the native language of the newspaper in question) containing the terms uncertain or uncertainty, economic or economy, and one or more policy-relevant terms like policy, tax, spending, regulation, central bank, budget, and deficit.



Source: https://www.policyuncertainty.com/

FIG. 3-7. Monthly Economic Policy Uncertainty Indices 1997M01 to 2020M05 in the UK and in G7 countries

Baker et al. (2016) noted that the shocks to EPU index can be transmitted across segments of the economy. In figure 3-7 we can check that the individual indicator captured in the UK EPU has evolve broadly in line with the G7 overall indicator. The UK EPU peaked during the Brexit period, while the G7 EPU remained relatively contained, probably reflecting the policy response to this new framework into both, the UK economy and world´s economy. The UK's decision to leave the EU generated large increase in uncertainty, as we can check that the UK EPU index increases substantially after the UK 2016 referendum results. It started to decline short after June 2016, but after four years its average level did not reach the same levels as before the EU leave vote.

3.8. Conclusion

Both, the increasing uncertainty and growing instability could be the most prominent phenomenon of modern economic systems. The UK economic outlook seems to be more sensitive to uncertainty and instability than ever have been before. Some drivers of those uncertainties and instabilities are likely to be related to the 2016 UK referendum results. The lack of clarity regarding the timing of events, the new trade agreements, the frequency of government changes and government instability are just some of the factors that supported our decision to study the correlation between referendum results and exchange rate and inflation rate.

Thus, in the following two chapters we will analyse separately, the impact of the political stability indicator and the economic policy uncertainty index on the real effective exchange rate. In the third empirical chapter, the impact of EPU on inflation rate is analysed.

In this chapter, we used the latest surveys of balance of payments, which generates a measure of cross-border transactions between the UK and rest of the world each month and we have summarised economic facts, for the British economy for the period 1996 to 2020 which will help us to frame the following three empirical chapters.

The importance of the UK economy across the world economy and across G7 countries is also under continuous concerns of the International Monetary Fund as they note that is expected the UK economy to grow, in general, faster than its G7 trade partners. This means that the light of the UK economy must shift toward the nature of the recovery after the Brexit shock and in the period following 31 January 2020, to offset any possible weaker trade links with the EU after Brexit, for the UK economy it would be essential to achieve successful trade and investment links with other economies.

CHAPTER 4

Equilibrium exchange rate and its determinants: the role of political stability in the UK using a BEER/PEER approach

This chapter details the research methodology implemented for the current study. It presents the statistical methods and necessary diagnostic tests within time series analysis to investigate the effect of a set of macroeconomic variables on the UK's real effective exchange rate. The BEER model is assessed using the equilibrium of the real effective exchange rate given a particular set of macroeconomic fundamentals. The PEER model is used to compute currency misalignments.

4.1. Theoretical approach

Time series

A time series is a sequence of numbers collected at regular intervals over a time period and reflects how an economic variable change over time or how it changes compared to other variables over the same time period.

Stationary processes

To develop a practical understanding of econometrics methodologies and concepts several publications have been taken into account, as follows: Cochrane (2005), Tsay (2005), Verbeek (2008), Wooldridge (2010).

The mean of the series is its own expected value and is denoted by $\mu_t = E[y_t]$ and the variance of time series is defined as:$Var(y_t) = \sigma_t^2 = E[(y_t - \mu_t)]^2]$. The autocovariance of lag s is the covariance between y_t and y_{t-s}, given by $\gamma(t, s) = Cov(y_t, y_{t-s})$ and we can observe that $\gamma(0) = Cov(y_t, y_t) = Var(y_t)$. We can say that a time series, $y_t, t = 1, \ldots, T,$, is stationary if the statistical properties of the process do not change over time. If a time series is stationary, the occurrence of any shock is transitory, its individual effects diminish and eventually disappear as far as $t \to \infty$. For most practical analysis, it is sufficient for a time series to be weakly stationary. A weakly stationary time series must have the following characteristics: the mean and the variance are constant over time and the covariance only depends on the lag and not on time. Formally we can write this as:

- $E[y_t] = \mu_t, \forall\ t$ in T,
- $Var(y_t) = \sigma_t^2$,
- $Cov(y_t, y_{t-s}) = \gamma(t, s)$.

where γ is the constant mean, σ_t^2 is the constant variance and y_s is the covariance of lag s of the time series y_t. If at least one of the conditions fails, it is said that the time series is nonstationary, which translates into a long-term memory effect of a shock to the time series. In practice, most of the economic time series, when expressed in their original units of measurement, are nonstationary. Usually, we apply the (first order) difference operator to obtain a stationary time series because the difference stationary series transformation stands on the fact that, if the mean, variance, and autocorrelations of the original series are not constant over time, perhaps the statistical moments of the changed series will be constant.

One reason for trying to transform a nonstationary time series into a stationary one is to be able to obtain meaningful sample statistics, since such statistics are useful as descriptors of future behaviour but only if the series is stationary. Having said that, at least two features of the nonstationary time series can be highlighted. Firstly, if a time series is nonstationary its behaviour can be studied for the time period under consideration, but it would not be possible to generalise its behaviour to other time periods nor to forecast it. Secondly, in a regression analysis, one or more nonstationary time series may be the drivers of a spurious regression which is more likely to draw erroneous conclusions. In time series literature, nonstationary processes are integrated processes, and therefore by differentiating them we obtain stationary processes.

Integrated processes

Consider the model:

$(1-L)^d y_t = x_t, t = 1, 2, \ldots, T$, where L is a lag operator such that$Ly_t = y_{t-1}$. The process y_t is said to be integrated of order d (denoted by I(d)), if x_t is integrated of order zero.

An integrated of order 1 time series I (1) is differentiated once to become I (0), where I (0) means a stationary time series and following the above notation it can be written as $(1-L)^1 y_t = x_t$.

Random walk processes

A random walk process is defined as a model of a time series with a stochastic trend and it assumes that within each period the variable takes a random step away from its previous value. These steps are independently and identically distributed in size. A random walk model is said to have drift or no drift according to whether the distribution of step sizes has a zero mean or non-zero mean.

The random walk without drift (no intercept or constant term) model is defined as a process where the current value of y_t is composed of its past value plus an error term, ε_t (defined as a white noise), and can be expressed as:

$$y_t = y_{t-1} + \varepsilon_t \tag{4.1}$$

The implication of this type of model is that the change of y is random. The random walk is the typical (standard) nonstationary/unit root process, where the coefficient of $y_{t-1} = 1$. A drift acts like a trend and the random walk with drift (a constant term is present) takes the following form:

$$y_t = \delta + y_{t-1} + \varepsilon_t \tag{4.2}$$

where δ is a drift or a constant, ε_t is a white noise error term.

Autoregressive and moving average process

Dependence is a common feature in observations. To model this dependence, one of the most frequently used and probably one of the most relevant classes of time series models are autoregressive processes. The general p-th order autoregression process, AR(p) is expressed as follows:

$$y_t = c + a_1 y_{t-1} + a_2 y_{t-2} + ... + a_p y_{t-p} + \varepsilon_t \tag{4.3}$$

where c is the constant, $a_1, \ldots, a_p$ are the model parameters, the integer constant p is the order of the model and ε_t is the error term.

The moving average model of order q, MA(q) is defined as a weighted sum of the white noise process lags (which are always stationary) and can be written as:

$$y_t = \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + ... + \theta_q \varepsilon_{t-q} \tag{4.4}$$

where θ_1,...,θ_q are the model's parameters, q represents the order of the model,ε_t is white noise. By joining AR(p) and MA(q) we obtain the ARMA(p,q) model.

Autoregressive integrated moving average (ARIMA)

The autoregressive integrated moving average models (ARIMA) can be used when the data shows evidence of nonstationarity, where an initial differencing step can be applied to eliminate the nonstationarity. ARIMA(p,d,q) model is characterized by three terms: p, d, q, where p and q are as defined before and d is the minimum number of differencing needed to make the series stationary. More formally, following Lutkepohl and Kratzig (2004), a stochastic process y_t is called an ARIMA(p, d, q) process ($y_t \sim$ ARIMA(p, d, q)) if it is I (d) and the d times differenced process has an ARMA(p,q) representation, that is $\Delta^d y_t \sim$ARMA(p,q).

Unit root process and testing for unit root

The random walk model is known in econometric literature as the standard unit root process (where $\rho = 1$) and is expressed as follows:

$$y_t = \rho y_{t-1} + u_t \tag{4.5}$$

with ρ a real parameter and u_t an error term. Generally, three possible cases can be analysed under these circumstances $| \rho | < 1$, meaning that y_t is zero-mean I (0), stationary;$| \rho | = 1$, y_t has a unit root, meaning that the first difference of y_t, is I (0), and y_t, is I (1); and$| \rho | > 1$, y_t diverges.

Testing for unit roots is the first step in cointegration analysis to confirm the long-run relations or to avoid spurious regression. Granger (2007) states that one approach to prevent spurious regression is to test, asking whether the time series in the regression analysis are I (1) and if so (and there is no cointegration between the variables), computing the differences or other data transformations before entering the variables into the regression.

Testing for unit roots

Before pursuing formal tests, to analyse the data, it is always advisable to plot the time series under study and to use descriptive statistics. This approach allows us to make conclusions beyond the data or to reach conclusions regarding any hypotheses we might have made (like we have or not drift, we have linear trend or not, we have nonlinear correlation or not). This method is likely useful for summarising data using a combination of tabulated description, graphical description and statistical comments. Such an intuitive feel is the starting point in formal tests of stationarity. For a unit root test which relies on an AR (1) process where we subtract y_{t-1} at both sides of the equation, that is:

$$\Delta y_t = \alpha + \gamma T + (\rho - 1)y_{t-1} + u_t \tag{4.6}$$

where Δ represents the first difference, α is a constant, γ a real parameter, T is a deterministic trend, y_{t-1} is the autoregressive term, $(\rho - 1)y_{t-1}$ is a stochastic trend and u_t represents the white noise error term.

When testing for unit root, to characterize the trend properties of the time series under analysis, it is important to specify the null and the alternative hypotheses to be tested. In other words, if the data do not exhibit an increasing or decreasing trend, then the appropriate null and alternative hypotheses should reflect this. The two most common trend cases in the unit root testing, in regression equation (4.6), are represented below.

If $\gamma = 0$ and $\rho \neq 1$, then there is no linear trend in the data and the null and alternative hypotheses to be tested are: $H_o :\mid \rho \mid= 1 \rightarrow y_t$ is I (1) with drift, against $H_1 :\mid \rho < 1 \rightarrow y_t$ is I (0) with nonzero mean.

If $\gamma \neq 0$ and $\rho \neq 1$ then there are stochastic and deterministic trend in the data. The null and the alternative hypotheses in the unit root test are: $H_o :\mid \rho \mid= 1 \rightarrow y_t$ is I (1) with drift against $H_1 :\mid \rho < 1 \rightarrow y_t$ is I (0) with linear trend.

The test statistic is $t_{\rho=1} = \frac{\widehat{\rho}-1}{SE_{\rho}}$, where $\widehat{\rho}$ is the least squares estimate and SE_{ρ} is the usual standard error estimate. We reject the null when the test statistic is less than the left-side critical point.

Very often, economic and finance theory suggest the existence of long-run equilibrium relationships amongst nonstationary time series. In trying to decide whether the economic data under investigation is stationary or not it would be useful to perform unit root tests, e.g., the ADF test (Dickey and Fuller, 1979), and the PP test (Phillips and Perron, 1988) as well as stationarity tests such as the KPSS test (Kwiatkowski, Phillips, Schmidt and Shin, 1992). The most emphasised caution in performing the ADF and PP unit root tests have to do with the lack of power in situations where the unit root is very close to the nonstationary threshold, which may act as an incentive to not reject the null hypothesis when it should be rejected. This is the main motive that defends the choice of running both, unit root and stationarity tests in targeting robust conclusions with respect to the time series stationarity.

Dickey-Fuller test for Unit Root

Fuller (1976) and Dickey and Fuller (1979, 1981), proposed a test, referred to as the DF test, based on the t-ratio $t(\rho)$ in the equation (4.5). The null hypothesis and the alternative in the DF unit root test are: $H_o :\mid \rho \mid= 1$ against $H_1 :\mid \rho \mid< 1$. For a more convenient version of this test a transformation of equation (4.5) is done by subtracting y_{t-1}) from both sides obtaining a new equation as follows:

$$\Delta y_t = (\delta - 1)y_{t-1} + u_t \tag{4.7}$$

where $\delta = (\rho - 1), u_t$ error term. Under this new equation, the hypotheses to be tested are: $H_o : \delta = 0$ against $H_1 : \delta < 0$. The null hypothesis is rejected and the conclusion of stationarity of y_t is reached if the test statistic is smaller in absolute terms than the critical values proposed by MacKinnon (1996).

Augmented Dickey-Fuller (ADF) Test

As the error term is unlikely to be white noise, Dickey and Fuller extended their test procedure suggesting an augmented version of the test (hereafter refer to as the ADF test) which includes extra lagged terms of the dependent variable in order to eliminate autocorrelation in the test equation. Assume that the serial correlation in u_t(which can be represented by an autoregressive AR(p) process) can be corrected by adding the p lagged terms of y_t such the following terms: $\Delta y_{t-1}, ..., \Delta y_{t-i}$ will be introduced in the regression. The Augmented Dickey Fuller test (ADF), relies on estimating the following equation:

$$\Delta y_t = \delta y_{t-1} + \sum_{i=1}^{p} \beta_1 \Delta y_{t-1} + u_t \tag{4.8}$$

where β_i are parameters, $\delta = (\rho - 1)$, and u_t is the error term. To use the ADF unit root test, uncorrelated error terms with constant variance are required. The distribution of the test statistic would be unaffected by the addition of these lagged differences. The lag length on these extra terms is either determined by Akaike Information Criterion (AIC) or Schwarz Information Criterion (SIC), or more usefully by the lag length necessary to whiten the residuals. The null hypothesis in the ADF test is H_o : y_t has a unit root, therefore δ must equal zero, and the alternative hypothesis is H_1 : y_t is a stationary process. If the null hypothesis is rejected, the examined time series is stationary. The critical values of the ADF unit root tests are provided by MacKinnon (1991, 1996).

Phillips and Perron (PP) test

An alternative unit root test used in the context of models with weakly dependent errors is that proposed by Phillips (1987) and Phillips and Perron (1988), known as the Phillips Perron (hereafter referred to as the PP test) unit root tests. Fundamentally, the PP test is closely based on the standard DF or ADF tests. However, the t-ratio has been modified so that the serial correlation does not affect the asymptotic distribution of the test statistic of the coefficient δ. Therefore, PP statistics are just modifications of the ADF t statistics that take into account the less restrictive nature of the error term. One advantage of the PP test is that the user does not have to specify a lag length for the test regression, and the main criticism is that the power of the tests is low if the process is stationary but with a root close to the non-stationary boundary. The PP test usually yields the same conclusions as the ADF test. The application of the PP unit root tests is based on the ordinary least squares (OLS) parameter estimate, $\widehat{\alpha}$ from the AR(p) process in equation (4.6) where the decision is made whether to include a constant and/or a time trend. The null and alternative hypotheses of the PP unit root test are: $H_o : y_t$ has a unit root against the alternative $H_1 : y_t$, stationary process.

The asymptotic distribution of the PP test statistic is the same as the ADF test statistic and thus the MacKinnon (1991,1996) critical values are still applicable. In practice, the ADF test and the PP test can be performed with the inclusion of a constant and a linear trend, or neither, in the test regression as presented in equation (4.6). *The*

Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test

Blough (1992) signals the need for performing complementary unit root tests due to the fact the ADF test tends to perform less well if the process is stationary with roots close to one (see Blough, 1992 for a discussion of this issue). The Kwiatowski-Phillips-Schmidt-Shin (1992), hereafter referred to as the KPSS test, is the statistical test to check for stationarity of a time series around a deterministic trend. The KPSS test is motivated by the fact that those unit root tests developed by Dickey and Fuller (1979), Dickey and Fuller (1981) and Phillips and Perron (1988) indicate that most aggregate economic series had a unit root. In both tests, the null hypothesis is that the series has a unit root. Kwiatkowski et al. (1992) consider the problem of testing for stationarity concerning a level or a time trend as the null hypothesis, and the unit root should be the alternative. Rejection of the null hypothesis could then be viewed as convincing evidence in favour of a unit root.

In equation (4.6), the KPSS test breaks the time series down into a deterministic trend, a random walk and a stationary error. The KPSS test is based on the null hypothesis of the absence of the random walk. Its test procedure consists of three steps. First is to regress y_t on an intercept and/or a time trend and obtain OLS residuals ε_t second is to calculate partial sums of the residuals for all t; and third is to calculate the KPSS test statistic and compare it to the critical values provided by Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1). We say that we have a stationary time series if the null hypothesis is not rejected in the KPSS test, that is, when, the test statistic is lower than the critical value provided in table 4-1. [1]

	Upper tail percentiles			
Distribution	0.10	0.05	0.025	0.01
$\int_0^1 V(r)\,\mathrm{d}r$	0.347	0.463	0.574	0.739
$\int_0^1 V_2(r)\,\mathrm{d}r$	0.119	0.146	0.176	0.216

TABLE 4-1. Percentiles of the distribution of the KPSS statistic

Cointegration

The concept of cointegration for the time series was first introduced by Granger (1981) developed further by Engle and Granger (1987), Phillips (1986 and 1987), Stock and Watson (1988), Johansen (1988, 1991, 1995) and Phillips and Ouliaris (1990). Cointegration is defined as the existence of a long-run relationship between nonstationary (or same order integrated) variables, where the linear combination of them demonstrates a lower level of integration (generally stationary).

A linear combination of two non-stationary I (1) time series, x_t and y_t, can be expressed by estimating the following simple linear regression:

$$y_t = \beta_1 + \beta_2 x_t + u_t \tag{4.9}$$

where β_1 and β_2 are parameters. If the residuals, which are given by, $\widehat{u}_t = y_t - \widehat{\beta}_1 - \widehat{\beta}_2 x_t$, are I (0), then it is said that x_t and y_t are cointegrated.

It is commonly recognised that trended time series can potentially cause major problems in empirical econometrics due to spurious regressions. One way of resolving this is to differentiate the series successively until stationarity is achieved and then use the stationary series for regression analysis, but in this way, we lose the link between variables in the long-run. In the short-run, the variables can move in different ways, driven by different dynamic processes, but cointegration ties the variables together in the long-run. If integrated I (1) variables are cointegrated, this means that although they are individually nonstationary, they are moving together so that there is some long-run relationship between them. Economic theory leads us to expect that cointegration should exist between some variables. If the variables do not cointegrate, we are more likely to face problems of spurious regression and such econometric work becomes meaningless. Thus, cointegration is acknowledged as a robust way to detect long-run relationship among nonstationary variables.

The Engle-Granger test for cointegration

Gujarati (2011) states that the difference between the unit root and cointegration tests is that the first are performed on single time series, whereas simple cointegration deals with the relationship among a group of variables, each having a unit root. The ADF, PP and

[1] For more detailed information on KPSS stationary test critical value table, see Kwiatkowski et al. (1992)

KPSS tests on OLS residuals ε_t (on the equation below) from a static regression provide a way of testing cointegration. Engle and Granger (1987) recommended such a two-step procedure for cointegration analysis. Their approach implies verifying if both x_t and y_t are I (1) and then estimating through the following long-run equation:

$$y_t = \theta' x_t + \varepsilon_t \tag{4.10}$$

The OLS residuals from equation (4.10) are a measure of disequilibrium: $\widehat{\varepsilon_t} = y_t - \widehat{\theta}' x_t$ A test of cointegration is a test whether $\widehat{\varepsilon_t}$ is stationary. Since most of the unit root tests test the null hypothesis of a unit root, cointegration tests assess $H_0 : \varepsilon_t \sim I(1)$ i.e., zero cointegrating vectors; and the alternative is $H_1 : \varepsilon_t \sim I(0)$ i.e., one cointegrating vector. If these tests reveal that the residuals are stationary in their levels, then the variables in the long-run model are cointegrated. In sum, the steps to take in order to run the Engle-Granger cointegration test are as follows: test each variable to determine its order of integration; estimate the possible cointegrating relationship if the variables are I (1); check for stationarity in the residuals.

Error correction model

Suppose x_t and y_t are I (1) and cointegrated. Then ε_t is I (0) in the cointegrating equation (4.10). These types of equations are often interpreted as long-run or equilibrium relationships between time series x_t and y_t. If the interest lies in the way that x_t and y_t fluctuate around this long-run relationship, and its impact on their short-run dynamics, estimation of an error correction model (hereafter referred to as ECM) is required, which contains first differences of x_t and y_t, their lags, and an error correction term. Having said this, an ECM incorporates both short-run and long-run effects.

Following Asteriou and Hall (2015) and Kilian and Lütkepohl (2017) we represent the ECM as:

$$\Delta y_t = \mu + \gamma_1 \Delta y_{t-1} + ... + \gamma_p \Delta y_{t-p} + \omega_0 \Delta x_{t-1} + ... + \omega_r \Delta x_{t-r} + \lambda EC_{t-1} + u_t \tag{4.11}$$

where $EC_t = y_t - (\alpha + \beta x_t)$, the error correction term, is the lagged OLS errors from the cointegrating equation, and p and r are lag orders, λ is the speed of adjustment, it measures the speed at which y returns to equilibrium after a change in x.

Due to its feature of describing how y and x behave in the short-run consistent with a long-run cointegrating relationship, Asteriou and Hall (2007) argue that ECM are important for at least two reasons. First because their features come from the fact that the disequilibrium error term is a stationary variable and adjustment process will prevent errors in the long-run relationship becoming larger and larger, and second because by formulating the models in terms of first difference the problem of spurious regressions is eliminated. This section has explored the single equation approach to cointegration. In the following section, this analysis is extended to multivariate cases.

Vector Autoregressive models (VAR)

A Vector autoregressive (VAR) model is useful for predicting multiple time series using a single model to analyse the response of the variables when one deviation shock is applied. VAR models pioneered by Sims (1980) have acquired a permanent place in the toolkit of applied macroeconomists both to summarise the information contained in the data and to conduct certain types of policy experiments. Suppose we have two series, in which y_t is affected by not only its past (or lagged) values but also by the current and lagged values of x_t. Simultaneously, x_t is affected by its lagged values and by the current and lagged values of y_t. A simple bivariate VAR model is given by the equation:

$$y_t = A_1 + B_1 x_t + \sum_{i=1}^{p} C_i y_{t-i} + \sum_{i=1}^{p} D_i x_{t-i} + u_{1t} \tag{4.12}$$

$$x_t = A_2 + B_2 y_t + \sum_{i=1}^{p} E_i y_{t-i} + \sum_{i=1}^{p} F_i x_{t-i} + u_{2t} \tag{4.13}$$

where A_1 and A_2 are constant, B_1, B_2, C_i, D_i, E_i and F_i,for $i = 1, \ldots, p$, are coefficients of the lags of y and x. By assumption u_{1t} and u_{2t} are white noise error terms or uncorrelated innovation shocks. All the variables must be stationary.

Determining the Order of a VAR

According to Stock and Watson (2007), choosing the order p of a vector autoregression model requires balancing the marginal benefit of including more lags against the marginal cost of additional estimation uncertainty.

The most commonly applied selection criteria are Akaike Information Criterion, AIC (Akaike, 1974) and the Schwarz Information Criterion, SIC (Schwarz, 1978),

$$AIC = ln(\sigma_\varepsilon^2) + \frac{2k}{T} \quad \text{and} \quad SIC = ln(\sigma_\varepsilon^2) + \frac{k}{T} ln(T) \tag{4.14}$$

where σ_ε^2 is the sum of squared residuals, k is the number of the estimated VAR parameters and T is the number of observations used for estimation. Both criteria are based on the estimated variance plus a penalty adjustment depending on the number of estimated parameters. It is in the extent of this penalty that these criteria differ. The penalty proposed by SIC is larger than AIC's if T is large. In practice both criteria are examined and despite this theoretical shortcoming, the AIC is widely used in practice. In general, the model with the number of lags corresponding to the smallest AIC is used for further analysis.

Pairwise Granger causality test

The basic principle of the Granger causality test, introduced by Granger (1969) to identify the short-term relationships between pairs of two variables was conducted. To examine whether a variable x Granger causes y, a restricted regression model represented by the following equation:

$$y_t = \alpha + \sum_{i=1}^{p} \alpha_i y_{t-i} + u_t \tag{4.15}$$

should be established. First to show that y can be explained by its own past values, and then past values of x as the explanatory variable are introduced into this equation to obtain an unrestricted regression model, yielding the equation:

$$y_t = \alpha + \sum_{i=1}^{p} \alpha_i y_{t-i} + \sum_{i=1}^{p} \beta_i x_{t-i} + u_t \tag{4.16}$$

where p represents the lag length of the model estimation. If introducing past values of x can significantly improve the prediction level of y, then x is said to Granger to cause y, ceteris paribus. Thus, under the regression in equation (4.16), the null and alternative hypotheses to test are $H_0 : \beta_1 = \beta_2 = ... = \beta_k = 0$ and $H_1 : \exists\beta_j \neq 0$. The rejection of the null hypothesis in the case of a p-value lower than the significance level implies that x_t Granger causes y_t.

Johansen cointegration test

The Johansen cointegration methodology is treated in detail in Johansen's (1995) book and implies a VAR representation in error correction form. It analyses the cointegration relationship among variables using the following (VEC or modified VAR) model of order p:

$$y_t = \Pi y_{t-1} + \sum_{i=1}^{p} \Gamma_i \Delta y_{t-i} + \varepsilon_t \tag{4.17}$$

where Δ is the difference operator, y_t is a vector of k variables integrated of order one, Π is a matrix of coefficients that contains information of the long-term relationships, Γ short-run matrix of coefficients, and ε_t is a vector of error terms.

We can decompose the matrix of long-term coefficients, $\Pi = \alpha\beta'$, where α represents the speed of adjustment toward equilibrium and β comprises the cointegration vectors or the long-term coefficients and where both α, β are $(k \times r)$ matrices, where r denotes the number of linear independent lines in Π_i three special cases are to be considered: $rank(\Pi) = 0$ meaning none of the variables are stationary, $0 < rank(\Pi) < k$, indicates r cointegrating relationship and r$ank(\Pi) = k$ meaning that the matrix π has full rank and indicates that the all the variables in y_t are stationary.

Johansen (1995) proposes two different approaches to test the reduced rank r of the Π matrix and in consequence, to determine the number of cointegration relationships between the considered time series: the trace test, which is a joint test and the maximum eigenvalue test, which is an individual test for each variable. These methods involve estimating the matrix Π from a restricted VAR and checking whether one can reject the restrictions implied by the reduced rank of Π. The null hypothesis to test for the trace test is that the number of cointegration vectors is less than r, formally written as: $H_0 : rank(\Pi) = r < k$, vs. the alternative $H_1 : rank(\Pi) = k$. The trace statistic for testing this pair of hypotheses is computed as: $LR_{trace}(r) = -T\sum_{n=r+i}^{n} \log(1 - \widehat{\lambda}_i)$ where r is the number of cointegrated vectors and $\widehat{\lambda}_i)$ is the estimated value of ordered eigenvalues from matrix Π. For the Johansen cointegration test based on the maximum eigenvalues the null hypothesis is that the number of the cointegration vectors is equal to r, $H_0 : rank(\Pi) = r < k$ against an alternative $H_1 : rank(< \Pi) = r + 1$.The maximum eigenvalue statistic for testing this pair of hypotheses is computed as: $LR_{max}(r, r+1) = -T\log(1 - \widehat{\lambda}_{r+1})$.

The rejection of the null hypothesis in both the trace test and maximum eigenvalue test occurs if the test statistic is greater than the critical values provided by Johansen and Juselius (1990). In general, for k number of variables, only up to k-1 cointegrating vectors can be assessed.

In summary, to check for the existence of cointegration relationships and their number among k variables, Johansen's cointegration methodology using a VAR system of equations involves the following steps:

- Testing the order of integration of all variables and ensuring all are I (1).
- Setting the appropriate lag length of the model. Setting the value of the lag length is affected by the omission of variables that might impact only the short-run behaviour of the model because omitted variables instantly become part of the error term. The most common procedure in choosing the optimal lag length is to estimate a VAR model including all variables in levels. Inspect the values of the AIC criteria, as well as the diagnostics concerning autocorrelation, heteroskedasticity, and normality of the residuals. In general, the model that minimises AIC is selected as the one with the optimal lag length.
- Determining the number of cointegrating vectors, using the trace and/or the maximum eigenvalues tests.
- After determining optimal lag length and number of cointegrating vectors, estimate vector error correction model.
- Validate the model (check the residuals assumptions).

Vector error correction models (VECM)

If some of the variables are cointegrated, the error correction term has to be included in the VAR model. The model becomes a vector error correction model (VECM) which can be understood as a restricted VAR or as a reparameterization of the VAR in levels; that is, constructed from first differences of cointegrated I (1) variables, their lags, and the error correction terms. Continuing with the two-variable example, a VECM(p) would be:

$$\Delta y_t = \sum_{i=1}^{p} \beta_{1,i}^{y} \Delta y_{t-i} + \sum_{i=1}^{p} \beta_{2,i}^{y} \Delta x_{t-i} + \lambda_y (y_{t-1} - \theta x_{t-1}) + u_{y,t} \tag{4.18}$$

$$\Delta x_t = \sum_{i=1}^{p} \beta_{1,i}^{x} \Delta y_{t-i} + \sum_{i=1}^{p} \beta_{2,i}^{x} \Delta x_{t-i} + \lambda_x (y_{t-1} - \theta x_{t-1}) + u_{x,t} \tag{4.19}$$

In estimating a VECM into a two-step procedure, it follows that: regressing y_t and x_t yields θ. Running a VAR in first differences, including the first lag of $y_t - \widehat{\theta}x_t$ on the right-hand side in both equations and then estimating by OLS again to get the model parameters.

Diagnostic tests

In order to validate the model, we check if the residuals fulfil the requirements of a gaussian white noise process. These assumptions imply that the residuals have constant variance, are not correlated (i.e., independent) and normally distributed. In any case, since we have small datasets, the normality condition can also be validated by plotting the residuals in a histogram.

For the autocorrelation of the residuals, we use the Serial correlation Lagrange multiplier (LM) test which implies the following test hypotheses H_0 : no autocorrelation vs. H_1 : autocorrelation.

For the constant variance assumption, the ARCH LM heteroscedasticity test is applied. Thus, the null hypothesis and the alternative are H_0 : variance is constant vs. H_1 : variance is not constant.

Jarque-Bera for normality of residuals is a LM test conducted to test the hypothesis that the data are from a normal distribution and it is based on estimates for the coefficients of the third moment, the skewness, and the fourth moment of the mean, the kurtosis. The skewness measures the degree of symmetry in the distribution where the equation for a random variable with μ mean and σ standard deviation it can be presented formally as:

$$S = E\left[\frac{(X-\mu)^3}{\sigma^3}\right] = E\frac{(X-\mu)^3}{\sigma^3} = \frac{\mu_3}{\sigma_3} \tag{4.20}$$

The skewness measure under a normal distribution around its mean is zero, but it can also be negative, meaning that the distribution has a long-left tail, and is skewed to the left; or positive and the distribution has a long-right tail, and is skewed to the right.

In the same manner, the fourth moment coefficients for a random variable with the mean μ and the standard deviation, σ can be formally written as:

$$K = E\left[\frac{(X-\mu)^4}{\sigma^4}\right] = E\frac{(X-\mu)^4}{\sigma^4} = \frac{\mu_4}{\sigma_4} \tag{4.21}$$

A distribution with kurtosis equal to three is known to be mesokurtic, a kurtosis greater than three is said to be leptokurtic or fat-tailed and a kurtosis less than three is called platykurtic. Thus, the Jarque-Bera test uses two statistical properties of the normal distribution, namely: a skewness equal to zero and a kurtosis equal to three. The test statistic of the Jarque-Bera test can be expressed as: $JB = n\left[\frac{S^2}{6} + \frac{(K-3)^2}{24}\right]$, which under the null hypothesis follows a chi-square distribution with two degrees of freedom. The normality hypothesis is rejected if $JB > \chi^2_2 - \chi^2_2$, the critical value at 5% significance level; and concludes that the normality assumption is rejected. For a detailed table of the chi square distribution please see Appendix A.4-1. If the null hypotheses are not rejected in all three tests, based on the p-value judgements, the model can be validated.

4.2. Data and research methods

The real effective exchange rate, referred as REER, analysed in this thesis is the UK pound sterling. All time series used for performing this analysis are in annual frequencies for the time period between 1996 and 2019. The choice of the year 1996 to start the sample is due to the availability of the data for the political stability indicator. Although the number of observations is not large, other papers reviewed in the literature have used a similar sample size. Clark and MacDonald (1998, 2004) to analyse the consistency of the real effective exchange rate with its economic fundamentals have used a sample of 36 annual observation in the first analysis and 17 annual observations in the second. Maeso-Francisco et al. (2004) examined the long-run relationship between exchange rates and fundamentals using the BEER approach in Central and Eastern European acceding countries, carrying out their analysis based on annual data composed of 27 observation from the year 1975 to 2002. Wang et al. (2007) studied the behaviour of the real effective exchange rate for China using a BEER model comprising the time period between 1980-2004, based on 24 observations. The use of the control variables is highly specific in that one is related to the trade flow while the other with the financial flow as in Clark and MacDonald (1998). More control variables could have been selected, but the small size of the sample prevented that.

The variables in the present research are expressed either in levels, as is the case of the real interest rates and the political stability indicator, or in logarithms, as for the real effective exchange rate and the terms of trade. The observations are obtained on a consistent basis from several sources and their definitions and sources are given below.

4.2.1. Data

Real effective exchange rate: *LNREER*

This variable is an index, is the weighted averages of bilateral exchange rates adjusted by relative consumer prices and is defined in terms of foreign currency per unit of domestic currency which means that an increase in it is translated into a real depreciation of the currency. According to the International Monetary Fund (IMF), an increase in REER implies that exports become more expensive, and imports become cheaper; therefore, an increase indicates a loss in trade competitiveness (real appreciation of domestic currency). This variable is expressed in logs: LNREER.

Source: International Financial Statistics IFS, Bank of England REER 2019: (2010 = 100).

Political stability indicator: *PSTAB*

The UK political stability indicator is an illustration of the confusion existing in the UK's political system since Brexit came to world's attention. Two dimensions are integrated into its measurement, namely political stability as the absence of violence and political stability as government efficiency. The aggregate indicators are reported in their standard normal units, ranging from approximately -2.5 to 2.5, with higher values corresponding to better outcomes.

The REER can be affected by news from the political arena, news that are reflected in its dynamics. Bahmani-Oskooee and Nasir (2002) argue that an unstable political system could drive away foreign investors, which, eventually, may lead to a significant revenue loss for the government. Carmignani (2003) noted that events, such as government terminations and electoral surprises generate uncertainty about the stability of the future course of economic policies like, state of aggregate demand, exchange rate policies, inflation policy. Barro (2013) underlines that if a country is politically stable new potential investors can be encouraged to invest their capital in safer political environments. Therefore, their investments will promote economic growth which will increase the standard of living. Lafrance and Schembri (2000) noted that a country's standard of living will be higher, the greater the size and quality of its supply of productive factors relative to its population, the higher the rates at which these factors are employed, the more productive these factors are in generating output, and the more valuable its domestic exports are in world markets.

Therefore, we can conclude that a country that is free of political instability could be more attractive for the foreign investors while, a political instability environment reduces investor's incentive to make productivity-enhancing investments which can destabilise the economy and can have a dramatic impact on the exchange rate. Consequently, our expectation about the coefficient of the PSTAB variable is that it will be negatively associated with a drop in the value of the pound sterling, accounting for a currency depreciation.
Source: Worldwide Governance Indicators (WGI) database.

Terms of trade: $LNTOT$
The terms of trade variable is expressed in logarithms and corresponds to the ratio of price of exportable goods and services to the price of importable good and services index 2019 (2013=100) in the domestic economy, in the UK relative to its G-7 partner terms of trade calculated in the same manner. The price of goods and services are fixed in the base year, usually annually updated, as a benchmark. The changes in the volume of goods and services exported and imported are measured against it.

Because the terms of trade are defined as the relative price of the UK exports and imports, the shifts in it will generally affect the exchange rate dynamics. For example, a worsening of the UK's terms of trade (possibly because of a decline in the trade partners price of certain commodities produced by the UK) will depreciate the exchange rate. A potential increase in terms of trade will appreciate the REER, while the terms of trade deteriorations usually lead to an equilibrium real depreciation. The terms of trade have either a substitution effect or an income effect. Edwards and Van Wijnbergen (1987) and Edwards (1989) argue that the income effect occurs if an increase in price of exports or a decrease in price of imports will produce an increase in domestic income, which is spent in tradable and non-tradable goods. There is an increased demand for domestic goods, and to restore domestic equilibrium it is necessary foreign demand of domestic goods decrease through an appreciation of the currency and appreciates the real exchange rate. The substitution effect may occur when an increase in the price of exports causes a decrease in the foreign demand for these exports. This generates a shift in production factors from tradable to non-tradable ones, a fall in the relative price of non tradables or a real depreciation of the REER. There is a lack of demand of domestic goods, that has to be restored by a depreciation of the real exchange rate. In other words, the trade balance worsens, leading to a decline in the real exchange rate.

Consequentially, the influence of LNTOT on LNREER cannot be taken for granted a priori because the shared effect of changes in the terms of trade on the real exchange rate will depend on whether the income or the substitution effect is more dominant (for further discussion about income effect and substitution effect, see Comunale, 2019; Fidora et al., 2018). If the income effect is dominant, a positive impact is more likely to be expected as a positive shock should generate additional export revenues and contributes to real effective exchange rate appreciation.
Source: Office for National Statistics, OECD.

Real interest rates: $RIR\ or\ r - r*$
The domestic real interest rates, r is a variable defined as in Clark and MacDonald (2004) is calculated as the difference between the UK's average nominal long-term government bond yield and the changes in the CPI from the previous year. The foreign real interest rates $r*$ is the weighted average of the real interest rates of G-7 partner countries calculated in the same way as r. Starting from the uncovered interest parity (UIP) condition which states that the difference in interest rates between two countries will equal the relative change in currency foreign exchange rates over the same period, Clark and MacDonald (2004) have shown that real interest rate differentials have a positive effect on the real exchange rate with the following equation: $q_t = E_t(q_{t+k}) + (r_t - r_t^*) + e_t$ 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, e_t is the error term.

As the authors account for a positive impact of RIR on LNREER, we would also assume that the impact of the real interest rates on the real effective exchange rate is more likely to have a positive impact on the estimated coefficient because an increase in its level will appreciate the currency. Source: OECD, Office for National Statistics, Bank of England database.

Thus, the specification of the overall variables vector is as follows:
$Y_t = [LNREER_t, PSTAB_t, LNTOT_t, RIR_t]$.

Visual inspection of the variables

The current empirical analysis started with the data visual inspection followed by the analysis of the descriptive statistics of the UK' s REER, its fundamentals and the political factor. Prior to the estimation of the model, the stationarity properties of the considered time series are checked.

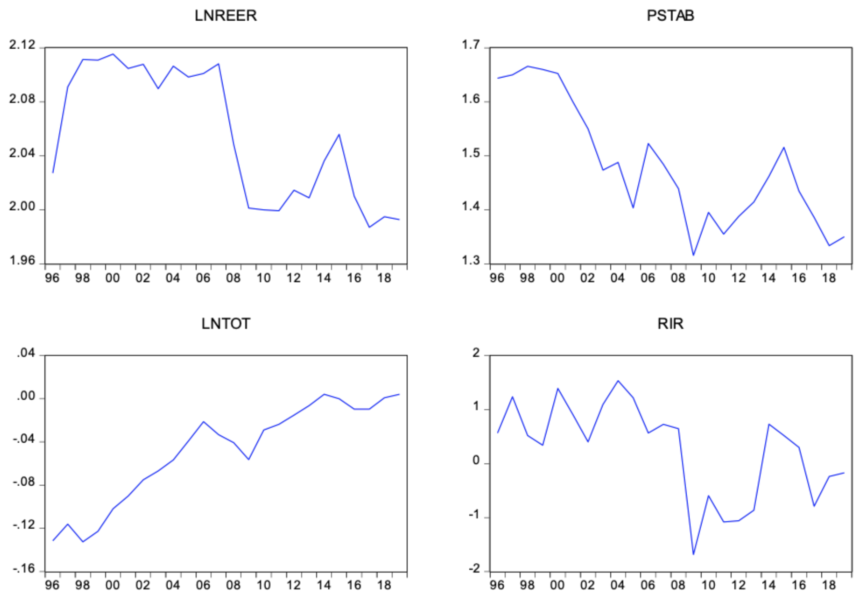


Fig. 4-1. The UK real effective exchange rate, macroeconomic fundamentals and political indicator

This empirical study started with an observation of the graphical representation of each of the time series. From the graphical representation we can observe that the variables illustrate deterministic or stochastic trends. Since most economic and financial time series are more likely to display nonstationary behaviour, an oscillation around a constant mean is not expected. Figure 4-1 shows the changes for the real effective exchange rate of the UK pound sterling and its macroeconomic fundamentals over the period 1996 to 2019. From 1996 to 1999 the UK REER increases from a level around 2.07 to a level around 2.11. From 2007 to 2009 it shows a fast decay toward a level of 2.00. From 1998 to 2007 and from 2009 to 2018 no clear trend can be observed, but shorter term up and down irregular motions are observed after 2013, and it had lost more than half of its competitiveness improvements gained after 2008 falling by some 30% on average. After 2016 until 2018 the sterling pound seems to increase. As per the table 4-2, in respect of volatility, by analysing the standard deviation it is possible to conclude that three explanatory variables present low levels of volatility while the real interest rate presents a high volatility of 0.87 % (the mean of this variable is only 0.25%).

Regarding the skewness, negative skewness estimates indicate that the empirical distribution of the real effective exchange rate, the terms of trade and the real interest rates is asymmetric negative and a positive skewness for the political stability indicator means the tail on the right side of the distribution is longer. The values of the kurtosis tend to be lower than three which means that the distribution displays a lower peak around the mean and produces fewer and less extreme outliers than the normal distribution. For instance, when comparing the RIR (kurtosis of 2.36) to the LNREER (kurtosis of 1.27), the RIR by presenting a higher kurtosis has a fairly high likelihood of extreme events as compared with the LNREER.

TABLE 4-2. Descriptive statistics of the variables

Variable	LNREER	PSTAB	LNTOT	RIR
Mean	2.055052	1.482633	-0.048699	0.258155
Median	2.052115	1.467713	-0.036257	0.519286
Maximum	2.115346	1.665879	0.004215	1.534286
Minimum	1.987091	1.315490	-0.132577	-1.685714
Std. Dev.	0.049011	0.113161	0.045763	0.877180
Skewness	-0.060627	0.358746	-0.603967	-0.583262
Kurtosis	1.271213	1.872231	2.032638	2.363779
Jarque-Bera	3.003417	1.786655	2.394894	1.765554
Probability	0.222749*	0.409291*	0.301964*	0.413633*

Note: * indicates statistical significance at 5% level

Finally, the Jarque-Bera normality test was undertaken to strengthen the conclusion that might have been made from the graphical representation. As all probabilities associated with the Jarque-Bera test are higher than the significance level (considering a 5% significance level), the normality assumption is validated.

TABLE 4-3. Correlation matrix between variables

	LNREER	PSTAB	LNTOT	RIR
LNREER	1			
PSTAB	0.74	1		
LNTOT	-0.60	-0.82	1	
RIR	0.78	0.65	-0.41	1

Table 4-3 contains the correlations between variables, so we can check that the political stability indicator and the real interest rate present a positive correlation with the real effective exchange rate, whilst the terms of trade are negatively correlated with it. A positive correlation seems to suggest that a decrease in these indicators is accompanied closely by a decrease in the real effective exchange rate, or a depreciation of the pound sterling from 1996 to 2019.

4.2.2. Unit root and stationarity test results

For Johansen's method of cointegration, is necessary all time series to be nonstationary and integrated of the same order, thus unit root and stationarity tests must be performed. Therefore, first we test the existence of a unit root and the stationarity of time series in levels in which the order of integration is assessed using the ADF test, PP test and the KPSS test. Secondly, we do the same for the first order differenced series. For the lag interval to be considered in these two tests, an automatic lag length selection was made automatically based on the Schwarz Info Criterion by EViews software. The software's three options to allow for the inclusion of an intercept and a trend in the ADF test and PP test are represented by the following: a model with intercept, a model with trend and intercept, or a model with none.

After conducting the ADF and PP unit root test (whose null hypothesis acknowledges the existence of a unit root), assuming the original time series values, as per table 4-4, all variables under consideration are nonstationary. MacKinnon (1996) provides the critical value for both tests. As the test statistic is larger than the provided critical value, the null hypothesis is not rejected, thus the presence of a unit root is signalled. After the first difference transformation, stationarity is achieved as provided by both tests, so all time series are I (1).

TABLE 4-4. Test statistic representation of the ADF and PP unit root tests

	ADF unit root test		PP unit root test	
Variable	*Level* Intercept Trend and Intercept None	Δ Intercept Trend and Intercept None	*Level* Intercept Trend and Intercept None	Δ Intercept Trend and Intercept None
	-1.005485	-4.324362*	-1.203471	-4.807897*
LNREER	-2.749362	-4.077341*	-3.686477	-4.373698*
	-0.296302	-4.307767*	-0.296302	-4.365765*
PSTAB	-1.392535	-5.501147*	-1.323246	-5.491922*
	-2.209704	-5.375527*	-2.315723	-5.369937*
	-1.15236	-5.279570*	-1.272128	-5.249123*
LNTOT	-1.49686	-4.351974*	-1.507369	-4.365131*
	-1.708921	-4.332165*	-1.708921	-4.327948*
	-2.874247	-3.790652*	-2.89017	-3.813740*
RIR	-2.355678	-6.070612*	-2.355678	-6.739099*
	-2.983859	-5.918636*	-2.983859	-6.567345*
	-2.347099	-6.178587*	-2.29067	-6.776840*

Note: The ADF, PP critical value at 5% significance level is -2.998 for the model with an intercept. The ADF, PP critical value at 5% significance level is -3.622 model with both intercept and trend. The ADF, PP critical value at 5% significance level is -1.956 for the model without intercept and trend. The ADF test lag lengths were selected automatically based on the SIC criteria. * denotes the rejection of the null hypothesis at the 5% significance level.

In the results of the KPSS test, both models, intercept and trend and intercept were taken into analysis (table 4-4). In the carrying out of the KPSS stationarity test, the lag length was determined ad-hoc based on the AIC criteria. Recall that in the KPSS test the null hypothesis is of a stationary time series and not of a unit root. The null hypothesis is rejected if the test statistic exceeds the critical values at 5% level of significance. In table 4-5, the KPSS test shows that at 5% level of significance the series are nonstationary in their levels, the null hypothesis is rejected as the test statistic is higher than the asymptotic critical value at 5%, 0.463 in the model with intercept; and 0.146 in the model with both trend and intercept. The series are stationary in first differences at 5% significance level as in these two models the test statistic is less than the critical values. Thus, the series under analysis, according to KPSS are integrated of order one.

Table 4-5. Test statistic of the KPSS stationarity test

KPSS test statistic			
	Level	Critical values (5% significance)	Δ
	Intercept Trend and intercept		Intercept Trend and intercept
LNREER	0.520901 0.100809	0.463 0.146	0.253650* 0.107099*
PSTAB	0.571255 0.128435	0.463 0.146	0.073017* 0.062317*
LNTOT	0.653173 0.144908	0.463 0.146	0.148748* 0.066230*
RIR	0.387611 0.084786	0.463 0.146	0.255443* 0.253437*

Note: 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 not rejection at 5% significance level of the stationarity hypothesis.

Thus, the combined results of both ADF test and PP test show that all the variables expressed in levels are (1), supported also by the KPSS stationarity test, whilst the variables' first differences are I (0). Based on these facts, the cointegration analysis is conducted.

4.2.3. VAR estimation and lag selection results

To address the primary research question, a VAR model is estimated using the UK's REER, the selected UK macroeconomic fundamentals and the political factor. In the first step we determine the optimal lag number by using the length lag criteria applied to a VAR model with the variables in levels. The maximum number of lags we allow is two because of the small sample size. The approach is to estimate the model and check for the optimal value based on the Akaike Information Criterion (AIC). The rule of thumb is to choose the lag length according to the data interval, which in this case is annual observation. At the same time, the choice of the optimal number of lags to be incorporated in the model was defined according to the majority of the tests that have identified the maximum order of lags as being two. Moreover, as shown in table 4-6, the AIC criteria also points out that the optimal lag to include in VAR estimation is two. Due to the sample size and frequency, the number of observations being small does not permit a very large number of lags.

TABLE 4-6. Lag length selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	199.0743	NA	2.34e-13	-17,73403	-17,53566	-17,6873
1	264.1922	100.6367*	2.77e-15	-22.19929	-21.20743*	-21,96564
2	286.3792	26.22101	1.88e-15*	-22.76174*	-20.9764	-22.34117*

* indicates lag order selected by the criterion LR: sequential modified LR test statistic (each test at 5% level) FPE: Final prediction error AIC: Akaike information criterion SC: Schwarz information criterion HQ: Hannan-Quinn information criterion

Johansen Cointegration Test results

In addition to the method proposed by Engle-Granger (1987), we performed the Johansen cointegration methodology (1988,1995) to check for the long-run relationship among variables because the first one can only be applied to study cointegration between two time series, while the former one is appropriate for an analysis which concerns more than two variables.

The Johansen based cointegration tests implies the estimation of a reparametrized VAR model containing of all I (1) variable and including the number of lags as determined before. To calculate the Johansen cointegration test only one lag is considered in this study (because above, in VAR, the optimal lag in levels was two), please see Appendix A.4-3 for a full explanation of these results. The next step in the Johansen cointegration procedure is to determine the number of cointegrating relationships. The cointegration ranks were obtained through the Trace and Maximum Eigenvalue tests for all five cointegration test specifications.

Table 4-7. Johansen's Cointegration Test with one lag

	Trace test		Maximum Eigenvalue test	
	Trace statistics	Probability	Maximum Eigenvalue Statistics	Probability
Hypothesized No. of CE(s)				
1) No intercept and trend in CE or test VAR				
None	28.13897	0.4576	13.38185	0.6583
At most 1	14.75712	0.4749	6.509034	0.8561
At most 2	8.248087	0.2181	6.148826	0.3331
At most 3	2.099262	0.1738	2.099262	0.1738
2) Intercept (no trend) in CE- no intercept in VAR				
None	52.52165	0.0684**	28.58290	0.0501**
At most 1	23.93876	0.4667	12.17567	0.6376
At most 2	11.76308	0.4703	6.215053	0.7635
At most 3	5.548031	0.2286	5.548031	0.2286
3) Intercept (no trend) in CE and test VAR				
None	45.53197	0.0813**	28.57935	0.0372*
At most 1	16.95262	0.6436	6.845647	0.9597
At most 2	10.10697	0.2726	5.573290	0.6684
At most 3	4.533679	0.0332*	4.533679	0.0332*
4)Intercept and trend in CE-no intercept in VAR				
None	64.52431	0.0441*	36.52736	0.0135*
At most 1	27.99695	0.6223	15.71719	0.5699
At most 2	12.27977	0.7923	6.786967	0.9146
At most 3	5.492801	0.5272	5.492801	0.5272
5)Intercept and trend in CE-intercept in VAR				
None	60.08441	0.0177*	35.96858	0.0107*
At most 1	24.11583	0.4373	12.31248	0.7382
At most 2	11.80336	0.3239	6.335266	0.7833
At most 3	5.468089	0.0194*	5.468089	0.0194*

* denotes rejection of the hypothesis at the 0.05 level, **denotes rejection of the hypothesis at the 0.10 level. The lag (p) order specified for all tests is set to be 1.

The results of the trace test for the cointegration rank are given in table 4-7. From these results it is evident that the number of cointegration relationships is different between models. At the 5% significance level, both trace and maximum eigenvalue statistics reject the null of no cointegration. At 10% significance level, the null of no cointegration is rejected in four out of five specifications.Although different cointegration relationships based on Johansen tests were found, to decide which of the models is to be considered suitable for our purposes, the Johansen Cointegration Test Summary is computed (table 4-8). The decision of the number of cointegration vectors in the VECM (1) is based both on the trace and maximum eigenvalues tests. The results suggest that one cointegration relationship can be found among variables in two out of five models.

Table 4-8. Johansen Cointegration Test Summary

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	0	0	0	1	1
Max-Eig	0	0	1	1	1

To draw some conclusions regarding the model to be used for the further analysis the Information Criteria by Rank and Model is computed. In table 4-9 results are shown and emphasise that the most appropriate model to be used, based on both AIC and SIC is the model intercept and trend in CE- intercept and no trend in VAR (model 4). This particular result is consistent within both the trace test and maximum eigenvalue test suggesting the presence of one cointegration vector.

Table 4-9. Information Criteria by Rank and Model in the Johansen Cointegration test

Information Criteria by Rank and Model					
Data Trend:	None	None	Linear	Linear	Quadratic
Rank or	No Intercept	Intercept	Intercept	Intercept	Intercept
No. of CEs	No Trend	No Trend	No Trend	Trend	Trend
Log Likelihood by Rank (rows) and Model (columns)					
0	145.2638	145.2638	148.7587	148.7587	150.9786
1	151.9548	159.5553	163.0483	167.0224	168.9629
2	155.2093	165.6431	166.4712	174.8809	175.1192
3	158.2837	168.7506	169.2578	178.2744	178.2868
4	159.3333	171.5247	171.5247	181.0208	181.0208
Akaike Information Criteria by Rank (rows) and Model (columns)					
0	-11.75126	-11.75126	-11.70533	-11.70533	-11.54351
1	-11.63225	-12.23230	-12.27712	-12.54749*	-12.45117
2	-11.20084	-11.96756	-11.86102	-12.44372	-12.28356
3	-10.75306	-11.43188	-11.38707	-11.93404	-11.84425
4	-10.12121	-10.86588	-10.86588	-11.36553	-11.36553
Schwarz Criteria by Rank (rows) and Model (columns)					
0	-10.95777	-10.95777	-10.71348	-10.71348	-10.35328
1	-10.44202	-10.99248	-10.88852	-11.10929*	-10.86420
2	-9.613872	-10.28140	-10.07567	-10.55919	-10.29985
3	-8.769349	-9.299384	-9.204989	-9.603176	-9.463797
4	-7.740754	-8.287050	-8.287050	-8.588331	-8.588331

* indicates the lowest value of the information criteria.

On the premise of the existence of cointegration relationships, VECM can be conducted further.

4.2.4. Vector Error Correction Model estimation

The VECM model incorporates a long-run equilibrium condition since evidence of cointegration between studied variables was found. According to the performed Johansen cointegration analysis and considering the 5% significance level conclusions, a long-run relationship is verified across variables. Based on both Akaike Information Criteria and

Schwarz Criteria, the model to be considered for the VECM representation is the model in which one cointegration vector was found according with both, the trace test and maximum eigenvalue test with one lag. Residuals diagnostic tests such as independence, normality and heteroskedasticity tests are performed to check if the VECM model can be validated.

TABLE 4-10. Diagnostic test for the VECM (1) residuals

Residuals Test	Autocorrelation LM test	Normality(Cholesky covariance) Jarque-Bera	Heteroskedasticity test (no cross term) Chi-sq
P value	0.6428	0.6977	0.4711
Decision	Do not reject the null	Do not reject the null	Do not reject the null

As per table 4-10 the three assumptions results on the residuals of the VECM equation, which represents the equilibrium model, are satisfied. Thus, if the VECM model's residuals are normally distributed, have constant variance and do not present serial autocorrelation among different order of lags, then a conclusion of no misspecification is achieved. The cointegration equation is presented in the table below (table 4-11), the full VECM outputs for the diagnostic tests are presented in Appendix A.4-5.

TABLE 4-11. Results of cointegration equation

LNREER	PSTAB	LNTOT	RIR	@TREND (96)	C
1.000000	-0.085264	-0.435286	-0.032381	0.005721	-2.016423
	(0.04541)	(0.18154)	(0.00403)	(0.00104)	
	[-1.87760]	[-2.39775]	[-8.03920]	[5.52129]	

Note: numbers within round parenthesis are the standard error and within square are t-statistics

The cointegration equation that can be derived from the VECM estimation from the table above can be represented as follows, with the coefficients having opposite signs:

$$LNREER_t = 2.016423 + 0.085264 PSTAB_t + 0.435286 LNTOT_t + \\ + 0.032381 RIR_t - 0.005721 @TREND(96) \quad (4.22)$$

This cointegration equation indicates (check Appendix A.4-5c where the significance test for the long-run coefficient is provided) that the political stability indicator, the terms of trade and the real interest rate, have a positive effect on the real effective exchange rate. If a 0.1 shock occurs upon the political stability indicator (this magnitude being equivalent to a standard deviation), the real effective exchange rate will appreciate by almost 0.85% (0.085*100*0.1). It is expected that political stability, which is only statistically significant at 10% level, to generate depreciation in the dependent variable, as if a political crisis will somehow negatively impact the economic performance of the UK as political stability is more likely to produce confidence, thus appreciation of the currency. Moreover, our results are in accordance with Ricci et al. (2013) which found that the terms of trade positively impact the real effective exchange rate in all the countries under their analysis. In the same vein with the study of Clark and MacDonald (2004), LNTOT has a positive impact on REER. Its coefficient suggests that a 1% increase in the terms of trade will appreciate the real effective exchange rate by 0.43%. This result is consistent with most of the empirical literature, indicating that an improvement in this macroeconomic fundamental leads to an appreciation in the real effective exchange rate, suggesting that the income effect of this variable is dominant with respect to the substitution effects. Meanwhile, an increase in the real interest rates, RIR, of 1 p.p. will appreciate the UK's REER by 3.2%.

The adjustment coefficient (-0.3440) suggests that previous years' deviations from the long equilibrium are corrected within the current year at a convergence speed of 34%. Having said that, we conclude that the UK's real effective exchange rate behaviour is driven by the dynamics of the economic fundamentals under analysis and the political stability indicator.

4.2.5. Granger causality test

By using the Granger causality test, the direction of the relationships between the real effective exchange rate, the political stability indicator, terms of trade and real interest rates are examined. In other words, the Granger causality which shows that one variable can help to predict the other one better, was performed to investigate whether LNREER Granger-causes PSTAB, LNTOT and RIR and vice-versa. The cointegration between two variables does not specify the direction of a causal relation, if any, between the variables. Econometric theory guarantees that there is always Granger Causality in at least one direction. The results for the Granger causality test between the variables are presented in table 4-12. The probability values obtained under the null hypothesis of non-Granger causality show that there is a causal relationship between variables since these probabilities are lower than the significance level-taking this level to be 5%.

Table 4-12. Granger Causality Test

Null Hypothesis:	Prob.	Decision
PSTAB does not Granger Cause LNREER	0.0375**	Reject the null
LNREER does not Granger Cause PSTAB	0.8521	Do not reject the null
LNTOT does not Granger Cause LNREER	0.0100*	Reject the null
LNREER does not Granger Cause LNTOT	0.2002	Do not reject the null
RIR does not Granger Cause LNREER	0.7077	Do not reject the null
LNREER does not Granger Cause RIR	0.0670***	Reject the null
LNTOT does not Granger Cause PSTAB	0.1196	Do not reject the null
PSTAB does not Granger Cause LNTOT	0.0060*	Reject the null
RIR does not Granger Cause PSTAB	0.4794	Do not reject the null
PSTAB does not Granger Cause RIR	0.0856***	Reject the null
RIR does not Granger Cause LNTOT	0.0400**	Reject the null
LNTOT does not Granger Cause RIR	0.1634	Do not reject the null

*Indicates the rejection of the null hypothesis at 1% significance level. **Indicates the rejection of the null hypothesis at 5% significance level. ***Indicates the rejection of the null hypothesis at 10% significance level.

The results in the above table show that, in the short-run, there is unidirectional causality running from LNTOT and PSTAB to REER. This implies that past values of terms of trade and the political stability indicator have a predictive ability in determining present values of the UK real effective exchange rate. Granger causality means that

LNREER follows its mature counterparts in the short-run, in other words, there exists a lead-lag relationship between the variables. As the lag considered for this analysis was one, we conclude that LNTOT and PSTAB at time $t-1$ impacts the LNREER at time t.

Testing for structural changes is significant to avoid model misspecification. To make sure that the equilibrium model is dynamically stable, the cumulative sum of recursive residuals (CUSUM) test is conducted. The recursive residuals may be understood as showing the effect of successively deleting observations from the data set. The CUSUM test was originally proposed by Brown et al. (1975) as a structural break test for the coefficient vector in the linear regression model. They argue that the recursive residuals behave exactly as under the null hypothesis, until a change occurs, and it would be preferable to use them to detect a change of model, rather than the ordinary residuals.

In this study the CUSUM test is run to evaluate the parameter stability over the analysed sample period on the REER equation, in which the behaviour of dependent variable LNREER is determined by the economic fundamentals, PSTAB, LNTOT and RIR. The CUSUM test is seen as a robust change in mean test that allows for long range dependence and thus, we defend that its performance here is necessary. As mentioned by Brown et al.(1975) the plot of the CUSUM test should look like a random walk within a parabolic envelope about the origin, since the expectation of these recursive residuals is zero where the straight lines are used to represent the critical bounds at 5% significance level.

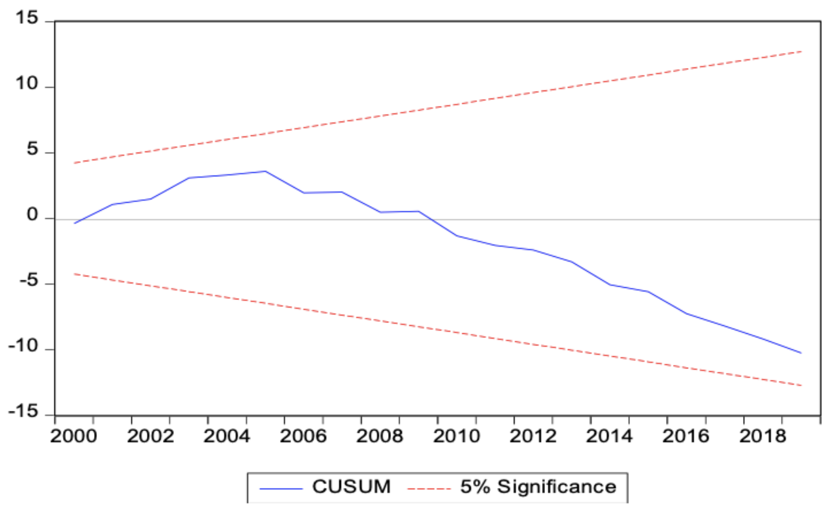


Fig. 4-2. Stability test of the cointegration equation

In figure 4-2 it is clearly shown that the model presents no structural instability since the recursive residuals, represented with blue lie within the red boundary, at 5% significance levels. More concisely, the model is set to be dynamically stable.

4.3. Behavioural Equilibrium Exchange Rate (BEER)

To estimate equilibrium exchange rates, a common approach is to identify equilibrium which is derived from the cointegration relationship between the actual exchange rate (real effective exchange rate) and its macroeconomic fundamentals, terms of trade and real interest rates, and the political stability indicator.

The Johansen cointegration framework to estimate the UK's exchange rate misalignment as the deviation of real effective exchange rates from their long-run equilibrium is used. In the present research, this framework requires that a misalignment ought to be related to a future adjustment of the real effective exchange rate toward the BEER model. The central idea is that the misalignments, or the estimated deviation between the real effective exchange rates and their equilibrium levels, should tend to be small. For an undervalued currency, negative values of misalignment are expected.

The systematic relationship between LNREER and its economic fundamentals is the basic equilibrium concept underlying the notion of BEER in this study. This section examines the BEER model derived from the VECM representation. The equation of the current equilibrium rate in the Behavioural Equilibrium Exchange Rate model is $q_t' = \beta_1' Z_{1t}$, and the short-run behaviour of the real effective exchange rate can be written as:

$$\Delta q_t = -\alpha(q - \beta Z)_{t-1} + \sum_{i=1}^{p} \beta_{1,i}\Delta Z_{t-i} + \sum_{i=1}^{p} \beta_{2,i}\Delta q_{t-i} + \varepsilon_t \qquad (4.23)$$

where α is the speed of adjustment parameter, $(q - \beta Z)_{t-1}$ represents the behavioural equilibrium exchange rate, the UK BEER, and the remainder is the short-run dynamics plus the error term. Thus, when the variables are cointegrated, a complex adjustment process concerning short-run and long-run dynamics is present. The vector Z_t has the following structure $Z_t = (PSTAB_t, LNTOT_t, RIR_t)$.

The current misalignment at time t, henceforward mentioned as CM, is computed according to Clark and MacDonald (1999) as the difference between the actual real exchange rate and the real exchange rate as given by the current values of the variables under consideration:

$$CM_t = LNREER_t - BEER_t \qquad (4.24)$$

where CM_t is the current misalignment. If $CM_t > 0$ indicates that the real effective exchange rate, $LNREER_t$ is larger than the equilibrium rate, $BEER_t$, this suggests that the real effective exchange rate is overvalued. Therefore, an increasing misalignment is more likely to worsen the economic performance and trade position as regards other economies.

4.4. Beveridge-Nelson Decomposition

In macroeconomic literature, the most commonly used trend-cycle decomposition methods are the Hodrick and Prescott (1980) filter, followed by the Beveridge–Nelson (1981) decomposition. The decomposition method introduced by Beveridge and Nelson (1981), hereafter referred to as the B-N decomposition, provides an appropriate way to estimate the permanent and transitory components of an integrated time series. The permanent component consists of the deterministic trend, and a stationary transitory component is defined as cyclical component. The permanent component is engaged as the sustainable level which is consistent with the concept of equilibrium level. The need for the PEER approach is urged by Clark and MacDonald (2004) and is supported by the fact that current values of the economic fundamentals may depart from the sustainable equilibrium given by the BEER. Morley et al. (2003) state that the B-N decomposition trend provides a definition of the permanent component of an integrated time series. We also apply in this study the convention of calling the permanent component of the B-N decomposition, trend and the transitory component, cycle (see Hecq et al., 2000 for further discussion on B-N decomposition).

We now move on to illustrate how an equilibrium rate based on B-N decompositions of the fundamentals was computed. We estimated a VECM framework to obtain the long-run relationship between the real effective exchange rate and the political stability indicator, terms of trade and real interest rates, and interpreted it as being the behavioural equilibrium exchange rate, we can proceed with analysis and use this relation to calculate the permanent equilibrium exchange rate as follows. We then replace the B-N decomposition from the fitted trend of each variable under consideration back into BEER equation and we obtain the permanent equilibrium exchange rate, the PEER.

This method implies that the observed time series are viewed as the sum of trend and cyclical components. In this approach, a time series can be written as follows:

$$y_t = \tau_t + c_t, \qquad \text{for} \quad t = 1, ..., T \tag{4.25}$$

where τ_t is the trend component and c_t is the cyclical component. The B-N trend of an integrated time series y_t is given as follows:

$$\tau_t = \lim_{n \to \infty} E_t(y_t - \eta\mu) \tag{4.26}$$

where $\mu = E(\Delta y_t)$ is the deterministic drift. In other words, the B-N trend is the optimal long-horizon conditional point forecast of the time series process $\{y_t\}$, with any future drift removed. The starting point for B-N decomposition is that most economic time series can be approximated by an ARIMA (p, 1, q) model, which is designed to capture the autocovariance structure of $\{y_t\}$.

When the model of choice is an AR (1) the B-N decomposition can be written as follows $\Delta y_t = \mu + \phi(\Delta y_t - \mu) + \varepsilon_t$, where $\mid \phi \mid < 1$ and ε_t are white noise, and the B-N trend is $\tau_t = y_t + \frac{\phi}{1-\phi}(\Delta y_t - \mu)$. The B-N cycle is the difference between the series and the B-N trend, $c_t = y_t - \tau_t$, see Morley (2002) and Kamber et al. (2018) for further discussion.

If the time series $\{y_t\}$ follows a MA(1) representation, the B=N decomposition can be written as: $\Delta y_t = \mu + \varepsilon_t + \theta_1 \varepsilon_{t-1}$, where $\sum_{i=1}^{\infty} \theta_{it} < \infty$ and the B-N trend is a random walk with drift, represented as $\tau_t = \mu + \tau_{t-1} + \sum_{i=0}^{\infty} \theta_i + \varepsilon_t$. Beveridge and Nelson

(1981) have shown that the B-N cycle is given by $c_t = (\sum_{i=1}^{\infty}\theta_i)\varepsilon_t) + (\sum_{i=2}^{\infty}\theta_i)\varepsilon_{t-1} + (\sum_{i=3}^{\infty}\theta_i)\varepsilon_{t-2})$, ...,which is a stationary process.

Following Chen et al. (2008) methodology to apply the B-N decomposition, it is necessary to investigate the autocorrelation function (ACF) and the partial autocorrelation function (PACF) to identify the ARIMA structure of each variable entering the VECM representation. We repeat this identification stage to identify candidate ARIMA models for each variable. The Box-Ljung chi-square test for white-noise residuals is performed to check whether the residual series contains additional information that might be used by a more complex model. Significance tests for parameter estimates, and the goodness-of-fit statistics, are used to: first, indicate whether some terms in the model may be unnecessary; and second, compare the model to others based on the smallest AIC values. Having said this, the structure of the ARIMA model for each variable is presented in table 4-13. In Appendix A.4-6 the complete outputs of the ARIMA representations can be found. [2]

Table 4-13. ARIMA model of each variable

Variable	Model	AIC criterion
LNREER	ARIMA (0,1,2)	-4.292880
PSTAB	ARIMA (0,1,3)	-2.824509
LNTOT	ARIMA (4,1,4)	-5.738870
RIR	ARIMA (1,1,0)	2.579115

4.5. Permanent Equilibrium Exchange Rate (PEER)

After we establish the best model to fit the variables, the B-N decomposition is performed taking into consideration the model specification for each of the fundamentals. Based on this decomposition, the PEER equation it can be written as:

$$LNREER_t = 2.016423 + 0.085264 Trend_{PSTAB_t} + 0.435286 Trend_{LNTOT_t} + \\ +0.032381 Trend_{RIR_t} - 0.005721@TREND(96) \quad (4.27)$$

where $Trend_{PSTAB_t}, Trend_{LNTOT_t}, Trend_{RIR_t}$ represent the permanent component obtained with the B-N decomposition.

The LNREER and PEER are plotted in figure 4-3 left-hand side chart. The total misalignment referred as TM is computed as the difference between LNREER and PEER.

$$TM_t = LNREER_t - PEER_t \quad (4.28)$$

where TM_t represents the total misalignment. If $TM_t < 0$ than, the sterling pound is undervalued.

The graphical representations of the real effective exchange rate against the estimated behavioural and permanent equilibrium real effective exchange rate and the current and

[2]For the PACF and ACF analysis we followed the book of Box et al. (2015), Time series analysis: forecasting and control

total misalignments of the sterling pound with respect to the level of the equilibrium real exchange rate given by the fundamentals are reported in figure 4-3. In the left-hand chart it can be observed that the three series, LNREER BEER and PEER follow almost the same path for the whole analysed period. In the right-hand chart it can be seen that, although the current and total misalignment change over time, the actual real effective exchange rate is close to its equilibrium rate apart from a short in duration period between 1996 and 1999. We conclude that the estimated misalignments, show very similar behaviour.

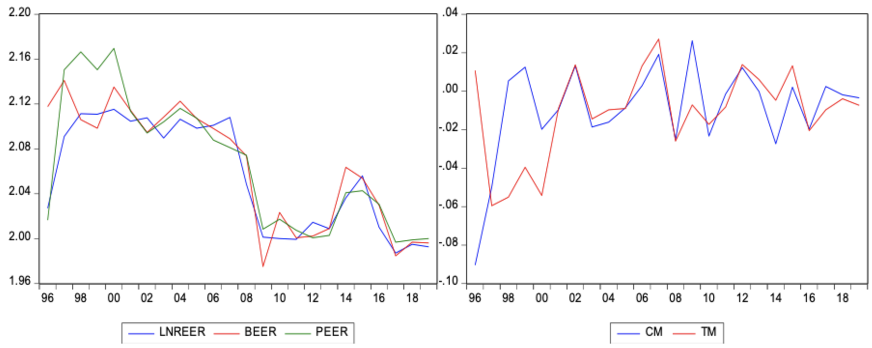


FIG. 4-3. Dynamics of the UK REER for 1996-2019 and currency misalignments

To avoid harmful economic performance, the UK's REER should be maintained as close as possible to its equilibrium level. Both BEER and PEER based measures indicate that the pound sterling in 2019 is broadly in line with the equilibrium exchange rate given by macroeconomic fundamentals. The estimated BEER, actual LNREER,the filtered PEER, the current and total misalignments for the period 1996-2019 are tabulated in table 4-14. Misalignment of the pound does not seem to be a huge issue during the analysed time period. This contrast with the result of Clark and MacDonald (1998) for the period 1960-1997, which found that BEER was a poor explanation of the exchange rate but acknowledged that PEER provided a much better approximation to the observed REER due to the importance of the permanent component of the real interest rate differential in explaining the exchange rate. In other words, the high volatility of the real interest rate differential up to the 1980s (due to the high inflation in the period) created a large gap between BEER and REER. But Clark and MacDonald (1998), just as we, for the UK in more recent period, find that the deviations between BEER and REER were small.

TABLE 4-14. British pound real effective exchange rate and currency misalignments over the period 1996-2019

	LNREER	BEER	PEER	CM (%)	TM (%)
1996	2.03	2.12	2.02	-9%	1%
1997	2.09	2.14	2.15	-5%	-6%
1998	2.11	2.11	2.17	0%	-6%
1999	2.11	2.1	2.15	1%	-4%
2000	2.12	2.14	2.17	-2%	-5%
2001	2.1	2.11	2.11	-1%	-1%
2002	2.11	2.09	2.09	2%	2%
2003	2.09	2.11	2.1	-2%	-1%
2004	2.11	2.12	2.12	-1%	-1%
2005	2.1	2.11	2.11	-1%	-1%
2006	2.1	2.1	2.09	0%	1%
2007	2.11	2.09	2.08	2%	3%
2008	2.05	2.07	2.07	-2%	-2%
2009	2	1.98	2.01	2%	-1%
2010	2	2.02	2.02	-2%	-2%
2011	2	2	2.01	0%	-1%
2012	2.01	2	2	1%	1%
2013	2.01	2.01	2	0%	1%
2014	2.04	2.06	2.04	-2%	0%
2015	2.06	2.05	2.04	1%	2%
2016	2.01	2.03	2.03	-2%	-2%
2017	1.99	1.98	2	1%	-1%
2018	1.99	2	2	-1%	-1%
2019	1.99	2	2	-1%	-1%

A LNREER level of below/above the level of the sustainable equilibrium given by the BEER model is associated with undervaluation/overvaluation of the currency, or a misalignment. As with the total misalignment, it is possible to check that over the analysed period the pound sterling displayed periods of overvaluation and undervaluation with respect to the equilibrium real effective exchange rate level ranging from -6% to 2.7%. The evolution over the whole period is depicted in figure 4-3, which distinguishes two types of currency behaviour with respect to the equilibrium values. In an attempt to explain those dynamics, we notice remarkable events that have impacted the world economic and financial environment between 1996 to 2019. The first is related to the Bank of England and its new role starting in 1997 as policy maker, and Economic and Monetary Union; the second is related to the economic and financial crisis that has engulfed the world; the third is linked to the European Sovereign Crisis; and finally, the fourth major impact for exchange rate dynamics is the UK's 2016 vote to leave the EU.

Two groups of factors that are believed to be major forces driving the value of a currency are mentioned in the economic exchange theory, as being the flow of traded goods and services and the flow of foreign investments.

If we follow these two particular groups of exchange rate forces to explain the high degree of the currency misalignment from 1996 to 2000, we could base our explanations on both the events that followed the third stage of Economic and Monetary Union (hereafter as EMU). EMU was likely to shift the structure of European industries and to change the structure of import and export of goods and services within the trade partners.

Our results point out that the pound sterling appeared to be undervalued from 1996 to 2001 by more than 3.4% in average and overvalued in 2002 reaching the level of 1.4%.

From 2003 to 2005 the undervaluation relative to 1997 was reduced and reached 0.9%, and in 2006 and 2007 our results demonstrate an overvalued currency.

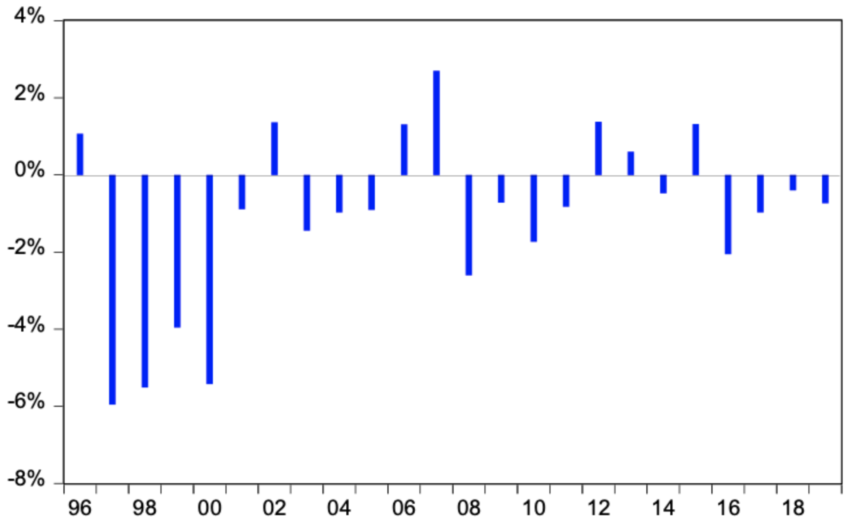
It seems that from 2006 to 2008, the UK was increasingly affected by the global credit crunch in the aftermath of the reduced ability of the interbank money market to provide loans, and the cut in UK interest rates. Since the banking system is internationally linked, and since governments removed barriers to move money around the world, the UK was affected also by the global economic decline. Although the crisis started in the US in mid-2007 with rising default rates on subprime mortgages and with banks that have experienced liquidity problems, in the UK it started only in mid-2008 when the UK government had to step in to rescue financial institutions that were facing bankruptcy due to severe banking failures.

The financial crisis led to a large drop in trade flows across the world, with under performing export of services. Although governments responded with massive emergency measures, the crisis continued to spread. From 2007 to 2009, a set of measures were taken in the United Kingdom to stimulate the economy and to rescue financial institutions that were failing following the collapse of the subprime mortgage sector in the US.

For the period of the European sovereign debt crisis, 2010 to 2013, when several countries were on the risk of defaulting on their debts and spent over the limit, our results show that the UK currency was close to its equilibrium level operating just below it by, on average, -1% for the first two year of the mentioned period and operating above the equilibrium level by on average 1% in 2012 and 2013.

From 2016 until 2019 on average, sterling was undervalued by 1% and this was more frequent and much larger than in the previous period from 2012 to 2015. In 2019 the deviation of the observed LNREER from the equilibrium is 0.7%, the misalignment has come down substantially comparing to 2015 as per figure 4-4 shows.

FIG. 4-4. Sterling pound total misalignment 1996-2019



Note: The pattern of total misalignment where positive bias expresses an overvalued exchange rate and the negative bias indicates undervalued exchange rate.

It is possible to conclude that the pound sterling is undervalued in terms of total misalignment in the majority of the years under study, and the average misalignment is only 1.1% in absolute terms, due to the post-referendum misalignment from –2.1% in 2016 to -1% in 2017. It has to be said that in 2016, the year of the referendum, there was a big undervaluation which in the next periods was corrected. Despite the degree of undervaluation, the UK's REER seems to move toward its equilibrium level very quick.

Although the BEER model makes no prediction of how long it will take the exchange rate to get back to fair-value, it is possible to conclude that the British currency has remained undervalued since 2016. Our results are in line with the Comunale (2019b) which founded that "the United Kingdom has an advantage in terms of competitiveness, having an undervalued REER for almost all the years under review".

4.6. Impulse response function and variance decomposition

To illustrate how the effects of shocks are magnified and distinct by the real effective exchange rate, and how shocks occurring in the real effective exchange rate itself influence the economy through political stability indicator, terms of trade and real interest rate, we analyse the impulse response functions and the variance decomposition.

The impulse response functions (IRFs) are a useful way of answering questions regarding the dynamics of the variables under analysis in the presence of a shock. The question stated in the purpose of this chapter was if the currency appreciates or depreciates in the presence of a shocks in the macroeconomic fundamentals and in the political factor. In order to determine the short-term and long-term effect of a shock on the UK currency we analyse the impulse response function using the Cholesky decomposition proposed by

Sims (1980). This requires a prior ordering of the variables. The variables ordering is as follows: first we consider the most exogenous of the variables, PSTAB, then the second and the third are LNTOT and RIR, and finally the last one is the LNREER on which all the variables have contemporaneous effect on it. Figure 4-5 reports the response of LNREER to the Cholesky one standard deviation shocks in PSTAB, LNTOT and RIR. In the ordering we put first the variable that takes more time to react, political stability indicator that it takes time to react due to the delay in political decisions. Terms of trade are slow to change due to price rigidity. Lastly, real interest rate and real exchange rate because both depend on market variables and are assumed to react quicker.

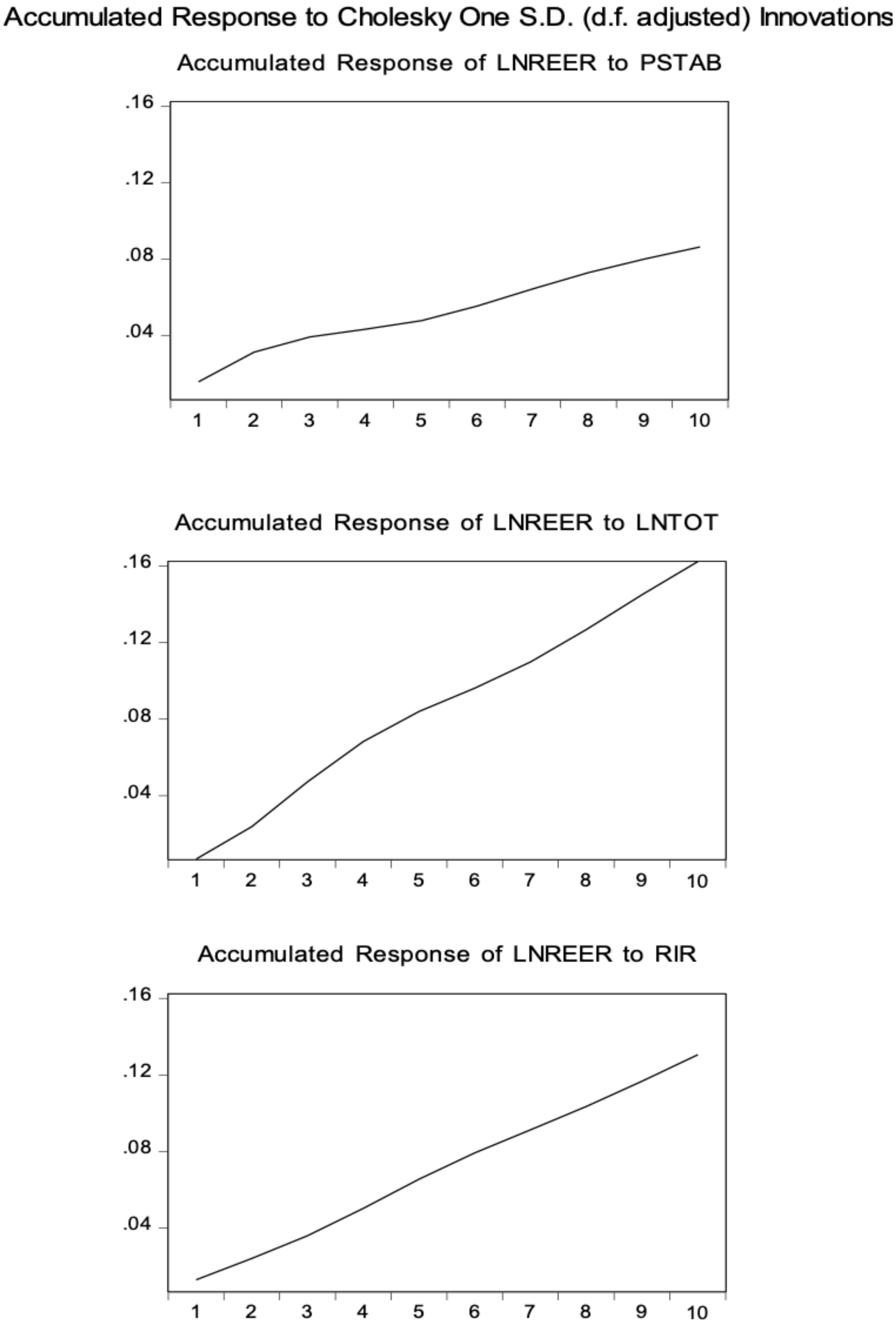


Fig. 4-5. Accumulated response of LNREER to Cholesky one standard deviation shock in PSTAB, LNTOT and RIR

The top graph shows that when LNREER is positively affected by one standard deviation shock in political stability indicator, the currency appreciates about 5% at the end of five years and about 8% at the end of ten years. Moreover, the interaction between political stability and the real effective exchange rate confirms first, the importance of the empirical foundations raised in this research and second, confirms our theoretical predictions of the effect of the UK political stability on the real effective exchange rate. The second graph shows that one standard deviation shock in the LNTOT will also appreciate the UK currency. The term of trade is an important factor contributing to a stable world economy. Our result can be interpreted as evidence in support of the view that a decrease in the terms of trade derives to a depreciation of the exchange rate, which will cause import prices to increase and export prices to decrease, while an appreciation causes the opposite effects. In the last graph we can observe that RIR will just appreciate the British pound. One explanation could be that higher real interest rates attract more financial capitals. An increase in interest rates, in general, appreciates exchange rate, making domestic goods and services more expensive compared with those produced outside the UK.

To check the robustness of the results obtained in the IRF analysis using Cholesky decomposition, the generalized impulse response function has been employed due to its main feature, it is invariant to the ordering of the variables in the VAR model. When comparing the observed output of the IRF using Cholesky decomposition with the generalized IRF, we can conclude that the LNREER response to a shock on PSTAB, LNTOT, RIR displays similar behaviour in both analyses. The full results are presented in Appendix A.4-7.

The IRF analysis was applied to examine how real exchange rate responds to shocks in each independent variable and the duration of the effect of the shock, whiles the variance decomposition analysis, applied next, is used to examine the percentage of the contribution of each variable in the dynamics of the real effective exchange rate over time.

We follow the theoretical framework of forecast error variance decomposition (or shortly, variance decomposition) described by Lütkepohl (1991) and Lütkepohl and Kratzig (2004) to examine the contributions of each variable innovation to the variance of the LNREER. According to Lütkepohl (1991) the forecast error variance in the endogenous variables can be attributed to shocks in themselves and in shocks in the other variables in the system. Based on the estimated VECM model, we investigate what are the main driving forces of the UK REER from year 1996 to 2019, covering Brexit vote period. The $h-th$ steps ahead forecast considered in this analysis is ten years and the Cholesky ordering of the variables is as follows: PSTAB LNTOT, RIR, LNREER.

Table 4-15. Forecast error variance decomposition of LNREER due to PSTAB, LNTOT, RIR shocks (percentage)

Period	S.E	LNREER	PSTAB	LNTOT	RIR
1	0.650138	20.33400	45.90016	11.56397	22.20187
2	0.959672	14.58074	39.06232	31.45195	14.90498
3	1.127296	13.15636	29.62557	44.43146	12.78661
4	1.261942	12.65938	25.46672	50.59840	11.27550
5	1.376372	12.49380	23.12791	53.94279	10.43550
6	1.481807	12.33718	21.73460	55.98610	9.942117
7	1.580925	12.25506	20.72883	57.40438	9.611731
8	1.675125	12.17939	19.98080	58.49382	9.345994
9	1.764007	12.11947	19.37108	59.37013	9.139318
10	1.848597	12.07074	18.88161	60.07694	8.970714

Table 4-15 gives the forecast error variance decomposition of LNREER due to innovations in PSTAB, LNTOT and RIR. As we can notice in these results, in the short-run, the main variation in LNREER is attributed to PSTAB, almost 46 %, to LNTOT, almost 12 % and to RIR 22%. Although LNTOT shocks are not very important on the short-run, they become more and more important in the tenth step ahead forecast error variance, accounting for about 60% of the variance of LNREER. Shocks in PSTAB in the long-run account for more than 18% of the error variance of the LNREER. Furthermore, the RIR shocks tend to decrease in a tenth step ahead forecast error variance of LNREER variation. We can conclude that, the variance decomposition approach confirms the importance of political stability in explaining dynamics of the UK real exchange rate.

4.7. Conclusion

Using a VECM model and the Johansen (1988) cointegration methodology, we have analysed the UK behavioural equilibrium exchange rate and assessed whether the dynamics in real effective exchange rate are consistent with a set of macroeconomic and political factors. We have shown that much of the long-term behaviour of the UK REER can be explained by the fluctuations in the political stability indicator, terms of trade and the real interest rate. We first estimate real effective equilibrium exchange rates relying on BEER approach, and second by applying Beveridge-Nelson decomposition method, from which we have obtained the PEER model from which, finally currency misalignments were derived.

Based on the estimation paths of the UK BEER and PEER, a clear pattern of undervaluation is observed. The real appreciation of the pound sterling exchange rate has brought the REER above its long-term equilibrium values only for short periods of temporary overvaluation (7 out of 24 period under the analysis). Our analysis has pointed out that although the paths of REER, BEER and PEER evolved similarly, there are differences in the impact of the fundamentals and the political stability indicator on the real effective exchange rate. These differences were referred to as the current misalignment and total misalignment. Furthermore, the speed of adjustment was obtained: the UK REER has a 34% speed of reverting to equilibrium levels in response to any shocks. The results indicate that, in general, the UK exchange rate is associated with the degree of persistence and the magnitude of REER misalignment given by estimates of the terms of trade, political stability indicator and the real interest rate.

Fischer (2019) notes that the equilibrium exchange rate and its corresponding misalignment estimates differ remarkably depending on the estimation method used to derive them. In sum, this study reiterates in the assessment of exchange rate misalignment the need for sensitivity analysis since the magnitude of misalignment could vary across methodologies due to the specific assumptions in each approach.

CHAPTER 5

The impact of Economic Policy Uncertainty on the real exchange rate: Evidence from the UK

5.1. Introduction

The first issue that emerged in the previous chapter was that political stability may impact real effective exchange rate dynamics. This was explored in relation to both terms of trade and real interest rates. Now, we address and enlarge the primary research question on how the UK real exchange rate reacts to economic policy uncertainty shocks motivated by the Brexit consequences. The aim of this chapter is to understand the dynamics of the real effective exchange rate in relation to the economic policy uncertainty index, terms of trade, and real interest rates.

In the previous chapter an indicator of political stability from the worldwide governance indicators (WGI) database was used to study this relationship between the UK real effective exchange rate and a set of independent variables. This indicator measures political stability as the absence of violence and in relation to government efficiency. World Governance Indicators are a summary of several indicators taken from a wide range of sources, having six dimensions of governance: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law and lastly, control of corruption. These indicators are built using over 30 individual data sources gathered by surveys on businesses, citizens and expert groups, with these surveys being created by institutes, non-governmental organizations, think tanks, international organisations and private sector firms. As this chapter develops, we will observe that the way both indicators, the political stability indicator and the economic policy uncertainty index are computed is rather different.

Moreover, whereas Economic Policy Uncertainty (EPU) focuses on uncertainty of economic policy, WGIs focus on the broader issue of political stability measured by absence of violence and government effectiveness.

In the last years, the world economy has been punctuated by uncertainty: 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, only to mention some. In such circumstances economic agents are conscious and aware of their limited knowledge about present facts and the unpredictable outlook for the economy, they are experiencing economic uncertainty. The use of the concept *economic policy uncertainty* gained fast importance. This increase was well established in literature and can be associated mainly with the observed negative effects of uncertainty on economic activity. Beckert and Berghoff (2013) point uncertainty as one of the universal characteristics of the economic activity. To reach the definition of economic policy uncertainty which will lead us through this study (chapter), the concepts of economic uncertainty and policy uncertainty must be first defined. In general, the concept of *economic uncertainty* can be defined as a circumstance in which economic agents are conscious and aware of their limited knowledge about present facts and unpredictable future outlook for the economy. The concept of *policy uncertainty* is described by Al-Thaqeb and Algharabali (2019) as the economic risk associated with unpredictable future government policies, ambiguous future regulatory frameworks or uncertainty over electoral outcomes that will influence any further economic development. Kaya et al. (2018) defined economic policy uncertainty as the economic agents being unable to foresee the outcomes of fiscal, regulatory, monetary and trade policies. [1]

According to economic theory, increased uncertainty affects economic activity through a number of channels or mechanisms. In assessing common sense on how to measure the economic policy uncertainty, it is important to be aware of the uncertainty related to its measurement due to language features or text-search methods used. In the recent development of an indicator to capture the economic policy uncertainty, from the literature we can highlight two types of indices, the first being a language dependent measurement, Baker et al. (2013, 2016) and the second, a language independent measurement, Kupfer and Zorn (2020).

On the one hand, The Economic Policy Uncertainty index, hereafter as EPU, developed by Baker, Bloom and Davis (2013, 2016), was brought to the attention of recent studies due to its economic outcomes. These authors have developed comprehensive indices on economic policy uncertainty for about 25 countries worldwide using words such as "economic" or "economy"; "uncertain" or "uncertainty"; "congress", "deficit", "federal reserve", "legislation", "regulation" or "white house" using a newspaper-based approach. In the index development it was also mentioned that to be considered as meeting the criteria, an article must contain terms in all three categories pertaining to uncertainty, economy, and policy. Besides meeting this criteria, the measure of the UK EPU index is based on the relative frequency of the number of newspaper articles regarding 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.

On the other hand, the Google Economic Policy Uncertainty index (hereafter referred as GEPU) was developed by Kupfer and Zorn (2020) for Eastern European Countries and is based on Google search volume in combination with search topics and search categories instead of newspaper articles. These authors urge the development of the index by the fact that, firstly, the assumption of unbiased and free press on which Baker et al. (2016) relied

[1]For a detailed discussion see Kaya, O., Schildbach, J., AG, D. B., and Schneider, S. (2018). Economic policy uncertainty in Europe. Deutsche Bank Research

may be violated in those countries and secondly, no language proficiency or sensitivity words are required. 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. Finally, they sum it up as follows: there is a high correlation between both indices, but the GEPU index is more flexible in including new trends and tendencies than the EPU index, and when linking both indices within a VAR model to macroeconomic variables, similar effects of shocks were found.

Since the mid-2000s, significant research was conducted on the EPU impacts on macroeconomic and financial market outcomes, such as monetary policy, investment decisions, economic growth, exchange rate. In particular, there are important works looking at the impact 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 market pressure (Olanipekun et al., 2019), economic growth (Bloom, 2009), financial trading markets (Mueller et al., 2017), international commodity markets (Andreasson et al., 2016), and bond market yields (Baker and Bloom,2013). For a detailed discussion of the use of the Economic Policy Uncertainty see Al-Thaqeb, and Algharabali (2019).

Nilavongse et al. (2020) added to the literature a study on the impact of EPU shocks in the aftermath of UK's 2016 Leave vote. Our study follows this same motivation by looking at the impact o economic policy uncertainty on the UK 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 chapter is structured as follows. Section 5.2 makes a literature revision, followed in Section 5.3 by an exposition of the stylized facts about Brexit and the UK EPU. Section 5.4 presents the econometric methodology and data. Section 5.5 discusses the results and finally Section 5.6 concludes.

5.2. Literature review

Economic uncertainty affects the economy through several channels, being the most important the cost of debt, stock markets, and economic growth; and through these impacts the exchange rate market is affected.

Wisniewski and Lambe (2015) studied the relationship between the US and European economic policy uncertainty indices and cost of credit insurance or credit default swap (CDS) market dynamics. Within a vector autoregressive (VAR) methodology, two indices are used, namely the iTraxx (European, Asian and Emerging Market tradable credit default swap index) and the CDX (North America and emerging markets tradable credit default swap) employing monthly data over a period which ranges from October 2006 to March 2014 for the US and from February 2007 to March 2014 for Europe. They found that economic policy uncertainty affects CDS spreads.

Bernal et al. (2016) analysed the impact of economic policy uncertainty on the risk spillovers between sovereign bond markets within the Eurozone for the period Q4 2008 to Q2 2013. The EPU indices used are EPU Germany, EPU France, EPU Italy and EPU Spain, as well as EPU United States. Their study relies on the ΔCoVaR (Conditional Value at Risk) methodology to analyse the determinants of systemic risk assessing the marginal contribution of a given country to the risk of the Eurozone as a whole using a set of macroeconomic variables as the determinants for risk spillovers on sovereign bond markets. They found not only strong evidence that economic policy uncertainty in Europe enhances the transmission of risk, but also that the US EPU index is important to explain the transmission of risk within the Eurozone sovereign bond market.

Arouri et al. (2016) analysis was on 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. It is used a three-regime switching model 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 and the impact differs according to market states.

Although recently the literature on the effects of economic policy uncertainty has grown substantially, covering different issues from multiple perspectives, the impact of the economic policy uncertainty index on the real effective exchange rate still needs further analysis. Firstly, note that economic policy uncertainty impacts adversely 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 stock market (Arouri et al., 2016; Phan et al., 2018). In opposition EPU increases credit risk of bonds (Wisniewski and Lambe, 2015; Chi and Li, 2017), stocks' risk premium (Pástor and Veronesi, 2013), and financial costs (Arouri et al., 2016). Tsai (2017) states that if the EPU in an economy is low, then economic policies are following prior expectations, but if the EPU is high, those policies cannot so easily be anticipated.

Thus, a high level of economic policy uncertainty decreases the economic outlook (notably GDP growth) and depresses the stock market, causing a depreciation of the exchange rate. Moreover, the increase in bonds' credit risk (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, it is expected that higher economic policy uncertainty depreciates the exchange rate, although the impact of economic and political factors can be highly correlated and interactive in a complex way (Wang et al., 2019).

Dai et al (2017) employing a quantile causality test (based on a perspective of sample distribution) on monthly data from 2006:M01 to 2017:M01, examined the relationship between EPU and the US dollar exchange rate against the Renminbi. Since macroeconomic volatility often increases the EPU, in their study the causality test is analysed from the investment perspective. They found that exists 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 higher risk premium on the currency leading to a devaluation.

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

Exchange rate movements caused by economic policy uncertainty are particularly important for some economies. Aizenman and Binici (2016) state that for an export-led economy, exchange rate fluctuations are important for appropriate policy designs and actions. Besides impacting the exchange rate level, economic policy uncertainty is expected to also affect the volatility. Krol (2014) investigates the impact of both home economic policy uncertainty and US economic policy uncertainty on exchange rates 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 for industrial countries when their economies are performing poorly, both economic policy uncertainty indices increase exchange rate volatility, while for some of the emerging countries only home economic policy uncertainty drives the exchange rate volatility.

The question on how the UK economy reacted 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 each is the real effective exchange rate of the British pound to the US dollar. They find that an increase in the EPU will worsen economic outputs, finding that dynamics of the UK currency are attributed to both US and UK EPU shocks and that 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 reviewed papers that explore economic policy uncertainty effects on economic and financial variables. In the present study we debate the hypothesis that EPU might impact the UK's REER both in the short-run and in the long-run.

5.3. Brexit vote result as an uncertainty generator

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 has been neglected as a policy variable. For several periods, this produced exchange rate misalignments translated in a currency too appreciated for the health of the UK's economy. The authors argue that this evidence occurs for two main reasons. First, because of UK's political stability and the extraordinary liquidity and attraction of its asset markets, the country can attract private capital flows that push up the real exchange rate. Secondly, due to a past of high inflation, the UK policy authorities use a strong currency as a way 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, which should include more specific and detailed options. Anyway, in June 23, referendum results were a shock to the UK, to the EU, and created uncertainties affecting worldwide relationships. The shock disrupted the governing of Europe's everyday projects, and transported de Union into a space of uncertainties and a period of trade negotiations with unclear outcome. Seddon and Niemeyer (2018) state that there were no obvious plans to put the result of the referendum into practice. Therefore, the economic policy uncertainty was amplified by the fact that trade agreements are themselves uncertain in what concerns their timing, negotiation outcomes and implementation. The effects of Brexit are also present 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 will apply after leaving the EU, and the ultimate UK economic structure after the agreement with the EU is finalised. Ries et al. (2017) acknowledge that the 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 its outcome is a unique process in the EU history, no other country has decided to leave by now the Union.

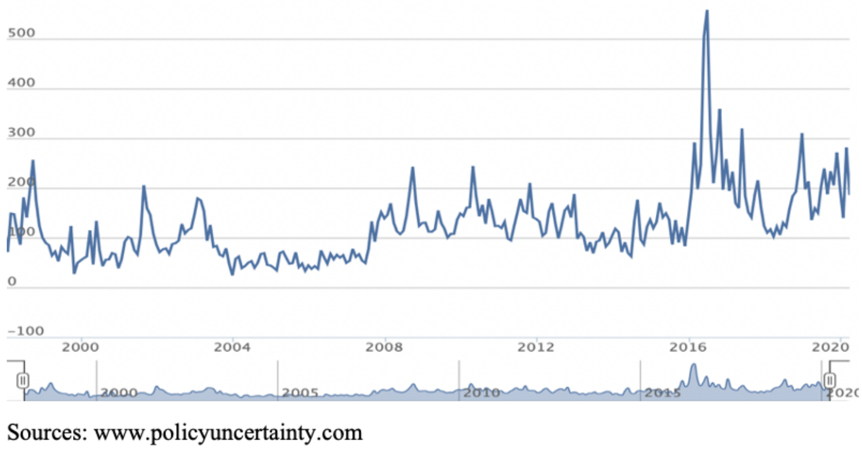


Fig. 5-1. The UK Economic Policy Uncertainty Index 1998M01-2020M06

As expected, the UK EPU index increased substantially after June 2016 when the leave vote won the referendum (Figure 5-1 below). Kostka and Van Roye (2017) noted that the impact of the referendum on financial conditions was not higher due to a clear commitment to an accommodative monetary policy by the Bank of England, by means of conventional and unconventional tools.

5.4. Empirical strategy

Our goal in this chapter is to analyse the long-run relationship between the real exchange rate and EPU for the UK. Following the Behavioural Equilibrium Exchange Rate (henceforth BEER) approach, there is an empirical link between the real exchange rate and a set of macroeconomic variables, which are not predefined by theory, but rather determined on an *ad hoc* basis (Clark and MacDonald, 1998). The notion of actual real effective exchange rate, q_t, is the same as in Clark and MacDonald (1998) and the same as used in chapter 4: $q_t = \beta_1' Z_{1t} + \beta_2' Z_{2t} + \tau' T_t + \epsilon_t$, 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. Recall, the current equilibrium rate is defined as the level of exchange rate given by the current values of the Z_{1t} and Z_{2t}, that is $q_t = \beta_1' Z_{1t} + \beta_2' Z_{2t}$.

To avoid spurious regression in the presence on 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 approach or the bound test of cointegration as an alternative to the Engle and Granger cointegration technique.

5.4.1. Autoregressive Distributed Lag (ARDL) approach

The ARDL model is one of the most general dynamic unrestricted models in econometric literature. 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 5.4, and so we next explain the ARDL approach in detail. Another reason for choosing method is that 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.

Following the work of Pesaran and Shin (1998) and Pesaran et al. (2001), the ARDL(p, q) model can be represented, for the case of one independent variable, by the following equation where the the independent variable is expressed by the current value and the first q lags of the independent variable, and the p lags of the dependent variable:

$$y_t = \beta_0 + \beta_1 T + \sum_{i=1}^{p} \phi_i y_{t-i} + \sum_{j=0}^{q} \delta_j x_{t-j} + \varepsilon_t \tag{5.1}$$

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 in detecting a single long-run relationship equation. If one cointegrating vector exists the ARDL model is reparametrized into an error correction model (ECM). The reparametrized result provides the ARDL short-run dynamics and long-run relationship in a single model. Equation (5.1) can be specified in the ARDL bounds test representation using the following unrestricted error correction model:

$$\Delta y_t = \beta_0 + \beta_1 T - \alpha(y_{t-1} - \theta x_{t-1}) + \sum_{i=1}^{p-1} \omega_{yi} \Delta y_{t-i} + \sum_{j=1}^{q-1} \omega'_{xi} \Delta x_{t-j} + \varepsilon_t \tag{5.2}$$

where Δ is the difference operator, α is the speed of adjustment coefficient which is define as $-\alpha = (1 - \sum_{j=1}^{p} \phi_i)$; θ are the long-run coefficients where $\theta = \frac{\sum_{j=0}^{q} \delta_j}{\alpha}$ and $\omega_{yi}, \omega'_{xi}$ 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 implying that 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 exist, the first difference variables in equation (5.2) have to be zero in the long-run equilibrium i.e. $\Delta y_{t-i} = \Delta x_{t-j} = 0$.

The ARDL estimation process involves the following steps. Firstly, it is specified the ARDL Bounds test model developed by Pesaran et al. (2001) to check if the series are cointegrated or not. The hypotheses to be tested in equation (5.2) are: $H_0 : (\alpha = 0) \cap (\sum_{j=0}^{q} \delta_j = 0)$ vs. $H_1 : (\alpha \neq 0) \cup (\sum_{j=0}^{q} \delta_j \neq 0)$. The existence of the cointegration is statistically evident if the null hypothesis is rejected. The test has two critical values, one set 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 in the ARDL model are I (1) – upper critical bound. In order to check the long-run relationship existence, the F statistics is carried out on the joint null hypothesis that the coefficients of the variables in levels and lagged are zero. When the F statistics is above the critical upper bound, we conclude for cointegration; when is below the lower critical value, there is no cointegration, and finally, when is in between the lower and upper critical values, no conclusion can be drawn.

Secondly, if using the F statistics bound test we conclude for existence of 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 different number of lag length 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, since the validity of the bounds test, first relies 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 to test 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.

5.4.2. 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 on hand and research purposes. Studies like Clark and MacDonald (1999), Ricci et al. (2013), Zhang and MacDonald (2014), Tipoy et al. (2017), Comunale (2019)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. In our study, in order to reduce the number of parameters to estimate, we were parsimonious in the number of control variables, selecting two, one related with trade flows (terms of trade), and another 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 both months of 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 is the case of the real interest rates, or in logarithms, as for the remaining variables. The observations are obtained on a consistent basis from several sources, with their definitions and sources being given 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. We retrieved the data from the Economic Policy Uncertainty webpage (www.policyuncertainty.com), for the maximum sample period available (1998 to 2020) and at a monthly frequency. . It is expected that an increase in this index will depreciate the currency, as explained above and taking into account that as Backer et al. (2016) have shown that an increase in the index is associated, in general, with a decline in economic performance.

Real effective exchange rate:*LNREER*
This variable 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 it 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 and corresponds to the ratio of the price of exportable goods and services to the price of importable good and services (2013=100). The reference group are the seven most important partners of the UK. 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 of domestic goods) dominates the substitution effect (the rise in the relative price of exports leads to a decline in the demand of domestic goods) a positive impact occurs, as 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. The domestic real interest rate, r, is a variable defined as in Clark and MacDonald (2004), computed as the difference between the UK average nominal long-term government bond yield minus the changes in the CPI. The foreign real interest rates 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) show that by starting from the uncovered interest parity (UIP) condition, which states that the difference in the nominal interest rates between two countries will equal the relative expected change in exchange rate. They get that real interest rate differentials have a positive effect on the real exchange rate by using the following equation $q_t = E_t(q_{t+k}) + (r_t - r_t^*) + e_t$, 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, e_t is the error term.

Following the data description above and equation (5.2), the ARDL model can be represented as follows:

$$\begin{aligned}\Delta LNREER_t = \beta_0 + \beta_1 T + \sum_{i=1}^{p} \phi_i \Delta LNREER_{t-i} + \sum_{i=0}^{q} \phi_j \Delta LNEPU_{t-i} + \\ + \sum_{i=0}^{r} \phi_k \Delta LNTOT_{t-i} + \sum_{i=0}^{s} \phi_l \Delta RIR_{t-i} + \gamma_1 LNREER_{t-1} + \gamma_2 LNEPU_{t-1} \\ + \gamma_3 LNTOT_{t-1} + \gamma_4 RIR_{t-1} + \upsilon_t \qquad (5.3)\end{aligned}$$

where β_0 is the intercept, and β_1 is the trend coefficient; p, q, r, s being the chosen lag lengths of the variables, Δ represents the difference operator; $\phi_(i, ..., l)$ are the short-run effects captured by the coefficients of the first difference variables (error correction dynamic); $\gamma_i (i = 1, ..., 4)$ are the long-run coefficients and υ_t the white noise.

The F statistics are applied to check for the existence of long-run relation where the null hypothesis H_0 is denoted by $F_{LNREER}(LNREER \mid LNEPU, LNTOT, RIR)$. The decision of rejecting the null hypothesis or not is framed in this study as follows if F_{LNREER} >critical upper bound, reject the H_0, meaning that the variables are cointegrated and if F_{LNREER} < critical lower bound, then the variables are not cointegrated.

5.5. Empirical analysis and discussion

To understand what drives exchange rates co-movement and the evolution of the real effective exchange rate, checking for correlations is relevant. In Appendix B.5-1, we present the descriptive statistics and the plots of the variables under consideration in this study. The correlation between variables is reported in following table:

Table 5-1. Correlation matrix between variables

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

Table 5-1 summarizes the analysis of the correlation between real effective exchange rates with regard to terms of trade, economic policy uncertainty and real interest rates. These results reveal a negative correlation between LNREER and LNEPU and LNTOT and a positive correlation with the RIR. A correlation coefficient of -0.62 between LNREER and LNEPU means that when economic policy uncertainty increases, the real effective exchange rate decreases. A negative correlation coefficient of -0.39 between LNREER and LNTOT can be seen as the depreciation of the exchange rate as terms of trades increases. An increase in the terms of trade it might be due to the increase in the economy exportation, as countries' exports increase, the demand for the home currency decreases. A positive correlation between the LNREER and the RIR may disclose that a higher real interest rate will increase the value of the UK's currency by 89%.

Two of the correlation signs were expected: LNEPU is negatively correlated with the LNREER, and the RIR is positively correlated and with the highest coefficient. The negative relationship between the LNTOT and the LNREER was not totally expected, but it can be explained by the dominance of the substitution effect.

5.5.1. Unit root tests

To ensure that the model does not crash in the presence of integrated stochastic trend of I (2), we employ the unit root tests and the stationarity test first, to identify the number of unit roots and second, to check for nonstationarity in the series under consideration. The ADF test, (Dickey Fuller (1979)), and the PP test, (Phillip and Perron (1988)) were conducted for all variables in levels and their first differences (including an intercept only, or intercept and trend or none) to test the null hypothesis $H_o : y_t$ has a unit root against the alternative hypothesis $H_1 : y_t$ has no unit root. The KPSS stationarity test (Kwiatkowski-Phillips-Schmidt-Shin (1992)) was employed for all the variables expressed in levels (intercept, intercept and trend or none cases) to test the null and alternative hypotheses $H_o : y_t$ is stationary against $H_1 : y_t$ is not stationary. Table 5-2 presents the results of the three above mentioned tests. As we can note in this table, the tests were also employed for all the variables expressed in first differences to ensure that the variables which were nonstationary in levels would be I (1).

TABLE 5-2. ADF, PP unit root tests and KPSS stationarity test for model variables in levels and in their first differences

Test	LNREER	LNEPU	LNTOT	RIR
		Intercept		
ADF test	-1.136699 [0]	-3.081310*[2]	-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)	(0.001)	(0.0000)	(0.4594)
KPSS test	1.700521	1.071649	1.045927	1.828222
		Intercept and trend		
ADF test	-2.106267 [0]	-4.727480*[1]	-6.805235 *[0]	-2.991902 [1]
	(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[a]	0.219333	0.079918[a]
		None		
ADF test	-1.169906 [0]	-0.189678 [2]	-1.123336[4]	-1.846281[1]
	(0.2209)	(0.6171)	(0.2374)	(0.0619)
PP test	-1.103351	-0.091195	-3.079344*	-1.865565
	(0.2447)	(0.6514)	(0.0022)	(0.0593)
	$\Delta LNREER$	Δ LNEPU	Δ LNTOT	ΔRIR
		Intercept		
ADF test	-14.97394* [0]	-16.11917* [1]	-13.22714* [3]	-13.37303* [0]
	(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[a]	0.058649[a]	0.458078[a]	0.035468[a]
		Intercept and trend		
ADF test	-14.94561* [0]	-16.09600* [1]	-13.37471*[3]	-13.35153* [0]
	(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[a]	0.044370[a]	0.124435[a]	0.030026[a]
		None		
ADF test	-14.93709* [0]	-16.14913* [1]	-13.24072*[3]	-13.34219* [0]
	(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. * denotes the rejection of the null hypothesis at the 5% significance level. Within the round parentheses are represented the p-values. Within the squared brackets the number of lagged dependent variables are represented. 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). [a] denotes the not rejection at 5% significance level of the stationarity hypothesis.

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

For the 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 ADF and the KPSS similar results, we can conclude that the 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 for the case of containing 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 an 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.

Pesaran et al. (2001) suggest that the ARDL model can be regarded as the equal number of lag length for all variables or different orders of lag without affecting the asymptotic distribution of the test statistic. Similar to the VAR approach described in previous chapter, we choose the optimal lag length based on the Akaike Info Criterion (AIC).

5.5.2. ARDL bounds test and diagnostic tests

The values for the ARDL bounds test for the long-run relationship among the variables was presented in Pesaran et al. (2001) in table CI(ii) Case II: Restricted constant and no trend for k=3. A detailed table of the bounds values from the aforementioned reference can be founded in Appendix B.5-2. The absence of serial correlation is a key element in the ARDL bounds test, a condition fulfilled in by the present model(see the Breusch-Godfrey Serial Correlation LM Test in table 5-4, Panel C). The results of the bounds test are presented in table 5-3. According to the results in table 5-3, the calculated F-statistic value 4.61 is above the I (1) table critical values value for 5% confidence intervals, thus indicating the existence of cointegration between UK REER and its determinants.

TABLE 5-3. ARDL bounds test Lags (2, 0, 9 0)

$F_{LNREER}(LNREER \mid LNEPU, LNTOT, RIR)$

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

Further diagnostic tests are in Panel C of table 5-4: the Ramsey's RESET test, the Jacque-Bera normality test, and the ARCH test. The model has a correct functional form, but residuals are not normally distributed and are heteroskedastic. The fact that the error term does not follow a normal distribution does not represent a major issue for the validation of the model under analysis, because the OLS estimation does not require this condition to produce unbiased estimates with the minimum variance. The large number of observations used (261) ensured by the Central Limit Theorem that the distribution of disturbance term will approximate normality. Also the existence of heteroskedasticity does not compromises the unbiasedness of the OLS estimators, but requires the HAC (Newey-West) correction of the covariance matrix. Newey and West (1987) argue that it is possible to account for both heteroskedasticity 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 5-2. Miller (1982) states that 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.

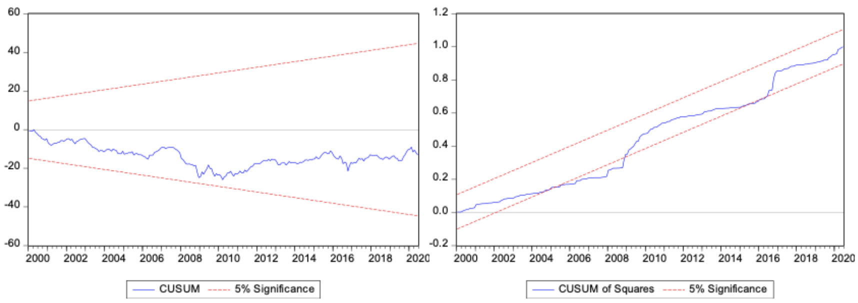


FIG. 5-2. Plot of CUSUM test and CUSUM of squares test for equation (5.3)

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. On the right-hand side, the CUSUMSQ is plotted, from which we can observe a structural change occurred from 2005 to 2009, but it is reverted latter on.

5.5.3. Long-run and short-run ARDL results

Now, we assess the short-term and long-term dynamics of the model. The error correction form of the ARDL model is presented in Table 5.4: the short-run coefficient estimates are in Panel A, and the long-run estimates coefficient in panel B.

TABLE 5-4. Short-run, long-run ARDL cointegration model in equation (5.3) and diagnostic tests

	Coefficient	Std.Error	t-Statistic
	Panel A. Short-run coefficient estimates		
$\Delta LNREER_{t-1}$	0.120**	0.059	2.016
$\Delta LNTOT_{t}$	0.007	0.033	0.227
$\Delta LNTOT_{t-1}$	-0.096***	0.037	-2.606
$\Delta LNTOT_{t-2}$	-0.016	0.040	-0.412
$\Delta LNTOT_{t-3}$	-0.117***	0.043	-2.664
$\Delta LNTOT_{t-4}$	-0.026	0.045	-0.587
$\Delta LNTOT_{t-5}$	-0.031	0.044	-0.722
$\Delta LNTOT_{t-6}$	0.023	0.042	0.559
$\Delta LNTOT_{t-7}$	-0.017	0.040	-0.433
$\Delta LNTOT_{t-8}$	-0.094***	0.037	-2.517
ECT_{t-1}	-0.061***	0.013	-4.683
	Panel B. Long-run coefficient estimates		
$LNEPU_{t}$	-0.133***	0.046	-2.872
$LNTOT_{t}$	0.475	0.799	0.594
RIR_{t}	0.033***	0.013	2.470
C	5.320**	0.242	21.953
	Panel C. Diagnostic tests		
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, the long-run relationship is represented. The LNEPU and RIR have the expected sign and their coefficients are statistically significant at 1%. The LNTOT do not affect the exchange rate in the long-run. The economic policy uncertainty coefficient is showing a negative sign, meaning 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%. $((1.01^{(-0.133)} - 1) * 100)$. 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 shows a monthly speed of adjustment of 6% toward the long-run equilibrium. That value at first sight looks small, but since we are using monthly data, the annual correction is significant (72%=6%*12).

As show in figure 5-3, the deviations of the real exchange rate from its equilibrium value tend to be relatively temporary.

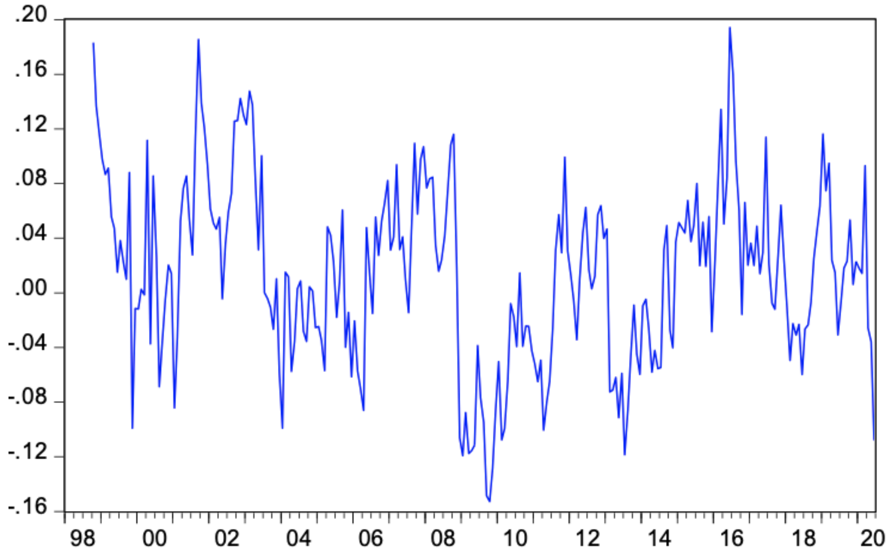


FIG. 5-3. Cointegration relationship representation

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 the terms of trade although not significant on the long-run, appear as 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 p.p., the change in the real exchange rate reduces 0.09 pp. after one month. If the change 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. [2] 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 an worsening of the trade balance. The adjusted R^2 of 98% suggest a very good explanatory power of the model.

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

5.6. Concluding remarks

This chapter 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 researched 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 was already performed as well, and we contribute to this debate by using both long-run and short-run perspectives, and studying a country that has been through periods of relatively low and very high uncertainty, as 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 existence of variables integrated of order one and zero. The model confirmed the existence of cointegration between the variables, and the EPU has an important role in the long-run, depreciating the exchange rate. However, no role was found in the short-run, something surely deserving further investigation. Interestingly, the oscillations in uncertainty did not cause structural breaks in the exchange rate relationship.

Our evidence suggests that EPU has significant 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, giving time for economic agents to adapt. Additionally, we found that the velocity of adjustment towards equilibrium in one-year horizon is quite good (72%). Anyway, huge swings in uncertainty may create large exchange rate fluctuations, with significant adjustment costs in foreign trade and investment. This urges 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, have a low explanatory power for the high observed exchange rate volatility. The literature has advanced explanations such irrational expectations, bubbles, omission of volatile fundamentals, or the "Peso" problem. This issue relates to the probability of occurring significant events, which are rare and difficult to measure. Regarding the "Peso" problem and the omission of fundamentals, this paper reinforces the idea that economic policy uncertainty may have an important role in exchange rate dynamics.

CHAPTER 6

Does Economic Policy Uncertainty impact inflation? Evidence from the UK

6.1. Introduction

This study investigates the effect of the economic policy uncertainty on inflation in the UK over the years from 1998 to 2020 by using a VAR framework. Three facts are put forward to support the research undertaken in this chapter. First, there is a lack of studies on the effect of policy uncertainty on inflation in developed markets. Second, there has been less previous evidence about the relationship between inflation and economic policy uncertainty in the UK. Third, whereas to the best of our knowledge, there is no published study that investigates a combination of inflation, unemployment, real effective exchange rate and economic policy uncertainty for the UK. This study aims to share new understandings on the link between economic performance and policy uncertainty in the study of inflation behaviour.While we have rather slight to add to the literature on theories of inflation, we consider that one link, in particular is especially relevant for such theories, namely the correlation between the Phillips curve and economic policy uncertainty. We develop a function of inflation, unemployment, economic policy uncertainty and real effective exchange rate, by applying one model that is useful to capture and describe dynamics between economic times series and which is available to draw conclusion for the variables integrated of the same order, the VAR model. This chapter begins with a short review of the literature regarding inflation and economic policy uncertainty. The data is introduced in Section 6.3 while in Section 6.4 the empirical results are presented. The impulse response analysis is conducted throughout Section 6.5, while Section 6.6 provides concluding remarks.

6.2. Economic Policy Uncertainty and inflation

The Phillips curve is a durable concept in economics which posited a simple relationship between wage growth and unemployment. A.W. Phillips (1958) published a paper in which he showed, using British data, that annual wage inflation and unemployment rates for the period 1861 to 1957 demonstrates a consistent inverse relationship as when unemployment was high, wages increased slowly, and the years of low unemployment rates were years of rising wages. This trade-off relationship became known as the Phillips curve hypothesis formulated as follows: rate of change of money wage rates can be explained by the level of unemployment and the rate of change of unemployment.

The hypothesis is likely to hold if monetary policy is set with the goal of minimising welfare losses and the Central Bank seeks to increase inflation when output is below potential. The relationship between inflation and unemployment is probably one of the most important ones that is explored in macroeconomics studies and in the literature we can find different theoretical and empirical methods of studying this relationship. Although the policymakers want to deliver both low unemployment and low inflation, according to the Phillips curve, the economy operates in such a way that when unemployment falls, inflation tends to go up and when inflation roses, unemployment goes down. The policymakers might be confronted to a choice between prioritising inflation or unemployment. Beggs (2015) states that the remedy for inflation is symmetrical to the remedy for unemployment. The only problems concern the accuracy of policymakers' projections, and the strength and dexterity of the policy instruments.

However, the empirical models explaining inflation in the Phillips curve literature generally fail to account economic policy uncertainty variables affecting inflation. One reason it could be that the economic policy uncertainty is considered as a variable that is quite hard to measure in a way which can be used in econometric work.

Aisen and Veiga (2006) argue that politically unstable countries are often susceptible to political shocks, which lead to discontinuous monetary and fiscal policies and high inflation volatility. It has been suggested that political instability increases policy uncertainty, which has negative effects on productive economic decisions and that the impact of political instability on inflation is much stronger for high inflation economies than for moderate and low inflation ones.

The perspective we offer about the link between economic policy uncertainty and inflation is based on the notion that uncertainty brings both demand and supply effects. Economic policy uncertainty shock affecting the economic activity can be seen as a negative shock on inflation because more uncertainty will be harmful to the economic performance. Indeed, on the demand side, if an uncertainty shock occurs, we can expect a decline in inflation, a rise in unemployment, and at the same time, consumption will contract since the uncertainty will trigger high motives to save. Higher policy uncertainty reduces inflation expectations (Liu et al., 2019), thus leading to lower inflation. Leduc and Liu (2016) studying the channel through which uncertainty affects aggregate economic activity conclude that increases in uncertainty are seen as aggregate demand shock because it increases unemployment and lowers inflation. While Easterly and Fischer (2001) state that from an economic perspective, the periods of price stability are always marked by order and harmony into a country, Bloom (2014) finds that high uncertainty leads to a decline in economic activity. Our basic intuition is that if economic policy uncertainty occurs uncertainty accumulates. In the supply side, we would expect a reduced output and from the Phillips Curve perspective more inflation and higher unemployment. Political uncertainty may difficult the production process and increase the cost of production, thus leading to higher inflation. Economic feasible outcomes could be limited by the economic policy uncertainty shocks.

Colombo (2013) investigating the effects of the US economic policy uncertainty indicator on the consumer price index using Structural VAR finds that the consumer price index is statistically significant suggesting a decline in production and a deflationary phase after uncertainty shock. Jones and Olson (2013) estimating monthly data by using dynamic conditional correlation (DCC) GARCH model analyse the correlation between macroeconomic uncertainty, inflation, and output. They found that the correlation between inflation and uncertainty turns from negative to positive during the late 1990s and early 2000s. Istrefi and Piloiu (2014) estimate a structural Bayesian VAR to study the link between economic policy uncertainty and inflation expectations for the US and for the euro area. Their result highlights that a shock in policy uncertainty will decrease the short-run inflation expectation while will increase long-run inflation.

Liu et al. (2019) using a mixed-frequency VAR (MF-VAR) approach when studying the impact of economic policy uncertainty shocks on inflation expectations in China found that inflation expectations are sensitive to policy-related uncertainty shocks. Their study concluded that uncertainty shocks generate rise in the inflation expectation in China. A recent study of Ghosh et al.(2020) analyses the macroeconomic factors such as output, monetary policy, and exchange rate, among the economic policy uncertainty in the determination of the inflation expectation in India. By using a Bayesian structural with exogenous variables (VAR-X) model concluded that an economic policy uncertainty shock leads to an increase in inflation expectation.

Selmi et al. (2020) studying the effects of the US EPU index on inflation prior to and post Trump's win based on a flexible copula-based with Markov-switching regime approach, find that economic policy uncertainties seem important for the observed changes in inflation. They showed that the period post Trump's inauguration displayed more inflation in comparison to the period prior to Trump's win.

Caggiano et al. (2017) analyse the effect of the US EPU on unemployment in recessions and expansions patterns in the economic activities using Smooth Transition VAR model. They found that the response of unemployment to EPU is higher in contraction periods that in expansionary periods.

Erer and Erer (2020) using a threshold VAR in analysing the effects of the US EPU on macroeconomic variables such as industrial production index, inflation, interbank rate and exchange rate for Turkey and BRICS economies, found that inflation and real effective exchange rate in Turkey, Russia and China respond more significantly to a shock in US EPU.

Together, the previous findings confirm that there is a link between economic policy uncertainty and inflation, but the extent to which it is possible to generalize about the increase or the decrease of inflation rate due to economic policy uncertainty shock is unknown.

6.3. Data

The purpose of this study is to test the hypothesis that economic policy uncertainty affects the inflation rate. We use VAR model to capture the existing dynamic relationship between economic policy uncertainty and economic activity. In the VAR model, we include four variables: economic policy uncertainty index (LNEPU), unemployment rate (UN), inflation rate (INF) and real effective exchange rate (LNREER). The inclusion of these four variables in the model is due to the fact that they are assumed to significantly affect the fluctuations in inflation. In these specifications, whereas the economic policy uncertainty index and the exchange rate are expressed in levels, the inflation rate and the unemployment rate are expressed in percentage. All the variables entering model are transformed using first differences due to their nonstationarity – see next section for details. The data considered in the VAR model under analysis comprises the time interval between January 1998 to September 2020 with monthly frequency. The choice of this period was determined by the availability of the EPU index. In the following we will define each variable and in figures we plot their evolution under the analysed period.

Economic policy uncertainty index: $LNEPU$

The EPU index incorporates uncertainty about different types of policies altogether, like fiscal, monetary, financial or any other type of regulatory policies. For EPU index, we retrieved the data from the Economic Policy Uncertainty webpage, monthly data for a sample period between 1998 and 2020.

Source: www.policyuncertainty.com

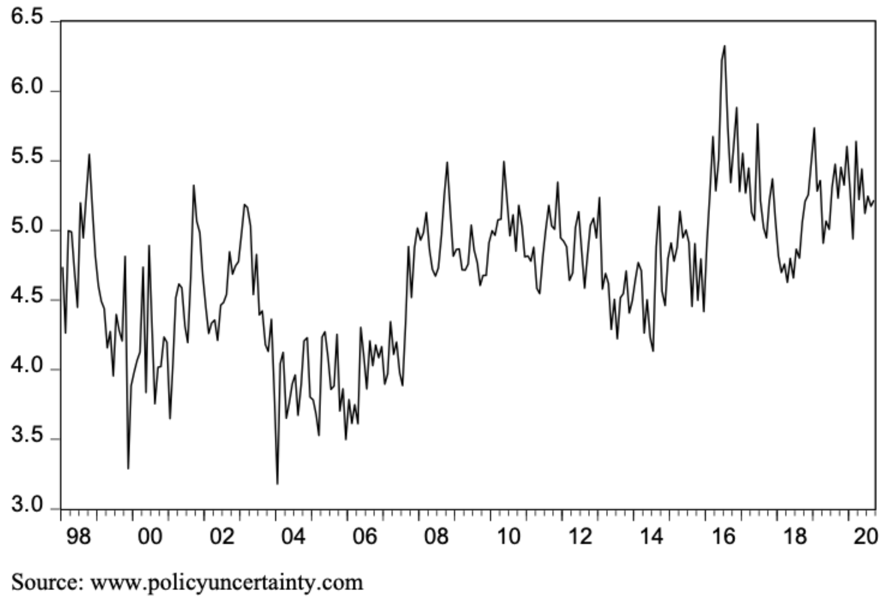


Fig. 6-1. Plot of the UK economic policy uncertainty index (1998M01-2020M08)

This series is an index, and its development reveals higher values of up to about 6.30 in July 2016, reflecting the results of the UK voting to leave the EU. The index current value is about 5.21.

Real effective exchange rate:*LNREER*
The variable is based on comparing multilateral consumer price index CPI- based. The weights are based on UK trades in the 2014-16 period, with 2010 as the indices' base year. REER is the weighted averages of bilateral exchange rates adjusted by relative consumer prices, and it calculates the number of units of foreign good that will pay for 100 units of equivalent domestic good where the weighting pattern is time varying.
Source: Bank of England, REER 2019: (2010 = 100)

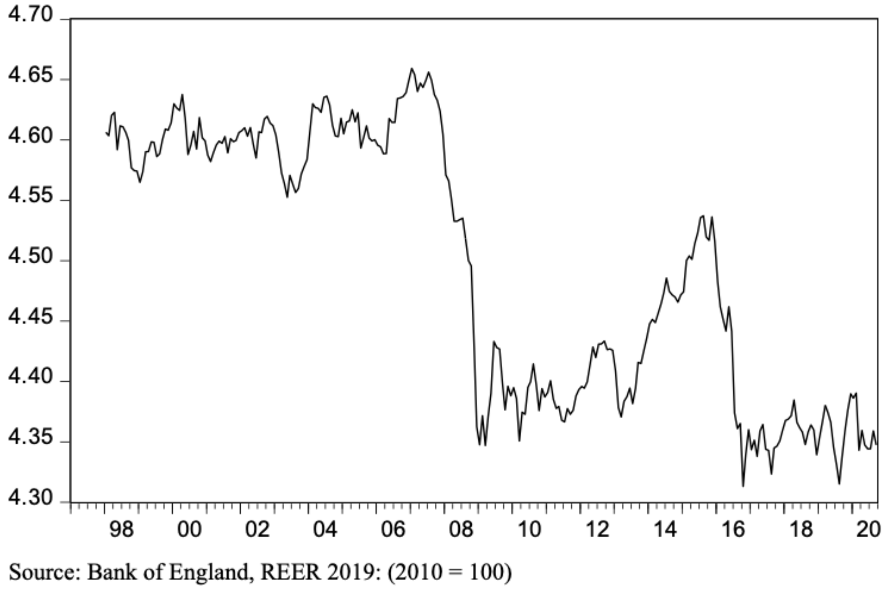


Fig. 6-2. Plot of the UK real effective exchange rate (1998M01-2020M08)

Between 1998 and 2006 the value of the pound rounded in average at 4.6 (this is the log of the index). From 2007 till the end of 2008, it shows a fast decay toward a level of 4.3. From 2009 to 2012 no clear trend can be observed, but shorter trend up and down irregular motions are observed after 2013. In 2016, the sterling pound it seems to increase to about a value of 4.3. After 2016, its value decreases and from there on its it was kept almost constant with a very small variation. Currently the real effective exchange rate value is about 4.3.

Inflation rate:*INF*
The UK rate of inflation (derived from the UK consumer price index) is the change in prices for goods and services over time. The time series expresses the inflation as percentage change relative to 2015, when the index is given a value of 100.
Source: Office for National Statistics, Inflation:2019 (2015=100)

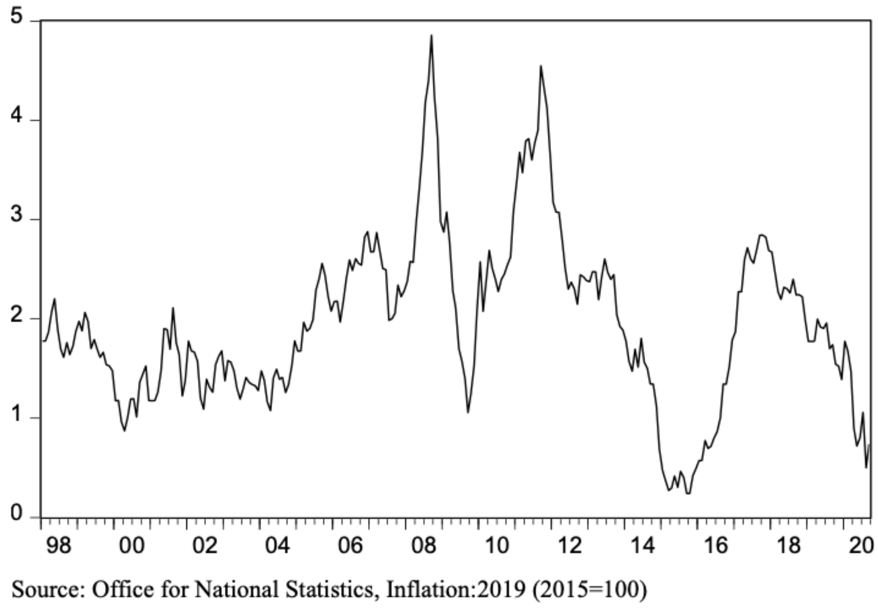


Fig. 6-3. Plot of the UK inflation rate (1998M01-2020M08)

The series reached its maximum at the end of the 2008 (at about 4.8 percent) and its minimum at the end of 2015 at about 0.2 percent. There are two pronounced peaks in its evolution, in September 2008, value that can be linked to the time preceding the 2008 Global financial crisis (characterized by high inflation on commodities). After the 2016 Brexit vote, the inflation rose for about 0.5 percent in January 2017, from about 1.8 percent to 2.3 percent. Currently, the value of the UK inflation is around 0.6 percent.

Unemployment rate: *UN*
The UK employment rate is the proportion of people aged between 16 and 64 years who are in paid work. In the UK, unemployment measures the number of people without a job who have been actively seeking work within the last four weeks and are available to start work within the next two weeks. It is the proportion of the economically active population (those in work plus those seeking and available to work) who are unemployed. It is expressed in percent.
Source: Office for National Statistics, Unemployment rate (aged 16 and over, seasonally adjusted): 2019

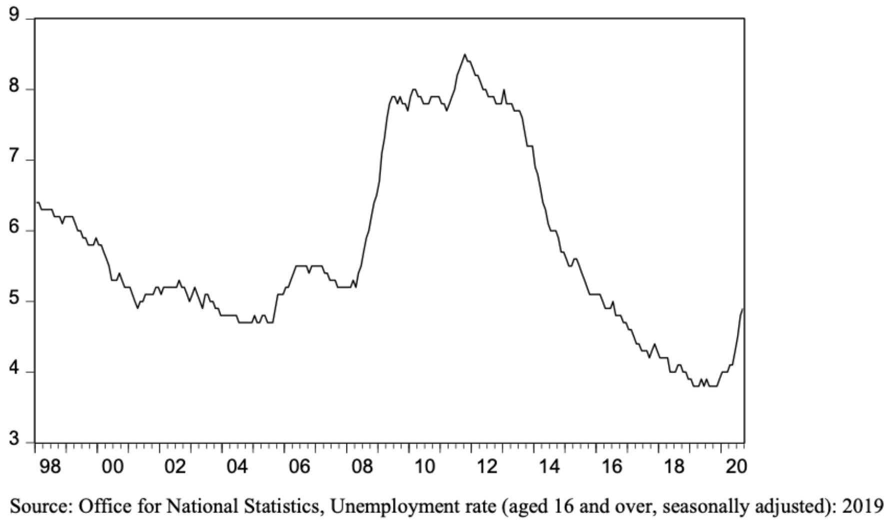


Fig. 6-4. Plot of the UK unemployment rate (1998M01-2020M08)

As we can observe the rate of unemployment ranges from 3.8 percent in the end of 2019 to 8.5 percent in end of 2011.

The discussion of the VAR methodology already described in Chapter 4, aims to provide answer to whether we can account for changes in inflation due to policy uncertainty shocks, and it focuses on issues relating to impulse response analysis. In the following section we are going to analyse the time series and the results obtained from the VAR model estimation.

6.4. Empirical Results

6.4.1. Unit root and stationarity tests

The first step in order to carry out our analysis is to test for stationarity in the four time series. For the VAR model to be feasible, all variables need to be stationary (I (0)) or first difference stationary (I (1)). To examine the nonstationarity of the variables, both ADF and PP unit root tests are conducted, while for the stationary we conducted the KPSS test. Results from unit root and stationarity tests for the levels and the first differences of the variables are shown in tables 6-1 and 6-2.

TABLE 6-1. Test statistic representation of the ADF and PP unit root tests

	ADF unit root test		PP unit root test	
Variable	Level	Δ	Level	Δ
	Intercept Trend and Intercept None	Intercept Trend and Intercept None	Intercept Trend and Intercept None	Intercept Trend and Intercept None
	-2.4161	-13.7592***	-2.5217	-13.8564***
INF	-2.3801	-13.7517***	-2.4845	-13.8487***
	-1.1616	-13.7812***	-1.1946	-13.8782***
	-0.9787	-14.6356***	-1.1495	-14.6356***
LNREER	-2.1148	-14.6120***	-2.4001	-14.6121***
	-1.0457	-14.6127***	-0.9466	-14.6140***
	-3.0802***	-16.2096***	-4.6758***	-29.6739***
LNEPU	-4.7524***	-16.1858***	-6.4059***	-29.6573***
	-0.1890	-16.2391***	-0.0450	-29.7039***
	-1.1939	-6.9324***	-1.1907	-12.7221***
UN	-1.2018	-6.9166***	-1.2068	-12.7044***
	-0.5759	-6.9408***	-0.7267	-12.7229***

Note: 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 model with both intercept and trend. The ADF, PP critical value at 5% significance level is -1.941 for the model without intercept and trend. The ADF test lag lengths were selected automatically based on the SIC criteria. * denotes the rejection of the null hypothesis at the 10% significance level. ** denotes the rejection of the null hypothesis at the 5% significance level. *** denotes the rejection of the null hypothesis at the 1% significance level.

TABLE 6-2. Test statistic of the KPSS stationarity test

	Level		Critical values	Δ	
	Intercept Trend and Intercept	Stationary decision		Intercept Trend and Intercept	Stationary decision
INF	0.2117*	Yes	0.463	0.0673*	Yes
	0.2100	No	0.146	0.0366*	Yes
LNREER	1.4539	No	0.463	0.0558*	Yes
	0.1075*	Yes	0.146	0.0513*	Yes
LNEPU	1.0374	No	0.463	0.0614*	Yes
	0.1234*	Yes	0.146	0.0427*	Yes
UN	0.2967*	Yes	0.463	0.1751*	Yes
	0.2999	No	0.146	0.1705*	Yes

Note: 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. * denotes the not rejection at 5% significance level of the stationarity hypothesis. The critical values according to Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

The ADF, PP and KPSS test results reveal that three variables under analysis, INF, UN and LNREER are nonstationary in levels. For INF the ADF and PP test showed that the variable is nonstationary at levels for all three possible test cases, only trend, trend and intercept, none; but the KPSS points to the stationarity of the variable in the case of the inclusion of the trend. Based on the three tests, we can conclude that, when we include both trend and intercept, the variable expressed in levels is nonstationary.

Based on the ADF and the PP test, both variable, LNREER and UN are nonstationary in levels in all three cases. The KPSS assigns stationarity in their value when in the LNREER analysis we consider trend and intercept and when in the UN we consider only intercept. On behalf of these tests results, we can conclude that LNREER and UN are nonstationary when expressed in level.

When counting for trend and intercept,in the unit root and stationarity analysis, of EPU we can conclude that the variable is stationary in levels. However, the ADF test, the PP test and KPSS test confirm all time series are stationary after taking the first difference.

6.4.2. VAR model

To study our question of interest we employ a VAR model with its full representation accessible in Chapter 4. Therefore, we fit a VAR model to the UK monthly data from 1998M01 to 2020M09. All of the times series entering the VAR analysis are computed in their first differences. Although the EPU is stationary in levels, when including both trend and intercept, for coherence with the other variables, we have used all the variables in their first differences. The VAR model also includes a constant.

Lag length determination

VAR models were estimated to include the number of lags from 1 until 12. Since the lag-length p is not derived from theory, we need to determine it by comparing different specifications. We compute selection order criteria, summarized in table 6-3 to gauge whether we have included sufficient lags in VAR estimation. Introducing too many lags wastes degrees of freedom, while fewer lags are likely to cause autocorrelation in the residuals and to drive to misspecification of the model. A VAR with autocorrelated residuals it might suggest that is there was some information which was not accounted by the model. The Schwarz information criterion (SIC) indicates a lag structure of $p = 1$. However, the Akaike information criterion (AIC) and the final prediction error (FPE) indicate a structure of lag where $p = 2$ and the sequential modified LR test statistic indicates a lag $p = 12$. The optimal number of lags, two suggested by the AIC criterion will be consider further considered in our VAR estimation.

TABLE 6-3. Lag length selection in VAR model

Lag	LogL	LR	FPE	AIC	SC
0	900.4098	NA	1.19e-08	-6.895460	-6.840681
1	949.3456	95.98938	9.23e-09	-7.148812	-6.874914*
2	973.8356	47.28458	8.65e-09*	-7.214120*	-6.721103
3	985.6697	22.48479	8.94e-09	-7.182075	-6.469939
4	995.9368	19.19149	9.34e-09	-7.137975	-6.206720
5	1005.958	18.42274	9.79e-09	-7.091981	-5.941607
6	1016.195	18.50587	1.02e-08	-7.047652	-5.678159
7	1029.731	24.05321	1.05e-08	-7.028702	-5.440090
8	1042.291	21.93207	1.08e-08	-7.002242	-5.194511
9	1047.278	8.553684	1.17e-08	-6.917522	-4.890673
10	1056.256	15.12522	1.24e-08	-6.863510	-4.617542
11	1061.480	8.639877	1.35e-08	-6.780619	-4.315532
12	1086.553	40.69470*	1.27e-08	-6.850408	-4.166202

* indicates lag order selected by the criterion (each test at 5% level) LR: sequential modified LR test statistic, FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion

6.4.2.1. *Residuals analysis.* Once we estimate the VAR model with two lags, the next step is to determine if the selected model provides an adequate description of the data by examining the model residuals: autocorrelation, normality and heteroskedasticity. The plot of the residuals is presented in Appendix C.6-4a.

Autocorrelation among the residuals test results

The Lagrange Multiplier (LM) test is used to check residual autocorrelation in estimated VAR model. The null hypothesis of no residuals autocorrelation up to lag two is tested against of the alternative of autocorrelated residuals. Based on the obtained chi-square probabilities when compared to the table values (chi-square (16) = 26.30, table presented in Appendix A.4-1), we do not reject the null of no residuals autocorrelation and we conclude that the residuals are independent. The complete information related to the LM test results is presented in Appendix C.6-4b.

Normality of the residuals test results

Two commonly used shape statistics are the skewness and the kurtosis. Skewness as a measure of the symmetry of distribution (skewness less than zero, means left tail and skewness more than zero means right tail) and kurtosis as the representation of outliers (distributions with kurtosis larger than 3 tend to have heavy tails indicating more variability due to extreme deviations, a larger number of outliers, whereas a smaller kurtosis coefficient indicates broader thinner tails). The symmetry is tested against the alternative of an asymmetric distribution and the kurtosis of 3 is tested against the alternative of a father/thinner tails distribution. The Jarque-Bera tests jointly consider both implication of skewness and kurtosis under the null hypothesis of normality against the alternative of non-normality of the residuals.

Table 6-4 and Appendix C.6-4c relate the normality test of Jarque-Bera for the VAR residuals based on the skewness statistic, kurtosis statistics and the joint test statistics. Based on skewness and kurtosis values, the VAR Residual Normality Test rejects the normality distribution of the residuals. The Jarque-Bera test, as a joint test of both, also fails to accept the null hypothesis of normality of the residuals.

There are few consequences associated with a violation of the normality assumption, as it does not contribute to bias or inefficiency in regression models. It is only important for the calculation of p-values for significance testing, but this is only a consideration when the sample size is very small. When the sample size is sufficiently large (>200), the normality assumption is not needed at all as the Central Limit Theorem ensures that the distribution of disturbance term will approximate normality.

TABLE 6-4. Normality test of the VAR (2) residuals

Residuals test	Skewness	Kurtosis	Normality (Cholesky covariance) Jarque-Bera
p value	0.0002	0.0000	0.0000
Decision	Reject the null	Reject the null	Reject the null

Heteroskedasticity test results

The ARCH LM heteroskedasticity test is applied testing the null hypothesis of constant variance against the alternative of not constant variance. The result of the test is presented in table 6-5 in terms of the chi-sq and p-value. Entire test representation can be founded in Appendix C.6-4d.

TABLE 6-5. Heteroskedasticity test VAR (2) residuals

Residuals Test	Heteroskedasticity test (no cross term) Chi-sq
χ^2	2408.7
p value	0.4465
Decision	Do not reject the null

In the heteroskedasticity test, the result reveals that the null hypothesis cannot be rejected, we conclude that the residuals have constant variance.

Therefore, based on the lag length selection and residuals tests we proceed with the analysis of the VAR(2) model with all the variables expressed in their first differences. The outcome of the estimated VAR model is fully represented in Appendix C.6-5a.

6.4.3. Determining cointegration in the VAR model

Recall, we want to determine if there exists cointegration relationship in our model and therefore perform Johansen Test, approach proposed by Johansen (1988). The Johansen cointegration test contains the variables in their levels (please see Chapter 4, section 4.1

for further rationalisations). Its results exposed in table 6-6 reveal that both, trace and maximum eigenvalue tests yield the same results, namely that there is no cointegration among variables under analysis.

TABLE 6-6. Johansen Cointegration Test with two lags

	Trace test		Maximum Eigenvalue test	
	Trace statistics	Probability	Maximum Eigenvalue Statistics	Probability
Hypothesized No. of CE(s)				
1) No intercept and trend in CE or test VAR				
None	18.19174	0.2410	14.67163	0.1390
At most 1	3.520113	0.7788	2.016408	0.9211
At most 2	1.503705	0.2581	1.503705	0.2581
2) Intercept (no trend) in CE- no intercept in VAR				
None	19.63024	0.7496	14.67406	0.4023
At most 1	4.956178	0.9824	3.062293	0.9896
At most 2	1.893885	0.7987	1.893885	0.7987
3) Intercept (no trend) in CE and test VAR				
None	18.18068	0.5527	14.67353	0.3124
At most 1	3.507147	0.9392	2.603475	0.9696
At most 2	0.903672	0.3418	0.903672	0.3418
4)Intercept and trend in CE-no intercept in VAR				
None	25.43717	0.7674	15.26301	0.6108
At most 1	10.17416	0.9173	8.128615	0.8099
At most 2	2.045545	0.9658	2.045545	0.9658
5)Intercept and trend in CE-intercept in VAR				
None	25.14824	0.3750	15.17710	0.4823
At most 1	9.971140	0.4833	8.066532	0.5956
At most 2	1.904608	0.1676	1.904608	0.1676

Since we have found no cointegration relationship in the Johansen test, we turn to the analysis of the estimation results of the VAR model.

As stated in the introduction we are especially interested in the factors that causally determine the inflation rate. The results from the VAR estimation presented in Appendix C.6-5a, suggest that the actual inflation rate is influenced by one period lagged inflation rate, ΔINF(-1) and second lag of REER, ΔLNREER(-2).

As the Phillips curve argues that unemployment and inflation are inversely related, we would expect past unemployment to have a negative impact on inflation. Moreover, usually a lagged term of inflation appears in the Phillips curve, justified by the fact some agents fix prices using backward looking rules. The positive coefficient on ΔINF(-1) of 0.16 is in line with the fact some agents use past inflation to fix prices, although it can also result from the reduced form nature of the model. The negative coefficient on ΔUN(-1) of -0.10 (although not statistically significant) are in line with prior expectations regarding the inverse causality between inflation and unemployment. At the same time, our estimated model suggests that economic policy uncertainty has no statistically significant influence on inflation.

6.4.4. Granger Causality

VAR model describes the joint generation process of the variables over time and Granger causality is investigating relationships between the set of variables under analysis. However, Granger causality cannot be interpreted as a real causal relationship but merely, shows that one variable can help to predict the other. Bose et al. (2017) claim that Granger causality states that if the prediction of one time series is improved by incorporating the knowledge of a second time series, then the latter is said to have a causal influence on the first.

Therefore, the null hypothesis to be tested by Granger causality test is that: one variable has no explanatory power on the other variable against the alternative hypothesis of causality relationship. In the following we provide the results of the Granger causality tests that we have carried out for detecting causality both, using the VAR model with all variables in first differences (the VAR model we studied up to this point) and using a VAR model for each pair of variables in levels.

Table 6-7 summarizes the Granger causality (exogeneity test) results when first, the inflation is the dependent variable and second when the LNREER is the dependent variable. These results when the LNREER is the dependent variable are brought into light due to our two previous empirical thesis chapters.

TABLE 6-7. Granger Causality Test results

Dependent variable	Independent variable	χ^2	p value	Result
	Δ(UN)	0.522837	0.7700	UN does not Granger causes INF
Δ(INF)	Δ(LNEPU)	0.629823	0.7299	LNEPU does not Granger causes INF
	Δ(LNREER)	3.409563	0.1818	LNREER does not Granger causes INF
	Δ(INF)	7.951811	0.0188**	INF Granger causes LNREER
Δ(LNREER)	Δ(UN)	10.06993	0.0065*	UN Granger causes LNREER
	Δ(LNEPU)	5.566713	0.0618***	LNEPU Granger causes LNREER

Note: * denotes the rejection at 1% significance level. **denotes the rejection at 5% significance level. *** denotes the rejection at 10% significance level.

When INF is the dependent variable, the Granger causality test result, presented also in Appendix C.6-6a, appoints that the null hypothesis cannot be rejected at 5% significance level, thus no causal relationship is established between variables. However, when LNREER is the dependent variable, the null hypothesis of the Granger causalit test is rejected at 1% significance level for UN, at 5% significance level for INF and at 10% level for LNEPU.

The results of the Pairwise Granger causality test are presented in table 6-8 and show that we cannot account for any bidirectional causality between INF and LNEPU. The results also indicate that INF Granger causes UN, which could show that the regulation of inflation has implication for the control of unemployment (usually controlling inflation increases unemployment), but the unemployment does not Granger causes inflation, LNREER is Granger caused by LNEPU as we could find in the Granger causality using the complete VAR model of this chapter.

Table 6-8. Pairwise Granger Causality Test results

Null Hypothesis	Obs	F-Statistic	Prob.
LNREER does not Granger Cause LNEPU	271	3.40958	0.0345**
LNEPU does not Granger Cause LNREER		9.25071	0.0001*
UN does not Granger Cause LNEPU	271	0.39366	0.6750
LNEPU does not Granger Cause UN		0.57012	0.5661
INF does not Granger Cause LNEPU	271	0.36983	0.6912
LNEPU does not Granger Cause INF		0.25443	0.7755
UN does not Granger Cause LNREER	271	3.90807	0.0212**
LNREER does not Granger Cause UN		0.48048	0.6190
INF does not Granger Cause LNREER	271	0.95718	0.3853
LNREER does not Granger Cause INF		0.00681	0.9932
INF does not Granger Cause UN	271	7.16978	0.0009*
UN does not Granger Cause INF		0.04307	0.9579

Note: * denotes the rejection at 1% significance level. **denotes the rejection at 5% significance level. *** denotes the rejection at 10% significance level.

Based on the Granger causality tests that were carried out to show causal relationship among the variables, we can conclude that LNEPU does not Granger causes INF, no causal relationship could be established between these two time series, nor inside VAR model, neither outside VAR model.

Christiano (2012) states that the impulse response functions are useful to explain the structure of the economy. Therefore, in order to get an idea about the impact of EPU on inflation rate, unemployment rate and real effective exchange rate, we presented in the next section the impulse response analysis.

6.5. Impulse Response Analysis

The Impulse Response Function (IRF) traces the effect of one-standard deviation shock on one variable to current and future values of all variables. Thus, a perturbation in one innovation in the VAR system sets up a chain reaction over time in all variables. There are three principal procedures cited in most literature to obtain the confidence intervals: asymptotic, bootstrap and Monte Carlo. The confidence intervals based on the asymptotic normal distribution and on Monte Carlo cannot be applied in this model since we could not rely on the normality of the VAR residuals. Thus, the bootstrap method in generating confidence intervals of the impulse response functions of VAR is used.

The link between variables is analysed with the Cholesky decomposition which imposes an ordering of variables in the VAR system and attributes all of the effect of any common component to the variable that comes first in the VAR system. Ordering means placing all variables under analysis in the decreasing order of exogeneity. As ordering is somewhat arbitrary, our choice is based on prior findings in literature. Lopez and Mitchener (2020) found that increased uncertainty caused a rise in inflation contemporaneously and for a few months afterword in Germany, Austria, Poland and Hungary, but this effect was absent or much more limited for other European countries.

Thus, the order imposed in the Cholesky decomposition is as follows: inflation (INF), unemployment (UN), economic policy uncertainty (LNEPU) and real effective exchange rate (LNREER). We based this ordering criteria on the speed of reaction of the variables toward a shock.

When considering the Cholesky ordering, the question is whether the variables under analysis react in the same period to one uncertainty shock. Economic theory advises us that, due to price rigidities, inflation is slow responsive to external shocks and unemployment also reacts slowly to the economic cycle. The economic policy uncertainty can be considered an intermediate variable in terms of reaction time upon a shock while the real exchange rate, which is a market variable, may have immediate response to shocks, as it depends on the nominal exchange rate. In the literature it was also acknowledged that political institutions react more slowly upon a shock than financial markets, which are considered more sensitive to policy shocks.

Hence, we bootstrap the confidence intervals of the IRFs and evaluate their performance, where the two dashed lines in each panel depict the 95% confidence bands and the impulse responses are plotted over a 10-month horizon. The general pattern supports the hypothesis that an increase in economic policy uncertainty corresponds to an increase in inflation (not statistically significant), a decline in unemployment and a drop-in real effective exchange rate (the latter being statistically significant). On the link between the variables under analysis, we can agree that the economy is stimulated because under a policy uncertainty shock, the exchange rate depreciates (the demand for goods increases) while the unemployment decreases (there is a need of more jobs creation). The responses of macroeconomic variables in the UK to a shock in the UK EPU are represented in figure 6-5 and in Appendix C.6-7.

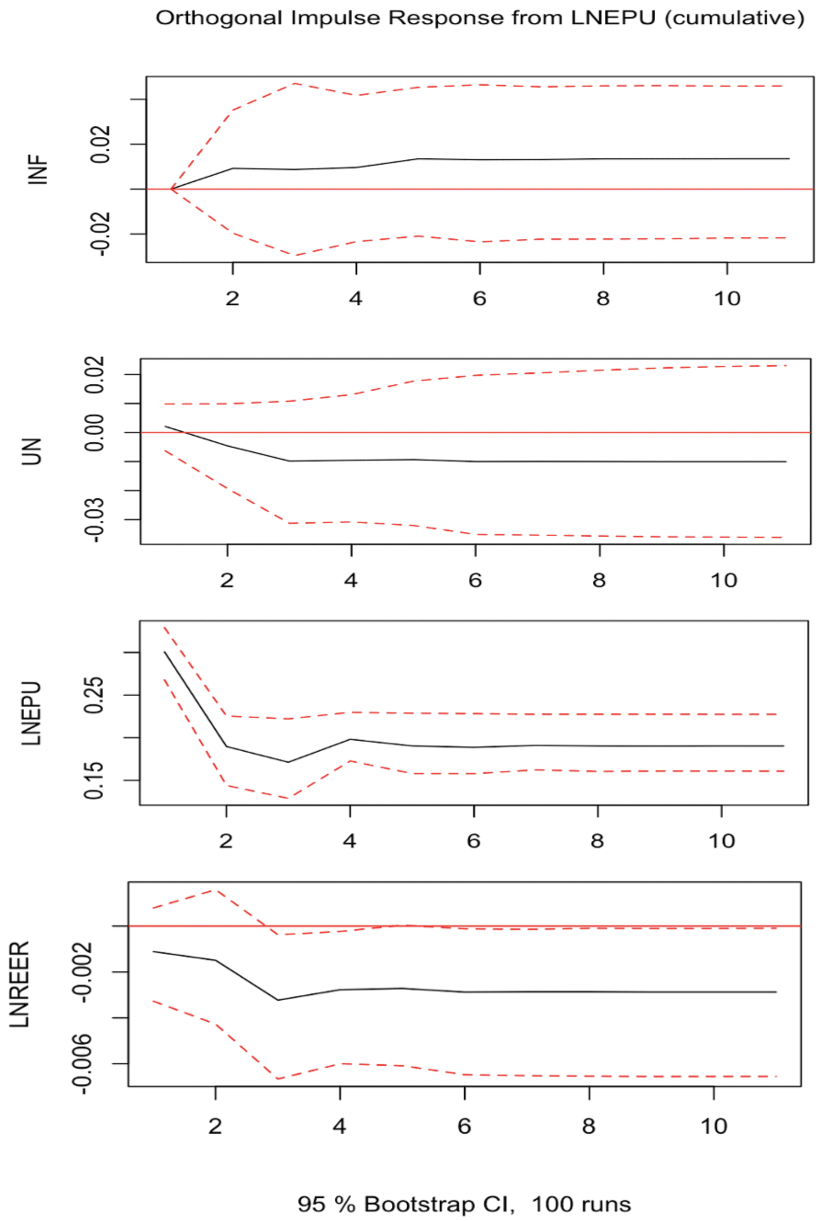


FIG. 6-5. IRFs of inflation rate, unemployment rate and real effective exchange rate to the UK EPU shocks

Thus, our empirical results support the view that uncertainty shocks lead to an increase in inflation in the contemporary month and in the following months the response of the inflation rate to a one-unit shock in the EPU index, increases for the first seven periods (months). Although, the inflation increases slowly, its response to EPU shock is mostly insignificant. Besides, a shock in EPU index, though also statistically insignificant, has decreasing effects on unemployment rate for about 3 months. These findings are in line with the theory about the Phillips curve, which trades off an increase in inflation rates for a decrease in unemployment rate. The results also suggest that the VAR model identifies that economic policy uncertainty shock results in a depreciation of the real effective exchange rate. This effect was also confirmed in our previous study of the present thesis, in Chapter 5 where we found that high economic policy uncertainty leads to currency depreciation.

6.6. Conclusion

This chapter considers the impact of uncertainty shocks on the UK economy, namely on inflation, unemployment and exchange rate. With the purpose of establishing a relation between the variables under analysis, we explore the relationship between uncertainty and economic activity in the UK using VAR analysis. Thus, we fit a VAR model to UK monthly data from 1998M01 to 2020M09. Our baseline VAR specification includes two lags of all variables. No cointegration among data was founded by the Johansen cointegration approach. We use Cholesky decomposition with the following order: inflation, unemployment, economic policy uncertainty and real effective exchange rate to recover orthogonal shocks.

The broad implication of the present research is that under economic policy uncertainty shock, the inflation and unemployment rate respond in accordance with the effects described by the economic theory and the Phillips curve, which emphasizes that there is a trade-off between inflation and unemployment. Moreover, we can observe that the economic policy uncertainty declines the value of the real effective exchange rate. Although in the IRF analysis the responses of the inflation and unemployment to a shock in economic policy uncertainty are statistically insignificant, the dynamics of inflation and unemployment seems to indicate some role for economic policy uncertainty in explaining those variables as established by previous findings of the studies by Caggiano et al. (2017), Selmi et al. (2020) and Ghosh et al. (2020).

Different countries' inflation is a theme discussed by numerous authors. While the findings in this paper are promising, it remains a challenge to apply such a VAR analysis to study the effect of the economic policy uncertainty on inflation in the UK. Thus, it could be of interest and of importance also to extend the analysis to other economies. The impulse response functions are in general consistent with the expected effects of economic policy uncertainty on real effective exchange rate. However, its effect on inflation in this study is mostly insignificant.

The present study could be viewed as a first step in the attempt to identify and study the link between inflation and economic policy uncertainty shocks in the UK. However, much work needs to be done to deal with the issues regarding this type of study.

CHAPTER 7

Conclusions

This thesis firstly emphasises the use of the political stability indicator and the economic policy uncertainty index in exchange rate modelling, where a VECM and an ARDL models are fitted to the data; and secondly investigates the effect of economic policy uncertainty on inflation rate in a VAR framework. Over a long-run time horizon, it establishes the link between the real effective exchange rate, its fundamentals, and the two previous mentioned indicators. In order to adjust to current economic challenges which occurred due to events such as referendum outcomes, high frequency government changes and political/policy crises, a broader understanding of the factors that are linked to real effective exchange rate and inflation rate behaviour is essential. Thus, in the introduction of this doctoral thesis, we very briefly overviewed each of the chapters; through the second and third chapter we introduce the concepts we work with and we describe the main measures used in empirical analyses; chapters four to six covered three empirical independent studies. In what follows, we present a brief summary of chapters and findings, limitations of the study, avenues of further research, and conclusions.

7.1. Summary of chapters and findings

Chapter 1, the Introduction, establishes the foundation of this thesis by highlighting the importance of instabilities and uncertainties in exchange rate behaviour amongst its macroeconomic fundamentals; sets out the methodological foundation, econometric methods and the empirical sequence of the three studies; and presents the two contributions of the thesis. Overall, it presents a comprehensive framework in which this dissertation is developed.

Chapter 2 presents the theoretical framework of modelling equilibrium exchange rates. Firstly, it defines both the equilibrium exchange rate that guided us throughout this study and the real effective exchange rate as being the whole economy measure of the exchange rate. Secondly, considering different approaches and presenting their strengths and weaknesses, two equilibrium exchange rate frameworks emerge which provide the basis for the fourth chapter: the BEER and the PEER. Lastly, papers describing the relationship between the exchange rate, its fundamentals and indicators such as population, fiscal stance and political stability are reviewed with the purpose of framing our study. This chapter highlights that use of different equilibrium exchange rate models enables the assessment of the validity of the impact of an underlying set of macroeconomic fundamentals also including governance indicators on exchange rate dynamics.

Chapter 3 describes the setting of the UK economy over a period of 24 years, from 1996 to 2020, with extensive focus on the Brexit period. It has two main aims: firstly, to define and measure the variables of use in a consistent way; secondly, to illustrate the impact of confusion, outlined as instabilities and uncertainties, existing in the UK's economy since the 2016 leave vote results. Thus, this chapter shows that measurements such as the political stability indicator and the economic policy uncertainty index can be useful in considering and evaluating their impacts on exchange rate behaviour because the UK economic outlook seems to be more sensitive to uncertainty and instability than ever before. Above all, this chapter provides the foundations for the selection of the following three empirical representations.

Chapter 4 explores the link between the real effective exchange rate, the political stability indicator, terms of trade and the real interest rate from 1996 to 2019. The purpose of the chapter is twofold: to find the equilibrium relationship based on this set of particular variables; and to calculate total currency misalignments. Thus, it presents two empirical models, the Behavioural Equilibrium Exchange Rate and the Permanent Equilibrium Exchange Rate. The first establishes the equilibrium relationship between the four variables under analysis through a VECM representation. The latter one is obtained using the BEER model by decomposing the variables on permanent and transitory component using the Beveridge and Nelson decomposition method. Therefore, the new equilibrium relationship is considering only the long-run effects (the permanent component) of the variables on the real effective exchange rate. Once the long-run was established, the total currency misalignment is calculated as being the difference between the observed value of the real effective exchange rate and the value of the real effective exchange rate obtained from the PEER model. Our results confirm that the political stability indicator among other variables can be used to explain the movements of the real effective exchange rate on the analysed period and have shown that, despite the calculated degrees of misalignments, the currency moves toward its equilibrium level very quickly.

Chapter 5 analyses the dynamics of the real effective exchange rate in relation to the economic policy uncertainty index, terms of trade, and real interest rates from January 1998 to June 2020 within an ARDL bound testing and an error correction model. The main aim of this chapter is to understand the long-run relationship between the UK REER and UK EPU. The ARDL model results support the concept that these variables are indeed the drivers of the real effective exchange rate movements in both the short-term and the long-term. Moreover, the economic policy uncertainty index in the UK has no short-run effects, rather it has long-run effects on currency behaviour.

Chapter 6 studies the relationship between the EPU index, inflation rate, unemployment rate and real effective exchange rate from January 1998 to September 2020, using monthly data, in a VAR model framework. We started by checking for the optimal lag length and the cointegration vectors among variables. It turns out that the optimal lag to use in the VAR model estimation is two, and no cointegration relations are supported by the data. According to model selection criteria and the properties of the residuals, (no autocorrelated and homoskedastic residuals), the VAR (2) model was chosen for the final specification to study the effect of EPU index on inflation rate, unemployment rate and real effective exchange rate. Although the impact of the EPU index on the mentioned variables is mostly statistically insignificant, we proceed with the Granger causality test and the impulse response functions analyses. The Granger causality test was applied to investigate if the EPU index can help to predict the variables under study. We found that the model predicts that the EPU index has predictive power on the other variables. From the IRF analysis we were able to check whether the behaviour of the variables after the occurrence of a shock in the EPU index is in accordance with economic literature findings. Our model demonstrates that an increase in EPU will produce an increase in the inflation rate, and a decrease in both the unemployment rate and the real effective exchange rate. To summarise, the primary insights gained in this chapter are that shock on the EPU index will depreciate the UK´s currency; results that are in accordance with our previous results founded in chapter 5.

7.2. Limitations of the study

The thesis has been conducted under certain constraints. The main constraint is that there is a general absence of extended/alternative databases with respect to both the political stability indicator and economic policy uncertainty index. Consequently, the lack of observations should be noted, as it could infer lack of control on data quality, as a possible disadvantage. However, the data sets in all empirical chapters are from official sources and are available in archives. Consequently, further attempts at replication of the studies could easily been achieved for other economies and for other currencies.

Given the nature of the research, and the nature of concepts such as equilibrium exchange rate, it is necessary to set out some limitations on this doctoral thesis.

The first limitation, common to first two empirical chapters, is that there could have been a variables preference, as no direct way to represent a based model in the exchange rate modelling is established by the theory. One remark in regard of this first limitation is that in chapter 5, the number of observations did not allow the inclusion of more control variables.

The second limitation is related to the sample size in chapter 4. Considering the need of the study, chapter 4 has created primary steps in analysing the equilibrium exchange rate under BEER and PEER approaches by including in the analysis the political stability variable. The dataset was conditioned by the data available in the Worldwide Governance Indicators reports for the political stability indicator, only annual data from 1996 to 2019 is available. We acknowledge that there might be statistical errors and deviations from the actual situation due to the limited sample. Although the number of observations is limited, in paper such as Clark and MacDonald (2004) a small sample size is also used (17 annual observations) to analyse the consistency of the real effective exchange rate with its economic fundamentals. However, the estimated model result reveal that the sample size seems to be acceptable in this research and it is able to provide satisfactory fit.

The third limitation is associated with the selection of the economic policy uncertainty index in attempting to link it with real effective exchange rate and inflation rate. In chapter 5 we outline a means of establishing links between the economic policy uncertainty, real effective exchange rate amongst macroeconomic fundamentals, such as terms of trade and the real interest rate. In chapter 6, together with the effective exchange rate and economic policy uncertainty indicator, the inflation rate and unemployment rate are included. Because the EPU index impact on the currency dynamics and inflation rate behaviour has little evidence on the literature, these two last empirical chapters of the thesis should be seen as a preliminary attempt at this type of analyses. In the literature we cannot find many studies to compare with our results. As we have said, the EPU index contains certain predefined keywords; due to its subjective nature, this could be queried as the words used in the computer searches of newspapers may or may not be adequate to encompass and expose one country's economic policy uncertainties. Another question about this measure could be posed regarding the frequency and volume of newspapers reviewed. We acknowledge that the performance of the index was tested and there are advantages and disadvantages regarding its predictive powers. Dogru et al. (2019) found that the index EPU is a significant predictor, while Tobback et al. (2018), states that this index is disposed to measurement error. We have found that the UK EPU index is adequate for our analysis in both chapters, 5 and 6.

7.3. Avenues of further research

Further extensive research should be carried out on the drivers of the real exchange rate co-movement concentrating not only on macroeconomic fundamentals throughout distorted periods, but rather on governance factors, political turmoil, global trade patterns or economic policy factors. We advocate this because the above-mentioned factors were acknowledged in exchange rate literature as factors linked to long-run real effective exchange rates.

A comprehensive exchange rate behaviour analysis in presence of political instabilities and economic policy uncertainties should be undertaken to explore future currency dynamics, attempting to conduct policy-makers in assessing the proposed macroeconomic policies.

A tempting application, beyond the scope of this thesis, would be to evaluate the real exchange rate forecasting performance when including more fundamentals beyond those stated in literature. We hope to pursue this avenue of research in forthcoming academic work.

Thus, future research could clarify whether the economic policy uncertainty index can predict future changes in exchange rate behaviour, inflation rate and in the country's economic performance. This would imply checking for the appropriate forecast methods to achieve this purpose. As there is a lack of a clear best choice, one possible forecasting method could be the scapegoat model of exchange rate fluctuations proposed by Bacchetta and van Wincoop (2004, 2013). In essence, they state that there is confusion in the market about the true source of exchange rate fluctuations and that the exchange rates may change for reasons that have nothing to do with observed macroeconomic fundamentals.

7.4. Conclusions

Through the work undertaken in this thesis, it has been shown that both the political stability indicator and the economic policy uncertainty index provide consistent results when analysing the real effective exchange rate dynamics in their presence. Moreover, our results confirm that these two factors are two important elements producing the real effective exchange rate movements over the long-run horizon. As for the new indicator brought in chapter 4 into the equilibrium exchange rate analysis under the BEER and PEER approaches, it remains to be seen whether these results can be obtained for other economies, currencies and fundamentals. However, given the robustness of the results shown in chapter 5, we hope that the application of the economic policy uncertainty index to exchange rate behaviour will stand the test of time and at the same time will allow for better policy decision-making processes.

One interpretation for the policymakers based on the main results obtained in chapter 4, an undervalued pound due to the political instability indicator, suggest that policymakers should acknowledge that the UK's future growth depends on their ability to boost post-Brexit trade. An undervalued British pound is helpful, but not necessarily sufficient to improve country's external position and to rebalance its economy.

As founded in chapter 5 and 6, our results suggest that a higher economic policy uncertainty decreases the real exchange rate and increases the inflation rate. As policies tend to alter the economic effects of a given monetary policy measure, the policymakers should be aware of these harmful effects due to several ramifications in the economy. Our policy recommendation, based on these results is that it is important for policymakers to understand economic policy uncertainty shocks to accurately assess the impact of transmission process through exchange rate on the UK economy.

If all market participants understand and accept their responsibilities, policies should finally emerge to reflect the needs and interests of all concerned.

Altogether the three studies results indicate that there is a scope for applying similar studies for different countries' economies in future research.

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Appendix A

Appendix A.4-1: Chi-square Distribution

df	0.995	0.99	0.975	0.95	0.9	0.1	0.05	0.025	0.01	0.005
1	0.00	0.00	0.00	0.00	0.02	2.71	3.84	5.02	6.64	7.88
2	0.01	0.02	0.05	0.10	0.21	4.61	5.99	7.38	9.21	10.60
3	0.07	0.12	0.22	0.35	0.58	6.25	7.82	9.35	11.35	12.84
4	0.21	0.30	0.48	0.71	1.06	7.78	9.49	11.14	13.28	14.86
5	0.41	0.55	0.83	1.15	1.61	9.24	11.07	12.83	15.09	16.75
6	0.68	0.87	1.24	1.64	2.20	10.65	12.59	14.45	16.81	18.55
7	0.99	1.24	1.69	2.17	2.83	12.02	14.07	16.01	18.48	20.28
8	1.34	1.65	2.18	2.73	3.49	13.36	15.51	17.54	20.09	21.96
9	1.74	2.09	2.70	3.33	4.17	14.68	16.92	19.02	21.67	23.59
10	2.16	2.56	3.25	3.94	4.87	15.99	18.31	20.48	23.21	25.19
11	2.60	3.05	3.82	4.58	5.58	17.28	19.68	21.92	24.73	26.76
12	3.07	3.57	4.40	5.23	6.30	18.55	21.03	23.34	26.22	28.30
13	3.57	4.11	5.01	5.89	7.04	19.81	22.36	24.74	27.69	29.82
14	4.08	4.66	5.63	6.57	7.79	21.06	23.69	26.12	29.14	31.32
15	4.60	5.23	6.26	7.26	8.55	22.31	25.00	27.49	30.58	32.80
16	5.14	5.81	6.91	7.96	9.31	23.54	26.30	28.85	32.00	34.27
17	5.70	6.41	7.56	8.67	10.09	24.77	27.59	30.19	33.41	35.72
18	6.27	7.02	8.23	9.39	10.87	25.99	28.87	31.53	34.81	37.16
19	6.84	7.63	8.91	10.12	11.65	27.20	30.14	32.85	36.19	38.58
20	7.43	8.26	9.59	10.85	12.44	28.41	31.41	34.17	37.57	40.00
21	8.03	8.90	10.28	11.59	13.24	29.62	32.67	35.48	38.93	41.40
22	8.64	9.54	10.98	12.34	14.04	30.81	33.92	36.78	40.29	42.80
23	9.26	10.2	11.69	13.09	14.85	32.01	35.17	38.08	41.64	44.18
24	9.89	10.86	12.40	13.85	15.66	33.20	36.42	39.36	42.98	45.56

Appendix A.4-2a: ADF, PP, KPSS tests in levels and first differences for the real effective exchange rate (LNREER)

Null Hypothesis: LNREER has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.005485	0.7336
Test critical values:	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNREER has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.749362	0.2284
Test critical values:	1% level	-4.440739	
	5% level	-3.632896	
	10% level	-3.254671	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNREER has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.296302	0.5679
Test critical values:	1% level	-2.669359	
	5% level	-1.956406	
	10% level	-1.608495	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNREER has a unit root
Exogenous: Constant
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.203471	0.6548
Test critical values:	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNREER has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-3.686499	0.0441
Test critical values:	1% level	-4.416345	
	5% level	-3.622033	
	10% level	-3.248592	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNREER has a unit root
Exogenous: None
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-0.296302	0.5679
Test critical values:	1% level	-2.669359	
	5% level	-1.956406	
	10% level	-1.608495	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNREER is stationary
Exogenous: Constant
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.520862
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: LNREER is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.100834
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(LNREER) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.324362	0.0029
Test critical values:	1% level	-3.769597	
	5% level	-3.004861	
	10% level	-2.642242	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.077341	0.0210
Test critical values:	1% level	-4.440739	
	5% level	-3.632896	
	10% level	-3.254671	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.307767	0.0002
Test critical values:	1% level	-2.674290	
	5% level	-1.957204	
	10% level	-1.608175	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) has a unit root
Exogenous: Constant
Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-4.807892	0.0010
Test critical values:	1% level	-3.769597	
	5% level	-3.004861	
	10% level	-2.642242	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-4.373697	0.0115
Test critical values:	1% level	-4.440739	
	5% level	-3.632896	
	10% level	-3.254671	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) has a unit root
Exogenous: None
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-4.365597	0.0001
Test critical values:	1% level	-2.674290	
	5% level	-1.957204	
	10% level	-1.608175	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) is stationary
Exogenous: Constant
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.253650
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(LNREER) is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.107099
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Appendix A.4-2b: ADF, PP, KPSS tests in levels and first differences for the political stability indicator (PSTAB)

Null Hypothesis: PSTAB has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.392536	0.5680
Test critical values:	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: PSTAB has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.209703	0.4625
Test critical values:	1% level	-4.416345	
	5% level	-3.622033	
	10% level	-3.248592	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: PSTAB has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.152361	0.2195
Test critical values:	1% level	-2.669359	
	5% level	-1.956406	
	10% level	-1.608495	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: PSTAB has a unit root
Exogenous: Constant
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.323247	0.6008
Test critical values:	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: PSTAB has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-2.315722	0.4098
Test critical values:	1% level	-4.416345	
	5% level	-3.622033	
	10% level	-3.248592	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: PSTAB has a unit root
Exogenous: None
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.272129	0.1813
Test critical values:	1% level	-2.669359	
	5% level	-1.956406	
	10% level	-1.608495	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: PSTAB is stationary
Exogenous: Constant
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.571255
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: PSTAB is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.128389
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(PSTAB) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.501143	0.0002
Test critical values:	1% level	-3.769597	
	5% level	-3.004861	
	10% level	-2.642242	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(PSTAB) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.375524	0.0014
Test critical values:	1% level	-4.440739	
	5% level	-3.632896	
	10% level	-3.254671	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(PSTAB) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.279567	0.0000
Test critical values:	1% level	-2.674290	
	5% level	-1.957204	
	10% level	-1.608175	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(PSTAB) has a unit root
Exogenous: Constant
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-5.491919	0.0002
Test critical values:	1% level	-3.769597	
	5% level	-3.004861	
	10% level	-2.642242	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(PSTAB) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-5.369934	0.0014
Test critical values:	1% level	-4.440739	
	5% level	-3.632896	
	10% level	-3.254671	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(PSTAB) has a unit root
Exogenous: None
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-5.249120	0.0000
Test critical values:	1% level	-2.674290	
	5% level	-1.957204	
	10% level	-1.608175	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(PSTAB) is stationary
Exogenous: Constant
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.072960
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(PSTAB) is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.062297
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Appendix A.4-2c: ADF, PP, KPSS tests in levels and first differences for terms of trade (LNTOT)

Null Hypothesis: LNTOT has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.496860	0.5172
Test critical values:	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNTOT has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.708921	0.7143
Test critical values:	1% level	-4.416345	
	5% level	-3.622033	
	10% level	-3.248592	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNTOT has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.874247	0.0061
Test critical values:	1% level	-2.669359	
	5% level	-1.956406	
	10% level	-1.608495	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNTOT has a unit root
Exogenous: Constant
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.507369	0.5121
Test critical values:	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNTOT has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.708921	0.7143
Test critical values:	1% level	-4.416345	
	5% level	-3.622033	
	10% level	-3.248592	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNTOT has a unit root
Exogenous: None
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-2.890224	0.0058
Test critical values:	1% level	-2.669359	
	5% level	-1.956406	
	10% level	-1.608495	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNTOT is stationary
Exogenous: Constant
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.653173
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: LNTOT is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.144486
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(LNTOT) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.351974	0.0027
Test critical values:	1% level	-3.769597	
	5% level	-3.004861	
	10% level	-2.642242	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNTOT) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.332165	0.0125
Test critical values:	1% level	-4.440739	
	5% level	-3.632896	
	10% level	-3.254671	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNTOT) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.790652	0.0006
Test critical values:	1% level	-2.674290	
	5% level	-1.957204	
	10% level	-1.608175	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNTOT) has a unit root
Exogenous: Constant
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-4.365131	0.0027
Test critical values:	1% level	-3.769597	
	5% level	-3.004861	
	10% level	-2.642242	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNTOT) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-4.327948	0.0126
Test critical values:	1% level	-4.440739	
	5% level	-3.632896	
	10% level	-3.254671	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNTOT) has a unit root
Exogenous: None
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-3.813740	0.0006
Test critical values:	1% level	-2.674290	
	5% level	-1.957204	
	10% level	-1.608175	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNTOT) is stationary
Exogenous: Constant
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.148683
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(LNTOT) is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.066230
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Appendix A.4-2d: ADF, PP, KPSS tests in levels and first differences for real interest rates (RIR)

Null Hypothesis: RIR has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.355678	0.1644
Test critical values:	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: RIR has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.983859	0.1575
Test critical values:	1% level	-4.416345	
	5% level	-3.622033	
	10% level	-3.248592	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: RIR has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.347099	0.0213
Test critical values:	1% level	-2.669359	
	5% level	-1.956406	
	10% level	-1.608495	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: RIR has a unit root
Exogenous: Constant
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-2.355678	0.1644
Test critical values:	1% level	-3.752946	
	5% level	-2.998064	
	10% level	-2.638752	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: RIR has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-2.983859	0.1575
Test critical values:	1% level	-4.416345	
	5% level	-3.622033	
	10% level	-3.248592	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: RIR has a unit root
Exogenous: None
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-2.290712	0.0242
Test critical values:	1% level	-2.669359	
	5% level	-1.956406	
	10% level	-1.608495	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: RIR is stationary
Exogenous: Constant
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.387622
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: RIR is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.084754
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(RIR) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.070612	0.0001
Test critical values:	1% level	-3.769597	
	5% level	-3.004861	
	10% level	-2.642242	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(RIR) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.918636	0.0005
Test critical values:	1% level	-4.440739	
	5% level	-3.632896	
	10% level	-3.254671	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(RIR) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=5)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.178636	0.0000
Test critical values:	1% level	-2.674290	
	5% level	-1.957204	
	10% level	-1.608175	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(RIR) has a unit root
Exogenous: Constant
Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-6.739099	0.0000
Test critical values:	1% level	-3.769597	
	5% level	-3.004861	
	10% level	-2.642242	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(RIR) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-6.567345	0.0001
Test critical values:	1% level	-4.440739	
	5% level	-3.632896	
	10% level	-3.254671	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(RIR) has a unit root
Exogenous: None
Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-6.776840	0.0000
Test critical values:	1% level	-2.674290	
	5% level	-1.957204	
	10% level	-1.608175	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(RIR) is stationary
Exogenous: Constant
Bandwidth: 12 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.255443
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(RIR) is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 12 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.253394
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Appendix A.4-3: VAR estimation and Lag Length selection

a)VAR estimation

Vector Autoregression Estimates				
	LNREER	PSTAB	LNTOT	RIR
LNREER (-1)	1.189221	1.489519	0.014894	10.41431
	(0.25731)	(0.67175)	(0.12753)	(9.45490)
	[4.62175]	[2.21736]	[0.11679]	[1.10147]
LNREER (-2)	-0.198685	-1.230027	0.020898	-11.37927
	(0.23785)	(0.62095)	(0.11788)	(8.73989)
	[-0.83533]	[-1.98087]	[0.17728]	[-1.30199]
PSTAB (-1)	-0.056590	0.283393	-0.101378	-0.915497
	(0.11360)	(0.29659)	(0.05630)	(4.17443)
	[-0.49813]	[0.95552]	[-1.80053]	[-0.21931]
PSTAB (-2)	0.060607	0.332944	0.048622	2.228667
	(0.12312)	(0.32143)	(0.06102)	(4.52416)
	[0.49225]	[1.03581]	[0.79680]	[0.49261]
LNTOT (-1)	0.898880	0.218421	1.134159	16.74365
	(0.59909)	(1.56403)	(0.29692)	(22.0138)
	[1.50041]	[0.13965]	[3.81975]	[0.76060]
LNTOT (-2)	-1.010907	-0.626874	-0.311051	-16.58745
	(0.49577)	(1.29429)	(0.24571)	(18.2171)
	[-2.03907]	[-0.48434]	[-1.26592]	[-0.91054]
RIR (-1)	-0.011677	-0.020376	-0.005995	0.200519
	(0.00822)	(0.02146)	(0.00407)	(0.30199)
	[-1.42079]	[-0.94965]	[-1.47175]	[0.66399]
RIR (-2)	0.000488	-0.000813	0.001815	0.280114
	(0.00831)	(0.02169)	(0.00412)	(0.30534)
	[0.05878]	[-0.03749]	[0.44063]	[0.91739]
R-squared	0.880120	0.815654	0.956174	0.480580
Adj. R-squared	0.820181	0.723481	0.934261	0.220870
Sum sq. resids	0.006374	0.043443	0.001566	8.606261
S.E. equation	0.021337	0.055705	0.010575	0.784049
F-statistic	14.68340	8.849166	43.63511	1.850450
Log likelihood	58.39562	37.28420	73.83856	-20.89257
Akaike AIC	-4.581420	-2.662200	-5.985324	2.626597
Schwarz SC	-4.184677	-2.265457	-5.588581	3.023340
Mean dependent	2.054684	1.467703	-0.041867	0.199675
S.D. dependent	0.050318	0.105933	0.041246	0.888256
Determinant resid covariance (dof adj.)		3.67E-11		
Determinant resid covariance		6.02E-12		
Log likelihood		159.3333		
Akaike information criterion		-11.57576		
Schwarz criterion		-9.988785		
Number of coefficients		32		

b) VAR Lag Order Selection - Criteria Endogenous variables: LNREER PSTAB LNTOT RIR

Lag	LogL	LR	FPE	AIC	SC	HQ
0	199.0743	NA	2.34e-13	-17,73403	-17,53566	-17,6873
1	264.1922	100.6367*	2.77e-15	-22.19929	-21.20743*	-21,96564
2	286.3792	26.22101	1.88e-15*	-22.76174*	-20.9764	-22.34117*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Appendix A.4-4: Johansen Cointegration test

a) Information Criteria by Rank and Model in the Johansen Cointegration test

Sample: 1996 2019
Included observations: 22
Series: LNREER PSTAB LNTOT RIR
Lags interval: 1 to 1
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	0	0	0	1	1
Max-Eig	0	0	1	1	1

*Critical values based on MacKinnon-Haug-Michelis (1999)

Information Criteria by Rank and Model

Data Trend:	None	None	Linear	Linear	Quadratic
Rank or	No Intercept	Intercept	Intercept	Intercept	Intercept
No. of CEs	No Trend	No Trend	No Trend	Trend	Trend
Log Likelihood by Rank (rows) and Model (columns)					
0	145.2638	145.2638	148.7587	148.7587	150.9786
1	151.9548	159.5553	163.0483	167.0224	168.9629
2	155.2093	165.6431	166.4712	174.8809	175.1192
3	158.2837	168.7506	169.2578	178.2744	178.2868
4	159.3333	171.5247	171.5247	181.0208	181.0208
Akaike Information Criteria by Rank (rows) and Model (columns)					
0	-11.75126	-11.75126	-11.70533	-11.70533	-11.54351
1	-11.63225	-12.23230	-12.27712	-12.54749*	-12.45117
2	-11.20084	-11.96756	-11.86102	-12.44372	-12.28356
3	-10.75306	-11.43188	-11.38707	-11.93404	-11.84425
4	-10.12121	-10.86588	-10.86588	-11.36553	-11.36553
Schwarz Criteria by Rank (rows) and Model (columns)					
0	-10.95777	-10.95777	-10.71348	-10.71348	-10.35328
1	-10.44202	-10.99248	-10.88852	-11.10929*	-10.86420
2	-9.613872	-10.28140	-10.07567	-10.55919	-10.29985
3	-8.769349	-9.299384	-9.204989	-9.603176	-9.463797
4	-7.740754	-8.287050	-8.287050	-8.588331	-8.588331

b) Trace statistics test and maximum eigenvalues test in the VECM representation

Sample (adjusted): 1998 2019
Included observations: 22 after adjustments
Trend assumption: No deterministic trend
Series: LNREER PSTAB LNTOT RIR
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.455706	28.13897	40.17493	0.4576
At most 1	0.256112	14.75712	24.27596	0.4749
At most 2	0.243832	8.248087	12.32090	0.2181
At most 3	0.091010	2.099262	4.129906	0.1738

Trace test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.455706	13.38185	24.15921	0.6583
At most 1	0.256112	6.509034	17.79730	0.8561
At most 2	0.243832	6.148826	11.22480	0.3331
At most 3	0.091010	2.099262	4.129906	0.1738

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Sample (adjusted): 1998 2019
Included observations: 22 after adjustments
Trend assumption: No deterministic trend (restricted constant)
Series: LNREER PSTAB LNTOT RIR
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.727256	52.52165	54.07904	0.0684
At most 1	0.425031	23.93876	35.19275	0.4667
At most 2	0.246105	11.76308	20.26184	0.4703
At most 3	0.222898	5.548031	9.164546	0.2286

Trace test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.727256	28.58290	28.58808	0.0501
At most 1	0.425031	12.17567	22.29962	0.6376
At most 2	0.246105	6.215053	15.89210	0.7635
At most 3	0.222898	5.548031	9.164546	0.2286

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Sample (adjusted): 1998 2019
Included observations: 22 after adjustments
Trend assumption: Linear deterministic trend
Series: LNREER PSTAB LNTOT RIR
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.727212	45.53197	47.85613	0.0813
At most 1	0.267408	16.95262	29.79707	0.6436
At most 2	0.223789	10.10697	15.49471	0.2726
At most 3 *	0.186229	4.533679	3.841466	0.0332

Trace test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.727212	28.57935	27.58434	0.0372
At most 1	0.267408	6.845647	21.13162	0.9597
At most 2	0.223789	5.573290	14.26460	0.6684
At most 3 *	0.186229	4.533679	3.841466	0.0332

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Sample (adjusted): 1998 2019
Included observations: 22 after adjustments
Trend assumption: Linear deterministic trend (restricted)
Series: LNREER PSTAB LNTOT RIR
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.809925	64.52431	63.87610	0.0441
At most 1	0.510523	27.99695	42.91525	0.6223
At most 2	0.265451	12.27977	25.87211	0.7923
At most 3	0.220944	5.492801	12.51798	0.5272

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.809925	36.52736	32.11832	0.0135
At most 1	0.510523	15.71719	25.82321	0.5699
At most 2	0.265451	6.786967	19.38704	0.9146
At most 3	0.220944	5.492801	12.51798	0.5272

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Sample (adjusted): 1998 2019
Included observations: 22 after adjustments
Trend assumption: Quadratic deterministic trend
Series: LNREER PSTAB LNTOT RIR
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.805035	60.08441	55.24578	0.0177
At most 1	0.428596	24.11583	35.01090	0.4373
At most 2	0.250213	11.80336	18.39771	0.3239
At most 3 *	0.220069	5.468089	3.841466	0.0194

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.805035	35.96858	30.81507	0.0107
At most 1	0.428596	12.31248	24.25202	0.7382
At most 2	0.250213	6.335266	17.14769	0.7833
At most 3 *	0.220069	5.468089	3.841466	0.0194

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Appendix A.4-5: VECM estimation, diagnostic tests and statistically significance test for the cointegration equation

a) Vector Error Correction Estimates

Cointegrating Eq:	CointEq1			
LNREER (-1)	1.000000			
PSTAB (-1)	-0.085264			
	(0.04541)			
	[-1.87760]			
LNTOT (-1)	-0.435286			
	(0.18154)			
	[-2.39775]			
RIR (-1)	-0.032381			
	(0.00403)			
	[-8.03920]			
@TREND (96)	0.005721			
	(0.00104)			
	[5.52129]			
C	-2.016423			
Error Correction:	D(LNREER)	D(PSTAB)	D(LNTOT)	D(RIR)
CointEq1	-0.344094	0.524909	0.324684	35.49134
	(0.35010)	(1.00860)	(0.16516)	(10.6840)
	[-0.98284]	[0.52043]	[1.96589]	[3.32193]
D (LNREER (-1))	0.213066	0.832281	-0.006795	7.350338
	(0.22029)	(0.63463)	(0.10392)	(6.72253)
	[0.96720]	[1.31145]	[-0.06539]	[1.09339]
D (PSTAB (-1))	-0.035959	-0.445673	-0.099568	-1.553979
	(0.09834)	(0.28329)	(0.04639)	(3.00089)
	[-0.36568]	[-1.57319]	[-2.14635]	[-0.51784]
D (LNTOT (-1))	1.003677	1.162451	0.474585	21.68715
	(0.47102)	(1.35694)	(0.22220)	(14.3739)
	[2.13087]	[0.85667]	[2.13585]	[1.50879]
D (RIR (-1))	-0.012314	-0.006722	-0.001100	-0.012934
	(0.00874)	(0.02519)	(0.00412)	(0.26683)
	[-1.40829]	[-0.26684]	[-0.26675]	[-0.04847]
C	-0.011160	-0.025944	0.001153	-0.206276
	(0.00568)	(0.01638)	(0.00268)	(0.17348)
	[-1.96322]	[-1.58423]	[0.42999]	[-1.18908]
R-squared	0.323145	0.191512	0.466933	0.527276
Adj. R-squared	0.111628	-0.061141	0.300350	0.379549
Sum sq. resids	0.007262	0.060270	0.001616	6.762877
S.E. equation	0.021304	0.061375	0.010050	0.650138
F-statistic	1.527748	0.758005	2.803002	3.569274
Log likelihood	56.96087	33.68289	73.48994	-18.24111
Akaike AIC	-4.632806	-2.516626	-6.135449	2.203738
Schwarz SC	-4.335249	-2.219069	-5.837892	2.501295
Mean dependent	-0.004471	-0.013636	0.005464	-0.064091
S.D. dependent	0.022603	0.059581	0.012015	0.825377
Determinant resid covariance (dof adj.)	1.07E-11			
Determinant resid covariance	2.99E-12			
Log likelihood	167.0224			
Akaike information criterion	-12.54749			
Schwarz criterion	-11.10929			
Number of coefficients	29			

b) Diagnostic tests for the VECM (1) residuals

VEC Residual Serial Correlation LM Tests						
Null hypothesis: No serial correlation at lag h						
Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	13.61181	16	0.6276	0.832033	(16, 28.1)	0.6428
Null hypothesis: No serial correlation at lags 1 to h						
Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	13.61181	16	0.6276	0.832033	(16, 28.1)	0.6428

VEC Residual Normality Tests				
Component	Skewness	Chi-sq	df	Prob.*
1	0.055296	0.011212	1	0.9157
2	0.728851	1.947823	1	0.1628
3	0.399109	0.584056	1	0.4447
4	0.101210	0.037560	1	0.8463
Joint		2.580650	4	0.6303
Component	Kurtosis	Chi-sq	df	Prob.
1	2.315936	0.428948	1	0.5125
2	4.391479	1.774861	1	0.1828
3	2.657679	0.107419	1	0.7431
4	2.154133	0.655867	1	0.4180
Joint		2.967095	4	0.5633
Component	Jarque-Bera	df	Prob.	
1	0.440160	2	0.8025	
2	3.722684	2	0.1555	
3	0.691475	2	0.7077	
4	0.693427	2	0.7070	
Joint	5.547746	8	0.6977	

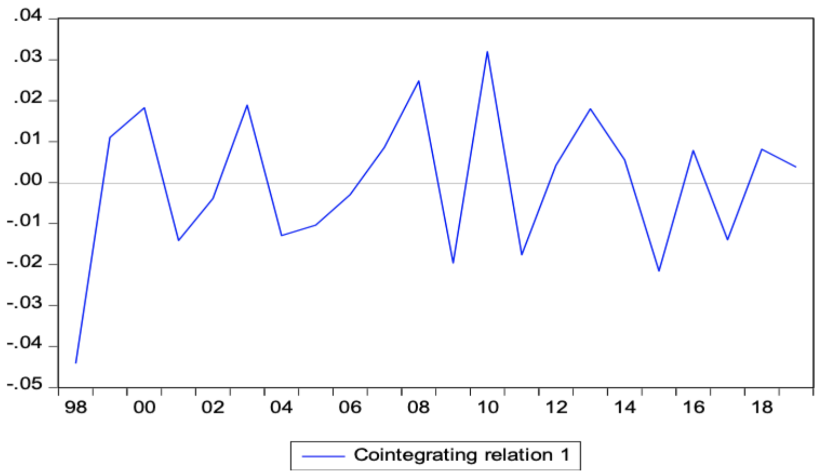
VEC Residual Heteroskedasticity Tests (Levels and Squares)		
Joint test:		
Chi-sq	df	Prob.
100.3578	100	0.4711

c) Significance test for VECM representation

Dependent Variable: D(LNREER)
Method: Least Squares (Gauss-Newton / Marquardt steps)
Sample (adjusted): 1998 2019
Included observations: 22 after adjustments
D(LNREER) = C (1) *(LNREER (-1) - 0.0852641975419*PSTAB (-1) -
0.435285923078*LNTOT (-1) - 0.0323807163909*RIR (-1) +
0.00572097476097*@TREND (96) - 2.01642327079) + C (2)
*D (LNREER (-1)) + C (3) *D (PSTAB (-1)) + C (4) *D (LNTOT (-1)) + C (5)
*D (RIR (-1)) + C (6)

	Coefficient	Std. Error	t-Statistic	Prob.
C (1)	-0.037778	0.012703	-2.973824	0.0032
C (2)	0.213066	0.220291	0.967202	0.3478
C (3)	-0.035959	0.098336	-0.365678	0.7194
C (4)	1.003677	0.471018	2.130865	0.0490
C (5)	-0.012314	0.008744	-1.408288	0.1782
C (6)	-0.011160	0.005685	-1.963219	0.0672
R-squared	0.323145	Mean dependent var	-0.004471	
Adjusted R-squared	0.111628	S.D. dependent var	0.022603	
S.E. of regression	0.021304	Akaike info criterion	-4.632806	
Sum squared resid	0.007262	Schwarz criterion	-4.335249	
Log likelihood	56.96087	Hannan-Quinn criter.	-4.562711	
F-statistic	1.527748	Durbin-Watson stat	2.018584	
Prob(F-statistic)	0.236599			

d) Cointegration graph for the VECM estimation



e) Granger causality test

Pairwise Granger Causality Tests
Sample: 1996 2019
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
PSTAB does not Granger Cause LNREER	23	4.96715	0.0375
LNREER does not Granger Cause PSTAB		0.03569	0.8521
LNTOT does not Granger Cause LNREER	23	8.10298	0.0100
LNREER does not Granger Cause LNTOT		1.75486	0.2002
RIR does not Granger Cause LNREER	23	0.14462	0.7077
LNREER does not Granger Cause RIR		3.75285	0.0670
LNTOT does not Granger Cause PSTAB	23	2.64463	0.1196
PSTAB does not Granger Cause LNTOT		9.45025	0.0060
RIR does not Granger Cause PSTAB	23	0.51948	0.4794
PSTAB does not Granger Cause RIR		3.27039	0.0856
RIR does not Granger Cause LNTOT	23	4.82472	0.0400
LNTOT does not Granger Cause RIR		2.09368	0.1634

Appendix A.4-6: ARIMA representations for the B-N decomposition method

a) ARIMA representation

Dependent Variable: D(LNTOT)
Method: ARMA Maximum Likelihood (OPG - BHHH)
Sample: 1997 2019
Included observations: 23
Failure to improve objective (singular hessian) after 49 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.005968	0.002700	2.210091	0.0396
AR (4)	-1.000000	0.001648	-606.6869	0.0000
MA (4)	0.999931	0.001416	706.3264	0.0000
SIGMASQ	0.000122	5.76E-05	2.113189	0.0480
R-squared	0.104728	Mean dependent var		0.005902
Adjusted R-squared	-0.036631	S.D. dependent var		0.011925
S.E. of regression	0.012141	Akaike info criterion		-5.738870
Sum squared resid	0.002801	Schwarz criterion		-5.541393
Log likelihood	69.99700	Hannan-Quinn criter.		-5.689205
F-statistic	0.740865	Durbin-Watson stat		1.899619
Prob(F-statistic)	0.540758			
Inverted AR Roots	.71+.71i	.71+.71i	-.71-.71i	-.71-.71i
Inverted MA Roots	.71+.71i	.71+.71i	-.71-.71i	-.71-.71i

Dependent Variable: D(PSTAB)
Method: ARMA Maximum Likelihood (OPG - BHHH)
Sample: 1997 2019
Included observations: 23
Convergence achieved after 7 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.012693	0.007069	-1.795594	0.0877
MA (3)	-0.408253	0.182995	-2.230959	0.0373
SIGMASQ	0.002614	0.000995	2.626221	0.0162
R-squared	0.197717	Mean dependent var	-0.012770	
Adjusted R-squared	0.117488	S.D. dependent var	0.058359	
S.E. of regression	0.054823	Akaike info criterion	-2.824509	
Sum squared resid	0.060112	Schwarz criterion	-2.676401	
Log likelihood	35.48185	Hannan-Quinn criter.	-2.787260	
F-statistic	2.464422	Durbin-Watson stat	2.343587	
Prob(F-statistic)	0.110479			
Inverted MA Roots	.74	-.37+.64i	-.37-.64i	

Dependent Variable: D(RIR)
Method: ARMA Maximum Likelihood (OPG - BHHH)
Sample: 1997 2019
Included observations: 23
Convergence achieved after 4 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.039835	0.134961	-0.295155	0.7709
AR (1)	-0.276653	0.381581	-0.725017	0.4768
SIGMASQ	0.592684	0.134483	4.407134	0.0003
R-squared	0.080406	Mean dependent var	-0.032112	
Adjusted R-squared	-0.011553	S.D. dependent var	0.820854	
S.E. of regression	0.825583	Akaike info criterion	2.579115	
Sum squared resid	13.63173	Schwarz criterion	2.727223	
Log likelihood	-26.65982	Hannan-Quinn criter.	2.616363	
F-statistic	0.874367	Durbin-Watson stat	2.098693	
Prob(F-statistic)	0.432474			
Inverted AR Roots	-.28			

Dependent Variable: D(LNREER)
Method: ARMA Maximum Likelihood (OPG - BHHH)
Sample: 1997 2019
Included observations: 23
Convergence achieved after 72 iterations
Coefficient covariance computed using outer product of gradients

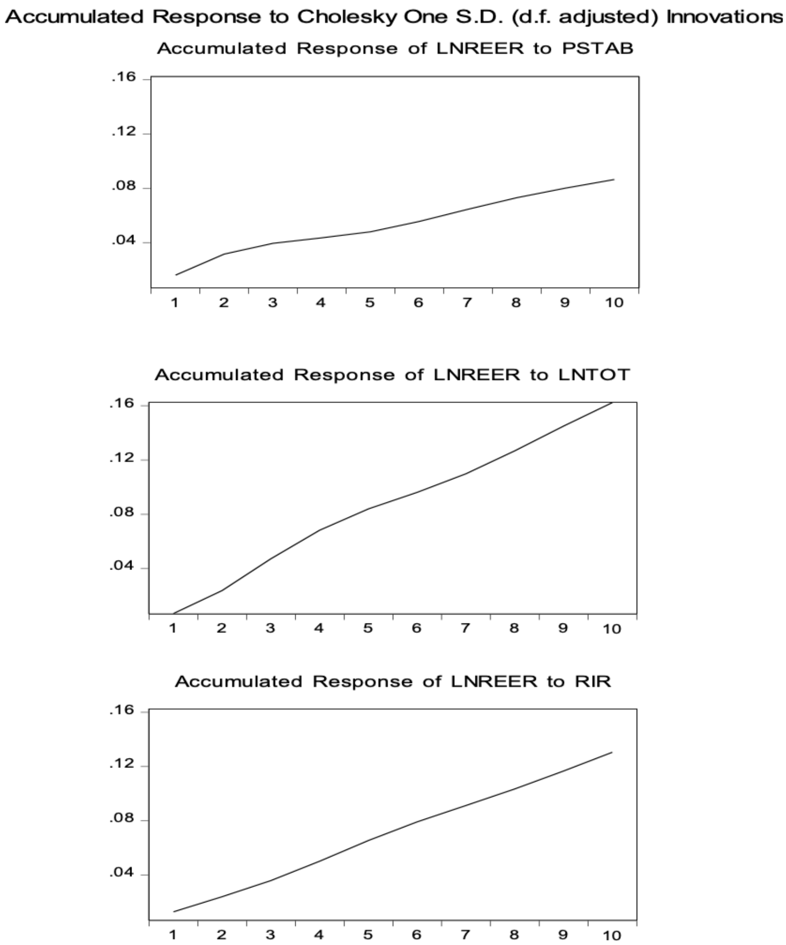
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.004382	0.002309	-1.897988	0.0722
MA (2)	-0.736657	0.239287	-3.078554	0.0059
SIGMASQ	0.000576	0.000234	2.466010	0.0228
R-squared	0.128679	Mean dependent var	-0.001498	
Adjusted R-squared	0.041547	S.D. dependent var	0.026286	
S.E. of regression	0.025734	Akaike info criterion	-4.292880	
Sum squared resid	0.013245	Schwarz criterion	-4.144773	
Log likelihood	52.36813	Hannan-Quinn criter.	-4.255632	
F-statistic	1.476831	Durbin-Watson stat	1.094435	
Prob(F-statistic)	0.252220			
Inverted MA Roots	.86	-.86		

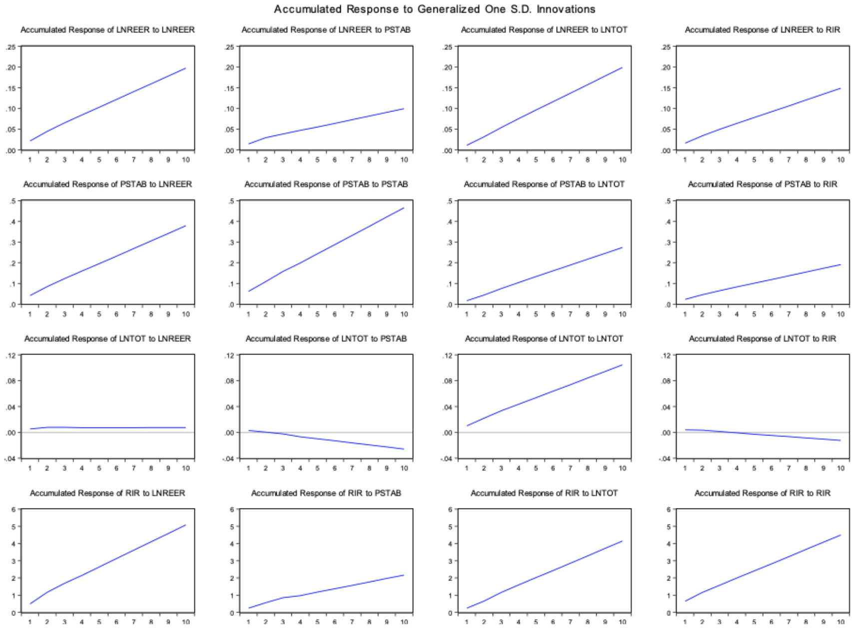
B) B-N decomposition actual value of the variables and the BN trend

	LNREER	LNREER_TREND	PSTAB	PSTAB_TREND	LNTOT	LNTOT_TREND	RIR	RIR_TREND
1996	2.0271	2.0834	1.6437	1.6833	-0.1316	-0.1358	0.5657	0.8725
1997	2.0911	2.0888	1.65	1.6626	-0.1161	-0.1264	1.2371	0.8801
1998	2.1114	2.0937	1.6659	1.6416	-0.1326	-0.117	0.5186	0.8847
1999	2.1109	2.0974	1.66	1.6196	-0.1227	-0.1074	0.34	0.8867
2000	2.1153	2.0996	1.6525	1.5964	-0.1019	-0.0976	1.3929	0.883
2001	2.1047	2.1002	1.6	1.5722	-0.0901	-0.0878	0.9043	0.865
2002	2.1078	2.099	1.5502	1.5475	-0.0751	-0.0782	0.4014	0.829
2003	2.0897	2.096	1.4735	1.5235	-0.0669	-0.069	1.0943	0.7721
2004	2.1064	2.0913	1.4877	1.501	-0.0567	-0.0604	1.5343	0.6867
2005	2.0984	2.0849	1.4037	1.4806	-0.0391	-0.0526	1.2186	0.5688
2006	2.101	2.0769	1.5228	1.4626	-0.0212	-0.0457	0.5643	0.4225
2007	2.1081	2.0676	1.4842	1.4467	-0.0334	-0.0398	0.7257	0.2587
2008	2.0483	2.0575	1.4392	1.4329	-0.0407	-0.0346	0.6443	0.0895
2009	2.0013	2.0476	1.3155	1.4219	-0.0564	-0.0298	-1.6857	-0.0681
2010	2	2.0387	1.3953	1.4143	-0.029	-0.0252	-0.5971	-0.1918
2011	1.9993	2.0312	1.3551	1.4097	-0.0237	-0.0207	-1.0829	-0.2753
2012	2.0145	2.025	1.3878	1.4074	-0.0152	-0.0164	-1.06	-0.3163
2013	2.0088	2.0199	1.4142	1.4063	-0.0063	-0.0125	-0.8643	-0.3209
2014	2.0363	2.0154	1.462	1.4051	0.0042	-0.009	0.73	-0.3022
2015	2.0559	2.011	1.5157	1.4023	0	-0.0059	0.52	-0.2792
2016	2.0101	2.0063	1.4347	1.3973	-0.0096	-0.0031	0.2986	-0.2601
2017	1.9871	2.0015	1.3859	1.3906	-0.0097	-0.0005	-0.79	-0.2454
2018	1.9949	1.9966	1.3336	1.3829	0.0009	0.0021	-0.2414	-0.23
2019	1.9927	1.9918	1.35	1.3749	0.0041	0.0047	-0.1729	-0.2142

Appendix A.4-7: Accumulated response of LNREER to Cholesky one standard deviation shock in PSTAB, LNTOT and RIR and forecast error variance decomposition of LNREER due to PSTAB, LNTOT, RIR shocks

a) Impulse response functions





b)Variance decomposition of LNREER, Cholesky Ordering: PSTAB, LNTOT, RIR, LNREER

Period	S.E.	LNREER	PSTAB	LNTOT	RIR
1	0.650138	20.33400	45.90016	11.56397	22.20187
2	0.959672	14.58074	39.06232	31.45195	14.90498
3	1.127296	13.15636	29.62557	44.43146	12.78661
4	1.261942	12.65938	25.46672	50.59840	11.27550
5	1.376372	12.49380	23.12791	53.94279	10.43550
6	1.481807	12.33718	21.73460	55.98610	9.942117
7	1.580925	12.25506	20.72883	57.40438	9.611731
8	1.675125	12.17939	19.98080	58.49382	9.345994
9	1.764007	12.11947	19.37108	59.37013	9.139318
10	1.848597	12.07074	18.88161	60.07694	8.970714

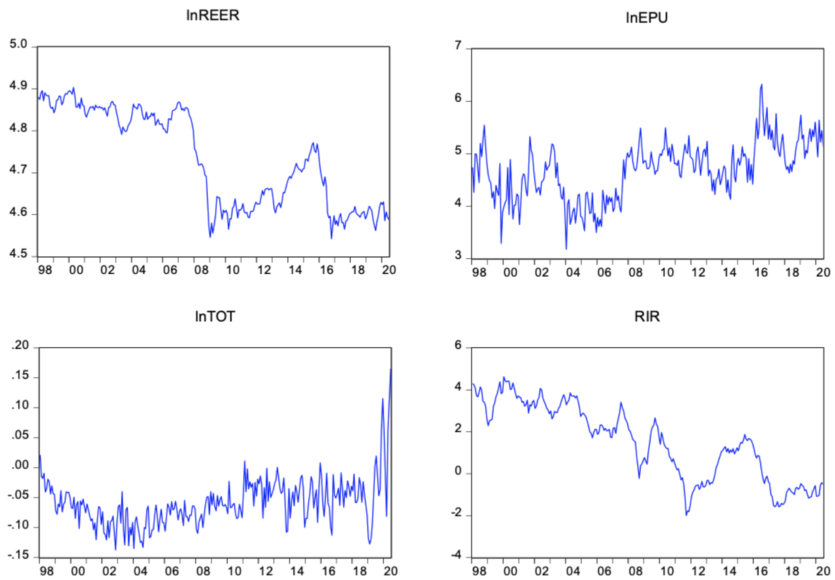
Appendix B

Appendix B.5-1: Descriptive statistics and graphical representation of the variables

a) Descriptive statistics

	LNREER	LNEPU	LNTOT	RIR
Mean	4.731953	4.682814	-0.058761	1.503301
Median	4.721619	4.752297	-0.062005	1.644600
Maximum	4.903273	6.324760	0.165346	4.622700
Minimum	4.542124	3.179550	-0.137565	-1.996000
Std. Dev.	0.114228	0.537386	0.039544	1.777588
Skewness	-0.032158	-0.123865	1.448120	-0.144193
Kurtosis	1.346638	2.876078	8.627095	1.768433
Jarque-Bera	30.79962	0.863180	450.5895	17.99914
Probability	0.000000	0.649476	0.000000	0.000123
Sum	1277.627	1264.360	-15.86545	405.8914
Sum Sq. Dev.	3.509916	77.68282	0.420653	849.9911
Observations	270	270	270	270

b) Graphical representation of the variables



Appendix B.5-2: Pesaran et.al (2001) Bounds test critical values

Table CI(ii) Case II: Restricted intercept and no trend

	0.100		0.050		0.025		0.010		Mean		Variance	
k	$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$
0	3.80	3.80	4.60	4.60	5.39	5.39	6.44	6.44	2.03	2.03	1.77	1.77
1	3.02	3.51	3.62	4.16	4.18	4.79	4.94	5.58	1.69	2.02	1.01	1.25
2	2.63	3.35	3.10	3.87	3.55	4.38	4.13	5.00	1.52	2.02	0.69	0.96
3	2.37	3.20	2.79	3.67	3.15	4.08	3.65	4.66	1.41	2.02	0.52	0.78
4	2.20	3.09	2.56	3.49	2.88	3.87	3.29	4.37	1.34	2.01	0.42	0.65
5	2.08	3.00	2.39	3.38	2.70	3.73	3.06	4.15	1.29	2.00	0.35	0.56
6	1.99	2.94	2.27	3.28	2.55	3.61	2.88	3.99	1.26	2.00	0.30	0.49
7	1.92	2.89	2.17	3.21	2.43	3.51	2.73	3.90	1.23	2.01	0.26	0.44
8	1.85	2.85	2.11	3.15	2.33	3.42	2.62	3.77	1.21	2.01	0.23	0.40
9	1.80	2.80	2.04	3.08	2.24	3.35	2.50	3.68	1.19	2.01	0.21	0.36
10	1.76	2.77	1.98	3.04	2.18	3.28	2.41	3.61	1.17	2.00	0.19	0.33

Appendix B.5-3: Unit root and stationarity tests

Appendix B.5-3a: ADF, PP and KPSS tests in levels and first differences for real effective exchange rate (LNREER)

Null Hypothesis: LNREER has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.136699	0.7018
Test critical values:	1% level	-3.454534	
	5% level	-2.872081	
	10% level	-2.572460	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNREER has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.106267	0.5395
Test critical values:	1% level	-3.992540	
	5% level	-3.426619	
	10% level	-3.136553	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNREER has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.169906	0.2209
Test critical values:	1% level	-2.573587	
	5% level	-1.942008	
	10% level	-1.615912	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNREER has a unit root
Exogenous: Constant
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.210566	0.6706
Test critical values:	1% level	-3.454534	
	5% level	-2.872081	
	10% level	-2.572460	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNREER has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-2.335698	0.4128
Test critical values:	1% level	-3.992540	
	5% level	-3.426619	
	10% level	-3.136553	

*MacKinnon (1996) one-sided p-values.
Null Hypothesis: LNREER has a unit root
Exogenous: None
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.103351	0.2447
Test critical values:	1% level	-2.573587	
	5% level	-1.942008	
	10% level	-1.615912	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNREER is stationary
Exogenous: Constant
Bandwidth: 12 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		1.700521
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: LNREER is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 12 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.148273
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(LNREER) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-14.97394	0.0000
Test critical values:	1% level	-3.454626	
	5% level	-2.872121	
	10% level	-2.572482	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-14.94561	0.0000
Test critical values:	1% level	-3.992670	
	5% level	-3.426682	
	10% level	-3.136590	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-14.93709	0.0000
Test critical values:	1% level	-2.573619	
	5% level	-1.942013	
	10% level	-1.615909	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) has a unit root
Exogenous: Constant
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-14.97394	0.0000
Test critical values:	1% level	-3.454626	
	5% level	-2.872121	
	10% level	-2.572482	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-14.94561	0.0000
Test critical values:	1% level	-3.992670	
	5% level	-3.426682	
	10% level	-3.136590	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) has a unit root
Exogenous: None
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-14.93709	0.0000
Test critical values:	1% level	-2.573619	
	5% level	-1.942013	
	10% level	-1.615909	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) is stationary
Exogenous: Constant
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.051924
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(LNREER) is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.051603
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Appendix B.5-3b: ADF, PP and KPSS tests in levels and first differences for economic policy uncertainty index (LNEPU)

Null Hypothesis: LNEPU has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.081310	0.0292
Test critical values:	1% level	-3.454719	
	5% level	-2.872162	
	10% level	-2.572503	

*MacKinnon (1996) one-sided p-values.
Null Hypothesis: LNEPU has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.727480	0.0008
Test critical values:	1% level	-3.992670	
	5% level	-3.426682	
	10% level	-3.136590	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNEPU has a unit root
Exogenous: Constant
Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-4.707134	0.0001
Test critical values:	1% level	-3.454534	
	5% level	-2.872081	
	10% level	-2.572460	

*MacKinnon (1996) one-sided p-values.
Null Hypothesis: LNEPU has a unit root
Exogenous: None
Lag Length: 2 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.189678	0.6171
Test critical values:	1% level	-2.573652	
	5% level	-1.942017	
	10% level	-1.615906	

*MacKinnon (1996) one-sided p-values.
Null Hypothesis: LNEPU has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-6.366760	0.0000
Test critical values:	1% level	-3.992540	
	5% level	-3.426619	
	10% level	-3.136553	

*MacKinnon (1996) one-sided p-values.
Null Hypothesis: LNEPU has a unit root
Exogenous: None
Bandwidth: 19 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-0.091195	0.6514
Test critical values:	1% level	-2.573587	
	5% level	-1.942008	
	10% level	-1.615912	

*MacKinnon (1996) one-sided p-values.
Null Hypothesis: LNEPU is stationary
Exogenous: Constant
Bandwidth: 12 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		1.071649
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: LNEPU is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 11 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.136357
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(LNEPU) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-16.11917	0.0000
Test critical values:	1% level	-3.454719	
	5% level	-2.872162	
	10% level	-2.572503	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNEPU) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-16.09600	0.0000
Test critical values:	1% level	-3.992801	
	5% level	-3.426745	
	10% level	-3.136628	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNEPU) has a unit root
Exogenous: None
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-16.14913	0.0000
Test critical values:	1% level	-2.573652	
	5% level	-1.942017	
	10% level	-1.615906	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNEPU) has a unit root
Exogenous: Constant
Bandwidth: 14 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-29.40096	0.0000
Test critical values:	1% level	-3.454626	
	5% level	-2.872121	
	10% level	-2.572482	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNEPU) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 14 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-29.38486	0.0000
Test critical values:	1% level	-3.992670	
	5% level	-3.426682	
	10% level	-3.136590	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNEPU) has a unit root
Exogenous: None
Bandwidth: 14 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-29.42914	0.0000
Test critical values:	1% level	-2.573619	
	5% level	-1.942013	
	10% level	-1.615909	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNEPU) is stationary
Exogenous: Constant
Bandwidth: 20 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.058649
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(LNEPU) is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 20 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.044370
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Appendix B.5-3c: ADF, PP and KPSS tests in levels and first differences for terms of trade (LNTOT)

Null Hypothesis: LNTOT has a unit root
Exogenous: Constant
Lag Length: 4 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.500781	0.5319
Test critical values:	1% level	-3.454906	
	5% level	-2.872244	
	10% level	-2.572547	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNTOT has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.805235	0.0000
Test critical values:	1% level	-3.992540	
	5% level	-3.426619	
	10% level	-3.136553	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNTOT has a unit root
Exogenous: None
Lag Length: 4 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.123336	0.2374
Test critical values:	1% level	-2.573718	
	5% level	-1.942026	
	10% level	-1.615900	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNTOT has a unit root
Exogenous: Constant
Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-5.228514	0.0000
Test critical values:	1% level	-3.454534	
	5% level	-2.872081	
	10% level	-2.572460	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNTOT has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-6.423745	0.0000
Test critical values:	1% level	-3.992540	
	5% level	-3.426619	
	10% level	-3.136553	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNTOT has a unit root
Exogenous: None
Bandwidth: 21 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-3.079344	0.0022
Test critical values:	1% level	-2.573587	
	5% level	-1.942008	
	10% level	-1.615912	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNTOT is stationary
Exogenous: Constant
Bandwidth: 10 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		1.045927
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: LNTOT is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 10 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.219333
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)
Null Hypothesis: LNTOT is stationary
Exogenous: Constant
Lag Length: 3 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-13.22714	0.0000
Test critical values:	1% level	-3.454906	
	5% level	-2.872244	
	10% level	-2.572547	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNTOT) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 3 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-13.37471	0.0000
Test critical values:	1% level	-3.993066	
	5% level	-3.426874	
	10% level	-3.136704	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNTOT) has a unit root
Exogenous: None
Lag Length: 3 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-13.24072	0.0000
Test critical values:	1% level	-2.573718	
	5% level	-1.942026	
	10% level	-1.615900	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNTOT) has a unit root
Exogenous: Constant
Bandwidth: 92 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-25.96648	0.0000
Test critical values:	1% level	-3.454626	
	5% level	-2.872121	
	10% level	-2.572482	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNTOT) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 75 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-28.86437	0.0000
Test critical values:	1% level	-3.992670	
	5% level	-3.426682	
	10% level	-3.136590	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNTOT) has a unit root
Exogenous: None
Bandwidth: 94 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-25.52941	0.0000
Test critical values:	1% level	-2.573619	
	5% level	-1.942013	
	10% level	-1.615909	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNTOT) is stationary
Exogenous: Constant
Bandwidth: 114 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.458078
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(LNTOT) is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 86 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.124435
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Appendix B.5-3d: ADF, PP and KPSS tests in levels and first differences for real interest rates (RIR)

Null Hypothesis: RIR has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.613109	0.4745	
Test critical values:	1% level	-3.454626	
	5% level	-2.872121	
	10% level	-2.572482	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: RIR has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.991902	0.1364
Test critical values:	1% level	-3.992670	
	5% level	-3.426682	
	10% level	-3.136590	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: RIR has a unit root
Exogenous: None
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.846281	0.0619
Test critical values:	1% level	-2.573619	
	5% level	-1.942013	
	10% level	-1.615909	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: RIR has a unit root
Exogenous: Constant
Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.642610	0.4594
Test critical values:	1% level	-3.454534	
	5% level	-2.872081	
	10% level	-2.572460	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: RIR has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-3.050919	0.1205
Test critical values:	1% level	-3.992540	
	5% level	-3.426619	
	10% level	-3.136553	

*MacKinnon (1996) one-sided p-values.
Null Hypothesis: RIR has a unit root
Exogenous: None
Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.865565	0.0593
Test critical values:	1% level	-2.573587	
	5% level	-1.942008	
	10% level	-1.615912	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: RIR is stationary
Exogenous: Constant
Bandwidth: 12 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		1.828222
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: RIR is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 12 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.079918
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(RIR) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-13.37303	0.0000
Test critical values:	1% level	-3.454626	
	5% level	-2.872121	
	10% level	-2.572482	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(RIR) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-13.35153	0.0000
Test critical values:	1% level	-3.992670	
	5% level	-3.426682	
	10% level	-3.136590	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(RIR) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-13.34219	0.0000
Test critical values:	1% level	-2.573619	
	5% level	-1.942013	
	10% level	-1.615909	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(RIR) has a unit root
Exogenous: Constant
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-13.39093	0.0000
Test critical values:	1% level	-3.454626	
	5% level	-2.872121	
	10% level	-2.572482	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(RIR) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-13.36990	0.0000
Test critical values:	1% level	-3.992670	
	5% level	-3.426682	
	10% level	-3.136590	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(RIR) has a unit root
Exogenous: None
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-13.36313	0.0000
Test critical values:	1% level	-2.573619	
	5% level	-1.942013	
	10% level	-1.615909	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(RIR) is stationary
Exogenous: Constant
Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.035468
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(RIR) is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.030026
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Appendix B.5-4: ARDL model

a) ARDL representation

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LNREER (-1)	1.058644	0.062546	16.92581	0.0000
LNREER (-2)	-0.120534	0.061400	-1.963093	0.0508
LNEPU	-0.008285	0.002270	-3.649448	0.0003
LNTOT	0.007703	0.034791	0.221405	0.8250
LNTOT (-1)	-0.074981	0.040522	-1.850392	0.0655
LNTOT (-2)	0.080121	0.040745	1.966408	0.0504
LNTOT (-3)	-0.100526	0.041436	-2.426039	0.0160
LNTOT (-4)	0.090643	0.042556	2.129947	0.0342
LNTOT (-5)	-0.005501	0.042738	-0.128715	0.8977
LNTOT (-6)	0.055727	0.042604	1.308016	0.1921
LNTOT (-7)	-0.041519	0.043174	-0.961661	0.3372
LNTOT (-8)	-0.077016	0.043296	-1.778822	0.0765
LNTOT (-9)	0.094751	0.038931	2.433836	0.0157
RIR	0.002043	0.001184	1.725169	0.0858
C	0.329264	0.087231	3.774615	0.0002
R-squared	0.983829	Mean dependent var	4.726721	
Adjusted R-squared	0.982909	S.D. dependent var	0.112576	
S.E. of regression	0.014717	Akaike info criterion	-5.543820	
Sum squared resid	0.053284	Schwarz criterion	-5.338963	
Log likelihood	738.4686	Hannan-Quinn criter.	-5.461474	
F-statistic	1069.039	Durbin-Watson stat	1.989196	

b) ARDL long run and bounds test

Conditional Error Correction Regression				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.329264	0.087231	3.774615	0.0002
LNREER(-1)*	-0.061890	0.018043	-3.430238	0.0007
LNEPU**	-0.008285	0.002270	-3.649448	0.0003
LNTOT(-1)	0.029401	0.048264	0.609170	0.5430
RIR**	0.002043	0.001184	1.725169	0.0858
D(LNREER(-1))	0.120534	0.061400	1.963093	0.0508
D(LNTOT)	0.007703	0.034791	0.221405	0.8250
D(LNTOT(-1))	-0.096680	0.053232	-1.816187	0.0706
D(LNTOT(-2))	-0.016558	0.052949	-0.312718	0.7548
D(LNTOT(-3))	-0.117084	0.052674	-2.222811	0.0271
D(LNTOT(-4))	-0.026442	0.052061	-0.507899	0.6120
D(LNTOT(-5))	-0.031943	0.049994	-0.638938	0.5235
D(LNTOT(-6))	0.023784	0.047244	0.503423	0.6151
D(LNTOT(-7))	-0.017735	0.044001	-0.403061	0.6873
D(LNTOT(-8))	-0.094751	0.038931	-2.433836	0.0157
* p-value incompatible with t-Bounds distribution.				
** Variable interpreted as Z = Z(-1) + D(Z).				
Levels Equation				
Case 2: Restricted Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNEPU	-0.133868	0.046602	-2.872589	0.0044
LNTOT	0.475051	0.799107	0.594477	0.5527
RIR	0.033007	0.013359	2.470743	0.0142
C	5.320126	0.242339	21.95323	0.0000
EC = LNREER - (-0.1339*LNEPU + 0.4751*LNTOT + 0.0330*RIR + 5.3201)				
F-Bounds Test	Null Hypothesis: No levels relationship			
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	4.616071	10%	2.37	3.2
k	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66
Actual Sample Size	261		Finite Sample: n=80	
		10%	2.474	3.312
		5%	2.92	3.838
		1%	3.908	5.044

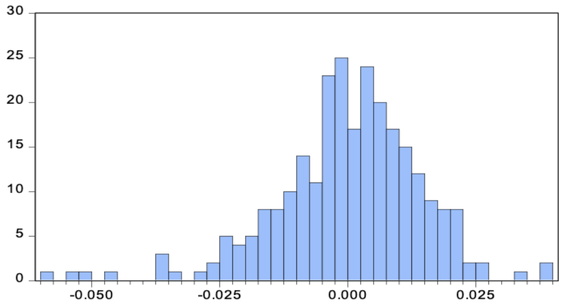
c) ARDL Error correction model

Case 2: Restricted Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D (LNREER (-1))	0.120534	0.059778	2.016355	0.0448
D(LNTOT)	0.007703	0.033905	0.227192	0.8205
D (LNTOT (-1))	-0.096680	0.037097	-2.606162	0.0097
D (LNTOT (-2))	-0.016558	0.040111	-0.412809	0.6801
D (LNTOT (-3))	-0.117084	0.043950	-2.664013	0.0082
D (LNTOT (-4))	-0.026442	0.045035	-0.587146	0.5576
D (LNTOT (-5))	-0.031943	0.044189	-0.722866	0.4704
D (LNTOT (-6))	0.023784	0.042506	0.559536	0.5763
D(LNTOT (-7))	-0.017735	0.040881	-0.433819	0.6648
D(LNTOT (-8))	-0.094751	0.037637	-2.517520	0.0125
CointEq(-1)*	-0.061890	0.013216	-4.683082	0.0000
R-squared	0.162786	Mean dependent var	-0.001133	
Adjusted R-squared	0.129297	S.D. dependent var	0.015646	
S.E. of regression	0.014599	Akaike info criterion	-5.574472	
Sum squared resid	0.053284	Schwarz criterion	-5.424243	
Log likelihood	738.4686	Hannan-Quinn criter.	-5.514085	
Durbin-Watson stat	1.989196			

* p-value incompatible with t-Bounds distribution.

F-Bounds Test	Null Hypothesis: No levels relationship			
Test Statistic	Value	Signif.	I (0)	I (1)
F-statistic	4.616071	10%	2.37	3.2
k	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66

d) Jacque-Bera normality test



Series: Residuals	
Sample 1998M10 2020M06	
Observations 261	
Mean	1.79e-15
Median	0.000895
Maximum	0.039966
Minimum	-0.057901
Std. Dev.	0.014316
Skewness	-0.778057
Kurtosis	5.054377
Jarque-Bera	72.23125
Probability	0.000000

e) Breusch-Godfrey Serial Correlation LM

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	0.177150	Prob. F (2,244)	0.8378
Obs*R-squared	0.378434	Prob. Chi-Square (2)	0.8276

f) ARCH test

Heteroskedasticity Test: ARCH			
F-statistic	23.73557	Prob. F (1,258)	0.0000
	21.90440	Prob. Chi-Square (1)	0.0000

g) Ramsey Reset test

Ramsey RESET Test			
Equation: UNTITLED			
Specification: LNREER LNREER (-1) LNREER (-2) LNEPU LNTOT LNTOT(-1) LNTOT(-2) LNTOT(-3) LNTOT(-4) LNTOT(-5) LNTOT(-6) LNTOT(-7) LNTOT(-8) LNTOT(-9) RIR C			
Omitted Variables: Squares of fitted values			
	Value	df	Probability
t-statistic	1.865969	245	0.0632
F-statistic	3.481839	(1, 245)	0.0632

Appendix C

Appendix C.6-1a: ADF, PP and KPSS tests in levels and first differences for inflation (INF)

Null Hypothesis: INF has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob. *
Augmented Dickey-Fuller test statistic		-2.416175	0.1382
Test critical values:	1% level	-3.454353	
	5% level	-2.872001	
	10% level	-2.572417	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: INF has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.380189	0.3891
Test critical values:	1% level	-3.992283	
	5% level	-3.426494	
	10% level	-3.136480	

*MacKinnon (1996) one-sided p-values.
Null Hypothesis: INF has a unit root
Exogenous: None
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.161600	0.2238
Test critical values:	1% level	-2.573523	
	5% level	-1.941999	
	10% level	-1.615917	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: INF has a unit root
Exogenous: Constant
Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-2.521725	0.1114
Test critical values:	1% level	-3.454263	
	5% level	-2.871961	
	10% level	-2.572396	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: INF has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-2.484515	0.3356
Test critical values:	1% level	-3.992156	
	5% level	-3.426433	
	10% level	-3.136443	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: INF has a unit root
Exogenous: None
Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.194684	0.2124
Test critical values:	1% level	-2.573491	
	5% level	-1.941995	
	10% level	-1.615920	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: INF is stationary
Exogenous: Constant
Bandwidth: 13 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.217767
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: INF is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 13 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.210007
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)
Null Hypothesis: D(INF) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-13.75929	0.0000
Test critical values:	1% level	-3.454353	
	5% level	-2.872001	
	10% level	-2.572417	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(INF) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-13.75178	0.0000
Test critical values:	1% level	-3.992283	
	5% level	-3.426494	
	10% level	-3.136480	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(INF) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-13.78128	0.0000
Test critical values:	1% level	-2.573523	
	5% level	-1.941999	
	10% level	-1.615917	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(INF) has a unit root
Exogenous: Constant
Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-13.85648	0.0000
Test critical values:	1% level	-3.454353	
	5% level	-2.872001	
	10% level	-2.572417	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(INF) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-13.84872	0.0000
Test critical values:	1% level	-3.992283	
	5% level	-3.426494	
	10% level	-3.136480	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(INF) has a unit root
Exogenous: None
Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-13.87823	0.0000
Test critical values:	1% level	-2.573523	
	5% level	-1.941999	
	10% level	-1.615917	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(INF) is stationary
Exogenous: Constant
Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.067339
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(INF) is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.036674
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Appendix C.6-1b: ADF, PP and KPSS tests in levels and first differences for economic policy uncertainty (LNEPU)

Null Hypothesis: LNEPU has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.080276	0.0292
Test critical values:	1% level	-3.454443	
	5% level	-2.872041	
	10% level	-2.572439	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNEPU has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.752469	0.0007
Test critical values:	1% level	-3.992283	
	5% level	-3.426494	
	10% level	-3.136480	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNEPU has a unit root
Exogenous: None
Lag Length: 2 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.189041	0.6173
Test critical values:	1% level	-2.573555	
	5% level	-1.942004	
	10% level	-1.615915	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNEPU has a unit root
Exogenous: Constant
Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-4.675859	0.0001
Test critical values:	1% level	-3.454263	
	5% level	-2.871961	
	10% level	-2.572396	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNEPU has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-6.405924	0.0000
Test critical values:	1% level	-3.992156	
	5% level	-3.426433	
	10% level	-3.136443	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNEPU has a unit root
Exogenous: None
Bandwidth: 19 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-0.045025	0.6670
Test critical values:	1% level	-2.573491	
	5% level	-1.941995	
	10% level	-1.615920	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNEPU is stationary
Exogenous: Constant
Bandwidth: 13 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		1.037423
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: LNEPU is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 13 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.123448
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(LNEPU) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-16.20965	0.0000
Test critical values:	1% level	-3.454443	
	5% level	-2.872041	
	10% level	-2.572439	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNEPU) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-16.18584	0.0000
Test critical values:	1% level	-3.992411	
	5% level	-3.426557	
	10% level	-3.136516	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNEPU) has a unit root
Exogenous: None
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-16.23916	0.0000
Test critical values:	1% level	-2.573555	
	5% level	-1.942004	
	10% level	-1.615915	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNEPU has a unit root
Exogenous: None
Bandwidth: 19 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-0.045025	0.6670
Test critical values:	1% level	-2.573491	
	5% level	-1.941995	
	10% level	-1.615920	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNEPU is stationary
Exogenous: Constant
Bandwidth: 13 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		1.037423
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: LNEPU is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 13 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.123448
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(LNEPU) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-16.20965	0.0000
Test critical values:	1% level	-3.454443	
	5% level	-2.872041	
	10% level	-2.572439	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNEPU) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-16.18584	0.0000
Test critical values:	1% level	-3.992411	
	5% level	-3.426557	
	10% level	-3.136516	

*MacKinnon (1996) one-sided p-values.

Appendix C.6-1c: ADF, PP and KPSS tests in levels and first differences for real effective exchange rate (LNREER)

Null Hypothesis: LNREER has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.978727	0.7613
Test critical values:	1% level	-3.454263	
	5% level	-2.871961	
	10% level	-2.572396	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNREER has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.114828	0.5348
Test critical values:	1% level	-3.992156	
	5% level	-3.426433	
	10% level	-3.136443	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNREER has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.045747	0.2664
Test critical values:	1% level	-2.573491	
	5% level	-1.941995	
	10% level	-1.615920	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNREER has a unit root
Exogenous: Constant
Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.149505	0.6965
Test critical values:	1% level	-3.454263	
	5% level	-2.871961	
	10% level	-2.572396	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNREER has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-2.400110	0.3786
Test critical values:	1% level	-3.992156	
	5% level	-3.426433	
	10% level	-3.136443	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNREER has a unit root
Exogenous: None
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-0.946667	0.3060
Test critical values:	1% level	-2.573491	
	5% level	-1.941995	
	10% level	-1.615920	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: LNREER is stationary
Exogenous: Constant
Bandwidth: 14 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		1.453970
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: LNREER is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 14 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.107501
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(LNREER) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-14.63568	0.0000
Test critical values:	1% level	-3.454353	
	5% level	-2.872001	
	10% level	-2.572417	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-14.61209	0.0000
Test critical values:	1% level	-3.992283	
	5% level	-3.426494	
	10% level	-3.136480	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-14.61275	0.0000
Test critical values:	1% level	-2.573523	
	5% level	-1.941999	
	10% level	-1.615917	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) has a unit root
Exogenous: Constant
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-14.63565	0.0000
Test critical values:	1% level	-3.454353	
	5% level	-2.872001	
	10% level	-2.572417	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-14.61216	0.0000
Test critical values:	1% level	-3.992283	
	5% level	-3.426494	
	10% level	-3.136480	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) has a unit root
Exogenous: None
Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-14.61405	0.0000
Test critical values:	1% level	-2.573523	
	5% level	-1.941999	
	10% level	-1.615917	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(LNREER) is stationary
Exogenous: Constant
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.055845
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(LNREER) is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.051315
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Appendix C.6-1d: ADF, PP and KPSS tests in levels and first differences for unemployment (UN)

Null Hypothesis: UN has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.193910	0.6778
Test critical values:	1% level	-3.454443	
	5% level	-2.872041	
	10% level	-2.572439	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: UN has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 2 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.201839	0.9075
Test critical values:	1% level	-3.992411	
	5% level	-3.426557	
	10% level	-3.136516	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: UN has a unit root
Exogenous: None
Lag Length: 2 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.575981	0.4671
Test critical values:	1% level	-2.573555	
	5% level	-1.942004	
	10% level	-1.615915	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: UN has a unit root
Exogenous: Constant
Bandwidth: 10 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.190762	0.6791
Test critical values:	1% level	-3.454263	
	5% level	-2.871961	
	10% level	-2.572396	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: UN has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 10 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.206834	0.9065
Test critical values:	1% level	-3.992156	
	5% level	-3.426433	
	10% level	-3.136443	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: UN has a unit root
Exogenous: None
Bandwidth: 10 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-0.726678	0.4011
Test critical values:	1% level	-2.573491	
	5% level	-1.941995	
	10% level	-1.615920	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: UN is stationary
Exogenous: Constant
Bandwidth: 14 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.296791
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: UN is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 14 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.299974
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Null Hypothesis: D(UN) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.932476	0.0000
Test critical values:	1% level	-3.454443	
	5% level	-2.872041	
	10% level	-2.572439	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(UN) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.916662	0.0000
Test critical values:	1% level	-3.992411	
	5% level	-3.426557	
	10% level	-3.136516	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(UN) has a unit root
Exogenous: None
Lag Length: 1 (Automatic - based on SIC, maxlag=15)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.940805	0.0000
Test critical values:	1% level	-2.573555	
	5% level	-1.942004	
	10% level	-1.615915	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(UN) has a unit root
Exogenous: Constant
Bandwidth: 8 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-12.72215	0.0000
Test critical values:	1% level	-3.454353	
	5% level	-2.872001	
	10% level	-2.572417	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(UN) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 8 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-12.70446	0.0000
Test critical values:	1% level	-3.992283	
	5% level	-3.426494	
	10% level	-3.136480	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(UN) has a unit root
Exogenous: None
Bandwidth: 8 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob. *
Phillips-Perron test statistic		-12.72297	0.0000
Test critical values:	1% level	-2.573523	
	5% level	-1.941999	
	10% level	-1.615917	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(UN) is stationary
Exogenous: Constant
Bandwidth: 10 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.175156
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

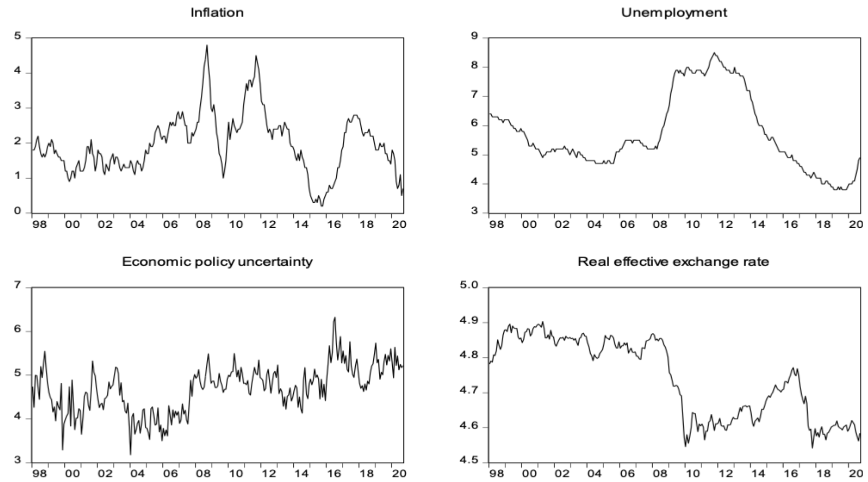
Null Hypothesis: D(UN) is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 10 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.170534
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

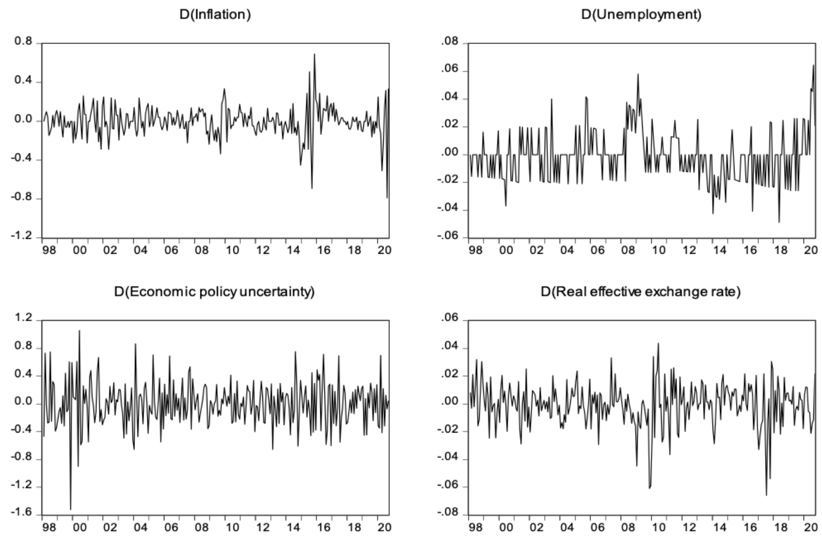
*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Appendix C.6-2: Variables representation

a) Data representation for variables in levels



b) Variables representation in their first differences



c) Summary statistics for variables in first differences

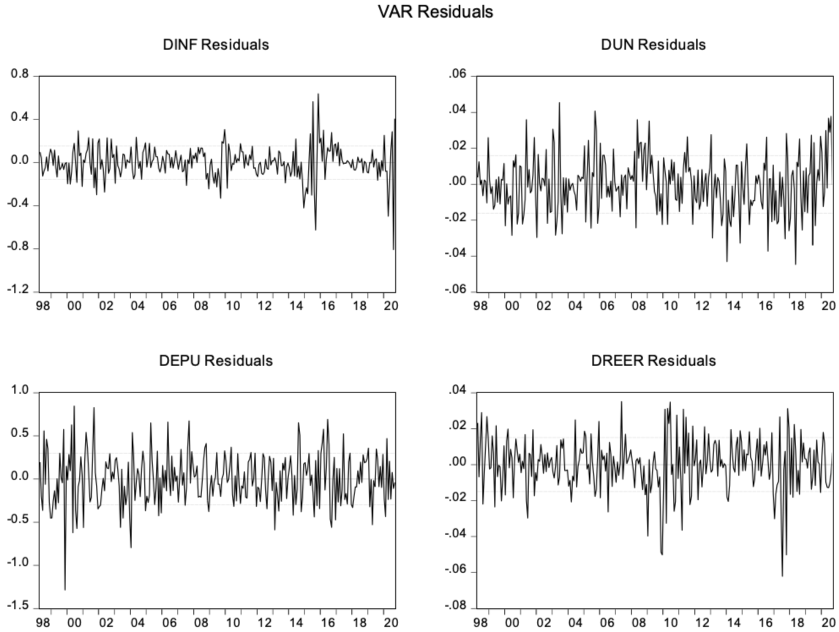
	DINF	DUN	DEPU	DREER
Mean	-0.003472	-0.000982	0.001763	-0.000728
Median	0.000000	0.000000	0.012743	4.41E-05
Maximum	0.693147	0.064539	1.055358	0.043682
Minimum	-0.788457	-0.048790	-1.523046	-0.065858
Std. Dev.	0.153082	0.017503	0.322781	0.015487
Skewness	-0.485048	0.549993	-0.125607	-0.727843
Kurtosis	8.231345	3.866895	4.631434	5.272351
Jarque-Bera	320.8246	22.23007	30.87976	82.53615
Probability	0.000000	0.000015	0.000000	0.000000
Sum	-0.944462	-0.267063	0.479500	-0.198012
Sum Sq. Dev.	6.350667	0.083024	28.23482	0.065000
Observations	272	272	272	272

Appendix C.6-3: Lag length selection model

Lag	LogL	LR	FPE	AIC	SC
0	900.4098	NA	1.19e-08	-6.895460	-6.840681
1	949.3456	95.98938	9.23e-09	-7.148812	-6.874914*
2	973.8356	47.28458	8.65e-09*	-7.214120*	-6.721103
3	985.6697	22.48479	8.94e-09	-7.182075	-6.469939
4	995.9368	19.19149	9.34e-09	-7.137975	-6.206720
5	1005.958	18.42274	9.79e-09	-7.091981	-5.941607
6	1016.195	18.50587	1.02e-08	-7.047652	-5.678159
7	1029.731	24.05321	1.05e-08	-7.028702	-5.440090
8	1042.291	21.93207	1.08e-08	-7.002242	-5.194511
9	1047.278	8.553684	1.17e-08	-6.917522	-4.890673
10	1056.256	15.12522	1.24e-08	-6.863510	-4.617542
11	1061.480	8.639877	1.35e-08	-6.780619	-4.315532
12	1086.553	40.69470*	1.27e-08	-6.850408	-4.166202

Appendix C.6-4: VAR residuals representation and validity check

a) Residuals representation



b) Autocorrelation LM test for VAR residuals

VAR Residual Serial Correlation LM Tests
Sample: 1998M01 2020M09
Included observations: 270

Null hypothesis: No serial correlation at lag h						
Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	24.21180	16	0.0850	1.523129	(16, 776.6)	0.0850
2	21.51536	16	0.1595	1.351162	(16, 776.6)	0.1596
Null hypothesis: No serial correlation at lags 1 to h						
Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	24.21180	16	0.0850	1.523129	(16, 776.6)	0.0850
2	41.88285	32	0.1134	1.317090	(32, 923.5)	0.1135

*Edgeworth expansion corrected likelihood ratio statistic.

c) Normality test VAR residuals

VAR Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
Null Hypothesis: Residuals are multivariate normal
Sample: 1998M01 2020M09
Included observations: 270

Component	Skewness	Chi-sq	df	Prob.*
1	-0.255286	2.932687	1	0.0868
2	-0.021533	0.020864	1	0.8851
3	-0.061515	0.170287	1	0.6799
4	-0.647760	18.88166	1	0.0000
Joint		22.00550	4	0.0002

Component	Kurtosis	Chi-sq	df	Prob.
1	3.410631	1.896954	1	0.1684
2	3.311522	1.091767	1	0.2961
3	3.859209	8.305198	1	0.0040
4	4.842499	38.19151	1	0.0000
Joint		49.48543	4	0.0000

Component	Jarque-Bera	df	Prob.
1	4.829640	2	0.0894
2	1.112631	2	0.5733
3	8.475485	2	0.0144
4	57.07317	2	0.0000
Joint	71.49092	8	0.0000

*Approximate p-values do not account for coefficient estimation

d) Heteroskedasticity test VAR residuals

ARCH (multivariate)
data: Residuals of VAR
Chi-squared = 2408.7, df = 2400, p-value = 0.4465

Appendix C.6-5: VAR model estimation and Johansen cointegration test

a) VAR (2) model estimation

Vector Autoregression Estimates
Sample (adjusted): 1998M04 2020M09
Included observations: 270 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	D(INF)	D(UN)	D(LNEPU)	D(LNREER)
D (INF (-1))	0.166990	0.035711	0.065595	0.005729
	(0.06180)	(0.02498)	(0.08487)	(0.00419)
	[2.70219]	[1.42968]	[0.77285]	[1.36686]
D (INF (-2))	0.055963	-0.001543	0.063718	-0.011569
	(0.06281)	(0.02539)	(0.08626)	(0.00426)
	[0.89102]	[-0.06079]	[0.73867]	[-2.71555]
D (UN (-1))	-0.102735	0.258333	0.120528	-0.029908
	(0.14493)	(0.05858)	(0.19905)	(0.00983)
	[-0.70885]	[4.40986]	[0.60551]	[-3.04228]
D (UN (-2))	0.026151	0.271043	0.007377	0.019787
	(0.14910)	(0.06027)	(0.20478)	(0.01011)
	[0.17539]	[4.49742]	[0.03602]	[1.95644]
D (LNEPU (-1))	0.027974	-0.023767	-0.368481	-0.000444
	(0.04391)	(0.01775)	(0.06031)	(0.00298)
	[0.63702]	[-1.33899]	[-6.10960]	[-0.14893]
D (LNEPU (-2))	-0.007140	-0.026569	-0.192662	-0.006688
	(0.04367)	(0.01765)	(0.05998)	(0.00296)
	[-0.16350]	[-1.50524]	[-3.21228]	[-2.25799]
D (LNREER (-1))	0.187181	0.144828	0.404832	0.126647
	(0.88543)	(0.35789)	(1.21606)	(0.06006)
	[0.21140]	[0.40467]	[0.33291]	[2.10874]
D (LNREER (-2))	-1.752793	-0.932403	0.921534	0.007307
	(0.87793)	(0.35485)	(1.20575)	(0.05955)
	[-2.09651]	[-2.62757]	[0.76428]	[0.12271]
C	-0.005264	-0.002226	0.004926	-0.000917
	(0.01345)	(0.00544)	(0.01847)	(0.00091)
	[-0.39134]	[-0.40945]	[0.26665]	[-1.00501]
R-squared	0.050832	0.221764	0.138979	0.093802
Adj. R-squared	0.021739	0.197910	0.112587	0.066026
Sum sq. resids	12.54122	2.048894	23.65580	0.057700
S.E. equation	0.219205	0.088601	0.301057	0.014868
F-statistic	1.747205	9.296729	5.266057	3.377086
Log likelihood	31.25571	275.8381	-54.41354	757.7612
Akaike AIC	-0.164857	-1.976578	0.469730	-5.546380
Schwarz SC	-0.044910	-1.856631	0.589677	-5.426432
Mean dependent	-0.004166	-0.005185	0.000815	-0.001011
S.D. dependent	0.221627	0.098930	0.319585	0.015385
Determinant resid covariance (dof adj.)		7.45E-09		
Determinant resid covariance		6.51E-09		
Log likelihood		1012.335		
Akaike information criterion		-7.232113		
Schwarz criterion		-6.752323		
Number of coefficients		36		

b) VAR (2) for cointegration test

Vector Autoregression Estimates
Sample (adjusted): 1998M03 2020M09
Included observations: 271 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	INF	UN	LNREER
INF (-1)	1.156258	0.041386	0.003000
	(0.06047)	(0.02520)	(0.00421)
	[19.1226]	[1.64205]	[0.71345]
INF (-2)	-0.196611	-0.014793	-0.003937
	(0.06175)	(0.02574)	(0.00429)
	[-3.18420]	[-0.57477]	[-0.91685]
UN (-1)	0.018942	1.290335	-0.023115
	(0.14140)	(0.05894)	(0.00983)
	[0.13396]	[21.8926]	[-2.35047]
UN (-2)	-0.015984	-0.301180	0.023804
	(0.14007)	(0.05839)	(0.00974)
	[-0.11411]	[-5.15836]	[2.44350]
LNREER (-1)	-0.076428	-0.096778	1.093388
	(0.86947)	(0.36242)	(0.06047)
	[-0.08790]	[-0.26703]	[18.0813]
LNREER (-2)	0.087960	0.081434	-0.104908
	(0.86974)	(0.36253)	(0.06049)
	[0.10113]	[0.22462]	[-1.73434]
C	0.007166	0.075204	0.048710
	(0.58953)	(0.24573)	(0.04100)
	[0.01216]	[0.30604]	[1.18803]
R-squared	0.934947	0.995175	0.981255
Adj. R-squared	0.933469	0.995065	0.980829
Sum sq. resids	12.57551	2.184958	0.060828
S.E. equation	0.218253	0.090974	0.015179
F-statistic	632.3716	9074.518	2303.249
Log likelihood	31.50249	268.6484	753.9152
Akaike AIC	-0.180830	-1.930985	-5.512289
Schwarz SC	-0.087787	-1.837941	-5.419245
Mean dependent	1.954613	5.717343	4.494843
S.D. dependent	0.846150	1.295017	0.109628
Determinant resid covariance (dof adj.)		9.08E-08	
Determinant resid covariance		8.40E-08	
Log likelihood		1054.074	
Akaike information criterion		-7.624164	
Schwarz criterion		-7.345033	
Number of coefficients		21	

c) Trace statistics test and maximum eigenvalues test in the Johansen cointegration test

Sample (adjusted): 1998M04 2020M09
Included observations: 270 after adjustments
Trend assumption: No deterministic trend
Series: INF UN LNREER
Lags interval (in first differences): 1 to 2
Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.052889	18.19174	24.27596	0.2410
At most 1	0.007440	3.520113	12.32090	0.7788
At most 2	0.005554	1.503705	4.129906	0.2581

Trace test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.052889	14.67163	17.79730	0.1390
At most 1	0.007440	2.016408	11.22480	0.9211
At most 2	0.005554	1.503705	4.129906	0.2581

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Sample (adjusted): 1998M04 2020M09
Included observations: 270 after adjustments
Trend assumption: No deterministic trend (restricted constant)
Series: INF UN LNREER
Lags interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.052898	19.63024	35.19275	0.7496
At most 1	0.011278	4.956178	20.26184	0.9824
At most 2	0.006990	1.893885	9.164546	0.7987

Trace test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.052898	14.67406	22.29962	0.4023
At most 1	0.011278	3.062293	15.89210	0.9896
At most 2	0.006990	1.893885	9.164546	0.7987

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Sample (adjusted): 1998M04 2020M09
Included observations: 270 after adjustments
Trend assumption: No deterministic trend
Series: INF UN LNREER
Lags interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.052889	18.19174	24.27596	0.2410
At most 1	0.007440	3.520113	12.32090	0.7788
At most 2	0.005554	1.503705	4.129906	0.2581

Trace test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.052889	14.67163	17.79730	0.1390
At most 1	0.007440	2.016408	11.22480	0.9211
At most 2	0.005554	1.503705	4.129906	0.2581

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Sample (adjusted): 1998M04 2020M09
Included observations: 270 after adjustments
Trend assumption: No deterministic trend (restricted constant)
Series: INF UN LNREER
Lags interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.052898	19.63024	35.19275	0.7496
At most 1	0.011278	4.956178	20.26184	0.9824
At most 2	0.006990	1.893885	9.164546	0.7987

Trace test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.052898	14.67406	22.29962	0.4023
At most 1	0.011278	3.062293	15.89210	0.9896
At most 2	0.006990	1.893885	9.164546	0.7987

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Sample (adjusted): 1998M04 2020M09
Included observations: 270 after adjustments
Trend assumption: Quadratic deterministic trend
Series: INF UN LNREER
Lags interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.054661	25.14824	35.01090	0.3750
At most 1	0.029434	9.971140	18.39771	0.4833
At most 2	0.007029	1.904608	3.841466	0.1676

Trace test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.054661	15.17710	24.25202	0.4823
At most 1	0.029434	8.066532	17.14769	0.5956
At most 2	0.007029	1.904608	3.841466	0.1676

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

d) Information Criteria by Rank and Model in the Johansen Cointegration test

Sample: 1998M01 2020M09
Included observations: 270
Series: INF UN LNREER
Lags interval: 1 to 2

Selected (0.05 level*) Number of Cointegrating Relations by Model					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	0	0	0	0	0
Max-Eig	0	0	0	0	0
*Critical values based on MacKinnon-Haug-Michelis (1999)					
Information Criteria by Rank and Model					
Data Trend:	None	None	Linear	Linear	Quadratic
Rank or No. of CEs	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Log Likelihood by Rank (rows) and Model (columns)					
0	1059.256	1059.256	1059.981	1059.981	1060.125
1	1066.592	1066.593	1067.317	1067.612	1067.714
2	1067.600	1068.124	1068.619	1071.676	1071.747
3	1068.352	1069.071	1069.071	1072.699	1072.699
Akaike Information Criteria by Rank (rows) and Model (columns)					
0	-7.713006	-7.713006	-7.696152	-7.696152	-7.675000
1	-7.722901*	-7.715502	-7.706054	-7.700830	-7.686767
2	-7.685924	-7.674992	-7.671252	-7.679084	-7.672199
3	-7.647049	-7.630155	-7.630155	-7.634808	-7.634808
Schwarz Criteria by Rank (rows) and Model (columns)					
0	-7.473111*	-7.473111*	-7.416275	-7.416275	-7.355140
1	-7.403041	-7.382315	-7.346212	-7.327660	-7.286943
2	-7.286100	-7.248513	-7.231445	-7.212622	-7.192409

Appendix C.6-6: Granger Causality test

a) Granger Causality Test

VAR Granger Causality/Block Exogeneity Wald Tests
Sample: 1998M01 2020M09
Included observations: 270

Dependent variable: D(INF)			
Excluded	Chi-sq	df	Prob.
D(UN)	0.522837	2	0.7700
D(LNEPU)	0.629823	2	0.7299
D(LNREER)	3.409563	2	0.1818
All	4.317651	6	0.6338
Dependent variable: D(UN)			
Excluded	Chi-sq	df	Prob.
D(INF)	2.391614	2	0.3025
D(LNEPU)	3.123925	2	0.2097
D(LNREER)	6.863879	2	0.0323
All	12.57292	6	0.0503
Dependent variable: D(LNEPU)			
Excluded	Chi-sq	df	Prob.
D(INF)	0.886236	2	0.6420
D(UN)	0.403547	2	0.8173
D(LNREER)	0.736224	2	0.6920
All	2.079932	6	0.9122
Dependent variable: D(LNREER)			
Excluded	Chi-sq	df	Prob.
D(INF)	7.951811	2	0.0188
D(UN)	10.06993	2	0.0065
D(LNEPU)	5.566713	2	0.0618
All	23.05816	6	0.0008

b) Pairwise Granger Causality test

Sample: 1998M01 2020M09
Lags: 2

Null Hypothesis	Obs	F-Statistic	Prob.
LNREER does not Granger Cause LNEPU	271	3.40958	0.0345**
LNEPU does not Granger Cause LNREER		9.25071	0.0001*
UN does not Granger Cause LNEPU	271	0.39366	0.6750
LNEPU does not Granger Cause UN		0.57012	0.5661
INF does not Granger Cause LNEPU	271	0.36983	0.6912
LNEPU does not Granger Cause INF		0.25443	0.7755
UN does not Granger Cause LNREER	271	3.90807	0.0212**
LNREER does not Granger Cause UN		0.48048	0.6190
INF does not Granger Cause LNREER	271	0.95718	0.3853
LNREER does not Granger Cause INF		0.00681	0.9932
INF does not Granger Cause UN	271	7.16978	0.0009*
UN does not Granger Cause INF		0.04307	0.9579

Note: * denotes the rejection at 1% significance level. **denotes the rejection at 5% significance level. *** denotes the rejection at 10% significance level.

Appendix C.6-7: IRFs of inflation rate, unemployment rate and real effective exchange rate to UK EPU shocks