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Asymmetric effects of oil shocks on economic policy uncertainty

Najmi Aimer [a, *], Abdulmula Lusta [b]

[a] Higher Institute of Marine Sciences Techniques, Sabratha, Libya
[b] University of Tripoli, Libya

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The aim of this paper is to investigate the asymmetric effects of the crude oil price on global economic policy uncertainty (EPU) using a nonlinear, autoregressive distributed lag approach. The results of the bounds test indicate that there is a long-run equilibrium relationship between economic uncertainty and crude oil price. Furthermore, we conclude that the long-run equilibrium relationship is a usual logical relationship and not a degraded relationship. The results of the asymmetric test also showed that the positive and negative shocks in oil prices do not have an asymmetric effect on the EPU in the long run and have an asymmetric effect in the short term. In addition, a negative shock may have a relatively greater effect in the long run compared to a positive shock while a positive shock may have a relatively greater impact in the short term compared to a negative shock. Our results are important to both investors interested in the oil market, as well as for policymakers.

1. Introduction

This research addresses an important question that has emerged in recent economic research; what is the asymmetric dynamic relationship between oil prices and the global economic policy uncertainty (EPU)? In particular, the research aims to study the asymmetric effects of the oil price on the EPU during the period (Q1:1997 to Q4:2020) by relying on a non-linear autoregressive distributed lag co-integration model that was developed by Shin et al. [1]. This modern approach allows the analysis of non-linear and symmetric integration relationships between variables.

Since oil is used as a production factor in various industries and is a major resource for fuel and power generation in the transportation sector, oil prices are an important macroeconomic variable for the economy (Hamilton [2]; Dbouk and Jamali [3]). For example, when oil prices rise, the increase in production costs in various industries can reduce gross production, profits, and investment, as well as cause inflation, leading to lower levels of real wages, prompting monetary authorities to adopt contractionary monetary policies, thus leading to a secondary effect on the economy (Herrera et al. [4]; Köse and Ünal [5]). In addition, in the oil market, prices are determined according to the general principle of supply and demand, but rapid price changes often occur due to geopolitical reasons. For example, several oil shocks occurred at the same time as supply disruptions caused by political events, most notably the Arab oil embargo in 1973–74, the Iranian revolution and the Iran-Iraq war in the late 1970s, and the Gulf War in 1990. More recently, unrest has been seen in the supply of political events in Iraq, Iran, Nigeria, Venezuela and Libya. In addition, these events may affect crude oil importers creating uncertainty about oil supplies and price volatility. On the other hand, geopolitical risks will affect economic activity to a certain extent, and thus cause uncertainty in the demand for oil. Moreover, in mid-December 2019, COVID-19, which began in the Chinese city of Wuhan, spread rapidly around the world, thus the demand for crude oil decreased, and global oil prices decreased in 2020 (Adedeji, Ahmed and Adam [6]). All these events caused a major change in oil prices, which means that the effect of oil prices on economic growth may be more important. In this context, the impact of oil prices on the economy and the confirmation of the long-term relationship between them is more urgent and necessary. These factors can be regarded as uncertainties that are difficult to predict in advance, and rapid fluctuations in oil prices due to uncertainties delay current consumption and investment to the future and raising the marginal

* Corresponding author.
E-mail address: najmimuftah@gmail.com (N. Aimer).

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cost of companies (Carruth et al. [7]). As a result, the present value of corporate stocks decreases, increasing uncertainty in the real and financial markets, negatively affecting economic activities (Pindyck [8]; Baumeister and Peersman [9]). In addition, since the first decade of the 21st century, oil-related uncertainties have increased due to increased volatility, regulations on oil use in industries, greenhouse gas problems and changes in oil policies and economic uncertainty. According to Bloom [10] and Baker at al. [11], the economic policy uncertainty index (EPU) has become a growing concern reflecting economic or political shocks, and the severity of recovery and recessions. Fig. 1 shows that oil prices and economic policy uncertainty move roughly in the opposite direction. In this paper, we explore this area further by exploring the question of the asymmetric relationships of oil prices with economic policy uncertainty. In particular, since the financial crisis, the rapid rise (decrease) of oil prices and the increase (decrease) of economic uncertainty occurred together, confirming that uncertainty and oil prices are more closely related. Economic policy uncertainty remained high even after 2014, except for the reversal in trend between 2017 and 2019. The uncertainty reached an all-new high in 2020 with the COVID-19 outbreak. Oil prices also declined significantly during these periods. These phenomena suggest that oil price shocks may be related to economic policy uncertainty, and thus it is important to analyze the dependency structure between oil prices and economic uncertainty.

In fact, in economic literature, the importance of separating oil price shocks is important in order to assess their real impact on the economy and to increase our understanding of the effects of these prices (Kilian and Park [12]; Kilian [13]; Baumeister and Peersman [9]; Degiannakis et al. [14]; Awartani et al. [15]; Nusair and Olson [16]). In addition, the previous literature does not study the kind of the cointegration relationship (nonsensical or either of the usual kind or valid, but degraded).

Therefore, our first contribution to the existing literature is the assessment of the impact of the asymmetry of crude oil prices on the global economic policy uncertainty (EPU). This is the first paper that applies a nonlinear ARDL approach to test the type of relationship between an oil price shock and economic policy uncertainty.

In this respect, this paper makes a unique contribution to the existing literature because it (i) to our knowledge, there is no empirical study examining the asymmetric effects of oil prices and the global economic policy uncertainty within a framework of cointegration. (ii) The literature identifying oil price shocks (positive and negative) is limited. In addition, in this process, it has been implicitly assumed that positive and negative oil price shocks will have similar effects on EPU in the long-run. Therefore, this study attempts to verify a non-linear relationship between oil price and economic uncertainty, using the newly developed NARDL approach developed by Shin et al. [1] which enables us to test the relationships simultaneously in the short and long run; it also allows measuring the corresponding reaction to EPU to changes in its regression. Moreover, this model has the advantage of being able to analyze the characteristics of the dependence structure between variables in consideration of extreme events. On the other hand, there is the problem that uncertainty is a variable that is difficult to capture directly. For this purpose, our study aims to answer the following questions:

- First, if there are different effects of positive and negative oil prices on uncertainty, how are these effects explained?
- Second, how important is the impact of positive and negative shocks of oil price changes on EPU?
- Third, is the equilibrating relationship between dependent variables and repressors is entirely?

Given the importance of economic policy uncertainty in the wake of the global financial crisis (GFC) and the COVID-19 crisis, it is critical that policy makers consider how economic policy uncertainty functions as a channel through which oil price shocks are transmitted to the macroeconomy.

In general, the method of decoupling oil price shocks is distinguished by capturing the full dynamics of the relationship between the EPU index and oil. In this context, these findings are important to policymakers and investors. More specifically, it is important for investors to understand that during volatile periods, attention should be drawn to the uncertainty index in economic policy, given the fact that the uncertainty index affects the market in which they operate. On the other hand, policymakers should exercise caution when formulating macroeconomic policies in relatively stable times, as oil price shocks can undermine the successful and important outcomes of such policies.

This paper is organized as follows. The second section reviews the theoretical background and previous studies on the relationship between oil prices and economic uncertainty, the third section reviews the methodology and data to be used in the analytical models. The fourth section discusses the results of the empirical analysis between the oil price and economic uncertainty, and the fifth section summarizes the conclusions drawn from the results of the empirical analysis and presents their implications.

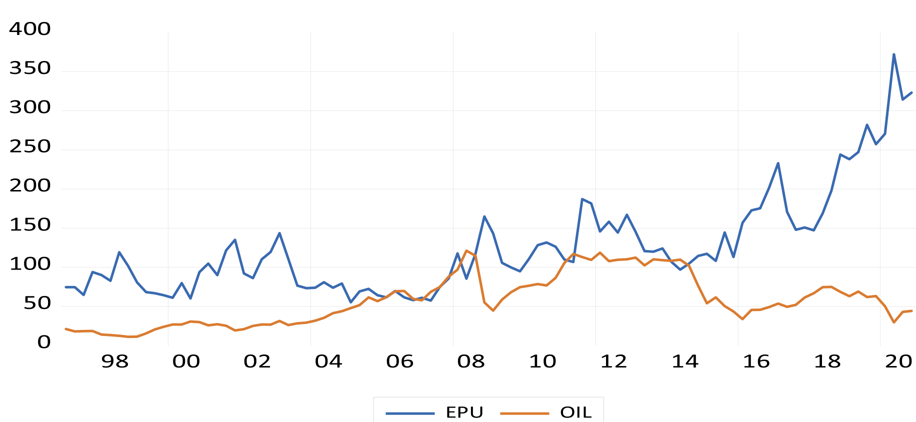

Fig. 1. Global Economic Policy Uncertainty and crude oil prices.

2. Literature review

In this section, we will literature review that analyzed the relationship between oil prices and the EPU. It is known that variables such as oil prices cause fluctuations in crude oil prices and fluctuations in oil prices rather than oil prices themselves to lead to an increase in EPU. Bernanke [17] notes that high uncertainty provides firms with an incentive to delay their investments when investment projects are costly to reverse. If an increase of EPU, consumption and investment are postponed to the future, negatively affecting economic activity, reducing oil demand and lowering oil prices. In addition, when oil prices fluctuate significantly, uncertainty arises in economic activities such as consumption, investment, cost, and profit (Elder and Serletis [18]). Sun et al. [19] explored the relationship between economic policy uncertainty and the price of oil and found that in the short term, there is no correlation between these two variables. Although, there is a strong correlation between these two variables in the medium and long term. As such, uncertainty and oil price have a mutually dependent relationship, so analyzing the relationship between the two variables is an important research topic (Herrera et al. [20]). Recently, Antonakakis [21,22], found that oil price shocks negatively affect the dynamic correlations of economic policy uncertainty because an increase in EPU can lead to a massive demand shock. In this context, Kang and Ratti [23] and Antonakakis et al. [22] emphasized that oil price shocks and economic policy uncertainty respond to each other negatively. According to Bloom [10]; Kang and Ratti [24], there is a positive effect of specific demand shocks on the uncertainty while a negative effect of an aggregate demand shock. Sun et al. [19] also found that the oil price shock has a short-term negative impact on economic policy uncertainty while positively affecting the long-term. More recently, many researchers have found that changes in oil prices are a specific driver of the EPU (Wei et al. [25]; Barrero et al. [26]). Additionally, Yang [27] revealed that oil prices are downstream of economic policy uncertainty. Some researchers have found that the asymmetric relationship between oil prices and EPU and that the uncertainty related to exchange rates and monetary policy are the drivers of the shocks of EPU and oil prices (Aimer [28]; Zhu, Liao and Chen [29]). Moreover, the effects of the EPU shock are much greater for negative oil price shocks than for positive shocks, especially during the 2007–2009 financial crisis (Lyu et al. [30]). Qin et al. [31] examined the relationship between the price of oil and US economic policy uncertainty and monetary, financial and trade policy, where they found that the effects of EPU on oil prices are both positive and negative and that EPU can affect the oil market. In contrast, oil prices have a positive effect on EPU, indicating that the bullish oil market is causing an increased EPU. The results also show evidence of asymmetric effects between uncertainty about stock market volatility and oil prices and vary according to cases of low and high price movements in crude oil (Dutta, Bouri and Saeed [32]). Kitous et al. [33] studied the relationship between uncertainty and oil price volatility. The nonlinear autoregressive distributed lag model (NARDL) results show an asymmetric short-run impact of global geopolitical risks on crude oil prices, however, an asymmetric long-run effect of economic policy uncertainty and global geopolitical risks on crude oil prices. In the same context, a pioneering study conducted by Kang and Ratti [23] found that uncertainty in economic policy and oil price shocks are interrelated and jointly affect the stock market. In a recent paper, Demir et al. [34] using the Non-Linear Distributed Lag Framework (NARDL) for the period before and after the COVID-19 outbreak, found that global economic policy uncertainty leads to lower real stock returns in Turkey for both sample periods. In addition, in the long run, positive changes in real oil prices have relatively fewer effects compared to negative changes on real stock returns, while positive changes in oil prices negatively affect the short run for the pre- and post-Covid-19 period. In addition, in long-run, geopolitical risks have positive effects on real stock returns for both periods. Finally, they found that Turkish real stock returns react less to the domestic response than to bad news caused by global factors.

Elder and Serletis [35] presented that the real economy is negatively affected by the increase in the total cost and marginal cost of a company due to the uncertainty arising from changes in oil prices. In particular, Elder and Serletis [35] presented the result that it had a negative effect on durable goods and fixed investment through an indirect route, suggesting the reason for paying attention to the relationship between oil price and economic uncertainty. Therefore, it is important to uncover the main factors driving EPU in order to facilitate effective macroeconomic management. In addition, although widening economic uncertainty and high oil prices are linked, it has been reported by several studies such as Scholtens and Yurtsever [36]; Xiao et al. [37] of an asymmetric relationship between lower EPU and lower oil prices. Most of the literature is based on the economic policy uncertainty of the USA, but the impact of the crude oil price on global economic policy uncertainty still needs some new insights. Other research also indicates that global economic policy uncertainty has a significant difference in terms of fiscal and monetary policy with other countries, in this regard, we believe that global economic policy uncertainty needs special attention. However, the uncertainty about global economic policy requires more attention to address the uncertainty about the policy of countries during the COVID-19 period.

However, none of this literature focuses on the asymmetric effects of the oil price shocks on the global economic policy uncertainty. Therefore, we fill this gap and test the effect of Brent crude oil prices on the global economic policy uncertainty. To our knowledge, this is the first paper that deals with the asymmetric relationship of oil prices on the economic uncertainty caused by global economic policy. Moreover, is the cointegration relationship illogical, or is it of the usual kind or correct, but degraded?

3. Methodology

3.1. Data and variables

In this study, we use quarterly data from 1997: Q1 to 2020: Q4 to detect the asymmetric effects of oil prices on economic policy uncertainty, we present the data descriptions in Table 1.

Given the importance that uncertainty has been taking, other methodologies have been sought to measure it, one of them is the frequency in which words appear in press articles, the economic policy uncertainty constructed by Baker et al. [11]. According to Baker et al. [11], this index is based on the gross domestic product-weighted average of the EPU indices for 21 countries. Each of these indicators reflects the relative frequency of country newspaper articles containing three terms related to economics, politics and uncertainty.

Additionally, the Chicago Board Options Exchange Volatility Index (CBOE) is a forward-looking measure of volatility expected within 30 days of the US stock market (that is, it represents what today's investors believe volatility will be in the future) it reflects what options traders think about future market volatility. The VIX is based on S&P 500 index prices and is calculated by aggregating short options over a wide range of strike prices and weighted index prices. The most important distinguishing feature of the VIX is the forward-looking nature of options prices. Accordingly, it has been shown that in terms of measuring volatility and forecasting the implied volatility index is more informative than historical

Table 1
Variable definition.

Variable	Symbol	Source
Global Economic Policy Uncertainty	*EPU*	Federal Reserve Bank of St. Louis
CBOE Volatility Index	*VIX*	Federal Reserve Bank of St. Louis
Crude Oil Prices: West Texas Intermediate (WTI)	*OILP*	Federal Reserve Bank of St. Louis

volatility (Maghyereh et al. [38]). However, all variables are in their natural logarithmic forms to eliminate the effect of heteroscedasticity on the empirical results.

3.2. Methodology

The traditional ARDL method by Pesaran et al. [39] ignores the nature of the asymmetric relationship for the dependent and independent variables as shown in Eq. (1).

$$\begin{aligned}\Delta \ln(EPU)_t = \beta_0 &+ \sum_{i=1}^{n1} \beta_{1i}\Delta\ln(EPU)_{t-i} + \sum_{i=0}^{n2} \beta_{2i}\Delta ln(VIX)_{t-i} \\ &+ \sum_{i=0}^{n3} \beta_{3i}\Delta\ln(OILP)_{t-j} + \lambda_0 \ln(EPU)_{t-1} \\ &+ \lambda_1 ln(VIX)_{t-1} + \lambda_2 ln(OILP)_{t-1} + \eta_t\end{aligned} \tag{1}$$

where $(\beta_1, \beta_2, \beta_3)$ denote the short run multipliers and $(\lambda_0, \lambda_1, \lambda_2)$ long-run coefficients. EPU_t represents EPU at time t, β_0 is a drift term. Furthermore, Δln indicates the first differences after taking the logarithm of each variable.

In contrast to the ARDL model, the NARDL model distinguishes asymmetric modulation of positive and negative shocks on the variable shown. This means that this model can detect if there are any short-run and long-run asymmetries in the model.

To investigate the asymmetric effects of both long- and short-run nonlinearities in the relationship between oil price shocks and EPU, we use the NARDL technique. The Autoregressive Distributed Lag (ARDL) model assumes that the dependent variable responds similarly to negative and positive changes in the explanatory variable.

To address the asymmetric effect the model can be modified in Eq. (1), so that the vector of the variable (OILP) is decomposed into a positive and negative partial sum as shown in Eq. (2).

Eq. (2) introduces the asymmetric NARDL model, where all the variables are described in Table 1. The long-run asymmetry of variables is tested using Wald's test where the null hypothesis assumes that:

$\lambda_3 = \lambda_4$. Conversely, in the short term, the null hypothesis is that: $\beta_4 = \beta_5$. Rejecting the null hypothesis implies an asymmetric relationship.

To uncover the asymmetric effects between oil price and economic uncertainty, we use the methodology by Shin et al. [1] as shown in Eq. (2).

$$\begin{aligned} OILP_t^- &= \sum_{J=1}^{t} \Delta OILP_j^- = \sum_{j=1}^{t} \min(\Delta OILP_j, 0) \\ OILP_t^+ &= \sum_{J=1}^{t} \Delta OILP_j^+ = \sum_{j=1}^{t} \max(\Delta OILP_j, 0)\end{aligned} \tag{2}$$

The short and long run asymmetry of the oil price on economic uncertainty can be described as shown in Eq. (3).

$$\begin{aligned}\Delta \ln(EPU)_t = \beta_0 &+ \sum_{i=1}^{n1} \beta_{1i}\Delta EPU_{t-i} + \sum_{i=0}^{n2} \beta_{2i}\Delta VIX_{t-i} + \sum_{i=0}^{n3} \beta_{3i}^{+}\Delta OILP_{t-i} \\ &{}^{+} + \sum_{i=0}^{n4} \beta_{4i}^{-}\Delta OILP_{t-i}^{-} + \lambda_0 \ln(EPU)_{t-1} + \lambda_1 \ln(VIX)_{t-1} \\ &+ \lambda_2^{+} OILP_{t-1}^{+} + \lambda_2^{-} OILP_{t-1}^{-} + \varepsilon_t\end{aligned} \tag{3}$$

where $LOILP^- = \frac{-\lambda_2^-}{\lambda_0}$ and $LOILP^+ = \frac{-\lambda_2^+}{\lambda_0}$ are the long-run coefficients of negative and positive shocks of oil prices, respectively. The negative and positive superscripts stand for the partial sums of positive and negative shocks of the oil price, β_{3i}^{+} *and* β_{4i}^{-} the short-run coefficients of negative and positive shocks of oil prices, respectively. ε_t is the error term.

After estimating the NARDL model, the existence of the asymmetric co-integration between the variables is tested using Fisher test-F, according to the following two hypotheses:

Null hypothesis: $H_0 : \lambda_0 = \lambda_1 = {\lambda_2}^+ = {\lambda_2}^- = 0$ (no asymmetric co-integration), versus the alternative hypothesis which states $H_1 :$ $\lambda_0 \neq \lambda_1 \neq {\lambda_2}^+ \neq {\lambda_2}^- \neq 0$ (asymmetric co-integration).

For the bounds test, a comparison of F-statistic with the two critical values of a bounds test by Pesaran et al. [39]. If the F-statistic is less than the minimum critical value, we accept the null hypothesis (no co-integration), and if the F statistic is higher than the higher critical value, we reject the null hypothesis, and we accept the alternative hypothesis, i.e. the existence of an equilibrium relationship between the variables.

Additionally, from the t-Bounds test, if the absolute value of the t-statistic is greater than the absolute value of I (0) or I (1) t-bound then we reject the null hypothesis of the T-Bounds test, this indicating the cointegrating relationship of either usual kind, or valid but it is degenerate. On the other hand, if the value of t is less than the absolute value of I (0) or I (1) t-bound, we accept the null hypothesis of the T-Bounds test and conclude that the cointegrating relationship is in fact nonsensical (see appendix A).

To reveal the kind of relationship in terms of the usual kind, or valid but it is degraded, we rely on the following two cases. Degenerate case (i) is the situation where the lagged dependent variable is significant but not for lagged independent variables, while degenerate case (ii) is the situation where significant for lagged independent variables but lagged dependent variable is significant (See McNown et al. [40]). In order to observe cointegration, we use NARDL bounds test approach, which is developed by Shin et al. [1]. The main advantage of this approach is that, it is applicable even if the variables are $I(0)$, I (1) or mutually cointegrated. Moreover, the series need not to be integrated in the same order to find a cointegrating relationship. Furthermore, the ARDL method provides unbiased estimates and valid t-statistics, irrespective of the homogeneity of some regressors.

The NARDL method is characterized by an additional test, which is the long-run symmetry test in which the next null hypothesis is tested, also using the Wald test. $H_0 : {\lambda_2}^+ = {\lambda_2}^-$, as shown in Eq. (4).

$$LOILP^{-} = \frac{-\lambda_2^{-}}{\lambda_0} \text{ and } LOILP^{+} = \frac{-\lambda_2^{+}}{\lambda_0} \tag{4}$$

Hence, the long-run asymmetry of negative and positive oil price impacts on the EPU will accept the long-run symmetry hypothesis.

The asymmetric effects in the short term of negative and positive oil prices on EPU can also serve as a Wald test of the null hypothesis of symmetry $H_0: \sum_{i=0}^{q}(\lambda_{1i}^{+}) = \sum_{i=0}^{q}(\lambda_{1i}^{-})$ against $H_1: \sum_{i=0}^{q}(\lambda_{1i}^{+}) \neq \sum_{i=0}^{q}(\lambda_{1i}^{-})$.

After verifying the symmetry test between oil prices and economic uncertainty, the asymmetric responses to the negative and positive oil price shocks are captured by the dynamic multipliers as shown in Eq. (5).

$$m_h^{-} = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial OILP_t^{-}} \; m_h^{+} = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial OILP_t^{+}} \tag{5}$$

where $h \to \infty$, $m_h^{-} \to a_1^{-}$, and $m_h^{+} \to a_1^{+}$, $h = 0, 1, 2, \ldots$ for $OILP^{-}$ *and* $OILP^{+}$; $OILP_h^{-} \to \beta_1$, $OILP_h^{+} \to \beta_1$

a_1^{-} and a_1^{+} are long-run coefficients that capture the asymmetric effects of oil price changes on the EPU.

To analysis, the paths of adjustment from disequilibrium to long-term equilibrium while following negative or positive partials sum of the oil price ($OILP^{-}$ *and* $OILP^{+}$), the multiplier adds useful information for short and long-run asymmetry patterns (see Charfeddine and Barkat [41]).

Finally, for model reliability, we apply diagnostic and stability test tests: Breusch-Godfrey Serial Correlation LM test is used for autocorrelation; heteroskedasticity test (ARCH) for autoregressive conditional heteroskedasticity; Jarque-Bera for testing normality. Heteroskedasticity test (Breusch-Pagan-Godfrey); Heteroskedasticity test (Harvey). Finally, to prevent bias and false inferences, we will use diagnostic tests (CUSUM and CUSUMQ tests) to check the independence of the residues in the model (see appendix A).

3.3. Lagrange multiplier (LM) unit root test

The Augmented Dickey-Fuller (*ADF*) and Phillips-Perron (*PP*) unit root *test* have low power if there are structural breaks or nonlinearities (e.g., Perron et al. [42]). Therefore, we rely on the LM unit root test by Lee and Strazicich [43] to improve the power of the unit root test as in Eq. (6).

$$y_t = \tilde{\delta} Z_t + \varepsilon_t, \; \varepsilon_t = \beta \varepsilon_{t-1} + u_t, \; u_t \sim iidN\left(0, \sigma^2\right) \tag{6}$$

where Z_t, is a vector of exogenous variables. The test for unit roots is based on the parameter β and the H_0 is $\beta = 1$. To accommodate a structural break in the intercept and a change in the slope of the trend, the vector of exogenous variables Z_t is specified as $Z_t = [1, t, D_t, DT_t]$, where $DT_t = t - T_B$ for $t > TB + 1$, and zero otherwise. TB denotes the time when a break occurs. To endogenously determine the location of the break, the LM unit-root procedure searches all possible break points with minimum unit-root t-test statistic in order to find the greatest lower bound as in Eq. (7).

$$LM_t = \inf \breve{T}(\bar{\lambda}) = inf_{\lambda} T\lambda, \; were \; \lambda = T_B \Big/ T \tag{7}$$

$\lambda \in (0, 1)$ is the proportion of observations occurring prior to the break, T is the total number of observations (sample size).

4. Empirical results and discussion

4.1. Unit root tests

At this stage, we conduct the stability test of the variables in order to determine the non-stationary properties and determine the degree of their integration as a prerequisite in the process of building models, especially the NARDL model that is not concerned with the degree of integrity of the chain, except for its integration in the second-order. Wherefore, we use the famous tests ADF and PP in the test of the presence of the unit root. Table 2 displays the stability results of the original variables using the ADF and PP test statistics.

The findings suggest that the variables are integrated of order $I(1)$ or $I(0)$. Based on these findings, we can utilize the NARDL model without any hesitation. To examine the asymmetric effects of oil price shocks (*OILP*) on the global economic policy uncertainty (EPU), our study focuses on the oil price variable due to high volatility in this variable. To this end, we use the non-linear autoregressive distributed lag co-integration (NARDL) approach to capture these positive and negative shocks in oil prices.

4.2. Lee-strazicich (2003) unit root test

The null hypothesis is rejected when the LM test statistics are greater than the critical values established by Lee and Strazicich [43], while rejection of the null hypothesis indicates a non-stationary process. The Time break 1 and Time break 2 columns of Table 3 show the estimated break point for each variable.

The t-statistics as in the second column show that all variables are not stationary at level, but are stationary at the first difference at the 1% significance level. From Table 3 the fourth and fifth columns indicate the dates of the structural breaks as defined economically by the procedure. As shown in Table 3, the dates of breaking the levels and the differences differ from one variable to another. The sixth and seventh columns represent the test results when there are breaks in the data generation process level. In addition, the results of the breaks test in the trend of the data are presented in the eighth and ninth columns. As we can see, the minimum LM test statistics are lower than the critical values at conventional significance levels for each variable. Therefore, we can reject the null hypothesis and this indicates that all of our variables are stationary at the first difference.

4.3. Estimate the co-integration relationship (non-linear ARDL model)

Table 4 shows, in the short run, that the estimated parameter of positive oil price shock has a statistically significant negative effect on the EPU; we conclude that increasing the positive oil price shock by 1% will reduce the EPU by 60%. Thus, positive oil prices may be among the most important drivers of economic policy uncertainty in the short-run, this result is consistent with the findings of (Barrero et al. [26]; Jeris and Nath [44]). While there is no significant effect of negative oil price shock on EPU. To avoid this dangerous situation, the results of this study can be used as an aid to policy-minded researchers. In addition, specialists in this matter should announce some policy packages related to the control of policy uncertainty. Since the results of this study also indicate a strong relationship in the short run between a positive oil price shock and economic policy uncertainty, therefore, policymakers should be more careful when implementing macroeconomic policies because positive oil price shocks can destroy the effective

Table 2
Unit root estimation of ADF and PP.

Variable	$I(0)$				$I(1)$			
	ADF		PP		ADF		PP	
	C	C&T	C	C&T	C	C&T	C	C&T
EPU	0.667	0.963	−0.820	−2.140	−9.173[a]	−9.376[a]	−11.494[a]	−12.085[a]
VIX	−3.971[a]	0.009[a]	−4.023[a]	−4.010[a]	−9.378[a]	−9.340[a]	−13.041[a]	−13.097[a]
oilp	−1.874	−1.553	−1.906	0.727	−7.984[a]	−8.050[a]	−7.734[a]	−8.045[a]

Notes: [a], indicate statistical significance at levels of 1%. The optimal lag selection is based on Akaike Information Criteria (AIC).

Table 3
Results of the unit root test of Lee and Strazicich [43].

	T-stat.	Lag	TB_1	TB_2	$B_1(t)$	$B_2(t)$	$D_1(t)$	$D_2(t)$	Critical Values		
Level									1%	5%	10%
EPU	−4.42	3	$2007Q_1$	$2013Q_3$	−24.84 (-1.05)	22.90 (0.93)	13.75 (2.180)	−34.41 (-3.15)	−6.97	−6.28	−5.99
OIL	−5.85	1	$2005Q_1$	$2014Q_4$	−6.53 (-0.75)	−16.57 (-1.85)	13.36 (4.26)	−7.30 (-2.92)	−7.03	−6.37	−6.01
VIX	−4.38	7	$2004Q_4$	$2011Q_4$	1.52 (0.27)	−7.36 (-1.33)	−3.77 (-2.02)	−6.09 (-3.13)	−6.97	−6.28	−5.99
First Difference											
EPU	−10.22	1	$2016Q_2$	$2017Q_4$	65.75 (2.50)	22.97 (0.92)	−37.79 (-3.33)	40.38 (2.99)	−6.75	−6.10	−5.77
OIL	−10.23	1	$2007Q_4$	$2009Q_1$	66.84 (6.29)	−14.43 (-1.57)	−44.07 (-7.34)	37.20 (6.65)	−6.86	−6.26	−5.95
VIX	−11.90	1	$2008Q_2$	$2009Q_2$	65.12 (11.62)	−4.59 (-0.90)	−36.43 (-11.14)	42.30 (11.92)	−6.86	−6.26	−5.95

Notes: The null hypothesis: Variable has a unit root. The number of lags was set at maximum 8. TB_1 and TB_2 refer to the time of the breaks. The numbers in parentheses represent the T-statistics.

Table 4
Short and long run non-linear ARDL model results.

Variable	Short-run coefficient	t-Statistic	Prob.
C	1.143***	8.731	0.000
@*TREND*	0.005***	7.075	0.000
$DLNEPU_{t-1}$	0.108	1.291	0.239
$DLNEPU_{t-2}$	−0.010	−0.113	0.910
$DLNEPU_{t-3}$	0.237***	2.887	0.005
$DLNOIL^{+}$	−0.510***	−2.958	0.004
$DLNOIL^{+}_{t-1}$	0.096	0.197	0.627
$DLNOIL^{+}_{t-2}$	−0.468**	−2.459	0.016
$DLNOIL^{-}$	0.158	1.008	0.317
$DLNOIL^{-}_{t-1}$	0.451**	2.976	0.004
$DLNOIL^{-}_{t-2}$	0.306**	1.951	0.055
$DLNOIL^{-}_{t-3}$	0.399***	2.700	0.009
ECT_{t-1}	−0.620***	−9.225	0.000
R^2	0.64	Adjusted R^2	0.59
Variable	Long-run coefficient	t-Statistic	Prob.
$DLNOIL^{+}$	−0.159	−1.109	0.271
$DLNOIL^{-}$	−0.374***	−3.750	0.003
$LNVIX$	0.710***	7.072	0.000

F-Bounds Test Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	20.46***	10%	3.47	4.45
K	3	5%	4.01	5.07
		1%	5.17	6.36

T-Bounds Test	Value	Signif.	I(0)	I(1)
T-statistic	−9.22***	10%	−3.13	−3.84
		5%	−3.41	−4.16
		1%	−3.96	−4.73

Note: *,** and *** represent 1%, 5% and 10% significance level, respectively. ARDL Error Correction Regression, Dependent Variable: $D(LNEPU)$, Selected Model: ARDL(4, 3, 4, 0), Case 5: Unrestricted Constant and Unrestricted Trend.

Table 5
Asymmetry test results.

Wald long-run asymmetry test			
Test Statistic	Value	df	Probability
T-statistic	0.524	81	0.601
F-statistic	0.275	(1, 81)	0.601
χ^2	0.275	1	0.599
Wald short-run asymmetry test			
T-statistic	5.403	81	0.000
F-statistic	29.189	(1, 81)	0.000
χ^2	29.189	1	0.000

Note: Delta method computed using analytic derivatives.

outcomes of these policies. This paper will be a good insight for other researchers who will demonstrate their interest in this sector in the future. On the contrary, the long-run results as shown in Table (4) showed that the estimated parameter of negative oil price shock has a significant negative effect on the EPU; we conclude that an increase in the negative oil price shock of 1% would cause the EPU to decrease by 37%. While there is no significant impact of the positive oil price shock on EPU. In both cases (negative and positive oil prices), we note that the effect of oil price increases in the long-run is much greater (equivalent to double) than the impact of lower oil prices in the short term. These results are consistent with Lin et al. [45], who emphasized that the positive shock is stronger in the short term, while the negative shock is stronger in the medium and long term. Therefore, policy makers and investors should consider these situations.

In particular, the negative relationship between economic uncertainty and the oil price can be explained by changes in the transmission mechanism of price shocks. The results in Table 4, related to the error correction model (ECT_{t-1}), show that the ECT_{t-1} coefficient is negative and statistically significant at 1%, which indicates that there is a statistically significant relationship between the variables in the long-run. We also note that the effect of the volatility index (VIX) is positive on economic uncertainty, more specifically, when increasing the volatility index by 1%, it will lead to an increase in economic uncertainty by 80% in the long-run. As for the speed of the adjustments and the return to equilibrium in the long-run that achieves the stability of the system, it is equal to 0.62, meaning that 62% for every 3 months (Quarterly) of the positive imbalance in the previous period, is adjusted quarterly to return to the equilibrium in the long-run. The negative sign of the correction factor means that the value of economic uncertainty is higher than the equilibrium level, so the value of this variable begins to decrease in the subsequent period.

Although the variables are integrated in the same order $I(1)$, this unique order of integration allows us to apply the NARDL bounds test to determine the existence of cointegration between the variables. The results of the bounds test as shown in Table 5.

The F-statistic value 20.46 is evidently greater than the 1% critical value for the upper bound. This means that the dependent variable and the independent variables are cointegrated. Therefore, we reject the null hypothesis and accept the alternative hypothesis that there is a long-run equilibrium relationship between the economic uncertainty and the independent variables. Furthermore, the absolute value of t-bounds test statistic is greater than the 1% critical value for the upper bound. It indicates that we reject the null hypothesis and accept the alternative hypothesis; we conclude that the cointegrating relationship is not “Nonsensical”. This means that the cointegrating relationship is either “usual” or it is “degenerate cointegration”.

In fact, we can visualize the suitability of the long-run equation and the dependent variable by extracting the error correction mechanism (ECM) and subtracting from it the dependent variable. However, a look at the fit between the dependent variable and the equilibrating equation should lead us to believe that the relationship is indeed true as shown in Fig. 2.

To reveal the kind of co-integration relationship, is it of the usual kind, or is it correct but deteriorating?

Table 4, both two cases; “The first case, the late independent variables are significant, but for the lagged level of the dependent variable is insignificant. While the second case, the lagged level of

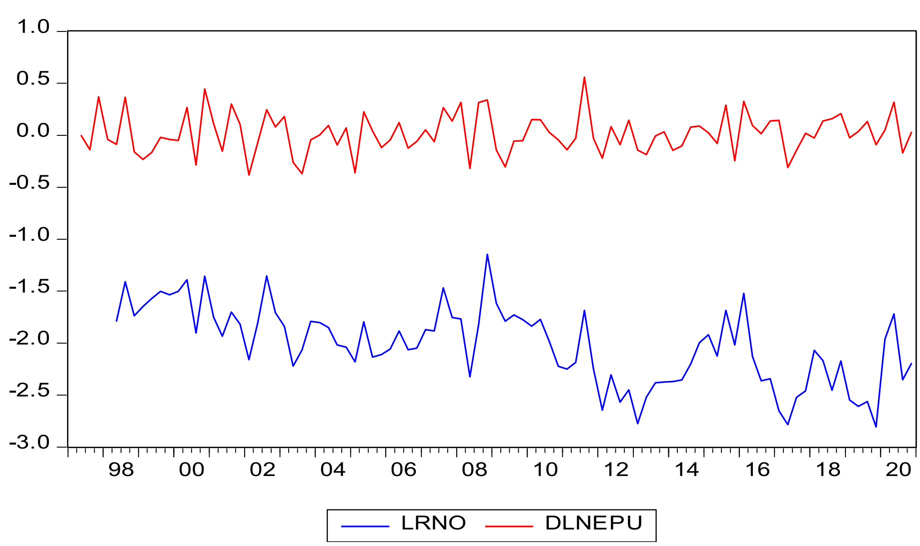

Fig. 2. Co-integration relationship between variables.

the dependent variable is significant, but for the lagged level of independent variables are insignificant" are not achieved, indicating that the logical relationship is a usual relationship and not degraded relationship.

4.4. Wald long-run asymmetry test

We notice through the results of the asymmetry test of Wald, the acceptance of the null hypothesis (asymmetric), and the rejection of the alternative hypothesis that there is symmetry, meaning that the positive and negative shocks in oil prices do not have an asymmetric effect on the EPU in the long-run. This result supports the results we obtained where we found that the EPU is not affected only by positive shocks. On the other hand, rejecting the null hypothesis (asymmetric), and accepting the alternative hypothesis that there is consistency, that is, positive and negative shocks in oil prices have an asymmetric effect on the EPU in the short term; this result supports the results we obtained, as we found that the EPU is affected by positive shocks only.

4.5. Dynamic non-linear multiplier results

Fig. 3 shows the dynamic multipliers effects of changes in oil prices of up to 15 quadrants, the thin dashed lines of red color indicating the confidence interval for this difference. In addition, the heavy dashed line in red color indicating the difference between the effect of positive and negative shocks of 1% for each. It can be seen in Fig. 3 that it takes about 7–8 quarters for the multiplier to work through their effects for a relatively stable effect to be achieved. An increase in oil prices appears to have a larger impact on the EPU than doing decrease in oil prices. According to the evidence in Fig. 3, the difference in effects appears to peak in the second and fifth quarters after the occurrence. The results in this paper indicate that upward movements in oil prices have impacts that are more negative on the EPU than downward movements. Furthermore, the impact of positive oil price shocks is greater in the short term than negative oil price shocks. In general, we can conclude that the dynamic multipliers also support the asymmetric effect of oil price variables on the previously existing uncertainty in NARDL model estimation. These findings are useful to both investors and policymakers who wish to engage in the oil market. Therefore, those interested and investors need to understand that the economic policy uncertainty indicator affects the markets differently.

4.6. Diagnostics tests

Moreover, the obtained results should be free from the heteroscedasticity of residuals or autocorrelation and misspecification. For the purpose of this, we apply the diagnostic and stability tests relating to specification, heteroscedasticity and autocorrelation tests as shown in Table 6.

The results of the ARCH and LM tests also show that there is no autocorrelation and heteroscedasticity problem. According to the results of Jarque-Bera (JB) that the error terms follow a normal distribution. In addition, from Fig. (4). CUSUM and CUSUM square graphs also confirm the stability of the coefficients in the model. Thus, all the tests presented in Table 5 confirm the reliability and

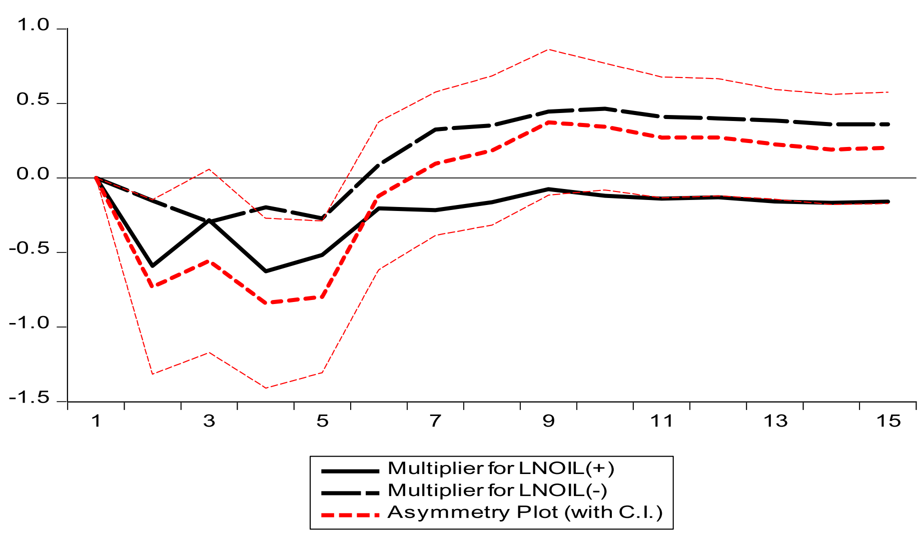

Fig. 3. Multiplier effects of changes in oil prices.

Table 6
Diagnostics tests.

Tests	F- statistics	Probability
LM test	1.752	0.181
Heteroskedasticity test by Glejser	1.000	0.464
ARCH	0.025	0.874
J-B normality	0.361	0.835
Heteroskedasticity test by Breusch-Pagan-Godfrey	0.950	0.515
Harvey test	1.604	0.093
CUSUM	stable	
CUSUMSQ	stable	

Notes: LM test is Breusch-Godfrey serial correlation, ARCH is heteroskedasticity test, J-B is Jarque-Bera normality, and Harvey test is heteroskedasticity test.

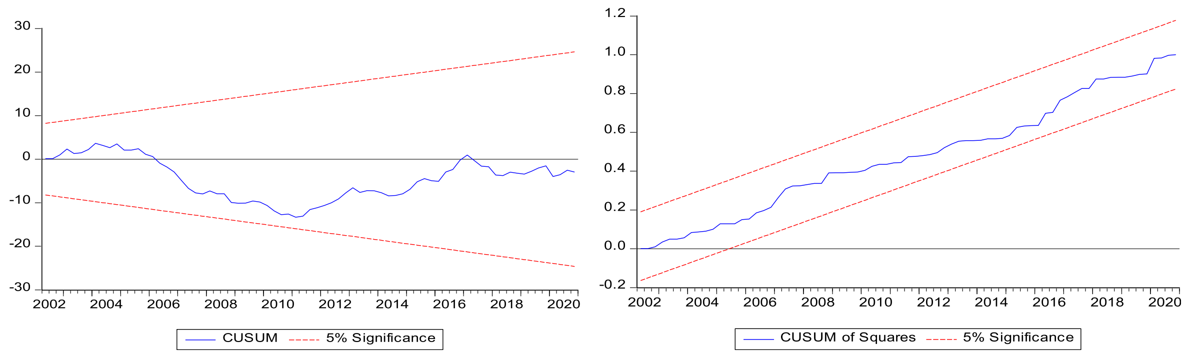

Fig. 4. CUSUM and CUSUMQ tests.

validity of the NARDL model estimates.

5. Conclusion

This paper revealed the asymmetric effects of the oil price on economic policy uncertainty for the period from 1997:Q1 to 2020:Q4 using a non-linear autoregressive distributed lag (NARDL) approach.

The results of the bounds test indicate that there is a long-run equilibrium relationship between the dependent variable (EPU) and the independent variables (oil price and VIX) and this relationship is a usual logical relationship and not a degraded relationship.

The short-run results showed that positive oil price shock has a statistically significant negative effect on the EPU. While there is no significant effect of negative oil price shock on EPU. On the contrary, in the long-run, the negative oil price shock has a significant negative effect on the EPU. While there is no significant impact of the positive oil price shock on EPU. We note that the effect of oil price increases in the long-run is much greater than the impact of lower oil prices in the short term. Regarding the error correction model, we find that the ECM_{t-1} coefficient is negative and statistically significant, indicating the existence of a statistically significant relationship between the variables in the long-run, meaning that the speed of adjustments and return to equilibrium in the long-run, which achieves 60% stability of the system. Given the results of the t-statistic of the bounds test, the long-run equilibrium relationship between the variables is a logical relationship from the usual kind and not a degraded relationship.

We found strong evidence of long-term asymmetry consistent, indicating that the EPU is more sensitive to oil price shocks. By comparing the results, that negative shock may have a greater absolute effect in the long run, while positive shock may have a greater absolute effect in the short term; this indicates a time-varying asymmetry. Moreover, the direction of asymmetry may change between the short and long term. Therefore, policymakers should consider these situations. In particular, the results of the asymmetry test, that the positive and negative shocks in oil prices do not have an asymmetric effect on the EPU in the long-run. On the other hand, that is, positive and negative shocks in oil prices have an asymmetric effect on the EPU in the short term. The results of our study are important to both policy makers and investors who want to get involved in the oil market. Therefore, investors need to understand that their markets are affected differently by uncertainty in economic policy.

Credit author statement

Nagmi Aimer: Conceptualization, Methodology, Software Data curation, Writing – original draft preparation, Supervision, Software, Validation, Writing- Reviewing and Editing. Abdulmula Lusta: Visualization, Investigation, Writing – original draft preparation.

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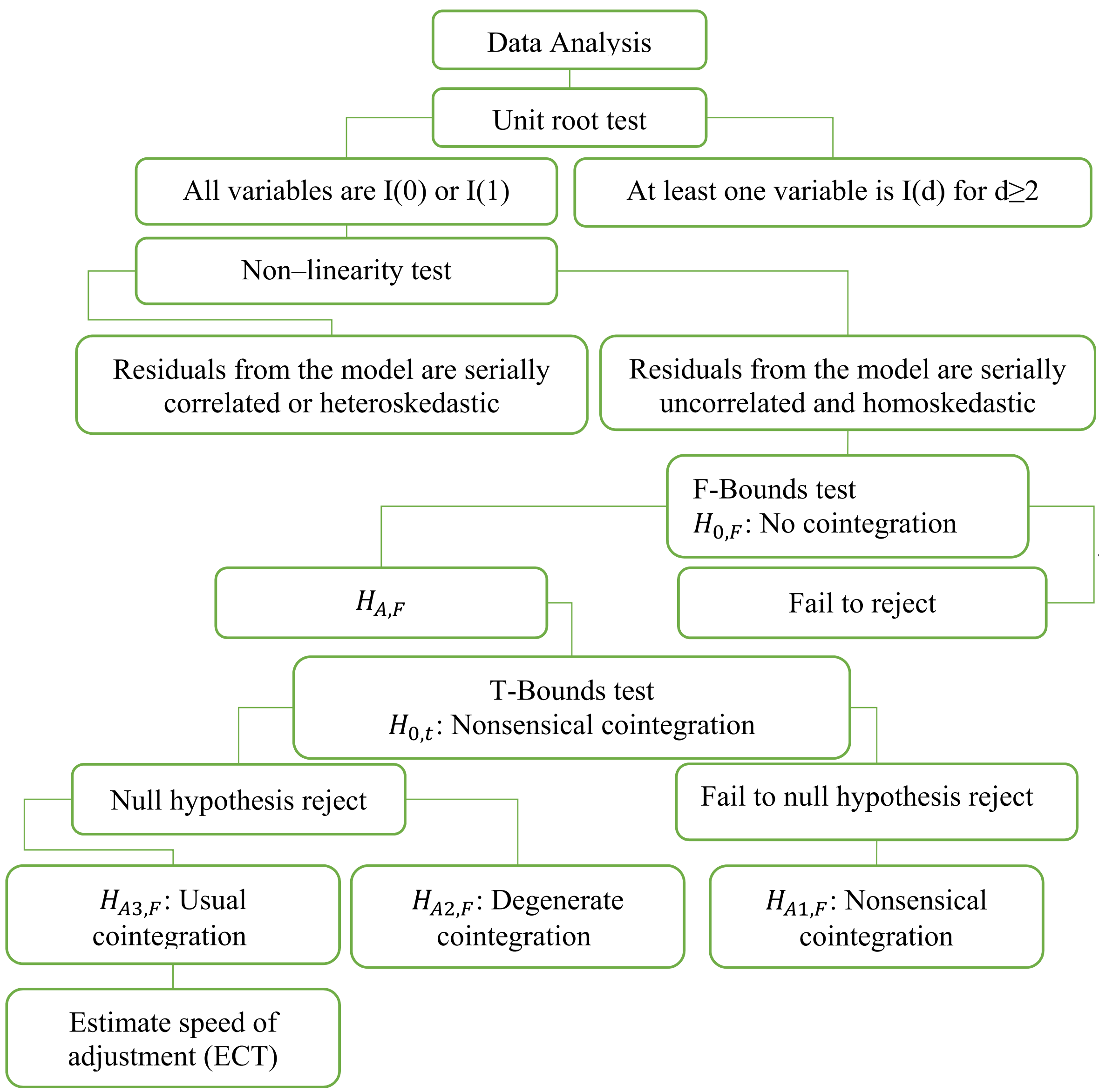
Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Schematic diagram of the study methodology



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