Contemporary Energy Issues: The Roles of Democracy, Economic Policy Uncertainty and the Real Sector

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ABSTRACT

The first essay revisits the position of the EKC hypothesis by incorporating the role of energy consumption and democracy in the environmental degradation function for a panel of nine countries between 1990 and 2014.Using Pooled Mean Group (PMG) methodology and Emirmahmutoglu and Kose (2011) Granger causality test, the results validate the EKC hypothesis in the long run. It also confirms that energy consumption significantly increases CO_2 emissions in the long-run and short-run, while the effect of democracy in reducing CO_2 emissions is statistically significant both in the short-run and in the long-run. The finding from the Granger causality test indicates two-way causal effects in the relationships of economic growth, its squared term and democracy with environmental degradation. Furthermore, there is two-way causality between democracy and income per capita terms and between energy consumption and income per capita. The study, therefore, recommends the need to strengthen democracy and promote stringent environmental policies that guarantee clean energy as a sure way to achieving economic growth despite rising energy consumption, without jeopardizing the quality of life.

The second essay examines the asymmetric causality effects in the relationship between prices of gasoline and economic policy uncertainty. A panel of 18 countries were examined within the period 1998-2017, with the application of a recently introduced panel causality approach by Hatemi-J *et al* (2016) because of its ability to show the asymmetric dynamics in the system and its efficiency against cross-sectional dependence and slope heterogeneity. Results reveal asymmetric causal relationships between gasoline prices and economic policy uncertainty in the sampled countries.

Specifically, results show that economic policy uncertainty and gasoline prices have positive and negative asymmetric bidirectional causality in 13 countries. No feedback causal relations were detected between gasoline prices and economic policy uncertainty in five countries. Based on the results, it can be inferred that positive and negative asymmetric causality exist between economic policy uncertainty and gasoline prices.

The final essay investigates the long-run relationship between oil price and agricultural productivity for India while disaggregating agricultural productivity into food and non-food production. Having applied four major cointegration tests via a technique that was the recently developed by Bayer-Hanck, significant cointegrating relationships are confirmed. However, long-run estimations show that the effect of oil price on both food and non-food agricultural production is insignificant but there is a short-run and long-run positive effect of gross capital formation on agricultural production, while inflation has a negative effect on agriculture only in the short-run. This suggests huge capital formation drives the agricultural sector in India, and not oil energy input. The conditional Granger causality result shows that there is no causal relationship between oil price and agricultural production but bi-directional causality runs between gross capital formation and agricultural production, while oil price has causal effects on capital formation. The study, therefore, implies that agricultural sector will cope in the case of oil price crises because its productivity is independent of oil price changes. This also suggests that there are alternative energy inputs which might be more important than oil in India’s agricultural industries.

Keywords: Asymmetric causality, Democracy, Economic policy uncertainty, Energy consumption, Environmental degradation, Food and non-food production, Gasoline prices, Granger causality, Oil price, Long-run relationships, Real sector

ÖZ

İlk deneme, 1990 ve 2014 yılları arasında dokuz ülkeden oluşan bir panel için çevresel bozulma işlevinde enerji tüketimi ve demokrasinin rolünü dahil ederek EKC hipotezinin pozisyonunu tekrar gözden geçirir. nedensellik testi, uzun vadede EKC hipotezini doğrulamaktadır. Ayrıca, enerji tüketiminin uzun vadede ve kısa vadede CO2 emisyonlarını önemli ölçüde artırdığını, demokrasinin ise CO2 emisyonlarını azaltmadaki etkisinin hem kısa vadede hem de uzun vadede istatistiksel olarak anlamlı olduğunu doğrulamaktadır. Granger nedensellik testinden elde edilen bulgular, ekonomik büyüme, karelerdeki terim ve demokrasinin çevresel bozulma ile ilişkilerinde iki yönlü nedensel etkileri olduğunu göstermektedir. Ayrıca, demokrasi ile kişi başına düşen gelir arasında ve enerji tüketimi ile kişi başına düşen gelir arasında iki yönlü bir nedensellik vardır. Bu nedenle, çalışma, yaşam kalitesini tehlikeye atmadan artan enerji tüketimine rağmen ekonomik büyümeyi sağlamanın kesin bir yolu olarak temiz enerjiyi garanti eden katı çevre politikalarını teşvik etmeyi ve demokrasinin güçlendirilmesini gerekli kılmaktadır.

İkinci makale, Hatemi-J ve arkadaşlarının (2016) asimetrik dinamiklerini ve Hem kesitsel bağımlılığa hem de eğim heterojenliğine karşı dayanıklıdır. Ampirik sonuçlar, örneklenen ülkelerde benzin fiyatları ile ekonomik politika belirsizliği arasındaki asimetrik nedensel ilişkileri ortaya koymaktadır. Spesifik olarak, sonuçlar ekonomik politika belirsizliği ve benzin fiyatlarının 13 ülkede pozitif ve negatif asimetrik çift yönlü nedensellik olduğunu göstermektedir. Beş ülkede benzin fiyatları ile ekonomik politika belirsizliği arasında herhangi bir geri bildirim nedensel ilişki tespit edilmedi. Elde edilen sonuçlara dayanarak, örneklenen bölgelerde görevli politika sonuçlarıyla

birlikte ekonomik politika belirsizliği ile benzin fiyatları arasında pozitif ve negatif asimetrik nedensellik olduğu sonucuna varılabilir.

Son deneme, Hindistan'da petrol fiyatı ile tarımsal verimlilik arasındaki uzun vadeli ilişkiyi araştırırken, tarımsal verimliliği gıda ve gıda dışı üretime ayırmaktadır. Yeni geliştirilen eşbütünleşme tekniğini, değişkenler arasında var olabilecek uzun dönem ilişkisini belirlemek için dört ana eşbütünleşme testini birleştiren Bayer-Hanck eşbütünleştirme tarafından uyguladıktan sonra, önemli uzun süreli ilişkilerin doğrulandığı teyit edildi. Bununla birlikte, uzun vadeli tahminler, petrol fiyatlarının hem gıda hem de gıda dışı tarımsal üretim üzerindeki etkisinin önemsiz olduğunu, ancak brüt sermaye oluşumunun tarımsal üretim üzerindeki kısa vadeli ve uzun vadeli olumlu bir etkisinin bulunduğunu göstermektedir. sadece kısa vadede tarım üzerindeki etkisi. Bu, büyük sermaye oluşumunun Hindistan'da tarım sektörünü yönlendirdiğini ve petrol enerjisi girdisini önlediğini gösteriyor. Koşullu Granger nedensellik sonucu, petrol fiyatı ile tarımsal üretim arasında nedensel bir ilişki olmadığını, ancak çift yönlü nedenselliğin brüt sermaye oluşumu ile tarımsal üretim arasında gerçekleştiğini gösterirken, petrol fiyatının sermaye oluşumu üzerinde nedensel etkileri olduğunu göstermektedir. Bu nedenle, araştırma, tarım sektörünün petrol fiyatlarındaki kriz durumunda başa çıkacağını, çünkü verimliliğinin petrol fiyatlarındaki değişimlerden bağımsız olduğunu göstermektedir. Bu aynı zamanda Hindistan’ın tarımsal endüstrisinde petrolden daha önemli olabilecek alternatif enerji girdilerinin olduğunu göstermektedir.

Anahtar Kelimeler: Asimetrik Nedensellik, Demokrasi, Ekonomik politika belirsizliği, Enerji tüketimi, Çevresel bozulma, Gıda ve gıda dışı üretim, Benzin fiyatları; Petrol fiyatı, Uzun süreli ilişkiler; Reel sektör, VECM Granger nedensellik

DEDICATION

IN LOVING MEMORY OF OLADOTUN

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LIST OF SYMBOLS AND ABBREVIATIONS

$\rightarrow$	Direction of Causality
Δ	Delta
Δ_{adj}	Delta Adjusted
ADF	Augmented Dickey-Fuller
AGRIC	Total Agriculture
AIC	Akaike Information Criteria
ARDL	Autoregressive Distributed Lags
BDM	Banerjee Dolado and Mestre
B-H	Bayer and Hanck Cointegration Test
BJP	Bharatiya Janata Party
BO	Boswijk
CD	Cross-sectional Dependency
CO_2	Carbon Dioxide
DEMO	Democracy
DH	Durbi-Hausman
ED	Environmental Degradation
EC	Energy Consumption
ECM	Error Correction Model
ECT	Error Correction Term
EG	Engle and Granger
EIA	Energy Information Administration
EKC	Environmental Kuznets Curve
EMP	Labour in Agriculture,

EPU	Economic Policy Uncertainty
FAO	Food and Agriculture Organization
GCF	Gross Capital Formation
GDP	Gross Domestic Product
GHG	Green House Gasses
INF	Inflation
JOH	Johansen
KPSS	Kwiatkowski–Phillips–Schmidt–Shin (KPSS)
MG	Mean Group
NFOOD	Non-food
PMG	Pooled Mean Group
PP	Phillips–Perron
SK	South Korea
U.S	United States
VECM	Vector Error Correction Model
WDI	World Development Indicators
Y	Income
Y^2	Income Squared

Chapter 1

INTRODUCTION

Energy is one of the significant basics of the economy. The consumption, supply and pricing of energy are important in the quality of economic development and real sector economic growth. Energy use continues to rise as the life styles of people change with increasing wealth in developed countries, while the developing countries mostly need unrestricted access to energy supplies even as their economies pace towards industrialization. With rising demand for energy, the energy sector has been under immense transformation to suit the energy efficiency requirements for decades, yet, there are economic and socio-political factors at stake in this transformation process. The important matters arising for stakeholders have been centred on how to cope with the energy-related issues.

The most important contemporary energy issues are centred on the energy pricing and consumption. These major energy issues pose serious challenges which spread over productive activities, policy making, environmental security and the general socio-economy. Following the importance of these aspects of the economy to the realization of macroeconomic goals, it becomes necessary to address the two major energy issues of pricing and consumption, and the unique ways in which they influence or are being influenced by the socio-economy. The broad objective of this study is to trace this phenomenon to economic policy and political structure justification. This entire study is has been motivated by anxiety over policy changes and the political structure, the role they play in influencing contemporary energy issues, and how these will affect the real sector economy.

First, energy consumption poses huge environmental challenge. Most energy are sourced from fossil fuel (coal, oil and natural gas), for instance, billions of tonnes of crude oil are being used worldwide to fuel cars, power industries and supply domestic heat energy. Consequently, increased Green House Gasses (GHG) have been overwhelmingly linked to coal, oil and natural gas consumption, and this is significantly contributing to climate change. Most existing literature have demonstrated how increased environmental challenges are the price attached to overdependence on energy in achieving rapid economic growth, but it is not yet known, what role the political accountability of the institutions that govern the system will play in this relationship between energy and the environment. For this reason, a section of this thesis investigates and establishes the mediating role of democracy in how energy consumption affects environment.

Second, among the conventional sources of commercial energy, oil is still the most important, it commands the highest demand in international market, among other alternative sources of energy. As one of the commodities that command the most significant attention all over the world, the price of oil is important to the domestic economies of both net oil importers and net oil exporters. With the view of such important position that oil assumes in the international market, its pricing continues to generate economic policy response among economic stakeholders. The change or expected change in economic policy during oil price distortion mostly have effects, not only on real economic activity, but also on the demand and supply of oil products.

Since, economic activities have been linked to oil prices through the demand and supply channels, therefore, uncertainty in economic policy which affects macroeconomic fundamentals, will have a relation with oil pricing. It is therefore expedient to examine the interaction between economic policy uncertainty and domestic prices of gasoline because of the major role gasoline plays in energy supply for most economic activities. Since it is also established in the literature that the negative impact of bad times is more severe on economic activity than the positive effects of good times, the uniqueness of this section lies in addressing the asymmetric relationship between retail prices of gasoline and economic policy uncertainty.

The last aspect of this thesis is focused on the long-run relationship between oil price and real sector productivity, with special focus on the primary sector, agriculture. This is to provide information on how an emerging economy might cope in the face of oil energy pricing challenge. Since oil price change disrupts real economic activity, it is necessary to understanding the possible channel of disruption whether through food production or through non-food production. This section also shows if there is long-run relationship between the primary sector and oil price. This is important for what it shows about the extent to which the attainment of general economic growth is possible considering oil energy as an important input factor.

Chapter 2

REVISITING THE ENVIRONMENTAL KUZNETS CURVE (EKC) HYPOTHESIS: THE EFFECTS OF ENERGY CONSUMPTION AND DEMOCRACY

2.1 Introduction

The need to address climate change as global energy consumption continues to increase in response to economic growth has become a contemporary energy issue. The overdependence of economies on fossil fuel (oil, gas, and coal) as the main sources of energy to power economic growth has contributed majorly to global warming and environmental degradation. This is largely because of the aggressive efforts by most countries of the world, particularly the developing countries, towards accelerating the pace of economic growth. However, the relationship between energy consumption and economic growth, and how they affect society's quality, is not independent of the political institutions that govern the process of policymaking (Farzin and Bond, 2006).

The pioneer work of Grossman and Krueger (1991) reveals the connection between economic growth and the environment, such that at the initial stage of economic growth, environmental degradation increases, and then begins to decline at the later stage of economic growth. Pictorial illustration in Figure 1 reveals that the Environmental Kuznets Curve (EKC) hypothesis could take the form of an inverted U-shape. Generally, more energy inputs are employed when economic activity increases, consequently, environmental pollution would increase. This is commonly referred to as the scale effect or pollution haven hypothesis in the literature (Dedeoğlu and Kaya, 2013; Stern and Van Dijk, 2017). A composition effect occurs when the shares of the intensive pollutant goods in the production processes are reduced. This leads to a structural change, from a carbon-intensive country, driven by agriculture, transport and service, to an information-intensive country (See Antweiler, Copeland and Taylor 2001; Stern, 2007). Finally, because of this paradigm shift, producers move to an advanced stage where emphasis is to achieve cleaner production processes due to technological advancement. This stage is called the technique effect stage.

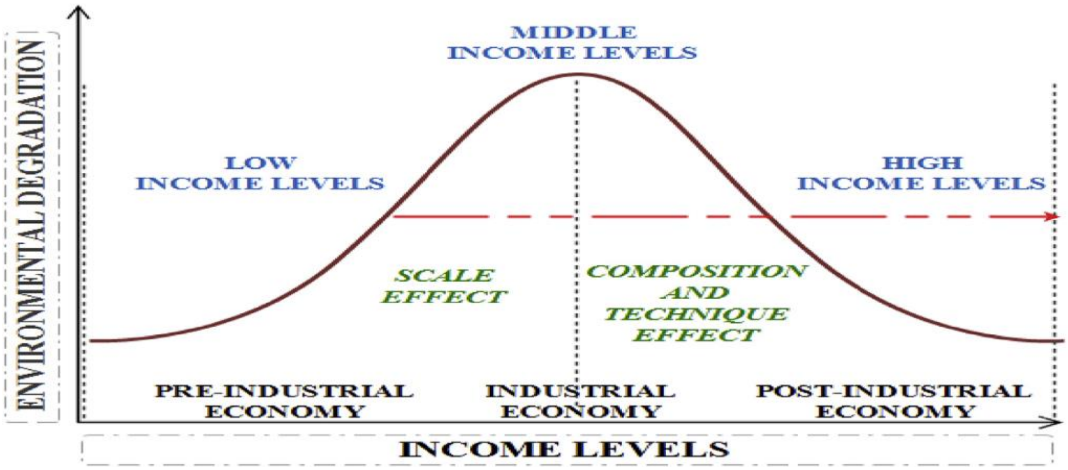


Figure 1: Schematic of Inverted U-Shaped Ekc Hypothesis
[Sourced from Sarkodie and Strezov (2018)]

Theoretically, how democracy can be a factor that influences the environment is centred on two major positions in the literature. First, some scholars argue that democratic countries tend to improve environmental quality through effective and adequate implementation of environmental friendly policies by the government. Furthermore, since democracy encourages the people to express their preferences, they can pressurize the government through protests to demand for environmental friendly policies (See Barrett and Graddy, 2000; Farzin and Bond, 2006; Payne, 1995; Shahbaz, *et al.* 2013b; Torras and Boyce, 1998). Second, an argument has been built on the existence of a positive relationship between income and democracy, which is the basis of the theory of modernization. Therefore, following this theory, environmental quality is threatened because as income increases with the level of democracy, energy use also increases thereby jointly causing $C0_2$ emissions to increase (See Heilbronner, 1974; Lv 2017; Midlarsky 1998; Roberts and Parks, 2007; You, *et al.* 2015).

To this end, the main objective of this paper is to revisit the pivotal effects of income, energy consumption and the democratic regime on environmental degradation measured by carbon dioxide emissions (CO_2) in the context of the EKC hypothesis. Therefore, this study is unique in three ways: First, the paper incorporates energy consumption and democracy in the function of environmental degradation to revalidate the EKC hypothesis for a cross-section of nine countries over the period 1990-2014. Second, the Durbin-Hausman (Westerlund, 2008) panel cointegration procedure is applied in order to examine cointegration among the series. This test of cointegration is suitable for mixed order of integration in the model. Therefore, the test avoids any conflict that may arise from the results of root tests and the determination of cointegration order in the model. Third, the Pooled Mean Group (PMG) is also used to determine the long- and short-run effects of the independent variables on environmental degradation. This shows the direct impact of democracy and energy consumption, as well as the impact of economic growth and its squared term on CO_2 emissions. Fourth, a panel Granger causality test through the bootstrap approach is conducted in order to analyse the directional causal relationships among the variables.

The remainder of this paper is organized and structured as follows: Section 2.2 is a brief review of literature while Section 2.3 describes the data and the methodology employed, and Section 2.4 reports and analyses the empirical results. This chapter is concluded in section 2.5 with relevant policy implications.

2.2 Literature Review in Brief

The role energy plays in the economic development processes of both developed and developing countries has been well documented (Alege, *et al*, 2018; Bhattacharya and Ghoshal, 2010; Omotor, 2007; Paramati, *et al.*, 2017; Sambo, 2008; Shahbaz, *et al.* 2010). A noteworthy volume of empirical literature has also examined the effect of energy consumption on CO_2 emissions (See Alege, *et al.* 2018; Al-Mulali, et al. 2015; Apergis and Ozturk, 2015; Bhattacharya, *et al.* 2016; Mesagan, *et al.* 2018; Kahia and Aissa, 2014; Katircioglu and Katircioglu, 2018; Pao and Fu, 2013). The results of these studies have provided interesting accounts of the relationship between energy consumption and $C0_2$ emissions in the context of the conventional Environmental Kuznets Curve (EKC).

The EKC hypothesis posits that environmental degradation initially increases as per capita income increases but subsequently reduces with increases in income thereby resulting to an inverted U-shaped relationship between income per capita and environmental pollutions (Gokmenoglu and Taspinar, 2015; Katircioglu, *et al.* 2014; Stern, 2003). In a related way, Shahbaz, et al. (2015) tested the EKC hypothesis for Portugal using ARDL bounds test for the period 1971 – 2008. The study augmented the traditional emission and income model with energy consumption, trade openness, and urbanization variables. The empirical result validated the existence of the EKC hypothesis. The study by Pao and Tsai (2010) examined the dynamic causal relationships between pollutant emissions, energy consumption and output for BRIC countries over the period 1971–2005. Their panel regression analysis shows an evidence of EKC as real output exhibits the inverted U-shape pattern. (See also, Dietzenbacher and Mukhopadhyay, 2007; Mukhopadhyay, 2008; Mukhopadhyay and Chakraborty, 2005a; 2005b), while others confirmed the validity of the EKC hypothesis (Bhattacharyya and Ghoshal, 2009; Kanjilal and Ghosh, 2013; Khanna and Zilberman, 2001). There are also literature that claim a sound and vibrant environmental policy exist in India (Bhattacharyya and Ghoshal, 2010; Kanjilal and Ghosh, 2013; Khanna and Zilberman, 2001; Perkins, 2007).

In panel analysis, Arouri, et al. (2012), Du, et al. (2012), Heidari, et al. (2015), Li, T., et al. (2016) and Tao, et al. (2008) have established noted that EKC hypothesis are validated using panel estimation techniques. A great number examined the Environmental Kuznets Curve (EKC) hypothesis by incorporating international trade, foreign direct investment, financial development, urbanization, education, population growth, and capital investment (See Alola, 2019; Emir and Bekun 2018; Gokmenoglu and Taspinar 2018; Katircioglu and Katircioglu, 2018; Katircioglu *et al.* 2018; Mesagan *et al.* 2018; Rafindadi 2016; Rafindadi *et al.* 2014; Shahbaz *et al.* 2013a, b; Shahbaz *et al.* 2016; Shahbaz *et al.* 2018). These studies may have provided interesting accounts of the effects of these variables on the EKC, but the research on energy consumption and environmental pollution still requires further investigation, especially an examination of the pivotal role of socio-political variables such as democratic regimes on their relationships.

2.3. Data and Methodology

2.3.1 Data

The study explores time series data for nine countries (Algeria, Hiati, Iran, Kenya, Romania, Srilanka, Turkey, Yemen and Zimbabwe) from 1990 to 2014. Countries were chosen based on the observation of high changes in democratic accountability over the period observed. (See Appendix A for the graphs of democratic accountability for other countries.) Environmental degradation as the dependent variable is proxied by CO_2 emissions, measured in metric tons per capita, income per capita (Y) is measured by Gross Domestic Product (GDP) per capita (constant 2010 US$). Energy consumption (EC) is measured in kilo tonnes of oil equivalent per capita, and democracy (DEM) is democratic accountability index in each country obtained from the PRS Group reports dataset on International Country Risk Guide. The remaining variables are sourced from the World Bank - World Development Indicators' database. All the variables are expressed in natural logarithms except the measure of democracy.

2.3.2 Model Specification

Following Lv (2017) and Shahbaz *et al.* (2017), the EKC model with the incorporation of energy consumption and the degree of democracy is given as:

$$ED_{i,t} = \beta_0 + \beta_1 Y_{i,t} + \beta_2 Y_{i,t}^2 + \beta_3 EC_{i,t} + \beta_3 DEMO_{i,t} + \varepsilon_{i,t} \quad (1)$$

Where β_0 is the intercept, the error term, ε_t has a zero mean, environmental degradation (ED) is measured by CO_2 emissions in metric tons per capita, Y denotes income, measured by Gross Domestic Product (GDP) per capita (constant 2010 US$), Y^2 is the square of income, *EC* indicates energy consumption while *DEMO* measures the degree of democracy. The transformation of the model in Equation (1) based on Autoregressive Distributed Lag (ARDL) approach is presented as follows:

$$lED_{i,t} = \beta_0 + \beta_1 lY_{i,t} + \beta_2 lY_{i,t}^2 + \beta_3 EC_{i,t} + \beta_4 lDEMO_{i,t} + \varepsilon_{i,t} \tag{2}$$

2.3.3 Preliminary Tests

The choice of methodology is based on the results obtained from preliminary tests which present the properties of the variables. The first test here is a test for cross sectional dependence (CD) to check the presence of common shocks and correlation among the countries. This is done by applying the Pesaran (2004) CD, Breusch-Pagan LM (1980), Pesaran (2004) scaled LM and the Bias-corrected scaled LM developed by Pesaran, Ullah and Yamagata (2008) all under the null of no cross-sectional dependence:

$$H_0: p_{ij} = corr(\mu_{it}, \mu_{it}) = 0 \; for \; all \; i \neq j$$

The Breusch-Pagan (1980) LM test statistic for dependence is written as:

$$LM = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij} \hat{p}_{ij}^2 \rightarrow \chi^2 \frac{N(N-1)}{2} \tag{3}$$

Where $\hat{p}_{ij}^2$ is the correlation coefficients from the residuals.

The Pesaran (2004) scaled LM test statistic is written as:

$$LM_s = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} (T_{ij} \, \hat{p}_{ij}^2 - 1) \rightarrow N(0,1) \tag{4}$$

As an improvement upon these two tests, Pesaran (2004) CD test is an alternative test statistic which does not suffer size distortion like the previous two. The LM statistic is specified as:

$$CD_p = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij} \, \hat{p}_{ij} \rightarrow N(0,1) \tag{5}$$

By averaging the pairwise correlation coefficients, $\hat{p}_{ij}$, the Pesaran CD test is able to avoid the size distortion problems.

Finally, the Bias-corrected Scaled LM test is an asymptotically bias corrected version of the scaled LM test. The test statistic is written as:

$$LM_{BC} = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} (T_{ij}\, \hat{p}_{ij}^2 - 1) - \frac{N}{2(T-1)} \to N(0,1) \qquad (6)$$

Next, is the test for slope homogeneity performed in the series using the Pesaran and Yamagata (2008) homogeneity test. This standardized version also referred to as the delta test is of homogeneity test is a modified version of Swamy (1970). The Delta tests presents two test statistics under the null hypothesis of slope homogeneity, the standard dispersion test statistics specified as:

$$\tilde{\Delta} = \sqrt{N\left(\frac{N^{-1}\tilde{S} - k}{2k}\right)} \qquad (7)$$

and the bias adjusted version of the standard dispersion statistics specified as:

$$\tilde{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}\tilde{S} - E(\tilde{z}_{it})}{\sqrt{var(\tilde{z}_{it})}}\right) \qquad (8)$$

We further checked for the presence of unit roots in the variables by conducting the cross-sectionally augmented IPS unit root test (CIPS) by Im, Pesaran and Shin (2003) and the cross-sectional augmented Dickey Fuller (CADF) by Pesaran (2007). These unit root tests are able to overcome the challenge of cross sectional dependence that may arise in the panel data unit roots test.

Pesaran (2007) specified the CADF unit root tests statistic as:

$$CADF_i = t_i(N,T) = \frac{\left(y_{i,-1}^T \bar{M} y_{i,-1}\right)^{-1} (y_{i,-1}^T \bar{M} \Delta y_{i,-1})}{\sqrt{\sigma_i^2 (y_{i,-1}^T \bar{M} y_{i,-1})^{-1}}} \qquad (9)$$

The CIPS gives the averages of CADF test statistic for all countries in the panel, it is tested under the null hypothesis of unit root against heterogeneous alternative. The test statistic is specified as:

$$CIPS(N,T) = N^{-1}\sum_{i=1}^{N} t_i(N,T) = \frac{\sum_{i=1}^{N} ADF_i}{N} \quad (10)$$

Where $t_i(N,T)$ is CADF test statistic for the ith cross-section.

2.3.4 Panel Cointegration Test

Long run relationships among the variables were tested using the Durbin-Hausman cointegration tests of Westerlund (2008) which is suitable under the conditions of cross sectional dependence among the variables, stationarity I(0) and nonstationarity I(1) of the regressors. The only condition required for the efficiency of this test is the nonstationarity I(0) of the dependent variable at level. The Durbin-Hausman cointegration tests are of two types, the panel test (DHp) and the group mean test (DHg).

The panel test (DHp) statistic can be specified as:

$$DH_p = \hat{S}_n(\tilde{\varphi} - \hat{\varphi})^2 \sum_{i=1}^{n}\sum_{t=2}^{T} \hat{e}_{it-1}^2 \quad (11)$$

The null hypothesis of the Durbin-Hausman panel test is no cointegration: $H_0: \varphi_i = 1, for\ all\ I = 1$, against an alternative hypothesis that is there is cointegration for all units: $H_i^p: \varphi_i = \varphi, and\ \varphi < 1$

The group mean test (DHg) statistic can be specified as:

$$DH_g = \hat{S}_i(\tilde{\varphi}_i - \hat{\varphi}_i)^2 \sum_{i=1}^{n}\sum_{t=2}^{T} \hat{e}_{it-1}^2 \quad (12)$$

The null hypothesis of the Durbin-Hausman group mean test is also no cointegration: $H_0: \varphi_i = 1, for\ all\ I = 1$, against an alternative hypothesis that is there is cointegration in some of the cross sectional units.

2.3.5 Panel Error Correction

Following Pesaran *et al.* (1999), Eq (2) may be written in an ARDL (m, n1,……nk) form as follows:

$$lEd_{i,t} = \beta_0 + \sum_{j=i}^{p_1} \beta_{1,ij}\, lED_{i,t-j} + \sum_{j=i}^{p_2} \beta_{2,ij}\, lY_{i,t-j} + \sum_{j=i}^{p_3} \beta_{3,ij}\, lY_{i,t-1}^2 + \sum_{j=i}^{p_4} \beta_{4,ij}\, EC_{i,t-j} + \sum_{j=i}^{p_5} \beta_{5,ij}\, lDEMO_{i,t-j} + \varepsilon_{i,t} \quad (13)$$

Here, t represents the number of years from 1,2,…….T, the number of groups from 1,2,…….N is represented by i. β_0 indicates the group specific effects, while β_1, β_2, β_3, β_4, and β_5 represent the coefficients of respective regressors.

The presence of cointegration requires that the above equation be specified in an error correction form as shown below:

$$\Delta lED_{i,t} = \emptyset_i (lED_{it-1} - \theta lY_{it}) + \sum_{j=i}^{p_1-1} \beta_{1,ij}^*\, \Delta lED_{i,t-j} + \sum_{j=i}^{p_2-1} \beta_{2,ij}^*\, \Delta lY_{i,t-j} + \sum_{j=i}^{p_3-1} \beta_{3,ij}^*\, \Delta lY_{i,t-1}^2 + \sum_{j=i}^{p_4-1} \beta_{4,ij}^*\, \Delta EC_{i,t-j} + \sum_{j=i}^{p_5-1} \beta_{4,ij}^*\, \Delta lDEMO_{i,t-j} + \varepsilon_{i,t} \quad (14)$$

Where, Δ represents the differences in the log of CO_2 emissions, income and its squared term, energy consumption and democracy. Based on equation (2), we expect that $\beta_2 > 0$ and $\beta_4 > 0$, and $\beta_3 < 0$ and $\beta_5 < 0$. The same applies to the short-run part of the equation. Here, $\emptyset_i = -(1 - \sum_{j=i}^{p_1} \beta_{1,ij})$ indicates the speed of adjustment to long-run equilibrium which must be negative for long run relationship to exist. The dependent variable i.e. CO_2 emissions might not immediately adjust to the path of its long-term equilibrium due to the changes in the explanatory variables. Therefore, the pace of adjustment to the long-run equilibrium level is captured by ECM_{t-1}, which is defined as the one period lagged residual in the long-run equation. Equation (14) is then estimated using both the PMG and MG estimators, and inferences are drawn from the more suitable between the two as determined through the Hausman test.

2.3.6 Panel Causality Tests

Our methodology also concludes with the test for Granger causality among the variables. Considering the mixed order of integration in the pre-tests of our variables, the standard Wald test for zero restrictions on the Vector autoregressive (VAR) or Vector Error Correction Model (VECM) coefficients are not appropriate in this model. Toda and Yamamoto (1995) had developed an approach which avoids pre-test of variables to determine their order of integration or cointegration process. With standard asymptotic chi-square distribution, their approach uses a modified Wald (MWALD) test in a lag augmented VAR (LA-VAR). The LA-VAR is enhanced by with asymptotic chi-square distribution when estimating a VAR(p+$dmax$). The maximum order of integration is $dmax$, while p is the lag order. Although the LA-VAR approach does not require pre-test of variables and can asymptotically avoid size distortion problems, it still requires the knowledge and choice of the maximum order of integration, $dmax$. To avoid this pre-tests conflicts and the cost of artificial lag augmentation, we employ the panel causality approach proposed by Emirmahmutoglu and Kose (2011). Emirmahmutoglu and Kose (2011) extended the LA-VAR approach of Toda and Yamamoto (1995) via Meta-analysis to test the null hypothesis on no Granger causality. Their approach is based on Meta-analysis as developed by Fisher (1932), the statistical technique for heterogeneous mixed panels is efficient for non-stationary heterogeneous panels and in the presence of cross sectional dependence. The test for Granger causality in the presence of cross-sectional dependence is through the bootstrap approach such that limit distribution of the Fisher test statistic becomes valid despite cross-sectional dependence in the panel. The regression equation for each model is as follow:

$$Y_{1,t} = \alpha_{1,1} + \sum_{i=1}^{ly_1+dmax_j} \beta_{1,1,i} Y_{1,t-i} + \sum_{i=1}^{lx_1+dmax_j} \gamma_{1,1,i} X_{1,t-i} + \varepsilon_{1,1,t}$$

$$Y_{2,t} = \alpha_{1,2} + \sum_{i=1}^{ly_1+dmax_j} \beta_{1,2,i} Y_{2,t-i} + \sum_{i=1}^{lx_1+dmax_j} \gamma_{1,2,i} X_{2,t-i} + \varepsilon_{1,2,t} \quad (15)$$

$$\vdots$$

$$Y_{N,t} = \alpha_{1,N} + \sum_{i=1}^{ly_1+dmax_j} \beta_{1,N,i} Y_{2,t-i} + \sum_{i=1}^{lx_1+dmax_j} \gamma_{1,N,i} X_{N,t-i} + \varepsilon_{1,N,t}$$

and

$$X_{1,t} = \alpha_{2,1} + \sum_{i=1}^{ly_2+dmax_j} \beta_{2,1,i} Y_{1,t-i} + \sum_{i=1}^{lx_2+dmax_j} \gamma_{2,1,i} X_{1,t-i} + \varepsilon_{2,1,t}$$

$$X_{2,t} = \alpha_{2,2} + \sum_{i=1}^{ly_2+dmax_j} \beta_{2,2,i} Y_{2,t-i} + \sum_{i=1}^{lx_2+dmax_j} \gamma_{2,2,i} X_{2,t-i} + \varepsilon_{2,2,t} \quad (16)$$

$$\vdots$$

$$X_{N,t} = \alpha_{2,N} + \sum_{i=1}^{ly_2+dmax_j} \beta_{2,N,i} Y_{2,t-i} + \sum_{i=1}^{lx_2+dmax_j} \gamma_{2,N,i} X_{2,t-i} + \varepsilon_{2,N,t}$$

Equation (16) tests causality running from X to Y and equation (16) tests causality running from Y to X. N represents the number of countries included in the panel *(j = 1,…, N), t* indicates the time period (*t = 1,…,T),* l is the lag length and $dmax_j$ indicates the maximal order of integration.

All significant p-values from each of the time series tests conducted present in the panel are combined using the Fisher's (1932) meta-analysis statistical procedure in Granger causality test. The Fisher test statistic is denoted as (λ) and is written as follow:

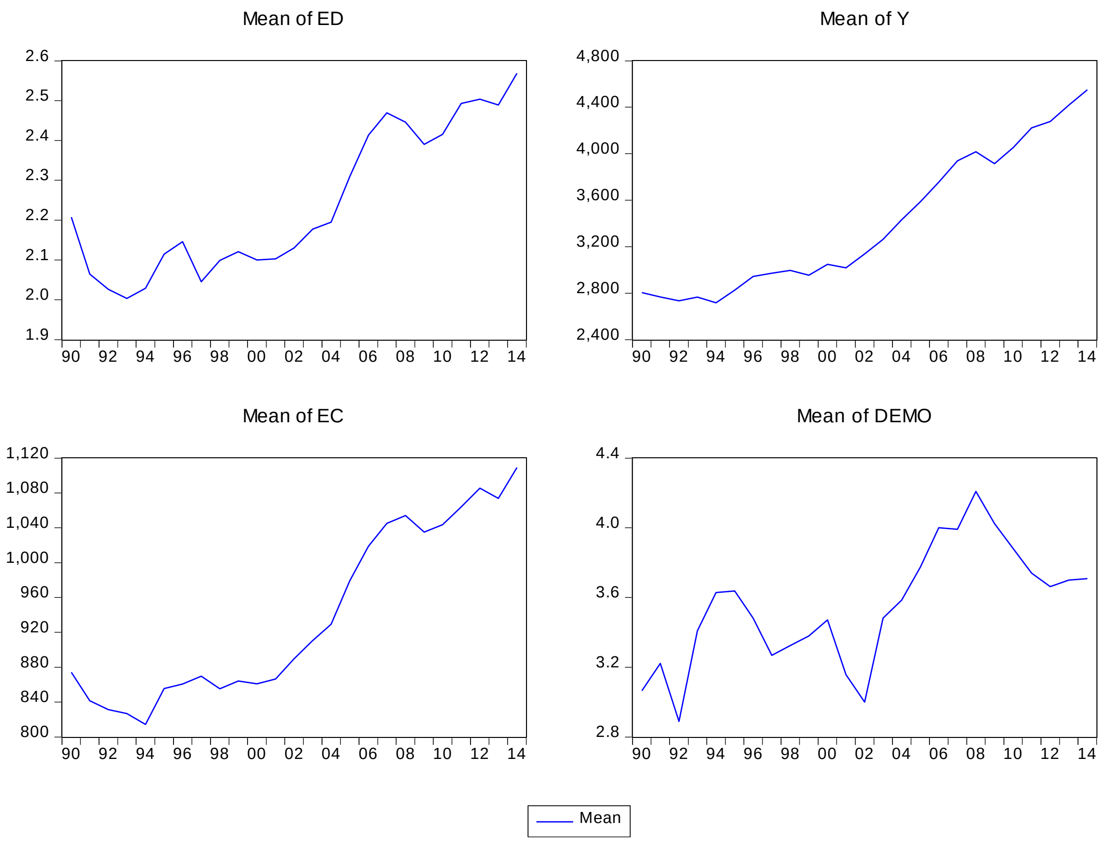
$$\lambda = -2 \sum_{i=1}^{N} ln_{(pi)} \;\; i = 1,2, \dots, N. \quad (17)$$

where pi represents the p-value for Wald statistic of the ith cross section.

2.4 Empirical Results and Discussion

2.4.1 Visual Properties of the Data

This section describes the visual properties of the variables. The time plots of the variables are reported in Figure 2. The time plots are the mean of the selected countries' information over the period observed, these suggest a trend in all the series with no clear evidence of breaks. This testifies to the fact that the, CO_2 emissions, economic growth and energy consumption have been increasing in these countries. For emphasis the data on democracy are presented for each country in the second part in order to observe the trend of each country's democratic accountability over the years.



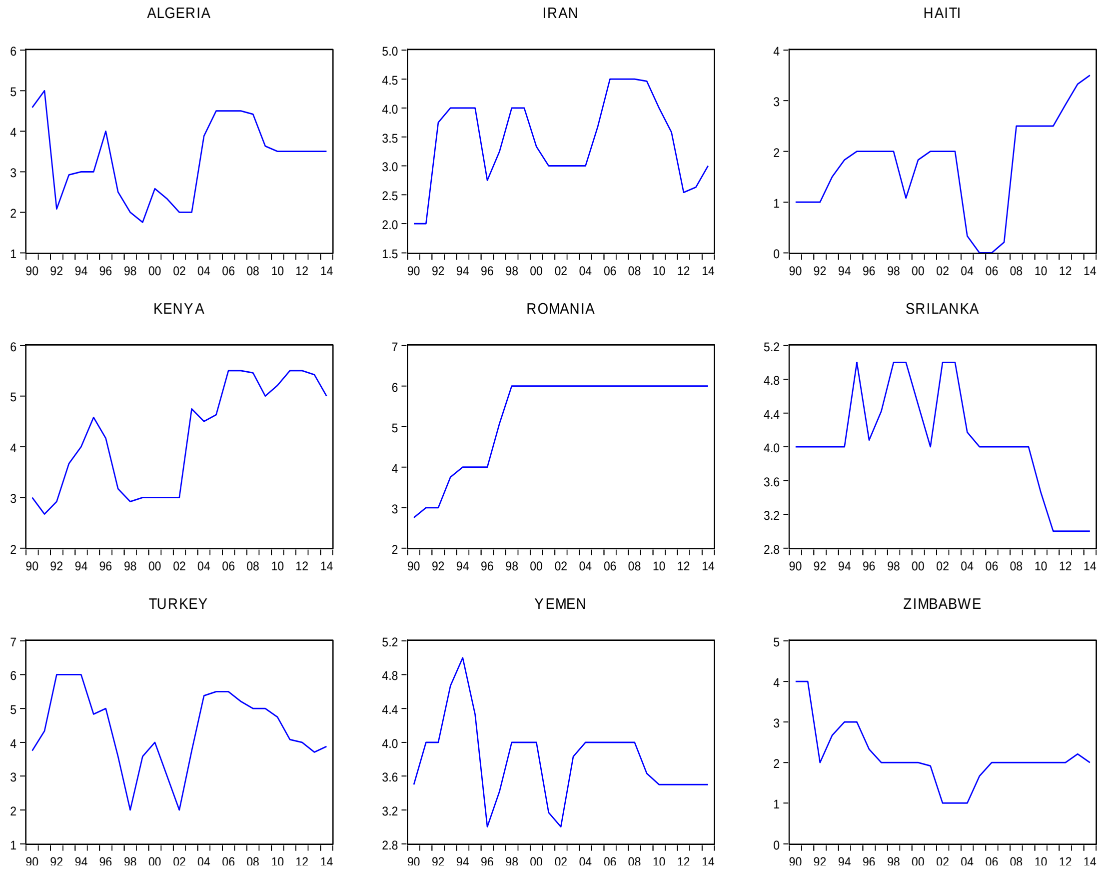


Figure 2: Time Series Plots of Variables: CO_2 Carbon Dioxide Emissions (ED), Income (Y), Energy Consumption (EC), and Democracy (DEMO) in their Natural Forms. The Second Part Shows the Time Plot of Democracy for each Country in the Panel.

2.4.2 Descriptive Statistics

Table 1 describes the statistics of the variables for each country. As can be observed, environmental degradation proxied by CO_2 emissions is highest in Iran with the mean value of 1.757 and lowest in Haiti with a mean value of -1.77. Turkey is the richest of all with a GDP per capita mean value of 9.092 while Haiti has the lowest GDP per capita of 6.61. Energy consumption is highest in Romania with a mean value of 7.528 while Yemen has the least energy consumption considering the mean value of 5.59. Finally, considering the mean values of democracy in descending order, Romania (7.528) is most democratic, followed by Turkey (4.393), Kenya (4,283), Sri-Lanka (4.065), Yemen (3.802), Iran (3.458), Algeria (3.307), Zimbabwe (2.152), and Haiti

(1.741) is the least democratic. Standard deviation values show the variations occurring in their democratic accountability, Romania has the highest variation (1.171) while Yemen has the least variation (0.469) in democracy.

Table 1: Descriptive Statistics

LED	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability
ALGERIA	1.134	0.089	0.138	2.142	0.847	0.655
HAITI	-1.772	0.417	-1.869	7.169	32.659	0.000
IRAN	1.757	0.267	-0.258	1.604	2.307	0.315
KENYA	-1.309	0.158	-0.355	2.178	1.230	0.541
ROMANIA	1.544	0.175	0.631	3.410	1.837	0.399
SRILANKA	-0.708	0.392	-0.593	2.191	2.146	0.342
TURKEY	1.231	0.169	0.162	1.752	1.731	0.421
YEMEN	-0.187	0.157	-0.250	2.091	1.122	0.571
ZIMBABWE	-0.051	0.392	-0.338	2.125	1.272	0.529
LY	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability
ALGERIA	8.254	0.136	0.049	1.376	2.757	0.252
HAITI	6.610	0.087	1.284	4.087	8.099	0.017
IRAN	8.567	0.147	0.169	1.474	2.545	0.280
KENYA	6.800	0.076	0.963	2.885	3.878	0.144
ROMANIA	8.723	0.269	0.264	1.447	2.804	0.246
SRILANKA	7.584	0.329	0.236	1.949	1.382	0.501
TURKEY	9.092	0.209	0.416	1.977	1.812	0.404

YEMEN	7.019	0.081	-0.006	2.067	0.907	0.636
ZIMBABWE	7.039	0.248	-0.604	2.162	2.253	0.324

LY2	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability
ALGERIA	16.508	0.272	0.049	1.376	2.757	0.252
HAITI	13.221	0.173	1.284	4.087	8.099	0.017
IRAN	17.134	0.294	0.169	1.474	2.545	0.280
KENYA	13.601	0.153	0.963	2.885	3.878	0.144
ROMANIA	17.446	0.537	0.264	1.447	2.804	0.246
SRILANKA	15.167	0.659	0.236	1.949	1.382	0.501
TURKEY	18.184	0.419	0.416	1.977	1.812	0.404
YEMEN	14.038	0.163	-0.006	2.067	0.907	0.636
ZIMBABWE	14.078	0.496	-0.604	2.162	2.253	0.324

LEC	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability
ALGERIA	6.868	0.151	0.615	2.108	2.403	0.301
HAITI	5.647	0.263	0.187	1.372	2.906	0.234
IRAN	7.631	0.274	-0.221	1.784	1.743	0.418
KENYA	6.113	0.037	1.769	6.771	27.856	0.000
ROMANIA	7.528	0.119	1.125	4.751	8.471	0.014
SRILANKA	6.030	0.170	-0.337	1.869	1.804	0.406
TURKEY	7.105	0.166	0.149	1.826	1.529	0.466
YEMEN	5.591	0.169	-0.075	1.730	1.704	0.427
ZIMBABWE	6.673	0.108	0.025	1.976	1.095	0.578

DEMO	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability
ALGERIA	3.307	0.971	-0.013	1.825	1.438	0.487
IRAN	3.458	0.752	-0.302	2.144	1.142	0.565
HAITI	1.741	0.965	-0.262	2.414	0.643	0.725
KENYA	4.203	1.062	-0.103	1.387	2.754	0.252
ROMANIA	5.263	1.171	-1.107	2.547	5.319*	0.070
SRILANKA	4.065	0.634	-0.141	2.459	0.388	0.824
TURKEY	4.393	1.117	-0.454	2.670	0.971	0.615
YEMEN	3.802	0.469	0.450	3.404	1.013	0.603
ZIMBABWE	2.152	0.740	0.969	4.312	5.706*	0.058

* indicates significance of the normality test at 10% level.

2.4.2 Cross-sectional Dependence and Homogeneity Tests

The test for cross sectional dependence is reported in table 2. We reject the null hypothesis of no cross sectional dependence for all test statistics at 1% significance level each. The tests for slope homogeneity are also reported in table 2. Evidence from the insignificant test statistics of the delta and adjusted delta tests shows that we are unable to reject of the null of slope homogeneity in all the variables except democracy.

Table 2: Cross-sectional Dependence and Homogeneity Tests

Variable	CD test				Homogeniety test	
	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD	$\hat{\Delta}$	$\hat{\Delta}_{adj}$
$\log CO_2$	363.862***	38.639***	38.451***	2.360**	-0.442	-0.471
	(0.000)	(0.000)	(0.000)	(0.018)	(0.671)	(0.681)
logY	518.375***	56.848***	56.661***	6.587***	1.068	1.138
	(0.000)	(0.000)	(0.000)	(0.000)	(0.143)	(0.127)
$\log Y^2$	518.375***	56.848***	56.661***	6.587***	1.068	1.138
	(0.000)	(0.000)	(0.000)	(0.000)	(0.143)	(0.127)
logEC	474.000***	51.619***	51.431***	6.042***	1.123	1.197
	(0.000)	(0.000)	(0.000)	(0.000)	(0.131)	(0.116)
DEMO	121.297***	10.052***	9.865***	-0.341	5.253***	5.599***
	(0.000)	(0.000)	(0.000)	(0.733)	(0.000)	(0.000)

*** and ** indicate significance of test statistics at 1% and 5% levels.

2.4.3 Results from Unit Root Tests

The methodology proceeds to test for the variables' orders of integration, using the CIPS test. Table 3 presents the results of the stationarity test. All variables are overwhelmingly confirmed to be stationary at first difference, however democracy and CO_2 emissions might be, at 10% level of significance, stationary at level when tested under the model with constant only. This led to our choice of estimation method, thus, we employ the error-correction based panel ARDL test and Emirmahmutoglu and Kose (2011) Granger causality approach which accommodate mixed order of integration and do require the stationarity of the variables.

Table 3: CIPS Unit Root Test Results

	Level		1st difference	
	CIPS Test Statistics		CIPS Test Statistics	
Variable	Constant	Constant and trend	Constant	Constant and trend
$logCO_2$	-2.174*	-2.441	-5,357***	-5.357***
logY	-1.296	-1.899	-4.089***	-4.164***
$logY^2$	-1.296	-1.899	-4.089***	-4.164***
logEC	-1.784	-1.988	-4.710***	-4.929***
DEMO	-2.144*	-2.311	-3.898***	-4.079***
Critical values				
1%	-2.51	-3.3	-2.44	-3.10
5%	-2.25	-2.94	-2.22	-2.82
10%	-2.12	-2.76	-2.10	-2.67

Notes: (i) *** and * respectively denotes 1% and 10 % significance levels.

2.4.4 Results of Cointegration Test

The results of the Durbin Hausman cointegration tests in Table 4 indicate that at 5% level of significance, the variables are cointegrated when tested with constant and trend, when tested without constant or trend, there is cointegration at 1% level of significance. This implies that the null hypothesis of no cointegration is rejected in the Durbin Hausman tests for cointegration and at least one cointegrating vector is present in the model. Based on these results, it can be concluded that there is a valid long-run relationship between environmental degradation, income per capita, square of income per capita, energy consumption and democracy in in the panel of these nine countries.

Table 4: Durbin Hausman Cointegration Test

Estimated models	Dh_g	Dh_ p	Conclusion
With constant only	-0.674	-0.914	No
	0.250	0.180	Cointegration
With constant and trend	30.936	-2.021**	Cointegrated
	1.000	0.022	
No constant, no trend	-0.232	-2.459***	Cointegrated
	0.408	0.007	

Notes: (i) The lag length for combined cointegration test is [1]. (ii) *** and ** show statistical significance at 1% and 5% levels respectively.

2.5.4 Long-term and Short-term Effects

The Hausman test results in Table 5 suggests that it is better to allow for heterogeneous short-run dynamics in the model and common long-run impacts. Given the p-value of 0.263, the null of homogeneity cannot be rejected, therefore, the model supports the PMG estimator. We therefore employ the error-correction based panel ARDL test, pooled mean group PMG estimator in our empirical analysis.

Table 5: Hausman Test

Coefficients				
	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	MG	PMG	Difference	S.E
logY	62.453	2.279	60.175	103.913
$\log Y^2$	-4.799	-0.144	-4.654	7.580
logEC	1.320	0.814	0.507	0.493
DEMO	-0.005	-0.035	0.030	0.015
chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)				3.99
Prob>chi2 =				0.263

Table 6 provides the long-run and short-run coefficients mean group (MG) and pooled mean group (PMG) approaches. The results of the PMG show that income per capita has an elastic and positively significant relationship with $\ln CO_2$ emissions. Specifically, a 1% increase in income per capita will cause environmental degradation to increase by 2.28%. Remarkably, the coefficient of the square of income per capita is negative, inelastic and statistically significant at 1% level signifying that the association between CO_2 emissions and income per capita is an inverted U-shaped. The finding is an indication that these countries' economies are affected by the *scale effect,* where an increase in income results to an increase in environmental degradation. This result concurs with the findings of Alola (2019) and Apergis et al. (2018) that economic growth measured by GDP notably exerts pressure on increasing environmental degradation, which hampers sustainability of the environment. This finding also agrees with the confirmation of EKC hypothesis by Bhattacharyya and

Ghoshal (2010), Kanjilal and Ghosh (2013), Khanna and Zilberman (2001) and Ozatac *et al.* (2017) in India and Turkey. Furthermore, these results divulge that, energy consumption is inelastic, positive and statistically significant while the effect of democratic regime is negative, inelastic and statistically significant, indicating a strong reducing effect of democracy on CO_2 emissions in the long-run. This, therefore, diverts from the theory of modernization, which infers a positive relationship between income and democracy, and hence increases environmental degradation. The result, however, supports the position that good democracy puts pressure on the government of the day to improve environmental quality through effective designing of stringent environmental policies that reduce changes in natural levels and distribution of chemical elements that threaten the well-being of the people.

For the short-run coefficients, the empirical result of the error correction term (ECM) coefficient as provided in Table 6 shows that the ECM is about -0.358 and it is statistically significant, easily passing the 1% significance level. This suggests that environmental degradation converges to long-run equilibrium by about 0.358 % through the channels of income per capital and its squared term, energy consumption, and democratic regime. The short-term coefficients of income per capita and its squared term is statistically insignificant. This suggests that the EKC hypothesis is not validated in the short-run. The result further shows that energy consumption has positive impacts on environmental degradation in short-run, has positive and significant effects. This indicates that if energy consumption increases by 1%, pollutant emissions would increase by 0.791%. Finally, the result of the effect of democracy is inelastic, negative and significant, suggesting that as the pace of democracy increases, environmental degradation decreases by through effective implementation of economic policies, which redirect resources to environment friendly developmental plans. Therefore, the result is consistent with Lv (2017) and Shahbaz *et al.* (2013a) who submitted that effective democratic government reduces carbon dioxide emissions since the people can express their wishes on the government to improve environmental quality. On the other hand, the result is not consistent with Heilbronner (1974) and Midlarsky (1998) who assert that democracy affects environmental quality through the channel of income. As income increases, more unsafe energy is consumed and hence reduces environmental quality.

Table 6: PMG/MG Estimation Results (Dependent Variable: LEFP)

Variable	PMG	MG
Error correction	-0.358***	-0.806***
Coefficient ($\emptyset_i$)	(0.003)	(0.000)
Long-run coefficients		
LogY	2.279***	62.453
	(0.006)	(0.374)
$LogY^2$	-0.144***	-4.799
	(0.003)	(0.349)
LogEC	.814***	1.320***
	(0.000)	(0.000)
DEMO	-0.035 **	-0.0050
	(0.000)	(0.675)
Short-run coefficients		
ΔLogY	9.945	-7.094
	(0.486)	(0.744)

ΔLogY^2	-0.671	0.751
	(0.519)	(0.624)
ΔLogEC	-0.791***	0.389
	(0.004)	(0.384)
ΔDEMO	-0.013	-0.009
	(0.318)	(0.651)
	-4.924***	-13.025
Constant	(0.002)	(0.865)

Notes: (i) *** and ** denote significance at 1% and 5% levels.

2.4.5 The Emirmahmutoglu and Kose Granger Causality Analysis

The causality among variables is revealed through the Emirmahmutoglu and Kose Granger causality test for panel variables. Results shown in Table 7 reveal that democracy causes energy consumption and $C0_2$ emissions. There are also evidences of bidirectional Granger causality between real income per capita and democracy, between per capita income and energy consumption and between income and $C0_2$ emissions. This result agrees with the existence of EKC hypothesis in India as reported by Ghosh (2010). These findings also agrees with Bekun et al. (2019) that the pursuit of growth in the 16 EU countries exert upward pressure on environmental degradation. The implication for the results is that the past values of the income, energy consumption and democracy have additional information regarding the future values of CO_2 emissions. Therefore, the finding is aligned with Alam *et al.* (2011), Ghosh, (2011) and Shahbaz *et al.* (2017) who reported that Granger causality runs from energy consumption to carbon dioxide emission.

Table 7. Emirmahmutoglu and Kose Granger Causality Test for the Panel

Hypothesis	Wald Statistic	P-Value	Conclusion
$CO_2 \rightarrow Y$	37.916***	0.000	$C0_2$ emissions causes income per capita
$Y \rightarrow CO_2$	66.088 ***	0.000	Income per capita causes $C0_2$ emissions
$CO_2 \rightarrow EC$	40.114 ***	0.002	$C0_2$ emissions causes energy consumption
$EC \rightarrow CO_2$	51.079 ***	0.000	Energy consumption causes $C0_2$ emissions.
DEMO→CO2	61.022***	0.000	Democracy causes $C0_2$ emissions.
Y→DEMO	45.126 ***	0.000	Income per capita causes democracy
DEMO→Y	40.676 ***	0.002	Democracy causes income per capita.
EC→Y	44.004***	0.001	Energy consumption causes income per capita
Y→EC	84.942***	0.000	Income per capita causes energy consumption.
DEMO→EC	86.294***	0.000	Democracy causes energy consumption.

Note: *** indicate statistic relationships are significant at 1% respectively.

2.5 Conclusion and Policy Implications

This present study investigates the validity of the EKC hypothesis in countries that experience high democratic variations by incorporating energy consumption and democratic regime in the environment-growth function for the period 1971–2014. The Durbin Hausman cointegration tests was employed to test the existence of cointegrating relationship among the variables.

The results revealed a valid long-run relationship between environmental degradation, income per capita and its squared term, energy consumption and democracy in these countries. The empirical results validated the EKC hypothesis for the panel. The results further revealed that environmental degradation can be attributed to increase in energy consumption both in the long- and short-run. The effect of democracy in reducing environmental degradation was significant in the long-run and in the short-run. The Granger causality test indicated that the CO_2 emissions has bidirectional relationships with that income, squared income, energy consumption and democracy.

The implication is that, the past value of income, square of income, energy consumption and democracy invariably predicted changes in CO_2 emissions. Therefore, for economies to reduce CO_2 emissions and increase growth, effort should be made to reduce energy consumption from fossil fuels, which is a major determinant of carbon emissions. To this extent, an appropriate energy policy should be anchored on expanding the use of energy from cleaner sources. Expanding the use of energy from renewables may also lead to a decrease in the dependence on fossil energy and ensure energy security for the country. In addition, environmental policy of taxes on carbon emissions could be considered for these countries. However, a care must be taken so that the taxes on carbon emissions will not drive away the firms and industries from the country. Furthermore, it is suggested that all the stakeholders in environment and energy must be given an opportunity to participate in crafting of such policy.

Furthermore, if democratic accountability has a reducing effects on environmental degradation, democratic institutions need to be strengthened in order to accelerate and stabilize economic growth. The experience of Romania after the abolition of communism in 1989 has demonstrated the efficacy of democratic regime in reducing pollutant emissions as revealed by Shahbaz *et al.* (2013a). This is also consistent with Lv (2017) that democracy downwardly pressurizes CO2 emissions in the emerging countries. It is suggested here, policymakers should pay precise attention to energy policy that overcomes the issues of environmental challenges while also strengthening of democracy will motivate policies that target the reduction of carbon emissions while achieving economic growth.

Chapter 3

GASOLINE PRICES AND ECONOMIC POLICY UNCERTAINTY: WHAT CAUSES WHAT? EVIDENCE FROM 18 SELECTED COUNTRIES

3.1 Introduction

It has been argued in literature that in economies that are highly dependent on oil as a major source of commercial energy, oil price changes attract policy attention. Policy decisions during these price disruptions have the potential to mar or enhance national energy security. Most economies place great emphasis on the stabilization of their domestic oil products prices due to its importance to transportation sector, output growth and general price stability. In addition, its influence on aggregate demand and supply of goods and services has made oil price stability crucial for economic policy formulation. This is because the choice of policy actions taken against price distortion has instant and direct effect on real economic activity. As existing macroeconomic policies are being interrupted and replaced with new ones, uncertainty about the direction of their effects arises, causing disruption in economic fundamentals.

Following the work of Bloom (2009) and the measure of economic policy uncertainty (EPU) index that was recently generated by Baker et al. (2013), economic policy uncertainty has been established to have negative effects on economic activities by influencing expected returns from investment, exchange rate volatility, inflation expectations and demand shocks (see Handley and Limao, 2015; Kang et al., 2014; Pastor and Veronesi, 2012, 2013; Rodrik, 1991). By implication, investors are forced to slow down on investment decisions while production processes tend to take a different course. These, in one way or another, have direct effect on commodity prices. Thus, it is a rightly placed assumption that increased level of uncertainty will directly or indirectly erode macroeconomic objectives and slow down economic growth processes. Since uncertainty in economic policy has its ways of disrupting economic growth process, it is expedient to examine its causal relationship with documented growth determinants in literature, especially gasoline prices. This is crucial for economies that export/import oil products or depend on gasoline for their economic and/or production activities. Stemming from these reasons, this study examines the causal relations between domestic pricing of gasoline and economic policy uncertainty.

In order to create a clearer picture of the potential relationship between the variables of interest, this study begins by theoretically illustrating the causal relationship between economic policy uncertainty and gasoline prices. Economic policy uncertainty has the ability to influence domestic pump price of oil products through its numerous effects on real sector activities. The relationship between economic policy uncertainty and gasoline prices appear in form of a vicious cycle, with negative spill over effects into other economic activities. This connection follows the work of Hamilton (1983), which linked oil price shocks to the U.S. recession. Hamilton (2008, 2009) also linked the U.S. recessions to increase in oil prices preceding the recessions. When gasoline price increases (decreases), it has a negative (positive) impact on economic activities (Brown and Yücel, 2002; Cunado and De Gracia, 2005; Lardic and Mignon, 2008; Lee et al., 1995; Stern, 1993). In the case of an increase, it reduces firms' production by increasing production costs, it feeds inflation by raising the general prices of commodities, affects consumer spending by reducing disposable income, and also reduces national savings and investment. This generates issues of concern for policymakers and mounts pressure on the central authority to change or introduce new policies to prevent further damage. As policymakers search for the best policy response to salvage the situation, anticipated response by the authority causes more damage which intensifies the decline in real sector activity. As both uncertainty and gasoline prices interact, economic activities suffer. Thus, it becomes expedient to trace the origin of these changes, through an examination of causal interactions between the variables of interest, which will go a long way in the course of proffering solution to the damaging economic activities (Kang et al, 2017).

Increase in the level of economic policy uncertainty increases aggregate demand. This occurs as high uncertainty levels trigger panic buying of commodities, most especially gasoline, for fear of the future or fear of possible supply shortage; particularly, within the economies that depend on oil or engage in exportation/importation of gasoline and other oil related products. Uncertainty about the future availability of oil product also creates panic demand, causing prices to rise. This leads to rise in dispense prices under a perfect market condition. On the other hand, uncertainty leads to uncertainty in aggregate demand for firms' output and low investment in productive activities. If most production depends on petroleum as a major source of energy, there will be lower demand for gasoline, which makes prices to fall (Filis et al., 2011; Hamilton, 2009; Kilian, 2009; Kilian and Park, 2009).

Furthermore, increase in the level of economic policy uncertainty would cause oil price changes and might lead to shortage in aggregate supply. In this situation, oil firms are forced to hold production until they are sure of the direction of economic policies. Some firms may be forced to shut down production for a while, thereby cutting oil product supply. This generates supply shortage and leads to price hike. In contrast, reduction in economic policy uncertainty level also tends to push down the gasoline prices, since oil firms can predict expected gains and make regular supply available. According to these illustrations, the movement of gasoline price can arise from demand or supply shocks, or both. The severity of the impact of this shock, however, largely depends on the variable that has stronger capability to move market prices, while the policy response to these price changes depends on whether the change is triggered from the supply side or from the demand side.

The negative impact of an increase in oil prices is more severe on economic activity than the positive effects of price fall. The economy easily declines faster during oil price increase than it accelerates during the fall. Bacon (1991) described these unequal patterns of adjustment to rise and fall of petroleum products price as "rockets and feathers". According to Hamilton (1988), two costs are involved when prices are rising—the cost of a price rise in production input cost and the cost of adjusting product prices, which make up the rapid rise in prices. This makes the impact more severe. When price falls, it is a gain for the economy. Such gain is challenged by the cost of adjusting to price changes. Therefore, the economy is confronted with two negative effects when gasoline prices rise, while both positive and negative effects tend to interplay when oil prices fall.

Similarly, the negative effects of rising oil prices could overwhelm the positive effects of falling oil prices if the origin of price changes is as a result of uncertainty in economic policy. It has been observed that economies do not recover at the same pace at which they declined during crisis (International Monetary Fund, 2014). Such asymmetric effects of uncertainty on oil prices imply that increased uncertainty causes prices to rise faster, but when the tension is off, prices do not fall at the same pace as the price rise. Since both have negative relationship with the economy, this does not make the economy recover as fast as it declined after the crisis. The negative effects of rising oil prices on uncertainty could also be stretched. Uncertainty about the direction of policy following oil price increase often offsets, to some degree, the positive effects of falling prices. This is because patterns of investment and consumption would have changed and it takes time to readjust the system back to the initial state. This makes it difficult for the economy to recover at the same pace at which it declined during the crisis of price increase. Hence, the negative effects of increase in uncertainty and oil price increase on each other could overwhelm the positive effects of their reduction.

Addressing the asymmetric relationship between retail prices of gasoline and economic policy uncertainty is a major gap in literature which this study seeks to fill. The contribution of this study is twofold. First, this study investigates the role of uncertainty arising due to changing economic policies in the changes that occur in gasoline prices, and also investigates the role of changing gasoline prices in generating economic policy uncertainty. This investigation allows give room for comparison between the feedback response of the domestic oil market to economic policies and the reaction of economic policy to changing oil market conditions. Second, an asymmetric causal relationship between economic policy uncertainty and domestic prices of gasoline is examined. This is considered necessary to address the asymmetric interaction between dispense prices of gasoline and economic policy uncertainty, since policy response to price increase can slow or hasten the speed of price fall during recovery. The response of gasoline price also determines how long the impact of economic policy will last, and whether the economy will return back to initial state or not.

The examination of domestic prices of fuel is of interest because of the major role it plays in energy supply for most of the countries examined. Gasoline is the most used of commercial energy derived from crude oil. This analysis is also important for what it shows about its roles in economic recovery, return to equilibrium and wealth redistribution during economic crisis. The relation between these prices and policy issues has implications on aggregate demand and supply, investment and production especially oil intensive production as well as policy making.

This study is further structured as follows; a brief literature review is presented in Section 3.2, followed by the description of data and methodology adopted for empirical analysis in Section 3.3, empirical results are discussed in Section 3.4, while Section 3.5 concludes and gives the policy implications.

3.1 Literature Review in Brief

The asymmetric relationship between oil prices and economic activity has been revealed by Davis and Haltiwanger (2001), Balke et al. (2002), Hamilton (2011), Kilian and Vigfusson (2011), Lee et al. (1995), Mork (1989) and Mory (1993) among others. Few studies have analysed the relationship between economic policy uncertainty and oil price. Antonakakis et al. (2014) examined this relationship for both net oil-exporting and net oil-importing and found both economic policy uncertainty and oil price shocks responding negatively to each other. Kang and Ratti (2013) observed that real oil price changes are not unconnected to economic policy uncertainty rather than oil supply or aggregate demand, while economic policy uncertainty is associated with oil-market specific demand shocks. They showed that positive oil shocks originating from increase in aggregate demand reduces the transmission of economic policy uncertainty. Kang et al. (2017) also established that oil prices among other variables influence economic policy uncertainty, while oil production thrives in the absence of economic policy uncertainty. Therefore, uncertainty is associated with oil supply shocks. Bekiros et al. (2015) showed that forecast of changes in oil prices can be based on economic policy uncertainty. These studies reveal that economic policy uncertainty is the predominant medium of transmitting long term oil price shocks and effects into the real sector while oil price shocks make the impact of economic policy uncertainty on the real economy last longer. The aggregate effect on the real economy has been associated with policy response to price changes.

A number of studies have established that changes in the price of crude oil stimulate changes in retail prices of oil products, but the extent of such changes depend on economic and energy policies. Such studies include Apergis and Vouzavalis (2018), Bettendorf et al. (2003), Borenstein et al. (1997), Chou and Tseng (2016), Honarvar (2009), Kristoufek and Lunackova (2015), Liu et al. (2010) and Pal and Mitra (2016). Pal and Mitra (2016) found asymmetric price transmission of from crude oil prices to oil product prices. They observed that oil products prices rise sharply when crude oil price increases but does not fall with the same speed when crude oil price drops sharply. Hence the expected relief from falling crude oil prices is not fully felt because prices of crude oil products are not as flexible as the prices of the raw materials.

3.3 Data and Methodology

3.3.1 Data

To examine the asymmetric causal relationships between gasoline prices and economic policy uncertainty (EPU), annual data on the dispense prices of gasoline from the 'World Development Indicators' (http://data.worldbank.org) and the national EPU index of Baker et al. (2016) are employed. The EPU data was retrieved at http://www.policyuncertainty.com/. Each country's national EPU index has been constructed from a historical search of economic policy uncertainty related issues in their newspaper articles. A monthly national EPU index obtained for each country is therefore a relative value of the share of the country's newspaper articles which focuses on issues related to economic policy uncertainty in that particular month. Yearly mean values have been calculated to convert the EPU monthly index to yearly values. All data cover the period 1998 to 2017. The countries sampled are Australia, Brazil, Canada, Chile, China, Colombia, France, Germany, Greece, Ireland, Italy, Japan, Mexico, Russian, South Korea, Sweden, United Kingdom and United States. The decision to use these countries is based on their collective status as developed and emerging countries that rely on and/or export/import gasoline products.

3.3.2 Methodology

The test for Granger causality in panel data series with cross country error terms and heterogeneous slope coefficients are susceptible to invalid estimation. Although, Hurlin (2008) causality technique accounts for heterogeneity but does not handle cross-sectional dependence which may exist among the individual countries.

Commonly used to address these issues of heterogeneity and cross sectional dependence is the bootstrap causality technique for panel models by Konya (2006) and Emirmahmutoglu and Kose (2011). This method adequately handles both but do not reveal asymmetric dynamics in variables. Hatemi-J (2011) and Hatemi-J et al. (2016) recently introduced a panel causality approach which reveals asymmetric forces at work in the underlying data and is also robust to both cross-sectional dependence and slope heterogeneity in the variables.

Following Hatemi-J (2011), two variables in a panel system can be specified as follows:

$$X_{i1,t} = X_{i1,t-1} + e_{i1,t} = X_{i1,0} + \sum_{j=1}^{t} e_{i1,j} \quad (1)$$

$$X_{i2,t} = X_{i2,t-1} + e_{i2,t} = X_{i2,0} + \sum_{j=1}^{t} e_{i2,j} \quad (2)$$

For i =1,…, 18 where 18 represents the number of panel cross-sections (18 countries), e_t indicates error term. The positive shocks are given as $e_{i1,t}^{+} = max(e_{i1,t}, 0)$, $e_{i2,t}^{+} = max(e_{i2,t}, 0)$, while the negative shocks are given as $e_{i1,t}^{-} = min(e_{i1,t}, 0)$, $e_{i2,t}^{-} = min(e_{i2,t}, 0)$. The cumulative partial sums of changes constructed from these positive and negative values take the following form:

$$X_{i1,t}^{+} = X_{i1,0}^{+} + e_{i1,t}^{+} = X_{i1,0} + \sum_{j=1}^{t} e_{i1,j}^{+} \quad (3)$$

$$X_{i2,t}^{+} = X_{i2,0}^{+} + e_{i2,t}^{+} = X_{i2,0} + \sum_{j=1}^{t} e_{i2,j}^{+} \quad (4)$$

$$X_{i1,t}^{-} = X_{i1,0}^{-} + e_{i1,t}^{-} = X_{i1,0} + \sum_{j=1}^{t} e_{i1,j}^{-} \quad (5)$$

$$X_{i2,t}^{-} = X_{i2,0}^{-} + e_{i2,t}^{-} = X_{i2,0} + \sum_{j=1}^{t} e_{i2,j}^{-} \quad (6)$$

Then, causality test is performed by the estimation of vector autoregressive seemingly unrelated regression model of order p, VAR-SUR (P). Testing causality between the positive components is as follows:

$$\begin{bmatrix} X_{i1,t}^{+} \\ X_{i2,t}^{+} \end{bmatrix} = \begin{bmatrix} \beta_{i0} \\ \gamma_{i0} \end{bmatrix} + \begin{bmatrix} \sum_{r=1}^{k} \beta_{i1,r} & \sum_{r=1}^{k} \beta_{i2,r} \\ \sum_{r=1}^{k} \gamma_{i1,r} & \sum_{r=1}^{k} \gamma_{i2,r} \end{bmatrix} x \begin{bmatrix} X_{i1,t-r}^{+} \\ X_{i2,t-r}^{+} \end{bmatrix} + \begin{bmatrix} e_{i1}^{+} \\ e_{i2}^{+} \end{bmatrix} \quad (7)$$

And testing causality between the negative components is in this form:

$$\begin{bmatrix} X_{i1,t}^{-} \\ X_{i2,t}^{-} \end{bmatrix} = \begin{bmatrix} \beta_{i0} \\ \gamma_{i0} \end{bmatrix} + \begin{bmatrix} \sum_{r=1}^{k} \beta_{i1,r} & \sum_{r=1}^{k} \beta_{i2,r} \\ \sum_{r=1}^{k} \gamma_{i1,r} & \sum_{r=1}^{k} \gamma_{i2,r} \end{bmatrix} x \begin{bmatrix} X_{i1,t-r}^{-} \\ X_{i2,t-r}^{-} \end{bmatrix} + \begin{bmatrix} e_{i1}^{-} \\ e_{i2}^{-} \end{bmatrix} \quad (8)$$

The lag order (p) for the test is determined through the minimal information criteria for panel models. These null hypotheses are tested through country specific Wald tests with country specific bootstrap critical values. The null hypotheses that $X_{i2,t}^{+}$ $\left(X_{i2,t}^{-}\right)$ do not Granger cause $X_{i1,t}^{+}\left(X_{i1,t}^{-}\right)$ for cross-section i is stated as: $H_0 = \beta_{i2,r} = 0, \forall r,$ where r = 1,…,p. If variables are used in levels, cointegration is not required between the variables, but if variables are used in their first differences, this technique does not require that the variables are stationary.

3.4 Empirical Results and Discussion

The asymmetric causal effects between economic policy uncertainty and gasoline prices as reported in Table 8 show both positive and negative bidirectional causal relations in Canada, China, Colombia, France, Italy, Russia, South Korea, Sweden and United Kingdom. Negative bidirectional causal effects were observed in Brazil, Chile, Greece and Mexico. In these 4 countries, positive causal effects run from economic policy uncertainty to gasoline prices. Positive and negative one way causal effects from economic policy uncertainty to gasoline prices were detected for Australia, Germany, Japan and United States. In Ireland, negative causality runs from economic policy uncertainty to gasoline prices without feedback, while positive causal effects were seen from gasoline prices to economic policy uncertainty without feedback.

Table 8: Asymmetric Causality between Gasoline Prices and Economic Policy Uncertainty

Country	Null hypothesis	MWALD stat	P-values	Null hypothesis	MWALD stat	P-val
Australia	GAS- $\not\Rightarrow$ EPU-	1.30	0.25	$EPU^{-} \not\Rightarrow GAS^{-}$	337.64^{***}	0.00
	GAS+ $\not\Rightarrow$ EPU+	1.87	0.39	$EPU^{+} \not\Rightarrow GAS^{+}$	345.82^{***}	0.00
Brazil	GAS- $\not\Rightarrow$ EPU-	570.25^{***}	0.00	$EPU^{-} \not\Rightarrow GAS^{-}$	69.98^{***}	0.00
	GAS+ $\not\Rightarrow$ EPU^{+}	4.18	0.12	$EPU^{+} \not\Rightarrow GAS^{+}$	338.23	0.00
Canada	$GAS^{-} \not\Rightarrow EPU^{-}$	19.12^{***}	0.00	$EPU^{-} \not\Rightarrow GAS^{-}$	186.61^{***}	0.00
	$GAS^{+} \not\Rightarrow EPU^{+}$	45.64^{***}	0.00	$EPU^{+} \not\Rightarrow GAS^{+}$	950.54^{***}	0.00
Chile	$GAS^{-} \not\Rightarrow EPU^{-}$	130.43^{***}	0.00	$EPU^{-} \not\Rightarrow GAS^{-}$	49.96^{***}	0.00
	$GAS^{+} \not\Rightarrow EPU^{+}$	0.16	0.92	$EPU^{+} \not\Rightarrow GAS^{+}$	635.96^{***}	0.00

China	$GAS^{-} \nRightarrow EPU^{-}$	46.61^{***}	0.00	$EPU^{-} \nRightarrow GAS^{-}$	23.49^{***}	0.00
	$GAS^{+} \nRightarrow EPU^{+}$	13.92^{***}	0.00	$EPU^{+} \nRightarrow GAS^{+}$	361.82^{***}	0.00
Columbia	$GAS^{-} \nRightarrow EPU^{-}$	726.33^{***}	0.00	$EPU^{-} \nRightarrow GAS^{-}$	105.14^{***}	0.00
	$GAS^{+} \nRightarrow EPU^{+}$	7.05^{**}	0.02	$EPU^{+} \nRightarrow GAS^{+}$	342.65^{***}	0.00
France	$GAS^{-} \nRightarrow EPU^{-}$	81.65^{***}	0.00	$EPU^{-} \nRightarrow GAS^{-}$	33.70^{***}	0.00
	$GAS^{+} \nRightarrow EPU^{+}$	62.82^{***}	0.00	$EPU^{+} \nRightarrow GAS^{+}$	264.63^{***}	0.00
Germany	$GAS^{-} \nRightarrow EPU^{-}$	1.08	0.29	$EPU^{-} \nRightarrow GAS^{-}$	10.51^{***}	0.00
	$GAS^{+} \nRightarrow EPU^{+}$	1.33	0.51	$EPU^{+} \nRightarrow GAS^{+}$	351.47^{***}	0.00
Greece	$GAS^{-} \nRightarrow EPU^{-}$	43.28^{***}	0.00	$EPU^{-} \nRightarrow GAS^{-}$	188.02^{***}	0.00
	$GAS^{+} \nRightarrow EPU^{+}$	0.67	0.71	$EPU^{+} \nRightarrow GAS^{+}$	31.02^{***}	0.00

Ireland	$GAS^{-} \nRightarrow EPU^{-}$	0.02	0.86	$EPU^{-} \nRightarrow GAS^{-}$	32.53***	0.00
	$GAS^{+} \nRightarrow EPU^{+}$	18.16***	0.00	$EPU^{+} \nRightarrow GAS^{+}$	3.58***	0.05
Italy	$GAS^{-} \nRightarrow EPU^{-}$	146.95***	0.00	$EPU^{-} \nRightarrow GAS^{-}$	247.95***	0.00
	$GAS^{+} \nRightarrow EPU^{+}$	8.00**	0.01	$EPU^{+} \nRightarrow GAS^{+}$	2607.11***	0.00
Japan	$GAS^{-} \nRightarrow EPU^{-}$	0.57	0.44	$EPU^{-} \nRightarrow GAS^{-}$	7.45**	0.02
	$GAS^{+} \nRightarrow EPU^{+}$	0.23	0.88	$EPU^{+} \nRightarrow GAS^{+}$	164.30***	0.00
Mexico	$GAS^{-} \nRightarrow EPU^{-}$	10.75***	0.00	$EPU^{-} \nRightarrow GAS^{-}$	40.151***	0.00
	$GAS^{+} \nRightarrow EPU^{+}$	3.24	0.19	$EPU^{+} \nRightarrow GAS^{+}$	85.675***	0.00
Russia	GAS- $\nRightarrow$ EPU-	105.51***	0.00	$EPU^{-} \nRightarrow GAS^{-}$	70.43***	0.00
	$GAS^{+} \nRightarrow EPU^{+}$	7.88**	0.01	$EPU^{+} \nRightarrow GAS^{+}$	508.96***	0.00

SK	$GAS^{-} \nRightarrow EPU^{-}$	148.90***	0.00	$EPU^{-} \nRightarrow GAS^{-}$	354.22***	0.00
	$GAS^{+} \nRightarrow EPU^{+}$	31.70***	0.00	$EPU^{+} \nRightarrow GAS^{+}$	356.77***	0.00
Sweden	$GAS^{-} \nRightarrow EPU^{-}$	4.92**	0.02	$EPU^{-} \nRightarrow GAS^{-}$	151.38***	0.00
	$GAS^{+} \nRightarrow EPU^{+}$	8.80**	0.01	$EPU^{+} \nRightarrow GAS^{+}$	334.15***	0.00
UK	$GAS^{-} \nRightarrow EPU^{-}$	67.70***	0.00	$EPU^{-} \nRightarrow GAS^{-}$	70.37***	0.00
	$GAS^{+} \nRightarrow EPU^{+}$	9.75***	0.00	$EPU^{+} \nRightarrow GAS^{+}$	760.98***	0.00
US	$GAS^{-} \nRightarrow EPU^{-}$	0.02	0.87	$EPU^{-} \nRightarrow GAS^{-}$	311.59***	0.00
	$GAS^{+} \nRightarrow EPU^{+}$	0.53	0.76	$EPU^{+} \nRightarrow GAS^{+}$	534.558***	0.00

Note: *** and ** is the significance at 0.01 and 0.05 level.

These feedback relationships between dispense prices of gasoline and economic policy uncertainty have followed the work of Hamilton (1983, 2008, and 2009) which found the source of economic crises to be oil price shocks and that oil price shocks originate from economic crises. The feedback positive relationship implies that gasoline price increase will increase economic policy uncertainty. Likewise, uncertainty that arises from policy changes will cause an increase in gasoline prices. This becomes a vicious circle which escalates shocks induced into the system through any of these, and the economy might not return back to initial long-run equilibrium. Where there are negative bidirectional causality, reduction in gasoline prices will reduce economic policy uncertainty, while reduced uncertainty will also reduce gasoline prices. Therefore policy that aims at reducing any of these will return the economy back to initial long-run equilibrium. Where both positive and negative bidirectional causal effects are observed, both positive and negative effects interplay to affect economic activities. As noted by Hamilton (1988), Mork (1989) and Bacon (1991) that the speed of price rise is faster than its speed when it descends, whether the positive casual effects will supersede the negative causal effects will not only depend on the origin of changes in prices and economic policy uncertainty, but also on the stronger force between price changes and economic policy uncertainty. The course this takes will determine whether the situation will take the economy to a new equilibrium or it will return back to initial equilibrium.

In addition, unidirectional positive causal effect running from economic policy uncertainty to gasoline prices implies that rising uncertainty concerning economic policy actions will trigger gasoline price increase. However, reduction in economic policy uncertainty may not have significant impacts on gasoline prices. It is possible that when uncertainty about the economy is over, gasoline prices may become rigid and likely not reduce. Such economies do not need to bother about the effect of increased gasoline prices on economic policy uncertainty because it is not enough to trigger uncertainty in their economies.

Furthermore, the results indicate one-way positive causal relationship from gasoline prices to economic policy uncertainty. This implies that embarking on economic policy that would lead to an increase in gasoline prices may likely create uncertainty in these economies. Price reduction might not be able to reduce economic policy uncertainty once it has been sparked by initial increase. On the other hand, one-way negative causation from gasoline prices to economic policy uncertainty would imply that reduction in gasoline prices will help to curb uncertainty in the economy. Thus, increase in gasoline prices cannot create an economic policy uncertainty in the concerned countries.

Interestingly, almost all the countries in this study exhibit positive and negative causation from economic policy uncertainty to gasoline price. However, results show non-Granger causal relationship running from dispense prices of gasoline to economic policy uncertainty in five of the countries. Based on these results, it appears that economic policy uncertainty is a significant and useful predictor of gasoline price, while gasoline price may not be a useful predictor of economic policy uncertainty in Australia, Germany, Ireland, Japan and USA, due to the fact that the determination of gasoline prices only depends on the direction of policy and uncertainty surrounding new policies in the countries and not otherwise. In Brazil, Chile, Greece and Ireland, reduced gasoline price may predict a reduction of economic policy uncertainty. In Ireland, there is no negative feedback from gasoline price to economic policy uncertainty, suggesting that reducing gasoline price cannot curb economic policy uncertainty when it is rising due to initial rise in gasoline price. The economy may not return back to initial equilibrium once price has risen. The general results of this analysis have been summarized in Table 9.

Table 9: Summary of Causality between Gasoline Prices and Economic Policy Uncertainty.

Null hypothesis	Countries
GAS- ≠> EPU-	Brazil, Canada, Chile, China, Colombia, France, Greece, Italy, Mexico, Russia, South Korea, Sweden, UK.
GAS+ ≠> EPU+	Canada, China, Colombia, France, Ireland, Italy, Russia, South Korea, Sweden, UK.
EPU^{-} ≠> GAS^{-}	Australia, Brazil, Canada, Chile, China, Colombia, France, Germany, Greece, Ireland, Italy, Japan, Mexico, Russia, South Korea, Sweden, UK, USA.
EPU^{+} ≠> GAS^{+}	Australia, Brazil, Canada, Chile, China, Colombia, France, Germany, Greece, Ireland, Italy, Japan, Mexico, Russia, South Korea, Sweden, UK, USA.

3.5 Conclusion

In this paper, the possible causal asymmetric relationship between gasoline prices and economic policy uncertainty were examined for 18 countries with noticeable fluctuations in their gasoline prices and economic policies over the period 1998-2017. This study is motivated by anxiety over policy changes during oil price fluctuations and the linkage of past economic crisis and policies that has led to rising oil prices. This relationship between economic policy uncertainty and domestic gasoline prices was examined using a panel Granger causality technique that is efficient in spite of the possibility of having cross-sectional dependence and slope heterogeneity, that may be present in the 18 countries examined. Asymmetric causal relationships were revealed.

The results imply that economic policy uncertainty has both positive and negative causal effects on gasoline prices. Feedback causal effects between gasoline prices and economic policy uncertainty were observed in 13 countries, while five countries showed neither positive nor negative feedback from gasoline prices to economic policy uncertainty. The positive or negative causal effects of economic policy uncertainty on gasoline price determine the direction of gasoline price changes, but where there is no feedback response, there might be no clear cut interaction between gasoline prices and economic policy uncertainty. Thus, this study establishes that that positive and negative asymmetry exists between economic policy uncertainty and gasoline price.

Conclusively, this study brings to the fore the role of energy in determining tranquillity in the economy. It also implies that economic policy uncertainty has consequences for energy security. The significant asymmetric causality between gasoline prices and economic policy uncertainty will help policymakers know whether the system will return to initial long-run equilibrium after policy and price disruptions or not. It is therefore important for policymakers to take proper caution while formulating macroeconomic policies because anticipated policy response to fuel price changes can further disrupt the system.

Chapter 4

THE LONG-RUN RELATIONSHIP BETWEEN OIL PRICE CHANGE AND REAL SECTOR PERFORMANCE: WITH SPECIAL REFERENCE TO AGRICULTURAL PRODUCTIVITY

4.1 Introduction

The real sector economy has always had to adjust to significant oil price changes, this is especially true of productive activities that are energy intensive. The effects of these changes on agriculture is noteworthy because agriculture tends to shift from labour intensive to energy intensive as economies pace towards development. While conventional methods of production in agriculture are energy intensive, most of the inputs employed cannot easily be substituted for less energy-intensive inputs when oil price rises. Where energy substitution is possible, there is bound to be a rise in the price of alternative energy resources due to shift in energy demand. It is therefore expected that the net impact of sharp increase in crude oil price and gasoline price is increased cost of production, slowed-down production process and reduced income for farmers. However, the overall impact of oil price changes on agriculture depends on whether the country is a net oil importer or net oil exporter, the intensity of oil price change at the particular time and the measures taken by policy makers to prevent the transmission into the domestic economy. While the impact is mild for net exporters of oil, the impact is high for net oil importers. Furthermore, among the heavy importers, countries with low import elasticity of demand for oil are at higher disadvantage when price rises since they cannot swerve to alternatives. In fact, both net oil importers and net exporters tend to experience significant changes in real sector activities during oil price fluctuations, but as high oil price tends to favour net exporters, the reverse brings adverse effects on the economy of net oil importers.

The effects of crude oil price change can be significantly transmitted through demand and supply channels into real economy. On the supply side, where crude oil is a basic energy input employed in production, oil price changes have a positive relationship with production cost. The impact of crude oil prices on real sector productivity is transferred from spot prices, refining and production costs from the oil market. In agriculture, the conventional systems require the use of heavy equipment which mostly depend on oil. Preservation, distribution and transportation in agricultural production process are also significantly influenced by oil prices because they are oil intensive. As oil price increases, increase in the cost of using farm machineries for large scale farming could discourage the most efficient method of mechanized farming, thereby resulting in delayed processing and supply shortage. In addition, the rising cost of other inputs which are produced from energy-intensive technologies, such as chemicals and manufactured fertilizers, also contribute to rise in final agricultural commodity prices. These, altogether, account for inefficiency and higher cost in distribution of agricultural products to final consumers when oil price rises.

On the demand side, oil price change has a negative relationship with disposable income and real investment. Since disposable income positively determines the level of consumption, thus, oil price change has negative relationship with aggregate demand through its negative effects on consumption and investment spending. As part of the consequences on net-income, industries are forced to lower production. Since raw materials from agriculture mostly feed the industry, if industries, especially agro-based industries are forced to cut production due to the rising cost of raw materials in the agricultural sector and lower aggregate demand, there will be low demand for primary and intermediate inputs in the agricultural sector. Finally, when prices of agricultural commodities rise, the country's agricultural products become less competitive in international market, causing export of agricultural goods to shrink. These might cause an increased mobility of factors of production and their reallocation, causing mobility of resources from areas of low demand to areas of higher demand, and from oil energy intensive production to less oil intensive production.

The world oil price has often been characterized by fluctuations and uncertainty due to Iraq crisis, supply imbalances and decline in global oil inventories. For example, from the recorded highs of the year 2008 oil price shocks, when crude oil sold for as high as $143 per barrel in global market, oil price dropped sharply before the end that year to $42.94 per barrel in December, 2008. In 2014, the spot price of the Brent crude oil increased again and it was $101.12 per barrel on August 25, 2014 and dropped continuously to $36.42 per barrel on April 1, 2016. Oil prices picked up in that same month and the price of Brent oil has risen steadily through the year 2017. It was $60.42 per barrel on October 30, 2017, by January 26, 2018, it reached $70.08 per barrel, and as at October 1, 2018, price was $85.12 per barrel. Although, the price volatilities in recent years seems to have been moderate, but as an engine of economic growth, oil price has often been transmitted into many aspects of the economy.

Hanson, Robinson, and Schluter (1993) established that there is a general loss in agriculture sector during oil price increase. The general loss in agriculture as oil price hikes implies a significant loss in real sector productivity. This is because the role of agriculture in the real sector goes beyond basic food supply to the population and it gets more complex during the transition period of a developing economy into a developed economy. It is a major facilitator of economic growth especially for less developed countries. According to Kuznets (1961) and Johnston and Mellor (1961), the direct contributions of agriculture to the real sector involves increasing total productivity which is essential for aggregate economic growth. Others include: increasing national income, aiding the growth of other sectors through exchange of products and resources as well as contributing directly to foreign trade through exports. Agriculture contributes significantly to real sector growth and economic growth indirectly by its direct contributions to both domestic and external sectors. Thus, it is theoretically right to assume that if oil price change will impact on the real sector and aggregate economic growth, it comes indirectly through its effects on the real sector productivity, of which agriculture is key.

Among the leading agricultural countries in the world is India, with large proportion of agro-based industries responsible for its rapid economic growth. For instance, India is the topmost producer of millet and milk, second largest producer of rice, wheat, potato, sugarcane, tea and tobacco, to mention a few.

India now ranks as the third-largest oil-consuming country in the world, ranking behind U.S. and China in the first and second positions respectively. It is expected that India will overtake China in its position as the second largest net-oil importing country by the year since 2035. India's growing dependence on oil imports reflects its rapid economic growth which can no longer be sustained by domestic oil supply alone. India's oil consumption increased by about 10.04 percent between 2017 and 2018 only, oil consumption was about 15 million tons in 2017 and rose to about 17 million tons in 2018. Within the same period, diesel consumption increased by 14.5 percent while gasoline consumption increased by 15.6 percent. Meanwhile, India's crude oil imports has been increasing, rising from about 111.50 million tons in 2007 to about 213.93 million tons in 2017 to 220.4 million tons in 2018. Over 80 percent of India's oil requirement are met from external sources and their diesel and gasoline retail prices of are connected to world oil prices.

Due to an extraordinary dependence of India on oil imports, changes in crude oil price in the global oil market will affect production, especially in oil intensive industries and this poses a challenge to their real sector productivity and thus, economic growth. As long as India continues to rely heavily on oil import, rising oil prices are expected to hit its economy through the price transmission mechanisms.

This paper forms an extension of the existing literature by looking directly into the effects of oil price on value added to agriculture rather than on agricultural commodity prices or specific food production. This is because value added to agriculture is important for economic growth. This study is unique in two ways:

First, it tests the long-run relationship between food production and international oil price change on one hand, and also tests the long-run relationship between non-food production and oil price on the other hand through the recently developed Bayer and

Hanck cointegration procedure. Since the previous research on the relationship between agriculture and oil price might have based their confirmation of relationships existing between the two on arbitrary choice of conflicting cointegration results, the Bayer and Hanck cointegration tests used in this new study unveils better, the true relationship that exists within the models of food, non-food and total agricultural production.

Second, it shows the effects of oil price change on food and non-food productivity separately, and compares this with the effects on aggregate agricultural production. Since oil price change disrupts agricultural activities which accounts for a significant percentage of real sector productivity, the effects of oil price change on agriculture is better assessed through its contribution to real economic growth. Understanding how the changing prices affect agriculture, whether through food production or through non-food production, provides remarkable signals for policy making on the channels through which oil price changes get to decline real economic activity. This also offers useful information to policy makers on the specific energy policy and macroeconomic policy that might improve general economic welfare. This research, therefore, seeks to find if India's agricultural productivity is subject to world oil price, and which aspect of such production is more affected, because it shows the extent to which the attainment of general economic progress is bound to waver with oil price.

The rest of this paper is organized as follows: Section 2 is a reviews of literature in brief, Section 3 explains the data and methodology, Section 4 discusses the results, and Section 5 presents the conclusions.

4.2 Brief Review of Literature

Macroeconomic behaviour following oil price shocks in the past has triggered research interest on the interaction between oil prices and the macro-economy (Brown & Yücel, 2002; Hamilton, 1983; Mork, 1989). Research on the relationship between oil price and economic activities has taken several dimensions, such as its effects on the GDP, national income and reserves, inflation, exchange rates and stock markets returns (Hamilton, 2011; Kilian & Vigfusson; 2011; Olanipekun, et al, 2017). For instance, Hamilton (1983) found negative correlation in the relationship of GNP of the US with oil price changes, the US recession that followed an oil price increase was also linked to the extraordinary rise in oil price. Generally, the decline in aggregate economic activity has been associated with oil price increase (Balke, Brown & Yücel, 2002; Hooker, 1996; Mork, 1989; Mory, 1993; Mork, Olsen, & Mysen, 1994; Rasche & Tatom, 1977).

Few have examined the impact of oil price change on agriculture, showing that oil price increase has negative effects on food production (Esmaeili & Shokoohi, 2011) and prices of produce (Chen, Kuo & Chen, 2010; Nazlioglu, 2011; Nazlioglu & Soytas, 2012; Wang, Wu & Yang, 2014; Zhang & Chen, 2014; Zhang & Qu, 2015). Nazlioglu and Soytas (2011) and Fowowe (2016) did not find any linkage between price of oil and prices of agricultural products in Turkey and South Africa respectively. Gohin and Chantret (2010) found that real income effect and cost push effect are the linkages through which energy price impact negatively on agriculture. Real income effect causes reduction in demand for the sector’s produce when oil price goes up, while the cost push effect comes via the rise in agricultural input cost. Wang and McPhail (2014) showed that the short-run impact of oil price increase on agricultural productivity growth is negative and this retards the influence of agriculture in the economy in the long-run.

4.3 Data and Methodology

4.3.1 Data

In this paper, annual data from 1985 to 2017 are used. Data on food and non-food production are value of gross production for various food and non-food agriculture aggregates as obtained from Food and Agriculture Organization (FAO) of the United Nations Statistics via http://www.fao.org/faostat/en/#data/. Total agricultural production is the addition of food and non-food production for each year. The data on agricultural land area measured in hectare were also sourced from FAO statistics. The annual average of Brent crude oil spot price is derived from the U.S. Energy Information Administration (EIA). The choice of Brent crude oil for this research is because India's oil imports are mostly from Iran and the benchmark for Iranian crude oil price is the Brent. Data on total employment in agriculture, gross capital formation, measured in constant 2010 US dollar, and inflation as measured by the consumer price index were obtained from World Development Indicators (WDI).

4.3.2 Model Specification

In order to achieve the study objective, the empirical model for this study follows the Cob-Douglas production function in which aggregate production is a function of three conventional inputs: land, labour and capital proxied by gross capital formation. Due to the multi-input nature of agricultural production, the production function is extended by two other variables, oil price and inflation which shows the effects of changing general prices. In order to find out the various effects of the determinants on the food and non-food production separately, three models emerged which are expressed in Eqs. 1 to 3 as:

Model 1:

$$FOOD = \alpha_0 + \phi_1 OIL + \phi_2 LAND + \phi_3 EMP + \phi_4 GCF + \phi_5 INF + \mu_t \qquad (1)$$

Model 2:

$$NFOOD = \beta_0 + \delta_1 OIL + \delta_2 LAND + \delta_3 EMP + \delta_4 GCF + \phi\delta_5 INF + \mu_t \qquad (2)$$

Model 3:

$$\text{AGRIC}= \gamma_0 + \theta_1 OIL + \theta_2 LAND + \theta_3 EMP + \delta\theta_4 GCF + \theta\delta_5 INF + \mu_t \qquad (3)$$

where α_0, β_0 and γ_0 are the constant coefficients, μ_t is the stochastic term in each model which are independently and identically distributed. *FOOD* is agricultural food production, *NFOOD* is non-food agricultural production while *AGRIC* is the total agricultural production. *OIL* indicates oil price, *LAND* indicates land, *EMP* is total labour in agriculture, while *GCF* is gross capital formation and *INF* represents inflation rate.

The transformed version of the models in their log form, is as follows:

$$lFOOD = \alpha_0 + \phi_1 lOIL + \phi_2 lLAND + \phi_3 lEMP + \phi_4 lGCF + \phi_5 INF + \varepsilon_t \qquad (4)$$

$$lNFOOD = \beta_0 + \delta_1 lOIL + \delta_2 lLAND + \delta_3 lEMP + \delta_4 lGCF + \delta_5 INF + \varepsilon_t \qquad (5)$$

$$lAGRIC = \gamma_0 + \theta_1 lOIL + \phi\theta_2 lLAND + \theta_3 lEMP + \theta_4 lGCF + \theta_5 INF + \varepsilon_t \qquad (6)$$

The models in Autoregressive Distributed Lag (ARDL) approach are as follow:

$$\begin{aligned} \Delta lFOOD = {} & \alpha_0 + \phi_1 lFOOD_{t-1} + \phi_2 lOIL_{t-1} + \phi_3 lLAND_{t-1} + \phi_4 lEMP_{t-1} \\ & + \phi_5 lGCF_{t-1} + \phi_6 INF_{t-1} + \sum_{i=0}^{P} \phi_7 \, \Delta lFOOD_{t-1} + \sum_{i=0}^{P} \phi_8 \, \Delta lOIL_{t-1} \\ & + \sum_{i=0}^{P} \phi_9 \, \Delta LAND_{t-1} + \sum_{i=0}^{P} \phi_{10} \, \Delta lEMP_{t-1} + \sum_{i=0}^{P} \phi_{11} \, \Delta lGCF_{t-1} \\ & + \sum_{i=0}^{P} \phi_{12} \, \Delta INF_{t-1} + \varepsilon_t \end{aligned} \qquad (7)$$

$$\Delta lNFOOD = \beta_0 + \delta_1 lNFOOD_{t-1} + \delta_2 lOIL_{t-1} + \delta_3 lLAND_{t-1} + \delta_4 lEMP_{t-1} + \delta_5 lGCF_{t-1} + \delta_6 INF + \sum_{i=0}^{P} \delta_7\, \Delta lFOOD_{t-1} + \sum_{i=0}^{P} \delta_8\, \Delta lOIL_{t-1} + \sum_{i=0}^{P} \delta_9\, \Delta LAND_{t-1} + \sum_{i=0}^{P} \delta_{10}\, \Delta lEMP_{t-1} + \sum_{i=0}^{P} \delta_{11}\, \Delta lGCF_{t-1} + \sum_{i=0}^{P} \delta_{12}\, \Delta INF + \varepsilon_t \qquad (8)$$

$$\Delta lAGRIC = \gamma_0 + \theta_1 lAGRIC_{t-1} + \theta_2 lOIL_{t-1} + \theta_3 lLAND_{t-1} + \theta_4 lEMP_{t-1} + \theta_5 lGCF_{t-1} + \theta_6 INF_{t-1} + \sum_{i=0}^{P} \theta_7\, \Delta lARIC_{t-1} + \sum_{i=0}^{P} \theta_8\, \Delta lOIL_{t-1} + \sum_{i=0}^{P} \theta_9\, \Delta LAND_{t-1} + \sum_{i=0}^{P} \theta_{10}\, \Delta lEMP_{t-1} + \sum_{i=0}^{P} \theta_{11}\, \Delta lGCF_{t-1} + \sum_{i=0}^{P} \theta_{12}\, \Delta INF_{t-1} + \varepsilon_t \qquad (9)$$

Where l indicates the natural logarithm of the variables, Δ is the difference operator for the variables. The first parts of Eqs. (7) to (9) show the long-run coefficients of food, non-food and total agricultural production respectively, while the second parts indicate the short-run coefficients. Given that the economy of India is significantly associated with massive agriculture, and the fact that India is a leading net oil importer, oil price is envisaged to have negative impact on agricultural production, it is expected that $\emptyset_2 > 0, \emptyset_3 > 0, \emptyset_4 > 0, and\ \emptyset_5 > 0$ from Eq. (4), on the other hand, we expect $\emptyset_1 < 0,\ and\ \emptyset_6 > 0$. From Eq. (5) we expect $\delta_2 > 0, \delta_3 > 0, \delta_4 > 0, and\ \delta_5 > 0$, on the other hand we expect $\delta_1 < 0,\ and\ \delta_6 > 0$ and from Eq. (6), we expect $\theta_2 > 0, \theta_3 > 0, \theta_4 > 0, and\ \theta_5 > 0,$ while we expect $\theta_1 < 0,\ and\ \theta_6 > 0$

Therefore, based on Eqs. (7) to (9), whenever any of the explanatory variables changes, agricultural productivity may not immediately change to its long-run equilibrium state, hence there will be short-run disequilibrium in the system. The adjustment of the short-run to its long-run equilibrium will take place through the error correction mechanism (ECM). The ECM equation is expressed as:

$$\Delta lFOOD = \alpha_0 + \sum_{i=0}^{P} \phi_7\, \Delta lFOOD_{t-1} + \sum_{i=0}^{P} \phi_8\, \Delta lOIL_{t-1} + \sum_{i=0}^{P} \phi_9\, \Delta lLAND_{t-1} + \sum_{i=0}^{P} \phi_{10}\, \Delta lEMP_{t-1} + \sum_{i=0}^{P} \phi_{11}\, \Delta lGCF_{t-1} + \sum_{i=0}^{P} \phi_{12}\, \Delta INF_{t-1} + \partial ECM_{t-1} + \varepsilon_t \qquad (10)$$

$$\Delta lNFOOD = \beta_0 + \sum_{i=0}^{P} \delta_7\, \Delta lNFOOD_{t-1} + \sum_{i=0}^{P} \delta_8\, \Delta lOIL_{t-1} + \sum_{i=0}^{P} \delta_9\, \Delta lLAND_{t-1} + \sum_{i=0}^{P} \delta_{10}\, \Delta lEMP_{t-1} + \sum_{i=0}^{P} \delta_{11}\, \Delta lGCF_{t-1} + \sum_{i=0}^{P} \delta_{12}\, \Delta INF_{t-1} + \gamma ECM_{t-1} + \varepsilon_t \qquad (11)$$

$$\Delta lAGRIC = \gamma_0 + \sum_{i=0}^{P} \theta_7\, \Delta lAGRIC_{t-1} + \sum_{i=0}^{P} \theta_8\, \Delta lOIL_{t-1} + \sum_{i=0}^{P} \theta_9\, \Delta LAND_{t-1} + \sum_{i=0}^{P} \theta_{10}\, \Delta lEMP_{t-1} + \sum_{i=0}^{P} \theta_{11}\, \Delta lGCF_{t-1} + \sum_{i=0}^{P} \theta_{12}\, \Delta INF_{t-1} + \partial ECM_{t-1} + \varepsilon_t \qquad (12)$$

The pace of adjustment to the long-run equilibrium level in Eqs. (10) to (12) is captured byECM_{t-1}, which is defined in the long-run equation, as one period lag of residuals.

4.3.3 Unit Root Tests

Ascertaining the stationarity of the underlying data series requires testing them for unit root, Zivot and Andrews (1992) structural break unit root test is preferred to the conventional unit root tests such as the Augmented Dickey-Fuller (ADF), the Phillips–Perron (PP) and KPSS because it accounts for and shows an information about structural breaks which may exist in the series. The conventional unit root tests fail to accommodate this, hence we might not possibly reject the null hypothesis of no unit root when it should otherwise be rejected. This makes the conventional unit root tests have lower predictive power, hence, reliance on their unit root test results alone tends to lead us to producing spurious results in our estimation, which are not reliable for drawing inferences. Judgment based on the Zivot-Andrew unit root test will help us to be fair enough so as not to reject or fail to reject the null hypothesis when we should have decided otherwise.

The null hypothesis for Zivot-Andrew unit root test is $H_0 : \theta = 0$, and the alternative hypothesis is $H_1 : \theta < 0$. For this study, the Zivot-Andrews unit root tests are performed in two ways with two different equations.

The equation for test with break in intercept is given as:

$$\Delta x_t = \alpha_0 + \alpha_1 + \lambda x_{t-1} + \phi DU_t + \sum_{j=1}^{k} \theta_j \Delta x_{t-j} + v_t \tag{13}$$

Equation for test with break in intercept and trend is given as:

$$\Delta x_t = \varphi_0 + \varphi_1 + \lambda x_{t-1} + \phi DU_t + \Phi DT_t + \sum_{j=1}^{k} \theta_j D x_{t-j} + v_t \tag{14}$$

$DU_t = 1$ if t > T_j^b, and 0 if otherwise.

Similarly, $\Phi DT_t = t - T_j^b$ if t > T_j^b, and 0 if otherwise.

In Eqs. (13) and (14) DU_t represents the dummy variable which indicates the shift in the mean of the data series that occurs at a possible breakpoint (T_j^b), while the trend variable represented by DT_t corresponds to the mean shift and T_j^b denotes the possible break point that may appear in the series. The null hypothesis of the Z-A single breakpoint test states that $H_0 : \theta = 0$. If we cannot reject this, then a unit root exists in the presence of single breakpoint, if otherwise, we go with the alternative hypothesis stated as $H_1 : \theta < 0$, then, we are able to reject the null hypothesis implying that no unit root is found in the presence of a single breakpoint.

4.3.4 Bayer and Hanck Cointegration Test

To examine cointegration among the variables, a cointegration test proposed by Bayer and Hanck (2013) is explored in this study. B-H cointegration test has an advantage over most of the cointegration tests applied by previous studies on the relationship between agricultural productivity and oil price. The B-H cointegration test combines four major cointegration tests - Engle and Granger (1987), Johansen (1995), Boswijk (1994) and Bannergee (1998) to give robust results (Shahbaz, Khan, Ali & Bhattacharya, 2017). This method by Bayer and Hanck (2013) overcomes the challenge of possible conflicts in results that may arise while using different types of cointegration tests, and it prevents random and inconsistent decision taking. The B-H test applies the formula proposed by Fisher (1932) to combine the statistical level of significance for the separate cointegration tests. The separate cointegration tests are written in the following form:

$$EG - JOH = -2[ln(Pro_{EG}) + ln(Pro_{JOH})] \tag{15}$$

$$EG - JOH - BO - BDM = -2[ln(Pro_{EG}) + ln(Pro_{JOH}) + ln(Pro_{BO}) + ln(Pro_{BDM})] \quad (16)$$

In Eqs. (15) and (16), EG indicates the Engle and Granger (1987) cointegration test with (Pro_{EG}) representing the corresponding p-value, and JOH indicates Johansen (1995) cointegration test with (Pro_{JOH}) representing the corresponding p-value. BO indicates the Boswijk (1994) cointegration test with its corresonding p-value as (Pro_{BO}), while BDM indicates the cointegration test proposed by Banerjee (1998) with the corresponding p-value as (Pro_{BDM}).

The decision on the existence of cointegration among our varables of interest is based Fisher's statistic. The null hypothesis of no cointegration is rejected if the B-H critical values are greater than the calculated Fisher statistics. If not, then we will fail to reject the null hypothesis of no cointegration. This implies that there exists a long-run relationship among the variables.

4.3.5 VECM Granger Causality Test

In the presence of cointegrating relationship among the variables, both short and long-run causal relationships among the variables are estimated. Under the framework for vector error correction mechanism *(ECM),* the Granger causality tests for each of the three models earlier specified are performed. The framework for VECM Granger causality model takes the following form:

Model 1

$$\begin{pmatrix} \Delta lFOOD_t \\ \Delta lOIL_t \\ \Delta LAND_t \\ \Delta lEMP_t \\ \Delta lGCF_t \\ \Delta INF_t \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{pmatrix} + \begin{pmatrix} \beta_{11}\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16} \\ \beta_{21}\beta_{22}\beta_{33}\beta_{24}\beta_{25}\beta_{26} \\ \beta_{31}\beta_{32}\beta_{33}\beta_{34}\beta_{35}\beta_{36} \\ \beta_{41}\beta_{42}\beta_{43}\beta_{44}\beta_{45}\beta_{46} \\ \beta_{51}\beta_{52}\beta_{53}\beta_{54}\beta_{55}\beta_{56} \\ \beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{65}\beta_{66} \end{pmatrix} \times \begin{pmatrix} \Delta lFOOD_{t-1} \\ \Delta lOIL_{t-1} \\ \Delta LAND_{t-1} \\ \Delta lEMP_{t-1} \\ \Delta lGCF_{t-1} \\ \Delta INF_{t-1} \end{pmatrix} + \cdots + \begin{pmatrix} \beta_{11}\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16} \\ \beta_{21}\beta_{22}\beta_{33}\beta_{24}\beta_{25}\beta_{26} \\ \beta_{31}\beta_{32}\beta_{33}\beta_{34}\beta_{35}\beta_{36} \\ \beta_{41}\beta_{42}\beta_{43}\beta_{44}\beta_{45}\beta_{46} \\ \beta_{51}\beta_{52}\beta_{53}\beta_{54}\beta_{55}\beta_{56} \\ \beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{65}\beta_{66} \end{pmatrix} \times \begin{pmatrix} \Delta lFOOD_{t-1} \\ \Delta lOIL_{t-1} \\ \Delta LAND_{t-1} \\ \Delta lEMP_{t-1} \\ \Delta lGCF_{t-1} \\ \Delta INF_{t-1} \end{pmatrix} + \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \end{pmatrix} ECT_{t-1} + \begin{pmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \\ \mu_5 \\ \mu_6 \end{pmatrix} \quad (17)$$

Model 2

$$\begin{pmatrix} \Delta lNFOOD_t \\ \Delta lOIL_t \\ \Delta LAND_t \\ \Delta lEMP_t \\ \Delta lGCF_t \\ \Delta INF_t \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{pmatrix} + \begin{pmatrix} \beta_{11}\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16} \\ \beta_{21}\beta_{22}\beta_{33}\beta_{24}\beta_{25}\beta_{26} \\ \beta_{31}\beta_{32}\beta_{33}\beta_{34}\beta_{35}\beta_{36} \\ \beta_{41}\beta_{42}\beta_{43}\beta_{44}\beta_{45}\beta_{46} \\ \beta_{51}\beta_{52}\beta_{53}\beta_{54}\beta_{55}\beta_{56} \\ \beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{65}\beta_{66} \end{pmatrix} \times \begin{pmatrix} \Delta lNFOOD_{t-1} \\ \Delta lOIL_{t-1} \\ \Delta LAND_{t-1} \\ \Delta lEMP_{t-1} \\ \Delta lGCF_{t-1} \\ \Delta INF_{t-1} \end{pmatrix} + \cdots + \begin{pmatrix} \beta_{11}\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16} \\ \beta_{21}\beta_{22}\beta_{33}\beta_{24}\beta_{25}\beta_{26} \\ \beta_{31}\beta_{32}\beta_{33}\beta_{34}\beta_{35}\beta_{36} \\ \beta_{41}\beta_{42}\beta_{43}\beta_{44}\beta_{45}\beta_{46} \\ \beta_{51}\beta_{52}\beta_{53}\beta_{54}\beta_{55}\beta_{56} \\ \beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{65}\beta_{66} \end{pmatrix} \times \begin{pmatrix} \Delta lNFOOD_{t-1} \\ \Delta lOIL_{t-1} \\ \Delta LAND_{t-1} \\ \Delta lEMP_{t-1} \\ \Delta lGCF_{t-1} \\ \Delta INF_{t-1} \end{pmatrix} + \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \end{pmatrix} ECT_{t-1} + \begin{pmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \\ \mu_5 \\ \mu_6 \end{pmatrix} \qquad (18)$$

Model 3

$$\begin{pmatrix} \Delta lAGRIC_t \\ \Delta lOIL_t \\ \Delta LAND_t \\ \Delta lEMP_t \\ \Delta lGCF_t \\ \Delta INF_t \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{pmatrix} + \begin{pmatrix} \beta_{11}\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16} \\ \beta_{21}\beta_{22}\beta_{33}\beta_{24}\beta_{25}\beta_{26} \\ \beta_{31}\beta_{32}\beta_{33}\beta_{34}\beta_{35}\beta_{36} \\ \beta_{41}\beta_{42}\beta_{43}\beta_{44}\beta_{45}\beta_{46} \\ \beta_{51}\beta_{52}\beta_{53}\beta_{54}\beta_{55}\beta_{56} \\ \beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{65}\beta_{66} \end{pmatrix} \times \begin{pmatrix} \Delta lAGRIC_{t-1} \\ \Delta lOIL_{t-1} \\ \Delta LAND_{t-1} \\ \Delta lEMP_{t-1} \\ \Delta lGCF_{t-1} \\ \Delta INF_{t-1} \end{pmatrix} + \cdots + \begin{pmatrix} \beta_{11}\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16} \\ \beta_{21}\beta_{22}\beta_{33}\beta_{24}\beta_{25}\beta_{26} \\ \beta_{31}\beta_{32}\beta_{33}\beta_{34}\beta_{35}\beta_{36} \\ \beta_{41}\beta_{42}\beta_{43}\beta_{44}\beta_{45}\beta_{46} \\ \beta_{51}\beta_{52}\beta_{53}\beta_{54}\beta_{55}\beta_{56} \\ \beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{65}\beta_{66} \end{pmatrix} \times \begin{pmatrix} \Delta lAGRIC_{t-1} \\ \Delta lOIL_{t-1} \\ \Delta LAND_{t-1} \\ \Delta lEMP_{t-1} \\ \Delta lGCF_{t-1} \\ \Delta INF_{t-1} \end{pmatrix} + \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \end{pmatrix} ECT_{t-1} + \begin{pmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \\ \mu_5 \\ \mu_6 \end{pmatrix} \qquad (19)$$

In Eqs. (17) to (19), Δ represents the difference operator. ECT_{t-1} is the lag of the error correction term obtained from the long-run equations. The error terms assumed to have zero mean and finite covariance matrices are represented by $\mu_1, \mu_2, \mu_3, \mu_4, \mu_5$ and μ_6. If the value of ECT_{t-1} is statistically significant, then long-run causal relationship exists among the variables. If F-statistic for first difference of variables is statistically significant, then short-run causal relationship exists between the variables.

4.4 Empirical Findings and Discussions

4.4.1 Descriptive Statistics

The descriptive statistics of the variables is presented in Table 10. Land has the highest mean value of 180534.7, followed by gross capital formation with 36.257. The standard deviation values show that all series, except land, are less volatile, as their standard deviation values range from 0.133 for employment in agriculture to 4.314 for gross capital formation. The statistics suggest that labour in agriculture has the least variation among the series in the study, while land is the most volatile with a standard deviation of about 710.764. Furthermore, the values of skewness are closed to zero for most of the variables, but gross capital formation tends to be negatively skewed with a value of -2.102 suggesting asymmetry. The series have positive kurtosis values, gross capital formation is not normally distributed as the kurtosis figure exceeds 5. Consequently, the null hypothesis for the Jarque-Bera normality test can only be rejected for gross capital formation at 1% significance level, because it is not normally distributed. The time plots of the variables presented in Figure 3 show that as value added to food, non-food and total agriculture are upward trending, land and labour employed in agriculture are downward trending. This is an indication of India's rapid move towards development, share of labour in agriculture declines.

Table 10: Descriptive Statistics

	*l*FOOD	*l*NFOOD	*l*AGRIC	*l*OIL	*L*land	*l*EMP	*l*GCF	INFLATION
Mean	18.935	15.941	18.984	8.123	180534.7	4.034	36.257	7.508
Median	18.910	15.820	18.954	7.824	180560.0	4.088	37.590	7.164
Maximum	19.360	16.515	19.416	9.320	181586.0	4.183	39.041	13.870
Minimum	18.475	15.311	18.521	7.152	179573.0	3.755	25.001	3.263
Std. Dev.	0.278	0.385	0.283	0.705	710.764	0.133	4.314	3.097
Skewness	0.040	0.291	0.061	0.437	-0.002	-0.800	-2.102	0.288
Kurtosis	1.901	1.800	1.893	1.726	1.439	2.317	5.783	1.970
Jarque-Bera	1.669	2.445	1.707	3.285	3.352	4.158	34.946	1.916
Probability	0.434	0.295	0.426	0.195	0.187	0.125	0.000	0.384

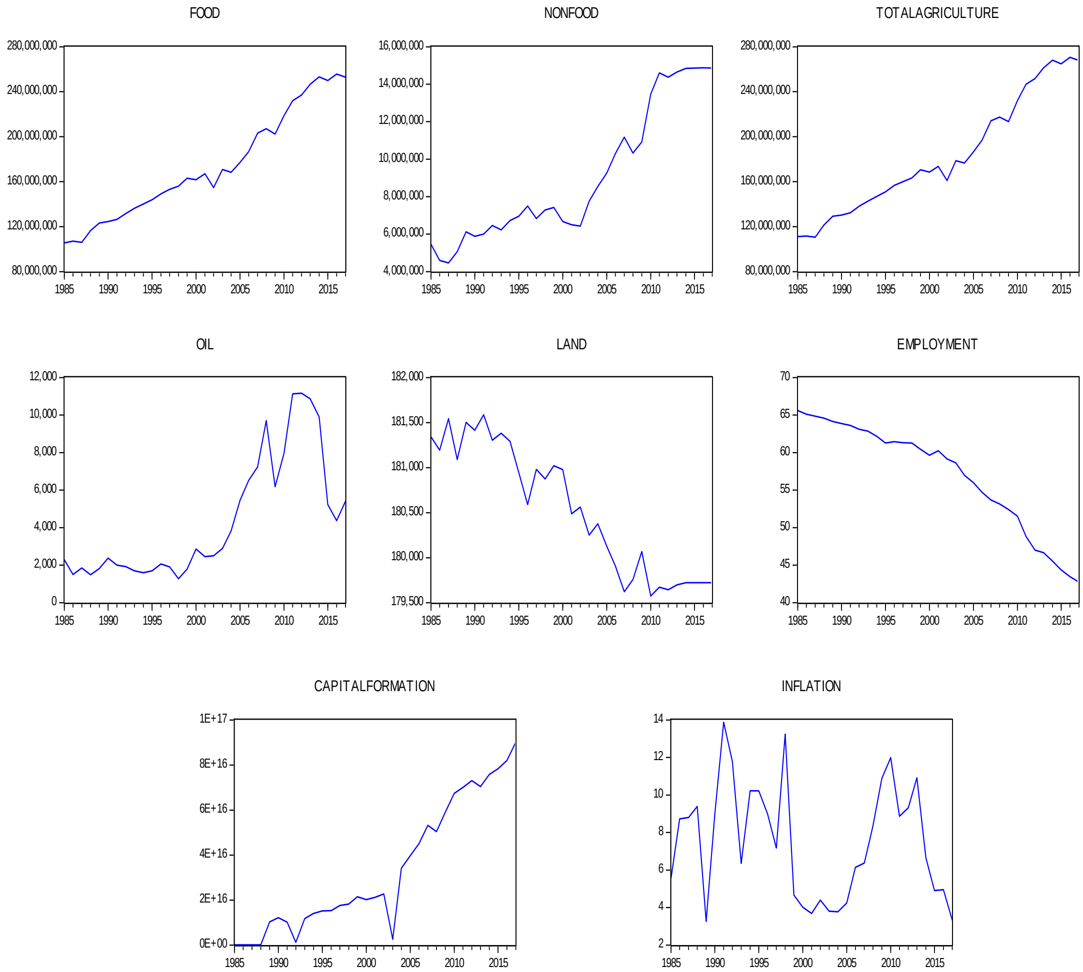


Figure 3: Time Plots of Variables- *l*food, *l*nfood, lagric, *l*oil, land, *l*emp, *l*gcf and Inflation

4.4.2 Unit Root Tests

The Z-A test results in Table 11 shows that all our variables are not stationary at level but Table 12 shows that they are stationary at first difference I(1). The Z-A test identified breaks in each of the variables which vary depending on the intercept or intercept and trend tests. ADF and PP tests results are also provided in Table 13 for robustness check on the unit root tests.

Table 11: Zivolt Andrew Unit Root Tests at Level

	Intercept		**Intercept and trend**	
Variables	**Statistics**	**Break date**	**Statistics**	**Break date**
lFOOD	-3.797	2000	-3.757	2002
lNON-FOOD	-3.635	1997	-3.446	1997
lAGRIC TOTAL	-3.693	2000	-3.639	2000
lOIL	-3.203 (1)	2004	-2.517 (1)	2005
lLAND	-4.282	2001	-4.364	2005
lEMP	-2.855	2011	-4.340	2001
lGCF	-2.645	2000	-6.041	1992
INFLATION	-4.243 (2)	1999	-4.420 (2)	1999
1 Percent	-5.57		-5.34	
5 Percent	-5.08		-4.93	
10 Percent	-4.82		-4.58	

Note: Except otherwise stated in parenthesis, chosen lag length reported for each estimation is 0

Table 12: Zivolt Andrew Unit Root Tests in First Difference.

	Intercept		**Intercept and trend**	
Variables	**Statistics**	**Break date**	**Statistics**	**Break date**
lFOOD	-8.115***	2003	-8.174***	2006
lNON-FOOD	-6.495***	2003	-6.415***	2003
lAGRIC TOTAL	-7.986***	2003	-7.827***	2003
lOIL	-5.510 (1)***	1999	-5.914 (1)***	2004
lLAND	-9.557***	2008	-9.465***	2008
lEMP	-5.659***	2004	-6.828***	2011

lGCF	-7.923 (4)***	2004	-7.466 (4)	2004
INFLATION	-6.516 (1)***	2002	-6.665(1)***	2006
1 Percent	-5.57		-5.34	
5 Percent	-5.08		-4.93	
10 Percent	-4.82		-4.58	

Notes: (i) Except otherwise stated in parenthesis, chosen lag length reported for each estimation is 0; (ii) *** indicates significance level at 1%, levels

Table 13: Philip Perron and ADF Unit Root Test Tests

Variable	Philip Perron unit root test		ADF unit root test	
	Level			
	Intercept	Intercept and trend	Intercept	Intercept and trend
lFOOD	-0.794179	-2.840842	-0.830562	-2.840482
lNON-FOOD	-0.041159	-2.567444	-0.211787	-2.567444
Ln AGRIC	-0.667022	-2.727119	-0.662059	-2.727119
lOIL	-1.007837	-2.260768	-1.007837	-2.143597
lLAND	-0.714812	-3.267690*	-0.973526	-3.267690*
lEMP	4.015014	-0.169002	3.614532	-0.313936
lGCF	-4133***	-2.974745	-2.831669*	-2.642520
INFLATION	-4.413303**	-2.974745	-3.195685**	-4.800329***
	1st difference			
	Intercept	Intercept and trend	Intercept	Intercept and trend
lFOOD	-7.441628***	-7.378448***	-7.321199***	-7.244175***
lNON-FOOD	-5.370239***	-5.188238***	-5.293090	-5.132154***
lAGRIC	-7.145161***	-7.016954***	-7.025679***	-6.938148***
lOIL	-5.532557***	-5.463122***	-5.535334***	-5.464698***

lLAND	-8.993704***	-8.833970***	-8.629459***	-8.485975***
lEMP	-3.537560**	-5.092413**	-3.577512***	-5.044803***
lGCF	-5.927***	-7.9550***	-5.854851***	-6.142563***
INFLATION	-5.912710***	-7.955010	-7.053234***	-6.964527***

Table 14: Bayer-Hanck and Bound Testing Cointegration tests.
Panel A: Bayer and Hanck Cointegration Analysis

Estimated Model	EG–JOH	EG–JOH–BO–BDM	Cointegration
$lFOOD_t = f(lOIL_t, lLAND_t, lEMP_t, lGCF_t, INF_t)$	55.7436	114.1118	Yes
$lOIL_t = f(lFOOD_t, lLAND_t, lEMP_t, lGCF_t, INF_t)$	55.6727	111.3542	
$lNFOOD_t = f(lOIL_t, lLAND_t, lEMP_t, lGCF_t, INF_t)$	56.4385	113.2419	Yes
$lOIL_t = f(lNFOOD_t, lLAND_t, lEMP_t, lGCF_t, INF_t)$	55.4621	118.3216	
$lAGRIC_t = f(lOIL_t, lLAND_t, lEMP_t, lGCF_t, INF_t)$	66.630	112.9859	Yes
$lOIL_t = f(lAGRIC_t, lLAND_t, lEMP_t, lGCF_t, INF_t)$	55.7191	111.9733	
1% Critical values	15.701	29.85	

Panel B: Robustness check through Bounds Testing Approach

Estimated Model	F-Statistics		T-Statistics	
$lnFOOD_t = f(OIL_t, lLAND_t, EMP_t, GCF_t, INF_t)$	6.887		-4.714	
$lnNFOOD_t = f(OIL_t, lLAND_t, EMP_t, GCF_t, INF_t)$	9.213		-5.954	
$lAGRIC_t = f(OIL_t, lLAND_t, EMP_t, GCF_t, INF_t)$	8.495		-4.707	
Critical Value	Lower Bound	Upper Bound	Lower Bound	Upper Bound
1 Percent	2.26	4.68	-3.13	-3.86
5 Percent	2.62	3.79	-2.86	-4.19
10 Percent	3.41	3.35	-2.57	-4.46

4.4.3 Cointegration Tests

Table 14 shows the evidence of cointegration among the variables in all three models using the Bayer and Hanck (2013) procedure for cointegration test and the robustness check for cointegration using ARDL bounds test procedure. Lag length was selected using the Akaike Information Criteria (AIC). Considering the Bayer and Hanck cointegration test, it was found that all F-statistics are significantly greater than the critical values in the three equations. All F-statistics and T-statistics are also greater than the upper bound of the ARDL bounds tests for cointegration in all three models. This agreement between Bayer and Hanck cointegration and ARDL test for cointegration results ascertains at least one cointegrating vector in the relationships within each model. Therefore, from the first model, a valid long-run relationship exists between food production, oil price, land used in agriculture, labour in agriculture, gross capital formation and inflation. From the second model, it is also evident that long-run relationship exists between oil price, non-food agricultural production, inflation and the three factors of production. Finally, this study also established that long-run relationship exists between total value added to agriculture, oil price, inflation, land labour and used in agriculture as well as capital formation. It also established that Bayer and Hanck cointegration procedure is valid for establishing this relationship. This finding is different from Fowowe (2016) who, with the use of structural breaks cointegration tests, could not establish any long-run relationship between oil prices and agricultural commodity prices.

Tables 15, 16 and 17, present the reports of the long- and short-run ARDL estimations for the three models in Eqs. 7, 8, 9 respectively.

4.4.4 Short-Run and Long-Run Relationships

Table 15: Long- and Short-run ARDL Coefficients for Model 1

Dependent Variable: D(*l*FOOD) (2, 0, 0, 0, 0, 2)

Short-run equation				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	26.9717***	5.573	4.840	0.000
*l*FOOD(-1)	-0.4779***	0.101	-4.714	0.000
*l*OIL	0.0073	0.016	0.454	0.654
*l*LAND	-16.9385***	0.000	-4.246	0.000
*l*EMP	-0.3305**	0.148	-2.232	0.037

*l*GCF	0.0068***	0.002	2.907	0.008
INFLATION(-1)	0.0054**	0.002	2.740	0.012
D(*l*FOOD(-1))	-0.3780**	0.147	-2.582	0.017
D(INFLATION(-1))	-0.0031**	0.002	-1.821	0.083
Long-run Equation				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
*l*OIL	0.0152	0.034	0.447	0.659
*l*LAND	-35.4978***	0.000	-4.498	0.000
*l*EMP	-0.6916***	0.197	-3.514	0.002
*l*GCF	0.0142***	0.003	4.118	0.001
INFLATION	0.0114**	0.005	2.469	0.022
ECM	-0.4779***	0.067	-7.153	0.000

Diagnostic Tests	Statistic	P-value
$\chi^2 SERIAL$	1.142076	0.3401
$\chi^2 ARCH$	0.159217	0.8536
$\chi^2 RESET$	0.419653	0.6792
$\chi^2 NORMAL$	6.853702	0.032489

In table 15, having food production as the dependent variable. The impact of oil price on food production is not significant both in the short-run and in the long-run. However, the short-run and long-run impact of land, labour and capital on food production are highly significant. Specifically, a percentage increase in land causes food production decline by about 16.94% in the short-run while it also decreases food production by about 35.5% in the long-run. A percentage increase in labour in agriculture causes a decrease in food production by 0.33% in the short-run and 0.69% in the long-run. However, an increase in gross capital formation by 1% will increase food production by 0.068% in the short-run and 0.014% in the long-run. A unit increase in the rate of inflation will negatively affect food production by 0.31% in the short-run but in the long-run food production will increase by 1.1% even as inflation rate increases by 1 unit.

Table 16 presents the results of equation 8 estimated, in which non-food agricultural production is the dependent variable. Again, oil price change has no significant impact on value of non-food agriculture both in the short- and long-run. An expansion of land by one percent will decrease non-food production by 36% in the short-run but decrease it in the long-run by about 34%. In the short-run, a percentage increase in agricultural labour will reduce productivity by 1.796% and by 1.688% in the long-run. However, if gross capital formation is increased by 1%, non-food agriculture will increase by 0.238% and in the 0.016% in the short- and long-run respectively. A unit rise in inflation rate will increase value added to non-food agriculture in the short-run by 0.96% and about 2.08% in the long-run.

Table 16: Long- and Short-run ARDL Coefficients for Model 2
Dependent Variable: D(*l*NFOOD) (2, 0, 2, 0, 1, 1)

Short-run

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	59.6843***	9.414	6.340	0.000
*l*NFOOD(-1)	-1.0641***	0.179	-5.954	0.000
*l*OIL	-0.0040	0.031	-0.128	0.899

*l*LAND(-1)	-36.3195***	0.000	-4.685	0.000
*l*EMP	-1.7962***	0.387	-4.637	0.000
*l*GCF(-1)	0.0174***	0.005	3.586	0.002
INFLATION(-1)	0.0222***	0.004	5.906	0.000
D(*l*NFOOD(-1))	0.3433**	0.122	2.826	0.011
D(*l*LAND)	-31.3624***	0.000	-4.531	0.000
D(*l*GCF)	0.0238***	0.005	4.590	0.000
D(INFLATION)	0.0096**	0.004	2.733	0.013
Long-run				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
*l*OIL	-0.0037	0.029144	-0.127327	0.900
*l*LAND	-34.1480***	4.48E-05	-4.211575	0.000
*l*EMP	-1.6880***	0.156127	-10.81194	0.000
*l*GCF	0.0163***	0.002945	5.547960	0.000
INFLATION	0.0208***	0.003217	6.479534	0.000
ECM	-1.0641***	0.127341	-8.356258	0.000

Diagnostic Tests	Statistic	P-value
$\chi^2 SERIAL$	0.5137	0.607
$\chi^2 ARCH$	0.3566	0.703
$\chi^2 RESET$	0.2016	0.843
$\chi^2 NORMAL$	0.6406	0.726

Table 17: Long- and Short-run ARDL Coefficients for Model 3

Dependent Variable = *lAGRIC* (1, 0, 0, 1, 0, 2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Short-run				
Constant	31.5038***	5.437	5.794	0.000
D*l*AGRIC(-1)	-0.9389***	0.200	-4.707	0.000
*l*OIL	0.0028	0.015	0.179	0.859
*l*LAND	-12.6430**	0.000	-2.489	0.022
*l*EMP(-1)	-0.4089**	0.154	-2.648	0.015
*l*GCF	0.0069***	0.002	2.980	0.007
INFLATION(-1)	0.0101***	0.003	3.809	0.001
D(INFLATION(-1))	-0.0045**	0.002	-2.340	0.030
Long-run				
*l*OIL	0.0029	0.016206	0.180587	0.859
*l*LAND	-13.4744***	0.000	-1.925	0.069
*l*EMP	-0.4355***	0.153	-2.843	0.010
*l*GCF	0.0074***	0.002	3.277	0.004
INFLATION	0.0107***	0.002	4.739	0.000
ECM	-0.9389***	0.118	-7.982	0.000

Diagnostic Tests	Statistic	P-value
$\chi^2 SERIAL$	1.1485	0.339
$\chi^2 ARCH$	0.1165	0.891
$\chi^2 RESET$	0.5622	0.580
$\chi^2 NORMAL$	2.072568	0.354771

Table 17 presents the results of equation 9, having the aggregate of agricultural production as dependent variable. Once more, the effect of oil price change is insignificant neither in the long-run nor in the short-run, and the impact of land and labour in agriculture is negative. As land use in agriculture increases by 1%, total productivity will fall by 13.47% % in the long-run and 12.64% in the short-run. A percentage increase in labour employed in agriculture will reduce production by 0.409% in the short-run and by 0.436%in the long-run. Gross capital formation increases production by 0.007% both in the short- and long-run when increased by 1%. Inflation rate will reduce total production by 0.45% in the short-run when increased by 1 unit, but will cause an increase in value added to agricultural production by 1.07% in the long-run.

These findings imply that agricultural production in India is independent of international spot price of crude oil, hence there are agricultural inputs other than oil products which are being used as an input in agricultural production in India. The general finding conforms to the neutrality hypothesis already established in the study of link between agricultural commodity prices and global oil prices by Fowowe (2016), Nazlioglu (2011) and Zhang, Lohr, Escalante and Wetzstein (2010). Nazlioglu and Soytas (2011), with impulse response analysis also confirmed that agricultural commodity prices do not respond to both direct and indirect effects of oil prices changes in the long- and short-run. This is also buttressed by the findings of Hanson, et al. (1993) that the effects of global oil prices on energy costs in agriculture are dependent on the exchange rate policy adjustments and adjustments of government finance to higher oil import costs.

Contrary to the a-priori expectation, the coefficients of employment and land in agriculture are negative. This inverse relationship between employment in agriculture and food and non-food productivity implies that these sectors' productivity continues to grow even as the sector loses more of its labour to secondary and tertiary sectors. As a large emerging market economy, it is also expected that India will have a shift in factors of production from primary sector to manufacturing and tertiary sectors as it paces towards development. This is clearly depicted in appendix, Figure 1, where all the variables on agriculture maintain an upward trend even though employment in agriculture takes a downward trend for over three decades. This is an indication of development, and technological advancement in the real sector. This can also explain why there is an inverse relationship between agricultural land area and value of agricultural production. It is synonymous to the findings of Yotopoulos and Lau (1973) and Yotopoulos, Lau and Somel (1970) who for India, also found negative relationship between farm size and agricultural productivity while testing for relative economic efficiency of land in agricultural productivity (see also, Ahmad, et al., 1999). The empirical results proved that the relationship between gross capital formation and agriculture is positive both in the short-run and long-run, emphasizing the impact of capital inputs in production. Thus, increasing capital input supply and more conventional technology in production will stimulate the growth of agricultural production. It also shows that the negative effects of inflation on production is only a short-run phenomenon, the impact of inflation becomes positive in the long-run.

The coefficient of the ECM is negative and statistically significant at 1% in all three models. This indicates that the yearly adjustment of the deviations occurring in the short-run will be corrected by and 47%, 106% and 94% towards the long-run equilibrium path in the first, second and third models respectively. The speed of adjustment is highest in the model of non-food production and lowest in the model of food production. This implies that non-food production will adjust back to long-run equilibrium provided there is any distortion in the equilibrium. These adjustments mechanisms will be through the huge contribution of gross capital formation and inflation.

Going further, the diagnostic tests conducted on the models show that neither the null hypothesis of no heteroscedasticity nor the null hypothesis of no serial correction can be rejected. The ARCH test statistics for the existence conditional heteroscedasticity are above 5% and the Breusch–Godfrey LM test statistics for serial correction are above 5% in all. Thus, the problem of serial correlation and heteroscedasticity are not valid in the models. Additionally, the Ramsay RESET test statistics are above 5% in all three models, and the Jarque-Bera Normality test statistics, also show that the models are correctly specified in their functional forms, and the error terms are normally distributed in each model. Finally, the conducted stability tests for the models and the pictorial results are presented in figures 2-7. Both the CUSUM and CUSUM squared stability tests indicate the proper stability of the models at 5% level of significance each.

4.4.5 Conditional Granger Causality Tests

Tables 18 – 20 show both long-run and short-run directions of causality for each model estimated separately. In the short-run, it can be observed that the neutrality hypothesis is common to the relationship of oil price with food production, non-food production and the aggregate agricultural production. However, in the model of non-food production, one-way causality runs from oil price to gross capital formation in the short-run. In Tables 18 and 20, long-run causality is seen running from real sector variables, labour in agriculture, gross capital formation and inflation to oil price. Therefore, real sector variables, labour, capital formation and inflation help to predict the future values of oil price.

In Tables 18 and 20, bi-directional short-run causal relationships exist between gross capital formation and food production, and between gross capital formation and total agricultural production. This mutual interaction is an indication that agriculture, especially food production, is one of the major sources of India's economic wealth. There is no short-run causality from gross capital formation to non-food production in the second model as shown in Table 19. As expected, short-run causality runs from land and labour in agriculture to agricultural production. Also observed, is the short-run bi-directional relationship between inflation and gross capital formation, notable in all the three models. The implication of this result is that the mutual interaction between capital formation and inflation are the most crucial in the Indian agricultural sector and should receive proper policy attention provided there is any disequilibrium in the system. In the long-run results in Table 21, there are long run causal effects from oil price, land, labour and capital formation on food, non-food and total agricultural production, and from other variables to labour in agriculture. The long run causality also run from other variables to oil price only in the model of non-food production.

Table 18: Granger Causality Test for Model 1: $lFOOD, lOIL, LAND, lEMP, lGCF, INF$

Dependent	**Short-run Causality**					
variable	*l*FOOD	*l*OIL	*l*LAND	*l*EMP	*l*GCF	INFLATION
*l*FOOD	–	1.915	4.574	5.821*	4.760*	1.306
		(0.384)	(0.102)	(0.055)	(0.093)	(0.521)
	2.043	–	4.272	5.428*	10.417***	6.243**
*l*OIL	(0.360)		(0.118)	(0.066)	(0.006)	(0.044)
	7.715**	3.846	–	3.579	3.439	1.545
*l*LAND	(0.021)	(0.146)		(0.167)	(0.179)	(0.462)
	3.413	0.444	0.093	–	0.314	0.622586
*l*EMP	(0.182)	(0.801)	(0.954)		(0.855)	(0.7325)
	6.363**	1.360	6.517**	7.833**	–	7.132**
*l*GCF	(0.042)	(0.507)	(0.038)	(0.020)		(0.028)
	1.494	3.000	12.059	0.523	7.371**	-
INFLATION	(0.474)	0.223	(0.002)	(0.770)	(0.025)	

Note: The p-values are in parenthesis ( ); t-statictics are in parenthesis []

Table 19: Granger Causality Test for Model 2: $lNFOOD, lOIL, LAND, lEMP, lGCF, INF$

Dependent	**Short-run Causality**					
variable	*l*NFOOD	*l*OIL	*l*LAND	*l*EMP	*l*GCF	INFLATION
*l*NFOOD	–	1.505	1.450	2.612	0.414	0.981
		(0.471)	(0.484)	(0.271)	(0.813)	(0.612)
	1.574	–	0.830	0.386	0.857	1.414
*l*OIL	(0.455)		(0.660)	(0.825)	(0.652)	(0.493)

*l*LAND	10.190***	3.206	–	8.813**	1.202	2.668
	(0.006)	(0.201)		(0.012)	(0.548)	(0.264)
*l*EMP	3.220	0.451	0.067	–	1.098	0.000
	(0.200)	(0.798)	(0.967)		(0.578)	(1.000)
*l*GCF	25.223***	8.303**	9.343***	15.939***	–	23.861***
	(0.000)	(0.016)	(0.009)	(0.000)		(0.000)
INFLATION	0.063	1.421	6.763**	1.476	4.618*	-
	(0.969)	(0.492)	(0.034)	(0.478)	(0.099)	

Note: The p-values are in parenthesis ( )

Table 20: Granger Causality test for Model 3: $lAGRIC, lOIL, LAND, lEMP, lGCF, INF$

Dependent variable	**Short-run Causality**					
	*l*AGRIC	*l*OIL	*l*LAND	*l*EMP	*l*GCF	INFLATION
*l*AGRIC	–	2.614	5.614**	7.599**	5.517*	1.550
		(0.271)	(0.060)	(0.022)	(0.063)	(0.461)
*l*OIL	1.829	–	4.277	5.283**	9.564***	6.147**
	(0.401)		(0.119)	(0.071)	(0.008)	(0.046)
*l*LAND	8.444**	3.921	–	4.590	4.009	1.743
	(0.015)	(0.141)		(0.101)	(0.135)	(0.418)
*l*EMP	3.466	0.476	0.144	–	0.221	0.701
	(0.177)	(0.788)	(0.931)		(0.895)	(0.705)
*l*GCF	6.864**	0.032	6.845**	7.870**	–	7.910**
	(0.032)	(0.475)	(0.033)	(0.020)		(0.019)

	1.258	2.924	11.298***	0.545	7.374**	-
INFLATION	(0.533)	(0.231)	(0.004)	(0.762)	(0.025)	

Note: The p-values are in parenthesis ( )

Table 21: Long-run Causality Tests

Dependent variable	**Long-run causality** ECM_{t-1}	**Dependent variable**	**Long-run causality** ECM_{t-1}	**Dependent variable**	**Long-run causality** ECM_{t-1}
*l*FOOD	-0.632***	*l*NFOOD	-0.469**	*l*AGRIC	-0.710***
	[3.504]		[-2.301]		[-3.741]
	2.594*		0.856		2.842*
*l*OIL	[1.743]	*l*OIL	[1.219]	*l*OIL	[1.755]
	-0.007		0.008**		-0.007
*l*LAND	[-0.890]	*l*LAND	[-2.390]	*l*LAND	[-0.916]
	-0.006		-0.016		-0.019
*l*EMP	[-0.072]	*l*EMP	[-0.449]	*l*EMP	[-0.222]
	-30.602***		-22.988***		-33.725***
*l*GCF	[2.684]	*l*GCF	[6.920]	*l*GCF	[-2.752]
INFLATIO	-8.070	INFLATIO	2.501	INFLATIO	-8.156
N	[-0.554]	N	[0.369]	N	[-0.513]

t-statictics are in parenthesis []

4.5 Conclusion

The study examines the relationships between oil price changes and real sector growth with specific reference to agriculture productivity. Within the context of oil as an energy input in production, this research considered India's agricultural sector between the year 1985 and 2017. The recently developed test by Bayer and Hanck (2013) cointegration test was used in our three models featuring food production, non-food production and total agricultural production as dependent variables. This confirmed the existence of long-run relationships among the variables in each model and the evidence was also supported by the ARDL bounds test for cointegration.

Going further, the short-run and long-run coefficients of ARDL estimations showed that the effect of oil price on agricultural productivity is not significant, the effects of land and labour are both negative and statistically significant while the effects of gross capital formation is positive and also statistically significant. The effects of inflation in our models are positive in the long-run but negative in the short-run. This study also confirmed mutual causal interactions between gross capital formation and inflation, and between gross capital formation and agriculture. Therefore, how oil price affects the agriculture in the real sector economy is partly through its effects on gross capital formation both in the long-run and in the short-run. However, the error correction coefficient shows that non-food production will adjust faster from short-run to long-run equilibrium when there is a shock in the model.

On the basis on these findings, it is recommended that India should focus on capital formation because it is at the centre of this relationships in the real sector. The real sector growth through India's agriculture is hinged on its level of technological development and not oil energy consumption. This implies that the conventional methods of production in agriculture may not be oil intensive, and global oil price is not a direct input cost in production. Therefore, if oil price change will have any effect on India's real sector, it will not be through the agricultural sector. Moreover, if agriculture plays a key role in India's real sector growth, oil price change cannot constrain this development process. Economic policy adjustments and adjustments of government to the finance of oil import costs when price changes will be adequate to shield the system from the effects of changing oil prices.

Chapter 5

CONCLUSION

As a vital input in economic activities, energy demand is greatly associated with economic activities and dependence on commercial energy is in positive relation with the level of economic growth and development. As a vital component of economic growth and development, energy consumption and pricing-related problems are among the major energy issues faced by countries all over the world. With rising demand for energy as industrialization continues to rise, stakeholders are anxious about the causes and effects of the energy issues arising on daily basis. It is necessary to take into consideration that, apart from productive activities, economic and political strategies might as well be contributing to energy matters arising.

This thesis therefore examines the role of democratic accountability in the relationship between energy consumption and CO_2 emissions, and the interaction between oil price and the primary sector productivity for nine countries which have witnessed most varied political structure in recent years. It also examines the interaction between domestic prices of oil and economic policy uncertainty for 18 selected countries. This chapter summarizes the conclusion drawn out from each chapter.

Chapter 2 traces the phenomenon of environmental issues caused by massive energy consumption to the political system in nine countries characterized by political inconsistency. Through panel cointegration procedure, a long-run relationship between environmental degradation, income per capita, square of income per capita, energy consumption and democracy was confirmed. The ARDL long-run and short-run estimations did not only confirm the Environmental Kuznets Curve hypothesis, and the positive effects of energy consumption on CO_2 emissions, it is remarkable that it confirms that democracy has a reducing effect on CO2 emissions in the short- and long-run. However, this study has been able to establish that political structure has a mediating role to play in the energy consumption-environmental relationship. Strong democratic system is therefore recommended because the government of the day can often be pressurized by voters to improve environmental quality. Also, since democracy is a good platform for increasing national income and economic development, and a turning point is expected in the relationship between environmental degradation and squared term of income, it will get to a point where environmental degradation will begin to reduce even as the economy progresses.

As the most exclusively viable commercial energy, domestic oil pricing remains crucial for policy makers. Chapter 3 therefore examines the possible asymmetric causal effects of gasoline prices on economic policy uncertainty and vice versa for a panel of 18 countries between 1998 and 2017. Having established positive and negative asymmetric causal relationships between oil price and economic policy uncertainty, there is strong evidence, that oil price change is a source of economic policy uncertainty and policy uncertainty is responsible for oil price change. The feedback positive relationship found in this study implies that gasoline price increase will increase economic policy uncertainty, and economic policy uncertainty will also increase gasoline prices. Therefore, a vicious circle is expected when countries experiencing positive feedback relationship in this case have shock to one of these variables. In the case of a negative feedback relationship, a negative shock in economic policy uncertainty can be used to bring low gasoline prices under a perfect market condition. Provided both positive and negative feedback relations occur, the effects on the economy will be determined by the stronger between the magnitude of changes in both gasoline price and economic policy uncertainty, and on whether the positive effects supersede the negative effects. The implication of these findings is that economic policy has consequences for energy security. Conclusively, this study brings an insight into the role of economic policy uncertainty in determining domestic energy price. It is therefore recommended that macroeconomic policies be formulated with caution to prevent unstable energy prices.

Finally, the study in Chapter 4 has been able to establish a valid long-run relationship between India's primary sector, focusing on food and non-food production, and oil price. Having taken a non-arbitrary decision on their long-run relationship status, through judgement based on the combined cointegration procedure of Bayer and Hanck (2013), it can be concluded that both food and non-food production will not drift too far away from a combination of oil price change, inflation and other factors of production combined in agriculture in the long-run. This study also shows that the real sector variables, labour, capital and inflation, have influence on oil prices, this is a slight indication of the role India plays in global oil demand which in turn influences price. One unique feature of this finding is that, neither food production nor non-food production is subject to oil price changes, but both are highly dependent on factors of production and inflation. Therefore, if oil price change will impact on India's real sector, such will not occur via the agricultural sector. These imply that, as far as India is concerned, exchange rate policy adjustments to international spot price of oil and government policy on oil imports are efficient to quiet the effects of international price of oil on energy input costs in agriculture. However, since both inflation and capital are caused by oil price according to Granger causality results, it is right to assume that oil price will indirectly influence the real sector through its impact on gross capital formation and inflation.

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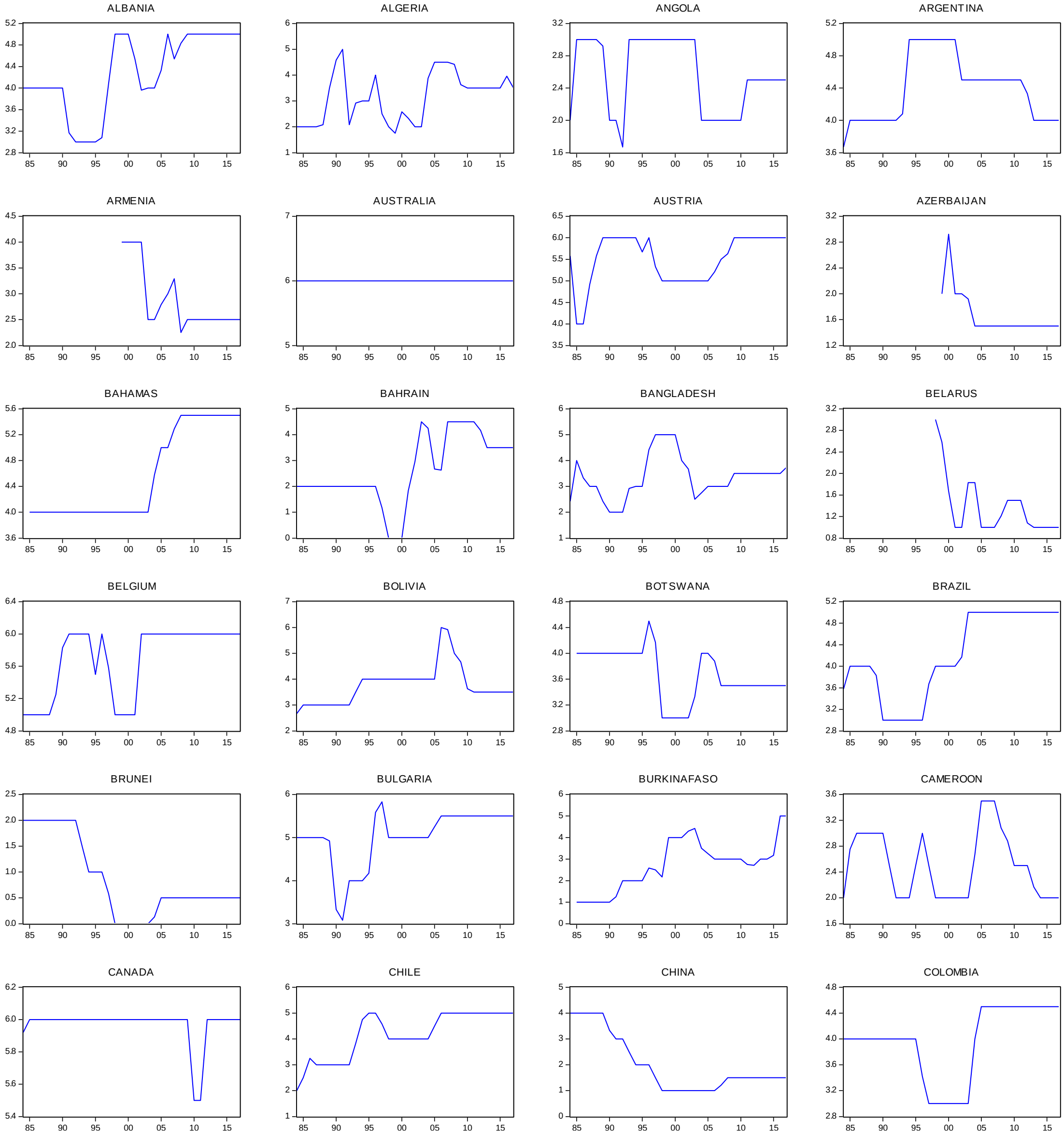
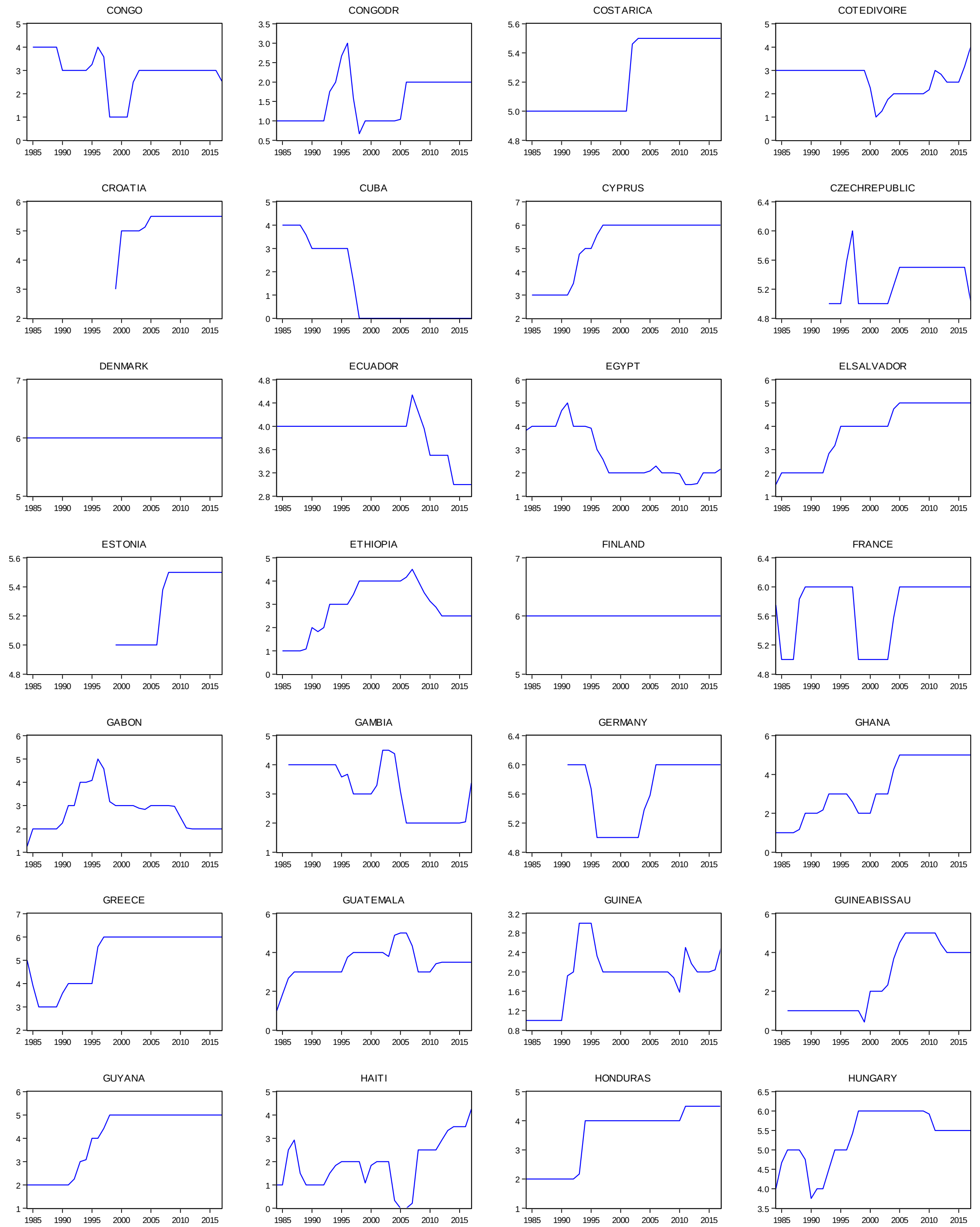
APPENDICES

Appendix A: Plot of Democratic Accountability for 139 Countries




CONGO
CONGODR
COSTARICA
COTEDIVOIRE
CROATIA
CUBA
CYPRUS
CZECHREPUBLIC
DENMARK
ECUADOR
EGYPT
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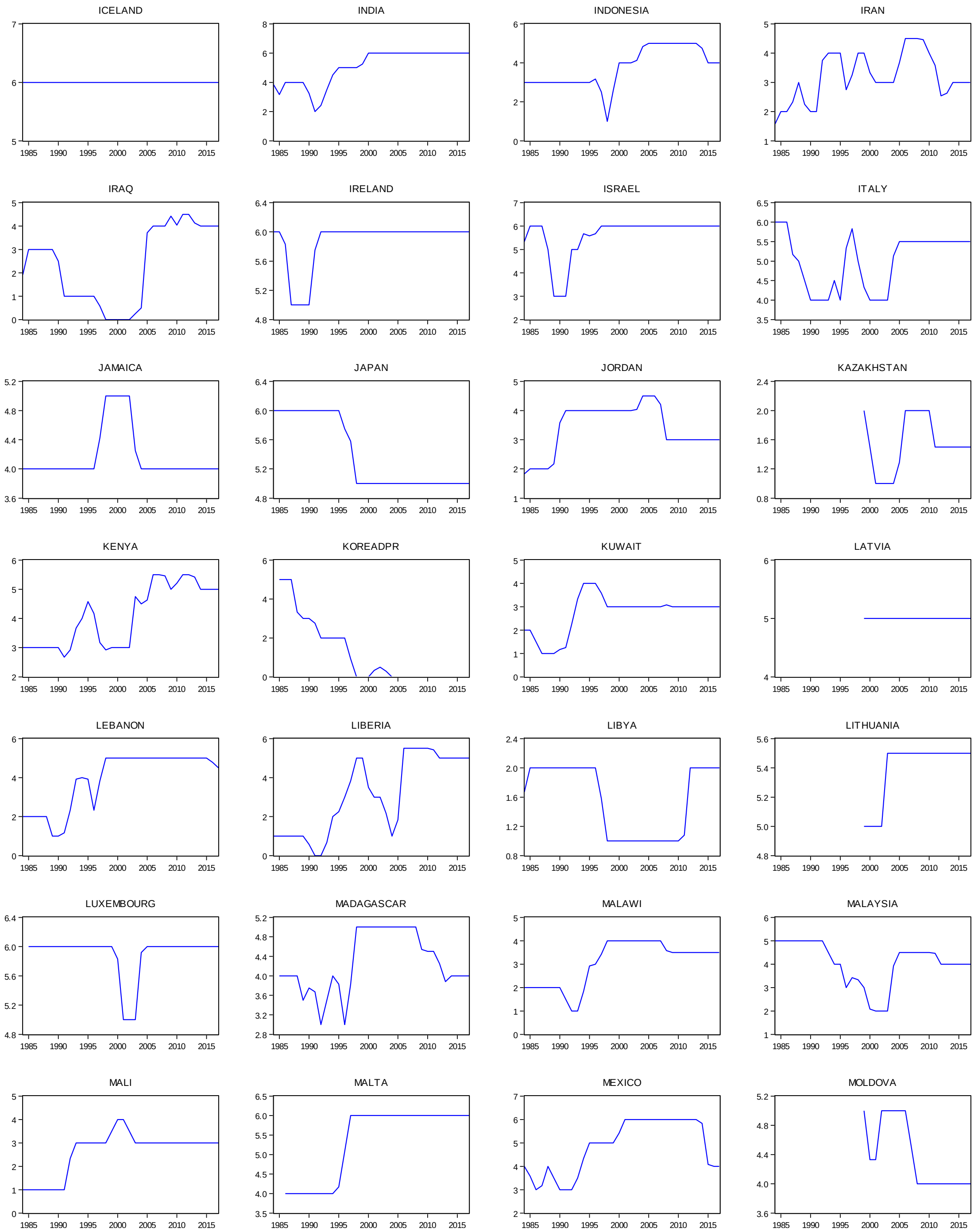
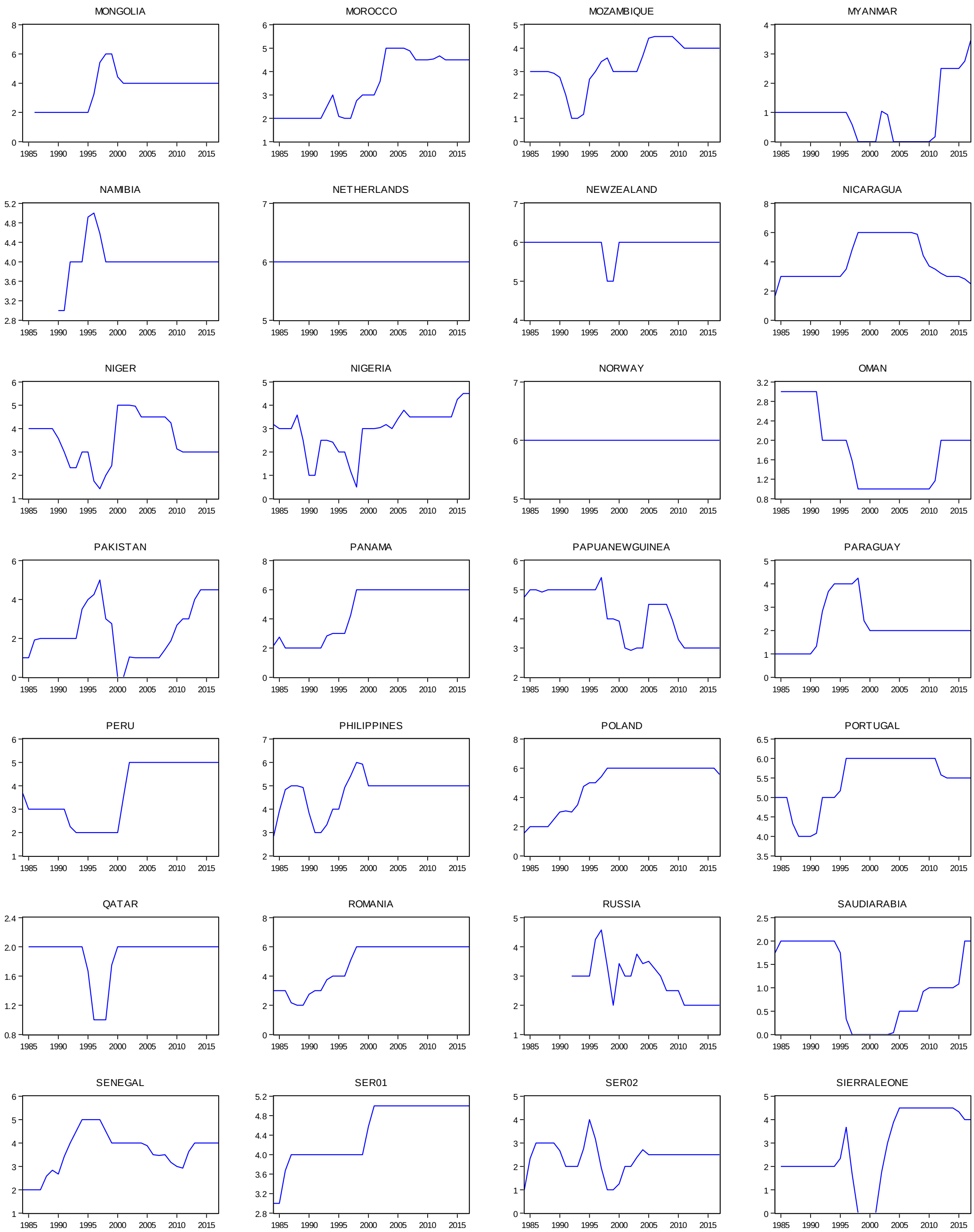
ESTONIA
ETHIOPIA
FINLAND
FRANCE
GABON
GAMBIA
GERMANY
GHANA
GREECE
GUATEMALA
GUINEA
GUINEABISSAU
GUYANA
HAITI
HONDURAS
HUNGARY


ICELAND
INDIA
INDONESIA
IRAN
IRAQ
IRELAND
ISRAEL
ITALY
JAMAICA
JAPAN
JORDAN
KAZAKHSTAN
KENYA
KOREADPR
KUWAIT
LATVIA
LEBANON
LIBERIA
LIBYA
LITHUANIA
LUXEMBOURG
MADAGASCAR
MALAWI
MALAYSIA
MALI
MALTA
MEXICO
MOLDOVA
1985 1990 1995 2000 2005 2010 2015


MONGOLIA
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MOZAMBIQUE
MYANMAR
NAMIBIA
NETHERLANDS
NEWZEALAND
NICARAGUA
NIGER
NIGERIA
NORWAY
OMAN
PAKISTAN
PANAMA
PAPUANEWGUINEA
PARAGUAY
PERU
PHILIPPINES
POLAND
PORTUGAL
QATAR
ROMANIA
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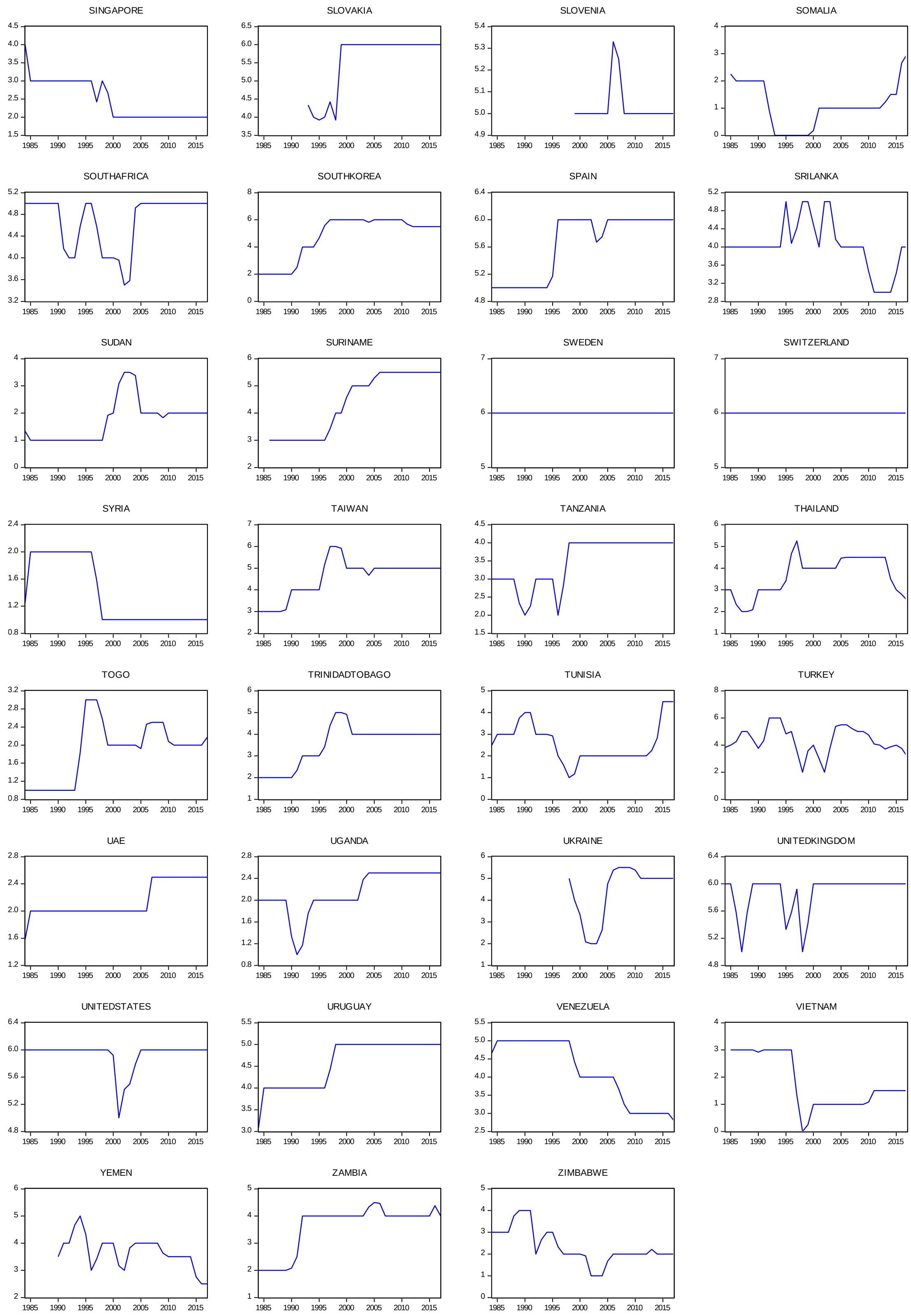

Figure 4: Plot of democratic accountability for 139 countries

Appendix B: CUSUM and CUSUM of Squares Tests for Model 1

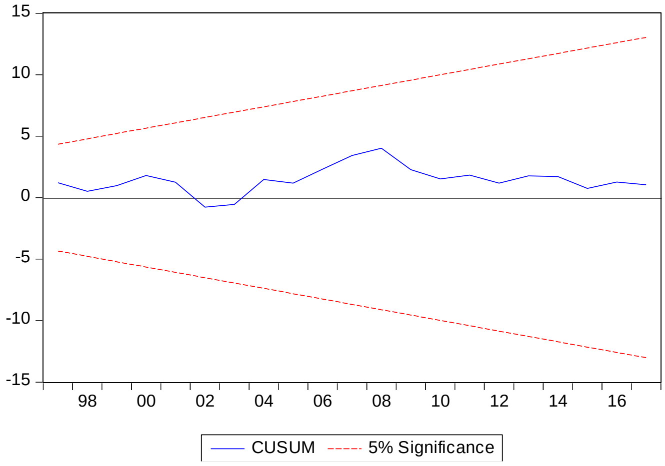

Figure 5: Cusum test for Model 1: $lnFOOD_t = f(OIL_t, LAND_t, EMP_t, GCF_t, INF_t)$

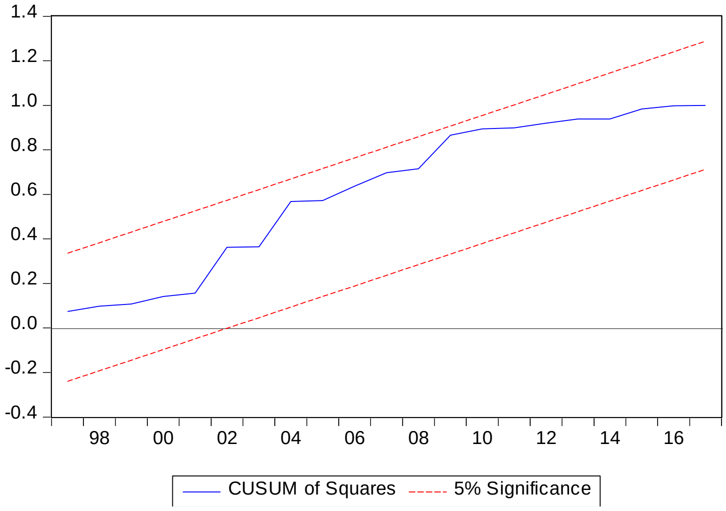

Figure 6: Cusum of squares test for Model 1: $lnFOOD_t = f(OIL_t, LAND_t, EMP_t, GCF_t, INF_t)$

Appendix C: CUSUM and CUSUM of Squares Tests for Model 2

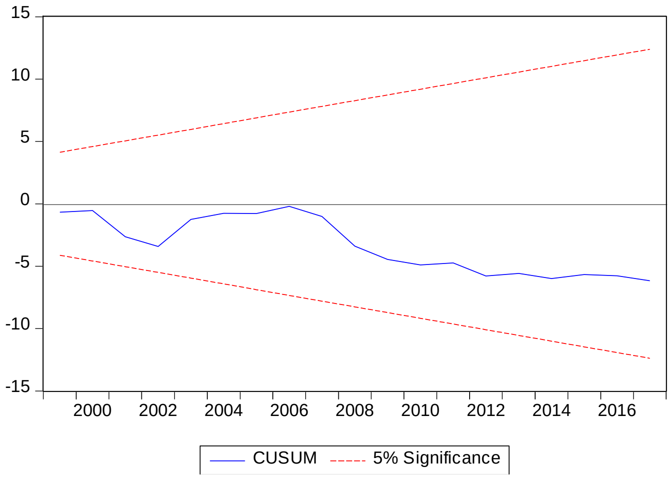

Figure 7: Cusum test for Model 2: $lnNFOOD_t = f(OIL_t, LAND_t,\ EMP_t,\ GCF_t, INF_t)$

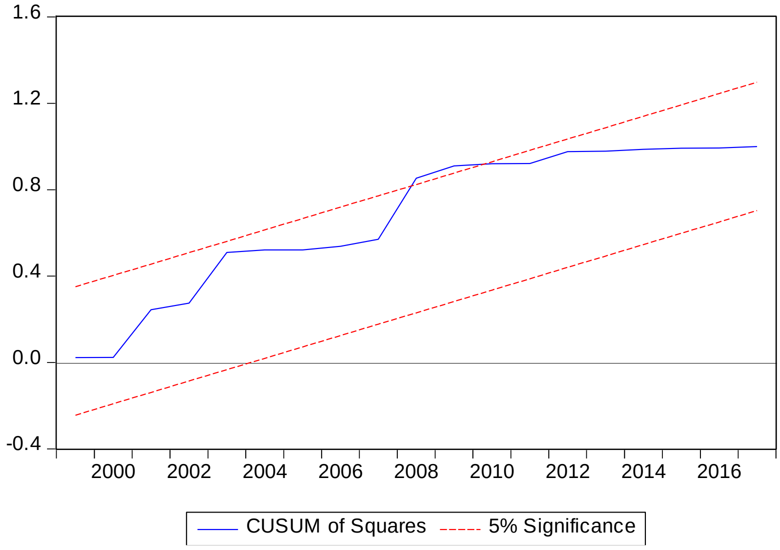

Figure 8: Cusum of squares test for Model 2: $lnNFOOD_t = f(OIL_t, LAND_t,\ EMP_t,\ GCF_t, INF_t)$

Appendix D: CUSUM and CUSUM of Squares Tests for Model 3

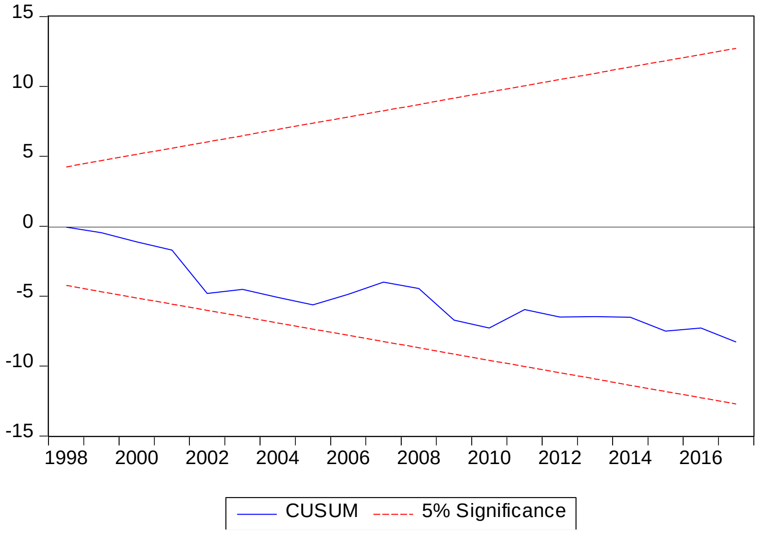

Figure 9: Cusum test for Model 3: $lAGRIC_t = f(OIL_t, LAND_t,\ EMP_t,\ GCF_t, INF_t)$

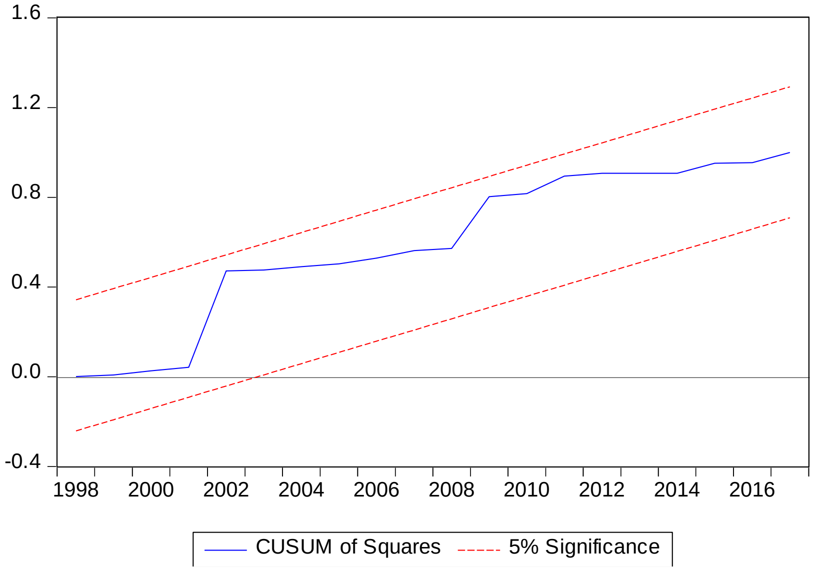

Figure 10: Cusum of squares test for Model 3: $lAGRIC_t = f(OIL_t, LAND_t,\ EMP_t,\ GCF_t, INF_t)$