Time-Varying Analysis of CO2 Emissions, Energy Consumption, and Economic Growth Nexus: Statistical Experience in Next 11 Countries

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Abstract: This paper detects the direction of causality among carbon dioxide (CO_2) emissions, energy consumption, and economic growth in Next 11 countries for the period 1972–2013. Changes in economic, energy, and environmental policies as well as regulatory and technological advancement over time, cause changes in the relationship among the variables. We use a novel approach i.e. time-varying Granger causality and find that economic growth is the cause of CO_2 emissions in Bangladesh and Egypt. Economic growth causes energy consumption in the Philippines, Turkey, and Vietnam but the feedback effect exists between energy consumption and economic growth in South Korea. In the cases of Indonesia and Turkey, we find the unidirectional time-varying Granger causality running from economic growth to CO_2 emissions thus validates the existence of the Environmental Kuznets Curve hypothesis, which indicates that economic growth is achievable at the minimal cost of environment. The paper gives new insights for policy makers to attain sustainable economic growth while maintaining long-run environmental quality.

Keywords: Energy, Growth, Emissions, Next 11 Countries

1. Introduction

The 21st century has not only advanced the pace of globalisation among the world's economies but has also documented an increasing competition level between developed and developing countries. With advancing globalisation and an increasing competition level, both developed and developing economies are closely linked with each other economically, socially, politically, and culturally. More specifically, developing countries want to increase economic activities, enhance physical and human capital formation, and desire to maintain their comparative advantages in the global economy. Developing countries also want to escape from the poverty trap through the process of growing industrialisation, urbanisation, and expanding production level. It is generally believed in economic theory that reducing poverty level requires a greater degree of government effort along with maintaining higher economic growth and sustainable development in developing countries. Without achieving sustainable development-driven higher economic growth, targeting the policy of poverty reduction perspective becomes effectual for developing countries at the local and global levels. Practically, it is often seen that most of the developing countries that are industrialised in nature are expanding their economic activities and production level. Therefore, their demand for energy consumption has necessarily been increased in recent years. Energy is regarded as one of the potential inputs in the various departments of economic activities, indicating that it primarily helps households and business firms in mitigating their energy demand for consumption and production purposes. Hence, the socioeconomic importance of energy demand has created the recent debate among researchers and development practitioners. This suggests that developing countries need to be cautious about the efficient use of energy and the use of different sources of energy (i.e. renewable and non-renewable). Otherwise, developing countries will face greater challenges from rising CO_2 emissions (i.e. carbon dioxide) linked with increased energy consumption in the short-run and in the long-run as both real output and energy usage are highly interdependent and influence each other in an economy.

In this perspective, the consequences of challenges are many folds for developing or industrial countries of the world. For instance, developing countries often experience climate change (i.e. rising sea levels, cyclones, drought, and flood), which primarily causes rising CO_2 emissions and thereby leads to global warming at the regional and global levels. Developing countries also realize the loss of environmental quality due to increased CO_2 emissions, climate change, and global warming. Environmental degradation not only hampers the viability of sustainable economic development in the long run, but also adversely affects the quality of life and living standard of people in the economy. Taking these challenges together, one can argue that climate change is considered an urgent and serious environmental issue in the fields of energy and ecological economics. According to the recent statistics of the Intergovernmental Panel on Climate Change (IPCC, 2006), CO_2 emissions is one of the most potential determinants in increasing greenhouse gas (GHG) emissions in the world as it accounts for 76.7% of GHG total emissions. Of this CO_2 contribution to GHG emissions, a fossil fuels energy mix, deforestation, and other sources contribute 56.6%, 17.3%, and 2.8%, respectively. This shows that carbon dioxide is largely responsible for more than 76% of the *greenhouse effect*. Therefore, the issue of growing per capita CO_2 emissions is often used as one of the proxy indicators for measuring environmental pollutants, frequently matched with increased per capita income. Growing CO_2 emissions constitutes a major ingredient of global warming and climate change and has become a serious concern worldwide in recent years (Holtz-Eakin and Selden 1995, Kijima et al. 2010, Ozturk and Acaravci 2010, Raza et al. 2015). Due to the harmful effects of global warming and climate change, policy makers in developing countries have become increasingly interested in reducing the adverse effect of environmental degradation on the economy by suggesting appropriate policy tools, such as environmental taxation and increased use of renewable energy. These environmental regulations suggested by policy makers have become an important intergovernmental issue, especially for developing countries as evidenced by the 1997 Kyoto protocol initiated by Japan, which came into effect in 2005 as an effort to reduce GHG emissions that largely cause global warming and climate change The Kyoto protocol is a protocol and binding agreement to the United Nations Framework Convention on Climate Change (UNFCCC), which aims to combat global warming (Halicioglu 2009, Ozturk and Acaravci 2010). Because of the global warming problem and a growing concern about scarce energy resources, and new thoughts on sustainable development and the quality of the environment for people the trivariate relationships between CO_2 emissions, energy consumption, and economic growth in Next 11 (N-11) countries (i.e. Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, Turkey, South Korea and Vietnam) are worth investigating through empirical research and policy agenda analysis. In this context, it is of higher significance to empirically validate whether economic growth and energy consumption lead to higher environmental pollution in N-11 countries. This is again significant because understanding the direction of causality between CO_2 emissions, energy consumption and economic growth in N-11 countries will not only offer policy insights on maintaining its environmental quality but also provide added similar benefits to other developing countries of the globalized world. The simple explanation is that if the quality of environment continues to be deteriorated in N-11 countries mainly due to the growth of its higher output and massive energy consumption, then it will have an effect on environmental quality of other developing countries of the globe. In such circumstance, N-11 countries and other developing nations in the course of changing climate change and global warming, need to strengthen their effective co-ordination and collaboration in solving the wholesale environmental consequences of higher economic growth and massive energy consumption at their domestic levels. In an effort of strengthening the effective co-ordination and collaboration among these economies, the constant blaming on the ground of increasing carbon emissions that often came from the advanced countries towards developing nations is expected to be minimised in the near future.

As part of our empirical analysis, we employ a novel method of time-varying Granger causality recently utilised by Ajmi et al. (2015) to investigate the dynamic relationships between the series. We also observe that most of the previous literature did not use such dynamic technique in their analysis and hence this could be one of the methodological limitations as they continue to ignore the time-varying patterns in empirically examining the trivariate relationships between economic growth, CO_2 emissions, and energy consumption. This can lead to elusive findings on the Environmental Kuznets Curve (EKC) hypothesis and on the policy agenda of protecting environmental quality in developing countries or in industrial countries. Influenced by the economic importance of the time-varying Granger causality test, our study prefers to use the time-varying Granger causality test proposed by Sato et al. (2007). However, the economic rationale behind employing a time-varying Granger causality test comes from the fact that the relationships among these variables tend to change due to the effects of changing economic conditions, natural disasters, energy and environmental policies as well as regulatory and new technological advancement with the passage of time. In addition, the changing trivariate relationships between economic growth, CO_2 emissions, and energy consumption establish the existence of the EKC hypothesis under the impact of a time factor, indicating that higher economic growth consumes greater amounts of energy and thereby environmental pollution (i.e. CO_2 emissions) tends to increase at the initial stage and subsequently higher economic growth consumes a lesser amount of energy leading to lower intensity of pollution in the economy after reaching a certain threshold level. This clearly indicates that the nature of the pollution happens to be an inferior good in the short-run when higher pollution is positively linked with economic growth and then it becomes a normal good when lower pollution is associated with higher economic development in the long-run. This changing shape of environmental pollution from an inferior good to a normal good is derived from the promising relationship between income and energy consumption in the economy (Ajmi et al. 2015). This further shows that environmental degradation can be lowered at some point by environmental policies that ultimately protect both quality of life and better economic growth. In reality, environmental policies take some time to reduce the levels of pollution in an economy. We can conclude that these trivariate causal links between the series are primarily possible because of the effect of the time factor and, as a result, a time-varying Granger causality approach may enable us to detect the time-varying causal links between the series. In this case, a conventional time-constant approach often used in applied energy economics literature appears to be less useful and provides erroneous results for policy makers and fiscal governments of developing economies because they do not consider the effect of a time factor which plays a pivotal role in the existence of dynamic relationships between the series and also eventually helps policy makers formulate viable environmental policies to control environmental pollution levels as well as protect the quality of the environment in industrial countries.

Furthermore, our study considers annual data i.e. 1972–2013 on a per capita basis for energy consumption, economic growth, and CO_2 emissions for N-11 countries. These N-11 countries are chosen for our empirical analysis as they are considered as the most industrialised in the world economy because of their potential output contribution to the world gross domestic product (GDP), share of energy demand, share of CO_2 emissions to world energy demand, and CO_2 emissions. In this way, it is evident that they operate in the world economy as a recognized group that influences a global open economy and successive implementation of environmental policies. These economies are also considered as 'next BRIC countries' or N-11 but not like the BRIC (Brazil, Russia, India, and China) economies with reference to rapid economic growth along with a greater degree of trade and financial openness at the global level. Following the growth experience, one can say that N-11 economies could grow more than their rivals and beat major markets in the world despite facing more challenges compared to the BRIC economies. In doing so, these N-11 economies have initiated economic reforms to preserve sustainable economic growth and development in the long run. For example, Nigeria has increased efforts to minimize the level of corruption in the country; Turkey has also struggled to obtain European Union membership and similarly, Pakistan has improved corporate laws, the taxation system, and its financial system through economic and financial reforms. Taken together, the N-11 countries are growing rapidly and increasing their share of world GDP. It is also noticed that these economies are participating in world trade and investment activities except Iran, which is a closed economy due to economic sanctions enforced by the United States and European Union. These economies are experienced with rising energy demand due to industrialisation and investment activities. The N-11 economies are more industry intensive but employing less energy-efficient technology to spur economic growth, which is accompanied by environmental concerns. To curb CO_2 emissions, Nigeria and Mexico have introduced incentives for firms to utilise energy-efficient technology for enhancing domestic production. In 2007, GDP contribution of N-11 countries to world GDP was 7%, aligned with energy consumption equivalent to 9% of global energy demand and 9% of the world's total CO_2 emissions (Sachs, 2007). Due to rising economic growth energy consumption in N-11 countries rose to 11% of global energy consumption (Yildirim et al. 2014), which affected CO_2 emissions. Sachs (2007) identified through his projection that in 2050, N-11 total GDP could be equivalent to two-thirds of the Group of Seven (G7) countries. This indicates that N-11 countries can affect political, economic, energy as well as environment developments globally because of their increasing contribution.

This study contributes to the existing literature, especially in the fields of energy and ecological economics, in four ways: i) the relationship between economic growth and energy consumption has been augmented in N-11 countries by adding CO_2 emissions as one of the potential determinants of environmental pollution; ii) a time-varying Granger causality novel approach advanced by Sato et al. (2007) has been employed; iii) our study detects the direction of causality between CO_2 emissions, energy consumption and economic growth in N-11 countries; and iv) we have verified the presence of the EKC following results of the time-varying vs constant Granger causality test. Our empirical analysis indicates that CO_2 emissions cause economic growth in Bangladesh and Egypt. Energy consumption is the cause of economic growth in the Philippines, Turkey, and Vietnam. Bidirectional causality is noted between energy consumption and economic growth in South Korea. For Indonesian and Turkish economies, the unidirectional time-varying Granger causality is found running from economic growth to CO_2 emissions, validating the existence of the EKC reflecting that economic growth is achievable at the cost of the environment.

The remaining sections of this study are structured as follows. Section-2 discusses review of the literature. Section-3 reports the data sources and methodology used in the analysis. Section-4 summarises results and discussion. Section-5 deals with concluding remarks, policy implications, and future directions.

2. **Literature Review**

Researchers have carried out numerous studies on the relationships between economic growth, energy consumption, and environmental pollution since the pioneering study conducted by Kraft and Kraft (1978). They found inconclusive findings across countries in the time series and panel data frameworks by using traditional econometrics techniques, indicating that a higher national income does not necessarily harness greater efforts to contain emissions of pollutants. Influenced by the seminal study of Kraft and Kraft (1978), Grossman and Krueger (1991, 1993), Shafik and Bandhopadhyay (1992), Panayotou (1993), Selden and Song (1994), and Stern et al. (1996) also initiated the debate of whether economic growth and energy consumption lead to higher environmental pollution. Eventually, they suggested a changing relationship between environmental pollution and income levels with increased usage of energy consumption. Since then, the well-known changing relationship between income level and environmental pollution has been reported in the form of an inverted U-shaped i.e. EKC, indicating that environmental degradation initially increases with the increased income level, reaches a crucial point of maximum income and then it declines with increased income level. More specifically, the EKC hypothesis further reveals that environmental pollution changes from an inferior good at lower income levels to a normal good at higher income levels (Ajmi et al. 2015) suggesting two pertinent issues for higher and lower levels of environmental pollution linked with income levels of an economy: i) In early stages of industrialisation, increasing environmental pollution is the cause of growing income levels in the short-run as industrial firms and households consume greater amounts of energy for both production and consumption purposes; additionally, people are more interested in earning higher income than protecting the quality of the environment and thereby people's respect towards a clean environment declines, ii) Clean environmental policy, structural change, technological advancements, increasing awareness of the people, governments, and academic efforts are responsible for reducing environmental pollution with the passage of higher income levels in the long run (Grossman and Krueger 1993, Komen et al. 1997, Roca 2003, Kijima et al. 2010, Shahbaz et al. 2013a, Onafowora and Owoye 2014, Baek 2015).

More recently, the issue of environmental pollution is becoming promising and receiving greater attention in the discussions of policy makers, development practitioners, and governments in industrial countries since environmental pollution is the root cause of climate change and global warming. It is also believed that both climate change and global warming will impose catastrophic adverse consequences on people's livelihoods and on the pace of economic growth in industrial countries of the world. In this context, Dinda (2004) argues that it is of utmost importance for all stakeholders (i.e. governments, households, business firms, academicians, and policy makers) who are responsible for making effective implementation of environmental policies to respect the clean environment as well as to study theoretically and predict empirically how environmental quality will evolve over time. Considering the socioeconomic importance of a green environment, it is an urgent and important subject to be studied across countries in a time series framework, especially in the fields of energy and ecological economics. In this vein, Johansson and Kristrom (2007) in their study claim that the existing literature on the EKC hypothesis is not enough and hence this topic requires further empirical investigation. Moreover, Stern (2004) argues that the econometric technique used in testing the EKC hypothesis is weakened. Therefore, it would be helpful for policy makers to articulate a sound environmental policy along with sustaining long-run economic growth for the individual country level if scholars in the field of energy economics use new econometric approaches for different panels and time series data. Otherwise, the use of conventional econometrics techniques in the empirical set up of examining the nexus between environmental pollution, energy consumption, and economic growth will produce inconclusive evidence that may not provide sufficient help to economic policy architects in developing comprehensive clean environment policy in order to sustain long-run economic growth, which is a significant requirement for the betterment of people in a society and for evaluating a single country in the competitive international commodity and investments markets (Payne 2010, Ozturk 2010). Therefore, the appropriate knowledge about the direction of causality between economic growth, energy consumption, and

CO_2 emissions is very important for academicians, policy makers, and governments in developing or industrial countries.

Given that significance, Zhang and Chen (2009) argue that existing literature offers three strands of relationship between energy consumption, CO_2 emissions, and economic growth for developed and developing countries. Taking it forward, our study will decompose these relationships between the series into three parts: 2.1) Studies on the nexus between energy consumption and economic growth, 2.2) Studies on the nexus between CO_2 emissions and economic growth, and 2.3) Studies on the nexus between energy consumption, CO_2 emissions and economic growth.

2.1. Studies on the nexus between energy consumption and economic growth

This strand of research is related to energy consumption and economic growth nexus. Recently, Ozturk (2010) and Payne (2010) devoted their efforts in reviewing the existing literature on the nexus between energy consumption and economic growth and also provided the following four competing useful hypotheses for researchers and policy makers: i) No causality between energy consumption and economic growth reveals the existence of a *neutrality hypothesis*, stating that both energy usage and economic output are not mutually associated with each other. This further indicates that the adoption of energy conservation policies related to energy usage for the purpose of reducing CO_2 emissions will not undermine the pace of economic growth; ii) The *growth hypothesis*, which clearly indicates the unidirectional Granger causality running from energy consumption to economic growth, suggests that a country may pursue any energy conservation policy for reducing environmental pollution that will adversely affect the pace of economic growth. In this sense, it is suggested in the literature that energy reduction policy for the sake of reducing environmental pollution should be discouraged and new sources of less consuming and lower polluting energy must be explored in order to increase the pace of economic growth; iii) If Granger causality running from economic growth to energy consumption claims the existence of a *conservation hypothesis*, it indicates that any adoption of energy conservation policy for reducing environmental pollution would not have an adverse impact on economic growth because economic growth of a country is not associated with energy consumption; and iv) The *feedback hypothesis* exists based on the existence of bidirectional causality between energy consumption and economic growth, which argues that a rise in economic growth leads to a rise in demand for energy and therefore using energy stimulates output in the economy. Accordingly, a country's pursuit of energy conservation policy to reduce environmental pollution will have a detrimental effect on economic growth. In such a situation, it is also suggested that adoption of updated technology and people awareness would be one of the instruments through which usage of an energy reduction policy could be possible without undermining the pace of economic growth and development in an economy.

Against the above hypotheses, we notice various existing empirical studies on the relationship between energy consumption and economic growth and find mixed or inconclusive findings probably the result of various possibilities of methodological differences and the time periods, time series, and panel data used along with the country characteristics (see, Ozturk 2010, Payne 2010). For instance, some studies find evidence of a unidirectional causality running from energy consumption to economic growth (e.g. Stern 2000, Chontanawat et al. 2008, Bowden and Payne 2009, Warr and Ayres 2010). We find another branch of study indicating unidirectional causality running from economic growth to energy consumption (e.g. Ang 2008, Zhang and Cheng 2009) while no causal relationship between these variables is found (Payne, 2009). In addition, Belloumi (2009), Fallahi (2011) and Fuinhas and Marques (2012) document an existence of bidirectional causality or a validation of the feedback hypothesis between energy consumption and economic growth. Mixed results are also found in recent studies of energy economics literature (Soytas and Sari 2003, Lee 2006, Chiou-Wei et al. 2008)[1]. In Next-11 countries, Yildirim et al. (2014) examined the causality between energy consumption and economic growth by using a bootstrapping autoregressive metric causality test. Their empirical analysis reported the presence of a neutral effect between both variables but Turkish economic growth was caused by Turkish energy consumption.

2.2. Studies on the nexus between CO_2 emissions and economic growth (EKC evidence)

The second strand of existing literature provides empirical evidence on the relationship between economic growth and CO_2 emissions suggesting the EKC hypothesis. In Table-1, it is seen that Padilla et al. (2006), Halicioglu (2009), Esteve and Tamarit (2012a), Shahbaz et al. (2012), Shahbaz et al. (2013a, b), Robalino-Lopez et al. (2013), Robalino-Lopez et al. (2014), and Robalino-Lopez et al. (2015), among others, use time series techniques for single country analysis and validate the existence of the conventional EKC hypothesis. Another branch of recent studies that include Robalino-Lopez et al. (2013), and Robalino-Lopez et al. (2015) use time series techniques and do not find the existence of the EKC hypothesis for Ecuador and Venezuela. Similarly, Ajmi et al. (2015) employ a time-varying Granger causality test for G7 countries and did not find the existence of a conventional EKC hypothesis. Moreover, we notice no connection between CO_2 emissions and economic growth for Turkey and India (Lise 2006, Alam et al. 2010). On the other hand, we also find some recent panel studies by Jaunky (2011), and Cowan et al. (2014) in which they did cross-country panel analysis and their results strongly supported the existence of the EKC hypothesis, indicating that carbon emissions fall with rising income levels. However, some mixed evidence of the EKC hypothesis based on the panel data analysis is also found (Cicea et al. 2014, Ibrahim et al. 2014).

Table-1: **Summary of recent studies on the EKC evidence**

Author	Relationship	Region	Methodology	Period	Findings
Kander and Lindmark (2004)	CO_2-Energy-GDP	Sweden	EKC analysis	1800–2000	EKC exists.
Lise (2006)	CO_2-Energy-GDP	Turkey	Decomposition analysis	1980–2003	Decoupling between the series is found.
Padilla et al. (2006)	CO_2-GDP	Groups of countries	Non-parametric estimations	1971–1999	EKC exists.
Coondoo and Dinda (2008)	CO_2-GDP	Group of 88 countries	Johansen cointegration technique	1960–1990	EKC does not exist.
Halicioglu (2009)	CO_2-Energy-GDP	Turkey	Causality relationship	1960–2005	EKC exists.
Alam et al. (2010)	CO_2-Energy-GDP	India	Dynamic modeling and causal relationship	1960–1995	No connection from CO_2-Energy to GDP is found.
Narayan and Narayan (2010)	CO_2-GDP	43 developing countries	EKC analysis	1980–2004	EKC exists for 35% of sampled countries.

[1] Omri (2014) presented a vast review on the energy–growth nexus.

Jaunky (2011)	CO_2-Energy-GDP	36 high-income countries	EKC analysis	1980–2005	EKC exists.
Esteve and Tamarit (2012a)	CO_2-GDP	Spain	Threshold cointegration	1857–2007	EKC exists.
Esteve and Tamarit (2012b)	CO_2-GDP	Spain	EKC analysis	1857–2007	EKC exists.
Fosten et al. (2012)	CO_2-GDP	UK	Non-linear threshold cointegration and error correction method	1830–2003	EKC exists.
Shahbaz et al. (2012)	CO_2-Energy-GDP	Pakistan	Cointegration, Granger causality and EKC analysis	1971–2009	EKC exists.
Shahbaz et al. (2013a)	CO_2-Energy-GDP	Romania	Cointegration and EKC analysis	1980–2010	EKC exists.
Shahbaz et al. (2013b)	CO_2-Energy-GDP	Turkey	Cointegration and EKC analysis	1970–2010	EKC exists.
Robalino-Lopez et al. (2013)	CO_2-Energy-GDP	Ecuador	System dynamics modelling and EKC analysis	1980–2025	EKC exists.
Sephton and Mann (2013)	CO_2-GDP	Spain	Multivariate adaptive regression splines	1857–2007	EKC exists.
Tiwari et al. (2013)	CO_2-Energy-GDP	India	Bounds testing cointegration	1966–2009	EKC exists.
Cicea et al. (2014)	CO_2-GDP	European Union	Indicator analysis	1990–2008	Mixed evidence is found.
Cowan et al. (2014)	CO_2-Energy-GDP	BRICS countries	Granger causality	1990–2010	EKC exists.
Ibrahim et al. (2014)	CO_2-GDP	69 countries	Generalized method of moments estimators	2000–2008	Mixed evidence is found.
Robalino-Lopez et al. (2014)	CO_2-Energy-GDP	Ecuador	System dynamics modelling and scenario analysis	1980–2025	EKC exists.
Shahbaz et al. (2014a)	CO_2- Industrial GDP	Bangladesh	Bounds testing cointegration	1975–2010	EKC exists.
Shahbaz et al. (2014b)	CO_2-Energy-GDP	Tunisia	ARDL cointegration and EKC analysis	1971–2010	EKC exists.
Ajmi et al. (2015)	CO_2-Energy-GDP	G7 countries	Time-varying Granger causality analysis	1960–2010	EKC does not exist.
Robalino-Lopez et al. (2015)	CO_2-GDP	Venezuela	Cointegration technique	1980–2025	EKC does not exist.
Baek, (2015)	CO_2-GDP	Korea	Bounds testing cointegration	1978–2007	EKC exists.

2.3. Studies on the nexus between energy consumption, CO_2 emissions, and economic growth

We briefly summarise the third strand of existing research which is in addition to the above two linkages, combing the literature on the relationships between energy consumption, CO_2 emissions, and economic growth and perhaps various empirical studies that exist in the field of energy economics literature. For instance, Soytas et al. (2007) examined the dynamic relationship between energy consumption, CO_2 emissions, and economic growth for the US and found that CO_2 emissions Granger cause income growth and energy consumption, leading to rising CO_2 emissions. Similarly, Ang (2007, 2008) also studied causal linkages between the series for France and Malaysia. The findings indicated that economic growth Granger causes energy consumption and CO_2 emissions in France and Malaysia; moreover, unidirectional causality running from economic growth to energy consumption is found for both countries. Chebbi (2010) empirically investigated the dynamic causal relationships between energy consumption, CO_2 emissions, and income for Tunisia and found that energy consumption leads to economic growth and Granger causes CO_2 emissions. Chang (2010) investigated the causal relationships between economic growth, energy consumption, and CO_2 emissions for the Chinese economy and found that economic growth Granger causes energy consumption that leads to CO_2 emissions. In the case of the South African economy, Menyah and Wolde-Rufeal (2010) found that energy consumption Granger causes CO_2 emissions and leading economic growth, which is also Granger caused by CO_2 emissions. Ozturk and Acaravci (2010) reinvestigated the cointegration and causality between economic growth, energy consumption, and CO_2 emissions for Turkey using the time series data 1968–2005. Their results reported the existence of cointegration between the series and found the neutral hypothesis for energy consumption, economic growth and CO_2 emissions, indicating that any adoption of energy conservation policy related to energy usage for reducing CO_2 emissions will not have an adverse effect on real income as these variables are unrelated. Lean and Smyth (2010) found causal relationships running from electricity consumption and CO_2 emissions to income as well as from CO_2 emissions to energy consumption in the Association of Southeast Asian Nations countries.

On the contrary, Soytas and Sari (2009) found that economic growth has no causal effect on CO_2 emissions but unidirectional causality running from CO_2 emissions to energy consumption is also found for Turkey. Shahbaz et al. (2013b) revisited the causality between energy consumption, economic growth, and CO_2 emissions for the Turkish economy and found the presence of feedback effect between energy consumption and economic growth, economic growth and CO_2 emissions, and energy consumption and CO_2 emissions. Ghosh (2009) investigated the causal relationship between income and CO_2 emissions by incorporating other variables into the emissions function and found no causality between income and CO_2 emissions for India. Tiwari et al. (2013) reported the feedback effect between CO_2 emissions and economic growth in India. Their empirical analysis further noted that energy consumption (coal consumption) causes economic growth and CO_2 emissions, resulting in CO_2 emissions and economic growth Granger causing energy consumption. Alam et al. (2011) examined the link between energy consumption, economic growth, and CO_2 emissions for the Indian economy and their findings revealed the existence of a bidirectional causal relationship between energy consumption and CO_2 emissions and also supported the neutrality hypothesis linking CO_2 emissions and economic growth in India. Ozturk and Uddin, (2012) re-examined the causal linkage between energy consumption, economic growth, and CO_2 emissions and found that energy consumption and CO_2 emissions Granger cause economic growth. Kanjilal and Ghosh, (2013) re-investigated the EKC hypothesis in the presence of structural breaks for India and confirmed the findings reported by Tiwari et al. (2013).

As far as our contribution is concerned to this strand of literature, it is important to note the recent literature on this topic. For instance, Alam et al. (2012) examined the cointegration and dynamic causal relationships between energy consumption, carbon emissions, and economic growth for the Bangladesh economy covering the annual time series data 1972–2006. Their results indicated a unidirectional causality running from energy consumption to economic growth, both in the short-run and long-run, while feedback long-run causality also exists between electricity consumption and economic growth and no causal relationship exists between the series in the short-run. Moreover, they also found unidirectional causality running from energy consumption to CO_2 emissions for the short-run, feedback causality existing in the long-run, and CO_2 emissions Granger causing economic growth both in the short-run and in the long-run. Shahbaz et al. (2014a) examined the relationship between industrialisation, electricity consumption, and CO_2 emissions for Bangladesh. They reported that electricity consumption causes CO_2 emissions. For the Indonesian economy, Shahbaz et al. (2013c) documented the bidirectional causality between economic growth and CO_2 emissions and between energy consumption and economic growth. In the case of Tunisia, Shahbaz et al. (2014b) investigated the causal relationship between energy consumption, economic growth, and CO_2 emissions and noted that CO_2 emissions and energy consumption cause economic growth.

In a similar fashion, Ajmi et al. (2015) examined the relationships between CO_2 emissions, energy consumption, and income for the G7 countries covering the annual data from 1960–2010. By employing time-varying dynamic Granger causality proposed by Sato et al. (2007), they found that there exists bidirectional causality between income and energy consumption for Japan, unidirectional causality running from income to energy consumption for Italy and unidirectional causality running from energy consumption to income for Canada. Moreover, a bidirectional time-varying causality between energy consumption and CO_2 emissions is found for the US, and causality from energy consumption to CO_2 emissions for France. In addition, they also found time-varying causality running from income to CO_2 emissions for Italy and Japan.

3. The Data and Methods

3.1. Data

The data for energy consumption (kt of oil equivalent), real GDP, and CO_2 emissions (metric tons) is collected from world development indicators (CD-RON, 2014). We have also used total population series to transform all the variables into per capita units. Energy consumption (E_t) is measured by energy consumption (kt of oil equivalent) per capita; CO_2 emissions (C_t) proxies by CO_2 emissions (metric tons) per capita. Y_t (Y_t^2) is the linear (squared) term of real GDP per capita proxy for economic growth[2]. The study time period is 1972–2013. The sampled countries are Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, the Philippines, Turkey, South Korea, and Vietnam. Figure-1, 2 and 3 show the trends of key macroeconomic variables, such as economic growth, energy consumption, and CO_2 emissions in N-11 Countries.

[2] Real GDP per capita is measured in constant 2005 US$ for all countries.

Figure-1: Economic Growth in N-11 Countries

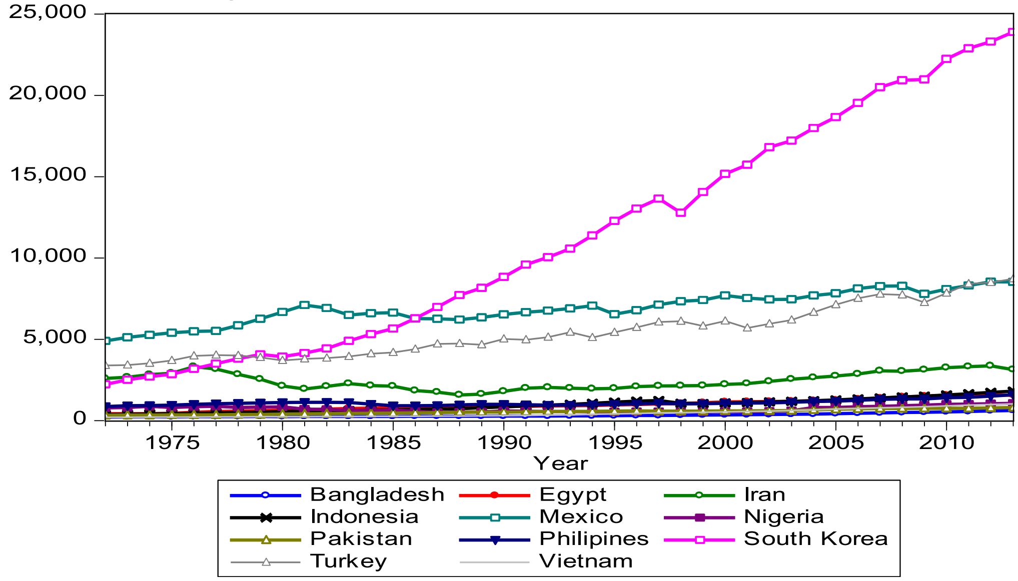


Figure-2: Energy Consumption in N-11 Countries

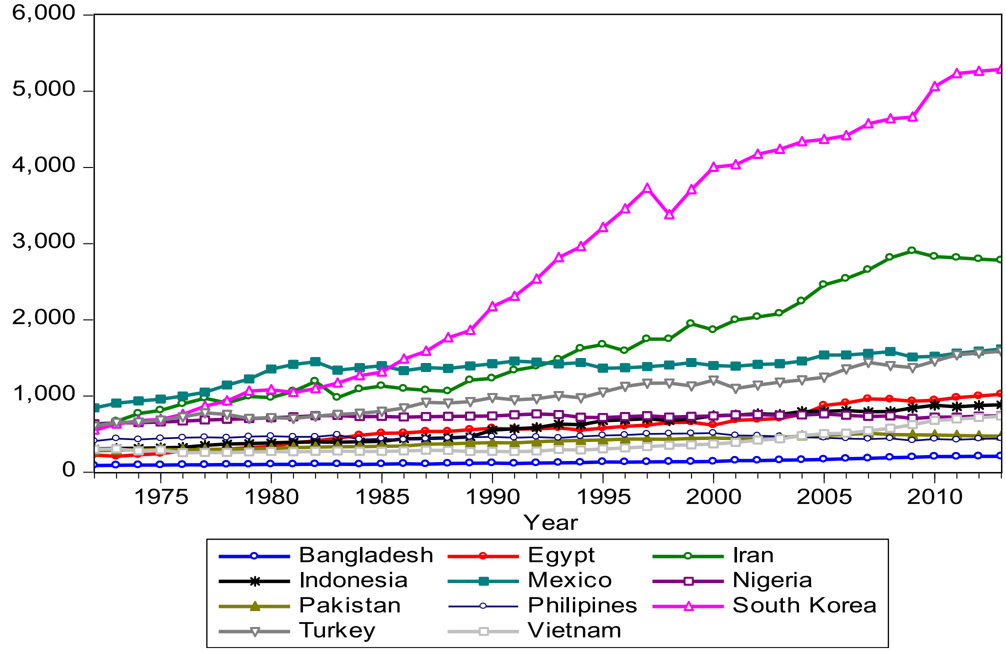
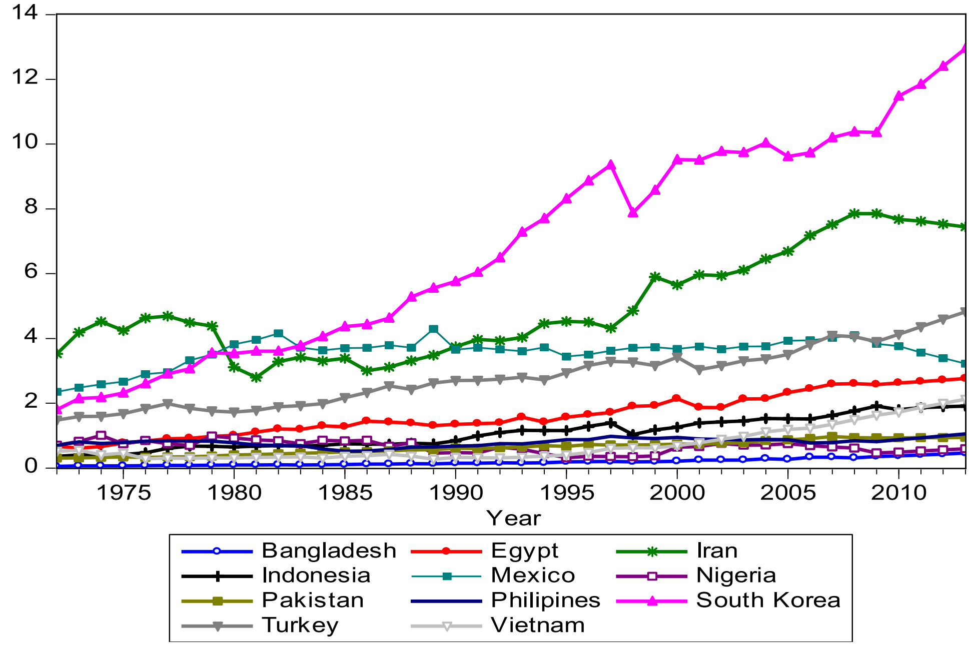


Figure-3: CO_2 Emissions in N-11 Countries



3.2. Methodology

We apply an extension of the Granger causality test implemented based on vector autoregressive (VAR) models. In order to extend this test to the cases considering possible time-varying features, Sato et al. (2007) introduced an approach based on the theory of locally stationary processes (Dahlhaus et al. 1999) and function decomposition. This model was denominated dynamic VAR (DVAR) and in the case of bivariate processes composed of two time series x_t and y_t, represented by:

$$x_t = c_x(t) + \alpha_1(t)x_{t-1} + \ldots\alpha_p(t)x_{t-p} + b_1(t)y_{t-1} + \ldots b_p(t)y_{t-p} + \varepsilon_i \quad (1)$$

$$x_t = c_x(t) + d_1(t)x_{t-1} + \ldots d_p(t)x_{t-p} + d_1(t)y_{t-1} + \ldots d_p(t)y_{t-p} + v_i \quad (2)$$

where ε_i and v_i are random variables with expectation equal to zero and variance equal to σ^2. The functions $c_x(t)$ and $c_y(t)$ are time-varying intercepts, and $a.(t)$, $b.(t)$, $c.(t)$, and $d.(t)$ are the functions representing time-varying autoregressive coefficients. Similar to Ajmi et al. (2015), the basic idea is to estimate this model and decompose these functions by using a linear combination of a constant summed to M- and B-splines functions (Eilers and Marx, 1996). In other words, the DVAR model is approximated by a linear multiple regression model, allowing the estimation via least squares method and also conducting hypothesis testing on the coefficients using Wald tests. The time-varying Granger causality from x_i to y_i can be assessed by testing whether all the coefficients $d_{i,k}$ are equal to zero. Analogously, it is also possible to test whether we have a constant vs time-varying Granger causality, by testing the significance of the $d_{i,k}$ associated to each B-spline function.

However, the main limitation of using this method is that it requires the estimation of many coefficients. Thus, due to the reduced number of observations (in time), we had to consider a bivariate DVAR of order 1 ($p = 1$) and $M = 3$. Thus, we had to do the Granger causality analysis in a pairwise fashion and constraint the number of B-splines used in functions decomposition. These analyses are analogous to the ones carried out in Ajmi et al. (2015). Moreover, due to the presence of unit roots, the DVAR model was estimated to the returns of the time series. For comparison reasons, the traditional Granger causality tests (i.e. time constant causality) are also based on a lag 1 bivariate VAR model and the returns.

4. Results and Discussion

Table-2 shows descriptive statistics. To confirm the integrating properties of energy consumption, economic growth, and CO_2 emissions, we have applied ADF, PP, N-P and LS unit root tests shown in Table-3. These tests show that all the variables contain a unit root problem at levels with intercept and trend. We find energy consumption, economic growth, and CO_2 emissions have stationarity at first difference. This shows that all the variables have a unique order of integration. The robustness of unit root analysis is tested by applying the LM unit root test developed by Lee and Strazicich (2013), with a single unknown structural break in the series[3]. The LM corroborates the findings by ADF (Dickey and Fuller, 1979), PP (Philips and Perron, 1988), N-P (Ng-Perron, 2001), and LS (2013) unit root tests. This indicates that energy consumption, economic growth, and CO_2 emissions are integrated at I(1). After knowing the unit root properties of energy consumption, economic growth, and CO_2 emissions, we move to apply the bounds testing cointegration procedure before approaching any Granger causality test to examine the causal relationship between the variables. Granger (1969) suggested that if cointegration exists between the variables and variables have a unique order of integration then there should be causality between the variables at least from one direction. The bounds testing approach has merits compared to traditional cointegration approaches. For example, this approach is suitable for a small sample size and provides reliable empirical results. The bounds testing approach is applicable as variables are found stationary at level, at first difference, or if a mixed order of integration exists for the variables.

[3]Information about structural breaks in economic growth, energy consumption, and CO_2 emissions is available upon request from the authors.

Table-2: Descriptive Statistics

Variable	Statistics	Bangladesh	Egypt	Indonesia	Iran	Mexico	Nigeria	Pakistan	Philippines	Turkey	South Korea	Vietnam
Economic Growth	Mean	5.7552	6.7953	6.7614	7.7788	8.8296	6.5438	6.2640	6.9838	8.5612	9.1007	5.9680
	Median	5.6446	6.8039	6.8810	7.7282	8.8301	6.4951	6.3284	6.9526	8.5400	9.2398	5.8429
	Maximum	6.4315	7.3566	7.5012	8.1224	9.0516	6.9620	6.6925	7.3660	9.0737	10.081	6.9359
	Minimum	5.3903	6.0434	5.8996	7.3647	8.4963	6.2030	5.7837	6.7647	8.1290	7.7086	5.2155
	Std. Dev.	0.3015	0.3841	0.4554	0.2125	0.1445	0.2328	0.2683	0.1456	0.2820	0.7334	0.5382
	Skewness	0.8131	-0.3675	-0.2611	0.0168	-0.4603	0.2348	-0.2347	0.9366	0.2109	-0.3372	0.3372
	Kurtosis	2.4251	2.2885	1.9063	1.9101	2.5380	1.5856	1.9566	3.1659	1.8664	1.7786	1.7469
	Jarque-Bera	5.2069	1.8314	2.5706	2.0806	1.8566	3.8866	2.2906	6.1895	2.5600	3.4068	3.5438
	Probability	0.0740	0.4002	0.2765	0.3533	0.3952	0.1432	0.3181	0.0452	0.2780	0.1820	0.1700
Energy Consumption	Mean	4.8529	6.2875	6.3121	7.2921	7.2022	6.5797	5.9609	6.1208	6.8930	7.6902	5.8643
	Median	4.7888	6.3478	6.3996	7.2665	7.2459	6.5896	6.0019	6.1126	6.8837	7.8903	5.6913
	Maximum	5.3744	6.8878	6.8241	7.9731	7.3936	6.6373	6.2336	6.2411	7.3701	8.5730	6.6574
	Minimum	4.4479	5.3321	5.7174	6.2911	6.7371	6.4521	5.6338	6.0066	6.4054	6.3122	5.5370
	Std. Dev.	0.2670	0.4470	0.3623	0.4538	0.1610	0.0450	0.1897	0.0553	0.2761	0.7187	0.3401
	Skewness	0.4943	-0.5331	-0.2162	-0.0612	-1.5382	-1.3497	-0.2723	0.3417	0.0418	-0.3930	1.0351
	Kurtosis	2.0602	2.4159	1.5411	2.0335	4.4253	4.2009	1.6559	2.6224	1.8468	1.7190	2.6983
	Jarque-Bera	3.2558	2.5869	4.0519	1.6608	20.1191	15.277	3.6803	1.0668	2.3393	3.9529	7.6596
	Probability	0.1963	0.2743	0.1318	0.4358	0.0000	0.0004	0.1587	0.5865	0.3104	0.1385	0.0217
CO_2 Emissions	Mean	-1.8567	0.4005	-0.0264	1.5568	1.2710	-0.4635	-0.5278	-0.2501	0.9824	1.7836	-0.5651
	Median	-1.8666	0.3590	0.0630	1.5039	1.3113	-0.3867	-0.4552	-0.2094	1.0052	1.9286	-0.8280
	Maximum	-0.9453	0.9663	0.7323	2.0718	1.4566	0.0069	-0.0311	-0.0225	1.5735	2.5615	0.7348
	Minimum	-2.9747	-0.4872	-1.0181	1.0274	0.8538	-1.1330	-1.1949	-0.6610	0.3897	0.5882	-1.3081
	Std. Dev.	0.5823	0.4203	0.4890	0.3205	0.1349	0.3039	0.3722	0.1565	0.3320	0.5652	0.6472
	Skewness	-0.0284	-0.3499	-0.2807	0.2658	-1.7421	-0.6375	-0.3610	-1.0132	-0.0948	-0.4804	0.7028
	Kurtosis	1.8545	2.2464	2.0876	1.8453	5.3490	2.4546	1.8518	3.4002	1.8739	1.9754	2.0632
	Jarque-Bera	2.3019	1.8511	2.0081	2.8276	30.9017	3.3660	3.2192	7.4668	2.2819	3.4528	4.9934
	Probability	0.3163	0.3963	0.3663	0.2432	0.0000	0.1858	0.1999	0.0239	0.3195	0.1779	0.0823

Table-3: Unit Root Analysis

Variable	Test		Bangladesh	Egypt	Indonesia	Iran	Mexico	Nigeria	Pakistan	Philippines	Turkey	South Korea	Vietnam
Economic Growth	ADF Test	Level	0.595 (1)	-1.543(1)	-2.120(2)	-1.529(1)	-2.704(1)	-0.390(1)	-1.846(2)	-1.100(1)	-2.677(2)	-0.447(1)	-2.120(1)
		1st diff.	-8.642(1)*	-4.440(2)*	-4.662(1)*	-3.537(2)**	-4.407(2)*	-5.901(1)*	-4.761(1)*	-3.608(2)**	-6.699(1)*	-5.994(3)*	-3.976(2)*
	PP Test	Level	1.324(3)	-1.697(1)	-2.020(3)	-1.239(3)	-2.819(3)	-0.459(3)	-1.816(3)	-0.700(3)	-2.667(3)	-0.388(3)	-1.421(3)
		1st diff.	-8.252(3)*	-4.441(2)*	-4.462(3)*	-3.486 (3)**	-5.033(3)*	-5.894(3)*	-4.461 (3)*	-3.578(3)**	-6.678(3)*	-6.015(3)*	-4.390(3)*
	NP Test	Level	-12.658(1)	-6.903(2)	-7.500(1)	-3.617(2)	-6.286(2)	-0.914(2)	-7.130(2)	-8.416(1)	-10.934(1)	-0.260(2)	-7.078(2)
		1st diff.	-18.941(2)**	-18.911(2)**	-18.541(2)**	-21.266(2)**	-19.035(1)*	-19.736(1)*	-18.624(1)**	-39.326(3)*	-19.969(1)**	-19.720(2)**	-19.473(2)**
	LS	Level	-1.275(0)*	-1.735(3)*	-0.978 (1)*	-1.212(0)*	-0.823(0)*	-1.226(0)*	-0.446(4)**	-0.185(1)	-0.592(1)*	-0.636(0)*	-0.187(3)**
		1st diff.	-2.819(1)*	-2.341(0)*	-2.514(2)*	-2.432(1)*	-2.784(0)*	-2.538(0)*	-2.655(2)*	-1.231(0)*	-1.475(0)*	-1.364(1)*	-1.486(1)*
Energy Consumption	ADF Test	Level	-1.070 (1)	-2.610(1)	-1.405(2)	-2.266(2)	-2.622(1)	-2.216(1)	-0.005(1)	-2.631(1)	-3.153(1)	-0.387(2)	-0.518(1)
		1st diff.	-6.337(2)*	-3.856(3)**	-4.834(3)*	-3.667(3)**	-4.892(1)*	-6.309(2)*	-5.568(2)*	-9.228(1)*	-6.513(2)*	-6.389(2)*	-4.216(2)*
	PP Test	Level	-0.693(3)	-1.493(3)	-1.519(3)	-4.255(3)	-2.888(3)	-2.166(3)	-0.006(3)	-2.675(3)	-3.302(3)	-0.371(3)	-0.907(3)
		1st diff.	-10.110(3)*	-6.630(3)*	-6.585(3)*	-8.099(3)*	-4.984(3)*	-6.682(3)*	-5.368(3)*	-8.822(3)*	-6.579(3)*	-6.338(3)*	-8.851(3)*
	NP Test	Level	-1.610(2)	-3.493(1)	-6.787(2)	-6.818(2)	-1.982(2)	-2.909(2)	-2.038(2)	-3.488(1)	-12.975(1)	-0.532(1)	-0.516(1)
		1st diff.	-19.057(4)**	-24.761(2)*	-27.870(3)*	-24.124(1)*	-18.519(3)**	-19.952(3)*	-19.700(2)**	23.903(1)*	-19.729(1)**	-19.815(2)**	18.514(2)**
	LS	Level	-1.448(1)*	-1.167(1)*	-1.078(0)*	-1.343(3)*	-1.188(2)*	-1.302(0)*	-1.097(0)*	-2.081(3)*	-0.931(0)*	-1.023(4)*	-0.834(0)*
		1st diff.	-2.529(0)*	-2.789(0)*	-1.332(0*)	-2.312(0)*	-2.077(0)*	-2.521(1)*	-1.712(0)*	-2.416(0)*	-1.729(0)*	-2.366(0)*	-1.743(0)*
CO_2 Emissions	ADF Test	Level	-2.580 (2)	-2.820(1)	-3.318(1)	-2.144(1)	-2.769(2)	-2.343(1)	-0.944(1)	-1.465(1)	-2.803(1)	-2.139(1)	-2.954(1)
		1st diff.	-6.691(1)*	-5.058(1)*	-5.206(2)*	-5.286(2)*	-3.923(1)**	-6.950(2)*	-8.038(2)*	-5.473(1)*	-6.210(2)*	-7.020(2)*	-4.093(2)*
	PP Test	Level	-1.334 (3)	-1.697(2)	-3.115(3)	-1.565(3)	-2.743(3)	-2.349(3)	-0.774(3)	-1.810(3)	-2.944(3)	-2.131(3)	-2.328(3)
		1st diff.	-9.903 (3)*	-4.442(3)*	-6.198(3)*	-5.525(3)*	-7.725(3)*	-7.081(3)*	-7.939(3)*	-5.507(3)*	-6.232(3)*	-7.114(3)*	-7.963(3)*
	NP Test	Level	-12.792 (2)	-6.391(2)	-13.994(1)	-6.800(2)	-2.702(1)	-8.957(2)	-3.590(2)	-6.188(1)	-11.024(2)	-2.758(1)	-1.703(1)
		1st diff.	-18.617(1)**	-29.013(3)*	-30.522(2)*	-22.760(1)**	-18.802(2)**	-19.672(2)**	-18.575(1)**	-27.805(3)*	-23.114(1)**	-19.393(2)**	-19.016(1)**
	LS	Level	-2.835(3)*	-0.797(3)*	-0.966(0)*	-0.888(0)*	-1.234(0)*	-0.994(0)*	-1.107(0)*	-0.687(0)*	-1.122(0)*	-1.231(0)*	-1.233(2)*
		1st diff.	-2.993(1)*	-1.853*(1)	`-2.206(0)*	-1.123(0)*	-2.987(0)*	-1.349(1)*	-1.672(0)*	-1.547(0)*	-2.339(0)*	-2.194(0)*	-2.398(1)*

The asterisk * and ** show significance at 1% and 5% levels, respectively. Maximum lag used has been shown in parenthesis.

To test the presence of cointegration between the variables by applying the bounds testing approach to cointegration, it is necessary to choose an appropriate lag length using the VAR approach. The empirical computation of the Autoregressive Distributed Lag (ARDL) F-statistic is accompanied by lag length selection. Using Akaike information criterion, which is superior due its empirical merits, solves the issue of lag length. An appropriate lag length based on Akaike information criterion is reported in Table-4 (row-2). The computed form of empirical function is $F_C(C/Y_t, Y_t^2, E_t)$ to test the hypothesis of no cointegration against the hypothesis of cointegration. We find that our computed ARDL F-statistic surpasses the upper critical bound at 1%, 5%, and 10% levels respectively. It reveals the existence of cointegration between energy consumption, economic growth, and CO_2 emissions in the cases of N-11 countries.

The results of diagnostic analysis are reported in the lower segment of Table-4. We find no evidence of serial correlation, ARCH, and White heteroscedasticity. There is no issue of non-normality and the empirical form of model is well specified. The application of Cumulative Sum (CUSUM) and CUSUM of square (CUSUMsq) tests also confirms the stability of ARDL estimates except in Bangladesh where CUSUMsq is unstable[4].

Table-4: The ARDL Bounds Testing Analysis[5]

Countries	Bangladesh	Egypt	Indonesia	Iran	Mexico	Nigeria	Pakistan	Philippines	Turkey	South Korea	Vietnam
Lag Length	2, 1, 2	2, 2, 1	2, 2, 2	2, 1, 1	2, 2, 2	2, 2, 2	2, 1, 1	2, 2, 1	2, 1, 2	2, 1, 1	2, 2, 2
F-Statistics	6.876**	12.500*	7.571**	5.879***	8.962*	5.986***	10.359*	8.440**	5.688**	8.741**	6.962**
R^2	0.5372	0.5363	0.7221	0.6134	0.6364	0.4870	0.7569	0.6533	0.8411	0.7350	0.8343
Adj-R^2	0.3151	0.3138	0.5887	0.4279	0.3600	0.2408	0.5567	0.4870	0.6571	0.5467	0.6547
D.W Test	2.3737	2.2326	2.2871	2.0878	1.8539	1.8760	1.8553	2.1377	1.8872	1.9039	2.0333
Diagnostic Tests											
$\chi^2 NORMAL$	0.4200	0.2188	1.1201	0.1329	1.5283	0.3543	0.3364	1.9898	0.0228	1.4999	4.2155
$\chi^2 SERIAL$	2.5993	1.5014	1.8858	0.6891	0.1469	2.1981	0.0726	1.5076	0.0065	0.0125	0.9855
$\chi^2 ARCH$	0.7401	0.0040	0.0663	0.0107	1.9712	1.1357	1.2815	0.3824	0.1590	0.0512	0.0361
$\chi^2 WHITE$	2.0806	0.8107	0.7914	1.1067	1.1308	0.8891	1.5371	0.4265	1.4281	1.8994	0.7279
$\chi^2 REMSAY$	1.9823	0.2328	2.6839	2.3021	1.8509	0.7548	2.8383	0.2237	0.7376	2.0262	1.6447
CUSUM	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable
CUSUMsq	**Unstable**	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable

Note: We use the ARDL empirical model with unrestricted intercept and unrestricted trend. The upper and lower critical bounds developed by Narayan (2005) are 8.803, 7.317 (6.373, 5.360) and 5.377, 4.437 at 1% (5%) and 10% levels, respectively. The asterisk *, **, and *** show significance at 1%, 5% and 10% levels, respectively.

4.1. The traditional Granger causality test

The results of conventional Granger causality are reported in Table-5. The neutrality hypothesis exists between economic growth and CO_2 emissions, economic growth, and energy consumption, as well as between energy consumption and CO_2 emissions in the Bangladesh economy. In the case of Egypt, we find the unidirectional causality is found running from energy consumption to

[4] We have not reported graphs of CUSUM and CUSUMsq due to space limitations for this paper; results are available upon request from the authors.

[5] We have compared our computed ARDL F-statistic with critical bounds provided by Nayaran (2005). The upper and lower critical bounds are suitable for a large sample size. If the upper critical bound is lower than the computed ARDL F-statistic it shows the presence of cointegration. The hypothesis of no cointegration should be accepted if the lower critical bound is more than the computed ARDL F-statistic.

economic growth. Furthermore, energy consumption and economic growth cause increased CO_2 emissions for the Egyptian economy. For the Indonesian economy, no causality is found between energy consumption, economic growth, and CO_2 emissions. The null hypothesis that energy consumption does not Granger cause economic growth is rejected at the 10% level of significance for Mexico and Nigeria. This implies that energy consumption Granger causes CO_2 emissions in the Mexican economy. Based on our findings, we note that energy consumption is caused by economic growth and economic growth (energy consumption) causes CO_2 emissions. This shows that economic growth is the main driver of CO_2 emissions in Pakistan[6]. There is no Granger causality between economic growth and CO_2 emissions but energy consumption is the Granger cause of CO_2 emissions in the case of the Philippines. Based on our analysis, we document that CO_2 emissions Granger cause energy consumption in the Turkish economy. In South Korea, the feedback effect exists between CO_2 emissions and economic growth but economic growth Granger causes energy consumption. Our findings show that in Vietnam energy consumption and CO_2 emissions Granger cause economic growth.

Our empirical analysis shows that implementation of environmental policy will not affect economic growth in Bangladesh, Egypt, Indonesia, Iran, Mexico, and Nigeria. The reason is that there are other factors involved that lead to CO_2 emissions besides energy consumption and economic growth. Our findings are contrary to Shahbaz et al. (2014) who reported the presence of the EKC and bidirectional causality between economic growth and CO_2 emissions in Bangladesh. Furthermore, Onafowora and Owoye (2014) also confirmed the validation of the EKC in Japan, Mexico, and Nigeria but reported a U-shaped relationship between economic growth and CO_2 emissions for the South Korean economy. Hwang and Yoo (2014) documented that economic growth being accompanied by CO_2 emissions contradicts our empirical findings i.e. we noted that there was no causal relationship between economic growth and CO_2 emissions in Indonesia. Similarly, Lotfalipour et al. (2010) reported that for Iran CO_2 emissions are the Granger cause of economic growth, which is caused by energy consumption.

In the cases of Pakistan, South Korea, and Vietnam, we find the presence of EKC as economic growth Granger causes CO_2 emissions. This empirical evidence is consistent with Shahbaz and Lean (2012) for Pakistan and Onafowora and Owoye (2014) for South Korea but contradictory with Al-Mulali et al. (2015) who unveiled that economic growth is positively accompanied by CO_2 emissions for Vietnam. It is argued by Sato et al. (2007) that the classical Granger causality test may provide ambiguous empirical findings due to the acceptance of the assumption of a time constant causality test. This leads us to apply the time-varying causality test by considering the time-varying assumption for reliable and efficient empirical results.

4.2. The dynamic Granger causality test

In Table-6, we have reported the results of the dynamic Granger causality test. The results are interesting but slightly changed. For example, we find that economic growth causes energy consumption and CO_2 emissions in Bangladesh. For the Egyptian economy, unidirectional

[6]The unidirectional causality is also found running from CO_2 emissions to energy consumption which shows that energy consumption does not lead to CO_2 emissions but via economic growth, energy consumption affects CO_2 emissions.

causality is found running from energy consumption and CO_2 emissions to economic growth. Economic growth is the cause of CO_2 emissions in Indonesia. The neutrality effect is noted between energy consumption, economic growth, and CO_2 emissions in Iran, Mexico, and Nigeria. In Pakistan's economy, economic growth causes energy consumption and CO_2 emissions. Our analysis indicates that economic growth and CO_2 emissions lead energy consumption in the case of the Philippines. Turkish CO_2 emissions Granger cause Turkish energy consumption. The bidirectional causal relationship exists between energy consumption and economic growth in the South Korean economy. Lastly, energy consumption is spurred by economic growth in Vietnam.

The exact information about directional of causality for energy-growth-emissions nexus is helpful to policy makers in formulating economic, energy, and environmental policies for better living standard and sustainable economic growth and hence economic growth. The controversy in mentioned (Table-5 and 6) empirical results could be due to presence of time-varying properties in energy-growth-emissions nexus. To overcome this issue, we have applied time-varying verses time-constant based Granger causality test.

The results of the time-varying compared with the time-constant Granger causality tests are reported in Table-7. We note that economic growth is caused by CO_2 emissions. This shows that the economic growth achieved in Bangladesh is not at the cost of the environment and that other factors are definitely responsible for the increase in CO_2 emissions. The unidirectional causality is found running from energy consumption to economic growth in Bangladesh. Egyptian economic growth is the cause of Egyptian CO_2 emissions. Indonesia attains economic growth at the cost of the environment as economic growth leads CO_2 emissions i.e. economic growth Granger causes CO_2 emissions[7]. For the Pakistan economy, CO_2 emissions Granger cause economic growth but the converse is not true. In the Philippines, unidirectional causality runs from economic growth to energy consumption, and no effect exists for the opposite direction. The Turkish economy attains economic growth at the cost of the environment as economic growth leads energy consumption and hence CO_2 emissions. For the Indonesian economy, based on our empirical findings, we note that economic growth Granger causes CO_2 emissions. Economic growth causes energy consumption and as a result, energy consumption causes economic growth in the Granger sense for South Korea. Unidirectional causality exists, running from economic growth to energy consumption in Vietnam but the same is not true for the converse.

Based on empirical findings, we conclude that economic growth Granger causes CO_2 emissions in Indonesia and Turkey, which further confirmed the presence of the EKC. It is argued by Narayan and Narayan (2010) that causality running from economic growth to CO_2 emissions is a corroboration of the EKC.

[7] No causality exists between energy consumption, economic growth, and CO_2 emissions in Iran, Mexico, and Nigeria. These findings are similar as those reported for the time-varying Granger causality test for Iran, Mexico, and Nigeria.

Table-5: Conventional Granger Test

Hypothesis	Bangladesh	Egypt	Indonesia	Iran	Mexico	Nigeria	Pakistan	Philippines	Turkey	South Korea	Vietnam
$E_t \rightarrow Y_t(Y_t^2)$	0.204	0.005*	0.584	0.085***	0.442	0.513	0.588	0.207	0.394	0.114	0.672
$E_t \leftarrow Y_t(Y_t^2)$	0.783	0.412	0.736	0.962	0.435	0.651	0.031**	0.23	0.859	0.023**	0.004*
$C_t \rightarrow E_t$	0.94	0.445	0.601	0.736	0.647	0.504	0.427	0.071***	0.047**	0.976	0.891
$C_t \leftarrow Y_t(Y_t^2)$	0.889	0.431	0.637	0.454	0.125	0.321	**0.042****	0.702	0.881	0.108***	0.001*
$C_t \rightarrow Y_t(Y_t^2)$	0.303	0.013**	0.728	0.728	0.831	0.573	0.902	0.347	0.218	0.011**	0.961
$E_t \leftarrow C_t$	0.857	0.059***	0.296	0.937	0.071***	0.083***	0.001*	0.194	0.387	0.477	0.554
Note: The significance level at1%, 5%, and 10% levels is shown by *, **, and *** respectively.											

Table-6: The Dynamic Granger Causality Test

Hypothesis	Bangladesh	Egypt	Indonesia	Iran	Mexico	Nigeria	Pakistan	Philippines	Turkey	South Korea	Vietnam
$E_t \rightarrow Y_t(Y_t^2)$	0.008*	0.004*	0.898	0.688	0.767	0.995	0.827	0.523	0.555	0.042**	0.633
$E_t \leftarrow Y_t(Y_t^2)$	0.413	0.786	0.408	0.564	0.399	0.855	0.044**	0.008*	0.176	0.002*	0.023**
$C_t \rightarrow E_t$	0.827	0.784	0.315	0.597	0.969	0.432	0.861	0.073**	0.068***	0.929	0.449
$C_t \leftarrow Y_t(Y_t^2)$	0.729	0.634	0.023**	0.531	0.478	0.251	**0.076*****	0.974	0.17	0.498	0.218
$C_t \rightarrow Y_t(Y_t^2)$	0.00*	0.019**	0.733	0.971	0.876	0.531	0.129	0.405	0.379	0.174	0.686
$E_t \leftarrow C_t$	0.347	0.789	0.208	0.995	0.557	0.425	0.146	0.588	0.707	0.912	0.997
Note: The significance level at1%, 5%, and 10% levels is shown by *, **, and *** respectively.											

Table-7: Time-Varying vs Constant Granger Causality Test

Hypothesis	Bangladesh	Egypt	Indonesia	Iran	Mexico	Nigeria	Pakistan	Philippines	Turkey	South Korea	Vietnam
$E_t \rightarrow Y_t(Y_t^2)$	0.005*	0.199	0.825	0.968	0.611	0.987	0.695	0.374	0.657	0.106***	0.464
$E_t \leftarrow Y_t(Y_t^2)$	0.564	0.649	0.314	0.436	0.464	0.882	0.567	0.048**	0.107**	0.008*	0.011**
$C_t \rightarrow E_t$	0.729	0.684	0.234	0.735	0.974	0.464	0.993	0.264	0.247	0.91	0.624
$C_t \leftarrow Y_t(Y_t^2)$	0.662	0.482	0.011**	0.382	0.892	0.265	0.128	0.951	0.103***	0.631	0.449
$C_t \rightarrow Y_t(Y_t^2)$	0.000*	0.036**	0.594	0.932	0.869	0.427	0.072***	0.295	0.424	0.848	0.565
$E_t \leftarrow C_t$	0.244	0.976	0.186	0.984	0.645	0.654	0.878	0.598	0.584	0.847	0.984
Note: The significance level at1%, 5%, and 10% levels is shown by *, **, and *** respectively.											

4.3. The EKC Hypothesis Analysis

The existence of the EKC is confirmed by the dynamic Granger causality test (Indonesia and Turkey) and by the time-varying vs constant Granger causality test (Egypt and Pakistan). Both causality tests validate the presence of unidirectional causality running from economic growth (Y_t, Y_t^2) to CO_2 emissions (C_t). We have tested the presence of EKC by applying the ordinary least squares (OLS) method rather than just rely on Granger causality results[8]. We have tested the validation of the EKC without and with energy consumption for both countries (see Table-8). The results show that energy consumption has a positive and significant impact on CO_2 emissions for both countries. Our empirical evidence corroborates that the relationship between economic growth and CO_2 emissions is inverted-U shaped. We note that a 1% increase in real GDP is connected with 3.37% (3.80%) while the negative sign of the squared term confirms the delinking of CO_2 emissions and real GDP at the higher level of income in the case of Pakistan (Turkey). This implies that environmental degradation is accompanied by economic growth initially and economic growth lowers CO_2 emissions after a threshold point of income per capita. The presence of the EKC in Pakistan is consistent with Nasir and Rehman (2011), Shahbaz et al. (2012), Ahmed and Long (2012), Ahmed et al. (2015), and Ali (2015). For the Turkish economy, our results are similar to Shahbaz et al. (2013b), and Elgin and Öztunalı (2014), but dissimilar with Halicioglu (2009), Ozturk and Acaravci (2010), and Kaplan et al. (2011) who supported the absence of EKC for Turkey.

[8] We are unable to find the presence of the EKC in the cases of Egypt and Indonesia.

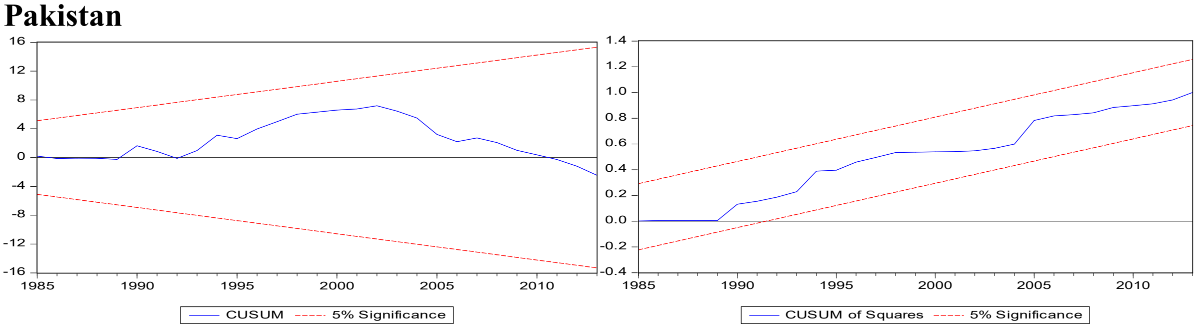
Table-8: The EKC Hypothesis Test

Dependent Variable = C_t								
Country	Pakistan				Turkey			
Variable	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Constant	-20.6276*	-6.6656	-18.6818*	-11.1416	-46.35098	-7.677288	-23.5856*	-4.7102
Y_t	5.0628*	5.0924	3.3777*	6.0136	9.8741*	7.019701	3.8003*	3.0789
Y_t^2	-0.2954*	-3.7055	-0.2091*	-4.7765	-0.5070*	-6.193630	-0.2217*	-3.3620
E_t	…	…	0.8752*	9.8346	…	…	1.2049*	7.3436
R^2	0.8918		0.8976		0.9879		0.9950	
F-stat	23.69*		54.8819*		15.9978*		25.3195*	
D-W	1.9311		2.2126		2.1107		2.04430	
Stability Tests								
Test	F-stat	Prob.	F-stat	Prob.	F-stat	Prob.	F-stat	Prob.
χ^2 *NORMAL*	1.1337	0.5672	0.2969	0.8620	0.1103	0.9463	1.5443	0.4620
χ^2 *SERIAL*	0.6571	0.4567	0.5499	0.4630	1.8610	0.1273	1.7279	0.1326
χ^2 *ARCH*	0.0415	0.8396	0.0013	0.9705	1.9154	0.1742	0.0734	0.7878
χ^2 *WHITE*	1.0347	0.3649	1.7762	0.1681	0.5047	0.6076	0.5043	0.6816
χ^2 *REMSAY*	0.2025	0.8102	0.2541	0.8008	1.3881	0.2200	1.1215	0.2693
CUSUM	Stable		Stable		Stable		Stable	
CUSUMsq	Stable		Stable		Stable		Stable	
Note: The asterisk * shows significance at the 1% level.								

Figure-4: Bivariate Model in Pakistan and Turkey of N-11 Countries

Bivariate Model

Pakistan



Turkey

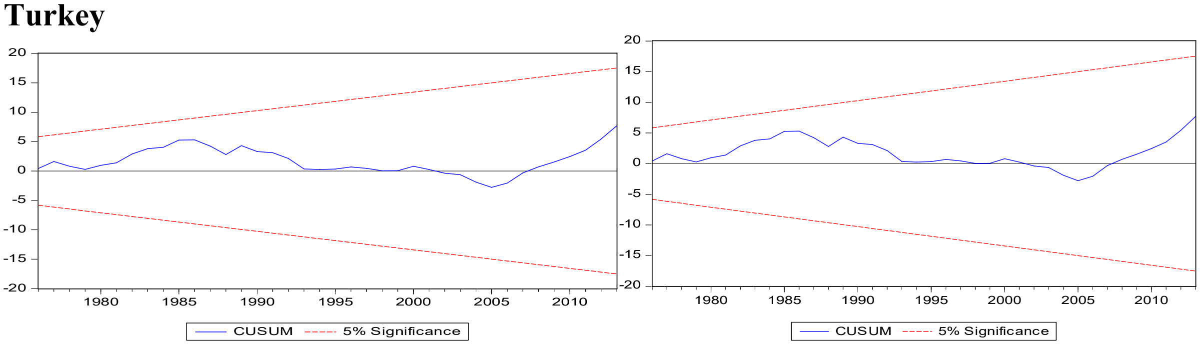
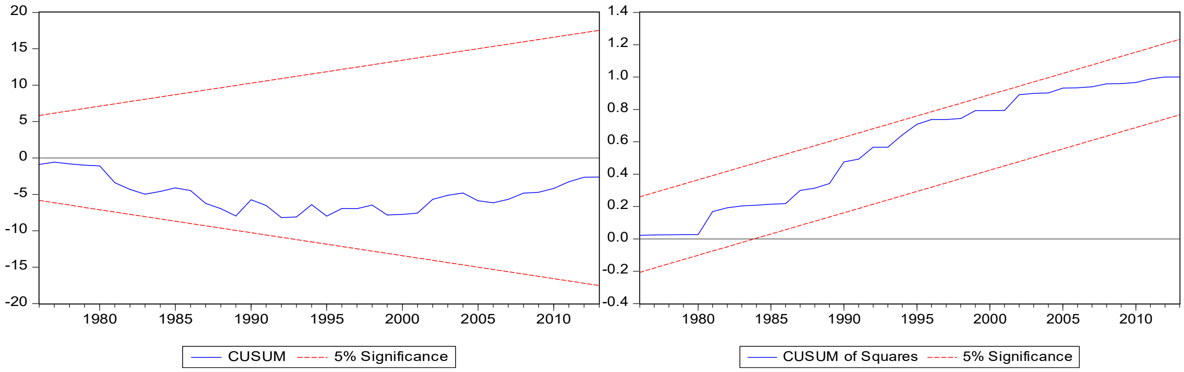


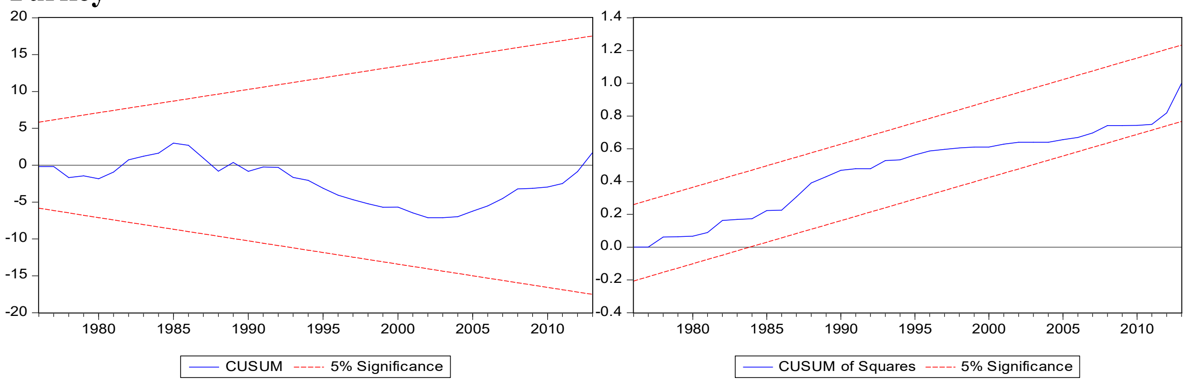
Figure-5: Trivariate Model in Pakistan and Turkey of N-11 Countries

Trivariate Model

Pakistan



Turkey



The diagnostic analysis confirms a normal distribution of error term. No evidence is found for serial correlation, auto-regressive conditional heteroscedasticity (ARCH), and White heteroscedasticity. The Jarque-Bera test validates the specification of the auto-regressive conditional lag (ARDL) empirical model. In addition, the stability of the ARDL CO_2 emissions models is investigated by employing cumulative sum (CUSUM) and cumulative sum of squares (CUSUMsq) proposed by Brown et al. (1975). Without testing the models' stability, we believe that the models' misspecifications can also lead to biased and incorrect coefficient estimates that might influence the explanatory power of the results. Both the CUSUM and CUSUMsq tests are widely used in the field of applied energy to test the constancy of estimated parameters. Furthermore, Brown et al. (1975) pointed out that these tests help in testing the dynamics of parameters. Hence, the expected value of the recursive residuals is zero leading to a non-rejection of the null hypothesis of parameters' constancy. The plots for both CUSUM and CUSUMsq are shown in Figures-4 and -5 at a 5% level of significance and the results indicate that plots for both the tests and for both the bivariate and trivariate models of Pakistan and Turkey of N-11 countries fall within the critical bounds of a 5% level of significance. This suggests that our estimated ARDL carbon emissions functions for Pakistan and Turkey of N-11 countries are found to be stable.

5. Conclusion, Policy Implications, and Future Directions

This paper uses both traditional time-constant and time-varying Granger causality tests between economic growth, energy consumption, and CO_2 emissions in the case of N-11 countries for the time series annual data period of 1972–2013. The implementation of environmental rules and regulation as well as financial, economic, and trade reforms raised the issue of the time-varying nature of linkages between the variables. For empirical purposes, we have applied ADF, PP, N-P, and LS unit root tests. The bounds testing approach is applied for examining cointegration between the variables. To examine the nature of static and dynamic causal relationships between economic growth, energy consumption, and CO_2 emissions, we have applied traditional as well as time-varying Granger causality tests.

The results confirm the unique order of integration of variables and the variables are cointegrated for long-run linkages. The empirical evidence reported by time-varying vs time-constant Granger causality reveals the neutral effect exists between economic growth and CO_2 emissions but economic growth is the cause of energy consumption in Bangladesh. The unidirectional causality is found running from Egyptian CO_2 emissions to Egyptian economic growth. Economic growth Granger causes CO_2 emissions for the Indonesian economy. Energy consumption is the cause of economic growth in the Philippines but unidirectional causality runs from CO_2 emissions to economic growth in Pakistan. Turkish economic growth leads energy consumption and CO_2 emissions. In Indonesia, economic growth is accompanied by CO_2 emissions. The feedback effect exists between economic growth and energy consumption for the South Korean economy. Vietnam's economic growth leads its energy consumption. Furthermore, in the cases of Pakistan and Turkey, the presence of the EKC hypothesis shows that the CO_2 emissions rising effect nullifies the CO_2 emissions declining effect confirmed by estimates of linear and squared terms of real GDP per capita. This suggests that governments of both countries should improve environmental quality by introducing a carbon emissions tax and trading schemes.

Our findings suggest that the Bangladesh government should explore new sources of energy by implementing energy exploration policies to maintain economic growth in the long run, as energy consumption (supply) plays a significant role in accelerating economic growth. The unidirectional causality running from energy consumption to economic growth implies that adoption of any environmental policy to reduce energy consumption will have an adverse impact on economic growth. In such a situation, our study on the policy front suggests that Bangladesh governments must encourage both local as well as foreign investors to adopt energy efficient technology while producing more output. The neutral effect between energy consumption and economic growth in Egypt implies that energy conservation policies would not harm economic growth because energy consumption plays a very minor role in enhancing economic growth and CO_2 emissions can be controlled by adopting energy conservation policies. The unidirectional causality running from CO_2 emissions to economic growth indicates the importance of advanced and energy efficient technology being employed for production in Egypt and Pakistan economies[9].

[9] Contrarily, Shahbaz et al. (2012) confirmed the unidirectional causal linkage running from economic growth to environmental degradation in Pakistan.

The implementation of energy conservation policies to reduce CO_2 emissions will not have an adverse effect on economic growth in Iran, Mexico, and Nigeria. In these economies, no causality is found between energy consumption and economic growth, economic growth and CO_2 emissions, or energy consumption and CO_2 emissions. This shows that energy consumption plays a minimal role in enhancing economic growth and increasing CO_2 emissions. Economic growth causes energy consumption and implies that there are other factors determining economic growth; implementation of reductions in energy supply is a suitable tool to decline CO_2 emissions in the Philippines. The feedback effect between energy consumption and economic growth indicates the important role of enhancing domestic production and hence economic growth in South Korea. Any reduction (supply) in energy will adversely affect economic growth and as a result, economic growth declines (increases) energy demand. It indicates that new sources of energy should be explored while managing existing sources of energy efficiently. In Vietnam, economic growth leads energy consumption, suggesting that government should implement an energy reduction policy not only to save the environment but also to shift competing and potential resources to other added determinants of economic growth. The directional causality running from economic growth to CO_2 emissions reveals that in Indonesia and Turkey, reduction in CO_2 emissions is achievable as economic growth is accompanied by CO_2 emissions (but the converse is not true). This indicates that implementation of an environmental friendly energy policy to reduce CO_2 emissions will not have a negative effect on economic growth in both countries although economic growth also Granger causes energy consumption in Turkey.

On a final note, we further find the unidirectional time-varying Granger causality running from economic growth to CO_2 emissions for Indonesia and Turkey which thus validates the existence of Environmental Kuznets Curve hypothesis, indicating that economic growth is achievable at the minimal cost of environment. The findings of this study provide new policy insights not only for policy makers and governments of these two economies but also urges policy-making authorities of other developing countries in the connected world how to attain sustainable economic growth while simultaneously maintaining long-run environmental quality.

Our study suggests a direction for future research on issues worth investigating. Future study on this topic is warranted in terms of using the novel threshold cointegration technique of Sephton (1994) and Sephton and Mann (2013a, b) in which they have postulated the new possibility of empirically examining non-linear cointegration and asymmetric dynamic relationships between CO_2 emissions, energy consumption, and economic growth in the case of N-11 countries. In doing this, other potential variables such as financial markets (Dogan and Turkrkul, 2016), trade reforms (Chang, 2015), energy mix (El Anshasy and Katsaiti, 2014), financial instability (Shahbaz, 2013), political stability (Galinato and Galinato, 2012), institutional quality (Tamazian and Rao, 2010) and black economy (Biswasa et al. 2010) etc. must also be incorporated in the model while investigating the relationship between economic growth and CO_2 emissions. The inclusion of potential factors not only solves the issue of specification but also provides reliable and consistent empirical results, which would be helpful for policy-making authorities in formulating comprehensive environmental policy for sustainable economic development.

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