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**Article**

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# Dynamic Relationships between Energy Use, Income, and Environmental Degradation in Afghanistan

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**ABSTRACT**

This study examines the dynamic relationship between energy use, income, and environmental degradation in Afghanistan using annual data from 1970 to 2016. The dynamic causal relationship among variables are being tested; grounded by four testable hypotheses (growth, conservation, feedback, and neutrality). The F-bounds test, Dynamic OLS, and VECM Granger causality are utilized. The empirical results confirm that there is a long-run relationship among the variables and the energy use and GDP both affects the $CO_2$ emissions in the long run. The conservation and environmental policies would have detrimental impact to economic growth of Afghanistan, as this country become an energy dependent country. In the short run, there is bidirectional causality running from energy use and economic growth. These results support the "feedback hypothesis" and possesses some policy implications which suggests that economic development and energy use may be jointly determined since economic growth is closely related to energy consumption.

**Keywords:** Causal Relationship, F-Bounds Test, Energy Consumption, Economic Growth, $CO_2$ Emissions, Afghanistan
**JEL Classifications:** Q2, Q4

## 1. INTRODUCTION

All energy sources have some impact on our environment. Fossil fuels like coal, oil, and natural gas do substantially more harm than renewable energy sources by most measures, including air and water pollution, damage to public health, wildlife and habitat loss, water use, land use, and global warming emissions. Based on the recent empirical estimates, the global energy demand has grew by 2.1% in 2017, more than twice the growth rate in 2016, where the global energy demand in 2017 reached an estimated 14 050 million tonnes of oil equivalent (Mtoe), compared with 10 035 Mtoe in 2000. In terms of global energy efficiency, its indicated that was a decline in global energy intensity where the rate of energy consumed per unit of economic output, slowed to only 1.7% 1 in 2017, much lower than the 2.0% improvement seen in 2016 (IEA, 2016). The growth in global energy demand was concentrated in Asia, with China and India together representing more than 40% of the increase. Notable growth was also registered in Southeast Asia (which accounted for 8% of global energy demand growth) and Africa (6%), although per capita energy use in these regions still remains well below the global average. In line with the global energy demand upward trend, it was found that global energy-related $CO_2$ emissions also rose by 1.4% in 2017, and this is contrasts with the sharp reduction needed to meet the goals of the Paris Agreement on climate change (WDR, 2018). The increase in carbon emissions was the result of robust global economic growth of 3.7%, lower fossil-fuel prices and weaker energy efficiency efforts. These three factors contributed to pushing up global energy demand by 2.1% in 2017 (IEA, 2016).

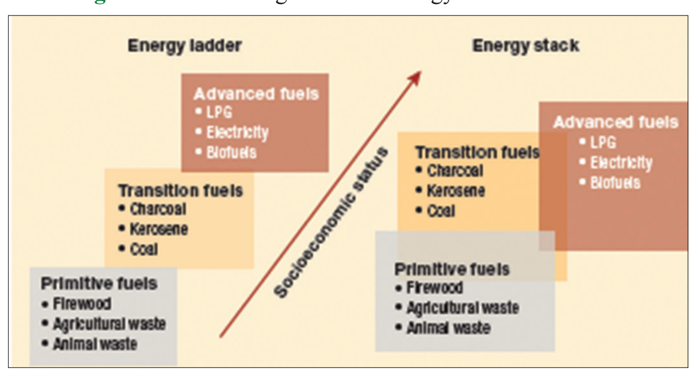
It is clear that there is difference in terms of energy demand and $CO_2$ emissions' growth values between those regions, which reflects the difference nexus and interactions between energy sources and economic development. It is often described as an "energy ladder" that characterizes changes in energy sources as development progresses and incomes rise (Figure 1). At low levels of income and economic development, economies rely predominantly on traditional biomass, such as fuelwood, charcoal, dung, and agricultural or household waste, for cooking and space heating, and on human power for productive agricultural and industrial activities (Bhatia and Angelou, 2015). These sources are replaced gradually by processed biofuels (charcoal), kerosene, animal power and some commercial fossil energy in the intermediate stages of the evolution and eventually by commercial fossil fuels and electricity in more advanced stages of structural transformation and economic development (Barnes and Floor, 1996).

Also, the relationship between energy, economic development and structural transformation is reflected not only in the combination of energy fuels used at each stage of the process, but also in the composition of energy demand. At lower levels of development, households account for the bulk of energy consumption, given scant levels of industrialization and the more limited use of energy for transportation (Bhatia and Angelou, 2015). For instance, the Least Developed Countries (LDCs) the residential sector is responsible for two thirds of total final energy consumption, as compared with less than 40% in ODCs and developed countries (Barnes and Floor, 1996). Besides the different in terms of energy structures and composition, there is also different in terms of causality directions between energy sources and economic progress for LDC, developing and developed countries, which reflects that these countries have different structures of economies, which adopted different kind of technologies and policy mechanisms. Nevertheless, significant barriers prevent some of developing and poor countries from adopting low-emissions and green technology adoptions (Barnes and Floor, 1996). LDCs struggle with gaps in technology and financial expertise and a lack of resources. It is in the best interest of the entire world to help least developed countries navigate these problems.

Thus, it is very clear that there are serious challenges related in achieving higher economic growth without compromising environmental, energy security and sustainable development. If humankind is to live sustainably, future economic growth must utilize energy resources efficiently, minimize the environmental pollutions and maximize economic and social benefits. Though, sustainable development must not only take into account the optimize use of energy supply-demand in the long-term and short-term, but it must also emphasis on the harmonized and balanced between energy, economy and environmental (Río et al., 2017). As the economic growth, energy use and environmental are interconnected, the links and causality directions between them become highly crucial as it can provide some favorable inputs, especially for environmentalist, economist and policy makers in compelling rationale for sustainable development (Squalli and Wilson, 2006; Azlina et al., 2014). Indeed, recently, there has been ever increasing interest among researchers in understanding the causal directions between energy use, $CO_2$ emissions and economic growth. Consequently, many empirical studies focuses on the link and crucial factors that drive between economic growth, energy use and environmental degradations in developed and developing countries (see for example, Ang, 2007; 2008; Squalli, 2007; Soytas et al., 2007; Magazzino, 2014; Omri et al., 2015; Azlina et al., 2014) as different causality indicates whether the country is less or more energy dependent.

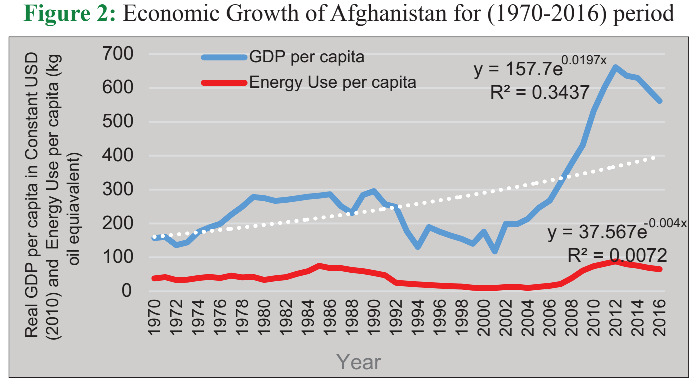
According to the Human Development Index, Afghan was ranked at 175th, the lowest in Asia in 2012 (UNDP, 2013). Afghan society has been very vulnerable and in terms of economic growth, Afghanistan's gross domestic product (GDP) has grown at a rate of 4.55% from 1970 to 2016 (Figure 2). In 2017, the real GDP for Afghanistan was 21,969 million US dollars. Real GDP of Afghanistan increased from 8,689 million US dollars in 2003 to 21,969 million US dollars in 2017, growing at an average annual rate of 7.00% (World Bank, 2017). However, from 2002 to 2016, the rate of economic growth has grown tremendously, estimated at 12.9% per annum. This growth is largely attributed to the recovery in the agricultural sector and service sector. Agriculture (32%) and services (38%) are the main contributors to Afghanistan's GDP. According to the International Monetary Fund, the opium sector represents about 40-50% of GDP (as an illegal activity it does not register in economic calculations, but it has a significant overall impact on income and purchasing power) (IMF, 2015). There are no large industries in the country but many small and medium enterprises. Nevertheless, the security issue is the main concern on private investment and foreign direct investment in Afghanistan (CIA, 2015). Business sentiment shows no sign of recovery. Due to the sluggish economic growth and the deteriorating security situation since 2011, the poverty rate increased to 39.1% in 2013-2014 (a), up from 36% in 2011-2012 (World Bank, 2015). Rural areas, where most of the population lives, observed the biggest increase from 38.3% to 43.6%. Labor demand in the off-farm

**Figure 1:** Economic growth and energy sources transition




Source: Bhatia and Angelou (2015)

**Figure 2:** Economic Growth of Afghanistan for (1970-2016) period

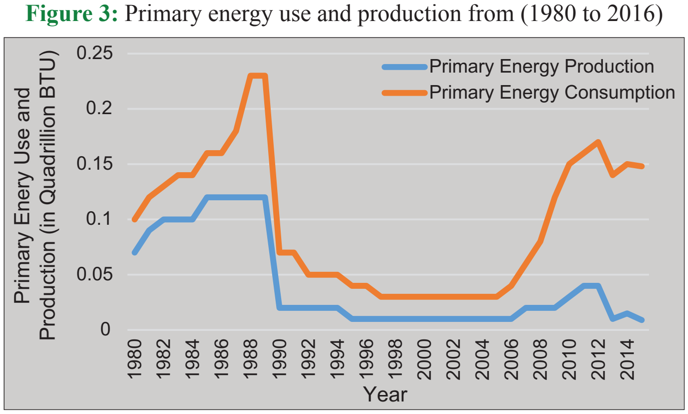


sector declined. Most of the jobs created in the service sector during the pre-transition phase were lost. On the other hand, revenue performance continues to improve, driven largely by stronger compliance. Revenues reached 11.9% in 2017, up from 8.5% in 2014.

In terms of energy resources, Afghanistan has one of the lowest rates of access to the electricity in the world. It is still a long way from achieving energy sufficiency, efficiency, and sustainability of energy supplies, as it suffers from a lack of sufficient and reliable energy via electricity supply, as well as undeveloped domestic power and fuel production. At present, the majority (70-75%) of Afghanistan's energy needs are met by traditional energy sources from solid biomass (Asian Development Bank, 2014). Annual biomass energy use in Afghanistan is equivalent to 2.5 million tonnes of oil. The remaining requirements are met by commercial energy sources mainly petroleum products, natural gas, coal, and hydropower (MEW, 2015). Thus, it can be denied that energy is one of the most vital driving forces for a nation to develop and grow. It has a central role in economic growth (Farajzadeh, 2015). Indeed, the global energy demand grew by 2.3% in year 2018, its fastest pace this decade, an exceptional performance driven by a robust global economy growth in some regions (IEA, 2019).

However, in the past three decades, the war has left Afghanistan's power grid badly and damaged the country's energy infrastructure, generation, transmission, and distribution (Fichtner, 2013). Due to the high commitment towards economic restructuring, energy security and country's energy sustainable development, the government of Afghanistan had to corporatize the National electricity service department Da Afghanistan Breshna Mossasa (DABM) into an independent state-owned utility. As such, all assets, staff and other Rights and Obligations of (DABM) were transferred to Da Afghanistan Breshna Sherkat (DABS) in May 2008 (World Bank, 2018). This is supported by the Figure 3, where there were significant gaps between Afghanistan primary energy supply and demand, especially after the 1990s. During this period, it shows that the primary energy demand has increased at an average rate of 4% per year, while the primary energy production was negatively growing at 3.9% per annum. The positive growth in energy demand per capita in these years indicates that Afghan people consumed more energy over time, whereas the negative growth in production reflects the insufficiency of supply to meet the demand. The insufficiency in the supply of energy would have

**Figure 3:** Primary energy use and production from (1980 to 2016)

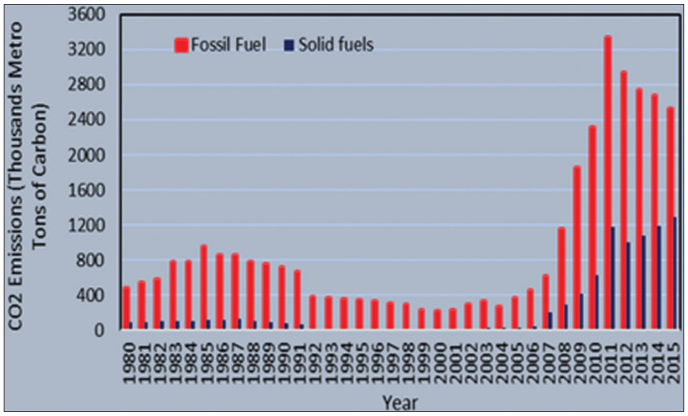



serious energy security issues and implications for sustainable energy in Afghanistan in the future. Currently, the people of Afghan suffer from an uneven distribution of energy within the country. As of 2015, approximately 33% of the Afghan population had access to electricity and in the capital Kabul, while 70% had access to reliable 24 h electricity and up to three quarters (67-75%) of the Afghan population were still cut off the power grids. Afghanistan's domestic power generation capacity was accounted for only 22% of its total consumption balance in 2015, corresponding to just over 1000 gigawatts/hour (GWh) (MEW, 2015).

Furthermore, Afghanistan has an extremely low level of rural electrification, while 75% of the population live in the rural areas and contribute to 67% of the gross domestic production. However, these areas only possess around 10% of the electricity distributed within the country (Inter-Ministerial Commission for Energy, 2015). Thus, the Afghan government is struggling to keep up with the rapid growth of energy demand in the country through the consumption of imported energy. In 2015, almost 70% of the total electricity consumed in Afghanistan was imported from neighboring countries such as Tajikistan, Turkmenistan, Uzbekistan, and Iran. Such dependency can be perceived as a threat to the energy security of Afghanistan. Although Afghanistan is blessed with abundant of oil and natural gas reserves in the northern part of the country, where the oil reserves are estimated to be around 15 million tons, it still has to import 10,000 tons of oil products or 97% of the country's requirement from Turkmenistan, Uzbekistan, Russia, Pakistan, and Iran, at a cost of approximately 1.5 billion US dollars per year (World Bank, 2018). This is due to the absence of gas and oil production refining capacities and investments. The current rate of domestic oil production is only 400 barrels a day, while the natural gas holds the potential (proven reserves range from 30 to 400 billion $m^3$) to become a significant source of energy for the country. Indeed, an excessive dependence on imported energy increases the vulnerability and insecurity of the country.

Afghanistan's fast-growing urban centers consume increasing amounts of energy. Due to over-population in many urban areas and high concentration of pollution sources such as cars and industries, the residents suffer from severe air pollution, poorly organized collection and disposal of waste, lack of sanitation and access to safe drinking water (Inter-Ministerial Commission for Energy, 2015). The initial greenhouse gas (GHG) inventory of Afghanistan indicates that deforestation plays a very significant role in the country's total greenhouse gas emissions compared to fossil fuel combustion (gasoline, coal, etc.). Afghanistan $CO_2$ emissions from fossil-fuels were at the level of 2,675 thousand metric tons in 2014, down from 2,731 thousand metric tons the previous year, exhibiting a change of 2.05% (Figure 4). Carbon dioxide emissions are those stemming from the burning of fossil fuels and the production of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels. At the same time, soils and remaining forests absorb large amounts of carbon dioxide annually, thereby compensating the GHG emissions. The current balance between emissions and removals of carbon dioxide in land use and forestry sector is fragile but positive. Therefore, further efforts should be executed in order to maintain this balance and other forms of climate change mitigation.

**Figure 4:** $CO_2$ emissions from fossil and solid fuel consumption from (1980 to 2015)




## 2. PAST STUDIES

There are numerous studies that investigate the relationship between energy consumption, real output, and carbon dioxide emissions. It appears that generally there are two strands of literature on economic growth, energy consumption, and emissions. The first strand mainly focuses on the nexus between environmental and economic growth, which is closely related to the environmental Kuznets curve (EKC) hypothesis testing. According to the EKC hypothesis, as income increases, emissions increase as well until some threshold level of income is reached after which emission begins to decline, revealing a U-shaped relationship. For instance, Grossman and Krueger (1995), Shafik and Bandyopadhyay (1992), Panayotou (1993), Stern (2004), Ang (2007), Apergis and Payne (2009), Salahuddin et al. (2016), Shahbaz et al. (2016), Dogan and Ozturk (2017) and Zi et al. (2016), Narayan et al. (2010), Jaunky (2010) found the inverted U-shaped relation as Environmental Kuznet curve (EKC). Also, several researchers used EKC to analyze the role of income elasticity of environment, as a key decreasing factor of environmental pollution level (Beckerman, 1992; Carson et al., 1997; McConnell, 1997).

The second strand is a body of literature that considers the energy-growth nexus which facilitates the examination of the dynamic causal relationships between economic growth and energy consumption (Ang, 2007; 2008), Squalli (2007), Soytas et al. (2007), Magazzino (2014), Omri et al. (2015), Ozturk and Acaravci (2010), Ahmed et al. (2017), Eggoh et al. (2011), Azlina, et al. (2010). This nexus suggests that economic growth is closely related to energy consumption, because higher economic development requires more energy consumption, and more efficient energy use requires a higher level of economic development (Halicioglu, 2009). However, the results of these studies vary. The contrast among these countries would have important policy implications, where there could reflect different structures of economies, as well as different policy mechanisms. Furthermore, the causality results are useful in determining the appropriate strategies to achieve sustainable development (Bekhet and Othman, 2017). In this regards, Squalli (2007) has classified the dynamic causal relationship between energy consumption and economic growth nexus into four directional, which have been tested on four testable hypotheses: (1) No causality between energy consumption and GDP which supports the "Neutrality Hypothesis," implying the absence of a causal relationship between these variables; (2) Unidirectional causality running from GDP to energy which supports the "Conservation hypothesis," implying that an increase in real GDP will cause an increase in energy consumption; (3) Unidirectional causality running from energy consumption to GDP growth, which supports the "Growth hypothesis;" implying that an increase in energy use may contribute to growth performance; and lastly (4) Bidirectional causality between energy use and economic growth which supports the "Feedback hypothesis; implying that energy consumption and economic growth are jointly determined and affected at the same time.

Squalli and Wilson (2006) investigated the electricity consumption-income growth hypothesis for six member countries of the GCC. Results indicated that the "feedback hypothesis" exist for Bahrain, Qatar, and Saudi; "conservation hypothesis" for Kuwait and Oman; while the 'neutrality hypothesis" emerges for the United Arab Emirates. In another study for Iran and Kuwait, Mehrara (2007) reported that there is a unidirectional long-run causality running from economic growth to energy consumption, where these results support the "conservation hypothesis". However, for Saudi Arabia, the study found that the "growth hypothesis" emerges for this country. By employing the same framework, Squalli (2007) conducted another study for the OPEC member. The study found that "feedback hypothesis" holds in Iran, Qatar, and Saudi Arabia; which contradicts with the findings of Mehrara (2007) for Saudi Arabia. Regarding the UAE, the "growth hypothesis" was confirmed, and the "conservation hypothesis" prevails in Kuwait. Hamdi and Sbia (2013) examined the direction of causality between electricity consumption and economic growth for Bahrain. The result of the study indicated that 'feedback hypothesis' exists in this country. However, the obtained results contradicted with Altaee and Adam (2013) findings, where the study revealed a "conservation hypothesis." The contrasting results could be explained by the different time period of the studies. Indeed, the different direction of causality among those countries would have important policy implications which reflect that the countries have a different degree of energy dependencies, economic structures, and policy.

Following Squalli (2007), Tiwari (2010) extended the four sets of testable hypothesis for testing directions causality between energy consumption and economic growth, with some policy implications. According to the "growth hypothesis" the energy consumption contributes directly to the economic growth or in other words there is uni-directional causality running from energy consumption to economic growth within the production process. In such situation, if energy conservation policies are adopted (i.e. carbon tax, fuel tax) in order to reduce the $CO_2$ emission, the reduction of energy use will have a detrimental impact on the economic growth of that country (Tiwari, 2011). This indicates that higher economic development requires more energy consumption and economies are energy dependents. These causality directions are normally applicable to the developing countries. Alternatively, the policymakers have to consider the role of technology and innovation that could use energy in efficient manner in order to improve the economy without damaging the environment. The second hypothesis tested was the "conservation hypothesis" where there was unidirectional causality running from economic growth to energy consumption. This hypothesis implies that energy conservation policies should be designed to improve energy efficiency by reducing the energy consumption, while $CO_2$ emission may not have a harmful impact on the economic growth, as these countries are less-energy dependent and their source of real income and economies are based on the non-energy intensive sectors, such as agriculture. Hence, given their stage of development, the energy use in these countries is not generally affected by the income. These causality directions are normally applicable to the poor or less developing countries (Jumbe, 2004).

The third hypothesis is the "feedback hypothesis" or bi-directional causality, which suggests that economic development and output may be jointly determined since economic growth is closely related to energy consumption. Similarly, more efficient energy use requires higher level of economic development. These causality directions are typically applied to the developed countries which are normally efficient in energy consumption. The fourth hypothesis is "neutrality hypothesis" where there is no causality between energy consumption and GDP, implying that energy conservation policies may not adversely impact the economic growth, as energy consumption is a relatively minor factor in the production of real output (Tiwari, 2011).

The empirical analyses of past studies enhances our knowledge on how economic growth and energy use interrelate environmental quality that is presented by $CO_2$ emissions. Indeed, there is serious lack of studies focuses on the role of energy use, economic growth and environmental degradation for Afghanistan. Thus, there is still additional room to develop upon recent literature by testing the nonlinear and dynamic relationship between $CO_2$ emissions, energy use and economic growth. Based on the above arguments and to achieve the objective of the current paper, the hypotheses are formulated as shown below (Ozturk, 2010):

$H_1$: There is unidirectional causality running from energy consumption to GDP growth s and its determinants in Afghanistan and support the growth hypothesis.

$H_2$: There is two-way causality between energy consumption and GDP growth in Afghanistan and support the feedback hypothesis.

$H_3$: There is unidirectional causality running from GDP growth to energy consumption in Afghanistan and support the conservation hypothesis

$H_4$: There is no causality between energy consumption and GDP growth in Afghanistan and support the neutrality hypothesis.

## 3. DATA SOURCES AND METHODOLOGY

The annual data of the energy use (EU), gross domestic product (GDP), and carbon dioxide ($CO_2$) emissions covering the 1970-2016 period were mainly obtained from World Bank. All data were converted to natural logarithms. This is particularly where some values are too large for some periods and other values are too small for other periods (Keene, 1995). This situation raises the outliers in data or scale effects (Feng et al., 2014). Log transformation, as a widely known method to address skewed data, was used to transform skewed data to approximately conform to normality (Feng 2014) and to reduce the variability of data. The log transformation can reduce the possibility of heteroscedasticity and autocorrelation (Bekhet and Othman, 2018), while inducing the stationary process (Narayan and Smyth, 2005; Lau et al., 2014; Bekhet and Othman, 2018).

Table 1 illustrates the summary statistics of the variables. The J-B statistics indicate that all the used variables have a log-normal distribution. It is evident from Table 1 that the standard deviation (SD) of energy use is the highest while the GDP is the lowest. The mean values of all log variables were negative. The interrelationships between coefficients were positively correlated to each other, which indicates the importance of energy use and $CO_2$ emission in economic development, while revealing the strong dependency on energy use in the 1970-2016 period, which sequentially contributed to higher environmental degradation. In other words, these positive correlations among the variables indicate that the data being employed was significantly moved together in the same direction and was prepared to be used in the subsequent step.

### 3.1. Model Specifications

In order to analyze the four testable hypothesis and to achieve the objective of this study, which is to evaluate the link and causal relationship between $CO_2$ emission, energy use and GDP, the work of Squallii (2007), Tiwari (2011), Azlina et al. (2014), and Shahbaz et al. (2016) were followed. The $CO_2$ emission was underpinned by GDP growth by assuming that they have a linear relationship (Bekhet and Othman, 2018). However, the dynamic relationship among variables was evaluated by the four testable hypotheses established by Tiwari (2010), which are growth, conservation, feedback, and neutrality hypothesis. The baseline estimation model between carbon dioxides emissions, income, and energy use are presented in a multivariate linear function and can be expressed as in Equation (1):

$$CO_{2t} = \delta + \alpha_1 Y_t + \alpha_2 EU_t + v_t \tag{1}$$

where $CO_{2t}$ is the volume of carbon dioxide emission at time $t$, $Y_t$ is the value of real income at time $t$, and $v_t$ is the time variant standard error term. Following Tiwari (2011), Shahbaz et al. (2014), and Bekhet and Othman (2018), the Equation (1) was divided by the population which obtains each series in per-capita

**Table 1: Summary results of data quality tests**

| | C | E | Y |
|---|---|---|---|
| Mean | 165.3125 | 41.12235 | 313.3728 |
| Maximum | 290.0000 | 88.36346 | 661.0753 |
| Minimum | 110.0000 | 9.711299 | 117.4256 |
| SD | 57.75278 | 27.71517 | 170.4248 |
| Jarque-Bera | 3.776785 | 3.799218 | 4.987568 |
| Probability | 0.151315 | 0.149627 | 0.082597 |
| Observations | 32 | 32 | 32 |
| C | - | - | - |
| E | 0.915 | - | - |
| Y | 0.875 | 0.806 | - |

All inter-relationship between the variables are significant at 1% level. Source: Output of EVIEWS package Version 9 form. Next, in order to provide a meaningful interpretation, the reliable and effectual model of the linear function (Equation 1) was converted to a log linear specification by taking the natural logs (L) as in Equation (2).

$$LCO_{2t} = \delta + \alpha_1 LY_t + \alpha_2 LEU_t + v_t \quad (2)$$

where $\delta = L\theta$, after taking the natural logs. The coefficient parameters $\alpha_i$ ($i$=1 and 2) were interpreted as elasticities. The details of the interpretation have been summarized in Table 2.

### 3.2. Estimation Procedure: Unit Roots, Co-integration, and Granger Causality

Following established econometric procedures, the test of the causal relationship between variables was conducted in three stages. First, a test was carried out to ascertain the order of integration in all variables. In other words, this test was conducted to analyze the presence of unit roots; whether the series was stationary or non-stationary in their level form. Evidence from past studies suggests the presence of a unit root in the most of the financial and economic variables (Bekhet and Othman, 2017; Bekhet and Mugableh, 2012). It is known that an important task in econometric modeling is to determine the integration order of the analyzed time series through unit root tests, while a common assumption in many time series techniques is that the data are stationary. A stationary process has the property that the mean, variance, and autocorrelation structure do not change over time with no periodic fluctuations. Nevertheless, this approach requires certain pre-estimations procedure as a macroeconomic variable is usually found as non-stationary and possesses a trend over time (Bekhet and Othman, 2018). Otherwise, the conclusion drawn from the estimation will not be valid (Tiwari, 2011).

Indeed, statistical theory offers a wide range of unit root tests, while the most common ones are Dickey and Fuller's DF-test and ADF test (Dickey and Fuller, 1981), Phillips-Perron test (Phillips and Perron, 1988), KPSS test (Kwiatkowski et al., 1992), the less frequently used ADF-GLS test (Elliot et al., 1996), and NGP test (Ng and Perron, 1995 and 2001). The selection of the most appropriate test depends primarily on a subjective judgment of the analyst (Arltova and Fedorova, 2016). Pesaran (2015) and Zivot and Wang (2006) state that the main problem of all the above-mentioned unit root tests subsists in their dependence on the length of the analyzed time series. In addition, they pointed out that in a situation where the parameter in the autoregressive process (1) is close to one, both tests would have low power and the invalid null hypothesis is not rejected.

On the other hand, Arltova and Fedorova (2016) showed that the ADF test is a reliable option for unit root testing, while the obtained results were promising especially in the case of time series with large number of observations (T = 100). PP test is a suitable substitute for very short time series (T = 25), while another recommendation could be a simultaneous use of N-P test (T = 50). Thus, this study (n = 47) adopted the N-P test due to its ability to overcome the problem of low power and short time series. Secondly, in order to estimate the short run and long run relationships, the F-bound test within the ARDL framework was utilized. According to Narayan (2005), the F-bounds test is appropriate for small sample sizes ($30 \leq n \leq 80$) and is superior to the multivariate co-integration. Equation (3) formulated the dynamic relationship between $CO_2$ emission and their determinants:

$$\Delta\begin{bmatrix} LCO2 \\ LEC \\ LY \end{bmatrix} = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{bmatrix}_j \begin{bmatrix} LCO2 \\ LEC \\ LY \end{bmatrix}_{t-1} + \sum_{j=1}^{m} \Delta \begin{bmatrix} \theta_{11} & \theta_{12} & \theta_{13} \\ \theta_{21} & \theta_{22} & \theta_{23} \\ \theta_{31} & \theta_{32} & \theta_{33} \end{bmatrix}_m \begin{bmatrix} LCO2 \\ LEC \\ LY \end{bmatrix}_{t-m} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{bmatrix}_t \quad (3)$$

where Δ is the first difference operator, $\delta_i s$ represents the intercepts, $\alpha_{ij}s$ and $\theta_{ij}s$ denote the long- and short-run coefficients of the variables, respectively. $\varepsilon_{ij}s$ represents the error terms, k is the utmost lag length, and m indicates the optimal number of lag. Thus, the third stage of the test for this study was to determine the optimal lag length. Two options which have been used in the study were Akaike information criterion (AIC) and Schwarz information criterion (SC). Generally, these two methods might provide different lag structures for the ARDL model (Bekhet and Othman, 2017). In addition, the information of causality relationship could also validate the existence of the four testable hypotheses of growth, conservation, feedback, and neutrality. Therefore, in order to identify the short-run and long run causality, as well as to test the four testable hypotheses, which were to determine the direction between economic growth and energy use, the Granger causality in the VECM framework was performed. The Granger-causality test could examine the causal effect between a set of variables by testing for their predictability based on past and present values (Azlina et al., 2014). In VECM framework, if variables are co-integrated, the joint Wald F-statistics of the lagged explanatory variables of the VECM model indicated the significance of short-run causality. Furthermore, the long-run causality was shown by the t-statistics for the coefficients of the ECT. Thus, for testing the presence of long- and short-run relationships among variables, hypotheses were formulated as $H_o:\alpha_{ijs}=0$ against $H_o:\alpha_{ijs}\neq 0$, and $H_o:\theta_{ijs}=0$ against $Ho:\theta_{ijs}\neq 0$, respectively. The decision to reject or accept $H_o$ was based on the following procedure (Pesaran et al., 2001; Shahbaz and Lean, 2012; Bekhet et al., 2017; Bekhet and Othman, 2017; Ivy-Yap and Bekhet, 2015):

**Table 2: Types and interpretation of elasticities**

| Coefficients | Type | Interpretation |
|---|---|---|
| $\lvert\alpha i\rvert < 1$ | Inelastic | 1 unit increase in IVs increase* $CO_2$ emissions <1 unit |
| $\lvert\alpha i\rvert = 1$ | Unitary elastic | 1 unit increase in IVs increase* $CO_2$ emissions with the same unit |
| $\lvert\alpha i\rvert > 1$ | Elastic | 1 unit increase in IVs increase* $CO_2$ emissions more than 1 unit |

Adapted from Bekhet and Othman (2017) and Ivy-Yap and Bekhet (2015); IVs=Independent variable (EC and GDP); *Decrease if the original $\alpha_i$ in negative value (inverse relationship)

- If the computed F-statistic was greater than the upper critical bound as tabulated by Narayan (2005), the null hypothesis of no long-run relationship was rejected.
- However, if the computed F-statistic was less than the lower critical bound, then, the test failed to reject the null, suggesting that a long-run relationship did not exist.
- In the case that the test statistic lies within the lower and upper critical bounds, a conclusive inference could only be made if the order of integration of each regressor was known (Pesaran et al., 2001).

If the sample size is relative small, (n < 100 observations), the comparison of F-statistic must be made with the critical value by Narayan (2005) (as the observation of the study was n = 47). On the other hand, If the sample size was larger (n > 100 observations), then comparison must be made between the computed F-statistics and the critical value by Pesaran et al. (2001). In this regard, the VECM model of Equation (4) was formulated to measure the short- and long-run causality among the variables of the current study.

$$\Delta\begin{bmatrix} LCO2 \\ LEC \\ LY \end{bmatrix} = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \end{bmatrix} + \sum_{j=1}^{m} \Delta \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{bmatrix}_j \begin{bmatrix} LCO2 \\ LEC \\ LY \end{bmatrix}_{t-j} + \begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \end{bmatrix} \left[ ECT_{i,t-1} \right] + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{bmatrix}_t \quad (4)$$

The $ECT_{t-1s}$ are the lagged error correction terms derived from the long-run relationship. By employing the t-test, the long-run causality relationship (unidirectional, bidirectional and neutral) can be identified by means of the coefficient of $ECT_{t-1}$ (Masih and Masih, 1996). On the other hand, the significance of the coefficient ($\alpha_{ij}$) for each explanatory variable by joint Wald F or $\chi^2$ test indicates the short-run causality relationship (unidirectional, bidirectional, and neutral). Importantly, the estimated VECM model should be robust and free from the misspecification problems such as not violating the standard assumptions where the white noise error terms, the $\varepsilon_i$ ($i$=1,….,6) should be normally distributed with zero mean and constant variance, $\varepsilon_i \sim N(0,\sigma^2)$ homoscedastic, free from autocorrelation problems, and have no multicollinearity. If one of the aforementioned test was violated, then it can affect the estimates of important parameters and derived quantities while being evident as a mis-fit or biased model. Thus, in order to ensure that all of the estimated models are free from the misspecifications problems, the Urzua normality test, serial correlation-LM tests, and heteroscedascity tests were performed. In addition, in order to assess the stability of the model, the CUSUM and CUSUMQ tests (Brown et al., 1975) were applied.

## 4. RESULTS AND DISCUSSION

### 4.1. Unit Root Results

The analysis of the dataset was initiated by testing the statistical properties of the time series. The stationarity of variable was investigated using the N-P test. Tests were computed under two different specifications, first represented by the intercept; secondly by intercept and trend. The result of N-P of unit root test has been shown in Table 3. The N-P unit root results indicate that only $CO_2$ is significantly at the level I (0), at the 5% level, while others are significantly stationary at the level I (1), at the 5% level. These results are in line with the idea that most of the macroeconomic variables are non-stationary at the level, but they become stationary after the first or second difference (Bekhet and Othman, 2011; Bekhet and Mugableh, 2012).

### 4.2. Multivariate Co-integration Test

Since there was a mixed stationery at different levels (I (O) and I (1)), and the size of observations was rather a small sample size, the F-bounds test was the most appropriate approach to test the long-run co-integration relationship (Narayan, 2005; Farhani et al., 2014). However, prior to the co-integration test, the optimal lag length to be used in the F-bound test was determined (Sugiawan and Managi, 2016; Matar and Bekhet, 2015; Bekhet and Othman, 2017). Based on the Akaike information criterion (AIC), the optimal lag length was 3. The empirical results of the F-bound tests have been reported in Table 4. The obtained results indicated that long-run relationship exists among the variables studied for the period of 1970-2016, at least at 5% significance level, which is consistent with values reported in the literature (Bekhet and Othman, 2017; Azlina et al., 2014; Tiwari, 2010; Shahbaz et al., 2016).

### 4.3. Long-run Equilibrium Relationship

Given that the variables are co-integrated, the long-run coefficients between $LCO_2$, LEU, and LGDP equation can be estimated using Dynamic Ordinary Least Squares (DOLS) estimator. The long-run elasticity has been reported in Table 5. The results indicate that in the long-run, energy use has inelastic and positive effects on $CO_2$ emission in Afghanistan. This positive elasticity between energy use and $CO_2$ emission are consistent with Azlina et al. (2014) and Tiwari (2010), but inconsistent with Bekhet and Othman (2017). The long-run elasticity of $CO_2$ emission with respect to energy use

**Table 3: Stationary test results**

| Variables | Stationary level | Mza statistics | Critical value | | | Decision |
|---|---|---|---|---|---|---|
| | | | 1% | 5% | 10% | |
| C | I(0) | −1.58 | −13.80** | −8.10** | −5.70** | I(1) |
| | I(1) | −11.245** | | | | |
| E | I(0) | −5.065 | | | | I(1) |
| | I(1) | −8.154** | | | | |
| Y | I(0) | −6.30 | | | | I(1) |
| | I(1) | −13.794** | | | | |

***, ** and *indicate 1%, 5% and 10% level of significant respectively. Source: Output of EVIEWS package version 9 was found to be 0.77, suggesting that a 1% increase in energy use is associated with 0.77% in $CO_2$ emission. Moreover, according to the estimation in Table 4, the real income was found to be insignificant with $CO_2$ emissions, which implies that GDP does not affect the $CO_2$ emission in the long-run, which is also consistent with the findings of Eggoh et al., (2011) for 12 Middle East and North African Countries (MENA). Their findings suggest that for all of these countries, economic growth doesn't lead to the increase in $CO_2$ emissions. In other words, these countries were not required to sacrifice their economic growth in order to decrease their emissions level, as they may achieve a reduction in $CO_2$ emission through reduction in energy demand via energy conservation without negative long-run effects on economic growth.

Since there is evidence of co-integration, the existence of causality relationship between the variables was studied. Table 6 displays the multivariate causal relationship among variables (Appendix). Specifically, the table reports the joint Wald *F*-statistics of the lagged explanatory variables of the VECM, which indicates the significance of short-run causality and the long-run causality exhibited by the t-statistics for the coefficients of the ECT. The results of the short-run causality test for $\Delta LCO_{2t}$ model indicate that there is a significant unidirectional causality running from energy use to $CO_2$ at 1%. On the other hand, the $\Delta LGDP_t$ model implies significant unidirectional short-run causality from $CO_2$ emissions to GDP, and energy use to GDP. Indeed, the existence of Granger-cause from energy use to $CO_2$ emission designates that Afghanistan should opt for policies that focus on energy conservation, environment, and efficient utilization of energy.

**Table 4: Results of F-bound test**

| Estimated models | F-statistics | Critical value I(0) | |
|---|---|---|---|
| Stationary level | | 1% | 5% |
| C\|E, Y | 5.037*** | 4.13 | 3.1 |
| E\|C, Y | 2.33 | | |
| Y\|C, E | 1.34 | | |
| Included observations (n)=44; k=2; $H_0$=No long-run relationships exist | | | |

***,**, and *as defined in Table 3. Source: Output of EVIEWS package version 9

**Table 5: Summary of the long run elasticities of C model**

| Dependent variable: $CO_2$ | Coefficient | SE | t-Statistic | Prob. |
|---|---|---|---|---|
| Explanatory variables E | 1.0054 | 0.269503 | 3.730332 | 0.0013 |
| Y | 0.1681 | 0.045174 | 3.721403 | 0.0013 |
| C | 72.770 | 8.988699 | 8.097331 | 0.0000 |

Source: Output of EVIEWS package Version 9

**Table 6: Short run and long-run granger causality results based on VECM**

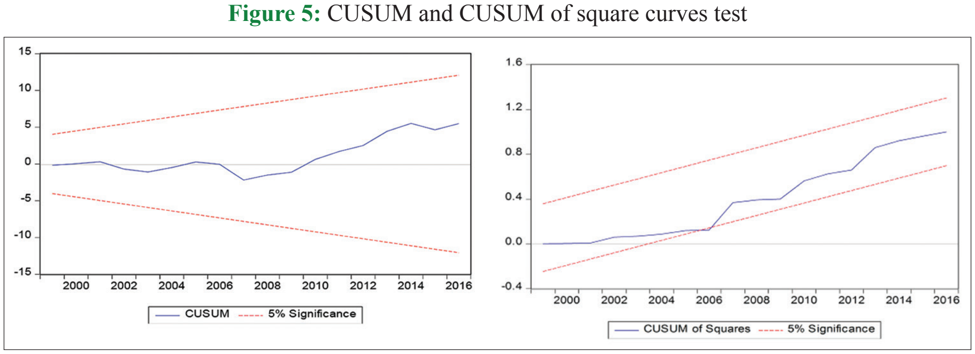
| Model | Chi-square statistics (F-statistics) | | | Coefficient | t-statistics |
|---|---|---|---|---|---|
| | $\sum\Delta C_{t-j}$ | $\sum\Delta E_{t-j}$ | $\sum\Delta Y_{t-j}$ | $ECT_{t-1}$ | |
| ΔCt | | 3.92*** | | −0.209 | −4.07*** |
| ΔEt | 1.66 | | 3.637*** | −0.039 | −1.327 |
| ΔYt | | 3.64*** | | 0.0099 | 0.788 |

(1) ***, **, and *indicate 1%, 5% and 10% level of significance, respectively.
(2) Diagnostic tests for VECM: (a) Normality test=8.544 (0.2009); (b) autocorrelation LM test = 14.3 (0.1111); (c) heteroscedasticity test=80.67 (0.5824). Source: Output of EVIEWS package version 9

According to the t-statistics, it can be observed that the coefficients of ECT for all equations were significant with negative signs, but the $CO_2$ equation has the highest significant level, which is at 1% level. These results indicate that given a deviation of $CO_2$ from the long-run equilibrium relationship, all three variables interact to restore long-run equilibrium. The evidence of unidirectional Granger-causality running from energy use to economic growth supports the "growth hypothesis", but rejects the conservation and feedback hypothesis. However, the Granger-causality running from energy use to economic growth and from energy use to carbon emission would have significant policy implications to Afghanistan. If the conservation policies are adopted, in the short-run it would have some detrimental impact on the economic growth in Afghanistan, but not in the long run. Alternatively, the policymakers have to consider the role of technology and innovation that can use energy in efficient manner in order to improve the economy without damaging the environment. However, this detrimental effects would be for a short period, as Afghanistan economy is highly reliable to the biomass energy, since at present 70-75% of Afghanistan's energy needs are met by solid biomass. Thus, in order to minimize the short-term detrimental effects, Afghanistan should diversify its economy sources and reduce its dependency on current energy sources, so that the energy conservation policies would not inhibit the economic growth.

Finally, the results of diagnostic tests of serial correlation, heteroscedasticity, and normality test for $CO_2$ function within the ARDL framework indicated that the model was free of the misspecification problem (Table 6). Also, it shows that the residuals from all equations have passed the diagnostic test and they do not violate the standard assumptions of normality. Thus,

**Figure 5:** CUSUM and CUSUM of square curves test



it can be confirmed that the $CO_2$ model (Equation 2) is reliable and stable. This is due to the fact that plots of CUSUM and CUSUMQ tests fall inside the critical bound of the 5% significant level (Figure 5).

## 5. CONCLUSION AND POLICY IMPLICATIONS

This study investigated the causality relationship between energy consumption (EC) and economic growth in Afghanistan during the period of 1970-2016. The dynamic causal relationship among variables was analyzed, grounded by four testable hypotheses (growth, conservation, feedback, and neutrality) established by Squalli (2007) and extended by Tiwari (2010). Through applying a multivariate model of energy use, income, and carbon emission, the obtained results significantly rejected the "neutrality hypothesis" in the short-run, indicating that there was no causality between energy consumption and GDP. Moreover, the estimation results indicated that there was unidirectional causality running from energy use to carbon emissions and from energy use to economic growth. The evidence of unidirectional Granger-causality supported the "growth hypothesis" and has policy implications for a short term. In addition, it was observed that in order to develop the country's economic development, Afghanistan requires more energy sources to boost the economy, which in turn would increase the country's energy dependency. On the other hand, if the conservation policies via energy efficiency regulations are adopted, mainly to protect the environment, the amount of energy use in the economy has to be reduced and this reduction would have some short-term adverse impact to the economic growth of Afghanistan. Alternatively, the policymakers have to consider the role of technology and innovation that can use energy efficiently in order to improve the economy without damaging the environment. However, this detrimental impact would be temporary. In the long-run, however, the result of DOLS established that energy use affects the $CO_2$ emission. Nevertheless, the real income was found to be insignificant with $CO_2$ emission, which implies that GDP does not affect the $CO_2$ emission. The obtained results suggest that in the long-term the economic growth of Afghanistan would not increase the $CO_2$ emission. This indicates that this country is not required to sacrifice their economic growth to decrease their emissions. This can be explained by the fact that currently more than third-quarter of Afghanistan's energy requirements are met by solid biomass and the economy of Afghanistan should be more dependent on renewable energies instead of fossil fuels. Thus, it's a great opportunity for Afghanistan to develop the country's economic performance by exploiting the abundance of renewable energy resources, especially its hydropower and biomass. Indeed, the initial greenhouse gas (GHG) inventory of Afghanistan indicates that deforestation is the main contributor of the country's total greenhouse gas emissions, as compared to fossil fuel combustion (gasoline, coal, etc.). Thus, renewable energy resources could play a significant role in the sustainable economic, social, and environmental development of Afghanistan. The high dependence of rural households on firewood, rising costs of fossil fuels, air pollution, and climate change are some of the encounters that can be addressed by diversifying power production fuel inputs and adopting renewable energy technologies. Nevertheless, it can be denied that the main obstacles to deployment of renewable in Afghanistan are the grid infrastructure inadequacy, insufficient institutional capacity, risks and security issues, as well as the investment incentives.

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