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The Causality Relationship between Economic Growth and Energy Consumption in the World's Top Energy Consumers

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ABSTRACT

The purpose of this paper is to empirically and economically investigate the causal relationship between economic growth and energy consumption in five countries with high consumption during the period of 1968-2016. These countries are China, India, Japan, the United States, and Saudi Arabia. Using the cointegration relationship between the variables procedure and the Granger causality test. This period witnessed various changes in the economy, consumption, and production of these countries. The causality results for the countries show that there is a unidirectional, and bidirectional Granger causality between the variables. Therefore, the energy conservation policy should be designed with caution, as energy is an engine for gross domestic product growth.

Keywords: Energy Consumption, Economic Growth, Granger Causality

JEL Classifications: C20, Q43, C32

1. INTRODUCTION

There has been a growing interest in global energy issues and international policies required to maintain the energy that is important for global economic growth and social welfare, which aims to reduce the level of global poverty and reduce greenhouse gas emissions stemming from large and inefficient uses of energy. Some energy-consuming countries have taken steps to conserve energy and exploit it optimally. Others use energy depending on availability as low-cost producers or low energy prices, which have been repeated over the past decades. There is debate as to whether energy conservation policies affect economic activity in countries or not; therefore, it is important to study the causal relationship between energy consumption and economic growth to provide advice and recommendations to countries as to what to do in the future to achieve a balance between economic growth and reduction of greenhouse gas emissions. Looking at the higher energy consumption countries, they contribute significantly to

global economic growth and to global energy consumption. China, for example, according to the British Petroleum Company report in 2016, is the world's largest energy consumer, with approximately 23% of total global energy consumption and contributing 27% to the growth of world demand for energy in (BP, 2016). Therefore, considering China and studying the causal relationship between energy consumption and economic growth is important to the study of this topic. Additionally, in terms of energy consumption, India is one of the top consumers, accounting for approximately 10% of the increase in global energy demand and India's global demand increased by 5.7% in 2013 (Priddle, 2015). It is also important to include Japan in this study as one of the industrial countries and one of the largest consumers of energy, with this country recently enacting many laws to maintain energy (Matsukawa, 2016). In Japan, energy consumption has been uneven in recent decades. For example, in 1979 after the second oil crisis, the Japanese government imposed a law on energy conservation to implement measures to regulate energy consumption. This law

required that companies that consumed large amounts of energy had to monitor annual energy consumption and provide long-term energy conservation plans (Matsukawa, 2016).

In addition to these countries, the USA is one of the most important and influential countries in the consumption of global energy, and is the second largest consumer of energy (after China) considering the total consumption of energy. Between 1950 and 2007, USA consumption nearly tripled, regardless of the recession of 2009 that resulted from the financial crisis. The energy sector is an important factor in the USA economy, accounting for 10% of gross domestic product (GDP) (Moore, 2010). In addition to these industrial consuming countries, which consume large quantities of energy and are responsible for the high demand for global energy, it is important to include one of the oil countries that consume energy in large quantities owing to different factors to that of the industrial countries.

As indicated by the Joint Organizations Data Initiative, Saudi Arabia is one of the few countries that burn crude oil directly to generate energy. During the summer, Saudi Arabia usually experiences an increase in electricity consumption with increasing domestic demand for air conditioners. In July 2014, for example, Saudi Arabia burned 0.9 million barrels per day of crude oil, which is one tiny example of their high energy consumption. This is contrary to most countries, which use natural gas or coal to meet their electricity requirements, but this is not the case in Saudi Arabia because of a lack of domestic coal production and most of the natural gas is a gas produced from that which produces oil as well as the high sulfur content in the local natural gas. Efforts to reduce energy consumption in Saudi Arabia have doubled as it plans to diversify energy sources and improve energy efficiency by 2032. It aims to do this by developing solar power generation and nuclear power so that there will be energy utilization during the production process. The Saudi Energy Efficiency Center was established in 2010, which reflects the interest in this aspect (US Energy Information Administration, 2014).

Over the past years, economists have tested the relationship between economic growth and energy consumption in many countries. The results found have been different from one country to another and sometimes in the same countries during different periods. Results have varied between economic growth and energy consumption in most cases. Some results have shown that there is unidirectional causality whereas other studies have shown that there is no evidence of a causal relationship between these two variables. For example, Kraft and Kraft (1978) studied the relationship between economic growth and energy consumption in the USA from 1947 to 1974. They found that there was a unidirectional causality originating from gross national product (GNP) to energy consumption. In contrast, Yu and Hwang (1984) updated this data by adding 5 years to the Kraft and Kraft (1978) data; therefore, they examined the period from 1947 to 1979. In this time, they found no evidence of any causality between GNP and the total energy consumption in the US. Both studies used the same method and methodology, apart from the periods, but the results were different. Additionally, Cheng and Lai (1997) studied the causality between GDP and total consumption and

found similar results to those of Kraft and Kraft (1978), which showed that there was unidirectional causality from GDP to total consumption. However, they studied this relation in a different country (Taiwan) from 1955 to 1993. Lee and Chang (2005) updated the data by adding 10 more years to the previous data and re-examined this relationship from 1954 to 2003 and found that there was a bidirectional causality between GDP and total energy. This causality came from the GDP to the total energy and gas as well as causality from the total energy and gas to the GDP (Banafea, 2014). Additionally, the relationship between economic growth and energy consumption may be changed by the economic crisis occurring because of energy price changes that can occur because of recession or inflation in importing countries. Thus, the present study focused on studying stability tests and cointegration ahead of the causal relationship between economic growth and energy consumption for the world's most important energy consumers.

2. TRENDS IN ENERGY CONSUMPTION

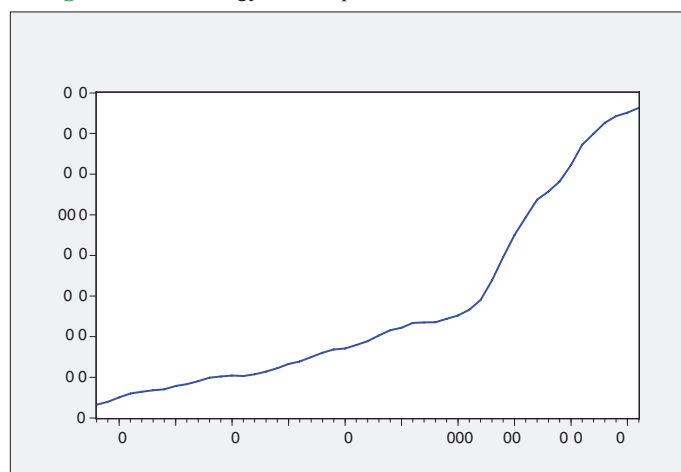
2.1. China

Figure 1 shows an increasing trend in total energy consumption in China since 2001, which might be caused by continuous economic growth. Data obtained from the National Bureau of Statistics (NBS) in China shows that the energy consumption in China increased from 131 million tons of oil equivalent (Mtoe) in 1965 to 3014 Mtoe in 2015, with GDP increasing from 172 billion yuan (in 1965) to 67.670 billion yuan (in 2015) (Dong et al., 2017).

China's energy needs have grown significantly since 2001. Sustained economic growth and structural changes in energy use, which preceded China's entry into the World Trade Organization in December 2001, were the major causes of growth in energy demand with a marked increase in GDP driven by the growth in investment and exports. From China's NBS, the growth in energy demand in China between 2002 and 2006 exceeded the growth in demand for the previous two decades (Kahrl and Roland-Holst, 2009).

Energy demand in China has increased on energy-intensive products such as automatic air conditioners. According to the State

Figure 1: Total energy consumption in China from 1970 to 2015



Statistics Bureau, registered vehicles in China increased markedly from 6.2 million in 1990 to 36.0 million in 2003, and the ownership of air conditioners by Chinese households increased from 11.6% to 61.8% between these years (Crompton and Yanrui, 2005).

2.2. India

India has contributed approximately 10% to the increase in global energy demand since 2000, as shown in Figure 2. Since 2000, demand for energy has almost doubled, making India's share in world demand up to 5.7% in 2013, compared to 4.4% at the beginning of the century. Demand for energy in India has grown by 46% since 2000 and remains at one-third of the average worldwide. One reason is that many of India's population are still without energy despite the rapid expansion of access to the energy systems in recent years. For example, 240 million people in India do not have access to electricity. Demand for energy in India has grown since 2000; however, this increase is lower than the rate of economic growth during this period. This is due to the low consumption of energy in the bioenergy consumption sector and the increasing importance of the services sector in India's economy and the policies of the country. Therefore, energy was reduced by 12% to increase the unit of GDP in 2013.

Since 2000, energy consumption in the industrial sector has grown significantly, exceeding the buildings sector until 2013. In the buildings sector, the main reason for the increase in energy consumption was the noticeable increase in household appliances in both rural and urban areas, where demand for electricity grew by 8% between 2000 and 2013.

The reference is:

[IEA] – International Energy Agency. India Energy Outlook, IEA publications, 2015, Paris.

https://www.gita.org.in/attachments/reports/indiaenergy_outlook_weo2015.pdf

2.3. Saudi Arabia

In Saudi Arabia, the consumption of energy increased during the mid-1970s in parallel with the establishment of basic infrastructure. As shown in Figure 3, there was also an increase in consumption during the oil recession in 1980 during. As the data shows, Saudi Arabia consumed 6,514 crude oil in 2008, which was more than that consumed by Japan. The Saudis also consumed 7,527 kilowatts per hour of electricity, which was almost equivalent to that of Japan (8,071). From this simple comparison with one of the developed countries, Saudi Arabia as an oil producer experiences inefficient use of energy (Hagihara, 2013).

The per capita energy consumption in Saudi Arabia is 3.6 times higher than the global average, which was 6.5 toe/capita in 2011 compared to 109 toe/capita for the world average. Energy consumption in the country is growing faster than that of GDP, which is against the general trend seen in most countries globally. This is because the industries in Saudi Arabia depend on energy-intensive industries in addition to the use of energy in buildings and transportation supported by low energy prices in Saudi Arabia (Saudi Arabia's Energy Efficiency Report, 2012). In Saudi Arabia, energy density increased by 2.3% annually between 2000 and 2010.

Figure 2: Total energy consumption in India from 1970 to 2015

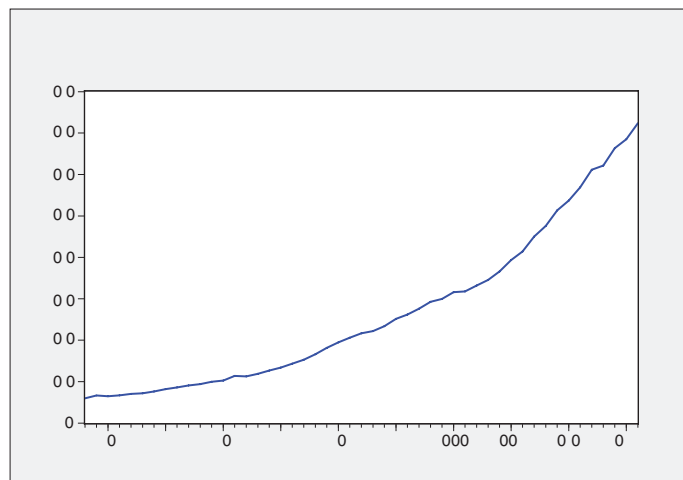
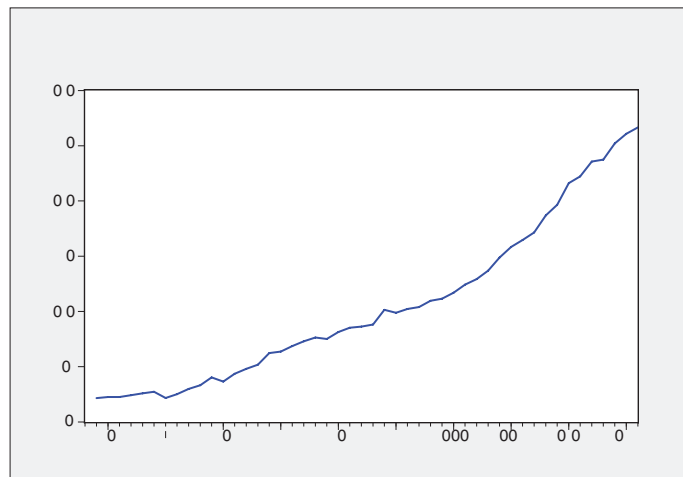


Figure 3: Total energy consumption in Saudi Arabia from 1970 to 2015



2.4. Japan

In Japan, energy consumption has been uneven in recent decades (Figure 4). For example, in 1979, the Japanese government imposed a law on energy conservation after the second oil crisis to implement measures to regulate energy consumption. This law required companies that consume large amounts of energy to determine annual energy consumption and provide long-term energy conservation plans. After these years, energy consumption continued to rise owing to various factors, such as an increase in the number of privately-owned cars (Matsukawa, 2016). During the 1990s, the consumption of energy increased steadily and expanded due to the increase of materials supported by public investment and the increase in the number of cars despite the economic recession. In addition, data from 1958 to 2000 showed the relationship between GDP and energy consumption was different from that of many countries. The oil shocks in 1973 stagnated energy use even though GDP continued to grow.

2.5. The USA

From 1970, the total domestic energy production in the USA slowed down while energy consumption continued to grow at a higher rate during this period (Figure 5).

3. RESEARCH METHODOLOGY

The trend in energy consumption is different in each country, owing to different economic and political reasons and as well as related to the prices of energy in the countries that produce the global energy. Therefore, this chapter examines and discussed the long-term causal relationship between many types of energy consumption and economic growth in five countries that have had an economic influence on the world's economy for many years. This chapter will discuss and find solutions to several questions, including:

1. What are the dates of structural breaks, and what are the economic and political interpretations behind these events?
2. What is the causal relationship between energy consumption, oil consumption, gas consumption, and GDP of the five top energy consumers?
3. Regarding results, what is the policy that policymakers should implement to spur the economy?

The methodology and this part of the chapter consists of three procedures to obtain results showing the causal relationship between energy consumption, oil consumption, gas consumption, and GDP. This chapter tests the relationship between these variables, with the model used containing the total energy, oil,

and gas consumption as the independent variables and GDP as the dependent variable.

3.1. Unit Root Test

The purpose of the unit root test is to know whether the data are stationary or not. It is an important test before starting the next steps. The existence of the unit root was tested by Dickey-Fuller (1979, ADF) and Philips and Perron (1988, PP) to test the null hypothesis of a unit root.

3.2. Cointegration

The second part in the methodology is to examine of the cointegration relationship between the variables. This test is very important because cointegration provides evidence of the long-term equilibrium between variables and is an indication that the variables move together over time. In contrast, the absence of cointegration between the variables indicates that there is no long-term equilibrium relationship.

3.3. Granger Causality

The third step in the methodology occurred when there was cointegration between the variables, with the Granger causality examined by the Granger causality test:

$$GDP_t = \alpha_0 + \alpha_1 EC_t + \alpha_2 Oil_t + \alpha_3 Gas_t + E_t$$

The research tested the causal relationship between economic growth (GDP) as the dependent variable and oil, gas, and energy consumption (EC) as the independent variables. Some tests were conducted to determine the relationship between economic growth and the independent variables using several steps to ensure the results are more accurate. Unit root tests were also conducted in GDP, and energy, gas, and oil consumption to determine whether these time series were stationary or not.

4. SOURCES OF DATA

Four basic variables were used to determine the casual relationship between economic growth and energy consumption. Data was obtained from two different sources, GDP growth was collected from the World Development Indicators produced by the World Bank, whereas energy, gas, and oil consumption were obtained from the BP Statistical Review of World Energy (Table 1).

Table 2 shows the mean, standard deviation, minimum, and maximum of each variable. The data were obtained from five countries, including China, India, Japan, the US, and Saudi Arabia from 1968 to 2016. The average GDP of the total exports for this period was 5.1%, which ranged from -20.72% to 58.6%. The average energy consumption was 782.8702 Mtoe with the maximum reaching 3053.00 of exports and the minimum 21.448.

5. LITERATURE REVIEW

5.1. Theoretical Underpinning

The relationship that ties the dynamics of economic growth with the drivers of energy consumption has attracted considerable

Figure 4: Total energy consumption in Japan from 1970 to 2015

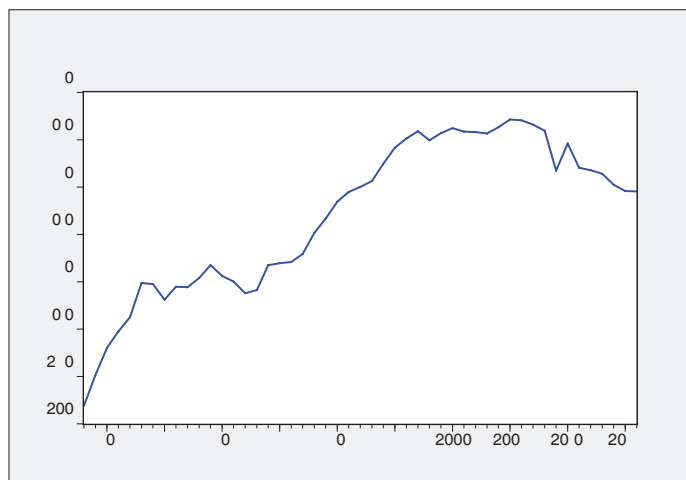


Figure 5: Total energy consumption in the USA from 1970 to 2015

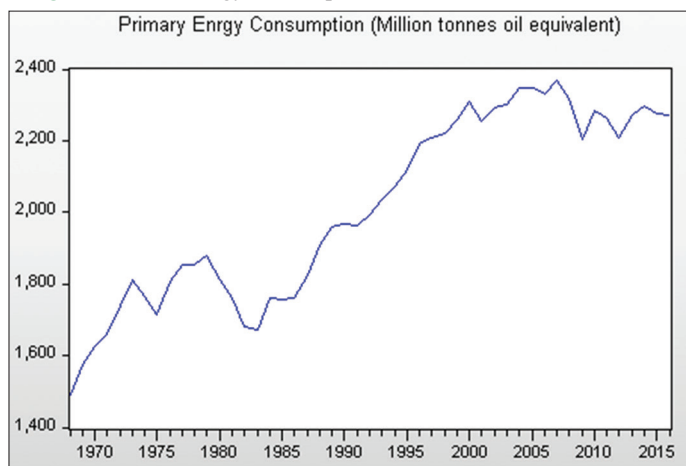


Table 1: Variables

Variables	Short definition	Code	Source
GDP per capita (constant 2010 USD)	GDP per capita is GDP divided by midyear population	GDP	World Bank national accounts data, and oecd national accounts data files
Primary energy consumption	The direct use at the source or supply to users without transformation of crude energy	EC	BP statistical review of world energy
Oil consumption		OIL	BP statistical review of world energy
Natural gas consumption		GAS	BP statistical review of world energy

Table 2: Summary statistics

Parameters	GDP	EC	OIL	GAS
Mean	5.146027	782.8702	279.5961	138.6160
Median	4.420124	417.0332	171.3237	36.61233
Maximum	58.64733	3053.000	938.3952	716.3203
Minimum	-20.72989	21.44800	15.20000	0.340000
Standard deviation	6.455122	824.8319	287.6931	212.0241

attention from global economists. From a generalized perspective, the fundamental pursuit in most of the previously conducted research was to assess and understand the levels at which economic growth affects the energy consumption and vice versa. Economists in the 1990s introduced the growth, conservation, feedback, and neutrality hypotheses to elaborate the connection between these two factors, which are believed to hold considerable importance for policymakers to plan and boost economic growth prospects based on their understanding of the economic consumption trends (Ozturk, 2010; Aneja et al., 2017; Hajkoa, 2012; Jakovac, 2018; Rezitis and Ahammad, 2015a; Wen-Chi, 2013; Bouoiyour et al., 2014). The growth hypothesis assumes that energy consumption stimulates economic growth, based on the assumption that with an increasing trend in energy consumption, the economic growth rate is also set to increase by a substantial amount. The hypothesis therefore suggests that with more capital invested in the expansion and innovation operations of the energy sector, economies can attain better growth with increased income and employment. Considering that both factors are strong contributors to a nation's GDP, the relationship between energy consumption and economic growth can be adequately interpreted (Adhikari and Chen, 2012; Rezitis and Ahammad, 2015b; Tang and Shahbaz, 2013).

The conservation hypothesis offers a different view of the perceived relationship between energy consumption and economic growth than that of the growth hypothesis. It assumes economic growth is the antecedent to increase energy consumption. In literary works, this hypothesis has often been used to interpret the ways through which capital investment in various industry sectors contribute to the aggregate of national income, which in turn boosts energy consumption in the economy (Ozturk et al., 2010). The type of relationship proposed by the growth and conservation hypotheses concerning energy consumption and economic growth can hence be denoted in terms of unidirectional causality, whereas the feedback hypothesis offers rationality to justify a bidirectional relationship amid these two components. The feedback hypothesis assumes the possibilities of a strong dependency between economic growth and energy consumption, wherein capital investments made within the different sectors of the economy can encourage the energy consumption trends in the demography. However, on

the other hand, investments made within the energy sectors may boost economic development (Sbia et al., 2014; Tang and Abosedra, 2014). Exploring further details into the type of characteristics of the relationship between energy consumption and economic growth, economists have offered an alternative viewpoint with the neutrality hypothesis. This hypothesis is based on the assumption that the dynamics of economic growth and energy consumption may in fact not be causally related at all, arguing that investment decisions adopted regarding the performance of energy sectors are unlikely to pose a tremendous influence on economic growth, thereby considering as per the classic economic theory that energy consumption does not drive the overall economic activities of a nation (Chen et al., 2007).

5.2. Empirical Evidence

As the issue was being discussed among economists worldwide, investigating the phenomenon within specific countries to either accept or reject these hypotheses became a common practice. For instance, the study by Cheng (1998) aimed at exploring the relationship of energy consumption with real GNP in Japan with the inclusion of employment/labor and capital investments as additional drivers for the production function [$Q = f(K, L, P, H)$]. The findings obtained by Cheng (1998) revealed that unidirectional causality existed between employment or labor components, real GNP of the economy, and its overall trend of energy consumption. Following the study by Cheng (1998), Lee (2006) offered empirical explanations for the relationship of economic growth and energy consumption based on Toda and Yamamoto's (1995) methodology, arguing that energy consumption is dependent on the economic growth prospects of Japan.

Simultaneous to the study of Lee (2006), the research conducted by Soytas and Sari (2006) was published that confirmed the unidirectional causality between these factors. However, the study findings obtained by Ajmi et al. (2013) that confirmed this relationship, rejected the claims for a unidirectional causality but supported the existence of a feedback effect in the Japanese context, whereas the findings by Mutascu (2016) confirmed a neutral effect correlating the determinants of energy consumption to that of economic growth. Furthermore, Ishida (2013) argued that a causal relationship did not exist between non-fossil energy and GDP, which apparently categorized the differences likely to persist in the various dimensions of the energy sector with regards to the economic growth prospects of the nation. Ishida (2013) argued that the intrinsic difference was observed in relation to the trends of fossil fuels and non-fossil energy consumptions within a specific nation, fundamentally because it was affected by the contemporary link between fossil fuels and non-fossil energy sources energy (Shahbaz et al., 2018).

Concentrating on China, on the other hand, literary investigations can be observed to have remained obstructed during the 1990s owing to a severe lack of data regarding the components of economic growth and energy consumption (Soytas and Sari, 2006). It was not before the late 2000s that the data regarding China's economic growth was available and, hence, a surge in the number of studies in the economic field was observed. Correspondingly, Wang et al. (2011) conducted a study investigating the relationship between economic growth and energy consumption trends in China. Yuan et al. (2008) further presented the opinion that because China was one of the leading energy consumers in the world, then it was imperative to have a closer understanding of the relationship between its energy consumption pattern and economic growth. Nonetheless, previous studies conducted in this regard have produced unimpressively mixed results, providing no additional clarity to understanding the relationship either at the aggregated energy consumption level or at the disaggregated level (Wolde-Rufael, 2004; Yuan et al., 2008). Arguably, Yuan et al. (2008) stressed the possibility that the research findings of these previous investigations might have been severely affected by the time induced differences, considering that neither the energy consumption trends nor the economic growth trends remain stable throughout an extended period, as their drivers are continuously affected by various other factors. In addition, Zhang and Cheng (2009) and Yuan et al. (2008) stated that the use of different methodological strategies for encoding and decoding of the data retrieved using a variety of econometric models produced different results in the research context. These facts apparently project a significant literature gap existing within the field that demands further in-depth investigations, into the realm of energy and economic growth determinants in China.

As was further argued by Sari et al. (2008), economic systems are well-known to exhibit the characteristics of feedback effects and/or bidirectional causality, when explaining the relationship between energy consumption and economic income generation or growth. For instance, the findings obtained by Lee (2006) implied the same notion with regards to energy consumption and the economic growth prospects for the US. Contradicting this finding, however, Stern (1993) argued that apart from the direction or existence of the feedback hypothesis, previous studies were observably ignorant of the neutrality of energy hypothesis, which assumes that there is no relationship connecting energy consumption with the overall economic income/output as these trends are believed to evolve independently from each other. This notion was proved empirically in the studies by Akarca and Long (1980), Eden and Hwang (1984), Yu and Choi (1985), among others. It is also observable that even though some unconventional studies, such as that of De Vita et al. (2006) have used the ARDL technique to interpret the correlation between the energy sector and economic growth, the literary context still lacks in terms of an explicit examination of the phenomenon using disaggregate data for the USA (Sari et al., 2008), again denoting a literature gap in the field (Soytas and Sari, 2006).

With regards to the studies based in India, Masih and Masih (1996) obtained results that confirmed unidirectional causality between energy consumption and economic income for the economy from

1955 to 1990. Using the Granger causality test, Cheng (1999) revealed a causal relationship between these factors, whereby the patterns and trends of economic growth appeared to affect the trends for energy consumption not only in the short term but also in the long term. Offering a contradictory view, however, Asafu-Adjaye (2000) confirmed the existence of the conservative hypothesis in this context, whereas Ghosh (2002) produced results that indicated no long-term equilibrium connecting electricity consumption with economic growth, when using the Granger causality test for the same set of data. Fatai et al. (2004) confirmed the existence of the growth hypothesis when they established the relationship between economic consumption and growth in India. Emphasizing more recent investigations conducted in the field, Alam et al. (2011) affirmed that no causal relationship existed amid the trends of economic growth in India and its energy consumption trends. Abbas and Choudhury (2013) further authenticated the feedback hypothesis or the bidirectional causality in the context of the electricity consumption pattern and GDP, especially focusing on the agricultural sector in India from 1972 to 2008. From a general perspective, however, Ghosh and Kanjilal (2014) revealed a unidirectional causality, whereas Sehrawat et al. (2015) depicted a neutral influence between the trends of energy consumption and economic growth in India by focusing on time series data from 1971 to 2011. Thus, the existing literature offers a widely divergent set of results regarding the phenomenon of economic growth and energy consumption that is inconclusive for drawing a precise and comprehensive conclusion for this issue. The results can be observed to resemble a certain degree of similarity to the context in Saudi Arabia, especially when considering the divergent nature of the findings achieved through different investigative studies (Blazquez et al., 2017; Howarth et al., 2017; Singh and Aneja, 2017).

5.3. Literature Gap

The most apparent literature gap identified reveals the lack of uniformity in the results obtained from different studies, conducted in different time periods as well as emphasizing different demographic features. In addition, the primary segregation existing within the energy industry and economic components of GDP for a country are known to be widely different, which may also be the cause of such divergent findings retrieved in the previous investigations. Altogether, these gaps indicate the need toward developing an all-inclusive research methodology to produce a more confirmative finding concerning the relationship between energy consumption and economic growth in terms of GDP for countries.

6. EMPIRICAL RESULTS

6.1. Unit Root Test Results

The results of testing the unit root for China showed that all variables have unit root at the levels and oil and GDP are stationary in the first difference (Table 3). Therefore, GDP and oil are integrated of order one, $I(1)$. As for the variables EC and gas they have the unit root at the first difference and levels.

Table 4 shows the results of the unit root test for India where we can determine whether the variables are stationary at the level or

stationary in the first difference. The results show that GDP, EC, oil, and gas have unit root at the levels and they are stationary in the first difference. Therefore, all the variables are integrated of order one, I (1).

The results of the unit root in Japan show that GDP, EC, and oil have unit root at the levels and they are stationary in the first difference; however, the variable gas is stationary in the levels (Table 5).

Table 6 shows the results of the unit root test for the USA and reveals that GDP, EC, oil, and gas do not reject the null hypothesis, which indicates that the variables have unit root at the levels, but they are reject the null hypothesis when using the first difference

and they are stationary in the first difference at the 1% level of significance.

Table 7 shows results for the Kingdom of Saudi Arabia, which has similar results to that of the USA where GDP, EC, oil, and gas have unit root at the levels, but they are stationary in the first difference.

6.2. Johansen Fisher Cointegration Test Results

The variables had a unit root in the levels and were stationary in the first difference; therefore, the cointegration could be tested to determine whether there is a long-term relationship between the independent variables and the dependent variable in the GDP in the capita model. Before starting the cointegration, the optimal lag length of both models should be tested. From the model and

Table 3: ADF and PP Unit Root Test Results for “China”

Variables	ADF		PP	
	Levels	First difference	Levels	First difference
GDP	0.925026 (1)	-2.018244 (0)***	4.717504	-1.897028***
EC	-1.907227 (1)	-2.121578 (0)	-0.479109	-2.121578
Oil	1.096127 (0)	-6.253107 (0)***	1.096127	-6.249579***
Gas	-2.340896 (10)	-0.412093 (9)	2.812403	-2952765

, *Denote significance at the 5% and 1% levels, respectively. The number of lag order is shown in parentheses

Table 4: ADF and PP unit root test results for “India”

Variables	ADF		PP	
	Levels	First difference	Levels	First difference
GDP	4.622478 (0)	-4.817579 (0)***	5.252140	-4.747387***
EC	2.334675 (6)	-2.933514 (1)	2.268579	-7.924606***
Oil	1.313817 (2)	-4.720670 (1)***	1.794589	-3.935800**
Gas	-0.076992 (8)	-3.993801 (7)**	-2.475896	-7.426786***

, *Denote significance at the 5% and 1% levels, respectively. The number of lag order is shown in parentheses

Table 5: ADF and PP unit root test results for “Japan”

Variables	ADF		PP	
	Levels	First difference	Levels	First difference
GDP	-0.816342 (0)	-6.048888 (0)***	-0.902295	-6.065635***
EC	-0.888757 (0)	-6.982437 (0)***	-1.032960	-6.978855***
Oil	-3.160069 (0)	-5.136384 (0)***	-3.116154	-5.089583***
Gas	-3.900967 (1)**		-2.902891	-8.633832***

, *Denote significance at the 5% and 1% levels, respectively. The number of lag order is shown in parentheses

Table 6: ADF and Phillips-Perron unit root test results for “USA”

Variables	ADF		PP	
	Levels	First difference	Levels	First difference
GDP	-2.629805 (1)	-4.813259***	-1.796427	-4.541684***
EC	-1.617279 (0)	-5.975843 (0)***	-1.846313	-5.936530***
Oil	-2.957539 (1)	-4.204678 (0)***	-2.519023	-4.077015**
Gas	-0.823023 (0)	-6.165424 (0)***	-1.148409	-6.156918***

, *Denote significance at the 5% and 1% levels, respectively. The number of lag order is shown in parentheses

Table 7: ADF and PP unit root test results for “Kingdom of Saudi Arabia”

Variables	ADF		PP	
	Levels	First difference	Levels	First difference
GDP	-2.323945 (0)	-4.855207 (0)***	-2.485452 (2)	-4.868225 (2)***
EC	-0.146447 (0)	-8.454831 (0)***	0.041768	-8.306488***
Oil	-0.021490 (0)	-7.419129 (0)***	0.168358	-7.421220***
Gas	-1.672026 (0)	-8.563352 (0)***	-1.642765	-8.409987***

, *Denote significance at the 5% and 1% levels, respectively. The number of lag order is shown in parentheses

through VAR lag order selection criteria, we can find the optimum lag, which will be used in the Johansen Fisher cointegration test.

From the GDP per capita model and the VAR lag order selection criteria, the optimum lag was found to be 6 for China (Table 8), which will be used in the Johansen Fisher cointegration test to determine the long-term relationship between the variables that were stationary in the unit root test.

Examining the trace and maximum eigenvalue tests for China, the null hypothesis stating that there is no cointegration was rejected (Table 9). However, the null hypothesis that states there is at most 1 cointegrating could not be rejected; therefore, there is a cointegration among the variables GDP and oil. Thus, in the long term, these variables are moving together. Cointegration indicates that causality exists between the variables; however, it does not show the direction of the casual relationship. This shows a long-term relationship between GDP and oil (Table 9).

From the VAR Lag Order Selection for India, the optimum lag was found to be 5, which will be used in the Johansen Fisher

cointegration test to determine the long-term relationship between the GDP, EC, oil, and gas variables (Table 10).

Examining the trace and maximum eigenvalue tests for India, the null hypothesis stating that there is at most 2 and at most 3 cointegrating could not be rejected; therefore, there is cointegration among the variables GDP, EC, gas, and oil. Thus, in the long term, these variables are moving together (Table 11).

Examining the trace and maximum eigenvalue tests for Japan, the null hypothesis that stated there was no cointegration was rejected (Tables 12 and 13). However, the null hypothesis stating that there was at most 1, at most 2, and at most 3 cointegrations could not be rejected; therefore, there was cointegration among the variables GDP, EC, gas, and oil. Thus, there was a long-term relationship between the variables.

From the VAR Lag Order Selection for the USA, the optimum lag was found to be 4, which was used in the Johansen Fisher cointegration test to determine the long-term relationship between the GDP, EC, oil and gas variables (Table 14)

Table 8: VAR lag length selection criteria from VAR estimates (Model I) for “China”

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-975.3238	NA	7.12e+14	45.54994	45.71378	45.61036
1	-647.4020	579.5826	3.58e+08	31.04195	31.86112	31.34404
2	-614.2925	52.35920	1.65e+08	30.24616	31.72066*	30.78991
3	-593.6086	28.86134	1.40e+08	30.02831	32.15813	30.81372
4	-566.2694	33.06138	91476546	29.50090	32.28605	30.52798
5	-535.4455	31.54067*	55079971	28.81142	32.25190	30.08016
6	-507.7868	23.15611	43272469*	28.26915*	32.36497	29.77956*

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

Table 9: Unrestricted cointegration rank test (trace and maximum eigenvalue)

Hypothesized number of CE (s)	Prob.	Fisher stat.* (from trace test)	Prob.	Fisher Stat.* (from maximum-Eigen test)	Prob.
None		14.64801	0.0668	14.34355	0.0486
At most 1		0.304465	0.5811	0.304465	0.5811

Probabilities are computed using asymptotic Chi-square distribution.

Table 10: VAR lag length selection criteria from VAR estimates (Model I) for “India”

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-770.9487	NA	5.30e+10	36.04413	36.20796	36.10454
1	-514.5987	453.0838	742496.4	24.86505	25.68422	25.16714
2	-496.6985	28.30731	694035.8	24.77667	26.25117	25.32042
3	-463.5626	46.23610	329773.0	23.97966	26.10948	24.76507
4	-437.3520	31.69652	227621.1	23.50474	26.28990	24.53182
5	-383.9006	54.69449*	47843.70*	21.76282	25.20330*	23.03156*
6	-365.1190	15.72413	56801.25	21.63344*	25.72926	23.14385

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

Table 11: Unrestricted cointegration rank test (trace and maximum eigenvalue)

Hypothesized number of CE (s)	Prob.	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from maximum-Eigen test)	Prob.
None		88.69612	0.0000	48.08646	0.0000
At most1		40.60965	0.0020	27.03635	0.0066
At most2		13.57330	0.0954	10.33542	0.1908
At most3		3.237879	0.0720	3.237879	0.0720

Probabilities are computed using asymptotic Chi-square distribution

Examining the trace and maximum eigenvalue test results for the USA, the null hypothesis stating that there was cointegration among the variables GDP, EC, gas, and oil (Table 15). Thus, in the long term, these variables were moving together.

Examining the trace and maximum eigenvalue test results for India (Table 17), the null hypothesis stating that there was no cointegration was rejected. However, the null hypothesis stating that there is at most 1, at most 2, and at most 3 cointegrating could not be rejected; therefore, there was cointegration among the GDP, EC, gas and oil variable (Table 17). Thus, there were three long-term relationships in these variables and they were moving together.

6.3. Causality Test Results

The existence of cointegration between the variables enables us to continue testing by knowing the causal relationship between the variables. The existence of cointegration shows that there is a causal relationship between the variables but it does not show the

direction of this causal relationship. Granger (1988) showed that when there is evidence of cointegration among variables, there must be at least one unidirectional Granger causality between variables.

For GDP, the causality results for China show that there is a one-way long-term relationship from oil consumption to GDP (Table 18). The p value rejects the null hypothesis of no causality at the 5% significance level. However, the null hypothesis of no causality from oil to GDP is not rejected based on the p value, and therefore there is a unidirectional Granger causality running from oil consumption to GDP. Because of this causality in China, there is a relationship and causality of oil consumption that leads to an increase in GDP. This has been shown in statistics from China's NBS, where China's energy consumption increased from 131 Mtoe in 1965 to 3,014 Mtoe in 2015, with GDP increasing from 172 billion yuan (in 1965) to 67,670 billion yuan (in 2015).

For the relationship between the long-term variables and the causal relationship in India, the Granger causality results between the

Table 12: VAR lag length selection criteria from VAR estimates (Model I) for “Japan”

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-969.9597	NA	5.54e+14	45.30045	45.46428	45.36087
1	-730.6276	423.0054*	1.72e+10*	34.91291*	35.73208*	35.21500*
2	-717.4538	20.83303	2.00e+10	35.04436	36.51886	35.58811
3	-708.8866	11.95427	2.98e+10	35.39007	37.51990	36.17549
4	-694.5963	17.28127	3.58e+10	35.46960	38.25475	36.49667
5	-673.5068	21.57994	3.39e+10	35.23288	38.67336	36.50162
6	-652.4569	17.62322	3.62e+10	34.99799	39.09381	36.50840

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

Table 13: Unrestricted cointegration rank test (trace and maximum eigenvalue)

Hypothesized number of CE (s)	Prob.	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from maximum-Eigen test)	Prob.
None		25.69050	0.0856	50.73289	0.0262
At most 1		18.38307	0.1162	25.04239	0.1599
At most 2		6.237121	0.5830	6.659319	0.6176
At most 3		0.422199	0.5158	0.422199	0.5158

Probabilities are computed using asymptotic Chi-square distribution

Table 14: VAR lag length selection criteria from VAR estimates (Model I) for the “USA”

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1129.140	NA	9.10e+17	52.70420	52.86803	52.76461
1	-890.5736	421.6526	2.92e+13	42.35226	43.17142*	42.65434
2	-870.9752	30.99284	2.52e+13	42.18489	43.65939	42.72864
3	-850.5579	28.48920	2.16e+13	41.97944	44.10926	42.76485
4	-824.0577	32.04681*	1.47e+13*	41.49106	44.27621	42.51813*
5	-806.1161	18.35883	1.62e+13	41.40075	44.84123	42.66949
6	-787.9510	15.20796	1.97e+13	41.30005*	45.39586	42.81046

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

Table 15: Unrestricted cointegration rank test (trace and maximum eigenvalue)

Hypothesized number of CE (s)	Prob.	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-Eigen test)	Prob.
None		87.40445	0.0000	42.08317	0.0004
At most 1		45.32128	0.0004	31.26711	0.0014
At most 2		14.05417	0.0815	12.40045	0.0965
At most 3		1.653720	0.1985	1.653720	0.1985

Probabilities are computed using asymptotic Chi-square distribution. From the VAR Lag Order Selection for the Kingdom of Saudi Arabia, the optimum lag was found to be 1, which was used for the Johansen Fisher cointegration test to determine the long-term relationship between the GDP, EC, oil, and gas variables [Table 16]

Table 16: VAR lag length selection criteria from VAR estimates (Model I) for the “Kingdom of Saudi Arabia”

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-853.4019	NA	6.34e+12	40.82866	40.99415	40.88932
1	-443.9939	721.3378	46535.89*	22.09495*	22.92241*	22.39825*
2	-432.3444	18.30639	58547.50	22.30212	23.79155	22.84805
3	-421.2151	15.36909	78159.12	22.53405	24.68545	23.32262
4	-396.4625	29.46731*	57659.29	22.11726	24.93063	23.14848
5	-386.7560	9.706495	94835.15	22.41695	25.89229	23.69080
6	-364.8781	17.71070	99663.75	22.13705	26.27436	23.65354

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

Table 17: Unrestricted cointegration rank test (trace and maximum eigenvalue)

Hypothesized number of CE (s) Prob.	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-Eigen test)	Prob.
None	57.53592	0.0048	32.79634	0.0097
At most 1	24.73958	0.1709	14.73208	0.3081
At most 2	10.00750	0.2802	9.164580	0.2727
At most 3	0.842923	0.3586	0.842923	0.3586

Probabilities are computed using asymptotic Chi-square distribution

consumption of gas and oil showed that the null hypothesis of no causality was rejected at the 10% significance level (Table 19). However, the null hypothesis of no causality running from oil to GDP and gas to GDP was not rejected. Therefore, there is a bidirectional Granger causality running from gas consumption to oil consumption and from oil consumption to gas consumption.

In Japan, because there was a long-term relationship obtained in the cointegration test, the causal relationship is between the variables where the p value rejects the null hypothesis; therefore, there is a Granger causal relationship from EC to oil, GDP to oil, and EC to GDP (Table 20).

The Granger causality relationship in the USA shows that there is a unidirectional Granger causality between GDP and gas consumption; therefore, the causality runs from GDP to gas consumption, there is a bidirectional Granger causality between oil consumption and energy consumption, and a unidirectional Granger causality from gas consumption to oil consumption (Table 21). The causality relationship between the variables in the USA is high. The country has a large economy, and thus needs large amounts of energy; therefore, the USA exports approximately 10 million barrels of oil per day and also imports approximately 10 barrels per day worldwide.

The Granger causality relationship in Saudi Arabia shows that there is a unidirectional Granger causality between EC and gas consumption, which shows that there is causality running from EC to gas consumption, and a unidirectional Granger causality from gas consumption to oil consumption (Table 22). The phasing out of energy subsidies could have a negative influence on GDP growth in Saudi Arabia.

6.3.1. Economic reasons behind the results of the causality tests

Experts have held the opinion that the energy consumption trends of an economy have a strong role in determining its overall growth prospects. Observably, the causal relationship connecting these factors reflects many differences in the contexts of China, India, the USA, Japan, and Saudi Arabia. This implies that these aspects

Table 18: Results of Granger causality tests for “China”

Null hypothesis	Obs.	F-Statistic	Prob.
Oil does not Granger cause GDP	43	4.17169	0.0036
GDP does not Granger cause oil		1.46029	0.2254

Table 19: Results of Granger causality tests for “India”

Null hypothesis	Obs.	F-Statistic	Prob.
OIL does not Granger cause GDP	44	0.83654	0.5334
GDP does not Granger cause OIL		1.78202	0.1439
GAS does not Granger cause GDP	44	0.55313	0.7348
GDP does not Granger cause GAS		1.29624	0.2893
GAS does not Granger cause OIL	44	2.19641	0.0783
OIL does not Granger cause GAS		2.06121	0.0955

Table 20: Results of Granger causality tests for “Japan”

Null hypothesis	Obs.	F-Statistic	Prob.
EC does not Granger cause GDP	48	3.67049	0.0618
GDP does not Granger cause EC		0.24317	0.6243
OIL does not Granger cause GDP	48	1.81849	0.1842
GDP does not Granger cause OIL		6.56572	0.0138
OIL does not Granger cause EC	48	0.02702	0.8702
EC does not Granger cause OIL		6.15753	0.0169

Table 21: Results of Granger causality tests for the “USA”

Null hypothesis	Obs.	F-Statistic	Prob.
EC does not Granger cause GDP	45	0.13238	0.9695
GDP does not Granger cause EC		0.81027	0.5269
OIL does not Granger cause GDP	45	2.09850	0.1013
GDP does not Granger cause OIL		1.88248	0.1347
GAS does not Granger cause GDP	45	1.56327	0.2051
GDP does not Granger cause GAS		2.90443	0.0351
OIL does not Granger cause EC	45	7.95389	0.0001
EC does not Granger cause OIL		4.69546	0.0037
GAS does not Granger cause EC	45	0.71040	0.5902
EC does not Granger cause GAS		1.36521	0.2653
GAS does not Granger cause OIL	45	2.22260	0.0859
OIL does not Granger cause GAS		1.07127	0.3850

and their corresponding determinants behave distinctively when positioned in varying economic circumstances.

Table 22: Results of the Granger causality tests for the “Kingdom of Saudi Arabia”

Null hypothesis	Obs.	F-Statistic	Prob.
EC does not Granger cause GDP	47	1.22894	0.2736
GDP does not Granger cause EC		0.30843	0.5815
OIL does not Granger cause GDP	47	1.08607	0.3030
GDP does not Granger cause OIL		0.50792	0.4798
GAS does not Granger cause GDP	47	1.47579	0.2309
GDP does not Granger cause GAS		0.59415	0.4449
OIL does not Granger cause EC	47	0.25347	0.6172
EC does not Granger cause OIL		1.86195	0.1793
GAS does not Granger cause EC	47	2.34084	0.1332
EC does not Granger cause GAS		9.05125	0.0043
GAS does not Granger cause OIL	47	3.42926	0.0708
OIL does not Granger cause GAS		1.99649	0.1647

6.3.1.1. China

The oil consumption patterns within China and its GDP growth trends show the characteristics of a long-term unidirectional Granger causality relationship. In China, since 1993, economic changes have shown an increase in oil consumption and imports of oil. In 2002, the proportion of oil imports increased to 33%, which further increased in 2005 and 2006 to 43% and 47%, respectively. These increases support domestic products contributing to the increase in the country's exports (Yuan et al., 2008). The results also show that oil consumption leads to the growth of the economy, which is elastic in China in the long term. The main reason behind this is that the use of oil in the industrial sector significantly enhances the economy. China is a global manufacturer, which is the major reason for the consumption of many natural resources and oil. For example, the country in 2002 consumed 89.9% of the total oil consumption, contributing to 43.7% of the country's real GDP (National Bureau of Statistics of China, 2004). In addition, transportation, storage, telecommunications, and agriculture were contributing factors to the increase in oil consumption. China's energy consumption increased from 131 Mtoe in 1965 to 3,014 Mtoe in 2015, with GDP growing from 172 billion yuan in 1965 to 67.670 billion yuan in 2015 (Dong et al., 2017).

Underlying issues related to environmental attributes are also affected by energy sources, which leads to hindering of economic growth prospects (Zou and Chau, 2006). Azam et al. (2015) also showed that energy consumption affects the determinants of economic growth. This, in turn, is affected by per capita carbon dioxide emissions, which is inversely correlated with the growth trends of the country. When assessing the evidence for China, Al-Mulali and Sheau-Ting (2014) revealed that the interaction among carbon dioxide emissions, energy consumption, and international trade within the country was relatively intense in the long-term. This is principally because economic growth trends become the solo determinant of energy consumption in the country in the long term, where continuous and rapid economic growth trends encourage its energy production capacity. Therefore, this leads to a greater supply of energy within the economy. As the economy increases, demand for energy supplies also increases and vice versa, which are simultaneously influenced by the income levels and living standards of the population.

6.3.1.2. India

In the context of India, unlike China, the causality directions observed between electricity consumption and economic growth prospects were either non-existent or were blurred together too much to be identified distinctively. The limited degree of predictability of changes in the demand for electricity supplied publicly resulted in inhibited dependency of investors on energy sources. This is mainly for manufacturing plants and has contributed to such a causality in the Indian context (Rezitis and Ahammad, 2015b). It is also because oil consumption in India is a leading determinant for assessing its economic progress, as its enormous usability of industry production and transportation purposes directly push the economy further toward growth. Therefore, in the long term, increased oil consumption in India imposes strong influences on employment that, in turn, leads to economic development and, hence, substantiates the observed relationship.

6.3.1.3. Japan

According to a study by Ishida (2013), the implications drawn from the Granger causality tests and based on the variance decomposition assessment revealed that in Japan fossil fuels are used as the major source of the economy's energy consumption. Ishida (2013) also showed that Granger causality from fossil fuel consumption leads to the GDP in the long term. Similar observations were also made by Bildirici et al. (2012). This is because, in the majority of cases, the production function in Japan is highly dependent on the consumption of fossil fuels. This aggravates the dependency of its energy consumption trends on the overall economic growth prospects of the country. In other words, the economic growth trends in Japan imply increased per capital income for its population, which, in turn, encourages greater energy consumption in the short term and vice versa. When focusing on the long-term aspects, increasing energy consumption implies increased transportations and industry production growth, which, in turn, contributes to the GDP in Japan.

6.3.1.4. The USA

With respect to the trends in the USA for energy consumption as well as economic growth, considerable fluctuations have occurred since the 1990s (Arora and Shi, 2015). The Granger causality reflects a bidirectional predictability between economic growth in the USA (based on its real GDP) as well as its coal consumption trends in the early 1990s. However, this reflects unidirectional predictability during the later years of the 1990s (Apergis and Payne, 2010). Similar observations were also obtained from the patterns of energy consumption when the economy was dependent on either natural gas or oil at its different stages of the economic cycle (Apergis and Payne, 2010). As per the observed statistical reports, energy intensity in the USA has been declining sharply, which is further anticipated to decline at the rate of 2% annually until 2040 by the US Energy Information. This would, in turn, obstruct continuity in its economic growth over the long term (Apergis and Payne, 2010). Therefore, the reason for such a relationship is the varying degree of dependency of the country on its stock of coal, natural gas, and oil. This affects the overall consumption patterns of the population, resulting in a diverse and often fluctuating demand.

6.3.1.5. Saudi Arabia

Unlike the studies related to the other countries previously mentioned, Saudi Arabia has a unique dependency on its energy consumption to determine its economic growth prospects. This is because the nation is one of the major international suppliers of oil at present. According to Belloumi and Alshehry (2015), a long-term dependency can be observed connecting energy consumption, carbon dioxide emissions, energy price, and economic growth in Saudi Arabia. Nonetheless, the Granger causality is different when looking at economic growth together with carbon dioxide emission rates in the country compared to the causality between such emissions with economic growth or that between energy price and economic growth. This further implies a major reason for the multi-directional causality observed in Saudi Arabia, where long-term unidirectional causality is observed from the energy consumption patterns to the economic growth trends together with the carbon dioxide emissions. This further includes bidirectional causality between economic growth and carbon dioxide emissions, whereas a long-term unidirectional causality has been observed from energy price to the rate of economic growth recorded in the country, in addition to trends in carbon dioxide emissions (Alkhathlan and Javid, 2013).

7. CONCLUSION

This paper discovered and tested the short- and long-term Granger causal relationships between economic growth and energy consumption by utilizing information from 1968 to 2012 in economically advanced countries that have high energy consumption. These countries included China, which is the world's largest energy consumer and consumes approximately 23% of the total global energy consumption and contributed 27% to the growth of world demand for energy in 2016 (BP, 2016). India is also one of the top countries in regards to energy consumption because of its significant contribution to global energy consumption. India accounts for approximately 10% of the increase in global energy demand and India's global demand increased by 5.7% in 2013 (Priddle, 2015). Japan was also included as another industrial country that has large amounts of energy consumption, and who recently enacted several laws to maintain energy demand. The USA is one of the most important and influential countries in the consumption of global energy, and is the second largest consumer of energy (after China) in terms of the total consumption of energy. In addition to these industrial countries, a causal relationship analysis of Saudi Arabia was included as this oil country consumes large quantities of energy, although different factors are involved to that of industrial countries.

The results from the analyses were different among the five countries. In China, the unit root test indicated that only two variables, namely GDP and oil consumption, were integrated in order one, $I(1)$. For the other countries, all variables were integrated in order one, $I(1)$ and were included in the cointegration test, which refers to the long-term relationship between variables. Thus, the results showed the variables in which we conduct the causal relationship test, which also determines whether the causal relationship between the variables is long- or short-term. For the USA, the Granger causality relationship showed that

there was a unidirectional Granger causality between GDP and gas consumption, a bidirectional Granger causality between oil consumption and energy consumption, and a unidirectional Granger causality from gas consumption to oil consumption. The Granger causality relationship in Saudi Arabia showed a unidirectional Granger causality between EC and gas consumption and a unidirectional Granger causality from gas consumption to oil consumption. The phasing out of energy subsidies could have a negative influence on GDP growth in Saudi Arabia. To ensure economic development in different countries, adequate energy supply and energy policy should be guaranteed. Energy consumption, energy efficiency, energy intensity, and the creation of new sources of energy will be a difficult task for policymakers.

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